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Preliminary Evaluation of the Subsurface Area Available for a Potential Nuclear Waste Repository at Yucca Mountain

Arthur J. Mansure, Terri S. Ortiz

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PRELIMINARY EVALUATION OF THE SUBSURFACE AREA AVAILABLE FOR A POTENTIAL NUCLEAR-WASTE REPOSITORY AT YUCCA MOUNTAIN

by

Arthur J. Mansure
Geotechnical Design Division

and

Terri Smith Ortiz
NNWSI Repository Performance Assessments Division
Sandia National Laboratories
Albuquerque, New Mexico 87185

ABSTRACT

The Nevada Nuclear Waste Storage Investigations (NNWSI) Project, managed by the Nevada Operations Office of the U.S. Department of Energy, is examining the feasibility of siting a repository for high-level radioactive waste at Yucca Mountain on and adjacent to the Nevada Test Site. The Topopah Spring Member of the Paintbrush Tuff has been recommended as the target geologic formation. One purpose of this study was to determine whether adequate area for the underground facility exists within the portion of the devitrified, densely welded Topopah Spring Member that contains less than 15-20% lithophysae. Areas were considered where the underground facility would be above the water table and at least 200 m below the surface. The thickness required for the repository zone was assumed to be 45 m. An area significantly larger than the area estimated to be required to accommodate the underground facility appears to be potentially useable from this study. However, because the primary area of exploration has been the central portion of north Yucca Mountain, adjacent areas are less well characterized. Portions of the areas identified in this study may not meet all of the above criteria. Additional exploration is required to determine the acreage of the useable area. Another purpose of this study was to identify a preliminary location within the primary area of exploration, where conditions are favorable for the proposed underground facility. Using available information, this study has identified a slab that meets the above criteria. The slab dips 5°6'NE from a strike direction of N11°18'W. The area of the slab is about 1850 acres (7.49 km^2).

ACKNOWLEDGEMENT

Our thanks are extended to Bruce Whittet, the computer graphics system manager for the NNWSI Project Department at Sandia National Laboratories, without whom this work could not have been accomplished.

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INTRODUCTION

The work described in this report was performed by Sandia National Laboratories (SNL) as a part of the Nevada Nuclear Waste Storage Investigations (NNWSI) Project, which is managed by the U.S. Department of Energy's Nevada Operations Office. SNL is one of the principal organizations participating in the project, along with the U.S. Geological Survey (USGS), Los Alamos National Laboratory (LANL), and Lawrence Livermore National Laboratory (LLNL). The project is a part of the Department of Energy's program to dispose of the radioactive waste from nuclear power plants.

The Department of Energy (DOE) has determined that the safest and most feasible method currently known for the disposal of such wastes is to emplace them in mined geologic repositories. The NNWSI Project is conducting detailed studies of an area on and near the Nevada Test Site (NTS) in southern Nevada (Fig. 1) to determine the feasibility of developing a repository there.

The primary objective of the project is to isolate existing and future high-level radioactive waste from the environment so it will not pose any significant threat to public health and safety. For a mined repository in a stable geologic setting, the waste emplacement host rock and the surrounding rock will function as natural barriers to isolate the waste. The underground facility should be designed to take maximum advantage of the natural barriers.

The Nevada Research and Development Area of the NTS and nearby areas were screened (Sinnock and Fernandez, 1982) for favorable locations for the permanent disposal of radioactive waste in a mined repository. Screening activities were based on data provided by the USGS, LANL, LLNL, and SNL. Twenty-three geographic attributes and eight host rock attributes of fifteen locations were assessed. Northern Yucca Mountain ranked highest in that study, although within a vast area surrounding Yucca Mountain the waste isolation criteria are met (Sinnock and Fernandez, 1982). The discussion that follows refers to northern Yucca Mountain.

Four potential repository units were identified (Johnstone and others, 1984). Two units are below the water table the welded, devitrified portions of the Bullfrog and Tram Members of the Crater Flat Tuff. Two units are above the water table the welded, devitrified Topopah Spring Member of the Paintbrush Tuff and the nonwelded, zeolitized, tuffaceous beds of Calico

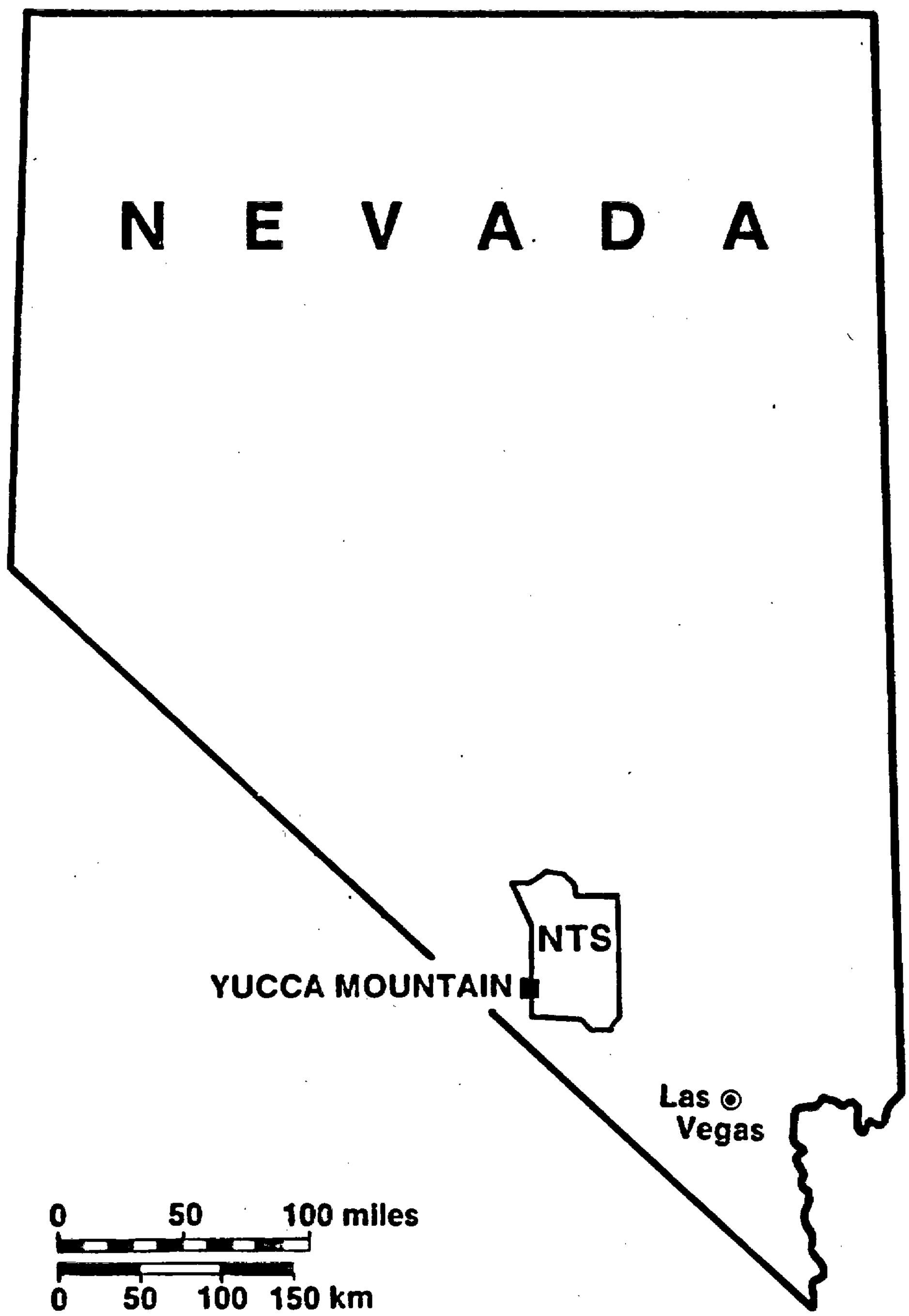

Figure 1. Location of Yucca Mountain on and adjacent to the Nevada Test Site (NTS).

Hills. These four units were evaluated (Johnstone and others, 1984) considering radionuclide isolation time, allowable repository thermal loading, and excavation stability. Information for this comparison was provided by the principal organizations participating in the project as well as their contractors. As a result of the evaluation, the portion of the Topopah Spring Member containing relatively few lithophysae was recommended (Johnstone and others, 1984). The other units were also found to be satisfactory but ranked lower than the Topopah Spring Member.

As a participant in the NNWSI project, SNL is responsible for the conceptual design of the underground facilities of the repository. The results of this study are a portion of information that will be used by the architect-engineer contractor for underground conceptual design.

The intent of this study is not to define precise boundaries or to identify areas where rock characteristics are unfavorable, but rather to identify sufficient area for consideration of characterization so that the underground facility construction can be flexible. The design of the underground facility probably will be refined continually, even during development, as new information becomes available.

GEOLOGY OF YUCCA MOUNTAIN

Yucca Mountain is a group of north-trending, fault-block ridges gently tilted eastward. Topography is controlled by high-angle, basin-and-range style normal faults. The mountain is comprised of a thick sequence of silicic volcanic rocks of Miocene age.

The geology has been interpreted from surface mapping and drill hole data. Four major ash-flow tuffs have been penetrated by drilling. These tuffs are, in ascending order, (1) Lithic Ridge Tuff, (2) Crater Flat Tuff, which includes three rhyolitic ash-flow tuff members, the Tram, Bullfrog, and Prow Pass Members, (3) a nonwelded sequence of rhyolitic ash-flow tuff and bedded tuffs, the tuffaceous beds of Calico Hills, and (4) Paintbrush Tuff consisting of two major ash-flow tuffs, the Topopah Spring Member and the Tiva Canyon Member (Scott and others, 1983). The Topopah Spring Member and Tiva Canyon Member are separated by two minor members at the north end of Yucca Mountain -- the Pah Canyon and the Yucca Mountain Members.

The Topopah Spring Member was erupted from the Claim Canyon cauldron about 2 km north of Yucca Mountain. The unit is compositionally zoned from high-silica rhyolite at the base to quartz latite near the top and is a multiple-flow compound cooling unit which originally covered about 700 mi^2 (Lipman and others, 1966). The Topopah Spring Member consists of moderately to densely welded tuff in the center. Vitrophyres are present at the top and bottom of the welded zone. Nonwelded zones are present at the top and base of the unit. The unit dips gently to the east.

As degassing of a cooling unit progresses during welding, pockets of gases (lithophysae) begin to form in portions or layers in the tuff that represent pulses of gas-rich magmatic material. Lithophysae probably occur in somewhat discontinuous stratigraphic tongues throughout the Topopah Spring Member (Scott and others, 1983), but, in general, the zones of high lithophysae are in the upper portion of the Topopah Spring. Scott and others (1983) state that determination of the three dimensional distribution of lithophysae in the Topopah Spring is being given high priority in their studies because lithophysae may affect rock mass properties, but those studies are unavailable at this time. Nimick (1983) performed a preliminary study of lithophysae distribution in the Topopah Spring Member. His study is based on lithologic logs from five drill holes, UE25-a#1 (Spengler and others, 1979), USW G-1 (Spengler and others, 1981), USW G-2 (Maldonado and Koether, 1983), USW GU-3 (Scott and Castellanos, 1984), and USW G-4 (Spengler and others, in preparation). An expanded study (Ortiz and others, in preparation) provides contacts of that unit in the primary area.

The potential emplacement horizon has been assumed to be the portion of the welded, devitrified, Topopah Spring Member that contains less than 15-20% lithophysae (Unit II-NL of Nimick, 1984; Johnstone and others, 1984; Lappin, 1982). Preliminary studies (Johnstone and others, 1984; Hustrulid, 1984; St. John, 1984) indicate that rock characteristics are favorable for the development of an underground facility in that horizon. Tillerson and Nimick (1984) present a summary of the bulk properties, thermal conductivity, thermal expansion and mechanical properties of that horizon. U.S. Geological Survey drill hole reports (e.g., Spengler and others, 1981; Maldonado and Koether, 1983) give discussions of lithology; Carroll and others (1981), for example, give a discussion of petrology and mineralogy.

Two styles of faults are present in the northern part of Yucca Mountain (Scott and others, 1983; Scott and Bonk, 1984). One consists of normal faults that strike N35°E to N40°W and generally dip 60 to 80° westward. The other consists of strike-slip faults that strike N30 to 55°W and also dip nearly vertically. North-northeasterly striking major normal faults separate the gently eastward-tilted major structural blocks at Yucca Mountain (Scott and others, 1983). Within these blocks, minor normal faults and fractures have strikes that fall into two dominant sets, one N15°W to N40°W and the other N5°E to N35°E. Most of these minor faults and fractures have steep dips, nearly perpendicular to the gently eastward dip of the strata.

AREA AND THICKNESS NEEDED

At present, two waste emplacement concepts are being investigated: horizontal boreholes and vertical boreholes. Vertical boreholes are the reference emplacement mode (Dravo Engineers, 1984a). Because vertical emplacement requires a slightly greater (2%) area, it has been used to evaluate the area needed.

Besides the dependence on emplacement mode, the area needed for the underground facility depends on the areal power density (APD), waste characteristics, and the amount of each type of waste that the repository will receive. High-level radioactive waste, in addition to giving off radiation, releases heat that must be taken into account during the planning and design of the underground facility to ensure that the maximum safe temperatures are not exceeded. The temperature of the underground facility can be controlled by designing the underground facility to distribute the waste heat throughout a large area of host rock.

An APD of 57 kW/acre (14 W/m^2) has been assumed (Johnstone and others, 1984). That APD is not necessarily a maximum; as the conceptual design progresses, it may change. The "Generic Requirements for a Mined Geologic Disposal System" (Department of Energy, 1984) states that the repository should accept a quantity of unreprocessed spent fuel from 70,000 metric tons of uranium initially loaded in power reactors. Thus, commercial reprocessed waste has not been considered in this study. The spent fuel has been assumed to be 10 years out of reactor and have an average burnup of 33,000 megawatt days per metric ton of uranium initially loaded in power reactors. The total area required to accommodate the waste at 57 kW/acre is 1520 acres (6.15 km^2) (Mansure, 1984). The specific area requirements are summarized in Table 1.

Table 1. Area Requirements for a 70,000 MTU Underground Facility with Vertical Emplacement Boreholes

	Acres	Square Kilometers
Spent Fuel at 57 kW/acre	1251*	5.06*
West Valley high-level waste**	2	.01
Spent fuel hardware waste***	10	.04
Other areas (e.g., underground shops)	70	.28
Main haulage ways	187	.76
TOTAL ACREAGE	1520	6.15

* Includes access drifts
** Waste from the West Valley Demonstration Project
***Waste from the consolidation of spent fuel

Information from Mansure (1984)

The thickness of the host rock must be sufficient for the excavations themselves plus additional rock of the required strength to ensure that the excavations will be stable. This additional thickness of the host rock around the excavations has been assumed to be approximately twice the drift height or 15 m in this report. Figure 2 shows that the reference emplacement mode (vertical emplacement) would define a 45-m-thick zone using this assumption. This underground facility zone thickness is not a minimum.

The boundaries of the useable area can be geologic features that terminate the continuity or suitability of the host rock for emplacement of waste. For

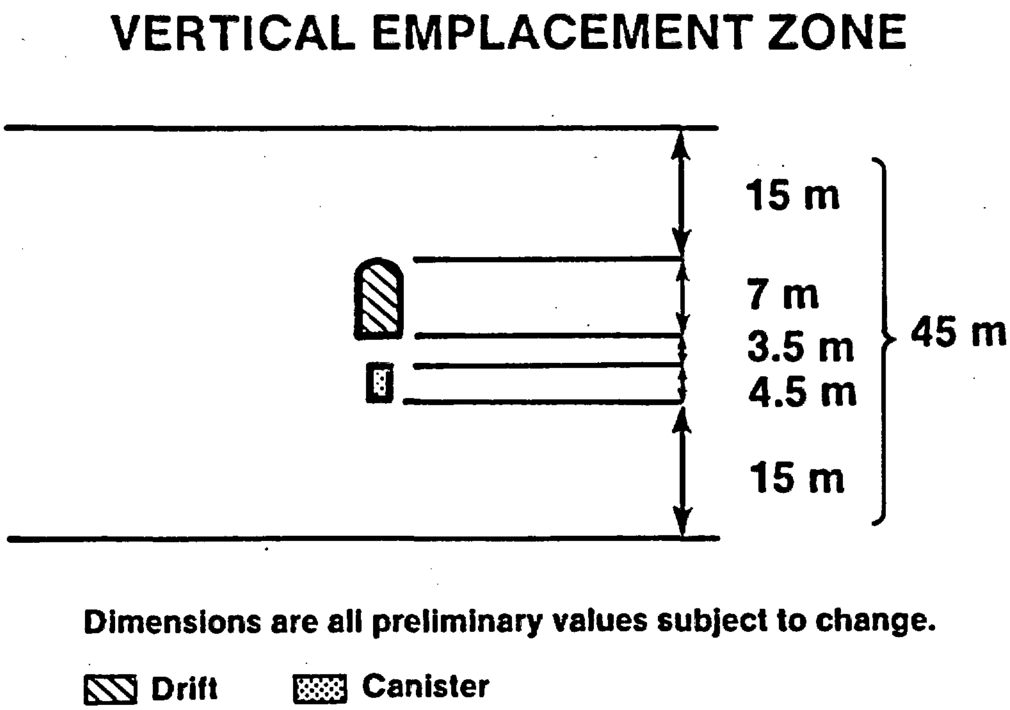

Figure 2. Underground facility zone for vertical emplacement.

example, faults may constitute a boundary if the underground facility horizon is significantly displaced. However, faults themselves do not limit underground-facility mining or development. With proper ground support, faults can be traversed (Dravo Engineers, Inc., 1984b). In addition, methods of sealing zones of water infiltration and methods of controlling hydrological conditions around canisters have been identified (Fernandez and Freshley, 1984), should such zones be encountered.

Flexibility in locating the underground facility is needed for several reasons. The repository must be able to fit into the area without causing design problems. Further, good design practice requires sufficient flexibility to orient the drifts relative to the in situ stress and fracture orientation to enhance stability of the drifts. If unexpected ground conditions are encountered, additional ground support can be installed, or the unexpected conditions can be avoided by working around them. While it is impossible to determine which of these approaches is better before development, to have the flexibility to mine around an anomaly is desirable. Finally, flexibility is desirable because there is considerable uncertainty in some of the parameters used to determine the area required (for example, waste characteristics) and because there is uncertainty in extrapolating drill hole data, as well as in extrapolating surface structural geologic data to the subsurface. To accommodate these uncertainties, it is important that there be enough area to allow the design of the underground facility to be flexible.

CRITERIA

For reasons explained below, the determination of the potentially useable area was based on the following criteria: (1) it is preferable that the underground facility be in the moderately to densely welded devitrified zone of the Topopah Spring Member containing less than 15-20% lithophysal cavities and above the basal vitrophyre, (2) all portions of the underground facility must be at least 200 m below the directly overlying ground surface, and (3) the underground facility should be above the water table.

The presence of high lithophysae content (probably near 30%) may adversely affect mineability and ground support. In addition, thermal properties will be degraded somewhat, perhaps limiting allowable average thermal loading. The effect of lithophysae upon mineability and ground support will be determined in future studies. For planning purposes only, the underground facility slab within the primary area has been placed in a thick zone with less than 15-20% lithophysae content near the base of the Topopah Spring Member.

For this study, the underground facility was placed above the basal vitrophyre of the Topopah Spring Member. The vitrophyre is a densely welded, hydrated, glassy unit. The importance of this constraint will be evaluated during conceptual design. The properties of the vitrophyre may make it acceptable for waste emplacement.

All portions of the underground facility must be at least 200 m below the directly overlying ground surface. The Final General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories (Dept. of Energy, 1984) state that all portions of the underground facility should be at least 200 m below the directly overlying ground surface so that erosional processes will not be likely to lead to radionuclide releases greater than allowed by the Environmental Protection Agency in 40 CFR Part 191, Subpart B.

In this study, only areas where the underground facility would be above the water table have been considered. The thickness required for the repository zone was assumed to be 45 m.

AREA 1 (Primary Area)

Area 1 (Fig. 3), which to date has been the focus of exploration, is the primary area for locating the underground facility. The area contains relatively few faults with only minor offset and rare breccia. Strata dip from 4 to 9° eastward. Area 1 is bounded on the west by the Solitario Canyon normal fault and Solitario fault, basin-and-range style faults; on the southeast by the Abandoned Wash normal fault and a transition to a zone of swarms of normal faults with relatively small offset; and on the northeast by Drill Hole Wash. A strike slip fault is located in Drill Hole Wash. However, no noticeable vertical offset is present across the wash and the fault could

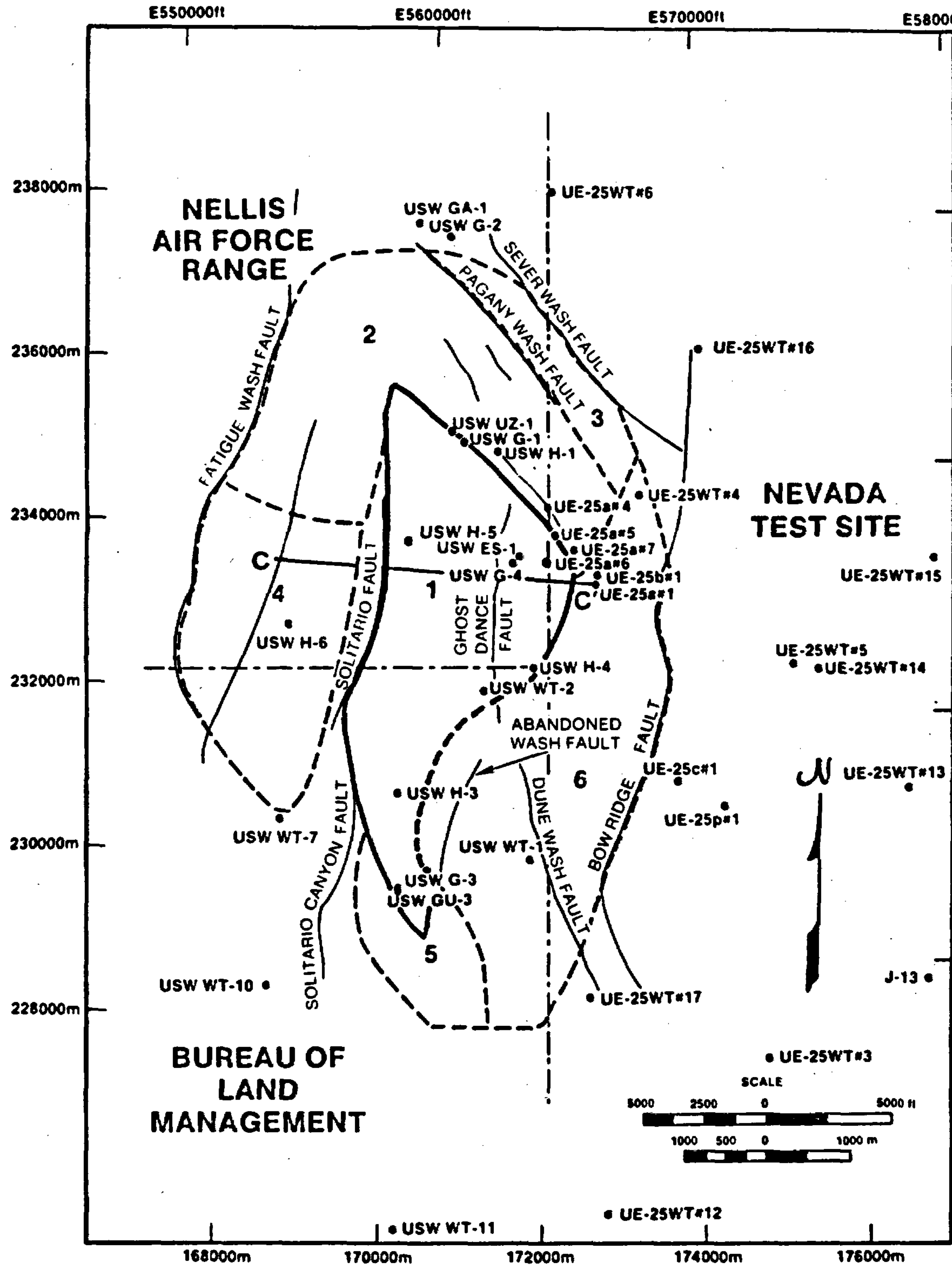

Figure 3. Potentially useable areas. Area 1 is the primary target area for the underground facility. Boundaries for all areas are approximate. See text for the characteristics of each of the areas. The numbers themselves carry no significance of ranking. Only faults mentioned in the text are shown on this map (modified from Scott and Bonk, 1984). Abundant minor faults not shown on this map are present in Area 6. See Scott and Bonk for a detailed map of the structural geology at Yucca Mountain. Drill hole locations and the location of the proposed exploratory shaft (USW ES-1) are shown for reference.

be traversed using standard mining technology. Exploration has been concentrated to the south of Drill Hole Wash to date, with less concentration to the north; however, future exploration will expand knowledge about the area north of the wash. The remainder of the areas shown in that figure will be discussed later.

To approximate the shape and size of Area 1 at the depth of the target geologic formation, the dips of faults mapped at the surface (Scott and Bonk, 1984) were extended to the depth of the Topopah Spring Member, although some faults may begin to flatten with depth. Where dips of faults were unavailable, dips were interpolated or 65° west was assumed. The dip of the edge of the area along Drill Hole Wash was assumed to be vertical.

The USGS has the responsibility for geological site exploration at Yucca Mountain. Sandia has used data gathered and interpreted by the USGS to develop a three dimensional computer model (Nimick and Williams, 1984) of the geology of the site. In addition, preliminary studies of the distribution of lithophysae by Nimick (1983) and Ortiz and others (in preparation) were used. The computer model was used in this study to define a location for the potential underground facility in Area 1. Figure 4 shows the thickness of the target unit in Area 1 as predicted by the model.

The topography and the dip of the host rock and underlying vitrophyre limit the area available on the west. Figure 5 shows the overburden from the base of the target emplacement unit (that is, to the vitrophyre). The figure shows that along the west, the required 200 m overburden from the ground surface to the vitrophyre becomes a constraint on the position of the underground facility.

Figure 6 shows that the transition line between Tpt-L and Tpt-NL, below which the lithophysae content is less than 15-20%, dips to the east. To place the underground facility as level as possible, the slab was selected just below the transition in the east corner of the primary area. The lithophysae transition line also becomes a constraint to the northeast. Thus, the slab dips to the northeast.

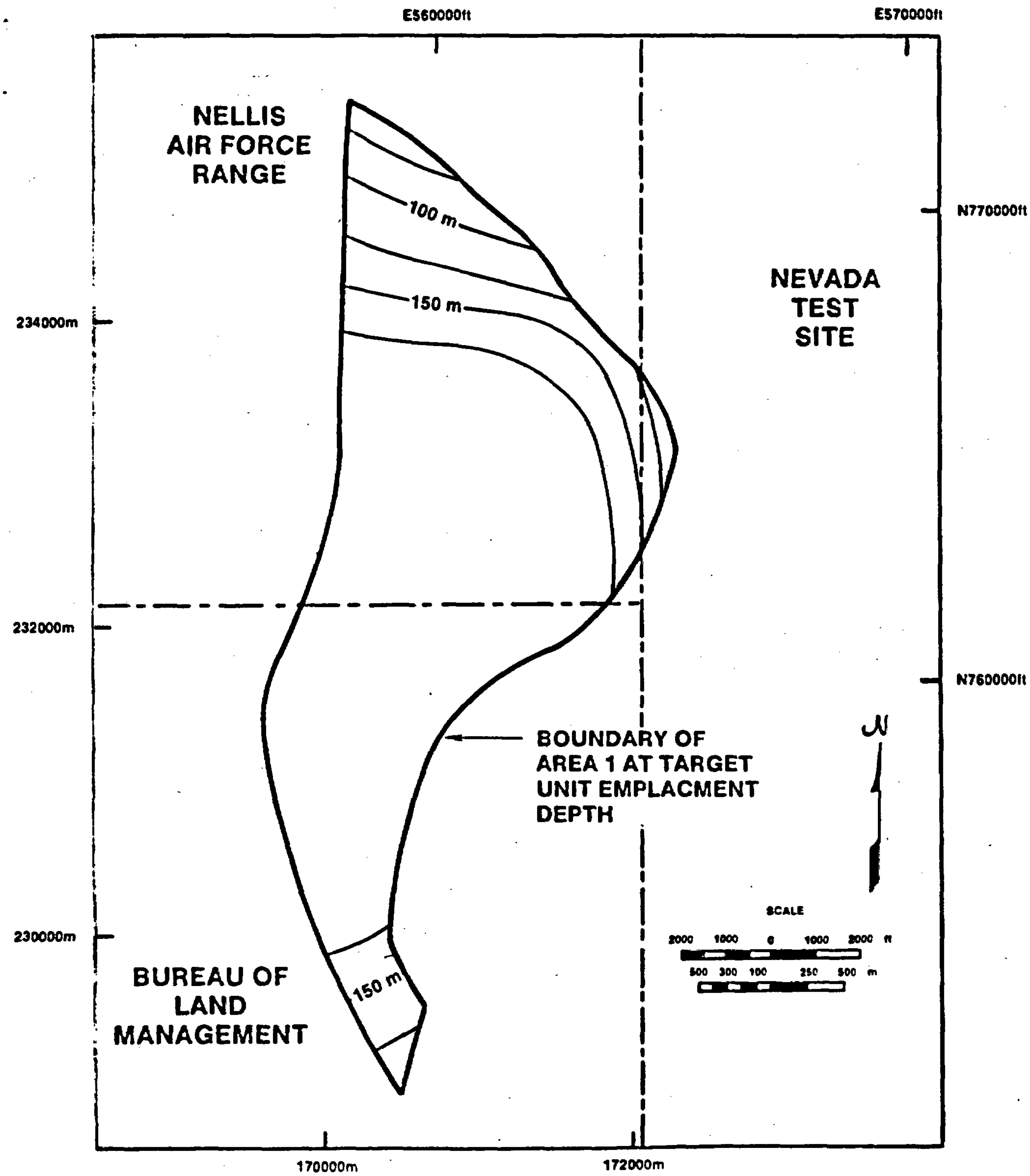

Figure 4. Approximate thickness predicted by the computer model for the target emplacement unit in Area 1. Contour interval is 25 m.

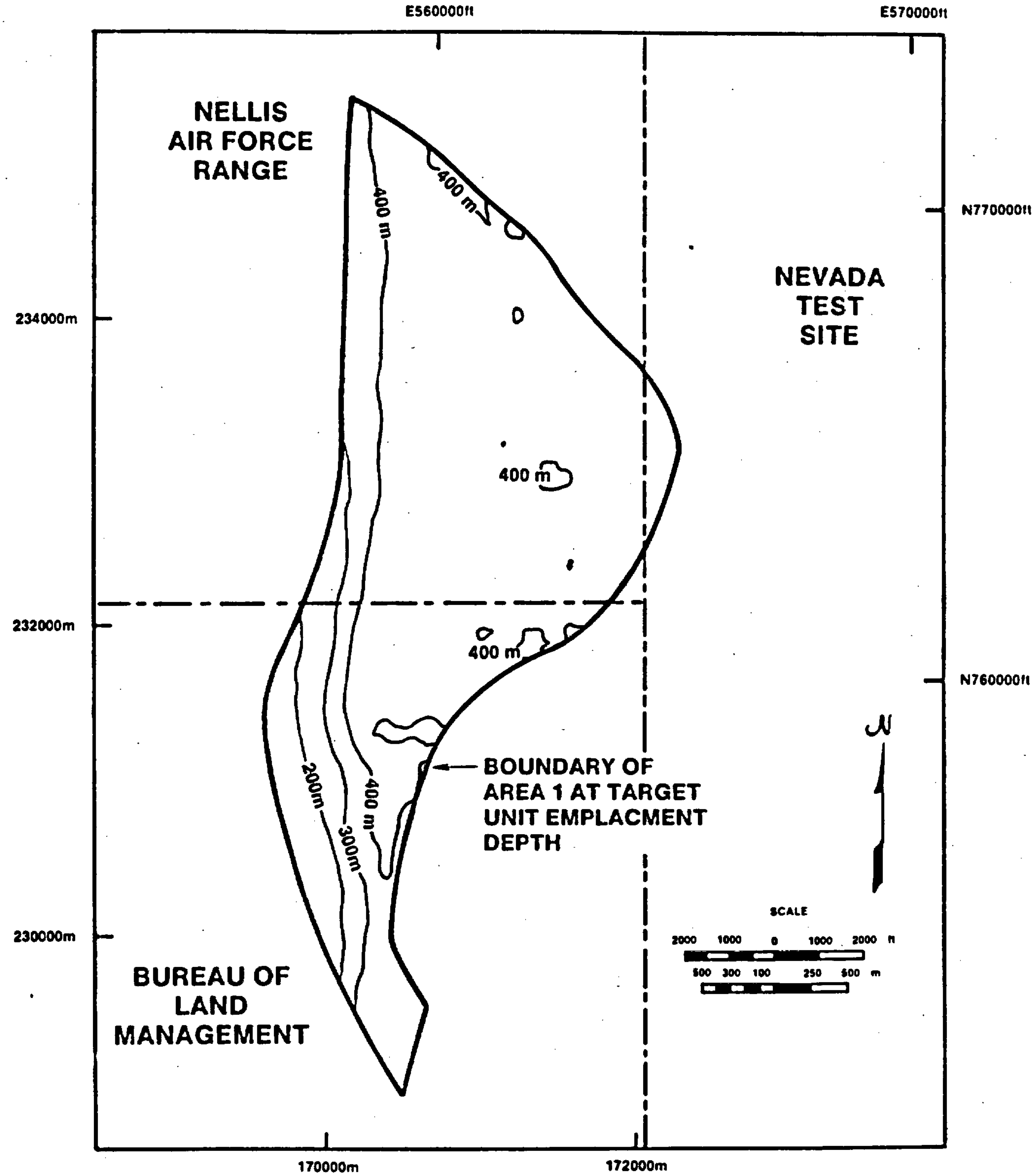

Figure 5. Overburden above the base of the target emplacement unit, that is, above the vitrophyre. Contour interval is 100 m.

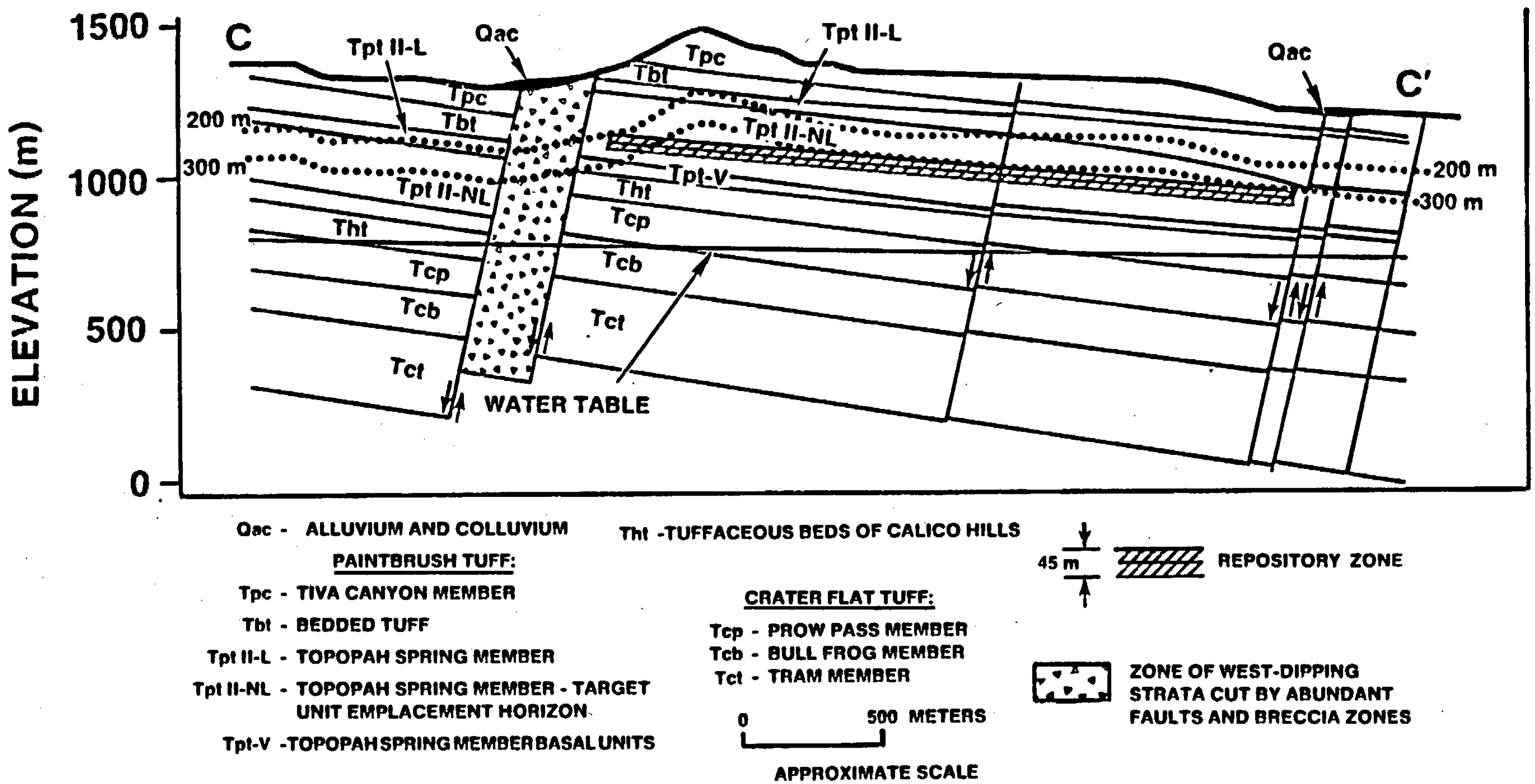

Figure 6. Cross section C-C' of Yucca Mountain showing proposed underground facility location and the 300-m and 200-m overburden lines (see Figure 3 for location of cross section). Modified from Nimick and Williams (1984). Based on information available in July 1984 from drill holes.

The three-dimensional computer model was used interactively to determine the position of the 45-m slab with the greatest area within Area 1. The slab was raised, lowered and inclined until the optimum attitude was determined. As can be seen in Figure 7, representing the underground facility as a flat slab results in some area being lost in the northern tip of the primary area. However, this area is small and could probably be recovered by bending the slab upward in this area. Figure 7 also indicates that a small area in the northeast is eliminated when the slab is kept in the lower lithophysae zone. Significant area is eliminated along the western edge because of the 200-m overburden requirement. In addition, the selected slab intersects the basal vitrophyre in the west.

The results of this study define a slab sloped 1°N and 5°E (strike N 11°18' W, dip 5°6' NE). The useable area of the slab is about 1850 acres (7.49 km), which is smaller than the primary area itself (almost 2200 acres, 8.90 km^2). The slab is approximately 200-400 m above the water table (Fig. 8) and varies from more than 200 m to more than 400 m below the ground surface (Fig. 9). The elevation of the top of the 45-m slab at the proposed exploratory shaft location (USW ES-1) is about 3231 ft (985 m), at USW H-5 is 3602 ft (1098 m), at USW H-3 is 3818 ft (1164 m), and at USW G-3 is 3881 ft (1183 m)(see Figure 3 for locations). Data gathered during site characterization may change the coordinates of the slab or slabs that are eventually selected.

The waste-handling equipment being designed will be able to negotiate the dip of the slab defining the underground facility (Foster-Miller, 1984). However, data gathered in the future will be used to determine whether the underground facility can be oriented more nearly horizontal.

The actual underground facility layout has not been determined. Nominally, the qualified portion of Area 1 offers more area than is required for the underground facility, but its irregular shape must be considered. Figure 10 shows an attempt to lay out about 1520 acres of fifty-five acre waste panels. This panel is the basic development unit for the preliminary conceptual design for horizontal emplacement. Current data suggest that some of the panels would overlap the slab boundary. The overlap is probably no more than the uncertainty in the boundary. Figure 10 serves to illustrate

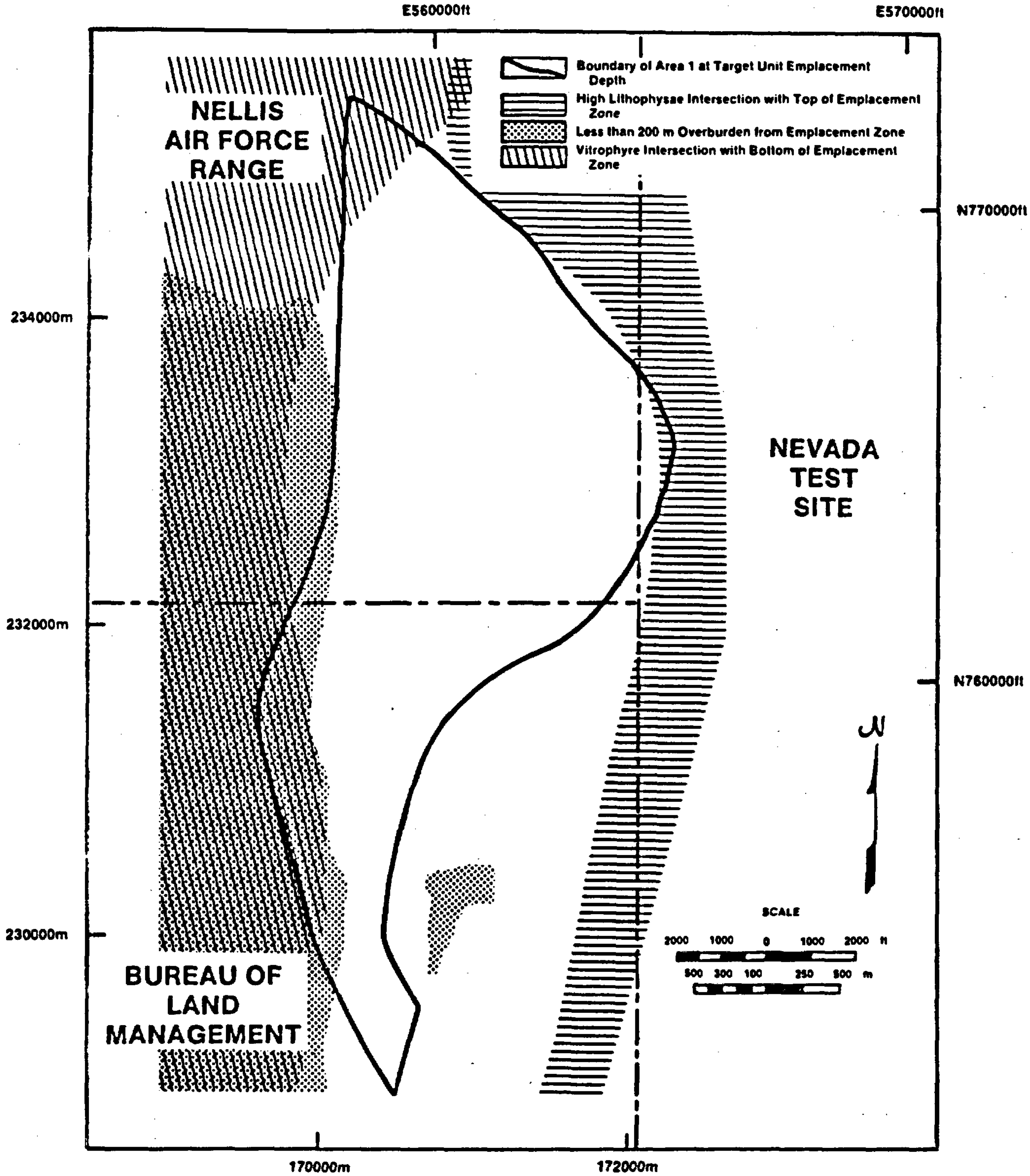

Figure 7. Determination of useable area for placement of a single flat slab representing the underground facility.

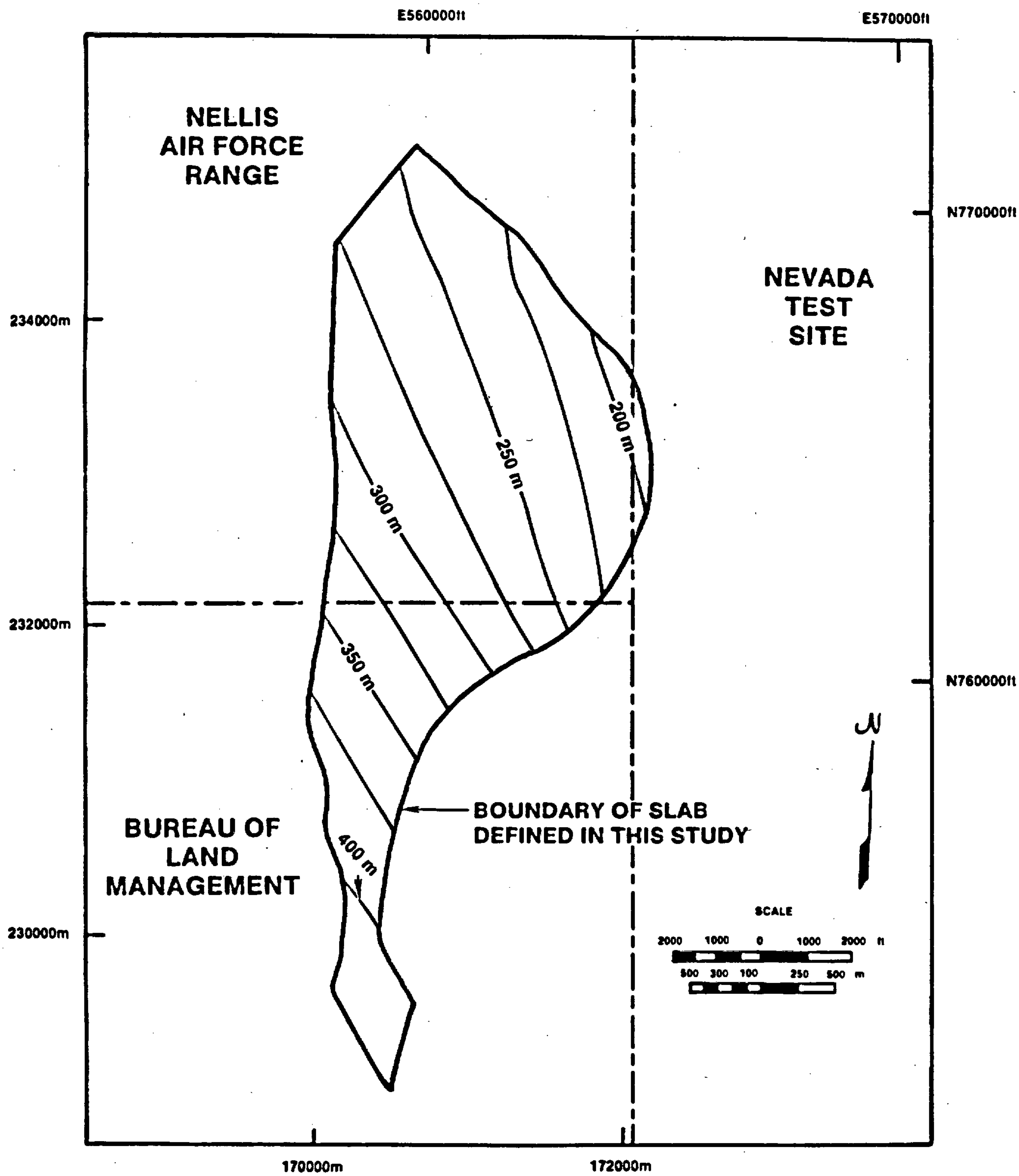

Figure 8. Distance from the underground facility to the water table. Water level altitudes at individual wells from Robison (1984). Contour interval is 25 m.

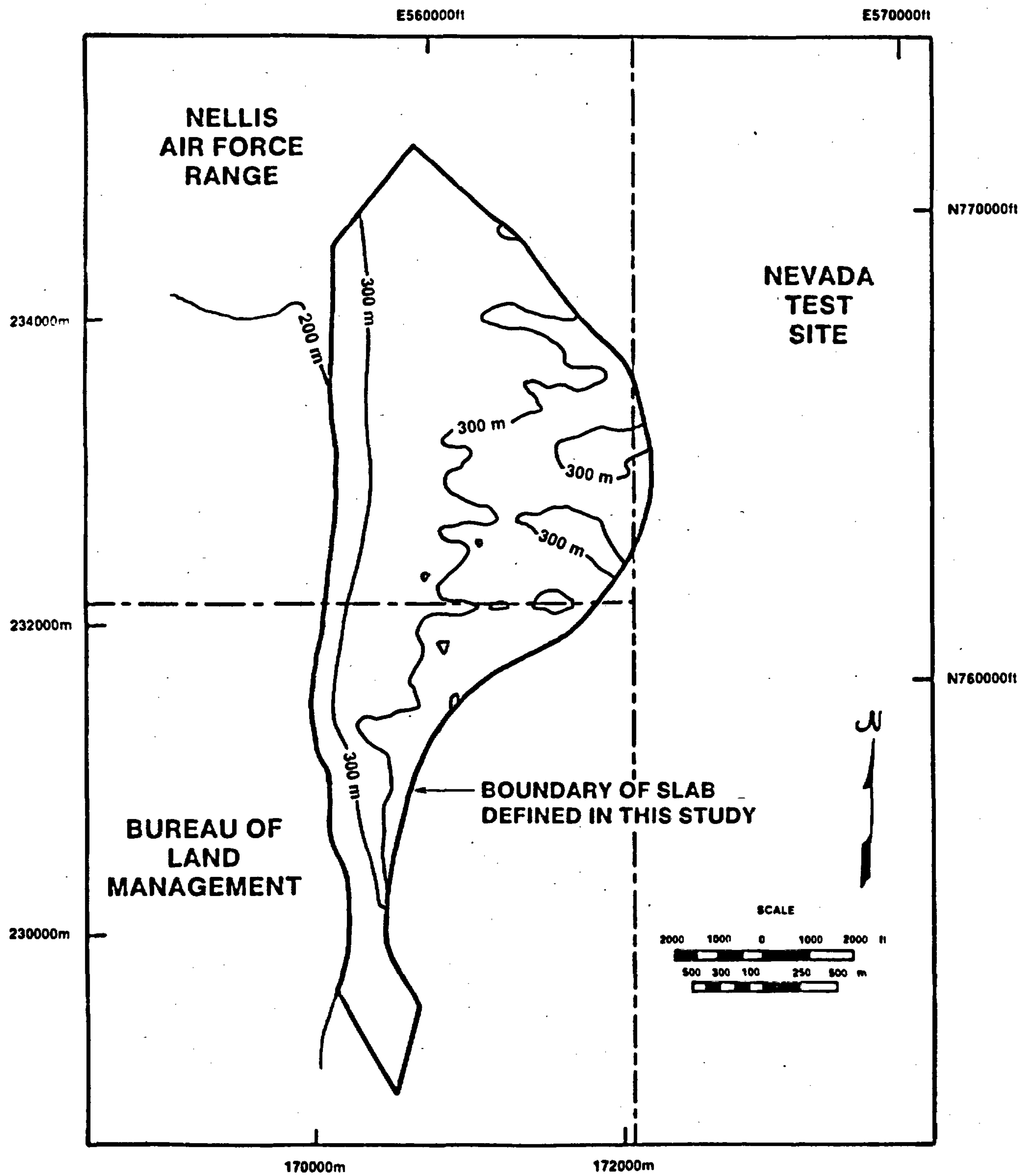

Figure 9. Overburden above the underground facility zone. Contour interval is 100 m.

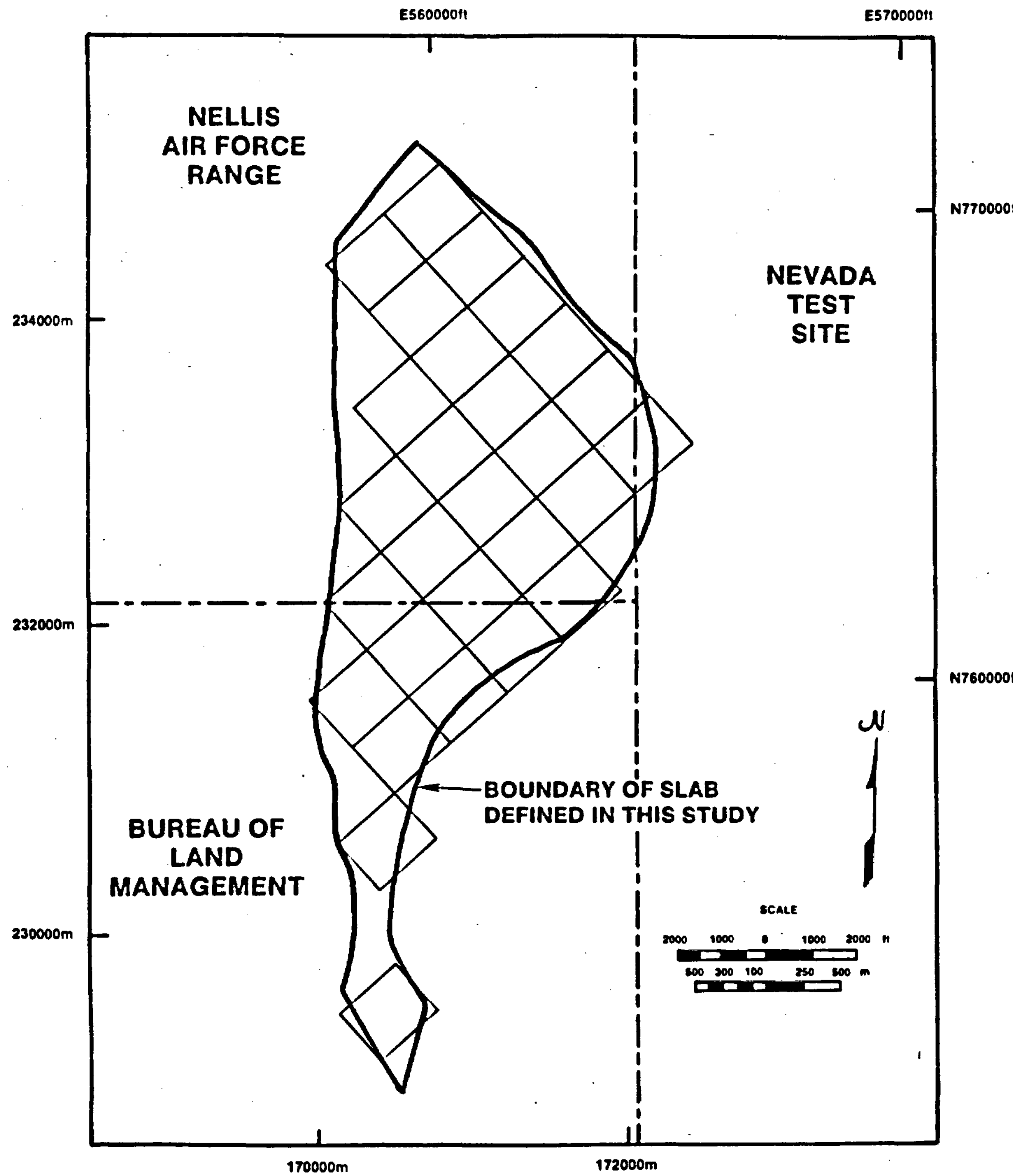

Figure 10. Sample panel layout (about 1520 acres) within the useable area of Area 1 defined in this study (about 1850 acres).

the difficulty in fitting regular panels into the irregular shape of the primary area. Fractional panels could be used to fit the entire layout within the boundaries, but would add to the complexity of the design. Further, since the directions of principal stresses and dominant joints vary with location (Scott and others, 1983; Scott and Bonk, 1984), it may be appropriate to vary the orientation of the panels, thus adding to the difficulty in fitting the panels into the area.

Uncertainties in the dip of the faults ($\pm10°$ was assumed) and in the elevation of the host rock contacts (±30 m was assumed) lead to uncertainties of approximately 100 m in the boundaries of the slab. As a result, the area of the primary area could change by 350 acres (1.4 km^2), the equivalent of about six panels in Figure 10.

OTHER AREAS

Figure 10 shows that the primary area does not allow significant flexibility in laying out the underground facility. If it were possible to use areas adjacent to Area 1, construction flexibility would be enhanced. Available data make it reasonable to assume that an adequate thickness of the densely welded Topopah Spring Member exists in areas adjacent to Area 1, although less is known about lithophysae content at this time.

Area 2, a primary area for extending the underground facility from Area 1, contains about 2250 acres (9.11 km^2). The area is bounded on the northeast by Pagany Wash fault and on the west by Fatigue Wash fault. The western part of Area 2 is terminated to the south because of the distance from the primary area and to the southeast by Solitario Canyon. The altitude of the water table increases rapidly to the northwest (Fig. 11), and therefore, the distance between the target emplacement unit and the water table decreases. The target unit also thins to the north and the northeast. Northwest striking strike-slip faults occur in Area 2 and there are exposures of basaltic dikes (Scott and Bonk, 1984). Otherwise, Area 2 is similar to Area 1 in geologic characteristics according to surface mapping and extrapolation of drill hole data. The area is characterized by relatively few minor faults and rare breccia. Strata dip from 4 to 15° (Scott and Bonk, 1984). Only minimal additional geologic characterization should be required to determine how much

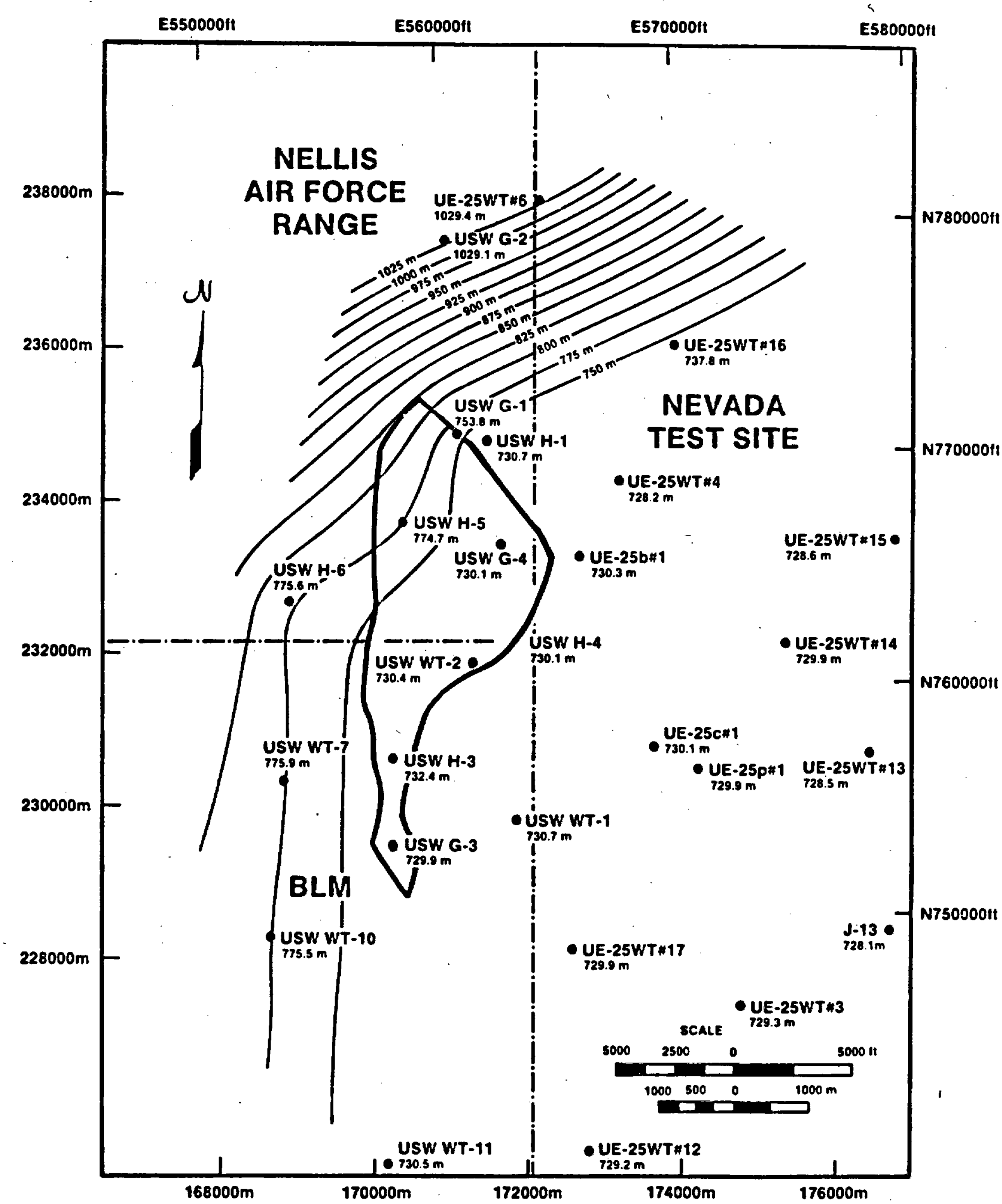

Figure 11. Altitude of the water table above National Geodetic Vertical Datum of 1929. Water level altitudes at individual wells from Robison (1984) were used. Note: water levels are approximate and preliminary. Contour interval is 25 m.

of this area is useable. The areal extent of the target unit in Areas 1 and 2 is more than two times the area needed.

Area 3 (about 400 acres, 1.62 km^2) is bounded to the northeast by Sever Wash fault, thinning of the target unit, and inadequate overburden. Area 4 contains about 1500 acres (6.07 km^2) and has similar geologic characteristics to Areas 1 and 2, but fewer data exist for this area and it is farther removed from the primary area. Dips vary between 10 and 15° (Scott and Bonk, 1984). The western portion of Area 4 is limited by overburden requirements and proximity to Fatigue Wash fault. To the east, Area 4 is bounded by Solitario Canyon. Area 5 (500 acres, 2.02 km^2) is separated from the most easily useable portion of Area 1 by the southern neck of Area 1. The geologic characteristics of Areas 3, 4, and 5 are similar to those of Areas 1 and 2 based on surface mapping.

The fault structure in Area 6 is very complex and makes it difficult to determine its subsurface structural qualities based on surface mapping and limited drill hole data. This area could be developed, however, as an extension of Area 1 depending on data obtained during actual mining of the southeastern edge of Area 1. In fact, small portions of Area 6 are geologically similar to Area 1 and it is difficult to define a precise boundary between Areas 1 and 6. In this report a smooth, general boundary between the two areas has been drawn. Area 6 contains about 2650 acres (10.72 km^2), but portions of Area 6 may not be useable because of the 200-m overburden requirement, as well as the complex fault structure and dips of strata up to and over 50°. The area is bounded on the east by proximity to Bow Ridge fault. If the need arises, future site characterization, performance assessment, as well as repository design, will address the significance of faults, fractures and zones of brecciation in the potential repository area.

SUMMARY

The target emplacement unit for planning purposes is the portion of the welded, devitrified Topopah Spring Member of the Paintbrush Tuff that contains less than 15-20% lithophysae. One purpose of this study was to delineate an adequate area of the target emplacement unit for the underground facility that meets the following criteria: (1) it is preferable for the underground facility to be in the zone of the Topopah Spring Member containing less than 15-20% lithophysae and to be above the basal vitrophyre, (2) the depth to the top of the underground facility must be at least 200 m, and (3) the underground facility zone should be above the water table. The thickness required for the underground-facility zone was assumed to be 45 m in this study.

An area that is significantly larger than the area estimated to be required to accommodate the underground facility has been defined as potentially useable in this study. Additional exploration will be required to determine exactly how much of that area is acceptable. Areas outside the boundaries defined in this study may also be acceptable.

Using available information, this study has identified a slab in the primary area; this slab dips 1°N and 5°E (strike N 11°18' W, dip 5°6' NE). It contains about 1850 acres (7.49 km^2). The thickness is highly variable but averages more than four times the underground facility envelope thickness used for planning purposes. The slab is about 200-400 m above the water table and lies from more than 200 m to more than 400 m below the ground surface.

About 1520 acres (6.15 km^2) are needed for the potential underground facility (Mansure, 1984). Although the area of the slab contains more than the area required, site characterization may encompass adjacent areas to ensure the flexibility needed for optimum design and to avoid anomalies encountered during mining.

While the dip of the slab is not excessive for the waste-handling equipment being designed, data gathered in the future will be used to determine whether the attitude of the repository could be closer to horizontal. In addition, potential extensions of the underground facility into adjacent areas will be evaluated.

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Washington, DC 20585

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505 King Avenue
Columbus, OH 43201

D. C. Newton (RW-23)
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Office of Geologic Repositories
U.S. Department of Energy
Forrestal Building
Washington, DC 20585

O. L. Olson, Manager
Basalt Waste Isolation Project Office
U.S. Department of Energy
Richland Operations Office
Post Office Box 550
Richland, WA 99352

D. L. Vieth, Director (4)
Waste Management Project Office
U.S. Department of Energy
Post Office Box 14100
Las Vegas, NV 89114

D. F. Miller, Director
Office of Public Affairs
U.S. Department of Energy
Post Office Box 14100
Las Vegas, NV 89114

D. A. Nowack (14)
Office of Public Affairs
U.S. Department of Energy
Post Office Box 14100
Las Vegas, NV 89114

B. W. Church, Director
Health Physics Division
U.S. Department of Energy
Post Office Box 14100
Las Vegas, NV 89114

Chief, Repository Projects Branch
Division of Waste Management
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

S. A. Mann, Manager
Crystalline Rock Project Office
U.S. Department of Energy
9800 South Cass Avenue
Argonne, IL 60439

K. Street, Jr.
Lawrence Livermore National
Laboratory
Post Office Box 808
Mail Stop L-209
Livermore, CA 94550

L. D. Ramspott (3)
Technical Project Officer for NNWSI
Lawrence Livermore National
Laboratory
P.O. Box 808
Mail Stop L-204
Livermore, CA 94550

J. E. Boudreau
Los Alamos National Laboratory
P.O. Box 1663
Mail Stop F-671
Los Alamos, NM 87545

D. T. Oakley (3)
Technical Project Officer for NNWSI
Los Alamos National Laboratory
P.O. Box 1663
Mail Stop F-671
Los Alamos, NM 87545

W. W. Dudley, Jr. (3)
Technical Project Officer for NNWSI
U.S. Geological Survey
Post Office Box 25046
418 Federal Center
Denver, CO 80225

NTS Section Leader
Repository Project Branch
Division of Waste Management
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

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Washington, D.C. 20555

P. T. Prestholt
NRC Site Representative
1050 East Flamingo Road
Suite 319
Las Vegas, NV 89109

M. E. Spaeth
Technical Project Officer for NNWSI
Science Applications
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Holmes & Narver, Inc.
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Las Vegas, NV 89114

J. A. Cross, Manager
Las Vegas Branch
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Las Vegas, NV 89114

V. M. Glanzman
U.S. Geological Survey
Post Office Box 25046
913 Federal Center
Denver, CO 80225

J. B. Wright
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Post Office Box 14400
Mail Stop 555
Las Vegas, NV 89114

T. Hay, Executive Assistant
Office of the Governor
State of Nevada
Capitol Complex
Carson City, NV 89710

R. R. Loux, Jr., Director (8)
Nuclear Waste Project Office
State of Nevada
Capitol Complex
Carson City, NV 89710

N. E. Carter
Battelle Columbus Laboratory
Office of Nuclear Waste Isolation
505 King Avenue
Columbus, OH 43201

John Fordham
Desert Research Institute
Water Resources Center
Post Office Box 60220
Reno, NV 89506

Department of Comprehensive
Planning
Clark County
225 Bridger Avenue, 7th Floor
Las Vegas, NV 89155

Lincoln County Commission
Lincoln County
Post Office Box 90
Pioche, NV 89043

Community Planning and
Development
City of North Las Vegas
Post Office Box 4086
North Las Vegas, NV 89030

J. L. Younker (15)
Science Applications, Inc.
2769 S. Highland Drive
Las Vegas, NV 89101

C. H. Johnson, Technical
Program Manager
Nuclear Waste Project Office
State of Nevada
Capitol Complex
Carson City, NV 89710

Dr. Martin Mifflin
Desert Research Institute
Water Resources Center
Suite 201
1500 East Tropicana Avenue
Las Vegas, NV 89109

Planning Department
Nye County
Post Office Box 153
Tonopah, NV 89049

Economic Development
Department
City of Las Vegas
400 East Stewart Avenue
Las Vegas, NV 89101

Richard Harig (3)
Parsons-Brinkerhoff
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