See Order for Hr. 102.2
To Copzou Atr Vieth
11-15-84

Sept 15, 1984

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See folder for Ltr. to Coplan fm. Wilson 8-13-84

USGS RESPONSE TO
NRC REQUESTS FOR HYDROLOGIC DATA,
DATA REVIEW, JULY 24-27, 1984

1. Statistical summary of unsaturated-zone parameters (porosity, moisture content, saturation).

   Comment: Data are preliminary and not contained in any formal report.

   Response: Compilation will be provided by 8/31.

2. Examples of plots of moisture-characteristics curves and relative permeability-moisture tension curves; list of such plots in files.

   Comments: List will have to be compiled.

   Response: Information will be provided by 8/31.

3. Sandia report (SAND-83-7474).

   Response: Please obtain from Sandia National Laboratories.

4. Copy of video (TV) log of USW UZ-1.

   Comment: Two tapes available.

   Response: Copies of both tapes will be provided by 8/31.

5. USW UZ-1 blueprint.

   Comment: Blueprint prepared by Holmes and Narver, Inc. (DOE contractor).

   Response: Copy will be provided by 8/31.

6. Isotopic map

   Comment: Map is part of a report in review.

   Response: Map will be provided following USGS approval of report, probably September or October, 1984.

7. Computer printout of water-quality analyses in and around Yucca Mountain.

   Response: Water-quality analyses will be provided by 8/31.

8. Details of a typical installation of a continuous water-level monitoring station using a pressure transducer.

   Comment: No such drawing exists.

   Response: USGS Quality Assurance Procedure HP-25 describes our general procedure for measuring water levels with transducers. It is enclosed.

9. Construction records and periodic water-level measurements.

Comment: Construction records are prepared by Fenix and Scisson, Inc. (contractor to DOE); USGS files are incomplete. Hydrographs are preliminary and do not have all corrections made to water levels.

Response: Please obtain construction records from F&S, inc., through DOE. Hydrographs are enclosed.

10. Geologic description and hole construction records for WT holes.

Response: See item 9, above, for construction records. Geologic descriptions have not been completed. Completion schedule is uncertain.

11. Map of Franklin Lake Playa showing well locations.

Response: Copy of map will be provided by 8/31.

12. Geologic map of Scott

Comment: Map is approved and in final drafting.

Response: Copy will be provided when drafting is complete (probably September).

13. Hydrotesting index

Response: Request was completed during review.

14. Montazer thesis

Response: Copy will be provided by 8/31.

15. Weeks and Wilson Open-File Report

Comment: Report is approved as WRI 84-4193. Manuscript is in final typing.

Response: Copy will be provided when available, probably September.

16. Letter and data from H&N to Montazer 10-4-83.

Response: Copy will be provided by 8/31.

17. All geologic logs and geophysical logs for all H-holes and WT-holes.

Comment: Fenix and Scisson, Inc. has the originals of geophysical logs.

Response: Please make request to F&S, through DOE. Suggest you indicate you want only logs that were run after hole was completed. Be aware that volume of logs is substantial; request for specific logs probably would be more favorably received.

18. Pictorial summary of geophysical and geologic logs or geologic

description for WT 25c-1, 2, 3; UE 25p#1, and WT 25b#1.

Response: No pictorial summaries are available. Lithologic logs will be sent when available.

19. Information concerning H_o in mV for injection tests.

Response: Suggest that person interested in the information contact Gene Rush in Nuclear Hydrology Program to discuss the information requested.

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THAT CAN BE VIEWED AT THE RECORD TITLED:

1983-1984
UE-25 WT#6

WITHIN THIS PACKAGE...

NOTE: Because of this page's large file size, it may be more convenient to copy thefile to a local drive and use the Imaging (Wang) viewer, which can be accessed from the Programs/Accessories menu.

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LIST OF TABLES (Continued)

Chapter 2

PROCESS BY WHICH YUCCA MOUNTAIN WAS SELECTED

The Nevada Nuclear Waste Storage Investigations (NNWSI) Project was established in 1977 by the Department of Energy's Nevada Operations Office (DOE/NV). The Project's objective was to evaluate the Nevada Test Site (NTS) and contiguous area for sites suitable for a geologic repository. The NTS and its vicinity seemed attractive as a potential repository location because the land was withdrawn from public use, the NTS itself was under DOE control, and some of the land was contaminated with radioactive material from nuclear-weapons tests. However, the NNWSI Project search for sites was directed mainly at suitable geologic conditions, rather than land-use considerations.

Nine types of rock and 15 alternative locations at or near the NTS were identified as potentially suitable for a repository. Eventually, a rigorous program of screening led to the selection of welded tuff and Yucca Mountain in southern Nye County, Nevada, as the preferred host rock and the preferred location, respectively. Among the attractive attributes of Yucca Mountain were its location in a closed hydrologic basin, the ability to locate the repository in the unsaturated zone (above the water table), and the excellent thermomechanical and radionuclide-retardation properties of tuff.

After Yucca Mountain was selected as the preferred location in Nevada, geologic and hydrolgic investigations were continued to collect information about the suitability of the site. The data thus collected indicated that the site is indeed suitable for both long-term and near-term objectives, and in February 1983, in accordance with the Nuclear Waste Policy Act of 1982, the DOE notified the State of Nevada that the site is potentially acceptable for a repository (letter from D. P. Hodel, Secretary of Energy, to Governor Richard H. Bryan, February 12, 1983).

The Yucca Mountain site is about 160 km (100 mi) northwest of Las Vegas, Nevada (Figure 2-1). The site is on Federal land under the control of three separate agencies. Most of the site is part of the Nellis Air Force Range (NAFR); a smaller portion is part of the NTS and managed by the Department of Energy (DOE). The remaining portion is managed by the Bureau of Land Management (BLM).

This chapter outlines the general process by which Yucca Mountain was identified as a potentially acceptable site. Section 2.1 describes the regional setting of the site to place in context the general types of alternatives from which Yucca Mountain was selected. The screening process by which Yucca Mountain was identified is described in Section 2.2. This discussion is followed by Section 2.3, which evaluates the Yucca Mountain site against the disqualifying conditions in the DOE siting guidelines (10 CFR Part 960). Such an evaluation is required by both the Nuclear Waste Policy Act and the DOE

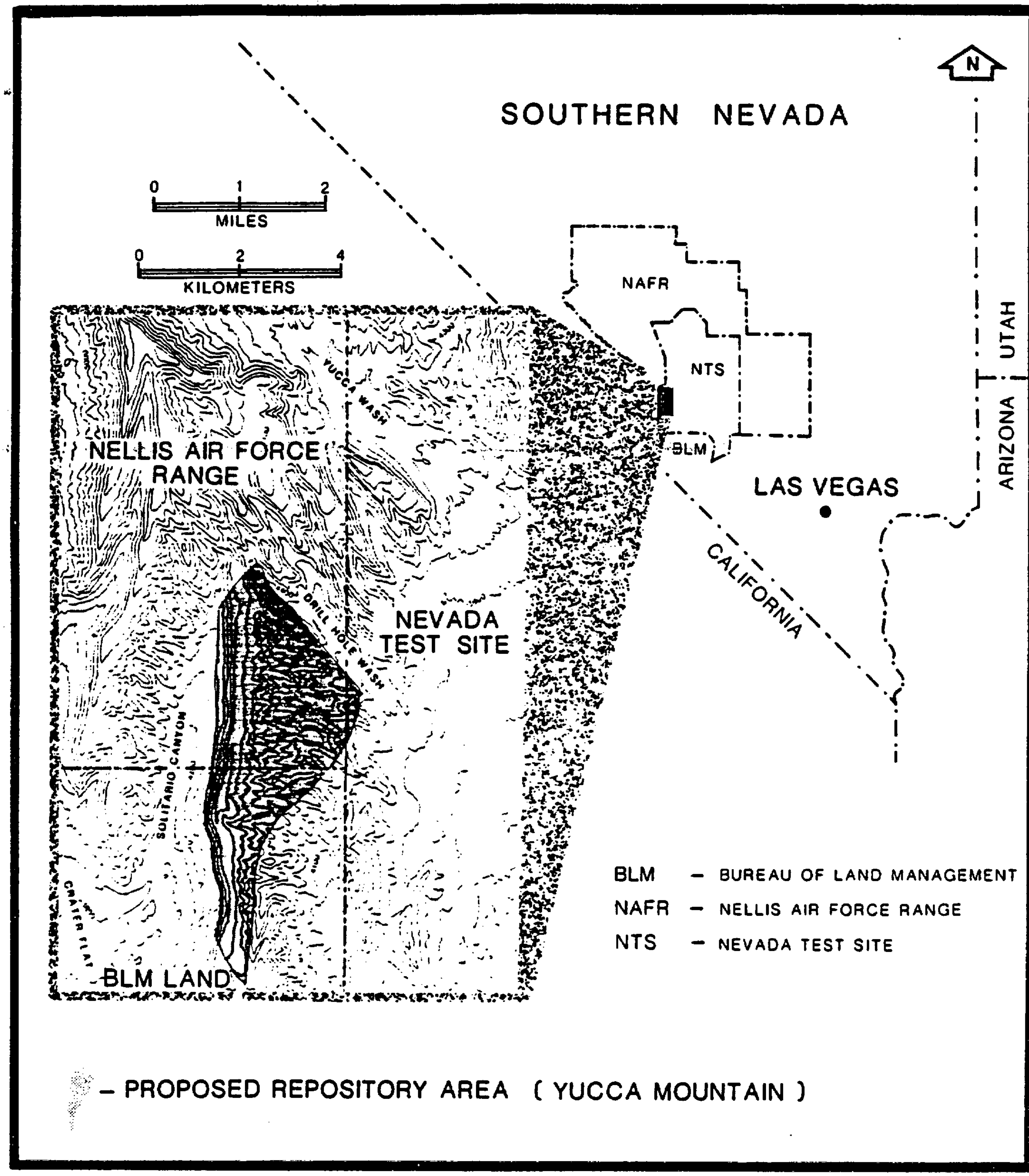


Figure 2-1. Location of proposed repository site at Yucca Mountain in southern Nevada.

siting guidelines (10 CFR 960.3-2), as a step in the nomination process and must be applied to all potentially acceptable sites.

2.1 REGIONAL SETTING OF YUCCA MOUNTAIN

The Yucca Mountain site is located within a broad desert region known as the Great Basin. The Great Basin is characterized by generally linear mountain ranges and intervening valleys. No streams or rivers flow out of the region. Primarily because of the scarcity of water, few people live in this vast desert. The few communities that exist are generally located around mining districts, water sources, or tourist attractions. Agricultural production is very limited because of the severe aridity and low nutrient value of the rocky desert soils. Irrigation is practiced only in a few acres where the ground water is shallow enough to be tapped by wells and where soils are suitable for tillage. As a result of the sparse population, paved roads are also widely spaced, commonly more than 80 km (50 mi) apart.

The basins and intervening mountain ranges of the region strongly influence the climate, vegetation, and surface drainage of local areas. Most precipitation falls on the cooler mountain terrain, whereas the basins are relatively warmer and dryer. As a result, the higher ranges generally support coniferous forests while the basins and lower ranges, such as Yucca Mountain (Figure 2-2), are covered with sparse desert vegetation. The large number of basins and ranges of various elevations result in several ecological communities within the region.

The mountain ranges are formed by fault blocks that rise above the intervening basins. On the basis of exposed rocks in the mountain ranges, the rocks can be divided into four major groups. The oldest are a billion or more years old and are made up of hard crystalline material, such as gneiss and granite. These rocks are part of the crystalline shield of the North American continent. Stratigraphically above the shield rocks is the second major group of rocks, a thick sedimentary sequence composed mainly of carbonates, quartzite, shale, and argillite. These rocks were deposited between about 800 million and 250 million years ago in a large trough-like basin, called the Cordilleran Geosyncline, that existed along the western edge of the continent. From about 250 to 100 million years ago, these sedimentary rocks were strongly squeezed, folded, and faulted in a process that created Cordilleran Geosyncline. During this time, granitic masses were intruded deep within the buried roots of local parts of these ancient mountains. Small outcrops of granite in the northern part of the NTS attest to this episode of granite formation.

From about 100 to 40 million years ago, the mountain building waned and the ancient ranges were eroded to a gentle rolling plain. Beginning about 40 million years ago, a third major group of rocks was formed on this plain when volcanic activity spread thick deposits of tuffaceous volcanic material over portions of the area. This volcanism lasted from about 40 to 10 million years ago and produced the layers of tuff that now form Yucca Mountain. Yucca Mountain was actually formed during the last 10 to 15 million years of this 30-million-year period.

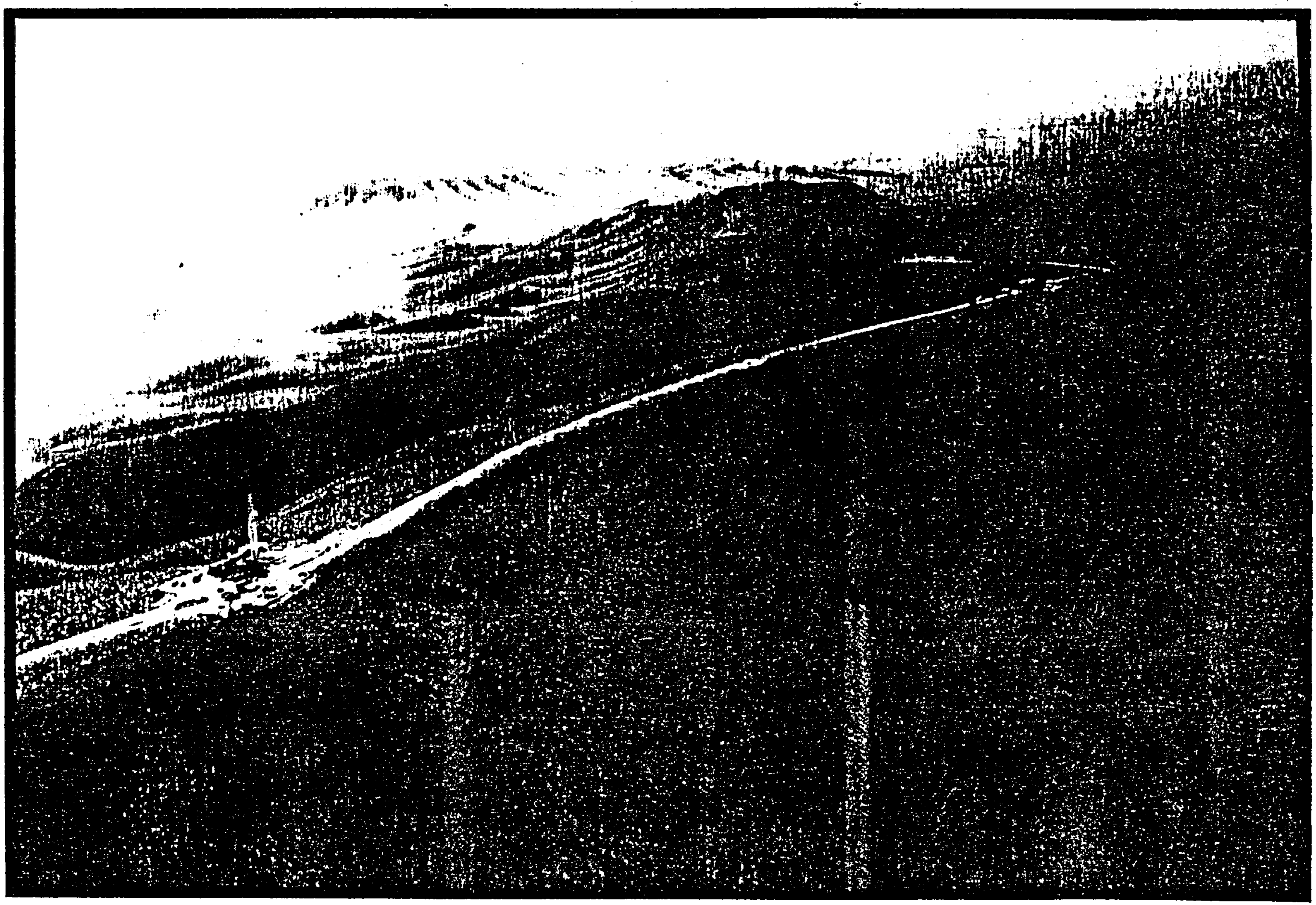


Figure 2-2. View of Yucca Mountain looking southeast. (Photo courtesy of Pan American, Inc.)

Faulting that produced the current basins and ranges took place at the same general time as the volcanism. In the last 10 million years, tectonic activity has waned (Stewart, 1978) and the basins have been partly filled with alluvium derived from erosion of the surrounding ranges. Minor volcanism continued during basin filling, most recently producing thin, locally restricted sheets and cones of basaltic material in Crater Flat, just west of Yucca Mountain.

Three regional cross sections, shown on Figures 2-3a and 2-3b, portray the complexity resulting from the geological history described above. The geological evolution involving deposition, folding, faulting, intrusion of granite masses, and eruption of volcanic material produced a complicated geologic pattern in the rocks of this area.

The hydrology of the southern Great Basin is characterized by deep water tables and closed ground-water basins; ground-water basins do not necessarily correspond with topographic basins. At some places in the southern Great Basin, including parts of Yucca Mountain, ground water is more than 500 m (1600 ft) deep. Recharge occurs by slow percolation of surface water through the rocks overlying the water table. Most, if not all, of this recharge is restricted to higher elevations of the ranges where precipitation is greatest. At lower elevations, including Yucca Mountain, most, if not all, precipitation evaporates before it is able to seep deeply into the rocks.

Generally, ground water in the southern Great Basin flows through major aquifers, which are deep beneath the surface of the ranges and most valleys. Winograd and Thordarson (1975) recognized six major aquifers in southern Nevada that transmit water and four major aquitards that retard the flow of water and act as barriers to ground-water movement (Figure 2-4). The lower and upper carbonate aquifers of the sedimentary sequences and the welded-tuff and lava-flow aquifers of the volcanic sequence transmit water primarily through fractures. Because the fractures are related to both the brittleness of the rock and the location of major structural features, local and regional flow is determined largely by the complex stratigraphic and structural conditions outlined above. The bedded-tuff and valley-fill aquifers, in contrast, store and transmit water chiefly through interstitial pores.

The potential repository site at Yucca Mountain lies in the Death Valley ground-water system, which is composed of several more or less distinct basins (Figure 2-5). The site is in the Alkali Flat-Furnace Creek Ranch ground-water basin at a position midway between the Ash Meadows and Oasis Valley basins, as shown in Figure 2-5 (Waddell, 1982). The Alkali Flat-Furnace Creek basin discharges at seeps in Alkali Flat, and springs in Death Valley. Regional flow east of the site is through the Ash Meadows basin and occurs principally in the lower carbonate aquifer (Figure 2-6). This basin partially discharges at the 30 or so springs in Ash Meadows where the lower clastic aquitard apparently is raised along a fault and blocks the flow through the aquifer, forcing water to rise to the surface. Some of the water may seep through the aquitard, eventually discharging at Death Valley. West of the site, local flow from recharge at Timber Mountain and Pahute Mesa occurs through the tuff aquifer and discharges at springs in Oasis Valley, just north of Beatty. This small flow system forms the Oasis Valley basin.

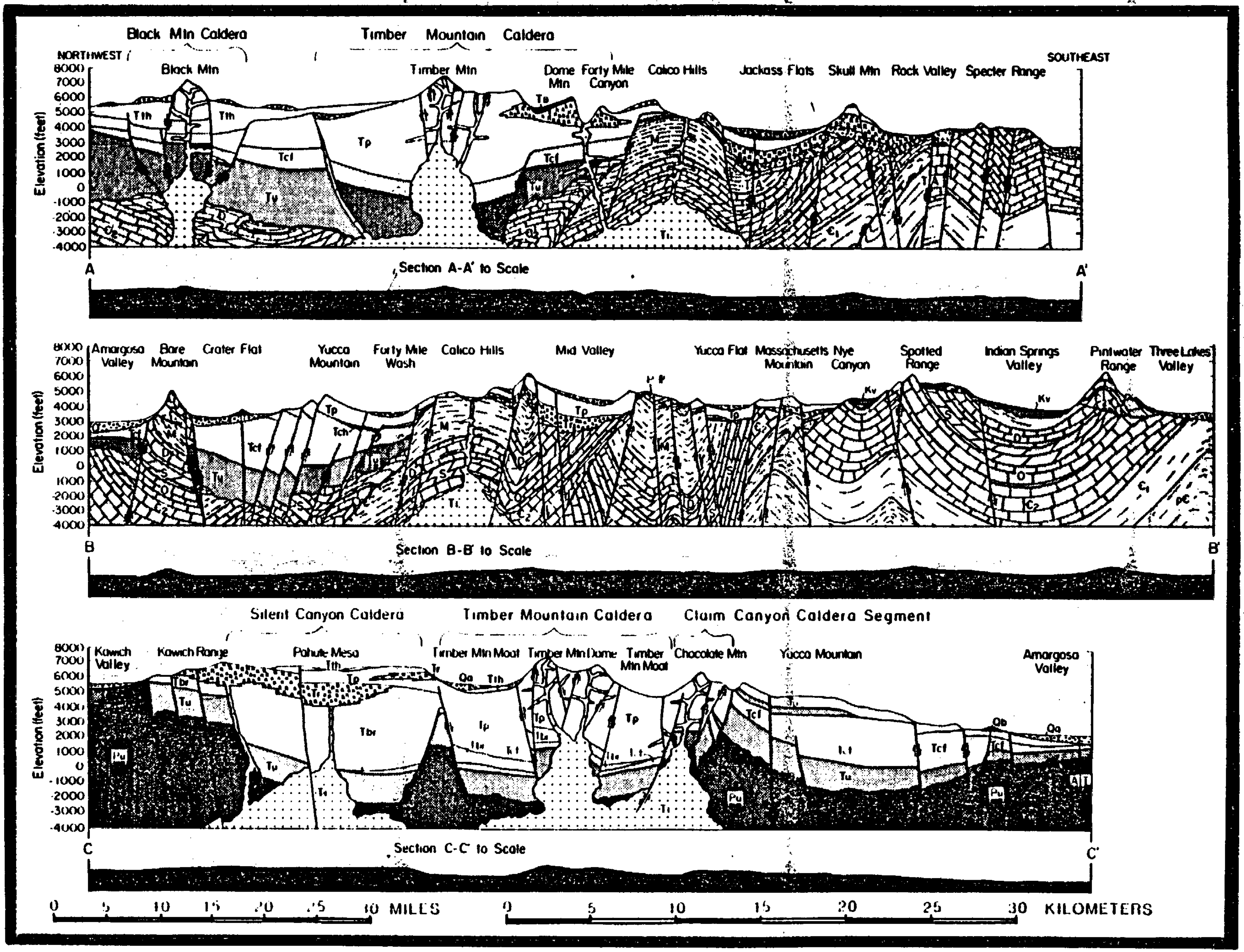


Figure 2-3a. Schematic cross sections portraying the geologic complexity surrounding Yucca Mountain in southwestern Nevada and showing the style of faulting and caldera complexes. See Figure 2-3b for location of cross sections and legend. (Source: Sinnock, 1982.)

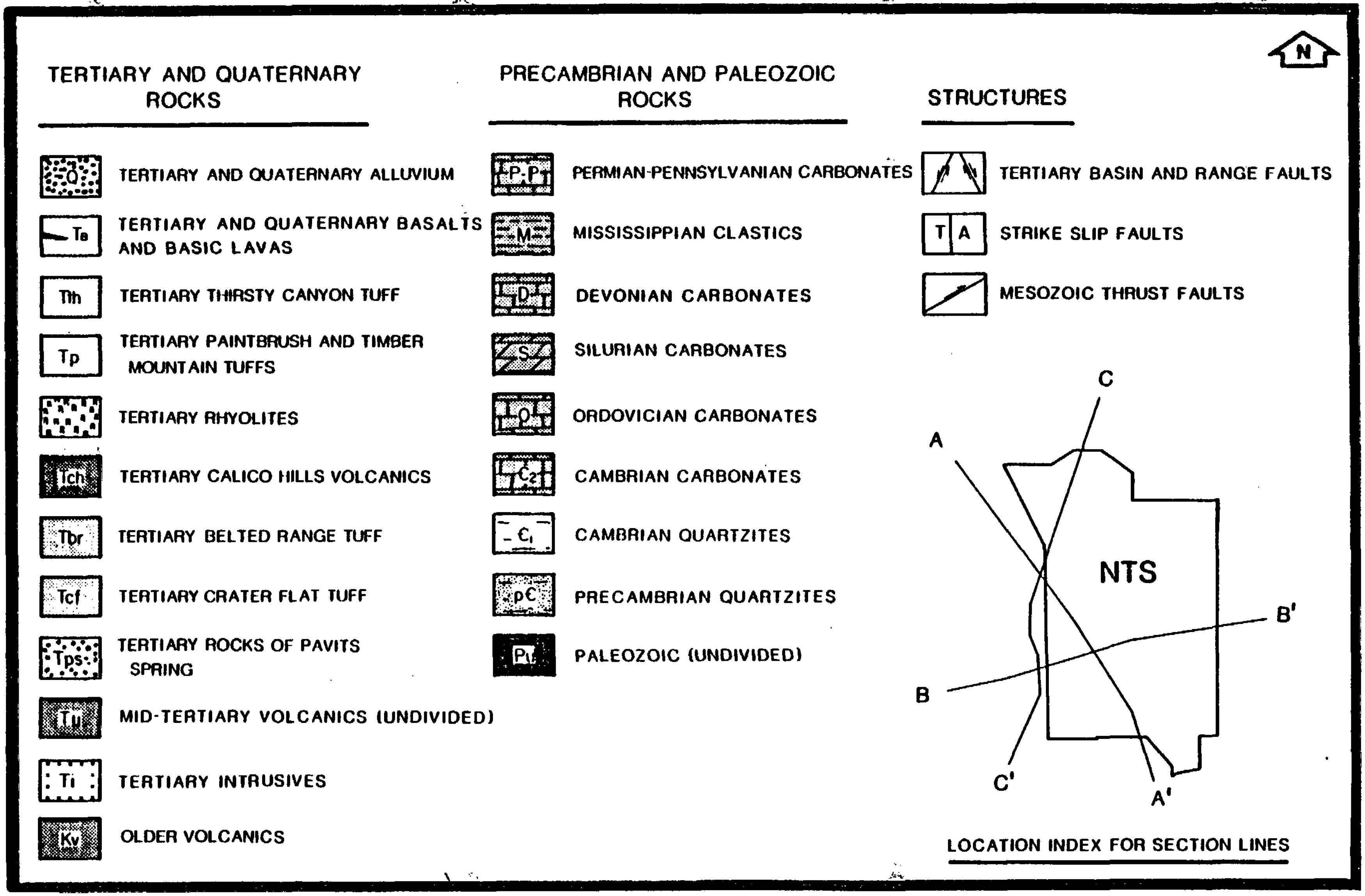


Figure 2-3b. Legend for cross sections of Figure 2-3a showing location of cross sections.

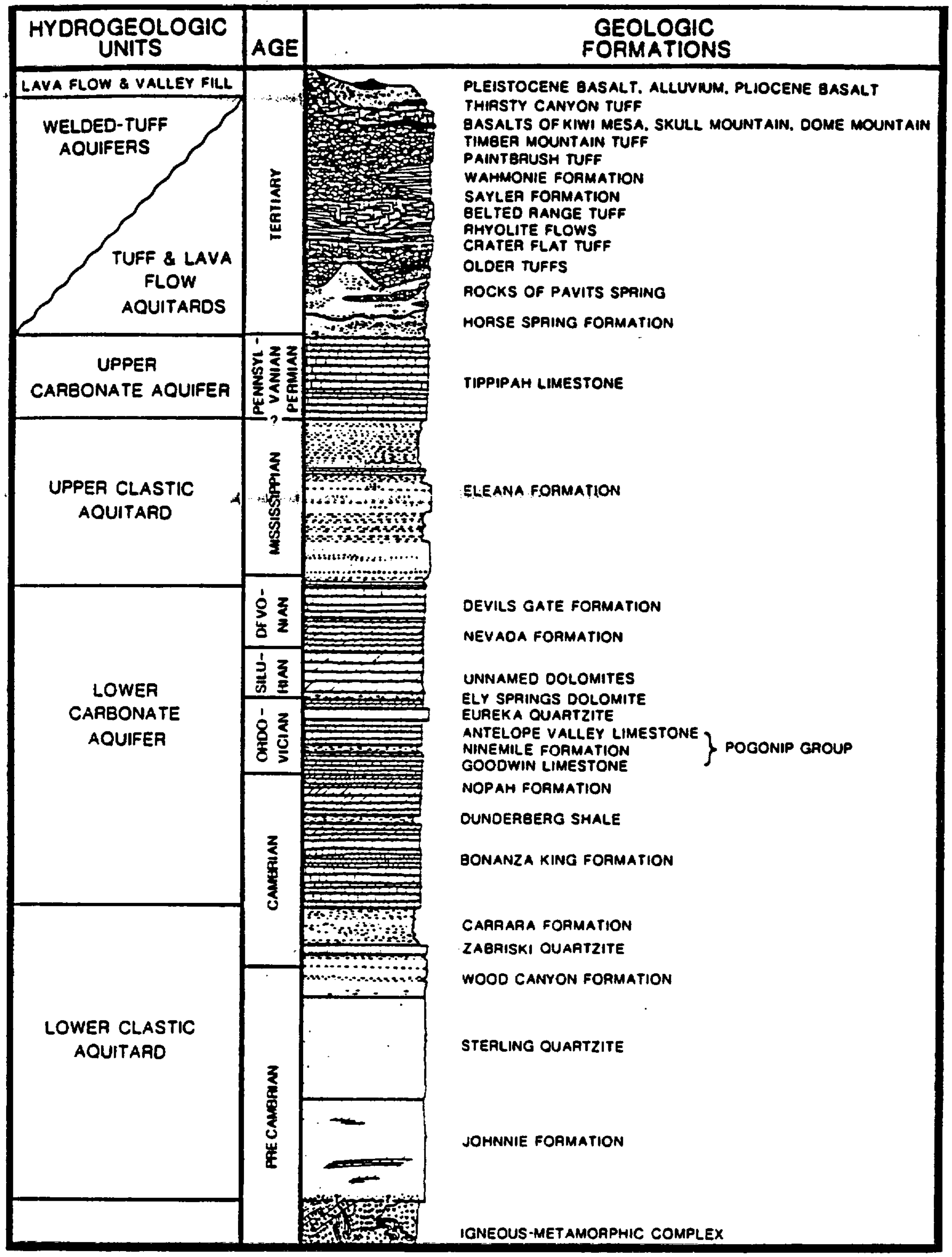


Figure 2-4. General relationships among hydrogeologic units and geologic formations in the southern Great Basin. (Modified from Sinnock, 1982.)

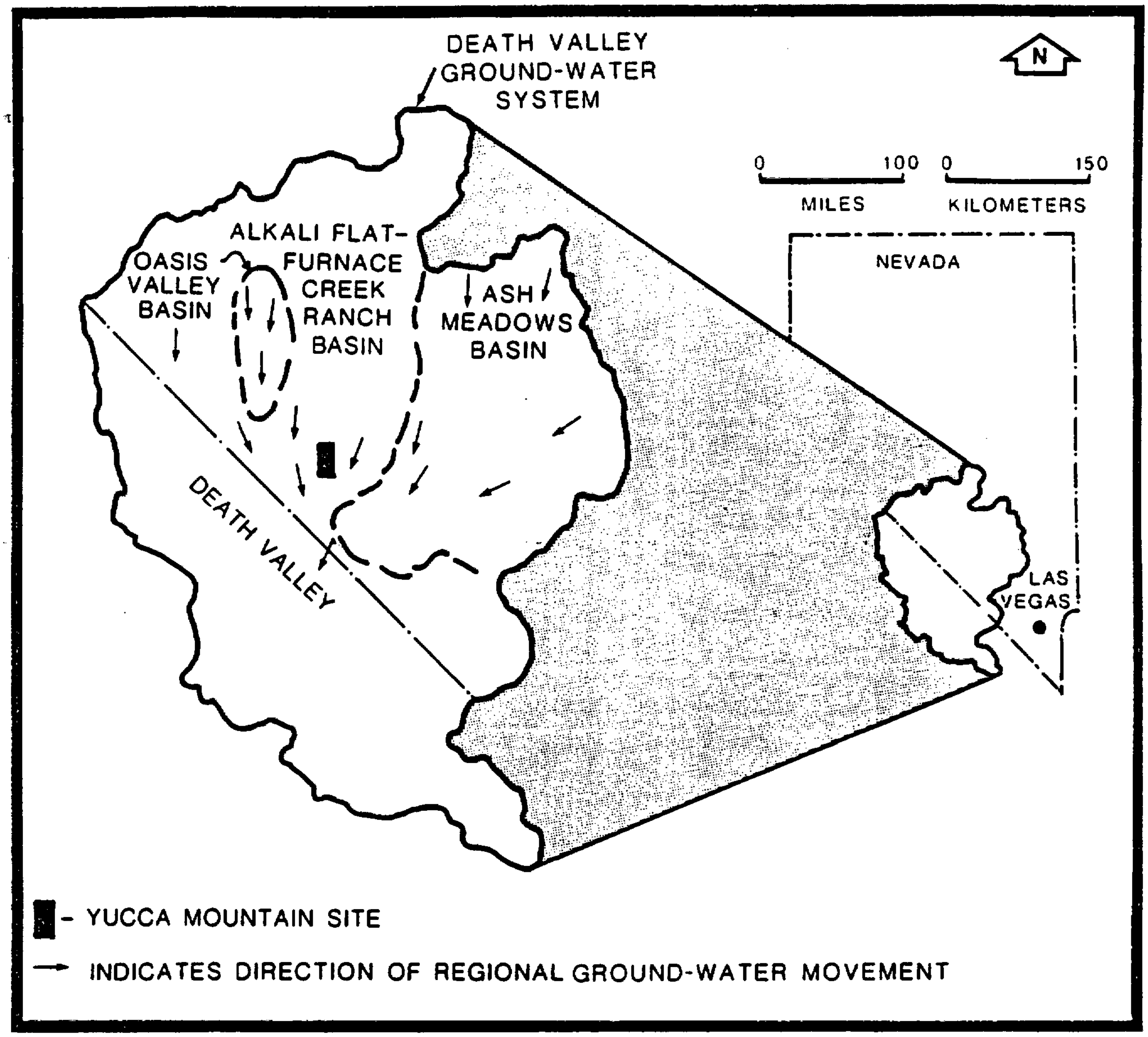


Figure 2-5. Location of Yucca Mountain site with respect to the basins of the Death Valley ground-water system.

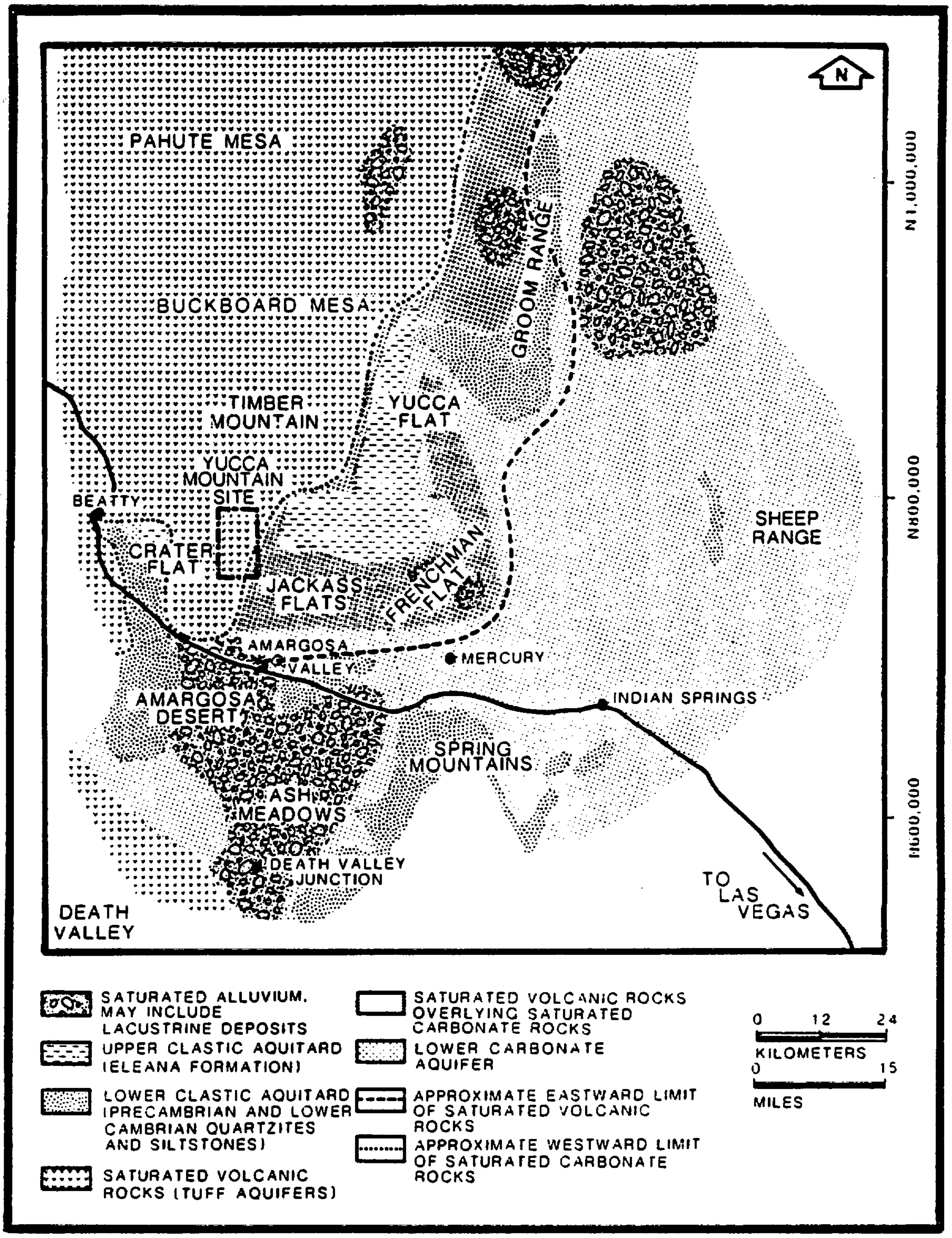


Figure 2-6. General distribution of the major aquifers and aquitards in the southern Great Basin near Yucca Mountain.

In summary, the southern Great Basin is generally characterized by sparse vegetation, low precipitation, few population centers, varied geology, and a hydrologic system that includes closed ground-water basins and a thick unsaturated zone which is thought, at the present time, to have little water movement. This section provides only the most general perspective on the overall setting from which Yucca Mountain was chosen from among other alternatives as discussed in the following section (Section 2.2). Detailed descriptions of Yucca Mountain and the surrounding region are provided in Chapters 3 and 6.

2.2 IDENTIFICATION OF YUCCA MOUNTAIN AS A POTENTIALLY ACCEPTABLE SITE

This section briefly summarizes the five step process by which Yucca Mountain and the Topopah Spring host rock were selected by the NNWSI Project for detailed study. The five steps, discussed in turn in the following subsections, are: (1) selection of the NTS (Section 2.2.1), (2) restriction of exploration to an area in and around the southwest NTS (Section 2.2.2), (3) selection of Yucca Mountain as the primary location for exploration (Section 2.2.3), (4) systematic reconsideration of potential locations in the southwest NTS (Section 2.2.4), and (5) selection of the target host rock for the repository (Section 2.2.5).

All steps in the selection process were completed before the Nuclear Waste Policy Act of 1982 (NWPA) was signed into law in January 1983. Accordingly, the selection of Yucca Mountain as a potentially acceptable site was not based on the DOE general siting guidelines (10 CFR Part 960). Nonetheless, the systematic screening studies of steps 4 and 5 used objectives very similar to those specified in the guidelines. ~~The identification of Yucca Mountain as a potentially acceptable site was consistent with the siting criteria formulated for the DOE's National Terminal Waste Storage (NWTS) Program (DOE, 1981) and is not inconsistent with 10 CFR Part 960.~~

2.2.1 Selection of the NTS as an area of investigation

The NWTS Program was established in 1976. During the early NWTS investigations, the prime geologic material of interest for a repository host rock was salt. Additional geologic host materials, including crystalline (granite, gneiss) and argillaceous rock (shale) were also considered. The initial approach to site screening was based on the occurrence of particular rock types and came to be known as the host-rock approach (DOE, 1982). In 1977, the program was expanded to consider prior land use as an alternative basis for initial screening. This prior land use approach considered the advantages of locating a repository on land already withdrawn and committed to long-term institutional control. Because the NTS was already dedicated to nuclear operations, it was a logical area for investigation for potential repository sites and formal consideration of the NTS for a repository location began at that time. The prior land use at the NTS establishes a firm reason for concluding that the government will continue to provide strict institutional control over future access to the site.

At the same time the NTS was being considered by the DOE on the basis of prior land use, the U.S. Geological Survey (USGS) proposed that the NTS also be considered for a number of geotechnical reasons. These geotechnical and other considerations identified later can be summarized as follows:

- Southern Nevada is characterized by closed hydrologic basins. This means that ground water does not discharge into rivers that flow to major bodies of surface water. It also means that the discharge points for the water can be clearly identified.

- The water table is at great depth (up to 600 m (2000 ft) below the surface). This provides the opportunity to build a repository in the unsaturated zone where the rock containing a repository would not generally release water to drill holes or tunnels. This lack of water would minimize: (1) corrosion of the waste canister, (2) dissolution of the waste form, and (3) transport of radionuclides from the repository.

- Long flow paths are present between potential repository locations and ground-water discharge points. Radionuclides would have to travel great distances before they could affect man and his surface environment. The corresponding time for travel to the accessible environment is long.

- Some of the geologic materials occurring on the NTS are highly sorptive. Radionuclides could be chemically or physically absorbed by rock and significantly slowed in their movement, making it extremely difficult for them to move in solution.

- The NTS is located in an arid region, with an annual rainfall of less than about 150 to 200 mm (6 to 8 in.). With the very low rate of recharge, the amount of moving ground water is also low, especially in the unsaturated zone.

By May 1977, the NWTS Program had undertaken evaluations of both the land-use and geological attributes of the NTS; the NNWSI Project was organized to consider the general suitability of the NTS for a repository and to identify locations, if any, on the NTS or adjacent areas that might be suitable for a repository. Figure 2-7 illustrates the various sites throughout the NTS initially considered.

2.2.2 Restriction of exploration to the southwestern part of the NTS and adjacent areas

The primary function of the NTS is to provide a testing ground for nuclear weapons. Figure 2-7 shows the past or current, and the proposed general areas dedicated to weapons testing. When the NWTS Program expanded its repository-exploration activities to include the NTS, a question arose concerning the compatibility of a repository with nuclear weapons testing. A task group was established to evaluate the conditions under which the weapons testing could fully function in the presence of a nearby repository. In August 1978, the Acting Assistant Secretary for Defense Programs of the Department of Energy formalized the task group's finding that locating a repository in certain areas of the NTS might hamper weapons testing. However, it was suggested that the southwestern portion of the NTS and adjacent offsite locations were acceptable for further investigation as potential waste-repository sites.

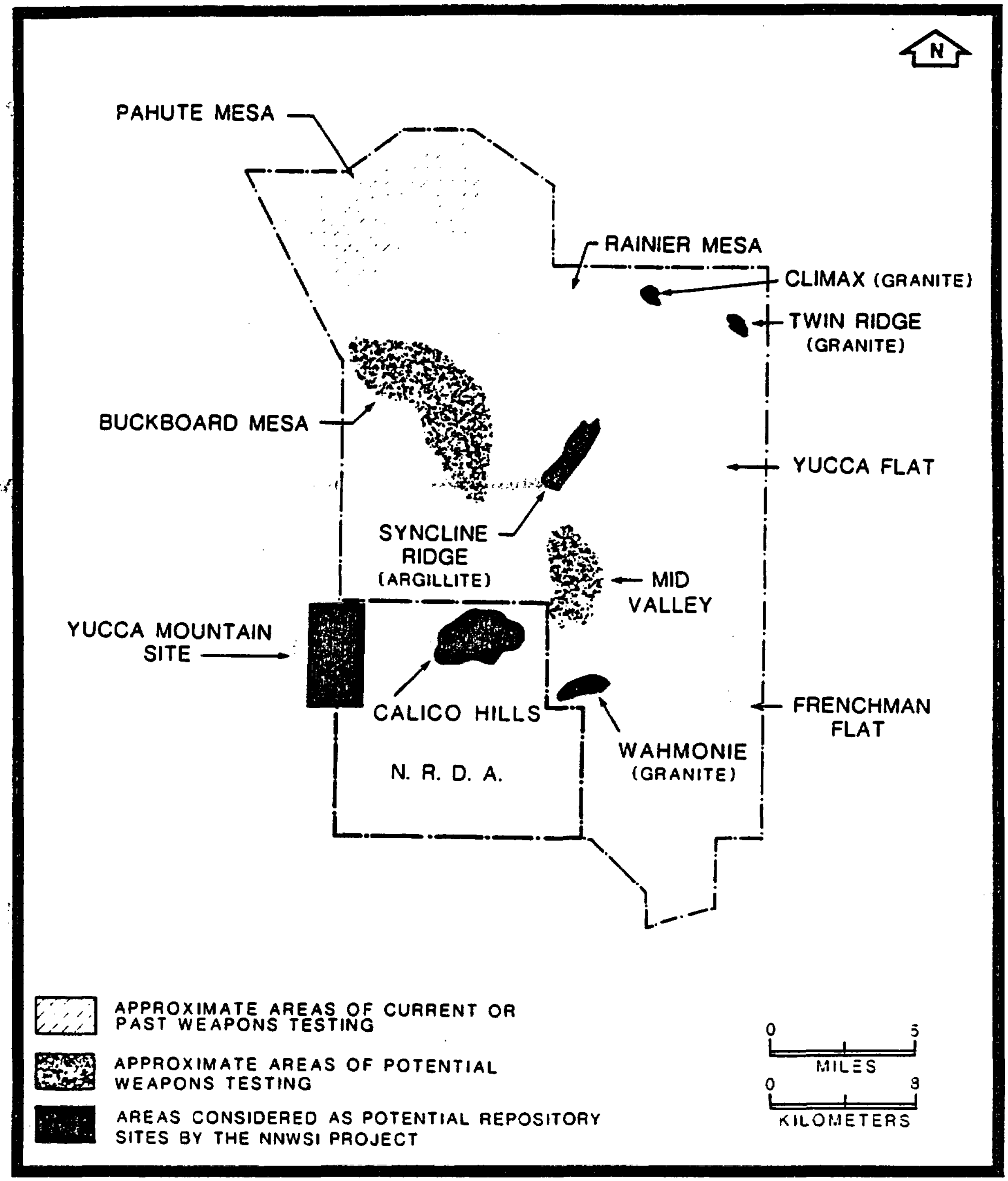


Figure 2-7. Past, current, or potential future weapons testing areas on the Nevada Test Site and areas initially considered for repository siting.

In 1977, the geologic medium of prime interest at the NTS was argillite. Argillite is present in the Eleana Formation, which underlies Syncline Ridge, a topographic feature along the west side of Yucca Flat (Figure 2-7). Geologic investigations there, including exploratory drilling, revealed a complex geologic structure in the center of the area being considered (Hoover and Morrison, 1980; Ponce and Hanna, 1982). It was concluded in July 1978 that the geologic complexity of Syncline Ridge would make characterization difficult, possibly so difficult that it could not be understood to the degree necessary to license a repository. At about the same time, the decision by the Assistant Secretary for Defense Programs included the Syncline Ridge area as unacceptable for a repository because of weapons testing. At this juncture, the program refocused on the area in and around the southwestern corner of the NTS. The portion of the redefined exploratory area that occurred on the NTS was subsequently named the Nevada Research and Development Area (NRDA) (Figure 2-7). The area being evaluated included some BLM land west and south of the NRDA and a portion of the Nellis Air Force Range west of the NRDA.

2.2.3 Selection of Yucca Mountain as the primary location for exploration

In August of 1978, a preliminary list of potential sites in and near the southwestern part of the NTS was compiled. The areas initially considered included Calico Hills, Skull Mountain, Wahmonie, Yucca Mountain, and Jackass Flats. Of these five areas, Calico Hills, Yucca Mountain, and Wahmonie were considered the most attractive locations for conducting preliminary borings and geophysical testing (Figure 2-7).

The Calico Hills location was of particular interest because an aeromagnetic survey showed that granite might occur approximately 500 m (1600 ft) below the surface. The first exploratory hole by the NNWSI Project in the southwest NTS was started in 1978 to explore for granite beneath the Calico Hills. At a depth of 900 m (3000 ft), drilling was discontinued without reaching granite (Maldonado et al., 1979). A high content of magnetite, discovered in a thick section of Eleana Argillite, was responsible for the aeromagnetic anomaly. The argillite was encountered throughout most of the drilling depth. Reevaluation of the geophysical data indicated that the granite is probably 1500 to 1600 m (5000 to 5300 ft) deep (Snyder and Oliver, 1981). Other geophysical surveys indicated that the thick section of argillite at Calico Hills and the adjacent areas is probably very complex structurally, similar to the situation at Syncline Ridge (Hoover et al., 1982). Because the granite was considered too deep and the argillite appeared too complex, further consideration of the Calico Hills was suspended in the spring of 1979.

Concurrent with drilling at Calico Hills, geophysical studies conducted at Wahmonie indicated that the granite, which occurs at the surface, would be only marginally large enough for a repository at the depth needed. These studies, plus surface mapping, also suggested that any granite within reasonable depths was probably altered by hydrothermal solutions (Smith et al., 1981; Hoover et al., 1982). Additionally, local surface deposits from a previous warm spring and the presence of faults indicated a potential for upward seepage of ground water, possibly from great depths. For these reasons, Wahmonie was eliminated from consideration in the spring of 1979.

In the summer and fall of 1978, the first exploratory hole was drilled at Yucca Mountain. This hole was drilled more than 600 m (2000 ft) deep and confirmed the presence of thick tuff beds containing highly sorptive material (Spengler et al., 1979). Preliminary surface mapping indicated the existence of generally undisturbed structural blocks possibly large enough for a repository. Because tuff previously had not been considered as a potential host rock for a repository, a presentation was made to the National Academy of Sciences (NAS) Committee for Radioactive Waste Management in September of 1978 to solicit its views on the potential advantages and disadvantages of tuff as a repository host rock. The concept of investigating tuff as a potential host rock was supported.

After comparing the results of preliminary exploration at Calico Hills, Wahmonie, and Yucca Mountain, the U.S. Geological Survey recommended, and the DOE concurred in April 1979, that attention be focused on Yucca Mountain. Immediately thereafter, in April, May, and July 1979, technical peer review meetings on (1) host-rock investigations, (2) geologic and hydrologic investigations, and (3) tectonic, seismic, and volcanic investigations, respectively, were held by the NNWSI Project.

These review meetings were attended by nationally known experts as well as prominent experts from Nevada. Before each meeting, the reviewers were provided with background information on specific NNWSI Project activities and overall goals. At the meetings, NNWSI Project participants made detailed presentations and answered questions posed by the reviewers. After each meeting, the review panel summarized its overall assessments and recommendations. The general consensus of the reviewers supported the DOE's decision to concentrate its Nevada exploration efforts on the tuffs of Yucca Mountain (DOE/NVO, 1980).

2.2.4 Confirmation of site selection by a formal system study

The foregoing process of selecting Yucca Mountain for early exploration was informal. A more thorough, formal analysis was begun in 1980 to evaluate whether Yucca Mountain was indeed appropriate for further exploration. This analysis was conducted in a manner compatible with the area-to-location phase of site screening described in the National Siting Plan (DOE, 1982), which was used by DOE before the NWPA and ensuing siting guidelines (10 CFR 960) were adopted.

The NNWSI Project screening activity is documented in five publications, each providing details about a separate element of the activity. The first (Sinnock et al., 1981) summarizes a method for screening the Nevada Test Site and contiguous areas for repository locations, documenting the proposed method before its application. The second (Sinnock and Fernandez, 1982) presents a summary description of the parameters used in the screening calculations and provides a detailed discussion of screening results. The last three (Sinnock and Fernandez, 1984; Sinnock et al., 1984; Sharp, 1984) provide detailed background material about, respectively, the performance objectives, physical attributes and associated quantitative criteria, and computer programs for rating alternative locations.

Many assumptions were quantified during the screening study, and the validity of the results and conclusions clearly depended on the reasonableness of these assumptions. The information in the referenced screening reports allows each assumption or set of assumptions to be traced to its effects on the results and conclusions. The remainder of this section contains an overview of the data and analyses contained in these reports.

The formal screening analysis (Sinnock and Fernandez, 1982) was applied to an area on and near the southwestern portion of the NTS (Figure 2-8). The analysis consisted of four basic elements:

1. Weighted performance objectives that identified ideal, or at least desired, site conditions.

2. Physical attributes of the screening area that distinguished the physical conditions of alternative locations and host rocks.

3. Favorability estimates that rated, on a relative scale of zero to ten, how well the physical conditions represented by each attribute satisfied each of the relevant objectives for assessing site performance (performance objectives).

4. Calculations of summary rating scores for alternative locations and host rocks based on how well the combined favorabilities of the attributes satisfied the performance objectives.

The performance objectives were organized in a three-tiered hierarchical tree (Table 2-1) which allowed site-specific objectives of the lowest level of the tree to be clearly tied to the broad goals of waste management (DOE, 1980) represented by the uppermost level of the tree (Sinnock and Fernandez, 1984). Each objective was correlated with existing criteria of the DOE and NRC to ensure that no relevant siting factors were overlooked (Table 2-2). A weight, or percentage describing relative importance, was assigned to each objective at each level of the tree to account for priorities within each level (see Figures 2-9a and 2-9b). The weights were obtained from a poll of experts familiar with nuclear waste management issues (Sinnock and Fernandez, 1984).

Each of the 31 attributes represented some physical condition that both (1) varied throughout the screening area and (2) might influence repository behavior (Sinnock et al., 1984). As Table 2-3 indicates, the attributes fall into two general categories, geographical (attributes 1-23) and host rock (attributes 24-31). A map of the screening area was prepared for each geographical attribute showing the distribution of physical conditions represented by that attribute. A value for appropriate rock properties was assigned to each candidate rock type for each host-rock attribute.

Favorability estimates for the various physical conditions represented by each of the attributes were compiled as graphs (Figure 2-10). These graphs constituted quantitative screening criteria by which the relevant physical attributes of the screening area were compared with the objectives. The attributes used to evaluate locations with respect to each of the lower level objectives were also weighted to allow the relative importance of various types of physical conditions to be distinguished (Table 2-4).

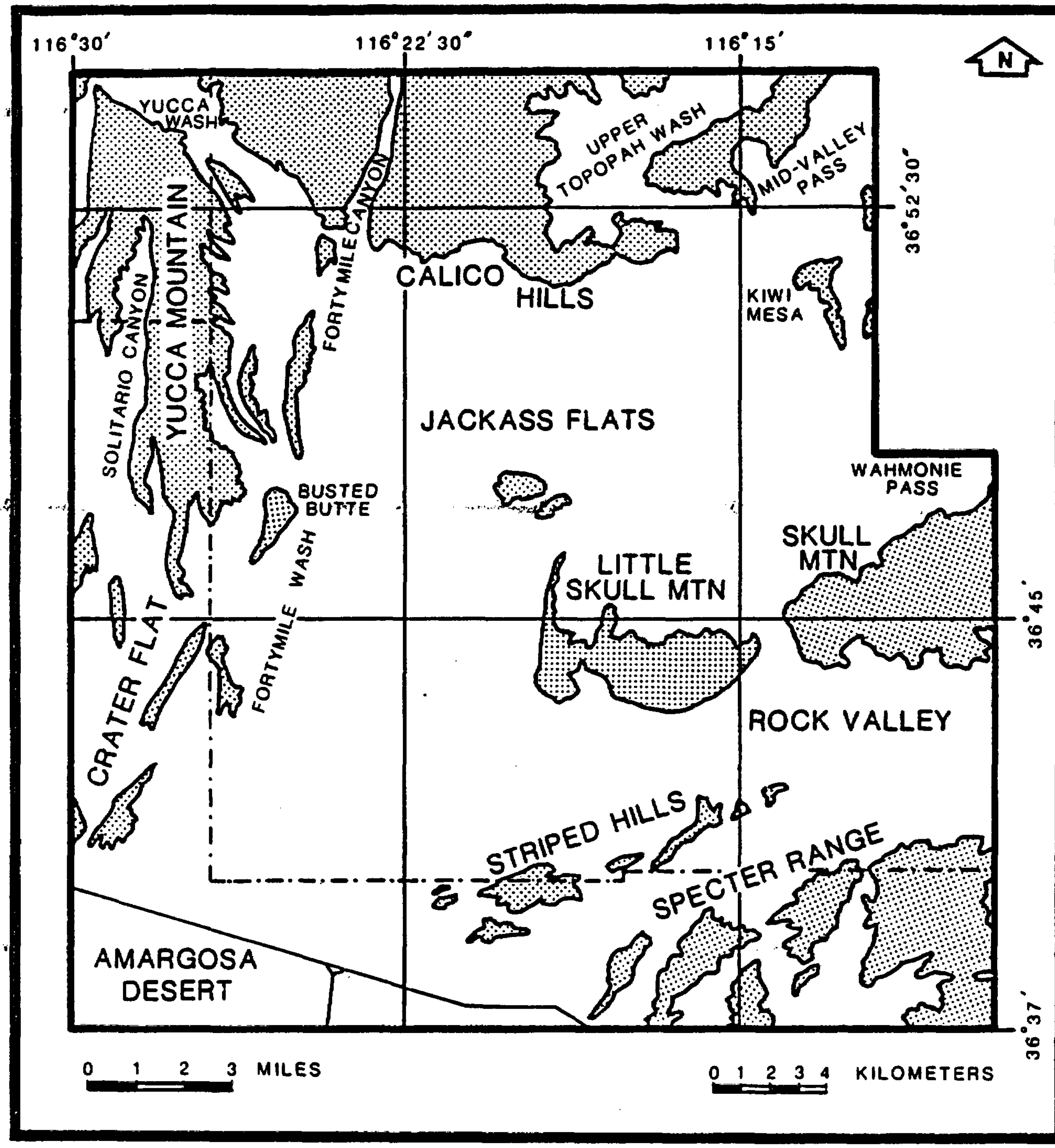


Figure 2-8. Map of the area on and adjacent to the Nevada Test Site within which screening for repository locations was conducted. Figures 2-11 and 2-12 show the results of screening analyses displayed on this base map.

Table 2-1. Three-tiered hierarchical arrangement of objectives used in site screening by the NNWSI Project[a]

1.0 Identify locations that permit adequate radionuclide containment in a sealed repository

- 1.1 Screen for natural systems with maximum potential to resist waste-package disruption processes
  - 1.1.1 Minimize potential for chemically induced release
  - 1.1.2 Minimize potential for mechanically induced release
- 1.2 Screen for natural systems with minimum potential for waste-package disruption processes
  - 1.2.1 Minimize the potential for seismic hazards to containment in a sealed repository
  - 1.2.2 Minimize the potential for erosional disruption of waste packages
  - 1.2.3 Minimize the potential for volcanic disruption of waste packages
  - 1.2.4 Minimize the potential for inadvertent human intrusion into a sealed repository
  - 1.2.5 Minimize the potential for events that might disrupt containment

2.0 Identify locations that permit adequate isolation of radioactive waste from the biosphere

- 2.1 Screen for natural systems that will retard migration of radionuclides
  - 2.1.1 Maximize ground-water flow time to the accessible environment
  - 2.1.2 Maximize retardation of radionuclides along flow paths
  - 2.1.3 Maximize extent of relatively homogeneous host rock
  - 2.1.4 Maximize migration times of volatile radionuclides
- 2.2 Screen for natural systems with minimum potential for adverse changes to existing radionuclide migration and retardation processes
  - 2.2.1 Minimize the potential for adverse impacts due to tectonic changes
  - 2.2.2 Minimize the potential for adverse impacts due to climatic changes
  - 2.2.3 Minimize the potential for adverse impacts due to geomorphic changes
  - 2.2.4 Minimize the potential for adverse impacts due to human activities
  - 2.2.5 Minimize the potential for miscellaneous events that might disrupt isolation

3.0 Identify locations where safe repository construction, operation, and decommissioning can be cost-effectively implemented

- 3.1 Screen for locations compatible with surface facility construction and safe operation
  - 3.1.1 Minimize seismic hazards to surface facilities
  - 3.1.2 Minimize cost of surface monitoring system
  - 3.1.3 Minimize adverse foundation conditions
  - 3.1.4 Minimize wind loading on surface structures
  - 3.1.5 Minimize flooding hazards to surface facilities
  - 3.1.6 Ensure availability of resources to construct and operate the repository

Table 2-1. Three-tiered hierarchical arrangement of objectives used in site screening by the NNWSI Project (continued)

- 3.2 Screen for locations suitable for subsurface facility construction and safe operation
  - 3.2.1 Minimize seismic hazards to subsurface facilities
  - 3.2.2 Minimize flooding hazards to subsurface facilities
  - 3.2.3 Minimize adverse mining conditions
  - 3.2.4 Optimize the geometry (thickness and lateral extent) of the host rock
  - 3.2.5 Optimize host-rock homogeneity
  - 3.2.6 Maximize compatibility of the host rock with standardized waste package
- 3.3 Screen for locations with characteristics compatible with safe radioactive-waste transportation to a repository
  - 3.3.1 Minimize adverse terrain along potential waste-transportation routes
  - 3.3.2 Optimize distance from existing transportation corridors

4.0 Identify locations for which environmental impacts can be mitigated to the extent reasonably achievable
- 4.1 Minimize or avoid adverse impacts on or from sensitive biotic systems
- 4.2 Minimize impacts on abiotic systems
  - 4.2.1 Minimize impacts on surface geology
  - 4.2.2 Minimize impacts on water quality and availability
  - 4.2.3 Minimize impacts on air quality
- 4.3 Minimize adverse impacts on the existing socioeconomic status of individuals in the affected area
  - 4.3.1 Minimize adverse impacts on local economies
  - 4.3.2 Minimize adverse impacts on life styles
  - 4.3.3 Minimize conflicts with private land use
- 4.4 Reduce impacts on institutional issues
  - 4.4.1 Cooperate with State and local officials
  - 4.4.2 Carefully implement Federal regulations
- 4.5 Minimize adverse impacts on significant historical and prehistoric cultural resources

[a] Source: Sinnock and Fernandez, 1982.

Table 2-2. Objectives used for site screening by the NNWSI Project and the DOE and NRC criteria existing at the time of screening[a]

NNWSI screening objectives		Comparable national criteria	
Number and title	NWTS 33(1) (DOE, 1981a)	NWTS 33(2) (DOE, 1981b)	10 CFR Part 60 (July 1981 proposed rule)
1.0 CONTAINMENT	3.1.2, 3.2.2(1), 4.2	3.2(par. 1), 3.4(par. 1), 3.3(par. 1)	60.111(b)(2)(i), 60.111(b)(2)(ii)(A), 60.111(b)(3)(i)
1.1 <u>Processes</u>		3.4(2)	
1.1.1 Chemical release		3.3(1), 3.4(2), 3.2(1), 3.2(4)	60.123(b)(5), 60.123(b)(13-14)
1.1.2 Mechanical release		3.4(2)	60.123(b)(15), 60.132(k)(1)
1.2 <u>Events</u>		3.5(par. 1), 3.5(1)	60.123(a)(7), 60.123(b)(6,7,10)
1.2.1 Seismic		3.5(2), 3.5(5)	60.112(a), 60.123(a)(5), 60.123(b)(9)
1.2.2 Erosion		3.5(4)	60.112(b), 60.122(i), 60.123(b)(4)
1.2.3 Volcanic		3.5(3)	60.112(a), 60.123(b)(11)
1.2.4 Human intrusion	3.2.2(3), 3.3.2(4)	3.6(par. 1), 3.6(2)	60.123(b)(1-3)
1.2.5 Miscellaneous	2.3		60.122(j)
2.0 ISOLATION	2.1, 3.1.2, 3.2.2(2), 4.2	3.4(par. 1), 3.1(par. 1), 3.2(par. 1), 3.3(par. 1)	60.111(b)(1), 60.111(b)(3)(ii)
2.1 <u>Nuclide migration</u>			
2.1.1 Groundwater flow time		3.2(1), 3.2(2)	60.112(c), 60.122(c), 60.122(f)(1-4)
2.1.2 Nuclide Retardation		3.3(1)	60.122(d), 60.122(g)(1-3), 60.122(h), 60.123(b)(13-15)
2.1.3 Host-rock homogeneity			
2.1.4 Volatile migration			
2.2 <u>Changes to existing systems</u>		3.5(par. 1), 3.5(1)	60.123(a)(7), 60.123(b)(7,12)
2.2.1 Tectonic		3.5(2-5)	60.112(a), 60.122(a,b), 60.123(a)(5), 60.123(b)(6,8,10,11)
2.2.2 Climatic		3.2(1)	60.112(b), 60.123(a)(8)
2.2.3 Geomorphic		3.1(1), 3.5(4)	60.112(b), 60.122(e,i), 60.123(b)(4)
2.2.4 Human activities	3.3.2(4)	3.6(par. 1), 3.6(2)	60.123(a)(3), 60.123(b)(1-3), 60.133(a)
2.2.5 Miscellaneous		3.4(1)	60.122(j)
3.0 CONSTRUCTION	3.1.1, 3.3.1, 4.1		60.111(a)(1,2), 60.130(b)(1), 60.130(b)(2)(ii), 60.131(e)
3.1 <u>Surface facilities</u>	3.2.1	3.7(par. 1)	60.123(a)(6), 60.131(a), 60.131(c)(1)
3.1.1 Seismic Hazards		3.5(5)	60.123(a)(4), 60.123(b)(9,10)
3.1.2 Monitoring and characterization costs	3.3.2(3)	3.7(2)	60.130(9), 60.131(c)(2)
3.1.3 Foundation conditions		3.7(2)	
3.1.4 Wind loads		3.7(3)	
3.1.5 Flooding		3.7(1)	60.123(a)(1)
3.1.6 Net resource availability	2.6	3.7(4), 3.10(2)	
3.2 <u>Subsurface facilities</u>	3.1.2, 3.3.2(2)	3.4(3)	60.123(b)(16), 60.130(10), 60.132(a)(1,4), 59.133(b)(4,5)
3.2.1 Seismic hazard		3.5(5)	60.123(a)(4), 60.123(b)(9,10)
3.2.2 Flooding		3.2(3)	60.122(f)(3), 60.132(a)(2), 60.132(i)(1), 60.132(g)(1,5)
3.2.3 Mining conditions		3.4(3)	60.123(b)(15,17), 60.132(a)(2), 60.132(e)(1,3), 60.132(f)
3.2.4 Host-rock geometry		3.1(par. 1), 3.1(2)	60.122(1), 60.132(a)(3)
3.2.5 Host-rock homogeneity		3.4(3)	
3.2.6 Waste-package compatibility	3.4.1, 3.4.2, 3.3.2(1,2)		60.132(a)(1,3), 60.132(i)(2), 60.135(a)(1,2), 60.135(c)(3)
3.3 <u>Transportation</u>			
3.3.1 Terrain		3.8(2)	
3.3.2 Distance		3.7(2)	
4.0 ENVIRONMENT	4.3	3.9(par. 1), 3.9.1, 3.9(2)	60.130(b)(2)(i)
4.1 <u>Sensitive biotic systems</u>			
4.2 <u>Abiotic systems</u>			
4.2.1 Geologic quality		3.9(1)	
4.2.2 Water quality		3.9(1)	
4.2.3 Air quality		3.9(1)	
4.3 <u>Socioeconomics</u>		3.8(par. 1), 3.10(par. 1)	
4.3.1 Local economies		3.10(1)	
4.3.2 Life styles			
4.3.3 Private land use		3.6(2)	60.121(a)
4.4 <u>Institutional issues</u>	2.2	3.9(2)	60.121(b)
4.4.1 State issues		3.6(2), 3.9(2)	
4.4.2 Federal regulation	4.1.1, 4.1.2	3.9(2)	
4.5 <u>Historic and prehistoric resources</u>		3.9(1)	

[a] Source: Sinnock and Fernandez, 1982.

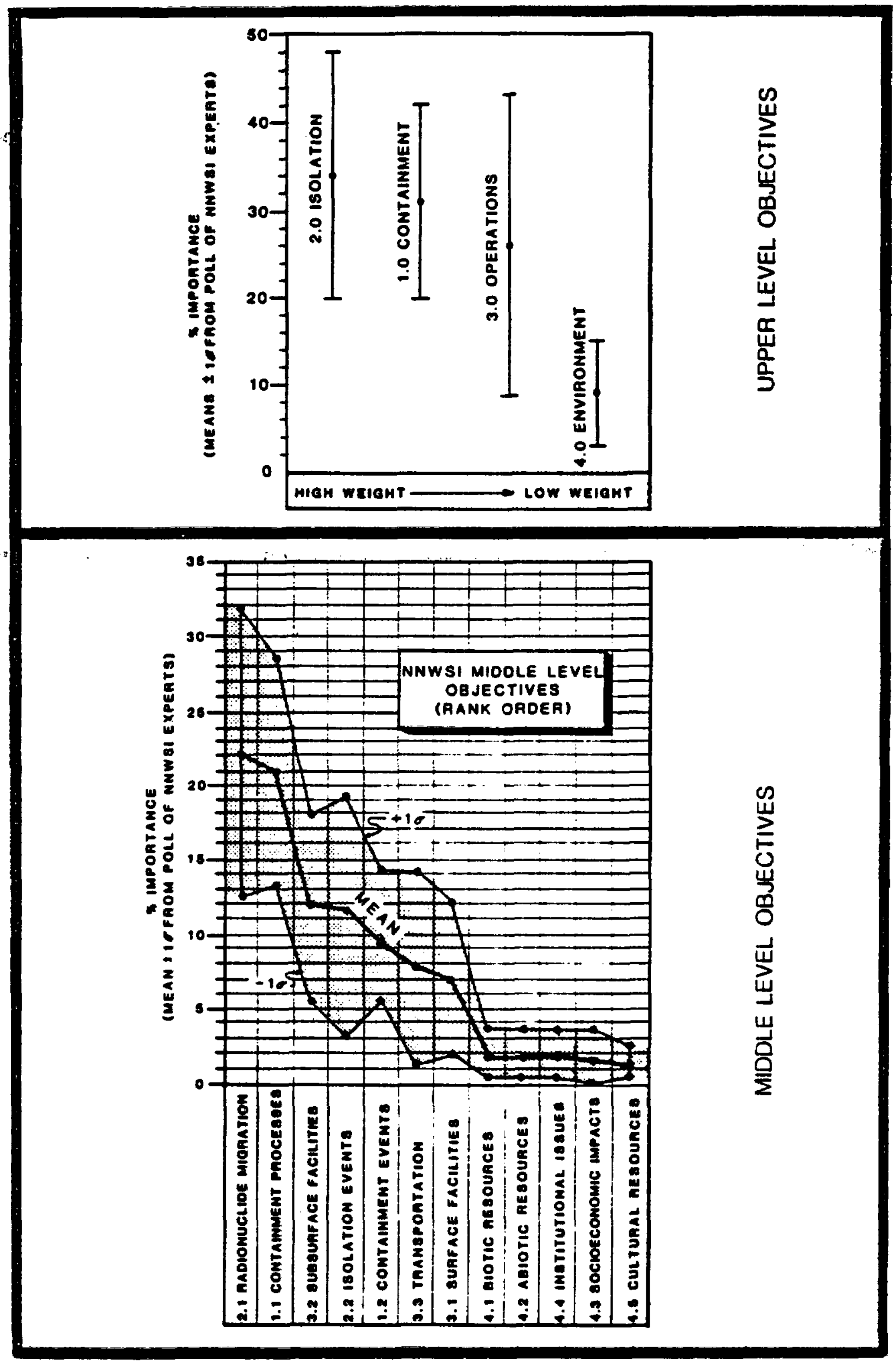


Figure 2-9a. Upper (upper diagram) and middle level (lower diagram) site screening objectives of the NNWSI Project ranked by weight for each level of the objectives tree. Weights and standard deviations (shading, brackets) were obtained from a poll of NNWSI Project participants. (Source: Sinnock and Fernandez, 1982.)

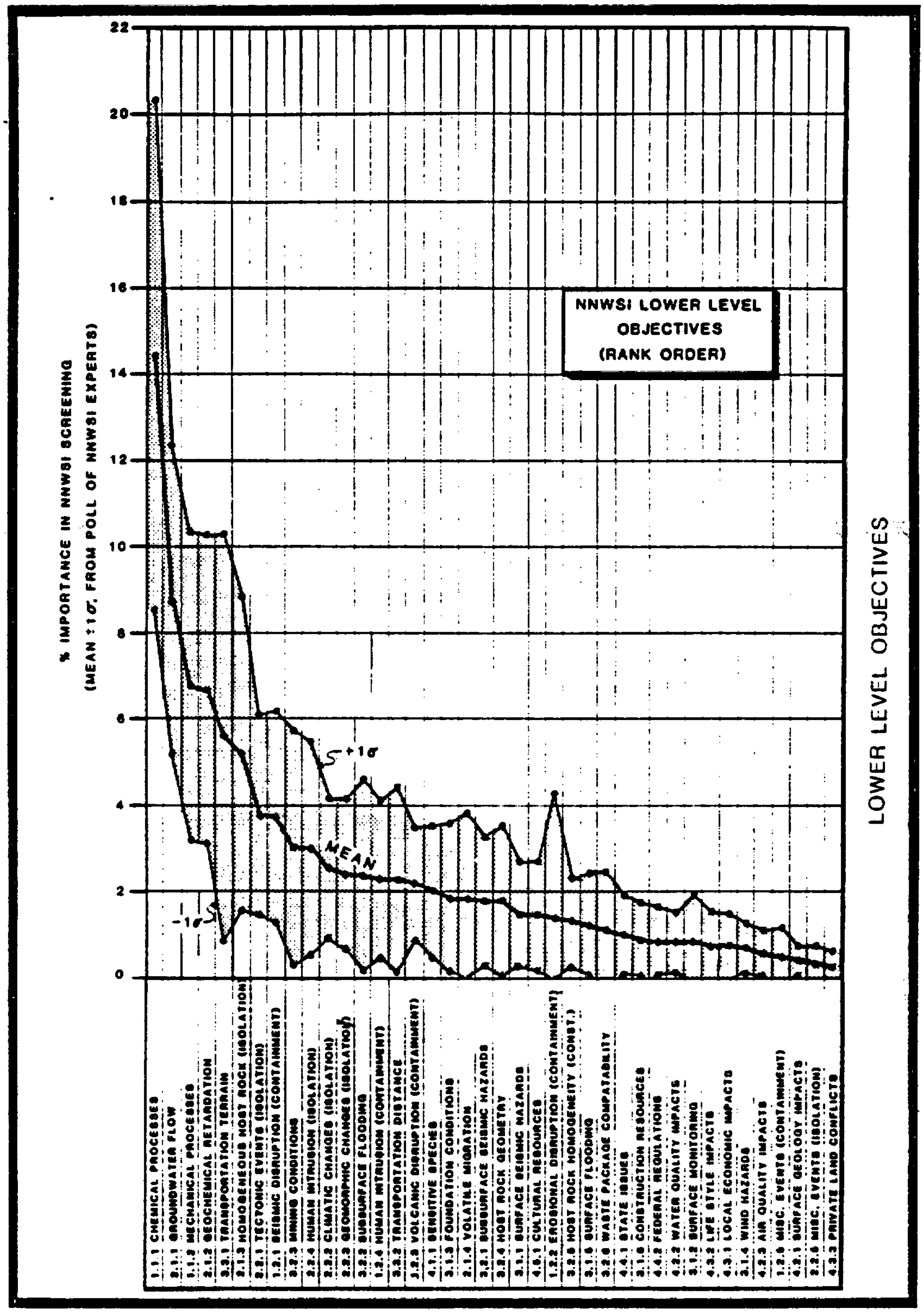


Figure 2-9b. Lower level site screening objectives of the NNWSI Project ranked by weight for each level of the objective tree. Weights and standard deviations (shading, brackets) were obtained from a poll of NNWSI Project participants. (Modified from Sinnock and Fernandez, 1982.)

Table 2-3. Physical attributes used to discriminate among alternative locations within the screening area[a]

No.	Attribute	Discriminating conditions
		GEOGRAPHICAL ATTRIBUTES
1	Volcanic potential	Relative potential for basaltic eruptions
2	Fault density	Relative density of faults and fractures
3	Fault trend	Relative potential for fault movement
4	Age of faulting	Fault ages
5	Natural seismic potential	Expected ground acceleration (g)
6	Weapons seismic potential	Expected ground acceleration (g)
7	Bed attitude	Amount of rock dip (degrees)
8	Erosion potential	Projected erosional intensity
9	Flood potential	Flood hazards
10	Terrain ruggedness	Slope steepness (%)
11	Resource potential	Potential for undiscovered metal ores
12	Ground-water resources	Potential for development of ground-water supplies
13	Ground-water flux	Saturated ground-water flux (m^3/s)
14	Ground-water flow direction	Upgradient distance from potential production areas
15	Thickness of unsaturated zone	Depth to water table
16	Sensitive floral species	Potential for the occurence of sensitive species
17	Sensitive faunal species	Likely species habitats
18	Revegetation potential	Vegetation assemblages
19	Known cultural resources	Types and sites of cultural resources
20	Potential cultural resources	Potential density of undiscovered cultural resources
21	Air pollution potential	Air quality zones
22	Permitting difficulties	Land ownership and control
23	Private land use	Private and nonprivate land
		HOST ROCK ATTRIBUTES
24	Thermal conductivity	Thermal conductivity (W/m-K)
25	Compressive strength (containment)	Unconfined compressive strength (psi)
26	Compressive strength (construction)	Unconfined compressive strength (psi)
27	Expansion or contraction	Expansion or contraction behavior on heating
28	Mineral stability	Mineral stability on heating
29	Stratigraphic setting	Stratigraphically weighted sorption potential
30	Hydraulic retardation	Potential for radionuclide diffusion into the rock matrix
31	Hydraulic transmissivity	Hydraulic transmissivity (m^2/s)

[a] Source: Sinnock and Fernandez, 1982.

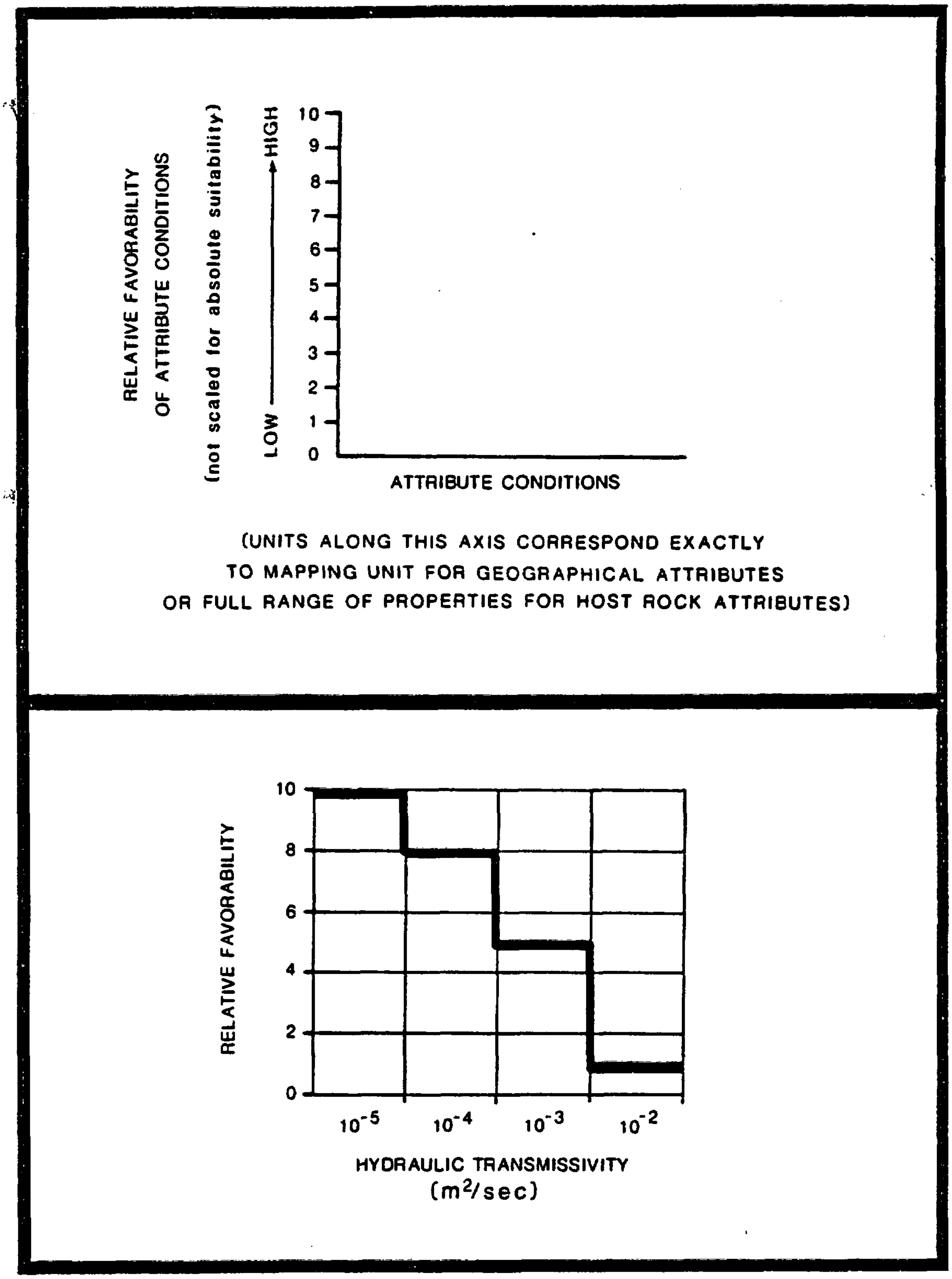


Figure 2-10. General form (upper left) of favorability estimates used to link the attributes to objectives. A specific example for attribute 31, hydraulic transmissivity, is shown on the lower right. (Source: Sinnock and Fernandez, 1982.)

Table 2-4. Attribute-level III objective matrix with weights assigned to attributes[a,b]

	Attributes	1.1.1 Chemical	1.1.2 Mechanical	1.2.1 Seismic	1.2.2 Erosional	1.2.3 Volcanic	1.2.4 Human intrusion	1.2.5 Miscellaneous	2.1.1 Ground-water flow	2.1.2 Nuclide retardation	2.1.3 Host rock thickness	2.1.4 Volatile migration	2.2.1 Tectonic	2.2.2 Climatic	2.2.3 Geomorphic	2.2.4 Human induced	2.2.5 Misc. & complexity
Level 1		1.0 Provide containment (31%)							2.0 Provide isolation (34%)								
Level 2		1.1 Disruptive processes (68%)		1.2 Disruptive events (32%)					2.1 Radionuclide migration (65%)				2.2 Disruptive events (35%)				
Geographical	1. Volcanic potential			5		100							40				
	2. Fault density	5							5			10					50
	3. Fault trend			5									10				
	4. Age of faulting			30									10				
	5. Natural seismic potential			60									40				
	6. Weapons seismic potential							100								10	
	7. Bed attitude rock dip																30
	8. Erosion potential				100										80		
	9. Flood potential														10		
	10. Terrain ruggedness														10		20
	11. Base & precious metal resource potential						50									45	
	12. Ground-water resource potential						50									45	
	13. Ground-water flux	5							10	10							
	14. Ground-water flow direction								30								
	15. Thickness of unsaturated zone								5					100			
	16. Sensitive floral species																
	17. Sensitive faunal species																
	18. Revegetation potential																
	19. Known cultural resources																
	20. Potential cultural resources																
	21. Air pollution potential																
	22. Permitting difficulties																
	23. Private land use																
Host rock	24. Thermal conductivity	20	30														
	25. Compressive strength (containment)		40								20						
	26. Compressive strength (construction)																
	27. Expansion-contraction		20														
	28. Mineral stability	10	10							10		5					
	29. Stratigraphic setting									70	80	30					
	30. Hydraulic retardation								10	10		15					
	31. Hydraulic transmissivity	60							40			40					

Table 2-4. Attribute-level III objective matrix with weights assigned to attributes (continued)

LEVEL 1: 3.0 PROVIDE SAFE, COST EFFECTIVE CONSTRUCTION & OPERATIONS (25%)

	LEVEL 2	3.1 SURFACE FACILITIES (27%)						3.2 SUBSURFACE FACILITIES (43%)						3.3 TRANSPORTATION SYS. (30%)	
	LEVEL 3 / ATTRIBUTES	3.1.1 SEISMICITY	3.1.2 MONITORING RQMT'S	3.1.3 FOUNDATION COND.	3.1.4 WIND LOADS	3.1.5 FLOODING	3.1.6 AVAIL. NAT. RES.	3.2.1 SEISMICITY	3.2.2 FLOODING	3.2.3 MINING COND.	3.2.4 HOST ROCK GEOM.	3.2.5 HOST ROCK DIMNS.	3.2.6 WASTE PKG. ACCEPT.	3.3.1 TERRAIN	3.3.2 EXISTING CORRIDOR
GEOGRAPHICAL	1. VOLCANIC POTENTIAL														
	2. FAULT DENSITY							10	10	20		50			
	3. FAULT TREND														
	4. AGE OF FAULTING														
	5. NATURAL SEISMIC POTENTIAL	90						85							
	6. WEAPONS SEISMIC POTENTIAL	10						5							
	7. BED ATTITUDE (ROCK DIP)										100	40			
	8. EROSION POTENTIAL			10											
	9. FLOOD POTENTIAL			20		100			5					30	
	10. TERRAIN RUGGEDNESS		70	70										70	
	11. BASE & PRECIOUS METAL RESOURCE POTENTIAL											10			
	12. GROUND-WATER RESOURCE POTENTIAL														
	13. GROUND-WATER FLUX								15						
	14. GROUND-WATER FLOW DIRECTION								10	10					
	15. THICKNESS OF UNSATURATED ZONE														
	16. SENSITIVE FLORAL SPECIES		3												
	17. SENSITIVE FAUNAL SPECIES		7												
	18. REVEGETATION POTENTIAL														
	19. KNOWN CULTURAL RESOURCES		5												
	20. POTENTIAL CULTURAL RESOURCES		15												
	21. AIR POLLUTION POTENTIAL														
	22. PERMITTING DIFFICULTIES														
	23. PRIVATE LAND USE														
HOST ROCK	24. THERMAL CONDUCTIVITY									10			20		
	25. COMPRESSIVE STRENGTH (CONTAINMENT)														
	26. COMPRESSIVE STRENGTH (CONSTRUCTION)									40					
	27. EXPANSION-CONTRACTION												40		
	28. MINERAL STABILITY									10			40		
	29. STRATIGRAPHIC SETTING														
	30. HYDRAULIC RETARDATION														
	31. HYDRAULIC TRANSMISSIVITY								60	10					

Table 2-4. Attribute-level III objective matrix with weights assigned to attributes (continued)

LEVEL 1: 4.0 PROVIDE ACCEPTABLE ENVIRONMENTAL IMPACTS (9%)

	LEVEL 2	4.1 BIOTIC SYS. (22%)	4.2 ABIOTIC SYS. (21%)			4.3 SOCIO-ECONOMIC IMPACTS (20%)			4.4 INSTITUTIONAL IMPACTS (21%)		4.5 CULT. RES. (16%)
	LEVEL 3	4.1.1 SENSITIVE SYS.	4.2.1 SURFACE GEOLOGY	4.2.2 WATER QUALITY	4.2.3 AIR QUALITY	4.3.1 LOCAL ECONOMIES	4.3.2 LIFE STYLES	4.3.3 LAND USE	4.4.1 STATE ISSUES	4.4.2 FEDERAL REGS.	4.5.1 ARCH. & HIST. SITES
	ATTRIBUTES										
GEOGRAPHICAL	1. VOLCANIC POTENTIAL										
	2. FAULT DENSITY										
	3. FAULT TREND										
	4. AGE OF FAULTING										
	5. NATURAL SEISMIC POTENTIAL										
	6. WEAPONS SEISMIC POTENTIAL										
	7. BED ATTITUDE (ROCK DIP)										
	8. EROSION POTENTIAL										
	9. FLOOD POTENTIAL		50								
	10. TERRAIN RUGGEDNESS		50								
	11. BASE & PRECIOUS METAL RESOURCE POT										
	12. GROUND-WATER RESOURCE POTENTIAL			100							
	13. GROUND-WATER FLUX										
	14. GROUND-WATER FLOW DIRECTION										
	15. THICKNESS OF UNSATURATED ZONE										
	16. SENSITIVE FLORAL SPECIES	40									
	17. SENSITIVE FAUNAL SPECIES	50									
	18. REVEGETATION POTENTIAL	10									
	19. KNOWN CULTURAL RESOURCES										30
	20. POTENTIAL CULTURAL RESOURCES										70
	21. AIR POLLUTION POTENTIAL				100						
	22. PERMITTING DIFFICULTIES									100	
	23. PRIVATE LAND USE							100			

[a]Source: Sinnock and Fernandez, 1982.

[b]Weights assigned to each geolographical and host rock attribute for evaluating site conditions with respect to each lower level objective. Three-tiered hierarchy is given in Table 2-1: percent importance for upper (I), middle (II), and lower (III) level objectives on Figures 2-9a and 2-9b; discriminating conditions for geographical and host rock attributes in Table 2-3; and weights assigned to lower level (III) objectives given in Table 2-5.

The objectives, attributes, favorability graphs, weights, and a base map of the screening area were digitized on a computer graphics system. Computer software was developed to calculate the relative favorability for each of 1514 half-mile centered grid cells of the base map and for each of nine candidate rock types (Sharp, 1984). In these calculations, the favorability value of each attribute for each grid cell or host rock, as appropriate, was first multiplied by the weight of the attribute (Table 2-4 shows the weights assigned to each attribute). The resulting numbers were then multiplied by the weights of the appropriate lower-level objectives (Table 2-5) and added together for a total rating score for each of the 1514 grid cells and for each rock type. Finally, the total scores were scaled to a maximum of 100,000.

Results of the calculations were displayed as maps showing ratings of all 1514 grid cells (Figure 2-11a) and as lists showing host-rock ratings for both saturated and unsaturated conditions (Figure 2-11b) (Sinnock and Fernandez, 1982). Grid cell ratings shown on the maps were grouped into high, intermediate, and low favorability categories. These categories correspond, respectively, to scores of greater than one standard deviation above the average, within one standard deviation of the average, and greater than one standard deviation below the average (Figure 2-11b). The histogram at the top of Figure 2-11b shows the range of scores from which the average and standard deviation were calculated. Figure 2-11a shows ratings obtained independently for grid cells and host rocks (Figure 2-11b) when all objectives and associated attributes were used to calculate the scores. Figure 2-12 shows the ratings obtained by adding the score of the highest rated rock type occurring beneath the surface at each grid cell to the scores of the grid cells represented on the map of Figure 2-11a. Since some localities within the screening area are not underlain by any of the nine rock types evaluated, their score for rock type was zero and hence the total scores of these grid cells were relatively low, as shown by the histogram at the top of Figure 2-11b.

Figures 2-11a, 2-11b, and 2-12 show the results of only two of 19 separate analyses that were performed. The other 17 were based on selected subsets of related objectives or attributes. These analyses, discussed by Sinnock and Fernandez (1982), were used to investigate the factors contributing most to the scores of alternative locations and rock types. Based on groupings of similarly rated grid cells for most or all of the separate analyses, 15 relatively distinct locations were identified (Figure 2-13). In this manner, alternative locations for a repository were established by the analyses.

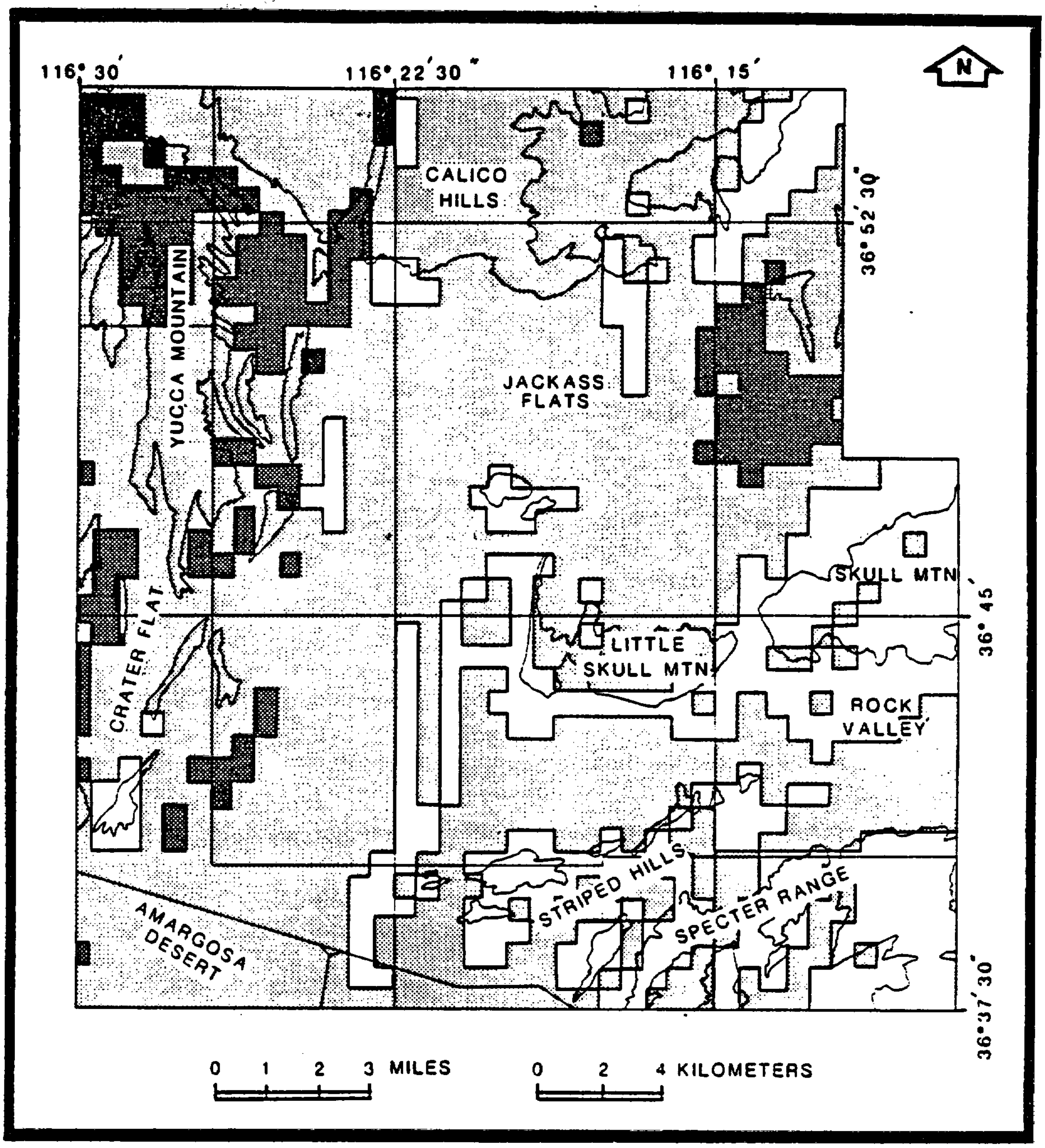
The 15 locations were ranked according to the number of analyses for which all or most of the grid cells within each location rated high, medium, or low (Figure 2-14). To quantify the basis for the rankings, the weights associated with each of the rating categories shown on Figure 2-14 were summed for each location for the 12 analyses that considered different combinations of objectives (Table 2-6).

As is apparent from Figures 2-11a, 2-11b, 2-12, and 2-14 and from Table 2-6, northern Yucca Mountain (location J, Figure 2-13) ranked highest, mainly because of high ratings for objectives related to long-term isolation; its ratings for near-term objectives, including the cost of constructing surface facilities and the environmental impacts of construction and operation, were relatively low (Figure 2-14). Three rock types at this location rated

Table 2-5. Weights assigned to lower-level objectives[a] for calculating rating scores for each of the 1514 grid cells and for each rock type[b]

Objective[c]	Weight (%)[d]
1.1.1 Chemical	68
1.1.2 Mechanical	32
1.2.1 Seismic	37
1.2.2 Erosional	14
1.2.3 Volcanic	21
1.2.4 Human intrusion	23
1.2.5 Miscellaneous	5
2.1.1 Ground-water flow	39
2.1.2 Nuclide retardation	30
2.1.3 Host-rock homogenity	23
2.1.4 Migration of volatiles	8
2.2.1 Tectonics	31
2.2.2 Climate	21
2.2.3 Geomorphic effects	20
2.2.4 Human effects on isolation system	25
2.2.5 Miscellaneous	3
3.1.1 Seismicity	21
3.1.2 Monitoring requirements	12
3.1.3 Foundation conditions	26
3.1.4 Wind loads	10
3.1.5 Flooding	18
3.1.6 Available natural resources	13
3.2.1 Seismicity	15
3.2.2 Flooding	21
3.2.3 Mining conditions	27
3.2.4 Host-rock geometry	15
3.2.5 Host-rock homogeneity	12
3.2.6 Waste-package compatibility	10
3.3.1 Terrain	71
3.3.2 Transportation distance	29
4.2.1 Surface geology	22
4.2.2 Water quality	46
4.2.3 Air quality	32
4.3.1 Local economies	41
4.3.2 Life styles	42
4.3.3 Private land use	17
4.4.1 State issues	53
4.4.2 Federal regulations	47

[a] See Figures 2-9a and 2-9b for depiction of weights and standard deviations.
[b] Source: modified from Sinnock and Fernandez, 1982.
[c] Only general designations; see Table 2-1 for complete statement of objectives.
[d] Weights for each group of lower-level objectives sum to 100%.

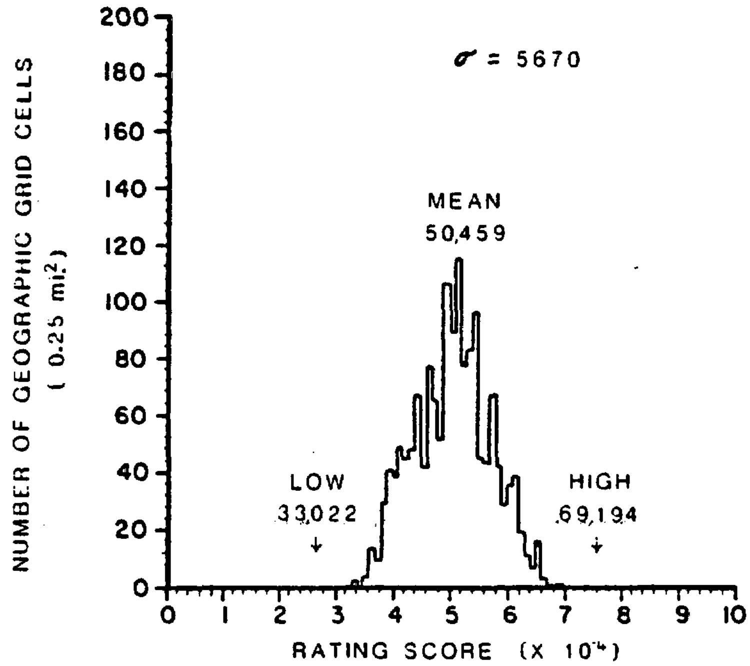


LEGEND FOR LOCATION RATINGS

(BASED ON ATTRIBUTES 1-23 ONLY)

- <45,000 (LOW FAVORABILITY)
- 45,000-60,000 (MEDIUM FAVORABILITY)
- >60,000 (HIGH FAVORABILITY)

Figure 2-11a. Example of results of screening analyses. Ratings of the 1514 grid cells that make up the base map are grouped into three categories (see legend). (Modified from Sinnock and Fernandez, 1982.)



HOST ROCK RATINGS

AGE	ROCK TYPE	SATURATED RATING	SATURATED RANK	UNSATURATED RATING	UNSATURATED RANK
YOUNGER	ALLUVIUM	45000	7	43000	8
	BASALT	49000	6	48000	7
	NON-WELDED PAINTBRUSH TUFF	55000	5	42000	9
	TOPOPAH SPRING TUFF	41000	8	58000	5
	CALICO HILLS TUFF	75000	3	62000	3
	CRATER FLAT TUFF	67000	4	60000	4
	GRANITE	76000	2	63000	2
	ARGILLITE	82000	1	72000	1
OLDER	CARBONATE	39000	9	55000	6

NOTE: Host rock ratings based solely on host rock attributes (numbers 24-31 for saturated list; for unsaturated list numbers 24-30 only). Ratings do not account for site dependent rock conditions such as in in-situ stress, in-situ temperature, depth, local structures and others. Unsaturated ratings omit hydraulic transmissivity, attribute #31.

Figure 2-11b. Typical histogram of host rock rating scores used to place individual grid cells into high, medium, and low categories. (Modified from Sinnock and Fernandez, 1982.)

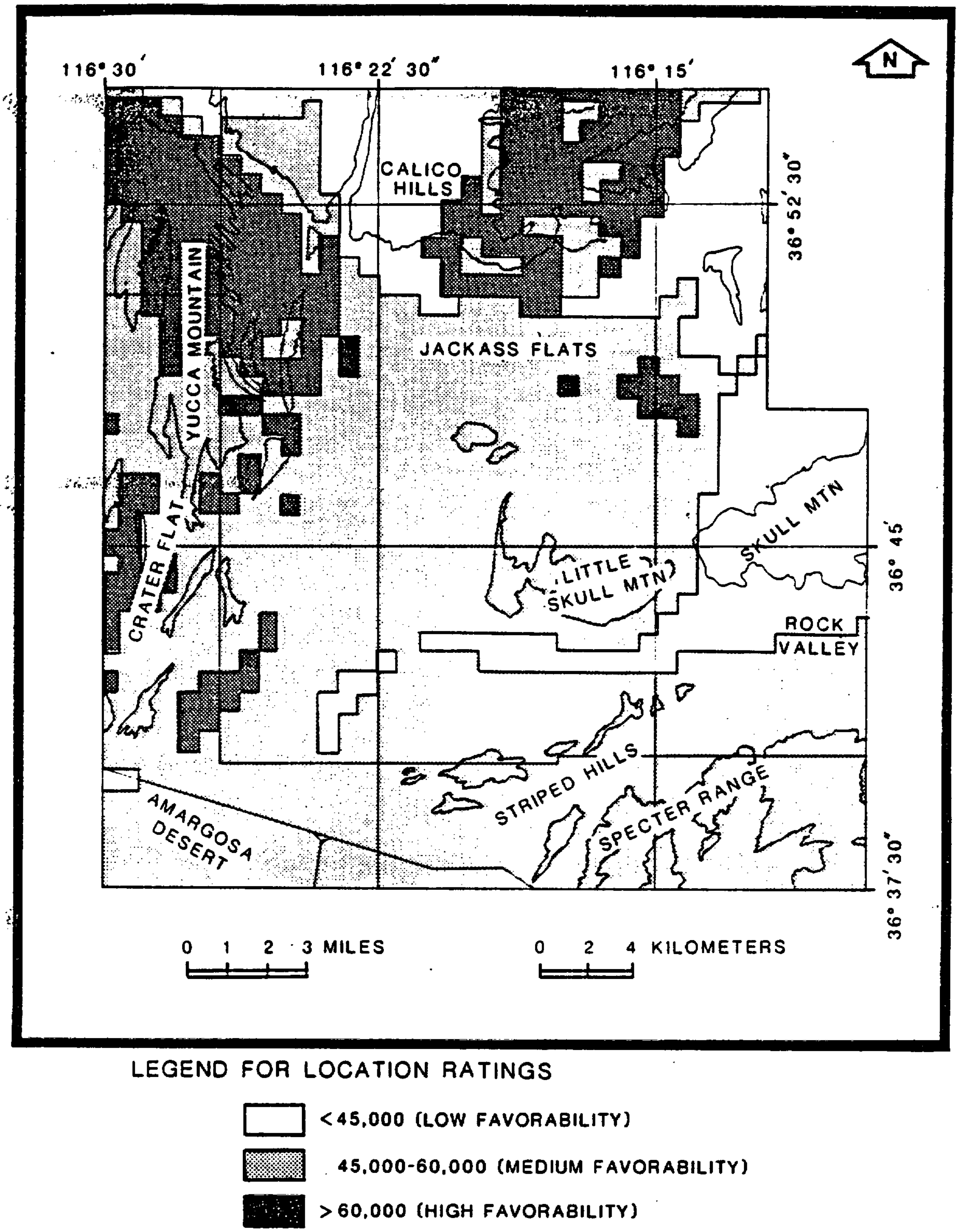
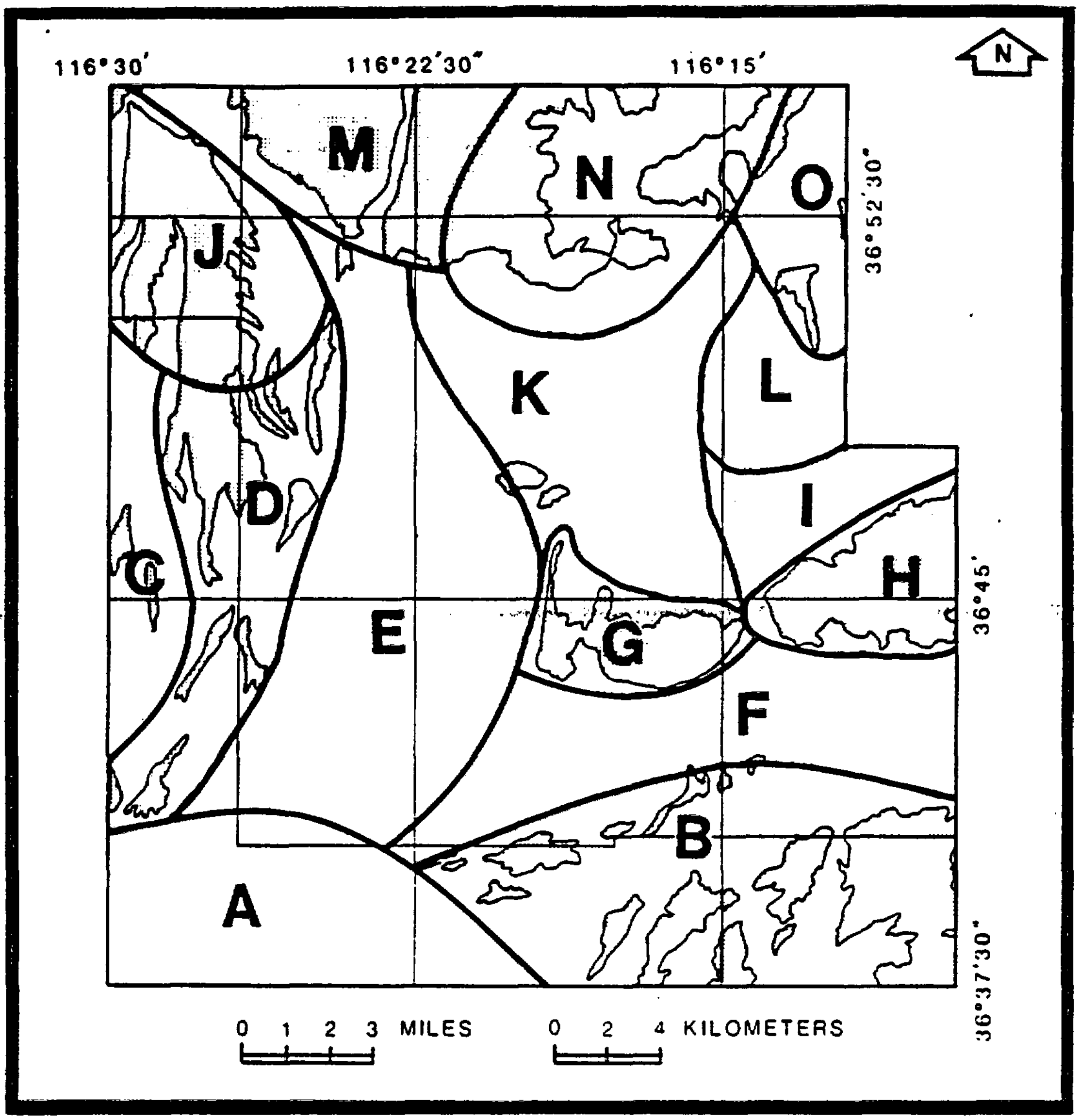


Figure 2-12. Screening analysis results with value of most highly rated host rock added to the grid cell ratings from Figure 2-11, and the scores rescaled to a total score of 100,000. (Source: Sinnock and Fernandez, 1982.)



ALTERNATIVE LOCATIONS

A AMARGOSA DESERT	H SKULL MOUNTAIN
B STRIPED HILLS-SPECTER RANGE	I EASTERN JACKASS FLATS
C EASTERN CRATER FLAT	J NORTHERN YUCCA MOUNTAIN
D CENTRAL-SOUTHERN YUCCA MOUNTAIN	K CENTRAL JACKASS FLATS
	L NORTHEASTERN JACKASS FLATS
E WESTERN JACKASS FLATS	M YUCCA WASH-FORTYMILE CANYON
F ROCK VALLEY	N CALICO HILLS-UPPER TOPOPAH WASH
G LITTLE SKULL MOUNTAIN	O KIWI MESA-MID VALLEY PASS

Figure 2-13. Approximate boundaries of 15 alternative locations identified from groupings of similarly rated grid cells for 25 separate analyses. The location identified as northern Yucca Mountain (location J) is larger than but encompasses the current target site. (Modified from Sinnock and Fernandez, 1982.)

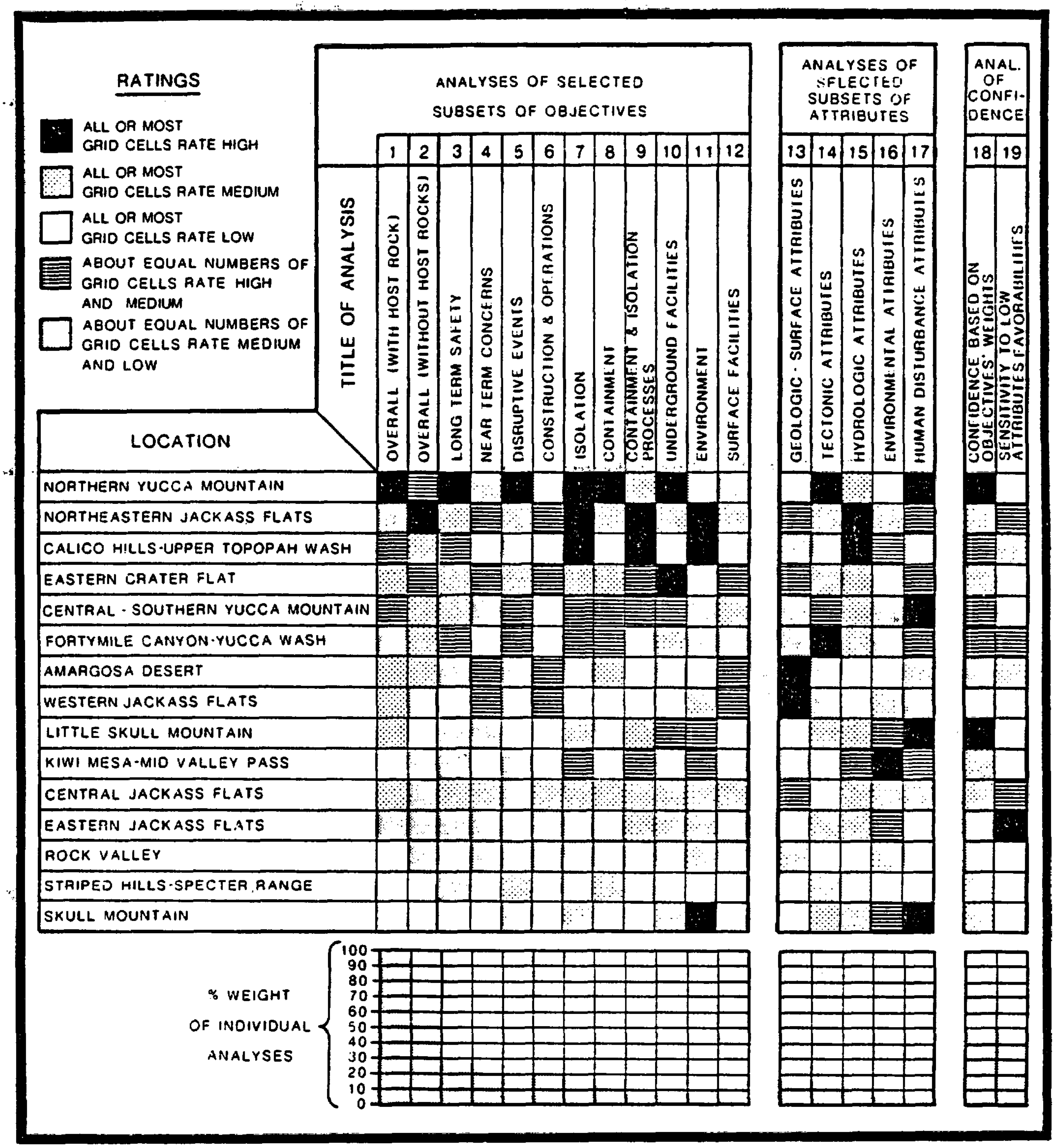


Figure 2-14. Ranking of locations (highest to lowest from top to bottom) based on ratings of all or most grid cells. Separate analyses of (a) objectives (columns 1-12), (b) attributes (columns 13-17), and (c) confidence in the ratings (columns 18-19). For each column, percent weights associated with individual analyses were obtained by polling experts, and are shown in histograms at bottom. (Modified from Sinnock and Fernandez, 1982.)

Table 2-6. Ranking of alternative locations (highest to lowest from top to bottom) based on the number and weights of rating categories for the 12 analyses of related objectives[a,b]

Location	Rating category from Figure 2-14									
	High		High and medium		Medium		Medium and low		Low	
	No.	Weight	No.	Weight	No.	Weight	No.	Weight	No.	Weight
Northern Yucca Mountain	6	178.79	1	52.42	2	30.59	3	29.41	0	0
Northeastern Jackass Flats	4	82.56	2	41.51	5	73.48	1	93.66	0	0
Calico Hills-Upper Topopah Wash	3	30.14	2	122.06	1	52.43	3	39.88	3	46.91
Eastern Crater Flat	3	6.56	5	105.91	3	172.24	0	-0-	1	6.51
Central-southern Yucca Mountain	0	0	6	156.97	3	86.22	2	30.52	1	17.50
Fortymile Canyon-Yucca Wash	0	0	4	78.58	2	58.97	4	112.15	2	41.51
Amargosa Desert	0	0	3	48.91	3	157.38	4	73.83	2	13.09
Western Jackass Flats	0	0	3	46.91	2	100.17	2	74.25	5	69.88
Little Skull Mountain	0	0	2	13.06	3	117.29	3	63.71	4	97.15
Kiwi Mesa-Mid Valley Pass	0	0	3	30.14	0	0	5	120.50	4	140.57
Central Jackass Flats	0	0	0	0	10	216.96	2	74.25	0	0
Eastern Jackass Flats	0	0	0	0	3	19.64	9	271.57	0	0
Rock Valley	0	0	9	0	1	6.51	9	162.64	2	122.06
Striped Hills-Specter Range	0	0	0	0	2	33.13	3	52.03	7	206.05
Skull Mountain	1	6.51	0	0	2	23.60	2	33.13	7	227.97

[a] Source: Sinnock and Fernandez, 1982.
[b] Subsets of objectives listed in Figure 2-14.

high enough to merit consideration as potential repository host rocks: the saturated and unsaturated Calico Hills unit, the unsaturated Topopah Spring Member, and the saturated Crater Flat Tuff (Figure 2-11b).

Two other locations, northeastern Jackass Flats and Calico Hills-Upper Topopah Wash (locations L and N, respectively, Figure 2-13), also rated generally high. High ratings at northeastern Jackass Flats are primarily due to favorable environmental, surface terrain, and hydrologic attributes. However, this location is not underlain by any of the host rocks evaluated and it had relatively low ratings when host-rock attributes were considered (Figure 2-12). Less favorable tectonic attributes also detracted somewhat from its ratings.

The third location, Calico Hills-Upper Topopah Wash, in contrast to northeastern Jackass Flats, rated low for geographical attributes, and high only when host-rock attributes were considered. Argillite and perhaps granite occur beneath Calico Hills and Upper Topopah Wash, though the granite may be too deep for repository use. Argillite was the first and granite the second rated rock type, for both saturated and unsaturated conditions, and they strongly contributed to the high ratings at this location (compare maps from Figures 2-11a and 2-12). Hydrologic attributes at Calico Hills-Upper Topopah Wash also rated very high, whereas tectonic, surface terrain, and human disturbance attributes generally rated low.

The other 12 locations rated significantly lower than those discussed above.

Yucca Mountain emerged from the formal screening, in agreement with the less formal siting activities described in Section 2.2.3, as the location on or near the NTS that offers the most attributes considered to be favorable for a repository site. The screening systematically compared only the relative merits of alternative locations considered in the study. The site-specific data needed for quantitative predictions of site suitability will be collected during site characterization if Yucca Mountain is recommended for characterization.

2.2.5 Selection of the target repository host rock

Complementing the screening for locations described in Section 2.2.4, a separate screening activity was conducted in 1982 and early 1983 to look in greater detail at the relative merits of alternative rock types at various depths beneath Yucca Mountain. By the end of 1981, four rock units had been identified, in part based on the location screening, as primary candidates for a repository. Two units are in the unsaturated zone: the Topopah Spring Member of the Paintbrush Tuff and the tuffaceous beds of Calico Hills. The two other units, the Bullfrog and Tram Members of the Crater Flat Tuff, are located below the water table (Figure 2-15). The objective of the formal evaluation of these four units was to rank them using existing data and analytical methods, supplemented by engineering and scientific judgment. A letter from the U.S. Geological Survey (J. B. Robertson, G. L. Dixon, and W. E. Wilson to M. Kunich, Nevada Operations Office, U.S. Department of Energy, February 5, 1982) pointed out the "considerable advantages that might be offered by the unsaturated zone. One strategy of locating a repository in the unsaturated zone beneath Yucca Mountain would be to place it in units of fractured welded tuff with high fracture conductivity, so that any recharge water that does reach the repository level will move rapidly through it." In July 1982, planning for an exploratory shaft required that a target horizon be chosen. Based on information available at that time, the Topopah Spring Member was designated as the design reference unit. The final evaluation of the four rock units (Johnstone et al., 1984), completed seven months later, generally supported this preliminary decision.

Several physical properties of the various rock units were used to compare excavation stability, minability, thermal loading limits, far-field thermomechanical behavior, and ground-water travel time. The rankings are summarized in Table 2-7. Minability considered specifically the anticipated ease and cost of the mining process. The Calico Hills unit was a clear choice with respect to this factor because continuous mining machines could be used rather than the more time consuming and expensive drilling and blasting techniques required for the welded units. Even so, the main result from the minability comparison was that no units were eliminated; all units can be mined successfully with conventional techniques.

Gross thermal loading did not allow significant discrimination among the four units. Loading densities required to keep the floor temperature of emplacement drifts within design limits varied only from 54 to 57 kW/acre. Considering the variability of thermal properties within each rock unit, the four units are nearly identical with respect to emplacement of heat-generating wastes. Far-field thermal effects also did not discriminate significantly among the units. All units were predicted to affect the far field in virtually the same way. None of the thermal calculations suggested any failure mode for repository performance due to the temperature changes expected in any of the units. Although the differences among them were very slight, the rock units were still ranked on these two thermal factors (see Table 2-7).

The stability of mined tunnels in each unit was evaluated by three different approaches. Near-field computer calculations indicated clear superiority of the three welded units. A subranking among these three units showed that the Topopah Spring Member would be expected to be the most stable. An evaluation of rock matrix properties provided a more traditional approach to comparing the expected stability among the four units. This method also showed that the Topopah Spring Member was clearly expected to be more stable than the other three units. Two published techniques for classifying the suitability of rock masses for mining, the Norges Geotekniske Institute (NGI) method and the Council for Scientific and Industrial Research (CSIR) method (Barton, 1976; Bieniawski, 1976), were also used to evaluate mine stability. Based on the NGI system, the Topopah Spring Member was clearly superior to the other three units. Distinctions based on the CSIR system were less dramatic, but this method also ranked the Topopah Spring unit first. However, none of the units was classified as unsuitable or unusually dangerous with respect to mine stability.

Table 2-7. Ranking of four rock units identified as primary candidates for a potential repository host rock[a]

Comparison factors	Relative rank[b]			
	Topopah Spring	Calico Hills	Bullfrog	Tram
Excavation stability				
Calculated near-field thermomechanical response	1	4	2	3
Rock-matrix properties	1	4	4	4
Norges Geotekniske Institute classification[c]	1	4	4	4
Council for Scientific and Industrial Research classification[d]	1	1	2	2
Minability	2	1	3	4
Gross thermal loading limit	1	1	1	1
Far-field thermomechanical response	1	1	1	1
Ground-water travel time to the water table	1	2	4	3

[a] Source: Johnstone et al., 1984.
[b] Lowest number (1) is highest rank; highest number (4) is lowest rank.
[c] Described by Barton, 1976.
[d] Described by Bieniawski, 1976.

Vertical ground-water travel times from the two unsaturated and two saturated candidate repository horizons to the water table were estimated to be thousands of years. Ground-water travel time estimates for each rock unit were based on the assumption of porous flow and did not include the effects of heat. Considerable uncertainty existed in the estimates for all of the rock units. For rock units in the saturated zone, extreme variability in the assumed hydraulic parameters yielded travel-time estimates that varied by as much as up to six orders of magnitude. Because it is located in the unsaturated zone, and because it is farther from the water table than the Calico Hills unit (see Figure 2-15), the Topopah Spring Member ranked highest for travel time.

On the basis of the unit evaluation studies, the first choice for the target horizon was the Topopah Spring Member of the Paintbrush Tuff. The second choice was the tuffaceous beds of Calico Hills. The third and fourth choices were the Bullfrog and the Tram Members of the Crater Flat Tuff, respectively. The exact depth and position of a repository in the Topopah Spring Member would be determined during site characterization, based on rock properties that affect predicted performance and mine design. Nothing in the unit evaluation study suggested that any of the rock units considered would be unsuitable for a repository.

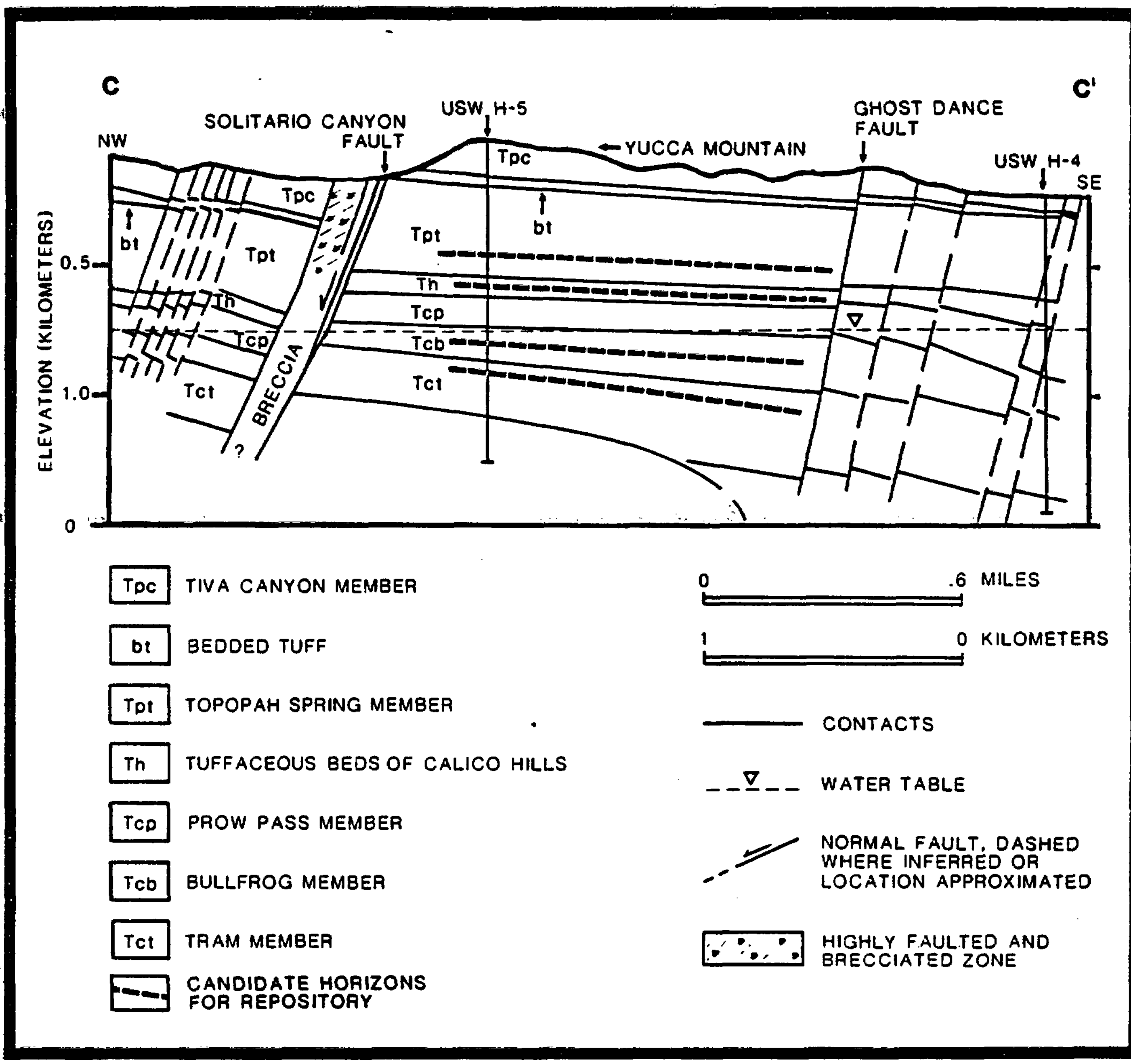


Figure 2-15. General stratigraphy and approximate fault locations at Yucca Mountain showing the depth of four potential repository horizons considered in the unit evaluation study. Source: compiled from Scott and Bonk, 1984.

2.3 EVALUATION OF THE YUCCA MOUNTAIN SITE AGAINST THE DISQUALIFYING CONDITIONS OF 10 CFR PART 960

From the nine sites identified as potentially acceptable for the first repository (see Chapter 1), the DOE is required by the Nuclear Waste Policy Act of 1982 and the DOE general siting guidelines (10 CFR Part 960) to nominate at least five as suitable for site characterization. The first step in the nomination process, as required by 10 CFR 960.3-2-2-1, is to evaluate each potentially acceptable site against the disqualifying conditions specified in the technical guidelines in accordance with Appendix III of the guidelines.

Altogether, 17 disqualifying conditions are specified in the technical guidelines. They are derived from Section 112 of the Nuclear Waste Policy Act, which requires the guidelines to specify "factors that qualify or disqualify any site from development as a repository." In particular, the Act specifies factors pertaining to the location of valuable natural resources, hydrology, geophysics, seismic activity, atomic energy defense activities, proximity to water supplies, proximity to populations, the effect upon the rights of users of water, and proximity to components of the National Park System, the National Wildlife Refuge System, the National Wild and Scenic Rivers System, the National Wilderness preservation System, or National Forest Lands. Each disqualifying condition describes a condition that is considered so adverse as to constitute sufficient evidence, without further consideration, that a site is disqualified. Thus, the presence of a single disqualifying condition is enough to eliminate a site from further consideration. Almost all of the 17 disqualifying conditions pertain to conditions whose presence or absence may be verifiable without extensive data gathering or complex analysis. The evaluation of the Yucca Mountain site against these disqualifiers is reported in this section and summarized in Table 2-8. (A more detailed discussion is presented in Chapter 6.)

Because no disqualifying conditions are judged to exist at Yucca Mountain on the basis of the information collected and analyzed to date, the DOE has carried out the remaining steps required by the Nuclear Waste Policy Act and 10 CFR 960.3-2-2-4 for the nomination of sites as suitable for characterization. These steps and the sections of this document in which they are discussed are listed below.

1. An evaluation of the site as to whether it is suitable for the development of a repository under the guidelines that do not require site characterization for their application (Section 6.2).

2. An evaluation of the site as to whether it is suitable for site characterization under the guidelines that require data from site characterization (Section 6.3).

3. An evaluation of the effects of site-characterization activities on public health and safety and on the environment, including alternative site-characterization activities that might be taken to avoid such effects (Chapter 4).

4. An evaluation of the regional and local effects of locating a repository at Yucca Mountain (Chapter 5).

Table 2-8. Summary of evaluations of the Yucca Mountain site against the disqualifying conditions

Disqualifying condition and Chapter 6 reference	Synopsis
10 CFR 960.4-2-1(d): GEOHYDROLOGY (6.3.1.1)	
A site shall be disqualified if the pre-waste-emplacement ground-water travel time from the disturbed zone to the accessible environment is expected to be less than 1,000 years along any pathway of likely and significant radionuclide travel.	Not disqualified: On the basis of present understanding, the most likely flow time to the accessible environment is more than 20,000 years.
10 CFR 960.4-2-5(d): EROSION (6.3.1.5)	
The site shall be disqualified if site conditions do not allow all portions of the underground facility to be situated at least 200 meters below the directly overlying ground surface.	Not disqualified: Shallowest parts of underground facility are more than 200 meters below directly overlying ground surface.
10 CFR 960.4-2-6(d): DISSOLUTION (6.3.1.6)	
The site shall be disqualified if it is likely that, during the first 10,000 years after closure, active dissolution, as predicted on the basis of the geologic record, would result in a loss of waste isolation.	Not disqualified: The potential host rock is welded tuff, which is not considered to be soluble.
10 CFR 960.4-2-7(d): TECTONICS (6.3.1.7)	
A site shall be disqualified if, based on the geologic record during the Quaternary Period, the nature and rates of fault movement or other ground motion are expected to be such that a loss of waste isolation is likely to occur.	Not disqualified: Consequences of volcanism or fault movement are expected to be minimal because of limited water flux and long ground-water travel times.

Table 2-8. Summary of evaluations of the Yucca Mountain site against the disqualifying conditions (continued)

Disqualifying condition and Chapter 6 reference	Synopsis
10 CFR 960.4-2-8/1(d): NATURAL RESOURCES (6.3.1.8)	
<u>A site shall be disqualified if--</u> (1) <u>Previous exploration, mining, or extraction activities for resources of commercial importance at the site have created significant pathways between the projected underground facility and the accessible environment; or</u> (2) <u>Ongoing or likely future activities to recover presently valuable natural mineral resources outside the controlled area would be expected to lead to an inadvertent loss of waste isolation.</u>	Not disqualified: No previous at-depth exploration at Yucca Mountain; no resources are expected to cause increased mining activities that could lead to loss of waste isolation.
10 CFR 960.5-2-1(d): POPULATION DENSITY AND DISTRIBUTION (6.2.1.2)	
<u>A site shall be disqualified if--</u> (1) <u>Any surface facility of a repository would be located in a highly populated area; or</u> (2) <u>Any surface facility of a repository would be located adjacent to an area 1 mile by 1 mile having a population of not less than 1,000 individuals as enumerated by the most recent U.S. census; or</u>	Not disqualified: No surface facility at Yucca Mountain would be located in a highly populated area; no surface facility would be adjacent to an area 1 mile by 1 mile with more than 1000 people, and an emergency-preparedness plan can be developed based on existing plan for the NTS.

Table 2-8. Summary of evaluations of the Yucca Mountain site against the disqualifying conditions (continued)

Disqualifying condition and Chapter 6 reference	Synopsis
(3) The DOE could not develop an emergency preparedness program which meets the requirements specified in DOE Order 5500.3 (Reactor and Non-Reactor Facility Emergency Planning, Preparedness, and Response Program for Department of Energy Operations) and related guides or, when issued by the NRC, in 10 CFR 60, Subpart I, "Emergency Planning Criteria."	
10 CFR 960.5-2-4(d): OFFSITE INSTALLATIONS AND OPERATIONS (6.2.1.5)	
A site shall be disqualified if atomic energy defense activities in proximity to the site are expected to conflict irreconcilably with repository siting, construction, operation, closure, or decommissioning.	Not disqualified: Coordination of repository schedules with NTS schedules, and engineering design would prevent irreconcilable conflicts with atomic energy defense activities.
10 CFR 960.5-2-5(d): ENVIRONMENTAL QUALITY (6.2.1.6)	
Any of the following conditions shall disqualify a site:	Not disqualified: No unacceptable adverse impacts have been identified or are expected and the repository is not expected to conflict with any other land use; it would not be sited on a federally protected area.
(1) During repository siting, construction, operation, closure, or decommissioning the quality of the environment in the affected area could not be adequately protected or projected environmental impacts in the affected area could not be mitigated to an acceptable degree, taking into account programmatic, technical, social, economic, and environmental factors.	

Table 2-8. Summary of evaluations of the Yucca Mountain site against the disqualifying conditions (continued)

Disqualifying condition and Chapter 6 reference	Synopsis
(2) Any part of the restricted area or repository support facilities would be located within the boundaries of a component of the National Park System, the National Wildlife Refuge System, the National Wilderness Preservation System, or the National Wild and Scenic Rivers System.	
(3) The presence of the restricted area or the repository support facilities would conflict irreconcilably with the previously designated resource-preservation use of a component of the National Park System, the National Wildlife Refuge System, the National Wilderness Preservation System, the National Wild and Scenic Rivers System, or National Forest Lands, or any comparably significant State protected resource that was dedicated to resource preservation at the time of the enactment of the Act.	
10 CFR 960.5-2-6(d): SOCIOECONOMIC IMPACTS (6.2.1.7)	
A site shall be disqualified if repository construction, operation, or closure would significantly degrade the quality, or significantly reduce the quantity, of water from major sources of offsite supplies presently suitable for human consumption or crop irrigation and such impacts cannot be compensated for, or mitigated by, reasonable measures.	Not disqualified: Repository water use is not expected to lower regional ground-water table or reduce water quality.

Table 2-8. Summary of evaluations of the Yucca Mountain site against the disqualifying conditions (continued)

Disqualifying condition and Chapter 6 reference	Synopsis
10 CFR 960.5-2-9(d): ROCK CHARACTERISTICS (6.3.3.2)	
The site shall be disqualified if the rock characteristics are such that the activities associated with repository construction, operation, or closure are predicted to cause sinificant risk to the health and safety of personnel, taking into account mitigating measures that use reasonably available technology.	Not disqualified: No rock characteristics that could lead to significant health or safety risks have been identified.
10 CFR 960.5-2-10(d): HYDROLOGY (6.3.3.3)	
A site shall be disqualified if, based on expected ground-water conditions, it is likely that engineering measures that are beyond reasonably available technology will be required for exploratory-shaft construction or for repository construction, operation, or closure.	Not disqualified: Significant amounts of ground water are not expected; engineering measures are expected to be more than adequate to prevent disruptions due to ground-water conditions.
10 CFR 960.5-2-11(d): TECTONICS (6.3.3.4)	
A site shall be disqualified if, based on the expected nature and rates of fault movement or other ground motion, it is likely that engineering measures that are beyond reasonably available technology will be required for exploratory-shaft construction or for repository construction, operation, or closure.	Not disqualified: Reasonably available technology is expected to be sufficient to construct an exploratory shaft, and construct and operate a safe repository; ground motion or volcanism is unlikely to disrupt repository activities.

5. A comparative evaluation of Yucca Mountain and all other sites considered for nomination for site characterization (Chapter 7).

Summaries of the findings for each of the disqualifying conditions are presented in the remainder of this section. Details of the evaluation of Yucca Mountain against the disqualifying conditions are presented in Sections 6.2 and 6.3.

Geohydrology (10 CFR 960.4-2-1(d); Section 6.3.1.1)

Disqualifying condition: A site shall be disqualified if the pre-waste-emplacement ground-water travel time from the disturbed zone to the accessible environment is expected to be less than 1,000 years along any pathway of likely and significant radionuclide travel.

Analysis of existing field and laboratory data indicates that the expected pre-waste-emplacement ground-water travel time along all paths of likely and significant radionuclide travel to the accessible environment would exceed 1000 years. The flow paths of interest at Yucca Mountain include segments in both the unsaturated and saturated zone. The travel time to the accessible environment from the base of the potential host rock at Yucca Mountain is expected to be greater than 20,000 years.

Flux through the potential host rock is determined by the volume and rate of infiltration and the hydraulic properties of rocks in the unsaturated zone. Upon reaching the water table beneath Yucca Mountain, this water joins other ground water in transit from sources of recharge north and northwest of Yucca Mountain, and moves generally horizontally to the accessible environment. Uncertainties in the estimate of travel time at Yucca Mountain include the lack of definition of the extent, and therefore the outer boundary, of the repository disturbed zone, and differing permeabilities along potential travel paths.

Erosion (10 CFR 960.4-2-5(d); Section 6.3.1.5)

Disqualifying condition: The site shall be disqualified if site conditions do not allow all portions of the underground facility to be situated at least 200 meters below the directly overlying ground surface.

The lower portion of the densely welded tuff of the Topopah Spring Member of the Paintbrush Formation is the potential repository host rock at Yucca Mountain. It has sufficient thickness and depth that all portions of the underground facility will be located at least 200 m (650 ft) below the directly overlying ground surface. Evidence indicates that approximately 75 percent of the waste could be located at depths greater than 300 m (1000 ft) deep.

Dissolution (10 CFR 960.4-2-6(d); Section 6.3.1.6)

Disqualifying condition: The site shall be disqualified if it is likely that, during the first 10,000 years after closure, active dissolution, as predicted on the basis of the geologic record, would result in a loss of waste isolation.

The minerals which compose the rock in and around the Yucca Mountain site are considered insoluble and no dissolution is expected to occur, even at the elevated temperatures anticipated near the waste canisters. The host rock for the proposed repository horizon at Yucca Mountain consists of the moderately to densely welded, devitrified tuff of the unsaturated Topopah Spring Member. About 98 percent of the host rock consists of alkali feldspars, quartz, and cristobalite, which are minerals that are not prone to aqueous dissolution.

Tectonics (10 CFR 960.4-2-7(d); Section 6.3.1.7)

Disqualifying condition: A site shall be disqualified if, based on the geologic record during the Quaternary Period, the nature and rates of fault movement or other ground motion are expected to be such that a loss of waste isolation is likely to occur.

The consequence of the maximum earthquake magnitude predicted for the repository site on the isolation of radioactive wastes is likely to be small. Historical earthquake records show that seven earthquakes were recorded before 1978 within about 10 km (6.2 mi) of the potential repository site; of these, five had unknown magnitude, and the remaining two had Richter magnitudes of 3.6 and 3.4. Prior to 1978, however, standard errors of locations varied from about 2 to 7 km. A new seismic network has recorded seven microearthquakes in the same area between August 1978 and the end of 1983; the largest magnitudes were approximately 2.0. Available geologic data indicate that faults within the same radius of Yucca Mountain have not had large (greater than 1 m (3 ft)) surface displacements in the last 250,000 years. Sixteen faults have been identified within this radius that may have had small displacements during the Quaternary Period, but there is no unequivocal evidence of surface displacement in at least the last 35,000 years.

Earthquake damage to underground facilities is generally less than surface damage. Even if a waste canister were damaged, water is required to dissolve radionuclides from the waste form, and to transport these radionuclides from the repository to the accessible environment. The expected flux of less than 1 mm/year through the repository has been shown (Section 6.4.2) to be insufficient to transport wastes in quantities that could exceed release limits at the accessible environment, even if some waste material were released from the repository immediately after closure. Travel times of greater than 20,000 years provide additional confidence that radionuclides will not be released to the accessible environment in excess of the limits specified in 40 CFR Part 191.

Human Interference: Natural Resources (10 CFR 960.4-2-8-1(d); Section 6.3.1.8)

Disqualifying condition: A site shall be disqualified if--

(1) Previous exploration, mining, or extraction activities for resources of commercial importance at the site have created significant pathways between the projected underground facility and the accessible environment; or

(2) Ongoing or likely future activities to recover presently valuable natural mineral resources outside the controlled area would be expected to lead to an inadvertent loss of waste isolation.

Thorough examination of the Yucca Mountain site and comprehensive searches of literature and mining claim files have disclosed no evidence of previous exploration, mining, or extraction activities for resources of commercial importance. The site is within an area of federally controlled lands, most of which were restricted in the early 1950s to prevent public access, and thereby excluded from exploration and development. The U.S. Geological Survey has also mapped the entire area by physical inspection of the ground surface, and it is extremely unlikely that unknown excavations exist at the site. Consequently, no significant pathways have been created between the projected underground facility and the accessible environment. Furthermore, there are no ongoing or anticipated future activities to recover presently valuable natural mineral resources outside the controlled area that could be expected to lead to an inadvertent loss of waste isolation.

Population Density and Distribution (10 CFR 960.5-2-1(d); Section 6.2.1.2)

Disqualifying conditions: A site shall be disqualified if--

(1) Any surface facility of a repository would be located in a highly populated area; or

(2) Any surface facility of a repository would be located adjacent to an area 1 mile by 1 mile having a population of not less than 1,000 individuals as enumerated by the most recent U.S. Census; or

(3) The DOE could not develop an emergency preparedness program which meets the requirements specified in DOE Order 5500.3 (Reactor and Non-Reactor Facility Emergency Planning, Preparedness, and Response Program for Department of Energy Operations) and related guides or, when issued by the NRC, in 10 CFR 60, Subpart I, "Emergency Planning Criteria."

The nearest highly populated area to Yucca Mountain with 1000 or more persons per square mile is Las Vegas which is about 150 km (95 mi) away by air. Consequently, surface facilities at Yucca Mountain would not be located within a highly populated area. In addition, an existing emergency preparedness plan covers accidental release of radionuclides as a result of weapons testing at the Nevada Test Site (DOE/NVO, 1983). No problems are anticipated for preparation of a plan covering airborne or waterborne releases from an operating repository at Yucca Mountain.

Offsite Installations and Operations (10 CFR 960.5-2-4(d); Section 6.2.1.5)

Disqualifying condition: A site shall be disqualified if atomic energy defense activities in proximity to the site are expected to conflict irreconcilably with repository siting, construction, operation, closure, or decommissioning.

The Yucca Mountain site is over 40 km (25 mi) from the nearest area presently used for underground nuclear detonations, and no area under consideration for future testing is closer to Yucca Mountain than approximately 23 km (14 mi). The potential repository site is not within an area where individuals are normally removed during underground testing activities elsewhere on the Nevada Test Site. However, depending on the size and nature of a particular test, workers may be removed from underground areas within about 80 km (50 mi) of underground tests as a matter of policy and as a precautionary measure. This practice could have a minor effect on the siting, construction, operation, and decommissioning phases of the repository. Temporary suspension of certain activities at the repository site can be planned as a standard operating procedure. These occurrences would be infrequent and of short duration, and would not have significant adverse impacts on any phase of siting or repository activities. Current radiation containment and safety measures for underground nuclear tests at the Nevada Test Site are very stringent, and the possibility of substantial releases of radioactivity to the atmosphere in the future is considered very small. All potential impacts from atomic energy defense activities occurring elsewhere on the Nevada Test Site can be addressed through facility design and construction, and through coordination of scheduling of repository operations and nuclear weapons testing activities.

Environmental Quality (10 CFR 960.5-2-5(d); Section 6.2.1.6)

Disqualifying conditions: Any of the following conditions shall disqualify a site:

(1) During repository siting, construction, operation, closure, or decommissioning the quality of the environment could not be adequately protected or projected environmental impacts in the affected area could not be mitigated to an acceptable degree, taking into account programmatic, technical, social, economic, and environmental factors.

(2) Any part of the restricted area or repository support facilities would be located within the boundaries of a component of the National Park System, the National Wildlife Refuge System, the National Wilderness Preservation System, or the National Wild and Scenic Rivers System.

(3) The presence of the restricted area or the repository support facilities would conflict irreconcilably with the previously designated resource-preservation use of a component of the National Park System, the National Wildlife Refuge System, the National Wilderness Preservation System, the National Wild and Scenic Rivers System, or National Forest Lands, or any comparably significant State protected resource that was dedicated to resource preservation at the time of the enactment of the Act.

Recognized environmental impacts associated with the siting, construction, operation, closure, or decommissioning of a repository at Yucca Mountain include (1) disruption of approximately 370 ha (900 acres) of desert habitat, (2) fugitive dust emissions, (3) vehicle emissions, (4) natural radioactivity releases from the excavation of volcanic rock for the repository, and (5) radioactivity releases during the operation of the repository, under both normal and accident conditions. The repository would be designed and operated in compliance with all applicable State and Federal health, safety and environmental protection regulations.

If a repository is located at Yucca Mountain, the evidence indicates that its siting, construction, operation, closure, or decommissioning would not result in any unacceptable adverse environmental impacts that would threaten the quality of the environment. Neither the restricted area, nor the supporting facilities for a repository at Yucca Mountain, would be located within the boundaries of or irreconcilably conflict with the previously designated use of the National Park System, the National Wildlife Refuge System, the National Wilderness Preservation System, the National Wild and Scenic Rivers System, or National Forest Lands, or any comparably significant State protected resource dedicated to resource preservation.

Socioeconomic Impacts (10 CFR 960.5-2-6(d); Section 6.2.1.7)

> Disqualifying condition: A site shall be disqualified if repository construction, operation, or closure would significantly degrade the quality, or significantly reduce the quantity, of water from major sources of offsite supplies presently suitable for human consumption or crop irrigation and such impacts cannot be compensated for, or mitigated by, reasonable measures.

Repository construction, operation, and closure would increase water consumption by onsite use at the repository facility, and would increase offsite use due to the population increase associated with the repository. Because the climate is arid and the water table is deep (more than 500 m or 1600 ft below the land surface), it is extremely unlikely that repository activities could degrade the quality of ground water in the Yucca Mountain region. Ground water would be the source of water for the repository and competing requirements for ground-water use have been considered. Well J-13 and the proposed locations of repository surface facilities are on the Nevada Test Site. Should the Federal government develop a repository at Yucca Mountain, a permanent land withdrawal will be necessary, in accordance with the Federal Land Policy and Management Act of 1976, and reservation of water rights would be explicit in the withdrawal.

Estimates of water requirements for the construction, operation, closure, and decommissioning of the repository have been based on preliminary repository concepts. For a 60-year period of repository activities an average of 220,000 m^3/year (180 acre-ft/year) of water will be used. The regional effects of withdrawing this volume of ground water are expected to be negligible. The water level in well J-13 has remained essentially constant after long periods of constant pumping between 1962 and 1980, which suggests that the aquifers beneath Yucca Mountain can produce large quantities of ground water, and this ground water can be withdrawn for long periods of time without lowering the regional ground-water table.

According to current information, the incremental increase in water supply requirements due to project-related population growth in the region may shorten slightly the time remaining during which present sources are adequate. The maximum one-year average project-related population increase is predicted to be about 4.3 percent for Clark County and 5.4 percent for Nye County, which is not likely to significantly aggravate the water supply situation. Proper planning is needed to ensure that the expansion of facilities occurs in a timely manner. The Nuclear Waste Policy Act of 1982 provides for financial assistance, which will enable local communities to prepare for increased growth.

Rock Characteristics (10 CFR 960.5-2-9(d); Section 6.3.3.2)

Disqualifying condition: The site shall be disqualified if the rock characteristics are such that the activities associated with repository construction, operation, or closure are predicted to cause significant risk to the health and safety of personnel, taking into account mitigating measures that use reasonably available technology.

The laboratory and field data collected and analyzed to date for Yucca Mountain and observations and experience in similar excavations at similar depths indicate that activities associated with repository construction, operation, and closure will not cause significant risk to the health and safety of personnel. Tunnels in similar rock types at the Nevada Test Site are generally supported with only roof bolts and wire mesh. Even when exposed to the ground motion induced by nearby nuclear tests, this support provides stable, safe openings. Opening stability in the potential host rock has been evaluated using thermomechanical stress analyses, rock-mass classifications, and linear calculations for mine design/pillar sizing. These evaluations show that existing mining technology is sufficient to construct and maintain underground openings in the Topopah Spring Member that will allow repository operations to be carried out safely from construction through closure.

Hydrology (10 CFR 960.5-2-10(d); Section 6.3.3.3)

Disqualifying condition: A site shall be disqualified if, based on expected ground-water conditions, it is likely that engineering measures that are beyond reasonably available technology will be required for exploratory-shaft construction or for repository construction, operation, or closure.

A repository at Yucca Mountain would be located 200 to 400 m (600 to 1300 ft) above the water table. No significant quantities of perched water are expected during exploratory shaft or repository construction. Current engineering and technology are more than adequate to handle the hydrologic conditions that are likely to be encountered during construction of the exploratory shaft or during repository construction, operation, and closure. The sealing of shafts and boreholes is also not expected to require special technology or to pose any significant problems.

Tectonics (10 CFR 960.5-2-11(d); Section 6.3.3.4)

Disqualifying condition: A site shall be disqualified if, based on the expected nature and rates of fault movement or other ground motion, it is likely that engineering measures that are beyond reasonably available technology will be required for exploratory-shaft construction or for repository construction, operation, or closure.

The Yucca Mountain site has had no significant surface displacement (greater than 1 m) for the past 250,000 years and shows no unequivocal evidence of surface displacement for 35,000 years. Seismic monitoring of Yucca Mountain from 1978 to 1983 has recorded seven small (Richter magnitude less than 2.0) microearthquakes within 10 km (6.2 mi) of the site boundary. In addition, historical records show that before 1978, seven earthquakes were recorded; in the same appriximate area; five of these had unknown magnitudes and the remaining two had magnitudes of 3.6 and 3.4.

Because of the sparse historical data, predictions of seismic risk during repository siting, construction, operation, and closure at Yucca Mountain are based on empirical relationships between earthquake magnitude and fault rupture length, and between probable earthquake magnitude and expected ground motion at sites away from the earthquake. The worst-case seismic hazard for the site is thought to be an earthquake on the closest potentially active fault with a Richter magnitude of 6.8. The estimated return period for this earthquake at Yucca Mountain is 900 to 30,000 years, which is well beyond the period of concern (approximately 90 years) for repository activities. The ground motion at Yucca Mountain that would result from this worst-case earthquake is uncertain. However, evidence indicates that available earthquake-resistant designs and technology should be more than sufficient to allow safe construction and operation of a repository at Yucca Mountain.

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Chapter 3

YUCCA MOUNTAIN AND THE EXISTING ENVIRONMENT

This chapter describes the existing environment of Yucca Mountain and the surrounding region including the areas that may be affected by proposed site-characterization activities (Chapter 4) and possible future development as a repository (Chapter 5). Yucca Mountain was selected by the Department of Energy (DOE) as a potentially acceptable site for a mined geologic repository (letter from D. P. Hodel, Secretary of Energy, to Governor Richard H. Bryan, February 12, 1983). The area identified as the Yucca Mountain site is shown on Figure 3-1 and in other figures in Chapter 3. The site is on limited-access Federal land administered by the Department of the Air Force, the Bureau of Land Management (BLM), and the DOE.

3.1 LOCATION, GENERAL APPEARANCE AND TERRAIN, AND PRESENT USE

The Yucca Mountain site, shown on Figure 3-1, is located on and immediately adjacent to the southwest portion of the Nevada Test Site (NTS), which is in Nye County, Nevada, about 105 km (65 mi) northwest of Las Vegas. The Yucca Mountain site is about 150 km (95 mi) by air and 160 km (100 mi) by road from Las Vegas.

The Yucca Mountain site lies within the Basin and Range physiographic Province, a broad region of generally linear mountain ranges and intervening valleys. The site is in the southern part of the Great Basin, a subdivision of the Basin and Range Province. Figure 3-2 shows the physiographic features in the region. The elevation of northern Yucca Mountain is approximately 1500 m (5000 ft), which is more than 370 m (1200 ft) above the western edge of Jackass Flats to the east and more than 300 m (1000 ft) higher than the eastern edge of Crater Flat.

Yucca Mountain is a prominent group of north-trending, fault-block ridges that extend southward from Beatty Wash on the northwest to U.S. Highway 95 in the Amargosa Desert. The terrain at the site is controlled by high-angle normal faults and eastward-tilted volcanic rocks. Slopes are locally steep (15° to 30°) on the west-facing side of Yucca Mountain and along some of the valleys that cut into the more gently sloping (5° to 10°) east side of Yucca Mountain. The valley floors are covered by alluvium. Sandy fans extend down from the lower slopes of the ridges. Fortymile Wash is cut from 13 to 26 m (40 to 85 ft) into the surface of Jackass Flats. North of Yucca Mountain is the high, rugged volcanic terrain of Pinnacles Ridge. To the west of Yucca Mountain, along the west side of Crater Flat, steep alluvial fans extend from deep valleys that have been cut into Bare Mountain. Basalt cones and small lava flows are present on the surface of the southern half of Crater Flat.

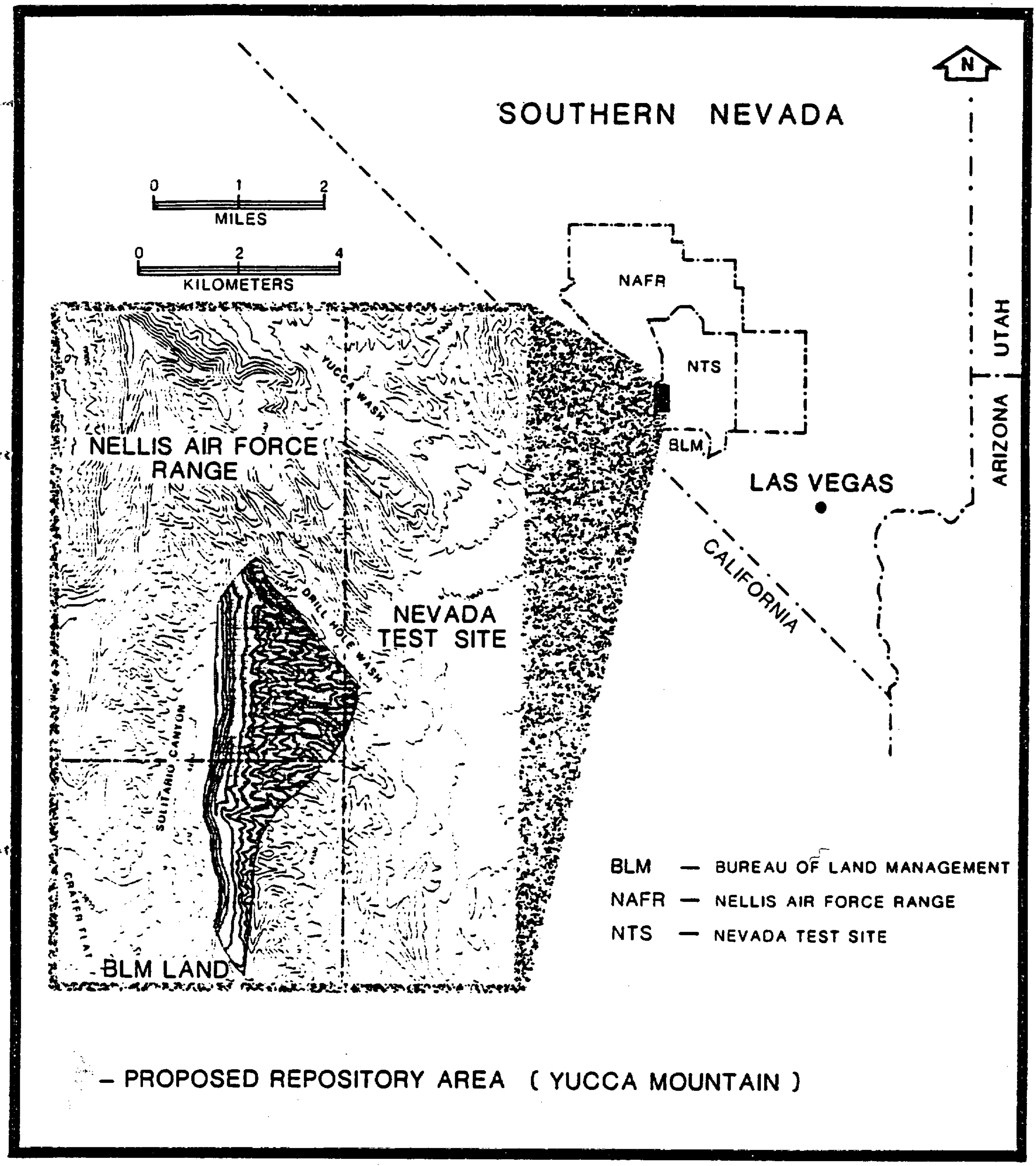

Figure 3-1. Location of proposed repository site at Yucca Mountain in southern Nevada.

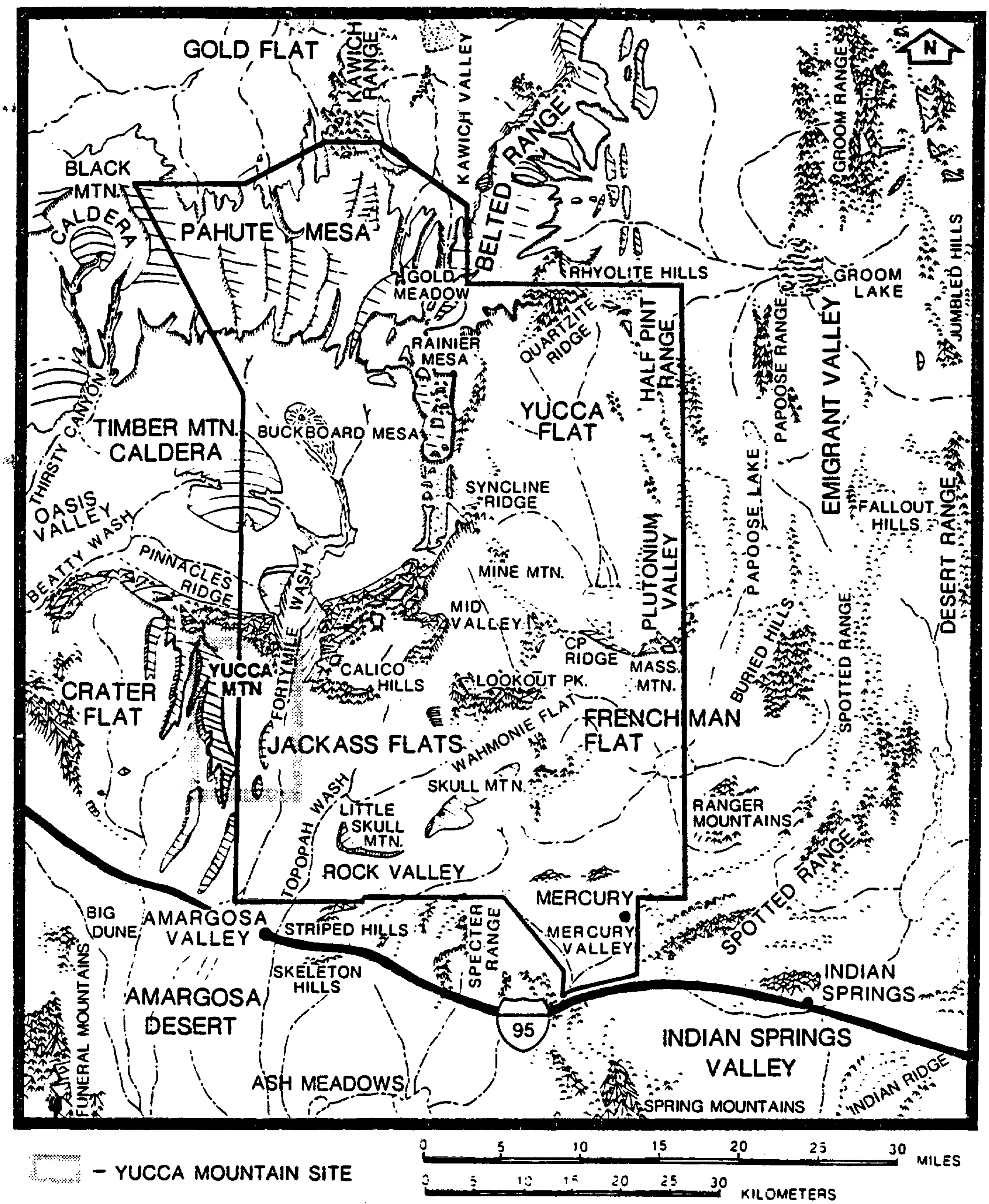

Figure 3-2. Physiographic features of Yucca Mountain and surrounding region. (Modified from Sinnock, 1982.)

The Yucca Mountain site is located exclusively within lands controlled by the Federal government. The land parcel under consideration, which includes the underground facilities, the surface facilities, and the controlled area for the repository, is divided as follows: (1) the DOE controls the eastern portion through the withdrawn land of the Nevada Test Site; (2) the Department of the Air Force controls the northwestern portion through the land-use permit for the Nellis Air Force Range (NAFR); and (3) the BLM holds the southwestern portion in public trust. These lands are currently free and clear of encumbrances, such as rights arising under general mining laws, easements for rights-of-way, and other rights arising under lease, right of entry, deed, patent, mortgage, appropriation, prescription, or other such potential encumbrances (Bell and Larson, 1982).

The preliminary site investigations conducted by the Nevada Nuclear Waste Storage Investigation (NNWSI) Project on the BLM portion of the Yucca Mountain site are governed by BLM/DOE Cooperative Agreement FCA-N5-2-2. Preliminary site investigations at the Nellis Air Force Range (NAFR) portion of the Yucca Mountain site are governed by Air Force Permit DACCA09-4-80-332. Because Congress has not yet acted on a Department of the Air Force request for a renewal of the withdrawal for the NAFR, administrative control of the land has reverted to the BLM. Therefore, BLM/DOE Cooperative Agreement FCA-N57-83-1 provides authority for the DOE to conduct preliminary site investigations at the NAFR land. Preliminary site investigations on the portion of Yucca Mountain on the NTS are governed by the environmental impact statement for the NTS (ERDA, 1977).

There are no competing land-use activities at the site. The Department of the Air Force portion of the site is used exclusively for overflight and contains no facilities. The BLM-administered portion of the land has no grazing permits or mineral claims and is not used for recreational purposes (Bell and Larson, 1982). The BLM Cooperative Agreements and the Department of the Air Force permit were each accompanied by an environmental assessment of the activities proposed. Each environmental assessment resulted in a finding of no significant impact, and each agreement requires mitigation activities and the restoration of disturbed areas.

3.2 GEOLOGIC CONDITIONS

This section describes the stratigraphy, structure, seismicity, and mineral-resource potential of the Yucca Mountain site and nearby areas. Unless otherwise referenced, the general descriptions of stratigraphy and structure are from Lipman et al. (1966), several articles in Eckel (1968), Byers et al. (1976), Christiansen et al. (1977), Stewart (1980), Sinnock (1982), and Maldonado and Koether (1983). Readers requiring additional information on the geologic development of southern Nevada are referred to these reports and to the many references contained therein. More detailed descriptions of the tectonics, rock characteristics, and geochemistry of the Yucca Mountain area are given in discussions of the corresponding technical guidelines in Chapter 6.

An understanding of the geology of the Nevada Test Site and surrounding areas has been developed through several decades of surface, subsurface, and geophysical investigations in support of the weapons-testing program. Geologic maps of the Yucca Mountain area were published in the mid-1960s (Christiansen and Lipman, 1965; Lipman and McKay, 1965). As described in Chapter 2, detailed geologic investigations of Yucca Mountain as a potential site for a repository began in 1978, when the first exploratory hole was drilled. Since that time, geologic studies at Yucca Mountain have centered on stratigraphy, structure, geochemistry, mechanical properties, volcanic history, and seismicity. Many of these studies are still in preliminary stages.

3.2.1 Stratigraphy and volcanic history of the Yucca Mountain area

The regional stratigraphic setting of Yucca Mountain is characterized by the four major rock groups discussed in Chapter 2. The first and oldest of these groups, the Precambrian crystalline rocks, are not exposed in the vicinity of Yucca Mountain but may occur at great depths beneath portions of the site. The second group, Upper Precambrian and Paleozoic sedimentary rocks, is present at the surface about 15 km (10 mi) east of Yucca Mountain at Calico Hills, where it is composed of Devonian and Mississippian argillite and carbonates. This group is also observed 30 to 40 km (19 to 25 mi) southeast of Yucca Mountain in the Specter Range and Skeleton Hills, where predominantly Cambrian and Ordovician carbonates and some quartzite are exposed. Carbonates and quartzite of similar age are also present in the Bare Mountains, about 20 km (12 mi) west of Yucca Mountain. Silurian carbonates have been encountered at a depth of 1250 m (4100 ft) in a drill hole about 2.5 km (1.5 mi) east of the Yucca Mountain area. Geophysical evidence suggests that, both east and west of the drill hole (UE-25p#1), the Paleozoic crystalline rocks occur at depths as great as 3000 m (10,000 ft) beneath the surface.

The third major group, Tertiary volcanic rocks, occurs at Yucca Mountain and comprises at least the upper 2000 m (6500 ft) of the total stratigraphic section. They are composed chiefly of rhyolitic ash-flow tuffs, with smaller amounts of dacitic lava flows and flow breccias, and minor amounts of tuffaceous sedimentary rocks and air-fall tuffs.

These rocks form the southern end of the southern Nevada volcanic field, a large plateau segmented by contemporaneous faults and built chiefly of rhyolitic ash flows and related volcanic material. The ash flows that formed this plateau were erupted between about 8 and 16 million years ago from a complex of overlapping nearly circular volcanic depressions called calderas (Figure 3-3). Collectively, the calderas comprise an area of about 1800 km^2 (700 mi^2). Outcrops throughout the region indicate that the volcanic rocks extruded from this caldera complex once covered an area of more than 6500 km^2 (2500 mi^2).

Quaternary (and uppermost Tertiary) deposits compose the fourth group. This is represented at Yucca Mountain by alluvium and unsorted debris-flow deposits in channels that are cut into the uppermost layers of volcanic rocks and by alluvial-fan deposits that form aprons along the east and west sides of the mountain. Thick alluvium (>200 m or 650 ft) blankets the volcanic rocks beneath Crater Flat to the west and Jackass Flats to the east of Yucca Mountain. Aeolian (windblown) sands, caliche, and soil zones also occur in these thicker Quaternary sections. In Crater Flat, basalt flows and cinder cones of Quaternary age are present at the surface, and flows occur also within the alluvium in the subsurface.

3.2.1.1 Caldera evolution and genesis of ash flows

The voluminous ash-flow sheets that comprise the major thicknesses of volcanic rocks at Yucca Mountain originated from eruptions during the development of calderas. To place the volcanic rock descriptions and terminology in a historical perspective, a brief summary of the evolution of a typical caldera is provided in this section. According to Smith and Bailey (1968), development of a typical caldera is characterized by seven general stages. Some stages overlap, some are repeated several times, and not all take place at every caldera. The Timber Mountain caldera, the source for the youngest volcanic rocks at Yucca Mountain (Table 3-1) went through all seven stages of evolution (Christiansen et al., 1977). Although volcanic activity at Timber Mountain ceased about 11 million years ago, the caldera is still a well-preserved topographic feature. Its evolution is probably similar to the evolution of the older calderas in the vicinity of Yucca Mountain that produced the older volcanic rocks present beneath the site (Figure 3-3).

The life span of a typical caldera, from stage 1 through stage 7, is generally about 1.5 to 2 million years (Smith and Bailey, 1968). During stage 1, magma is intruded into the crust, causing broad doming of the land surface and crustal extension. Minor eruptions of rhyolitic lavas occur along fissures through the dome and along a major zone of ring fractures, probably tens of kilometers in diameter. Stage 2 is characterized by massive eruptions in rapid succession through the ring fractures, producing massive ash flows that spread over thousands of square kilometers. The volume of material erupted from a single caldera is commonly many hundreds of cubic kilometers. Some of the ash flows produced during stage 2 from calderas in southwestern Nevada are among the most voluminous and widely distributed in the world. Stage 3 generally occurs at the same time as stage 2. As the magma feeds the ash flow eruptions, the source chamber is drained. The top of the volcano then collapses into the drained magma chamber along the ring fractures, forming a circular depression known as a caldera. Vertical displacement along the ring

Table 3-1. Generalized volcanic stratigraphy for Yucca Mountain showing probable source calderas and ages when caldera was active[a]

Volcanic center	Formation	Unit	Age (m.y.)[b]	Range in thickness[c] (meters)[d]
Timber Mountain caldera	Timber Mountain Tuff	Rainier Mesa Member	11.3	Not encountered
Claim Canyon caldera	Paintbrush Tuff	Tiva Canyon Member	12	0-69
		Yucca Mountain Member		0-36[e]
		Bedded Tuff		0-44
		Pah Canyon Member		11-83[e]
		Topopah Spr. Member	13	287-356
Northwest part the Calico Hills[f]		Tuffaceous beds of Calico Hills	13.4	95-306[g]
Crater Flat caldera	Crater Flat Tuff	Prow Pass Member	13.5	127-176[g]
		Bullfrog Member		99-161[e]
Tram caldera[f]		Tram Member		154-328
Northern Yucca Mountain area		Dacitic lava and flow breccia		0-112[h]
Northeastern Crater Flat[e]			ND[i]	
(f)		Tuff of Lithic Ridge	ND	42-311[g]
Northern Yucca Mountain area		Rhyolitic, quartz latitic and dacitic lava and flow breccia		9-323
Northeastern Crater Flat[f]			ND	
Northeastern Yucca Mountain		Older ash-flow and bedded tuffs	ND	

[a] Source: Maldonado and Koether (1983).
[b] m.y. = millions of years.
[c] Thicknesses based on four drill holes at Yucca Mountain, as reported in Maldonado and Koether (1983).
[d] 1 m = 3.28 ft.
[e] Includes overlying and underlying bedded tuffs.
[f] Volcanic center uncertain.
[g] Includes overlying bedded tuffs.
[h] Includes underlying bedded tuffs.
[i] ND = no age determination available.

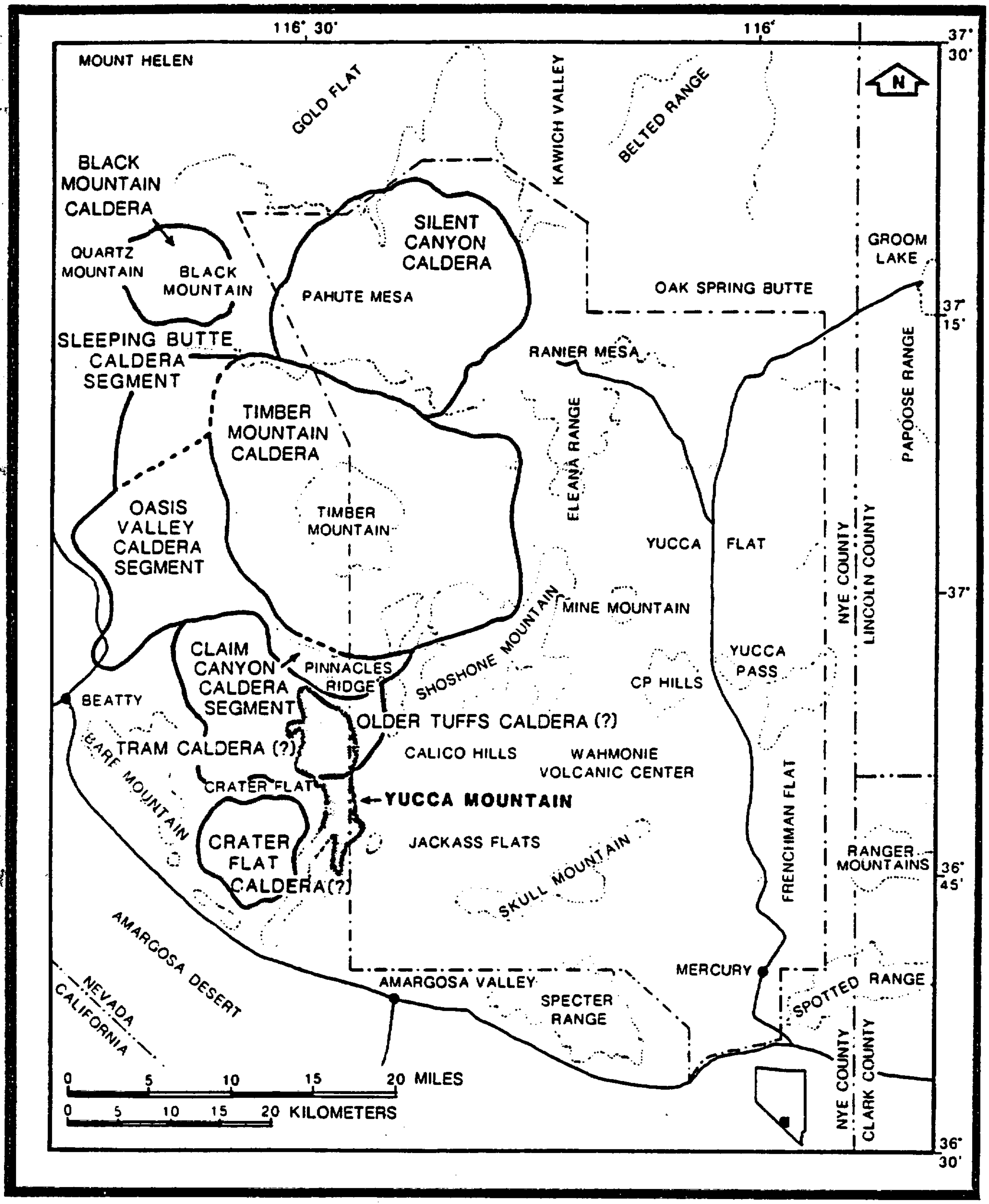

Figure 3-3. Southern end of southern Nevada volcanic field showing location of calderas in the vicinity of Yucca Mountain. (Source: Maldonado and Koether, 1983.)

fractures during the collapse of the caldera commonly amounts to many thousands of feet. During stage 4 minor volcanism occurs within the caldera, the unstable outer walls of the caldera undergo rapid erosion, and small lakes commonly form on the caldera floor. Stage 5 is characterized by rhyolitic volcanism and renewed doming within the central part of the caldera. The central dome is generally broken by a complex system of faults as the surface is displaced upward. During stage 6, rhyolitic lava flows and small volume ash-flow tuffs erupt along the ring fractures. These late-stage volcanic rocks often are interlayered within and near the caldera with debris flows, gravels, bedded tuffs, and sediments derived from the erupted material. The final stage of caldera evolution (stage 7) is hydrothermal alteration and fumarolic activity. Much of the alteration apparently occurs along fractures.

The ash flows of stage 2 described above generally originate from large volume gas-charged explosive eruptions. The explosions are caused by escape of volatiles and rapid expansion and fragmentation of the ascending rhyolitic lava into clouds of ash-sized particles consisting of hot glass shards and crystals. As the incandescent clouds of gas and superheated ash collapse back to the earth's surface, they flow rapidly down the volcanic slopes and spread across the surrounding terrain. After coming to rest, the glass shards and crystals become compacted, and weld together under their own weight and heat, forming the rock type known as welded tuff. Commonly the glassy shards develop crystals of feldspar and quartz minerals when hot vapors seep through the semi-molten mass during the cooling period. Further crystallization of the glassy shards may also occur through the process of devitrification. If devitrification does not occur, the rocks remain glassy and are referred to as vitric tuffs.

Single ash flows sometimes cool completely before being covered by another hot flow, thereby forming a single cooling unit characterized by densely welded, fractured, central parts surrounded above and below by less-welded parts. Complete cooling of earlier ash flows may not occur if several eruptions are closely spaced, forming volcanic sequences called compound cooling units. A glassy unit called a vitrophyre often occurs at the base or top of an ash flow, where rapid cooling was caused by contact with the earth or the atmosphere. Lithophysal cavities, formed as gas pockets in the viscous flows, commonly occur in the central parts of thick, densely welded zones. The lithophysae may be circular, elliptical, or flattened, depending on the amount of viscous flow and compaction that occurred after they formed. The interior, densely welded parts of the ash flows generally contain closely spaced vertical fractures that developed as the rock cracked during cooling. Fractures with other orientations are developed during sluggish movement of the partially consolidated ash flow or from later tectonic stresses.

Air-fall tuffs commonly occur in association with ash-flow tuffs. They originate from erupted ash that cools in the atmosphere before it settles on the land surface downwind from the source. These lower-volume and lower-temperature ash falls form rock types known as bedded tuffs, which are nonwelded, porous, and visibly stratified.

The following sections briefly describe the major Tertiary stratigraphic ash-flow and related units at Yucca Mountain. The general units and calderas are listed in Table 3-1. The rock types and thicknesses described below are based on a report by Maldonado and Koether (1983) of the results of exploratory drill holes at Yucca Mountain. General descriptions are from the publications listed at the beginning of this section and from a report by Guzowski et al. (1983).

3.2.1.2 Timber Mountain Tuff

The Timber Mountain Tuff is the youngest volcanic unit exposed at Yucca Mountain. It is commonly divided into the Ammonia Tanks Member and the underlying Rainier Mesa Member. Only the Rainier Mesa Member is preserved at Yucca Mountain (Lipman and McKay, 1965). It is an ash-flow unit that was erupted 11.3 million years ago from the Timber Mountain caldera (Figure 3-3). At Yucca Mountain, it occurs only in low-lying fault blocks (Section 3.2.2), indicating the fault blocks had formed by the time the Rainier Mesa Member was erupted. This unit is a moderately welded, devitrified tuff that grades downward into a nonwelded vitric tuff at the base.

3.2.1.3 Paintbrush Tuff

The Paintbrush Tuff at Yucca Mountain consists of four members with thin bedded reworked or air-fall tuffs between them. From youngest to oldest, the units are the Tiva Canyon Member, the Yucca Mountain Member, the Pah Canyon Member, and the Topopah Spring Member (Table 3-1). These units were erupted between about 12 and 13.2 million years ago from the Claim Canyon caldera and perhaps, in part, from the Oasis Valley caldera (Figure 3-3).

The Tiva Canyon Member forms the caprock at Yucca Mountain and ranges in thickness from zero where it has been eroded away in channels and washes to greater than 50 m (160 ft) on the ridge crests. It has a moderately to densely welded devitrified central portion, underlain by a less densely welded vitric zone. It is a compound cooling unit, compositionally zoned from rhyolite in the lower and middle parts to quartz latite near the top. Large xenoliths (fragments of preexisting rocks incorporated in the rising lava) occur at several places within the unit. Flattened lithophysae are common in the middle and upper parts. Bedded air-fall tuff and tuffaceous sediments a few meters thick occur at the base of the member. The total volume of the Tiva Canyon Member is 1000 km^3 (240 mi^3), indicating the massive eruption required to produce it.

The Yucca Mountain Member ranges in thickness from zero to 36 m (118 ft) and had an estimated original volume of only 17 km^3 (4.1 mi^3). It is a simple cooling unit with nonwelded to partly welded zones at the base, top, and distal portions. North of the site (drill hole USW G-2) the interior is moderately to densely welded with a lithophysal core. Compositionally, the unit is a rhyolite with little variation from top to bottom.

Bedded tuff and nonwelded ash-flow tuffs occur locally between the Yucca Mountain Member and the underlying Pah Canyon Member. These tuffs range in thickness from zero to 44 m (144 ft). The matrix is mostly vitric and contains abundant xenoliths of volcanic rocks.

The Pah Canyon Member at Yucca Mountain ranges in thickness from 11 to 83 m (36 to 272 ft). It is a simple ash-flow cooling unit with nonwelded to partly welded zones at the base and top, and an interior zone of moderate to dense welding north of the site. It is generally vitric, and tuffaceous sediments and air-fall tuff occur at the base.

The Topopah Spring Member contains the horizon currently being considered as the potential host rock for the repository. It is a compound cooling unit composed of as many as four separate ash-flow sheets, and varies in composition from low-silica rhyolite near the top to high-silica rhyolite near the base. At least 275 km^3 (66 mi^3) of ash-flow material were spread over an area of about 1800 km^2 (700 mi^2) during eruption of the Topopah Spring Member. At Yucca Mountain, this rock unit is about 350 m (1150 ft) thick, but it thins abruptly to the south and is absent near the southwest corner of the Nevada Test Site. It also appears to thin to the north where it is only about 290 m (950 ft) thick (drill hole USW G-2).

At Yucca Mountain, the Topopah Spring Member is characterized by four distinct zones, from top to bottom: a nonwelded to densely welded, generally vitric tuff; a moderately to densely welded, devitrified tuff that accounts for most of the total thicknesses of the member; a basal vitrophyre; and a vitric tuff grading downward from welded to nonwelded. The thick welded devitrified zone, second from the top, is currently being considered as the potential host rock for the repository. It contains abundant lithophysae in several intervals, but they are most common in its upper and central portions. In the lower part of the densely welded interval, lithophysae are less abundant, and it is this zone that is preferred as the host rock for the repository. The rock is intensely fractured and is composed almost exclusively of quartz and feldspar.

3.2.1.4 Tuffaceous beds of Calico Hills

The tuffaceous beds of Calico Hills is an informal name for tuffaceous rocks that may have originated from a currently obscured volcano near the north end of Calico Hills, east of Yucca Mountain (Figure 3-3). The unit ranges in thickness from 90-150 m (300-500 ft) at the site though it thickens to nearly 306 m (1000 ft) to the north (drill hole USW G-2). It is composed chiefly of nonwelded ash-flow tuffs, numerous thin tuffaceous sedimentary beds, and minor air-fall tuffs. The rocks in the northern and eastern part of the site are typically zeolitized, having undergone a low-temperature, low-pressure alteration to zeolite minerals. The rocks in the southern and western part of the site (drill holes USW G-3 and H-5) are vitric and not zeolitized.

3.2.1.5 Crater Flat Tuff

Beneath the Calico Hills unit is the Crater Flat Tuff which consists of three members; the Prow Pass Member at the top, the Bullfrog Member in the middle, and the Tram unit at the base. The Prow Pass Member is 127-175 m (417-574 ft) thick at Yucca Mountain. It contains six partly zeolitized, partly devitrified ash-flow tuffs that probably cooled as a compound unit (drill hole USW G-1). Most of the unit is partially to moderately welded;

however, bedded, reworked, and densely welded materials occur in it's central part, and zeolitized air-fall tuffs occur at the base. Mudstone fragments, derived perhaps from the Eleana Formation of Devonian-Mississippian age, are abundant in the Prow Pass Member. The Bullfrog Member ranges in thickness from 99-161 m (325-530 ft) and consists predominantly of partially to moderately welded ash-flow tuffs with isolated, thin, densely welded layers. The Tram unit is 154-327 m (507-1073 ft) thick and consists of at least four slightly to densely welded ash-flow tuffs, some of which are zeolitized and devitrified. Reworked bedded tuffs also occur in the Tram unit.

3.2.1.6 Older tuffs

In this document, all rocks below the Crater Flat Tuff are referred to as older tuffs. No formal stratigraphic units are recognized in the older volcanic rocks. Most of these units have been observed only in drill holes at Yucca Mountain. They generally consist of moderately to densely welded ash-flows, interspersed with rhyolitic lava flows, breccia flows, and nonwelded air-fall tuffs and bedded, reworked tuffs. The total thickness of the older tuffs is unknown. Four drill holes (USW G-1, USW G-2, USW G-3, and H-1) have penetrated more than 1800 m (6000 ft) without reaching the base of the volcanic rocks.

3.2.2 Structure

The structural development of southern Nevada and southeast California has been long and complex, as briefly discussed in Section 2.1. Crustal extension and associated volcanism, Basin and Range style faulting, and alluvial filling of intervening valleys during Cenozoic time (0 to 65 million years ago) has obscured the relationship of older, regional structural features. In Mesozoic time (65 to 150 million years ago), the Precambrian and Paleozoic sedimentary rocks of southern Nevada were strongly compressed. The folds and thrust faults formed during this interval indicate that compression was directed generally from west to east and that the age of deformation decreases to the east. The regional patterns of exposed pre-Tertiary rocks suggest that several thrust-fault systems and several broad, associated folds trend north to northeast through the area east of Yucca Mountain. The tectonic forces that created these ancient structures have long since been inactive (see detailed discussion in Section 6.3.1.7). The absence of pre-Tertiary rocks at the site constrains the discussion of pertinent structures to those produced by Tertiary extensional tectonics. These structures are complex and result from a long and complicated history. Nevertheless, field work conducted during the past few decades and recent studies at Yucca Mountain by the NNWSI Project have established a basic understanding of the structural and tectonic framework of this region.

The site lies in the southern Great Basin. Although topographic expressions of the Basin and Range style structures seem to indicate a relatively simple system of uplifted and downdropped crustal blocks, the deep structural configuration of some parts of the Basin and Range is complex (Allmendinger et al., 1983; Anderson et al., 1983). The origin of Basin and Range type structures has been attributed, in part, to right-lateral faulting along the western edge of North America during Cenozoic time (Hamilton and Myers, 1966; Atwater, 1970; Christiansen and McKee, 1978). Western North America lies within a broad belt of right-lateral movement caused by differential motion between the North American and Pacific crustal plates. Some of the right-lateral movement occurs along the San Andreas fault and similarily oriented faults in California (Figure 3-4). This type of motion may have occurred earlier in southern Nevada and eastern California along the Walker Lane, Death Valley, Furnace Creek, and Las Vegas Valley shear zones. This motion and the related extensional faulting caused fragmentation of the crust into basins and ranges oriented along trends oblique to the right-lateral fault zones. It is thought that the zones of extensional faulting are located above zones of pre-existing mantle upwelling (Atwater, 1970). Relatively high seismic activity continues today along the right-lateral Death Valley and Owens Valley shear zones northwest and southwest of Yucca Mountain, suggesting that these shear zones are still active.

Cumulative displacement across the entire zone of inferred right-lateral faulting in the western Great Basin, including fault-slip and large scale bending, may be in excess of 150 km (95 mi) (Albers, 1967). This estimate includes the bending of structural features to a northeasterly trend due to drag folding along the Walker Lane (Albers, 1967) and the Las Vegas Valley shear zone (Longwell, 1960). Maximum displacement along individual fault zones, however, is generally thought to be less than 48 km (30 mi). Several investigators suggest that the right-lateral fault zones became active about

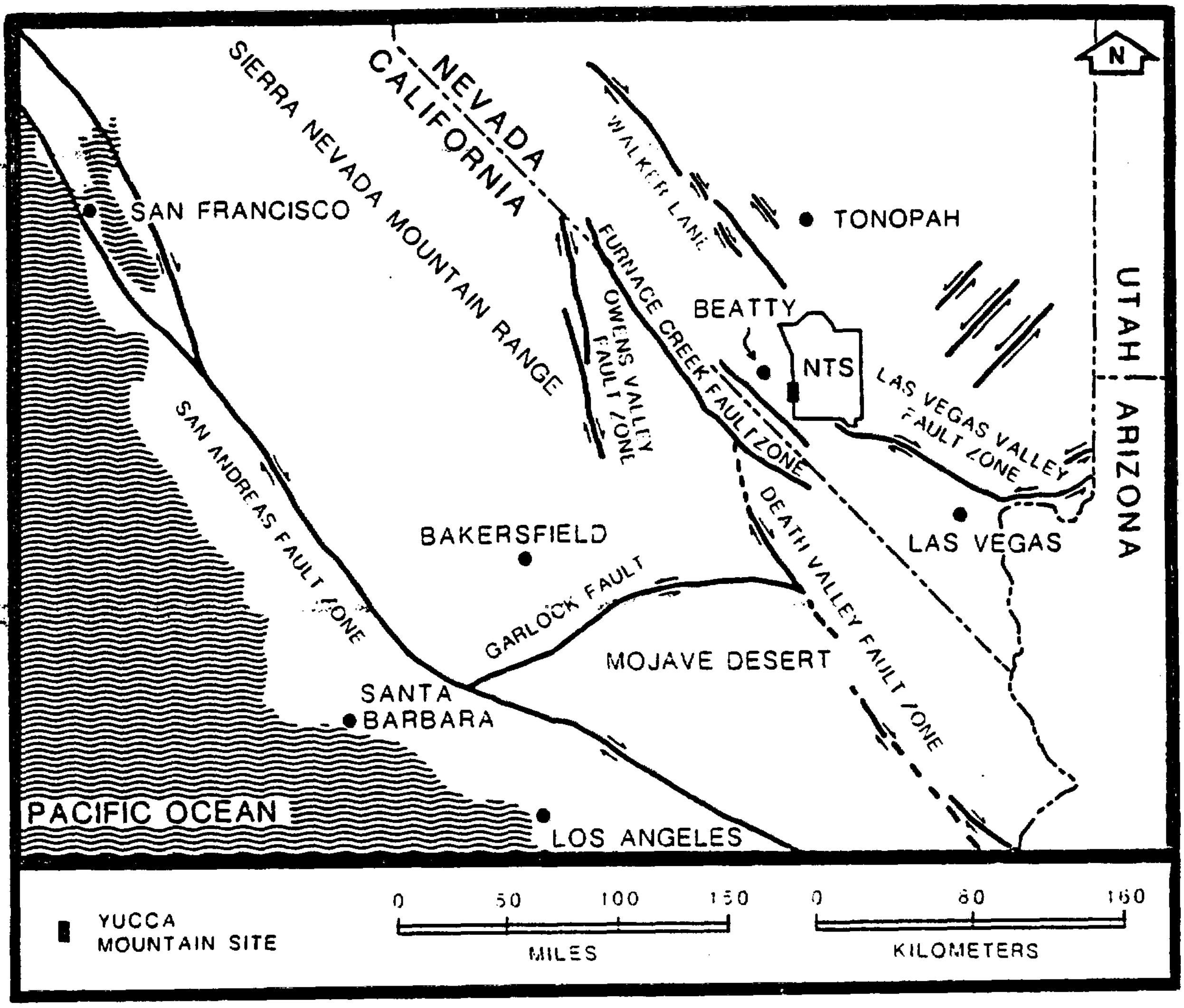

Figure 3-4. Map showing generalized strike-slip fault zones in Nevada and California. (Modified from Stewart, 1979, 1980; and Sinnock, 1982.)

25 million years ago, (Atwater, 1970; Carr, 1974), although others believe they were active for a much longer time (Albers, 1967).

Most displacement along the Las Vegas Valley shear zone southeast of Yucca Mountain has apparently occurred during the past 17 million years. Fleck (1970) and Carr (1974) reason that motion along this zone ceased about 10 million years ago. Although the Las Vegas Valley shear zone seems to have been inactive for millions of years, seismic activity and surface displacements have occurred during this century within the Walker Lane (Figure 3-4). Moreover, some surface displacements at Pahute Mesa and Yucca Flat north of Yucca Mountain, and along a trend between the Las Vegas Valley shear zone and the Walker Lane have been triggered by nuclear explosions (Hamilton et al., 1969). Therefore, some residual structural deformation may still be occurring along this zone.

The caldera complex in southwestern Nevada (described in Section 3.2.1) lies along a northwest trend connecting the Walker Lane and the Las Vegas Valley shear zone. Some investigators believe that the caldera complex at Timber Mountain is preferentially located where this northwest-trending zone of right-lateral faulting intersects Basin and Range faults extending southward from the Belted or Kawich Ranges, or where the northwest trending zone intersects the southwest-trending fault zones with components of left-lateral displacement (Carr, 1974) (Figure 3-5). Although no distinct faults can be traced between the two zones, structural, volcanic, and topographic features throughout this region suggest a connection between them (Christiansen et al., 1977).

Structural features at Yucca Mountain include local faults related to caldera collapse and longer faults of the Basin and Range style. The faults are shown on Figure 3-6 and on a structural cross section on Figure 3-7. The stratigraphic units are gently tilted to the east and are offset by several north-trending high-angle faults, down-dropped chiefly to the west, which created several large north-trending structural blocks (Lipman and McKay, 1965; Maldonado and Koether, 1983; Scott et al., 1983). Other fault systems trend northwest, particularly in the northern and southeastern parts of Yucca Mountain. Detailed mapping of the southern part of the site has revealed an area of very closely spaced, small faults that trend northeast. The primary repository area is shown on Figure 3-8. Rock strata in the primary area dip eastward at about 5 to 8°. This area is bounded on the west by a large fault zone along Solitario Canyon. Vertical displacement along the Solitario fault diminishes from about 200 m (700 ft) at the southern end to about 20 m (70 ft) at the northwest corner. To the east, the central area is bounded by several smaller, closely spaced faults. The northern edge of the primary area is defined by Drill Hole Wash, an informally named feature. The southern boundary is less well defined, but it is generally placed where the east- and west-bounding fault zones converge. One moderately sized fault, informally designated the Ghost Dance Fault, occurs within the primary repository area (Scott and Bonk, 1984).

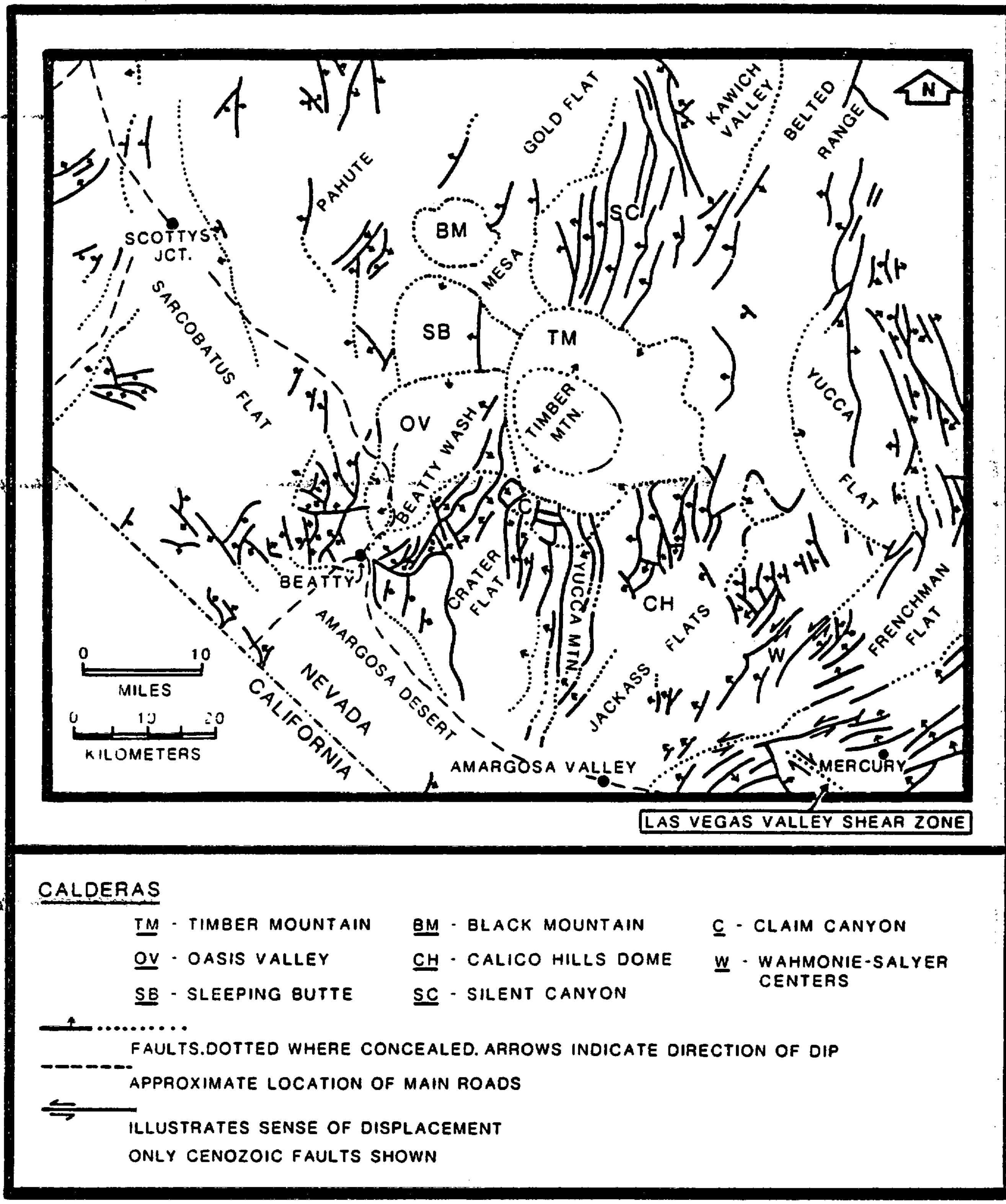

Figure 3-5. Generalized map of Yucca Mountain and vicinity showing calderas and late Cenozoic normal faults and a few strike-slip faults. (Source: Christiansen et al., 1977.)

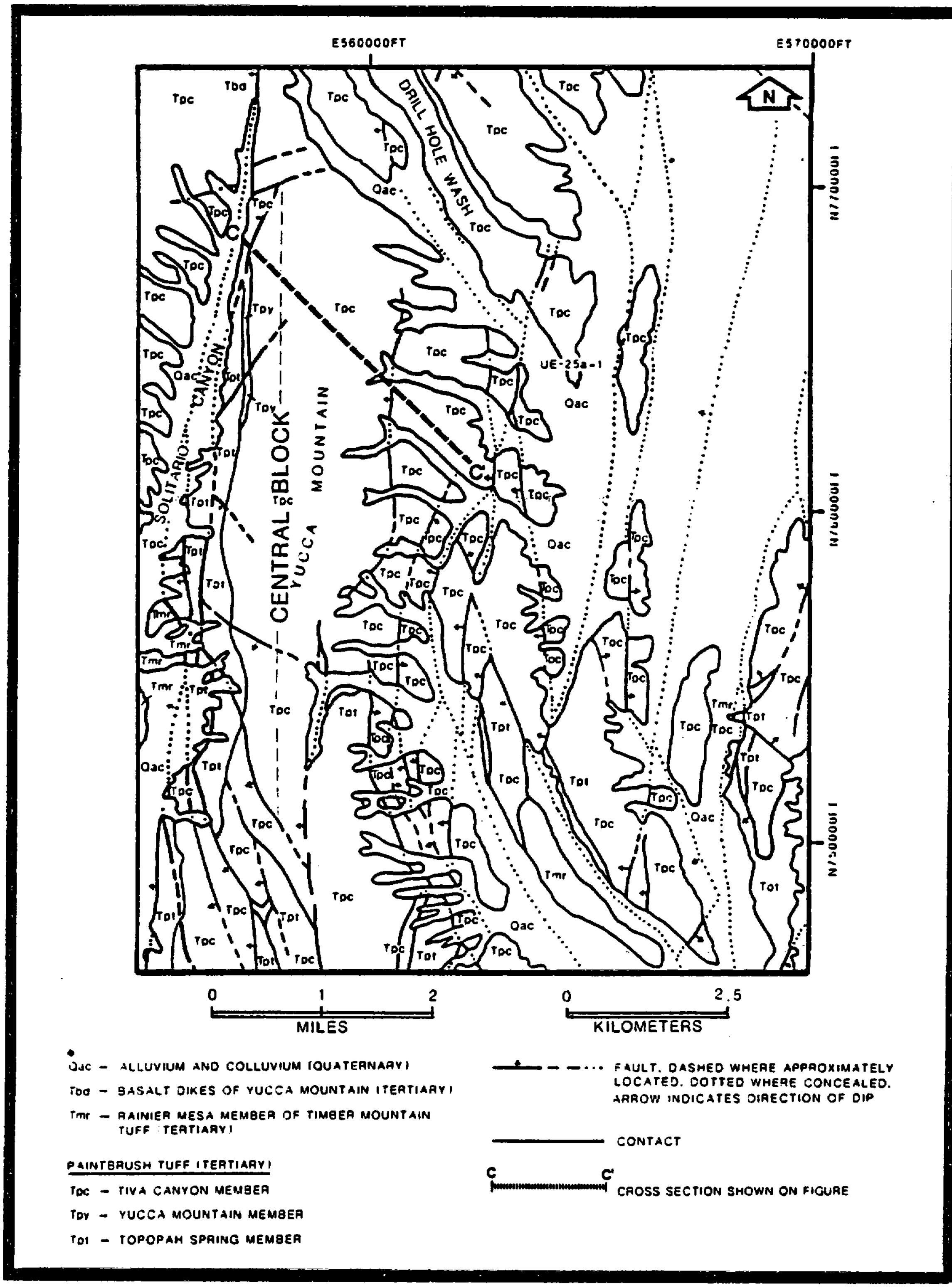

Figure 3-6. Geologic map of Yucca Mountain. Cross section C-C' is shown on Figure 3-7. (Modified from Maldonado and Koether, 1983.)

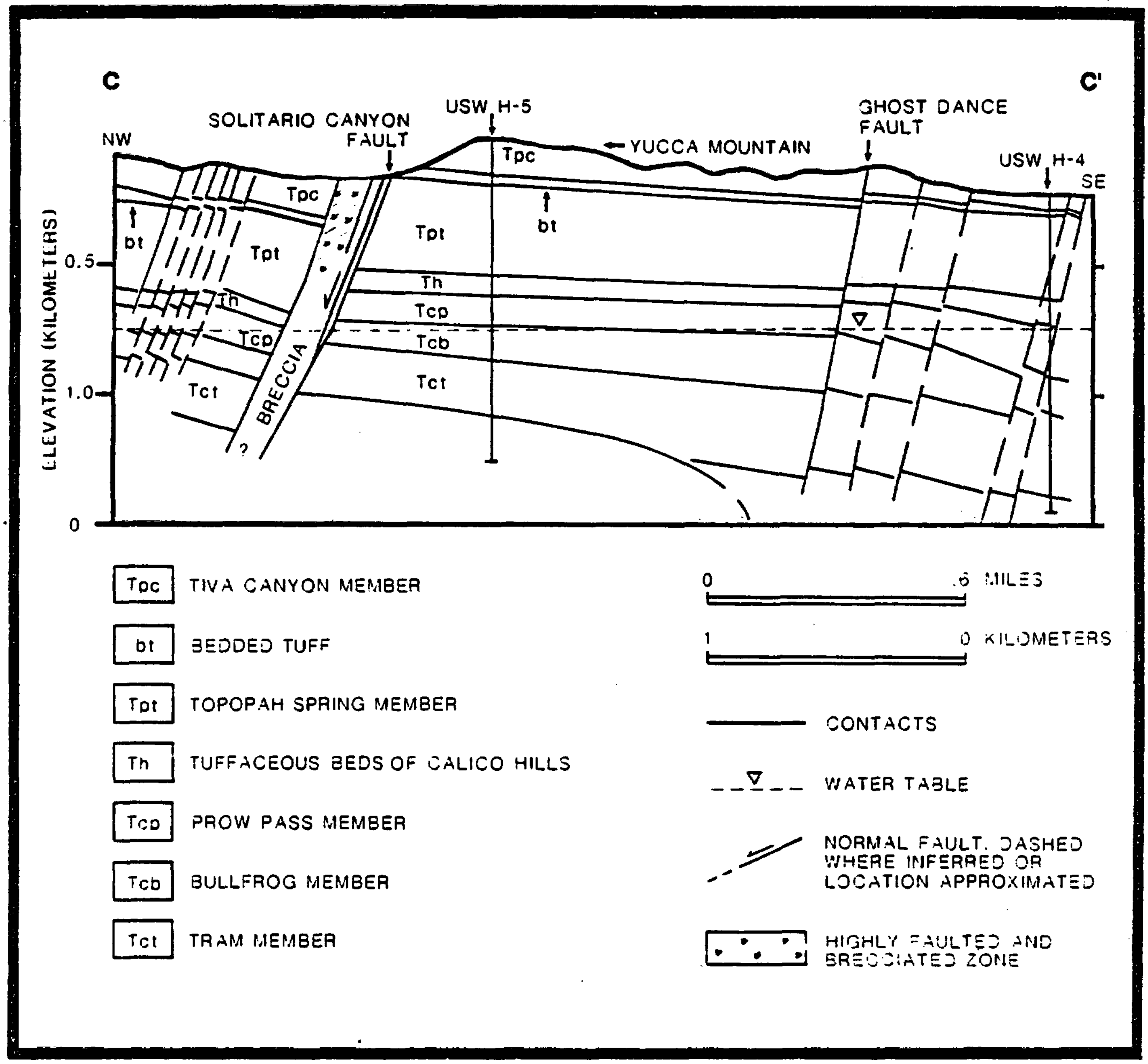

Figure 3-7. Northwest-southeast geologic cross-section through drill holes USW H-5 and USW H-4, showing recent evidence for fault characteristics. See Figure 3-6 for location of C-C' on geologic map. Source: Scott and Bonk, 1984

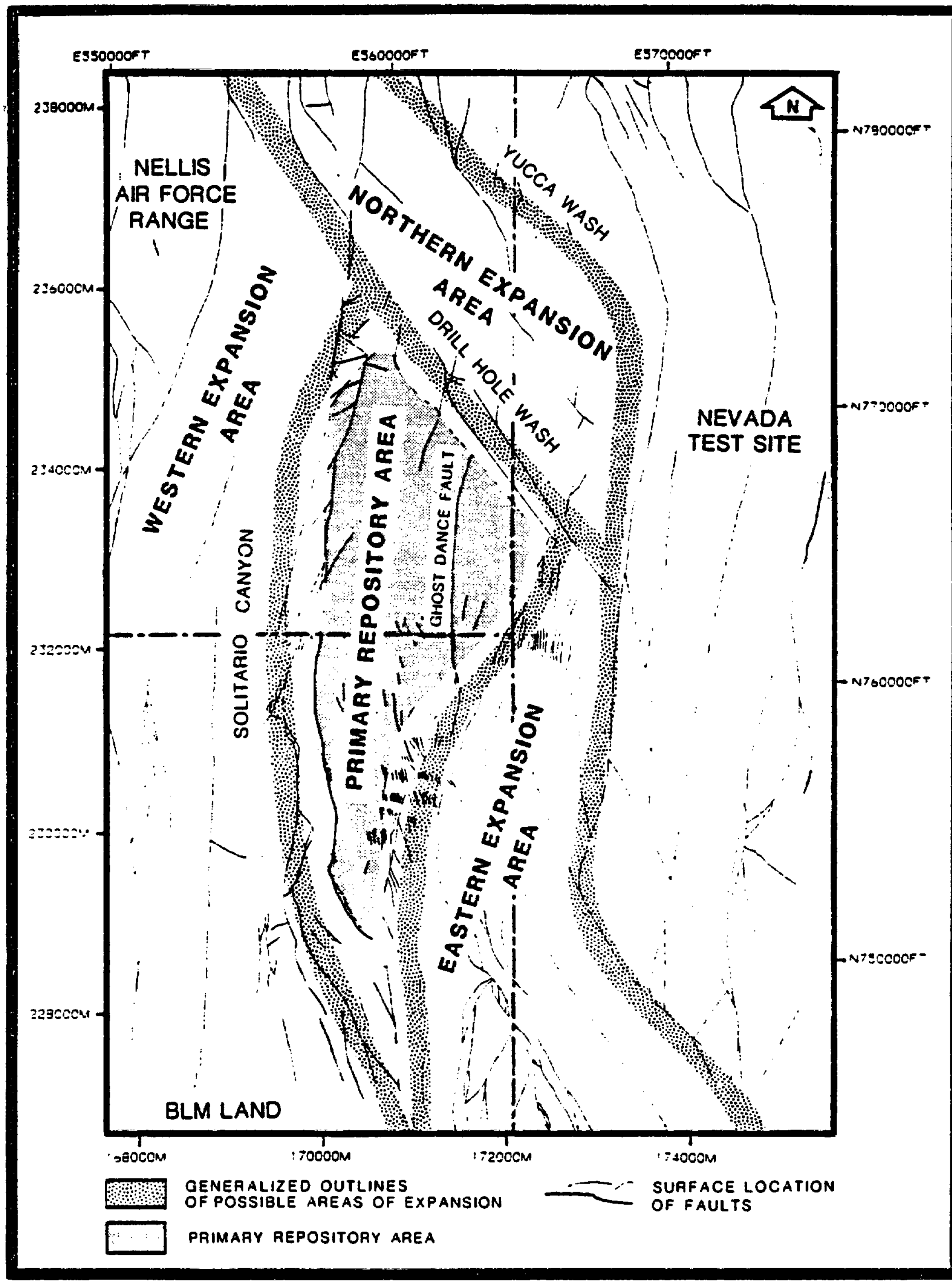

Figure 3-8. Generalized outlines of areas considered for location of the repository. (Modified from Sinnock, 1982.)

Drill-hole data indicate that some minor high-angle faults may have lateral as well as vertical components of displacement, particularly along northwest-trending faults north of the primary repository area (Maldonado and Koether, 1983.) Displacements along individual faults within the primary repository area are generally less than a few meters, whereas faults that separate major structural blocks may have a hundred or more meters of offset. The density of fractures is generally proportional to the degree of welding of the stratigraphic units. Near the major faults and in some local areas of abundant, small-offset faults, fracture density probably increases.

The age of the large block-forming faults at Yucca Mountain can be bounded between about 12 and 11.3 million years (Lipman and McKay, 1965; Marvin et al., 1970). The Tiva Canyon Member, which forms the surface rock throughout most of the site, is about 12 million years old and is displaced by the large block-forming faults in the area. Surface offsets of the Tiva Canyon Member north of the primary repository area indicate that movement along the faults occurred after this unit was deposited. At several locations around Yucca Mountain, the younger Timber Mountain tuff, which is about 11.3 million years old and is essentially undisturbed by major faults, occurs within the present valleys which are formed by the range-bounding faults that offset the Tiva Canyon Member. Thus, much of the displacement along the major block-forming faults had occurred by about 11 million years ago. Since then, faulting has apparently waned. Displacement of Quaternary alluvium within about 10 to 20 km (6 to 12 mi) of the site is limited to a few, very small, degraded scarps less than a meter or so in height. Dating of materials gathered from trenches dug across these low fault scarps has produced no unequivocal evidence that movement has occurred in the last 35,000 years (Swadley et al., 1984). Carr (1982) suggests that local Quaternary faulting along the east side of Crater Flat was related to, and synchronous with, nearby eruptions of small basaltic lava flows dated as about 1 million years old.

3.2.3 Seismicity

As shown in Figure 3-9, Yucca Mountain lies in an area of relatively low historic seismicity, just south of the southern Nevada East-West Seismic Belt (Smith, 1978). This belt connects the north-trending Nevada Seismic Zone, about 160 km (100 mi) west of Yucca Mountain, with the north-trending Intermountain Seismic Zone about 240 km (150 mi) to the east (Figure 3-9). Much remains to be learned about regional or local seismic cycles or the relation between seismicity and fault length in the Basin and Range province (Thenhaus and Wentworth, 1982). As pointed out by Smith (1978), the pattern of historic earthquakes in the western United States is marked by relatively brief episodes of intense activity in areas that may have been inactive for tens, hundreds, and perhaps thousands of years. Geologic field evidence suggests that Yucca Mountain has been relatively stable for the past eleven million years. However, until there is a better understanding of seismic cycles, and of why seismically stable and unstable areas exist within the same structural province, earthquakes near Yucca Mountain should be considered possible.

Seismic activity prior to 1978 within 10 km (6 mi) of Yucca Mountain shows seven earthquakes; of these, five had unknown magnitudes, and the remaining two had magnitudes of 3.6 and 3.4 on the Richter scale. Before 1978, however, standard errors of locations varied from about ± 2 to ± 7 km (1 to 4 mi). A new and more intensive seismic network has recorded seven microearthquakes in the same area between August, 1978 and the end of 1983. The largest magnitudes were approximately 2 on the Richter scale (Carr et al., 1984). There is some uncertainty in the seismic sources for many signals recorded by the seismic monitoring network in the vicinity of the Nevada Test Site and Yucca Mountain, because underground nuclear explosions, surface drilling, and explosions to support geophysical investigations may produce earthquake-like signals. Therefore, the information about earthquake frequencies and magnitudes should be regarded as preliminary. Surface faulting in response to nuclear tests has been observed at Pahute Mesa and Yucca Flat. The closest historical surface faulting accompanying natural earthquakes occurred in 1872 in Owens Valley, California, about 150 km (95 mi) west of Yucca Mountain; the related earthquakes had a magnitude of at least 8 (Rogers et al., 1977, p. 1588). Two historical earthquakes with a magnitude of 6 have been reported; one occurred in 1908 about 210 km (130 mi) southwest of Yucca Mountain, and one occurred in 1966, about 210 km (130 mi) northeast of Yucca Mountain. The peak historical acceleration at a location 20 km (12 mi) east of Yucca Mountain was estimated to be less than 0.1g (Rogers et al., 1977). The maximum magnitude earthquake expected on one potentially active fault at a distance of 15 to 33 km (9 to 21 mi), which is thought to present the greatest hazard to the Yucca Mountain site has been estimated to be a magnitude of 6.8. This earthquake would have a return period of from 900 to 30,000 years, and could produce a peak acceleration at Yucca Mountain of 0.4g (Carr et al., 1984).

The age and length of fault displacements may not be reliable indicators of future earthquake size and frequency, particularly for older faults (Ryall, 1977; Smith, 1978; Rogers et al., 1983). Some seismologists suggest that zones of low seismic activity in the Great Basin may indicate an accumulation of unreleased strain, thereby dictating caution in concluding that large earthquakes are unlikely (Ryall, 1977). Rogers et al. (1977) recognized this factor and applied probabilistic assessments to estimate the likely recurrence period of the maximum acceleration at any point in the southern Great Basin.

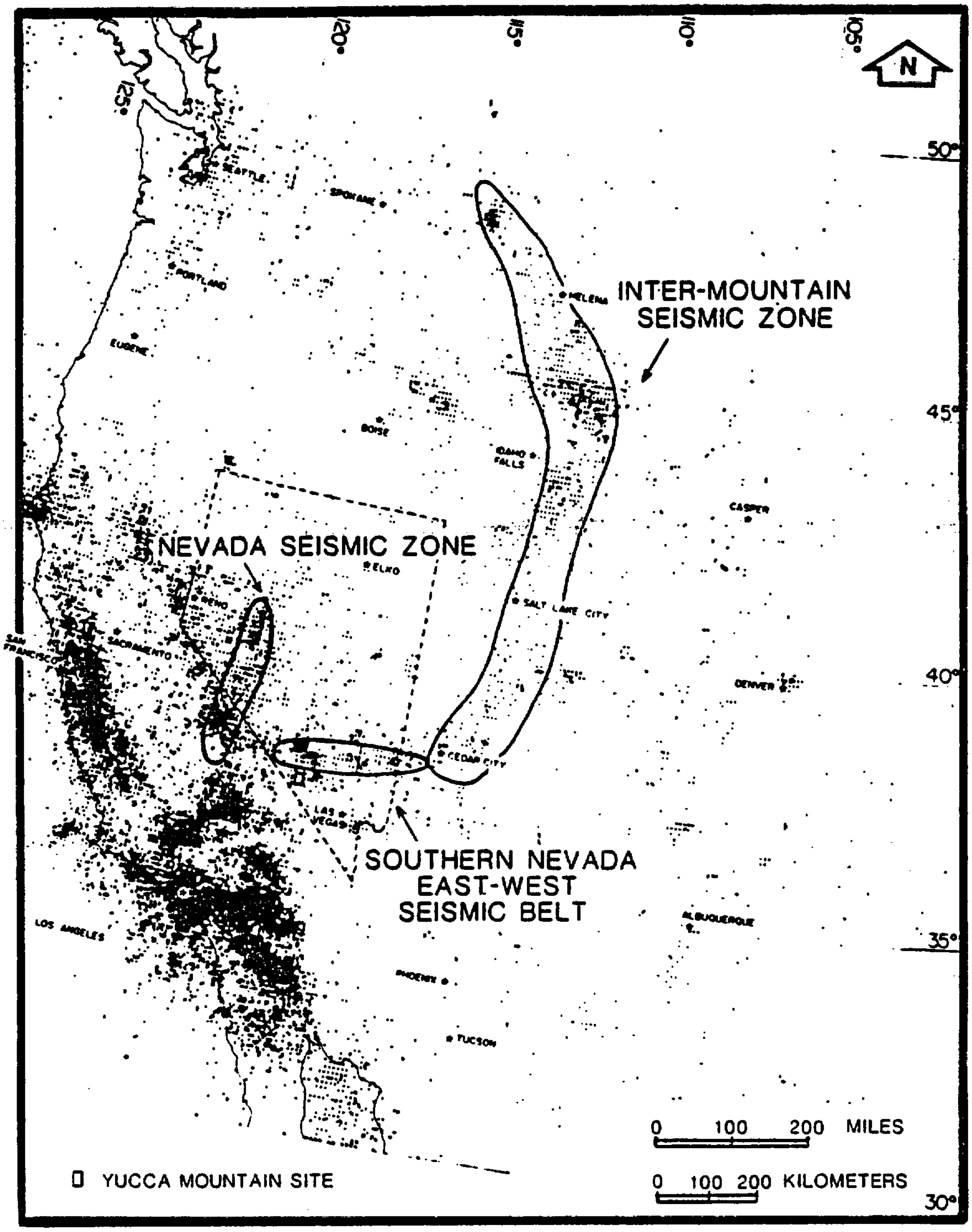

Figure 3-9. Historical seismicity in the western United States showing the Nevada Seismic Zone, the Intermountain Seismic Zone, and the southern Nevada East-West Seismic Belt. It should be noted that some of the seismicity in the western end of the East-West Seismic Belt represents underground explosions at the Nevada Test Site. (Source: Smith, 1978.)

Two models were used to estimate the relationship between acceleration and return period. Accelerations of 0.7g could have return periods of 15,000 years using one model, or could range from 100,000 to 1,000,000 years if the other model is used (Rogers et al., 1977).

Studies in progress suggest that fault orientation, with respect to current stress fields, is an important consideration in determining the potential for future seismic activity (Rogers et al., 1983; Carr et al., 1984). Initial results indicate that faults near Yucca Mountain trending from north to northeast are approximately perpendicular to the direction of minimum horizontal stress. As a result, these faults are potentially more susceptible to renewed dip-slip normal movement than faults with other trends (Healy et al., 1983).

3.2.4 Energy and mineral resources

The energy- and mineral-resource potential of Yucca Mountain and surrounding areas has been evaluated by Bell and Larson (1982). This study, as well as analyses from several drill holes in support of the NNWSI project (Maldonado and Koether, 1983; Spengler et al., 1981; Spengler and Chornack, 1984), indicates that the overall potential for exploration or development of mineral or energy resources at Yucca Mountain is low.

3.2.4.1 Energy resources

There is no evidence to indicate that Yucca Mountain contains any hydrocarbon, uranium, or geothermal resources (Bell and Larson, 1982). None of the drill holes at or near Yucca Mountain have shown evidence of hydrocarbons. The only potential energy resource near Yucca Mountain is low- to moderate-temperature springs more than 30 km (20 mi) from the site (Garside and Schilling, 1979; Trexler et al., 1979). However, there are no warm springs at Yucca Mountain. The geothermal gradient measured in several drill holes at Yucca Mountain (Sass and Lackenbruch, 1982) also indicates that no high-temperature waters could be present at depths that are economically attractive. The geothermal gradient is about 2°C/100 m (1.1°F/100 ft) in the unsaturated zone, and about 2.9°C/100 m (1.61°F/100 ft) in the saturated zone. This gradient is equal to, or less than the gradient over one-half the continental United States, and thus presents no unique or unusual attraction for future exploration.

Minor amounts of uranium have been reported west of the site at Bare Mountain, but no uranium mines or prospects have been developed. Under current economic conditions, uranium resources identified in the Bare Mountain area are not attractive targets for uranium development (Bell and Larson, 1982). The volcanic rocks from the Silent Canyon caldera north of the site are petrologically similar to the rocks from the McDermitt caldera in northern Nevada which contain minor amounts of uranium (Bell and Larson, 1982), but no prospects or claims have been developed.

3.2.4.2 Metals

Table 3-2 identifies the status, number, and types of mining operations for base and precious metals in the Yucca Mountain area, and Figure 3-10 shows the location of these deposits. Historically, Nevada's metallic industry centered around the mining of precious metals in the Comstock district in west-central Nevada and in the Tonopah and Goldfield districts more than 150 km (95 mi) northwest of the site. Although there are numerous small mining districts throughout the southern Great Basin, the only active silver and gold mine in the region is the Sterling (Panama) mine near Bare Mountain. Bell and Larson (1982) estimate gold reserves at the Sterling mine to be 930 kg (2000 lb). The total value of gold produced from the mine since early 1980 is estimated to be no more than $1.8 million; the mine is profitable but small by industry standards.

Table 3-2. Mining operations in the vicinity of the Yucca Mountain site[a]

Location	Number and status of operations	Type of operations
Bare Mountain (gold, silver, mercury, tungsten, lead)	4 active 10 inactive 10 unknown status	Prospect pits, open pits, placer, underground tunnels, and shafts
Mine Mountain (silver, lead, mercury)	None active 3 inactive	Underground tunnels and shafts
Wahmonie (gold, silver, copper)	None active	Prospect pits, underground shaft
Lee (gold, copper, tungsten)	None active 1 inactive	Prospect pits, shallow diggings, underground shafts
Northern Yucca Flat (Climax District) (gold, silver, lead)	None active 1 inactive	Shallow surface diggings, underground shafts
Amargosa Desert (tungsten, iron)	None active 1 inactive	Prospect pits

[a] Source: Bell and Larson, 1982.

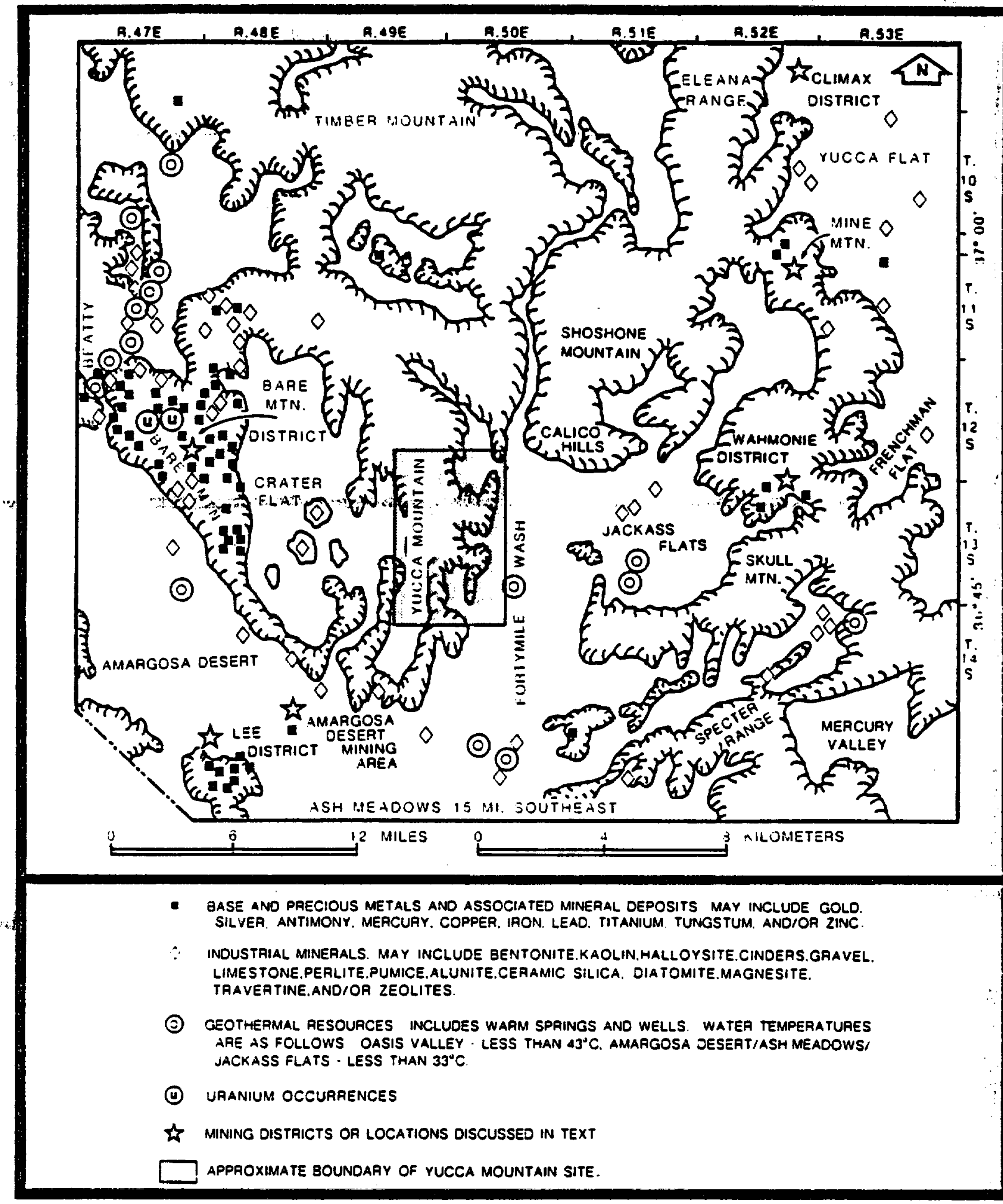

Figure 3-10. Location of metal deposits, industrial minerals, thermal waters, and mining districts in the vicinity of Yucca Mountain. (Modified from Bell and Larson, 1982; Trexler et al., 1979.)

A mine located northwest of Yucca Mountain has produced a small amount of mercury from cinnabar distributed in seams and spheres in silicified and opalized rhyolite tuff (Cornwall and Kleinhampl, 1961). Base and precious metals have also been prospected and mined east of the site in the Mine Mountain and Wahmonie districts. Information on the mining history in these districts, however, is limited. The land around these districts was withdrawn from public domain more than 30 years ago as part of the Nevada Test Site. The Wahmonie district apparently produced gold and silver sometime between 1905 and 1910 and again in 1928, but the amount was not recorded. Geophysical surveys suggest that the Wahmonie district may contain some precious metal deposits, but the potential amounts remain undetermined (Hoover et al., 1982). The Calico Hills area northwest of the Wahmonie district has been the location of substantial prospecting, but no production has been recorded. Trace amounts of silver and gold occur in the lower Tram Member at about the 1070-m (3515-ft) depth in drill hole USW G1 (Spengler et al., 1981). The concentrations are 0.5 ppm (0.016 oz/ton) gold and 20 ppm (0.64 oz/ton) silver, and are not high enough to be considered of commercial interest, especially at this depth. Although mercury, lead, zinc, and uranium have been identified along fault and fracture zones in volcanic rocks in Nevada, no occurrences of these metals have been reported along fractures of the Yucca Mountain site. On the basis of this preliminary information, Yucca Mountain is not considered to have any potential for the development of metal resources under foreseeable economic conditions and extraction techniques.

3.2.4.3 Nonmetals

A large variety of industrial minerals and rocks are present in the Yucca Mountain region, including clays, ceramic silica, zeolites, alunite, fluorite, sand, gravel, and lightweight construction aggregate (volcanic cinders, perlite, and pumice). Clay resources are dominantly kaolinite, montmorillonite, and halloysite and are extracted from shallow surface pits. A small amount of silica has been produced from the Silicon Mine in the Bare Mountain district. Zeolites occur at the site at depths of 400 m (1300 ft) or more, but there is no evidence to suggest that they are of a quality or extent to make them commercially attractive. Fluorite occurs widely in the Bare Mountain district, 16 km (10 mi) east of the site.

Sand and gravel deposits are ubiquitous in the Yucca Mountain area. These materials are extracted from shallow, surface pits and are used chiefly for road construction. Volcanic cinder, perlite, and pumice occur in Crater Flat. These materials are mined from surface pits and used for lightweight aggregate, concrete blocks, road base, and decorator stone. Other than sand and gravel, none of these surface resources occur at the Yucca Mountain site.

3.3 HYDROLOGIC CONDITIONS

This section describes the hydrology of Yucca Mountain and nearby areas. Topics discussed include surface water, ground water, and present and future water use. Much of the descriptive information in this section is summarized from a report by Winograd and Thordarson (1975), and from the discussions presented in Section 6.3.1.1.

Numerous investigations of the geohydrology of Yucca Mountain and nearby areas have been conducted since 1978 (Section 6.3.1.1 for list of studies). These studies have resulted in a general understanding. Detailed studies of water movement, including flow through the unsaturated zone, are in progress or are planned.

3.3.1 Surface Water

No perennial or intermittent streams occur at or near Yucca Mountain. The only reliable sources of surface water are the springs in Oasis Valley, the Amargosa Desert, and Death Valley. Because of the extreme aridity of this region, where annual precipitation averages about one-third of potential evapotranspiration, most of the spring discharge travels only a short distance before evaporating or infiltrating back into the ground.

Rapid runoff during heavy precipitation fills the normally dry washes for brief periods of time. Local flooding can occur where the water exceeds the capacity of the channels. The potential for flooding at Yucca Mountain, and its potential effects on a repository, are described in Section 6.3.3.3. In contrast to the washes, the terminal playas may contain standing water for days or weeks after severe storms. Runoff from precipitation at Yucca Mountain drains into Fortymile Canyon on the east and Crater Flat on the west, and both areas drain into the normally dry Amargosa River (Figure 3-11). If runoff is very high, water in the Amargosa River flows into the playa in southern Death Valley.

3.3.2 Ground water

Yucca Mountain lies within the Death Valley ground-water system, a large and diverse area in southern Nevada and adjacent parts of California composed of many mountain ranges and topographic basins that are hydraulically connected at depth. In general, ground water within the Death Valley system travels toward Death Valley, although much of it discharges before reaching Death Valley. Ground water in the Death Valley system does not enter neighboring ground-water systems.

The Death Valley ground-water system is divided into several ground-water basins. Information now available indicates that ground water moving beneath Yucca Mountain discharges in Alkali Flat and perhaps in Death Valley, but not in Ash Meadows or Oasis Valley. As shown in Figure 2-5, Yucca Mountain is in

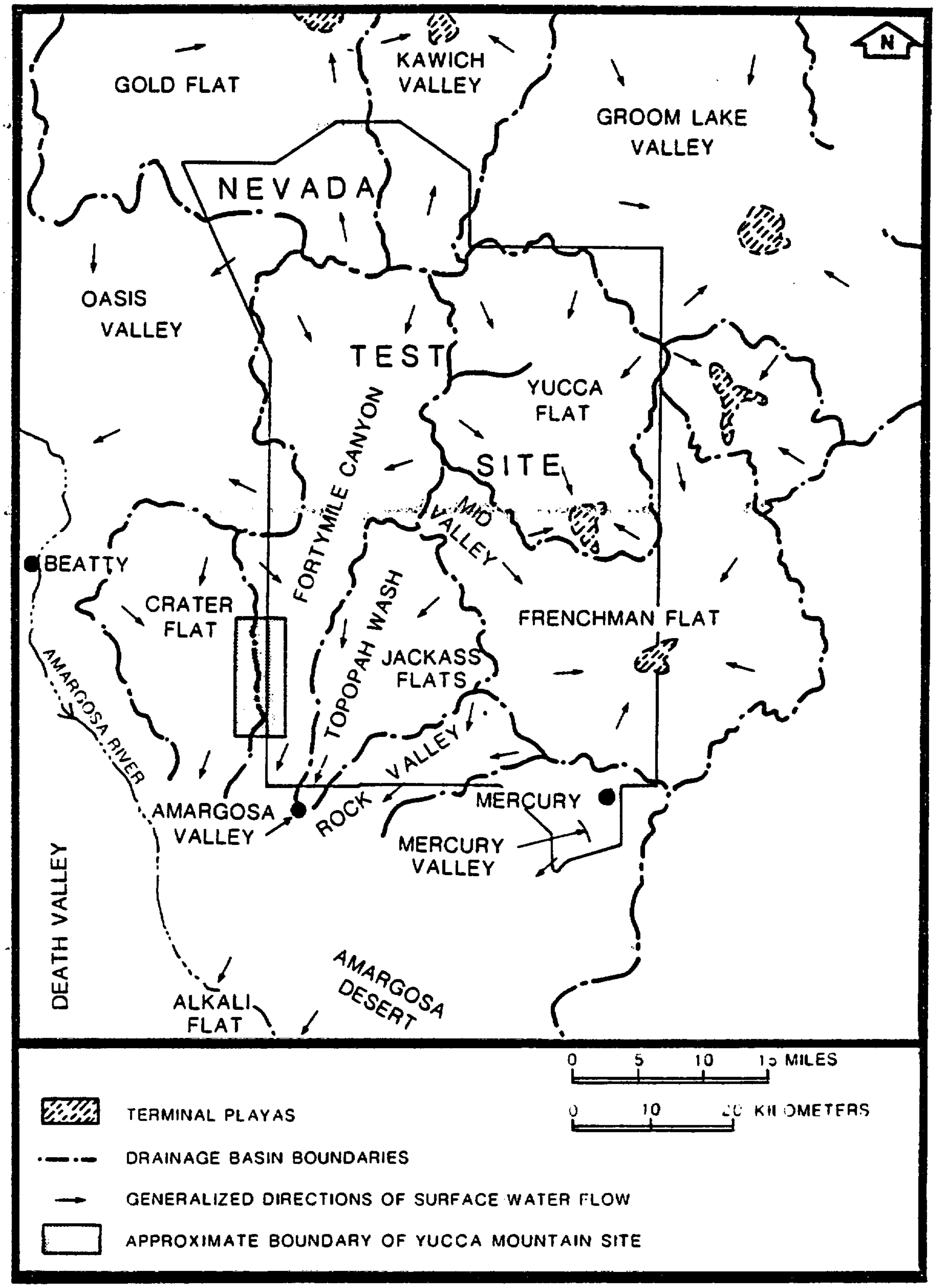

Figure 3-11. Drainage basins in the Yucca Mountain area showing direction of flow of surface water. (Source: ERDA, 1977.)

the Alkali Flat-Furnace Creek Ranch ground-water basin, at a position midway between the Ash Meadows and the Oasis Valley basins (Waddell, 1982).

Geologic formations in southern Nevada have been grouped into broad hydrogeologic units by Winograd and Thordarson (1975). Several of the units transmit water in sufficient quantities to supply water needs (aquifers), whereas other units have relatively low permeabilities that tend to retard the flow of ground water (aquitards). The geologic and hydrologic properties of the aquifers vary widely. Some of the hydrogeologic characteristics of the Tertiary volcanic rocks at Yucca Mountain are shown on Table 3-3. The lower and upper carbonate aquifers and the welded-tuff aquifers store and transmit water chiefly along fractures. In contrast, the valley-fill aquifers store and transmit water chiefly through interstitial openings. The lower carbonate and valley-fill aquifers are the chief sources of ground water in the eastern part of the Nevada Test Site.

3.3.2.1 Ground-water movement

The unsaturated zone within the boundary of the primary repository area at Yucca Mountain is about 500 to 750 m (1600 to 2500 ft) thick, but thins to as little as 200 m (600 ft) within 10 km (6 mi). Within this area, the water table slopes to the southeast, from an elevation of 800 m (2600 ft) to as low as 730 m (2400 ft) above sea level (see Figure 6.3.1.1-1 for a water table contour map). The water table is 200 to 400 m (600 to 1300 ft) below the horizon proposed for the repository (see Section 6.3.1.1 for detailed discussion of Yucca Mountain hydrology).

Most of the annual precipitation, 150 to 200 mm (5.9 to 7.8 in.), is returned to the atmosphere by evaporation and plant transpiration. A small part of the precipitation that falls on Yucca Mountain, probably less than 1 mm/year (Montazer and Wilson, 1984), percolates through the unsaturated zone and eventually enters the underlying tuff aquifer (~~see~~ Section 6.3.1.1). The principal source of recharge for the tuff aquifer is probably Pahute Mesa to the north and northwest of Yucca Mountain (~~see~~ Figure 3-2). The ground water then moves horizontally toward Alkali Flat and Death Valley. The paragraphs below characterize the most important aspects of ground-water movement in the vicinity of Yucca Mountain as they are currently understood.

From Yucca Mountain, ground-water travel in the saturated zone is to the south-southeast through tuff, and possibly through alluvium. Depth to the carbonate aquifer beneath the primary repository area has not been determined, but it is probably much greater than the 1250 m (4100 ft) observed in drill hole UE-25p#1 located 2.5 km (1.5 mi) east of the block. At drill hole UE-25p#1, the hydraulic head in the carbonate rocks is higher than in the overlying tuffaceous rocks. Because water cannot move in the direction of higher hydraulic head, it is concluded that ground water in the tuff aquifers beneath Yucca Mountain does not enter the carbonate aquifer.

Deep, regional movement of ground water south and east of Yucca Mountain occurs chiefly through the lower carbonate aquifer. This aquifer is composed of highly fractured and locally brecciated middle Cambrian to late Devonian

Table 3-3. Dual classification of Tertiary volcanic rocks at Yucca Mountain, stratigraphic units reflecting origin and hydrogeologic units reflecting hydrology characteristics and properties

STRATIGRAPHIC UNIT	HYDROGEOLOGIC UNIT (UNSATURATED ZONE)	APPROXIMATE THICKNESS (METERS)	SATURATED MATRIX HYDRAULIC CONDUCTIVITY (MONTAZER AND WILSON, 1984)	COMMENTS[a]
Alluvium	Alluvium	0-30+	Generally high	Underlies washes; thin layer on flats.
Paintbrush Tuff: Tiva Canyon Member	Unsaturated Zone: Tiva Canyon welded unit	70-150	1 mm/yr	Caprock that dips 5-8° eastward at Yucca Mountain. High fracture density.
Paintbrush Tuff: Pah Canyon Member; Yucca Mtn. Member; Topopah Spring Member, Nonwelded	Paintbrush nonwelded unit	3-200	19,000 mm/yr 77,000 mm/yr	Vitric, nonwelded, porous, poorly indurated, bedded in part. Low fracture density.
Paintbrush Tuff: Topopah Spring Member, Vitrophyre Welded	Topopah Spring welded unit	290-360	1 mm/yr	Densely to moderately welded; several lithophysal (cavity) zones; intensely fractured. Central and lower part is potential host rock for repository. Bulk hydraulic conductivity in saturated zone east of the site (at well J-13) about 1.0 m/day.
Paintbrush Tuff: Topopah Spring Member, Nonwelded; Tuffaceous Beds of Calico Hills (Vitric / Zeolitized); Crater Flat Tuff: Prow Pass Member, Nonwelded	Calico Hills nonwelded unit	100-400	Vitric: 2600 mm/yr Zeolitic: 1 mm/yr	Beneath Yucca Mountain, base of unit for unsaturated zone determined by water table. Unit is vitric in southwest Yucca Mountain, zeolitized in east and north. Includes bedded units. Bulk hydraulic conductivity in saturated zone from pumping tests about 0.2 m/day.
	water table			
Crater Flat Tuff: Prow Pass Member, Welded		120-200	28 mm/yr	
Crater Flat Tuff: Bullfrog Member		120-170	62 mm/yr	
Crater Flat Tuff: Tram Member	Saturated Zone	170-350	51 mm/yr	
Lava		0-250	Very low	Occurs in northwest part of repository block.
Lithic Ridge Tuff		30-190	Very low	
Older Volcanics			Very low	In USW H-1 hydraulic head about 50 m higher than water table.
Pre-Tertiary Rocks			Unknown	Occurs 2.5 km east of proposed repository at depth of 1250 m in UE-25p#1, where hydraulic head is about 20 m higher than water table. Bulk hydraulic conductivity high, probably due to high fracture density.

[a] Source: Modified from Winograd and Thordarson, 1975.

limestone and dolomites that are highly transmissive (Winograd and Thordarson, 1975). Because of complex geologic structure, flow paths in the lower carbonate aquifers are complex and are poorly defined. In places the ground-water flow is diverted laterally or vertically because of fault displacements that have juxtaposed the lower carbonate aquifer against less permeable rocks. Where the flow is blocked, such as at Ash Meadows in the southern Amargosa Desert, the water table may intersect the land surface causing springs.

3.3.2.2 Ground-water quality

Schoff and Moore (1964) recognized three types of ground water at the Nevada Test Site and vicinity: (1) sodium and potassium bicarbonate, which generally occurs in tuff aquifers and valley-fill aquifers that are composed chiefly of tuff detritus; (2) calcium and magnesium bicarbonate, which generally occurs in the carbonate aquifers and the valley-fill aquifers that are composed chiefly of carbonate detritus; and (3) mixed, which is defined as having the chemical characteristics of both types 1 and 2.

All of the three types of ground water occur in the Ash Meadows basin, which in the definition by Winograd and Thordarson (1975) included Yucca Mountain. More recent information (Waddell, 1982) places Yucca Mountain in the Alkali Flat-Furnace Creek Ranch basin of the Death Valley ground-water system (Figure 2-5). Winograd and Thordarson (1975) report and summarize total dissolved solids from many analyses of these three types of waters; the values range from 91 to 1071 mg/l, with mean values ranging from 217 to 580 mg/l.

3.3.3 Present and projected water use in the area

Water in southern Nevada (excluding the Las Vegas area) is used chiefly for irrigation, and to a lesser extent for livestock, municipal needs, and domestic supplies. Almost all the required water is pumped from the ground, although some springs supply water to establishments in Death Valley and other areas south of Yucca Mountain (Pistrang and Kunkel, 1964; Hunt et al., 1966; Thordarson and Robinson, 1971; Waddell et al., 1984). The ground water in the tuff aquifers underlying the Yucca Mountain site (see Figures 2-5 and 2-6, Chapter 2) is part of the Alkali Flat - Furnace Creek Ranch ground-water basin, which discharges in Alkali Flat or Death Valley (Waddell, 1982). This aquifer becomes shallower to the south and the flow is through alluvium rather than tuff. Wells which are located between Yucca Mountain and Death Valley are likely to be pumping ground water from this same tuff-alluvium aquifer. In addition, springs in Oasis Valley near Beatty, Nevada, about 30 km (20 mi) northwest of Yucca Mountain are a significant source of water for public and domestic needs and for irrigation (Thordarson and Robinson, 1971; White, 1979). (See Section 3.6.3 for the amounts of water used annually by towns and communities in the vicinity of Yucca Mountain.)

The principal users of ground water in this area are in the Amargosa Desert south of the town of Amargosa Valley and in the Pahrump Valley. According to McNealy and Woerner (1974), 800 ha (2000 acres) of land were being irrigated in the Amargosa Desert in 1969. The amount of water used in the

Amargosa Desert is not known, but individual family wells are limited to 2500 m^3 (2 acre-ft) per year. Pahrump Valley uses about 58,000,000 m^3 (47,000 acre-ft) per year. In 1970, because of a declining water table, the State Engineer stopped granting ground-water permits for irrigation in the Pahrump Artesian Basin. Permits for other uses are being considered on a case-by-case basis. The only projections for future ground-water use in this area are for the planned communities in Pahrump Valley.

From 1967 to 1970 an extensive well field was developed for irrigation in the Ash Meadows area along the east side of the Amargosa Desert. In a study by the U.S. Geological Survey at the request of member organizations of the Desert Pupfish Task Force,* Dudley and Larson (1976) concluded that withdrawals of ground water from parts of this well field caused a 0.8-m (2.5-ft) reduction in the water level in the pool in nearby Devils Hole, thereby threatening the survival of the Devils Hole pupfish (Cyprindon diabolis). Subsequent law suits and a final ruling by the U.S. Supreme Court in 1976 (Cappaert v. United States, 426 U.S. 128 (1976)) ordered a restriction in pumping from specific wells in the Devils Hole area.

The mining industry in southern Nevada uses a small amount of water for processing. Water for this purpose is supplied from nearby shallow wells or is trucked in from nearby towns. Many of the mines currently recycle process water, which reduces their consumptive water demand.

* Includes representatives of the National Park Service, the Bureau of Reclamation, the Bureau of Land Management, the Bureau of Sport Fisheries and Wildlife, and the Geological Survey.

^ U.S.

3.4 ENVIRONMENTAL SETTING

This section contains a detailed description of existing land use, ecosystems, air quality, noise, aesthetics, archaeological resources, and the radiological background of Yucca Mountain and the surrounding region. The data provides a baseline for assessing potential impacts during site characterization (see Chapter 4) and during construction, operation, and decommissioning if Yucca Mountain is selected for a repository (see Chapters 5 and 6).

3.4.1 Land use

Land use in the Yucca Mountain area includes Federal use, agriculture, mining, recreation, and private and commercial development. These uses are discussed below. Land-use patterns in southwestern Nevada are shown in Figure 3-12.

3.4.1.1 Federal use

The Yucca Mountain site is on limited-access Federal land that is controlled by three Federal agencies. As shown on Figure 3-12, the Nellis Air Force Range includes 10,670 km^2 (4120 mi^2) controlled by the Department of the Air Force, the Nevada Test Site includes 3500 km^2 (1350 mi^2) controlled by the DOE, and many thousands of square kilometers are controlled by the BLM. The Nellis Air Force Range is used for military weapons testing and personnel training. The portion of the range in the immediate vicinity of Yucca Mountain is reserved for occasional overflights and provides air access to the bombing and gunnery areas located further north and west of the site. Land use at the Nevada Test Site supports nuclear weapons research and development. The site is dedicated to underground nuclear testing, development and testing of nuclear explosives for peaceful applications, and testing of weapon effects. The BLM applies a multiple use concept in administering the public domain lands and forests. These lands are currently used for recreation, grazing, forest management, and wildlife management.

3.4.1.2 Agriculture

A limited amount of agriculture is supported in the Oasis valley, the Amargosa valley, Ash Meadows area, and the Pahrump valley. None of these areas is considered to contain prime agricultural land. A portion of the extensive Federal lands in southern Nye County is used for cattle grazing and, as such, these lands are the major agricultural resource near the site (Collins et al., 1982).

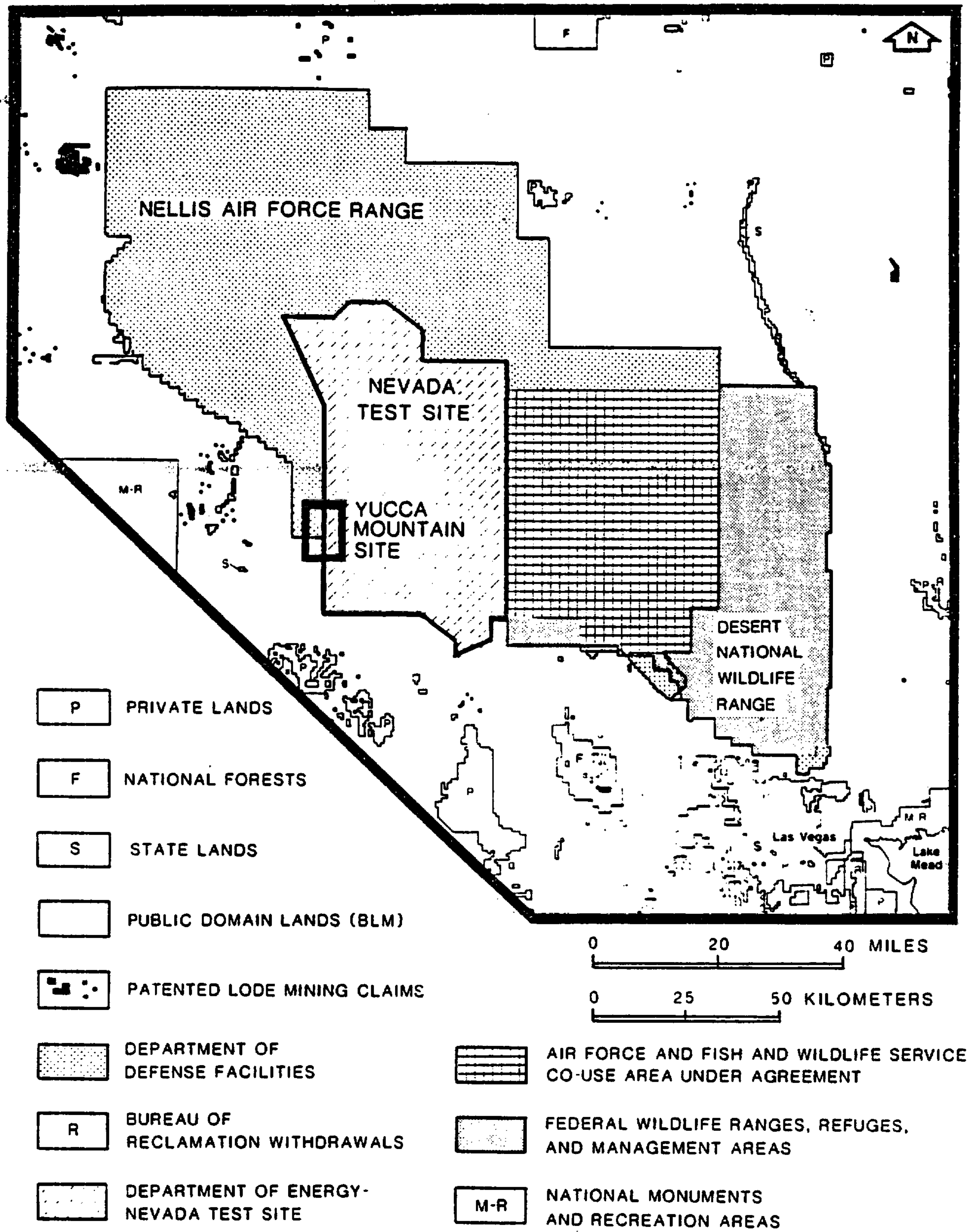

Figure 3-12. Land use in southern Nevada. (Source: State of Nevada, Nevada Bureau of Mines and Geology, 1972.)

Grazing land

The Bureau of Land Management controls large parcels of range land south and west of the site, portions of which are leased for cattle grazing. Five leases exist near the site (Figure 3-13). With two exceptions, no grazing leases have been issued for lands lying north or east of U.S. Highway 95 from Las Vegas to Tonopah. No grazing leases have been issued at Yucca Mountain.

Cropland

Blocks of private land in the Amargosa valley, Oasis valley, Ash Meadows area, and Pahrump valley contain the only farming and ranching operations in the region. The Amargosa and Pahrump valleys contain the only extensive cultivation. An informal poll conducted by the Department of Agriculture's County Cooperative Extension agent in Pahrump indicates that farms located south of Beatty had a total of 3850 ha (9500 acres) under irrigation in July 1981 as follows: 2430 ha (6000 acres) alfalfa, 810 ha (2000 acres) irrigated pasture, 325 ha (800 acres) cotton, 130 ha (320 acres) small grains, 97 ha (240 acres) Sudan grass, 25 ha (60 acres) turf, 25 ha (60 acres) orchard, and 8 ha (20 acres) melons (Collins et al., 1982).

3.4.1.3 Mining

There are 17 active mines and mills in southern Nevada. Most of the mining operations employ less than 10 workers per mine, although a few operations employ as many as 250 workers. The mineral resources in the area near Yucca Mountain are described in Section 3.2.4.

3.4.1.4 Recreation

Recreational land uses are abundant in southern Nevada. In general, the camping and fishing sites in the northern part of the region are used during spring, summer, and fall, and those in the south are utilized throughout the year. The Desert National Wildlife Range, a joint-use area with the Department of the Air Force and the U. S. Fish and Wildlife Service, also provides some recreational opportunities.

The Mojave Desert in California, which includes Death Valley National Monument, extends along the southwestern border of Nevada about 56 km (35 mi) from Mercury. The National Park Service estimates that the population within the Monument boundaries ranges from a minimum of 900 permanent residents during the summer months, to as many as 35,000 tourists per day during the major holiday periods in the winter months. Up to 80,000 tourists have visited Death Valley during the Death Valley 49ers Encampment Weekend in November. The Spring Mountains 80 km (50 mi) to the southeast are also a major recreation area.

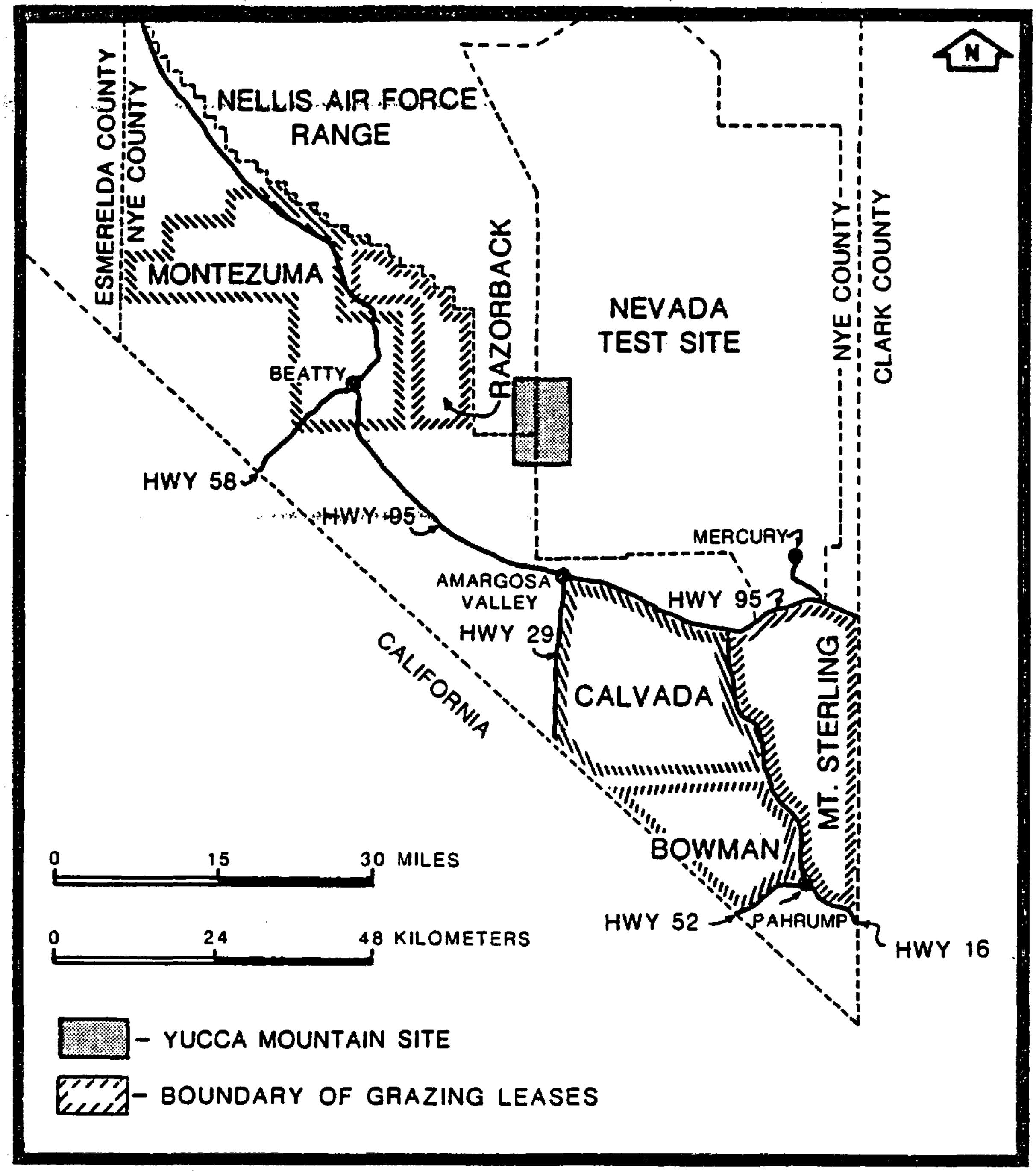

Figure 3-13. BLM grazing leases near the Yucca Mountain site. (Source: Collins et al., 1982.)

3.4.1.5 Private and commercial development

Most private and commercial development is concentrated in the Las Vegas metropolitan area (Figure 3-12). Private lands are scarce in the area immediately surrounding the site and are located as follows (see Figures 3-2 and 3-13):

1. Amargosa Desert - 600 ha (1500 acres).
2. Town of Amargosa Valley - limited acreage at intersection of U.S. Highways 95 and 29.
3. Beatty - limited acreage along U.S. Highways 95 and 58.
4. Indian Springs - limited acreage along U.S. Highway 95.
5. Pahrump Valley - small planned community development.
6. Ash Meadows - planned subdivisions totalling approximately 100 ha (260 acres).
7. Oasis Valley - unknown acreage.

Future subdivisions are planned in Ash Meadows and Pahrump Valley. In Ash Meadows, Johnnie Townsite is planned to be about 65 ha (160 acres), and Forty Bar Estates is planned to be about 40 ha (100 acres). The largest subdivision in Pahrump Valley is planned to be located near the center of the valley around the old Pahrump Ranch (O'Farrell et al., 1981). Other parcels of former farmlands in the valley have been purchased for future subdivision.

3.4.2 Terrestrial and aquatic ecosystems

An extensive literature review was performed in 1981 to determine the current state of knowledge about the ecological characteristics of the NNWSI Project study area (Collins et al., 1982). Based upon the review findings, a field study was initiated in 1982 to gather site-specific information of the ecological characteristics of the Yucca Mountain area (O'Farrell and Collins, 1983). The findings of these studies are summarized in the following sections.

3.4.2.1 Terrestrial vegetation

The southwestern Nevada Test Site encompasses three floristic zones: (1) the Mojave Desert, which is a warm dry desert occurring below an elevation of 1200 m (4000 ft); (2) the Great Basin Desert, which is a relatively cooler and wetter desert occuring at elevations above 1500 m (5000 ft); and (3) the transition zone, often called the Transition Desert, which extends in a broad east-west corridor between the Mojave and Great Basin deserts at elevations of between 1200 and 1500 m (4000 and 5000 ft). Literature reviews indicated that the following five major vegetation associations occur in the southwest portion of the Nevada Test Site within the three floristic regions: Larrea-Ambrosia (creosote bush-bursage), Larrea-Lycium-Grayia (creosote bush-boxthorn-hopsage), Coleogyne (blackbrush), Artemisia (sagebrush), and Artemisia-pinyon-juniper.

During the 1982 site-specific investigation, six, rather than five, vegetation associations were observed and their characteristics and distribution were described (Figure 3-14). Five of the associations were named for the species of woody perennials that were dominant; the determination was based upon either numbers of individuals or percentage of cover. Comparisons of the percentage and area of the project area covered, percentage of shrub cover, and average perennial plant biomass for these five associations are shown on Table 3-4. The sixth association included vegetation reclaiming an old burn. These six associations are described below. Detailed lists of the species composition can be found in O'Farrell and Collins (1983).

Larrea-Ambrosia

An association dominated by Larrea tridentata and Ambrosia dumosa exists on the bajada (an area of coalescing alluvial fans) on the southeastern side of the study area (Figure 3-14). The association generally occurs below 1000 m (3400 ft) in loose soils either with or without pavements of small rocks. Larrea-Ambrosia is at its upper elevational limit and contains elements of Transition Desert vegetation.

Larrea-Lycium-Grayia

The association dominated by Larrea tridentata, Lycium andersonii, and Grayia spinosa predominates on the eastern bajadas of central Yucca Mountain at elevations ranging from 1000 to 1300 m (3400 to 4300 ft). Relief is generally low to moderate, and soils are rocky with an imperfectly developed surface pavement. Larrea is absent on upper bajadas and at the bases of high hills or mountains where slopes begin to steepen sharply, but it is present along drainages in mountainous areas. The Larrea-Lycium-Grayia vegetation association is characterized by a relatively large number of winter annual species.

Lycium-Grayia

The Lycium-Grayia vegetation association is a fairly complex, highly variable association which contains many subassociations and locally dominant species. The ubiquitous presence of both Grayia and Lycium, however, is a unifying factor. Lycium-Grayia occurs above the Larrea dominated associations on upper bajadas and slopes of all grades and exposures and seems to prefer rocky soils. It is the dominant vegetation on slopes and ridge tops throughout the southern and central sections of Yucca Mountain (Figure 3-14). This association is similar to Larrea-Lycium-Grayia vegetation, contains most of the same species commonly found with Larrea, and occurs primarily near the top of Yucca Mountain and on the highest hills.

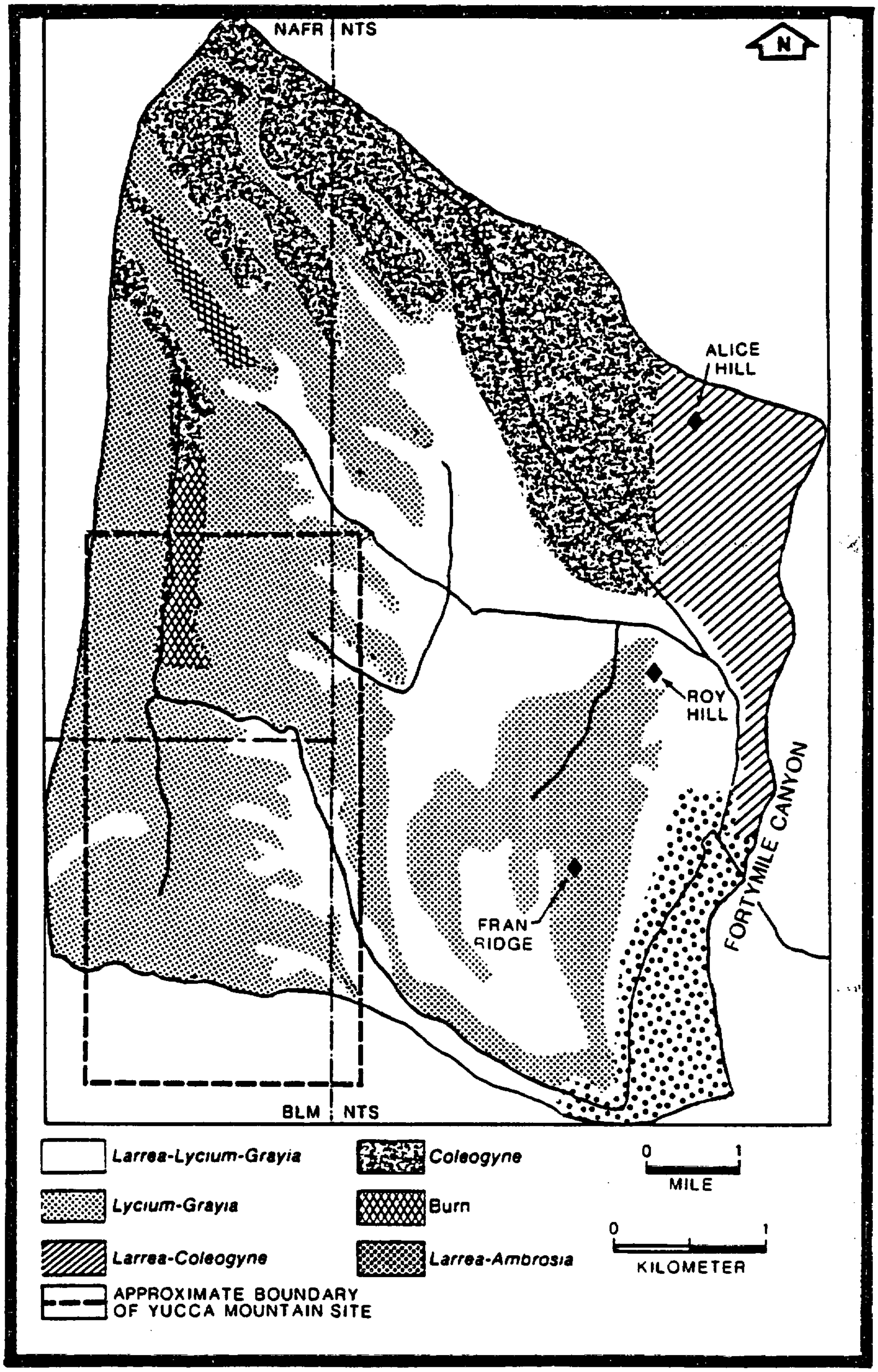

Figure 3-14. Vegetation associations of the Yucca Mountain area. (Source: O'Farrell and Collins, 1983.)

Table 3-4 dropped here

Coleogyne

Vegetation in which Coleogyne ramosissima predominates occurs in two distinct locations: (1) on the tops of the larger, flatter ridges of the northern portion of the project area, including the northern portion of Yucca Mountain, and (2) on the bajada south of Pinnacles Ridge and east of Prow Pass in the upper Yucca Wash drainage. This association is an indicator of and is restricted to the Transition Desert. Coleogyne favors sites with moderate- to low-slope angles and does not occur on steep, rocky, or boulder-strewn slopes. Coleogyne is absent where relatively level ridge tops give way to steep, rocky slopes. Desert pavements are often well developed on bajadas where Coleogyne occurs. The density of annual plants seems to be lower than in any other association surveyed. Coleogyne tends to form near monocultures having few associated species. Bromus rubens, an introduced winter annual grass, does not occur in the thick stands that usually characterize Coleogyne in other parts of the Nevada Test Site.

Coleogyne-Larrea

A distinct area on the bajada near Fortymile Wash (Figure 3-14) supports an association dominated by both Larrea tridentata and Coleogyne ramosissima. This association probably best represents the ecotone between Mojave and Transition Desert vegetation. It more closely resembles Coleogyne association both because of the paucity of associated shrub and annual species and because of the well-developed desert pavement soils.

Table 3-4. Comparison of shrub cover, and perennial plant biomass of vegetation associations in the Yucca Mountain area

Vegetation association	Project area covered[a]		Average shrub cover[b] (percentage)	Average perennial plant biomass[b] (kg/km^2)[d]
	Percentage	Area[c] in km^2		
Larrea-Ambrosia	7.3	4	18.3	12,465
Larrea-Lycium-Grayia	34.5	18	22.0	17,230
Lycium-Grayia	26.2	14	34.7	29,770
Coleogyne	21.4	11	45 to 51	31,700
Coleogyne-Larrea	8.8	4.7	26.0	26,750

[a] Source: Beatley (1976).
[b] Source: Romney et al. (1973).
[c] 1 km^2 = 0.386 mi^2.
[d] 1 kg/km^2 = 0.112 lb/acre.

Grassland-Burn Site

A large portion of the ridge top of central Yucca Mountain was burned either shortly before or in 1978. This burn, which extended for 2.3 km (1.4 mi) and occupied 77 ha (190 acres), is old enough that a community of perennial and annual grasses, with only scattered shrubs, has had time to develop. Composition of the original vegetation was difficult to determine because dense *Coleogyne* existed at the northern boundary of the burn, but at the southern boundary a diverse *Grayia-Lycium* community with only scattered *Coleogyne* predominated. Because *Coleogyne* has higher susceptibility to fire, it most likely predominated throughout most of the site prior to the burn.

A more recent burn covering 15 ha (38 acres) occurred on a small ridge northwest of Yucca Ridge. The former vegetation was certainly *Coleogyne* since this association occurs at the edges and in scattered unburned patches throughout the burn. Charred shrub stumps are still standing and there is some sprouting from stumps. The vegetation consists mainly of herbaceous species, primarily grasses. These two burns comprise 1.8 percent of the project area.

3.4.2.2 Terrestrial wildlife

Mammals

Forty-six mammal species potentially occur within the study area; rodents account for nearly half of this number (Collins et al., 1982). Two rodent families are most abundant: (1) the Heteromyidae, which includes kangaroo rats and pocket mice; and (2) the Cricetidae, or New World, mice. Activity patterns, food habits, population dynamics, life spans, and home ranges are well documented for the small mammals of the area (Jorgensen and Hayward, 1965).

The 1981 literature survey shows that rodent diversity is greatest in Transitional desert vegetation where species characteristic of the two deserts overlap. The precise composition and abundance of rodent populations in a given habitat are difficult to predict, primarily because many rodent species occur over a wide range of habitats but are abundant in only a few.

During the June and July 1982 site-specific investigations, rodents were trapped using live traps. The results of these surveys are shown in O'Farrell and Collins, 1982.

Comparatively little is known about populations of medium to large mammals. Black-tailed jackrabbits, Nuttall's cottontails, and desert cottontails are the most conspicuous and wide ranging of the larger mammals. The coyote is the most widely distributed and the most numerous carnivore, but the kit fox, badger, bobcat, and long-tailed weasel are also common. Mule deer live primarily at higher elevations and are the most abundant large mammal. Feral horses are most commonly sighted in the northern portions of the Nevada Test Site. Burros have been sighted near Cane, Topopah, and Captain Jack Springs, but sightings are rare (O'Farrell and Emery, 1976).

During a study of the site (O'Farrell and Collins, 1982) evidence of mule deer was observed at all elevations and in all vegetation associations sampled. However, there were concentrations of sign both in sheltered upper canyons on the eastern slope of Yucca Mountain and along some ridge lines that may represent access routes. Scats were fresh and in various states of decomposition and had been deposited by both adults and fawns. Skeletal material of adults and a fawn were also observed. Sightings and fresh sign of deer decreased in late spring.

Although it is sometimes difficult to distinguish between horses and burros on the basis of tracks and scats alone, it was determined that only burros were present on Yucca Mountain. Burro tracks and scats of various ages were observed throughout the project area except in the lower elevations of the Larrea-Ambrosia vegetation association. Yucca Mountain ridge and the valley along the southern boundary of the project area contained significant concentrations of fresh sign. However, the highest concentrations were observed in Solitario Canyon, which is also called Hinge Fault Valley in several publications, where a herd of about 20 burros was observed. No evidence of bighorn sheep was found in the area.

Birds

The literature describes the avifauna on the Nevada Test Site (Hayward et al., 1963). Sixty-six species of birds are recorded as either seasonal or permanent residents in the area. Many other species visit the area briefly during spring and fall migration. There are 27 permanent breeding residents, most of whom inhabit sagebrush-pinyon-juniper vegetation, and a number of more widely distributed spring and summer residents. The Nevada Test Site is a winter feeding ground for large flocks of migrating passerine birds (sparrows and finches). Several species remain as winter residents because disturbed areas have an abundance of tumbleweed seed, which is an important winter food source. Migratory waterfowl and shore birds frequent the temporary lakes formed by precipitation runoff in Yucca and Frenchman playas.

During the 1982 site-specific investigations (O'Farrell and Collins, 1983), a total of 35 species of birds were recorded. Black-throated sparrows (Amphispiza bilineata) were observed most frequently. Rock wrens (Salpinctus obsoletus) were also observed at all elevations, especially in rocky habitats and along washes. Mourning doves (Zenaida macroura) arrived during the first week in May and bred at the site. Common ravens (Corvus corax) were also conspicuous residents, although they were not present in large flocks.

Six species of raptorial birds were observed, but sightings were infrequent. A red-tailed hawk (Buteo jamaicensis) was nesting in the project area. No waterfowl or suitable habitats for waterfowl were found.

Reptiles

The literature survey reported one species of tortoise, 14 species of lizards, and 17 species of snakes as occurring in habitats found in the study area (Collins et al., 1982). Mojave Desert vegetation supports the greatest numbers of reptiles. The most abundant and widespread lizards are: side-blotched lizards (Uta stansburiana), western whiptails (Cnemidophorus tigris), desert horned lizards (Phrynosoma platyrhinos), and desert spiny lizards (Sceloporus magister). The desert tortoise is discussed below as a special interest species.

3.4.2.3 Special interest species

No plant or animal on the Nevada Test Site is currently listed, nor is one an official candidate for listing, under the Endangered Species Act of 1973. The Mojave fishhook cactus and desert tortoise, both of which are under consideration for Federal protection as threatened species, occur in the study area.

The Mojave fishhook cactus, Sclerocactus polyancistrus, which was distributed on the rocky ridges of Yucca Mountain (Figure 3-15), was more abundant than published information would suggest. Its areal distribution included the top of Yucca Mountain and the entire western slope to the western boundary of the project area (Figure 3-15). Twenty-two live and a number of dead Sclerocactus individuals were recorded during 40 km (25 mi) of surveys in Solitario Canyon. Most were found in the middle and southern portions of the Canyon. Eleven were recorded in 20 km (13 mi) of transects on Yucca Ridge; eight of the eleven were found together on the extreme southern portion of Yucca Ridge. The density of Sclerocactus observed on Yucca Ridge was significantly lower than the density in Solitario Canyon. No Sclerocactus were found during 34 km (21 mi) of ridge surveys conducted on the eastern slope of Yucca Mountain; however, an archaeologist reported the presence of a Sclerocactus between Fran Ridge and Roy Hill (Figure 3-15).

The desert tortoise, Gopherus agassizii ranges from northern Sinaloa, Mexico, into Arizona, California, southern Nevada, and southwestern Utah. Yucca Mountain is close to the northern range of the species. Evidence of the desert tortoise was observed throughout the project area to elevations of 1600 m (5240 ft) (Figure 3-16); however, densities were estimated to be low (less than 20 per square mile) when compared to other parts of its range.

3.4.2.4 Aquatic ecosystems

No permanent or major sources of seasonal free water, and hence no riparian habitats, exist on Yucca Mountain. The larger washes and drainages within the area tend to contain a distinct flora consisting of species found only in washes and species that, although present in the surrounding vegetation, are most common in washes.

Ash Meadows is about 40 km (25 mi) south of Yucca Mountain and contains approximately 30 springs. Relict populations of pupfish and many unusual endemic plants exist in these spring habitats.

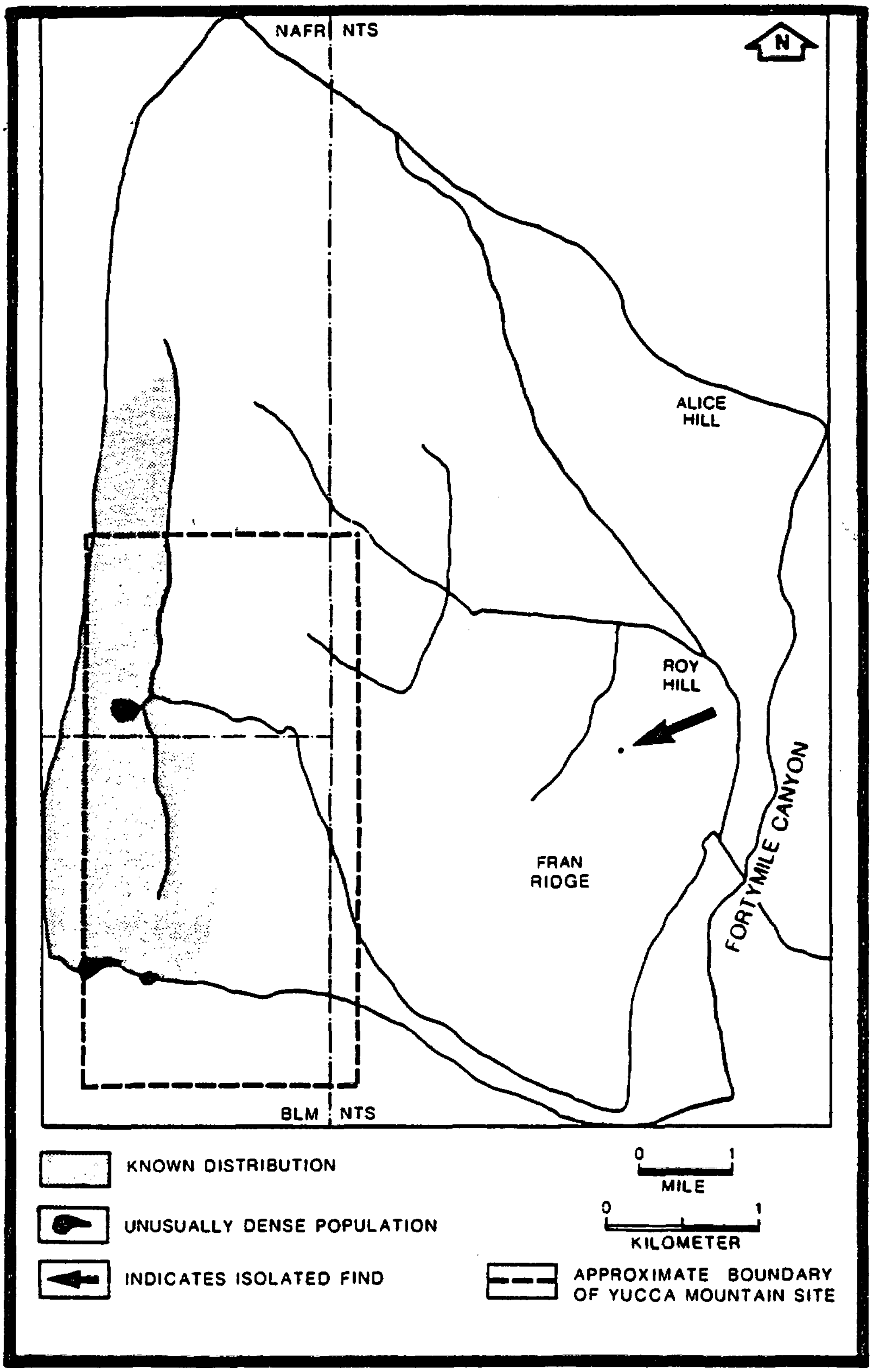

Figure 3-15. Distribution of Mojave fishhook cactus on Yucca Mountain. (Source: O'Farrell and Collins, 1983.)

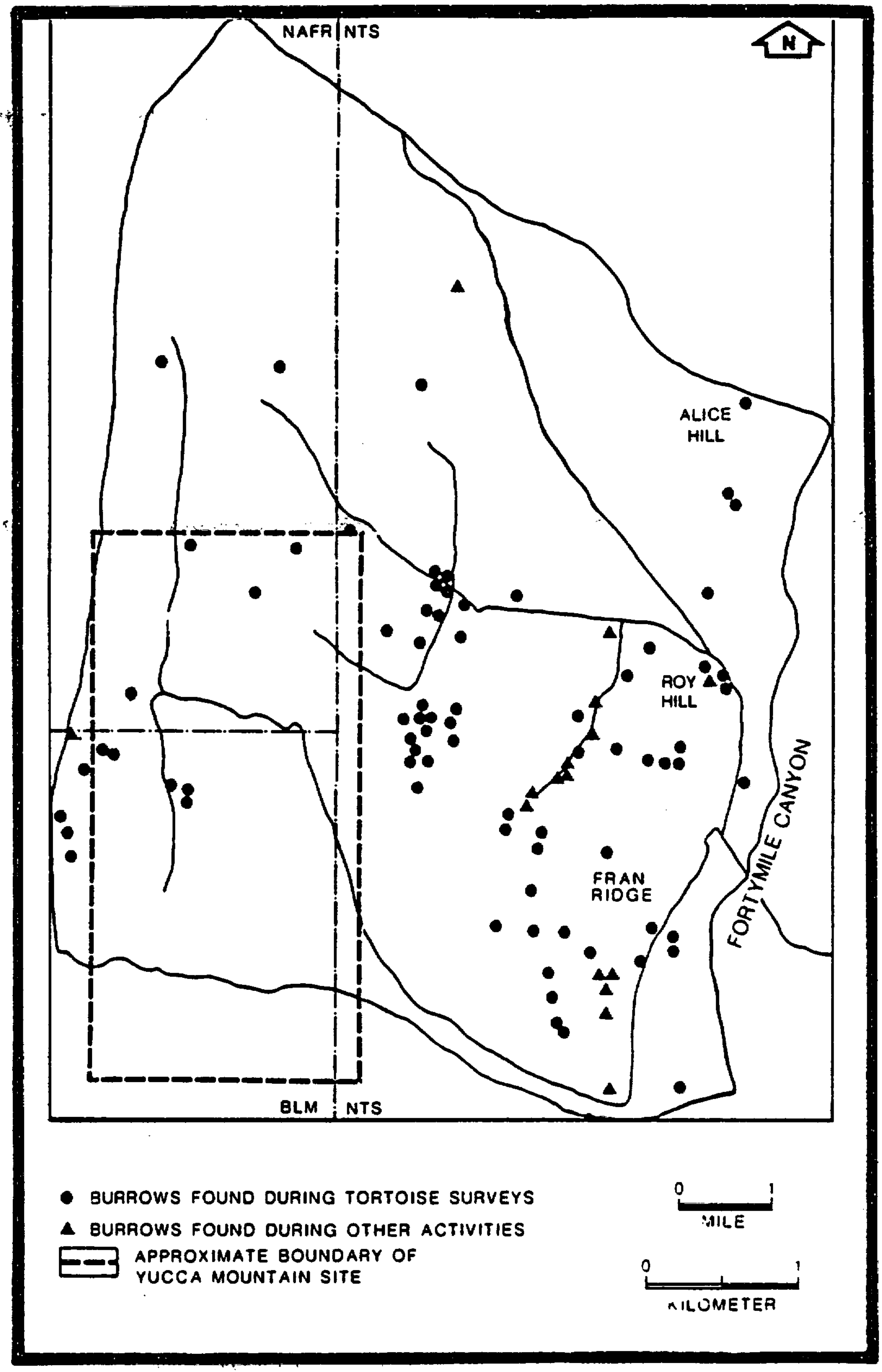

Figure 3-16. Distribution of desert tortoise burrows on Yucca Mountain. (Source: O'Farrell and Collins, 1983.)

Species of concern include three endangered species of fish: Devil's Hole Pupfish, *Cyprinodon diabolis*; Amargosa Pupfish, *Cyprinodon nevadensis pectoralis*; and Pahrump killifish *Empetrichthys latos* (Collins et al., 1982). Two additional endangered species and their critical habitats were recently listed by the USFWS (1983): Ash Meadows Amargosa pupfish, *Cyprinodon nevadensis mionectes*; and Ash Meadows speckled dace, *Rhinichthys osculus nevadensis*. Nine plant species, which are under review for protection, are also found in the Ash Meadows area (Collins et al., 1982). Recently, The Nature Conservancy purchased 5,121 ha (12,654 acres) of private land in the vincinity of Devils Hole (the Ash Meadows area). Current plans call for the U.S. Fish and Wildlife Service to purchase this land from The Nature Conservancy and to establish the area as a unit within the National Wildlife Refuge System (Sada, 1984).

3.4.3 Air quality and weather conditions

The climate of the Yucca Mountain site and the surrounding area has high solar insolation, limited precipitation, low relative humidity, and large diurnal temperature ranges. The lowest elevations are characterized by hot summers and mild winters, which are typical of other Great Basin desert areas. As elevation increases, precipitation amounts increase and temperatures decrease.

Daily minimum temperatures sometimes deviate from this pattern, because minimum temperatures occasionally occur at low elevations in closed topographic basins during calm, cloudless nights. Under these conditions, the ground surface cools quickly, thereby cooling the air near the surface. This cooler, denser air then "drains" down the terrain to form pools of cold air in closed topographic basins. These conditions generally dissipate quickly after sunrise when the ground surface is heated by the sun. Aside from these locally induced conditions, the overall weather patterns of the region are primarily influenced by continental air masses, which contain only limited amounts of moisture.

Meteorological data have been collected on the Nevada Test Site since 1956 at various locations. A ten-year climatological summary (1962 to 1971) for the weather station at Yucca Flat is given on Table 3-5. Yucca Flat is approximately 40 km (25 mi) northeast of Yucca Mountain. This summary is considered to be typical of conditions throughout the area, but local conditions may differ slightly due to site-specific influences. Because of its higher elevation, Yucca Mountain would be expected to have greater precipitation and lower temperatures than the Yucca Flat station.

Temperature is probably one of the most variable meteorological parameters of the Yucca Mountain area on both a daily and an annual basis. The hottest months are generally July and August, which have average monthly temperatures for the ten-year record at Yucca Flat of 24.8°C (76.6°F), and average daily maximums of 35.6°C (96.1°F) and 35.0°C (95.0°F), respectively. Average daily temperature ranges for these months are nearly 22°C (40°F). The highest temperature recorded at Yucca Flat is 42°C (107°F) and has occurred in June, July, and August. Conversely, December is usually the coldest month of the year with a monthly average temperature of 1.8°C (35.3°F) and an average daily minimum temperature of -6.7°C (19.9°F). The extreme low temperature recorded in December was -25°C (-14°F). Minimum temperatures at the site can be

Table 3.5. Climatological summary for Yucca Flat, 1962-1971[a]

MONTH	TEMPERATURE[b] (°F) Averages: Daily maximum	Daily minimum	Monthly	Extremes: Highest	Year	Lowest	Year	Degree days (Base 65°F): Heating	Cooling	PRECIPITATION[c] (inches): Average	Greatest monthly	Year	Least monthly	Year	Greatest daily	Year	Snow: Average	Greatest monthly	Year	Greatest daily	Year	Relative humidity (%) Hour (Pacific Standard Time): 04	10	16	22	WIND[d,e] (Speeds in mph): Average speed	Peak speed	Year	Resultant dir/spd: 23 02 PST	11 14 PST	STATION PRESSURE (inches): Averages	Highest	Lowest	Average sky cover sunrise to sunset[f]	AVERAGE NUMBER OF DAYS: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation: .01 inch or more	.10 inch or more	.50 inch or more	1.00 inch or more	1.0 inch of snow or more	Thunderstorms	Temperatures: Maximum: 90°F or more	32°F or below	Minimum: 32°F or below	0°F or below
JAN	52.1	20.0	36.3	73	1971	-2	1970	877	0	.53	4.02	1969	T	1971#	1.25	1969	0.9	4.3	1962	4.3	1962	67	49	35	60	6.6	58	1965	[illegible]	[illegible]	25.10	26.54	25.42	4.9	13	8	10	2	1	*	*	*	*	0	1	27	*
FEB	56.7	23.8	41.3	77	1963	5	1971#	662	0	.84	3.55	1969	T	1967#	1.16	1969	1.9	17.4	1969	6.2	1969	67	45	32	56	6.9	52	1967	[illegible]	[illegible]	26.05	26.42	25.56	5.0	11	8	9	3	2	*	*	1	0	0	*	25	0
MAR	60.9	27.1	44.3	87	1966	9	1969	634	0	.28	.60	1969	.02	1966	.38	1969	2.0	7.5	1969	4.5	1969	58	31	23	44	8.4	55	1971	[illegible]	[illegible]	25.95	26.43	25.48	4.8	12	9	10	3	1	0	0	1	1	0	0	24	0
APR	67.8	34.4	51.1	89	1962	13	1966	411	1	.45	2.57	1965	T	1962	1.08	1965	0.7	3.0	1964	3.0	1964	52	27	21	38	9.1	60+	1970#	150/2.2	198/3.1	25.96	26.39	25.50	4.5	13	9	8	3	1	*	*	*	1	0	0	12	0
MAY	78.9	43.5	61.2	97	1967	25	1967	147	38	.24	1.62	1971	T	1970#	.86	1971	0	T	1964	T	1964	46	22	17	31	8.3	60+	1967	260/3.5	175/7.2	25.94	26.39	25.47	4.3	14	11	6	2	1	*	0	0	1	4	0	2	0
JUN	87.6	49.9	68.8	107	1970	29	1971#	35	194	.21	1.13	1969	T	1971	.45	1969	0	0		0		39	19	14	26	7.9	60+	1967	[illegible]	[illegible]	25.92	26.20	25.56	3.0	19	7	4	2	1	0	0	0	2	14	0	*	0
JUL	96.1	57.0	76.6	107	1967	40	1964#	0	366	.52	1.34	1966	0	1963	.77	1969	0	0		0		40	20	15	28	7.5	55	1971	[illegible]	[illegible]	26.00	26.19	25.68	3.0	19	9	3	3	2	*	0	0	4	29	0	0	0
AUG	95.0	58.1	76.6	107	1970	39	1968	1	354	.34	1.04	1965	0	1962	.55	1968#	0	0		0		44	23	16	30	6.7	60+	1968	[illegible]	[illegible]	26.00	26.22	25.71	3.0	20	8	3	3	1	0	0	0	4	27	0	0	0
SEP	86.8	48.7	65.9	105	1971	25	1971	51	103	.68	2.38	1969	0	1968#	2.15	1969	0	0		0		43	21	17	32	7.0	52	1970	208/3.3	163/6.4	26.00	26.36	25.56	2.1	22	6	2	2	1	1	*	0	2	11	0	1	0
OCT	74.1	38.9	56.5	94	1964#	12	1971	266	9	.15	.45	1969	0	1967#	.42	1969	0	T	1971	T	1971	46	24	19	36	6.8	60	1971	206/3.5	138/3.7	26.06	26.40	25.52	2.9	20	7	4	1	1	0	0	0	*	2	0	9	0
NOV	61.8	27.6	44.7	82	1962	13	1966	602	0	.71	3.02	1965	0	1962	1.81	1970	0.5	4.8	1964	2.3	1964	61	35	31	52	6.1	51	1970	[illegible]	[illegible]	26.08	26.50	25.64	4.8	13	7	10	3	2	*	*	*	*	0	0	23	0
DEC	50.7	19.9	35.3	70	1964	14	1967	914	0	.79	2.66	1965	T	1967#	1.31	1965	2.3	9.9	1971	7.4	1971	68	50	41	64	6.6	55	1970	[illegible]	[illegible]	26.07	26.59	25.49	4.6	14	8	9	3	1	1	*	1	*	0	1	29	1
ANN	72.5	37.4	54.9	107	AUG 1970#	-14	DEC 1967	4600	1039	5.73	4.02	JAN 1969	0	SEP 1968#	2.15	SEP 1969	8.3	17.4	FEB 1969	7.4	DEC 1971	53	31	23	41	7.4	60+	APR 1970#	—	—	26.01	26.59	25.42	3.9	190	97	78	30	14	3	1	3	14	87	2	152	1

[a] Source: Air Resources Laboratory, Las Vegas, NV (Bowen and Egami, 1981).
[b] # = most recent of multiple occurences.
[c] T = trace, an amount too small to measure.
[d] * = one or more occurrences during the period of record but average less than 0.5 day.
[e] Average and peak speed are for the period starting with December 1964. The direction of the resultant wind are from a summary covering the period December 1964 through May 1969.
[f] Sky cover is expressed in the range from 0 for no clouds to 10 when the sky is completely covered with clouds. Clear, partly cloudy and cloudy are defined as average daytime cloudiness of 0-3, 4-7, and 8-10 tenths, respectively.

affected by the drainage flows described previously, and may differ from the temperatures recorded at Yucca Flat.

Precipitation in the region is sparse; it averages only about 145 mm (5.7 in.) annually at Yucca Flat. The sparseness of precipitation is due to the land-based air masses that influence the region's weather and the blocking effect of the Sierra Nevada Mountains. Pacific air masses that could bring moisture to the region generally drop most of their moisture on the western slopes of the Sierra Nevadas; little moisture is left to precipitate on the east side. Precipitation that does reach the area is concentrated in the winter months, but thunderstorms at other times of the year can also be significant sources of moisture for the area. Thunderstorms occur 13 percent of the days in July and August, but only 4 percent of the days annually. The greatest monthly precipitation for Yucca Flat is 102 mm (4.02 in.), and the greatest daily amount is 54 mm (2.13 in.). With an average of only 145 mm (5.7 in.) of precipitation annually, these maximums represent significant storm events. The statistical maximum 24-hour precipitation for 10-year and 100-year storm events for Yucca Flat is 38 mm and 57 mm (1.50 in. and 2.25 in.), respectively (DOC, NOAA, 1961).

High winds in the area are usually associated with the passage of winter storm fronts, but they can also accompany thunderstorms. Wind speeds in excess of 100 km/hr (60 mph), with gusts of up to 163 km/hr (101 mph) have been recorded on several occasions (Quiring, 1968). Such velocities are not common, however, as is evidenced by the Yucca Flat annual average wind speed of 11.9 km/hr (7.4 mph). Monthly average wind speeds do not deviate significantly from this value, with a high of 15 km/hr (9.1 mph) in March and a low of 10 km/hr (6.1 mph) in November.

Other than temperature extremes, severe weather in the area includes occasional thunderstorms, lightning, tornadoes, and sandstorms. Severe thunderstorms create a potential for flash flooding, but they generally do not last longer than an hour (Bowen and Egami, 1981). Tornadoes have been observed within 80 km (50 mi) of Yucca Flat, but are considered rare (DOC, NOAA, 1981).

3.4.3.1 Air quality

Site-specific air-quality data are not available for the study area. Data from similar desert locations, however, suggest that air quality at the site is probably very good. Elevated levels of either ozone or total suspended particulates may occasionally occur because of pollutants that are transported into the area, or from local sources of fugitive particulates (Bowen and Egami, 1981). Ambient concentrations of other criteria pollutants (sulfur dioxide, nitrogen oxides, and carbon monoxide) are probably low because there are no significant sources of these pollutants nearby. The nearest significant source of pollutants is the Las Vegas area, which is at least 150 km (95 mi) away, and is not expected to measurably affect the air quality in the Yucca Mountain area.

3.4.4 Noise

Although baseline noise levels have not been measured in the Yucca Mountain area, they can be estimated. There are two types of noise-producing areas in the study area: 1) uninhabited desert, and 2) small rural communities. In the uninhabited desert, the major sources of noise are natural physical phenomena such as wind, and rain, the activities of wildlife, and an occassional airplane. Annually, wind is the predominant noise. Table 3-5 presents an average annual wind speed at Yucca Flat. For noise assessment purposes, this area would be considered windy. Desert noise levels as a function of wind have been estimated at an upper limit of 22 dBA for a still desert and 38 dBA for a windy desert (Brattstrom and Bondello, 1983). For Yucca Mountain, 30 dBA is probably a reasonable estimate; it corresponds with noise levels presented in the environmental impact statement prepared for the MX Missile System for areas similar to Yucca Mountain (Henningson, Durham and Richardson Sciences, 1980).

Annual rural community noise levels have been estimated by the EPA at 50 dBA (EPA, 1974). This level would be characteristic of annual noise expected for Indian Springs, Mercury, or the town of Amargosa Valley.

3.4.5 Aesthetic resources

Yucca Mountain is in the southern part of the Great Basin and is characterized by dissected ranges that rise abruptly from moderate slopes of alluvial piedmonts. The terrain is rugged, arid, and has scant vegetation.

The project area is not visible from major population centers, public recreation areas, or public highways, and subsequently offers little value as an aesthetic resource.

3.4.6 Archaeological, cultural, and historical resources

A cultural resource overview (Pippin and Zerga, 1980) and an intensive reconnaissance was conducted of much of the Yucca Mountain area, and resources that may be affected by repository activities were identified and marked (Pippin et al., 1982). Limited test excavations on a sample of the identified sites were also conducted (Reno et al., 1984).

An archaeological site is identified as any location of past human activity evidenced by the presence of material items manufactured or altered by man (stone tools, pottery), architectural structures (walls, windbreaks), or functionally specific facilities (hearths, pits, and cairns). Thus, a location which contains anything from a single pottery shard to a large campsite would be recorded as an archaeological site.

A total of 178 prehistoric aboriginal sites were identified, which represented use of the Yucca Mountain area by small and highly mobile groups or bands of aboriginal hunter-gatherers. The sites consisted of two basic types: campsites, and extractive locations. Campsites are temporary locations where groups varying in size from single-family units to small bands of 20 to 30 individuals lived for days or months while using nearby resources or traveling through the area. Such campsites, 21 of which were identified on Yucca Mountain, are recognized by the presence of artifacts, structures, and facilities related to food preparation and consumption, shelter, and other maintenance activities such as the manufacture or repair of clothing and tools.

One hundred forty-one of the prehistoric sites are extractive locations. These are the remains of more limited, task-specific activities associated with hunting, gathering, and processing of wild plants, and procurement of other raw materials used in manufacturing tools and clothing. The survey identified several kinds of extractive locations, which are summarized in Table 3-6. In addition, 16 sites were identified but not classified.

According to Reno et al. (1984), the cultural resources of Yucca Mountain can be categorized according to four general adaptive strategies. The earliest strategy was reflected by a linear pattern of archeological sites along major ephemeral drainages. Although the terrace edges of these drainages continued to be occupied by later populations, there appears to have been a shift that began about 7000 years ago in settlement patterns away from these linear sources of water. During that time, temporary camps became established in the uplands of Yucca Mountain. About 1500 years ago, there appeared to be another shift in adaptation. Unlike earlier periods, the availability of plant resources seemed to have a major influence on site locations. Finally, a historic adaptation in the area was indicated by numerous cairns, several isolated tin cans, and a prospector's camp.

Although Nevada has been occupied since early times, it was the last state entered by white explorers during historical times. The first recorded entry of Euro-American travelers into the area now occupied by the Nevada Test Site was that of a group of emigrants to California in 1849 (Worman, 1969). This group had broken away from a party led by Captain Jefferson Hunt after hearing rumors of a shorter route to California than that afforded by the Old Spanish Trail. While Hunt headed southward over known territory, the splinter party plunged off into the unknown. A second split was made north of Indian Springs where a group of wagons, known as the Bennett-Arcane Party, decided to take a southerly route. The remaining wagons, the Jayhawkers, followed a westward course to Tippipah Spring, where another split occurred and the Jayhawkers went south between Skull Mountain and Fortymile Canyon. The Jayhawkers crossed Topopah Wash and entered the Amargosa Valley east of the Wash. The other group, the Briers, entered Fortymile Canyon west of Tippipah Spring and went on to Amargosa Desert. These trails are shown in Figure 3-17.

Later movements into the area involved prospectors, ranchers, wild-horse hunters, and the establishment of relay stations for stage and freight lines. Operating mines were the Horn Silver Mine and the short-lived town of Wahmonie (3 months in 1928) about 6.5 km (4 mi) west of Cane Springs, the Climax Tungsten Mine at the north end of Yucca Flat, a cinnabar mine and retort on Mine Mountain, and galena deposits at the Groom Mine (Worman, 1969).

Table 3-6. Prehistoric archaeological sites in the Yucca Mountain area[a]

Site type	Activities represented	Typical features, artifacts, location	Number
Temporary camps	Food Preparation and consumption; shelter; maintenance activities	Evidence of fire (hearths, pits, etc.), rock alignments (windbreaks, shelters), stone tools, bone, vessels, grinding implements, etc.; location variable	21
Tinajas (cisterns)	Water collection	Bedrock basins with rock covers to retard evaporation; often near other extractive locations or camps	19
Knapping stations	Stone tool manufacturing	Stone tools and waste material; locations quite variable	16
Quarries	Collection of tool-stone	Large amounts of waste, parent material, stone tools, located on or near sources of material, some very extensive	12
Milling stations	Processing of plant resources (seeds)	Grinding implements (manos); stone tools, locations vary but common in rock shelters	27
Caches	Storage of tools, raw materials	Rock alignments, piles; concentrations of raw materials, tools; common in small rock shelters	3
Isolated artifacts	Hunting and/or collecting activities	Isolated stone tools and waste, variable locations	64
Sites of unknown function	Diffuse concentrations of stone tools and waste; isolated artifacts with a suspected subsurface component. Variable locations but ioslates common in small rock shelters		16
Total			178

[a] Source: Pippin et al., 1982.

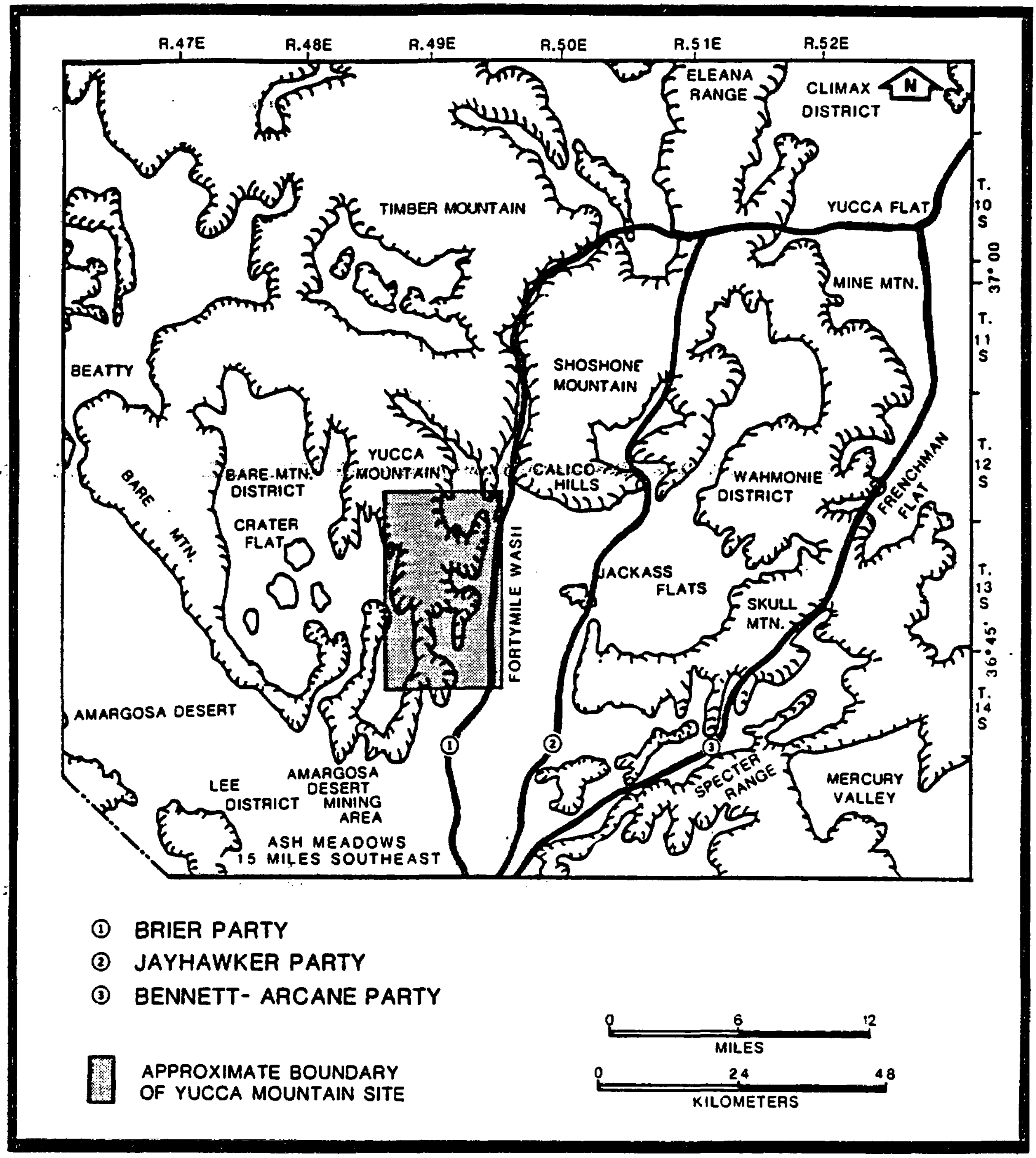

Figure 3-17. Location of historic trails near Yucca Mountain. (Modified from Worman, 1969.)

Other historic resources located in the region include ghost towns, mining camps, Mormon settlements, and ranches located in southern Nevada. A Department of Energy study revealed 145 historic and 5 prehistoric sites located within a 140-km (87-mi) radius of, but not inclusive of, the Nevada Test Site (information from limited distribution report: URS/John A. Blume and Associates, 1982, Survey of Historic Structures: Southern Nevada and Death Valley). The most common sites identified were mining-operations sites and ranches.

3.4.7 Radiological background

Environmental background radiation levels from all sources in the general area surrounding the Nevada Test Site vary considerably depending mainly on elevation and natural radioactivity content of the soil. A typical value for the southwestern United States is 130 mrem/yr (ERDA, 1977). In 1982, the environmental radiation dose rate at 82 monitored locations within 300 km (185 mi) of the Nevada Test Site ranged from 42 to 139 mrem/yr, with an average of 88 mrem/yr (Black et al., 1983). It has been observed that exposures (whole body radiation) measured at offsite stations nearest to the Nevada Test Site are decreasing with time (ERDA, 1977). This decrease is believed to result from radioactive decay of fallout deposited mainly during periods of atmospheric testing.

Radiation levels within the Nevada Test Site boundary increased from 1951 to the mid-1960s as a result of atmospheric weapons testing and other experiments. Radiation levels at specific locations within the test site vary considerably depending on the history of the location, and may approach very localized levels as high as 5 mrem/hr (ERDA, 1977). Most of the radioactivity created at the test site by underground tests remains in or near the respective underground cavity locations. Measurements of radioactivity in the principal test site water system during the 1982 measuring period showed only background tritium and other radionuclides except for wells that enter a test cavity (Black et al., 1983). Some radioactivity remains on the surface from pre-1962 atmospheric testing of weapons, nuclear cratering explosions, nuclear propulsion-systems tests, and radioactive wastes generated by other Nevada Test Site activities (ERDA 1977). The locations of these wastes on the Nevada Test Site are shown in Figure 3-18 (ERDA, 1977). Almost all of the sites shown are located in the northeastern quadrant of the Nevada Test Site, relatively removed from the potential repository site at Yucca Mountain.

3.4.7.1 Monitoring program

The Department of Energy is responsible for providing radiological safety services on the Nevada Test Site and maintaining an environmental surveillance program designed to control, minimize, and document exposures to the Nevada Test Site working population. Air and potable water samples are collected at specific areas where personnel spend significant amounts of time. Additional air-sampling stations are located at sites throughout the Nevada Test Site in support of the testing program and the radioactive-waste-management program. Water from supply wells, open reservoirs, natural springs, contaminated ponds, and sewage ponds is also sampled and analyzed to evaluate the possibility of any movement of radioactive contaminants in the Nevada Test Site water system. Thermoluminescent dosimeters (TLDs) are used to measure the ambient Nevada Test Site external gamma-radiation levels.

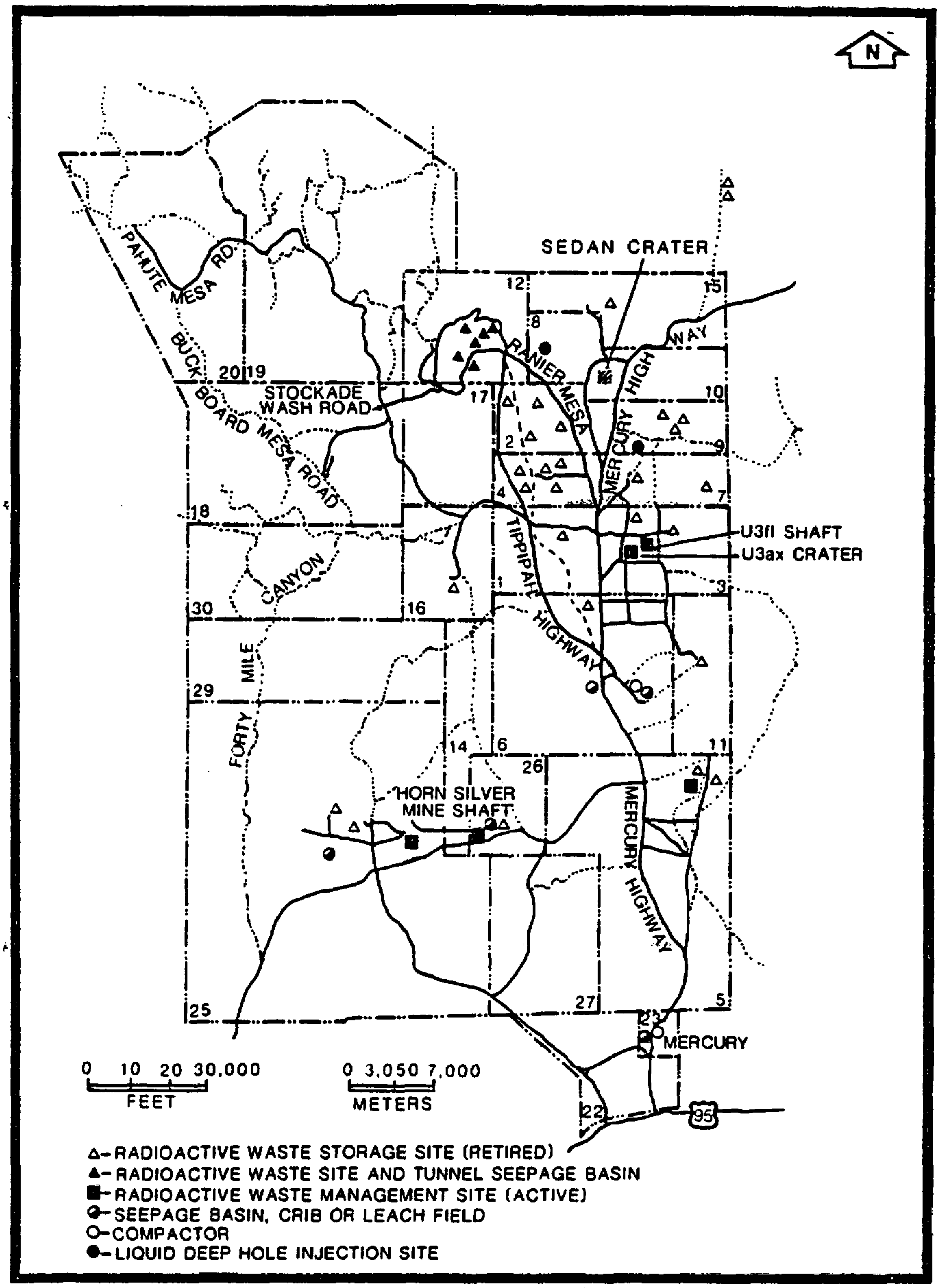

Figure 3-18. Locations of radioactive waste areas at the Nevada Test Site. (Source: ERDA, 1977.)

The Environmental Protection Agency, through its Environmental Monitoring Systems Laboratory in Las Vegas, has performed radiological monitoring in the Nevada Test Site offsite area. Since 1958, continuous monitoring has been performed to determine the levels of radiation and radioactivity present. Samples of air, water, and milk are routinely collected and analyzed, and external radiation exposures are measured. Radioactivity attributable to the resuspension of dust particles in the air from contaminated areas on the Nevada Test Site has never been detected in offsite samples. No contained underground tests have resulted in exposure to offsite residents which exceeded the radiation protection guidelines approved for underground nuclear testing. It is predicted that future containment will be as good or better (ERDA, 1977). No radioactivity released from activities at the Nevada Test Site during 1982 was measured off-site by any of the monitoring networks (Black et al., 1983).

A recent major innovation in this long-term monitoring program has been the establishment of a network of Community Monitoring Stations in 15 offsite communities (Douglas, 1983) (see Figure 3-19). It differs from other network in the offsite radiation monitoring and public safety program in that it incorporates Federal, State, and local Government participation. The DOE Nevada Operations Office and the EPA Environmental Monitoring Systems Laboratory provide technical guidance for the program.

3.4.7.2 Dose assessment

Using the measured quantities of radioactivity in various environmental media, the maximum dose to a hypothetical individual living at the Nevada Test Site boundary may be estimated. This was done by calculating the 50-year committed dose equivalent for the individual receiving a 1-year intake of air and water conservatively assumed to be contaminated with radionuclides at concentrations measured on the site. The maximum calculated dose to the total body, bone, and lung was 0.18 mrem, 2.0 mrem, and 0.24 mrem, respectively. These doses to the hypothetical individual at the Nevada Test Site boundary represent increases of less than 0.5 percent over natural background for total body and lung, and less than 1.5 percent over natural background for bone (Scoggins, 1983).

Airborne releases from Nevada Test Site activities for 1974 through 1982 are listed on Table 3-7. Although no radioactivity released during 1982 was detected off the site, the theoretically possible dose to the offsite population from releases on the Nevada Test Site can be calculated by using annual average weather data and atmospheric diffusion equations. Based on the 1982 noble gas releases listed in Table 3-7, the estimated annual population dose from NTS activities to the 4600 people residing within 80 km (50 mi) of a central point on the Nevada Test Site was slightly less than one hundred-thousandth of 1 man-rem (9.9×10^{-6} man-rem) (Black et al., 1983). For comparison, the annual population dose to this same population from natural background radiation is approximately 410 man-rem. To estimate the annual population dose to the 19,908 people estimated to reside within 80 km (50 mi) of a central point at Yucca Mountain, the population dose to 4600 people due to natural background radiation was linearly extrapolated to the larger population. Using this method, the population dose due to natural background was estimated to be about 1800 man-rem within 80 km (50 mi) of Yucca Mountain.

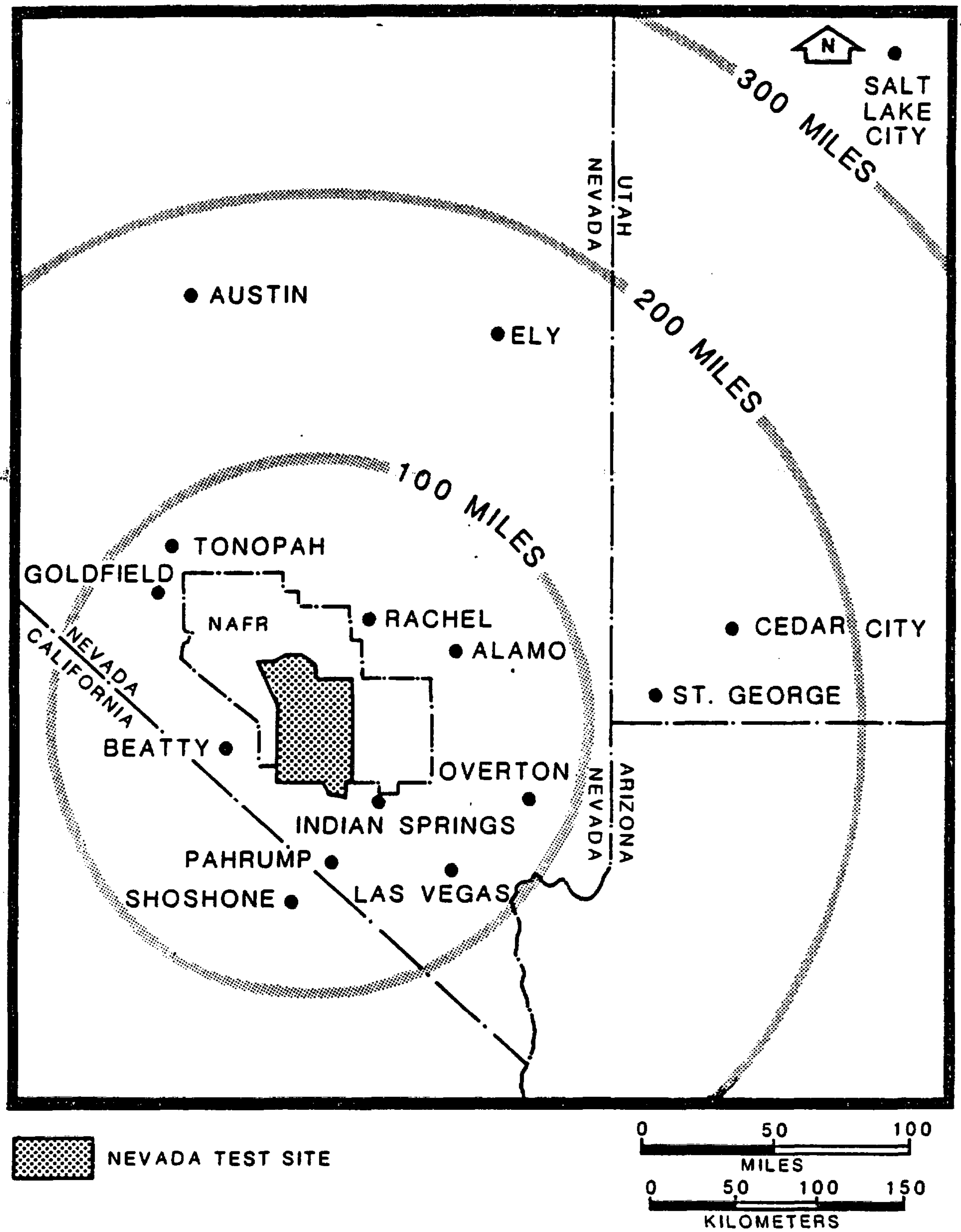

Figure 3-19. Community monitoring stations around the Nevada Test Site. (Source: Douglas, 1983.)

The highest estimated dose was 3×10^{-6} mrem per year to an individual living in Rachel, with lesser amounts to individuals in the town of Amargosa Valley, Beatty, and Indian Springs, Nevada. Natural radioactivity in the body causes individual annual internal doses ranging from 26 to 36 mrem/yr, and environmental background averages 88 mrem/yr. Therefore, the maximum theoretical dose estimate of 3×10^{-6} mrem/yr from airborne radionuclide emissions during 1982 on the Nevada Test Site is a very small fraction of the natural internal and external radiation background.

Table 3-6a. Airborne radionuclides from the Nevada Test Site detected off the site, 1974 through 1983[a]

Year	Stations[b]	Radionuclides detected	Highest Calculated individual whole-body dose[c] (μrem)	Population dose[d] (man-rem)
1974	Beatty, Diablo*	Xe-133	2	0.003
1975	Beatty, Diablo*, Hiko*, Indian Springs, Las Vegas*	Xe-133, Kr-85, H-3	2.1	0.00065
1976	Death Valley Junction	H-3	1.3	0.00078
1977	Beatty, Diablo*, Hiko*, Las Vegas*, Tonopah*	Xe-133	2.5	0.0013
1978	Diablo*, Indian Springs	Xe-133, H-3	6.2	0.000037
1979	None	None	0	0
1980	Lathrop Wells (Amargosa Valley)	Xe-133, Xe-135	11	0.00072
1981	None	None	0	0
1982	None	None	0	0
1983	None	None	0	0

[a] Data from EPA (1975, 1976, 1977), Grossman (1978, 1979), Potter et al. (1980), Smith et al. (1981), Black et al. (1982, 1983), Patzer et al. (1984).

[b] All communities in Nevada. Those communities marked with an asterisk (*) are within 80 km (50 mi) of a central point on the NTS.

[c] Dose calculated from the largest amount detected (not necessarily within the 80-km (50-mile) circle. For perspective, the largest dose listed (6.2 rem or 6.2×10^{-6} rem) is only 0.005% of the average annual dose an individual in this area receives from naturally occurring internal and external radiation and 0.001% of NRC radiation protection standard of 0.5 rem per year (10 CFR 20).

[d] Population dose calculated using the radionuclide detected and the population within the 80-km (50-mile) circle. The population dose is the sum of the maxiumu individual doses multiplied by the population in the area within the 80-km (50-mile) circle. These population doses are extremely small compared with the population doses natural background of 400 man-rem (Patzer et al., 1983).

3.5 TRANSPORTATION

This section describes the existing and projected transportation network in the vicinity of the site. This information will be used in Chapters 4, 5, and 6 to evaluate the potential impact of transporting people, materials, and radioactive waste.

3.5.1 Highway infrastructure and current usage

Figure 3-20 shows the existing highway network near the site. U.S. Highway 95, a four-lane road between Las Vegas and the Mercury turnoff, is the major artery over which construction material and people would be transported. West of Mercury, U.S. 95 becomes a two-lane road. Access to the site would be via a proposed 25-km (15-mi) access road from Highway 95. This access road would only be used by site-related traffic.

Table 3-8 presents traffic counts along U.S. Highway 95 for 1982. Annual average daily traffic represents the average number of vehicles passing over a road segment for any day of the year. The average annual weekday traffic represents the average number of vehicles passing over the same road segment for any given 24-hour weekday of the year. When the annual average weekday traffic count exceeds the average annual daily traffic, weekday traffic dominates weekend traffic. Therefore, Table 3-9 indicates that weekday usage of U.S. Highway 95 dominates traffic flow between Las Vegas and Mercury. However, from Mercury west, weekend traffic dominates usage. This usage pattern reflects worker traffic between Las Vegas and the Nevada Test Site.

Worker traffic between the Nevada Test Site and Las Vegas is characterized by morning and early-evening peaks. As is typical for rush hour traffic, the evening peak dominates as shown in Table 3-8. Of critical importance is the ability of the roadway to handle the traffic volume or density during this peak period. This ability can be assessed by noting the level of service (LOS) realized during the peak period. The level of service describes the flow of traffic and the propensity for traffic accidents at different traffic volumes. Table 3-10 presents a description of LOS at different traffic volumes. Table 3-9 compares evening peak-hour traffic volumes and level of service for each road segment. This table indicates that service level B is maintained along the entire four-lane segment of U.S. Highway 95 from Las Vegas to Beatty.

Traffic levels through metropolitan Las Vegas are high, and certain sections of U.S. Highway 95, south of the northern city limits, and I-15 are congested. Congested streets include the following: Fremont Street (U.S. 95) from Charleston Boulevard to Bruce Street; I-15 northbound from Sahara Avenue to Charleston Boulevard; I-15 southbound from U.S. 95 to Charleston Boulevard;

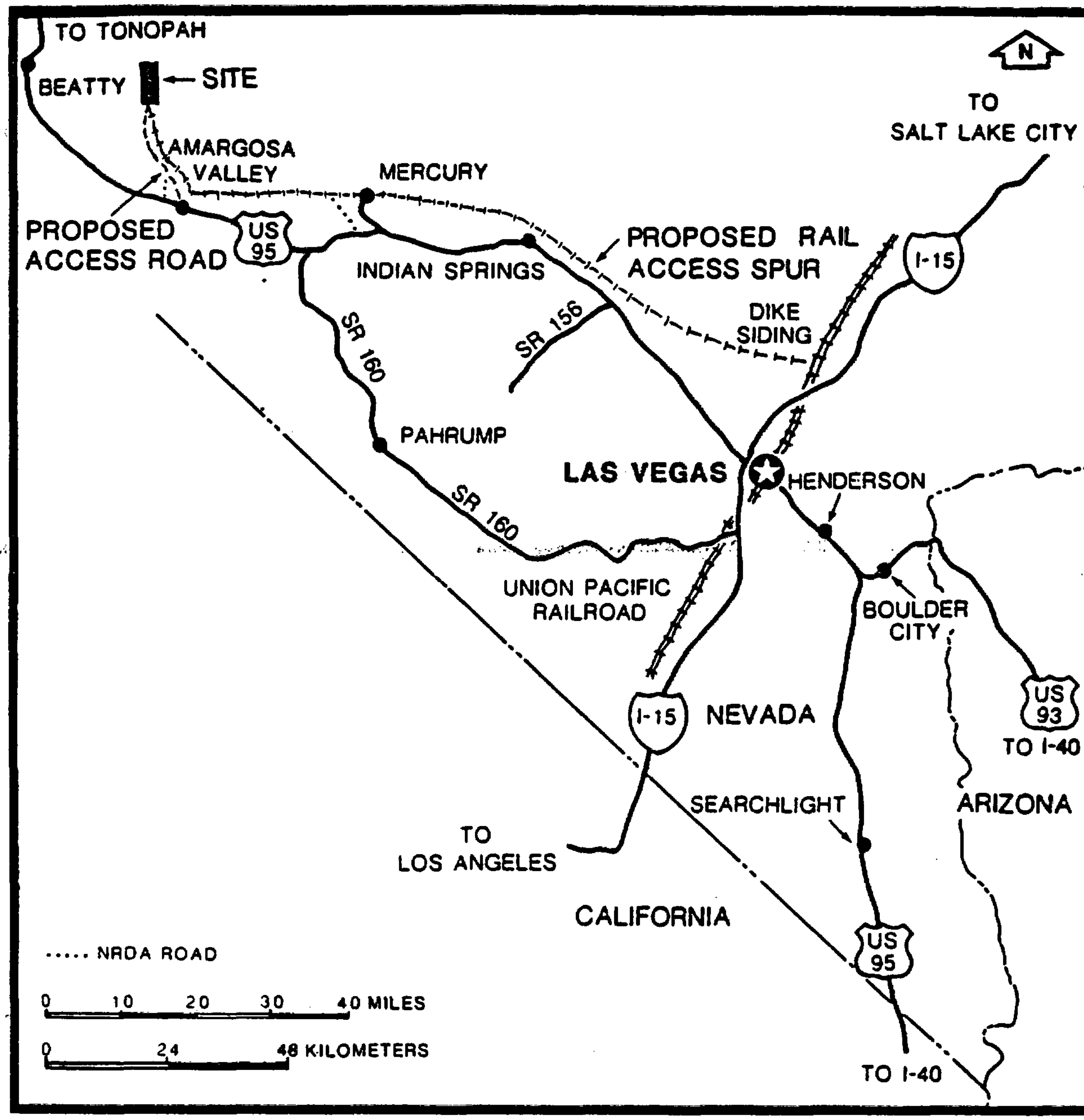

Figure 3-20. Regional transportation network and proposed road and rail access to the Yucca Mountain site.

Table 3-8. Traffic patterns on U.S. 95, 1982[a]

Highway segment[b]	Distance[c] (km)	Traffic volume: Average annual daily traffic	Traffic volume: Average annual weekday traffic	Peak-hour traffic as a percentage of annual average weekday traffic: morning (6-7 a.m.)	Peak-hour traffic as a percentage of annual average weekday traffic: evening (5-6 p.m.)
Amargosa Valley to Beatty	47	1450	1433	2.5	6.0
SR160 to Amargosa Valley	27	1685	1665	2.5	6.0
NRDS Rd. to SR160	8	1785	1764	2.5	6.0
Mercury Intersection to NRDS Rd.	5	1960	1937	2.5	6.0
Indian Springs to Mercury Intersection	29	2820	2883	7.49	9.3
SR156 to Indian Springs	21	3030	3098	7.49	9.3
Northern city limits Las Vegas to SR156	22	3500	3579	7.49	9.3

[a] Source: Personal communication from State of Nevada, Department of Transportation, Carson City, Nev., 1983 regarding traffic flow, accidents, and traffic projections.
[b] See Figure 3-21 for location of highway segments.
[c] 1 km = 0.621 mi.

Table 3-9. Evening peak hour (5-6 p.m.) traffic patterns on U.S. 95, 1982[a,b]

Highway segment[c]	Distance[d] (km)	Traffic volume	Maximum service volume (passenger car/hr)		
			Service Level A	Service Level B	Service Level C
Amargosa Valley to Beatty	47	86	285	822	1,104
5 mi. east of Amargosa Valley to Amargosa Valley	8	100	304	810	1,134
SR 160 to 5 mi. east of Amargosa Valley	19	100	228	684	1,053
NRDA Rd. to SR 160	8	106	61	427	875
Mercury Intersection to NRDA Rd.	5	116	66	442	929
Indian Springs to Mercury Intersection	29	268	996	1,660	2,490
SR 156 to Indian Springs	21	288	996	1,660	2,490
Northern city limits Las Vegas to SR 156	22	333	996	1,660	2,490

[a] Source: State of Nevada, Department of Transportation, 1983. Information on Traffic Flow, Accidents, and Traffic Projections, Carson City, Nev.

[b] Traffic data for the highway section between Las Vegas and Mercury represent actual counts. Data for the section beyond Mercury has been calculated from average annual daily traffic data.

[c] See Figure 3-21 for location of highway segments.

[d] 1 km = 0.621 mi.

Table 3-10. Traffic service levels and characteristics[a]

Level	Characteristics
A[b]	• Highest level of service • Free flow with little or no restrictions on speed or maneuverability due to presence of other vehicles • Lane density is approximately 10 vehicles/mile
B	• Zone of stable flow • Operating speed is beginning to be restricted, however restrictions on maneuverability by other vehicles is still negligible • Typical design criteria for rural highways • Lane density is approximately 20 vehicles/mile
C	• Still a zone of stable flow • Speed and maneuverability is becoming constrained • Typical design criteria for urban highways • Lane density is approximately 30-35 vehicles/mile
D	• Approaching unstable flow • Tolerable average speeds can be maintained but are subject to considerable and sudden variation • Probability of accidents has increased • Most drivers would consider these conditions undesirable • Lane density is 40-50 vehicles/mile
E	• Unstable flow • Wide fluctuation in flow • Little independence in speed selection and maneuverability • Lane density is 70-75 vehicles/mile
F	• Forced-flow operations • Speed may drop to zero for short periods • Lane density continues to increase, reaching "jam density" at approximately 150 vehicles/mile

[a] Source: Carter et al., 1982.
[b] Level A is currently illegal since to obtain the lane density, vehicle speeds greater than 55 mph is required.

U.S. 95 eastbound from "D" Street to I-15 (Clark County, 1980). The following ramps for I-15 and U.S. 95 interchange are also congested: I-15 South to U.S. 95 West; U.S. 95 West to I-15 South; and U.S. 95 East to I-15 South (Clark County, 1980).

3.5.2 Railroad infrastructure and current usage

As noted in Figure 3-20, the closest rail line to the site is the Union Pacific line which passes through Las Vegas. This line connects Salt Lake City with Los Angeles. To access the site, a spur line of approximately 137 km (85 mi) would have to be built from Dike Siding, which is 18 km (11 mi) northeast of Las Vegas, as shown in Figure 3-20.

The Union Pacific line passing through Las Vegas is designated as a class A mainline. A class A mainline meets at least one of the following three tests (DOT, 1977):

1. High Freight Density Test, which involves carrying at least 20 million gross tons per year.

2. Service to Major Markets Test.

3. National Defense Test, which requires a rail route of the highest physical category in corridors designated as essential in the Strategic Rail Corridor Network for national defense.

Class A mainline routes carry most of the nation's rail traffic. Furthermore, they typically show the best economic performance in terms of unit cost for maintenance and operation, and return on investment.

The line is primarily single track with frequent sidings, i.e., areas at which trains can pull off the main track to the "side." There is a total of 88 sidings on the 721 km (448 mi) section between Salt Lake City and Barstow, California, which is an average of approximately one every 8 km (5 mi). Train operations are controlled by a Centralized Traffic Control system in Salt Lake City, the majority of the line is continuously welded rail (Written communication from Ms. N. Nunn, Marketing Manager, Union Pacific Railroad Company, Omaha, Nebraska, 1983). A number of safety devices are included throughout the mainline route: hot box detectors, wide- and high-load detectors, dragging-equipment detectors, high-water detectors, slide-fence detectors, and a microwave communication system (WESTPO, 1981).

A hot box is used to detect overheated conditions. Wide- and high-load detectors are used to ensure that loads are within design limits for the track. High-water detectors are placed in areas that are prone to flooding. Slide-fence detectors are used to detect breaching in fencing used to constrain mud and rock slides. Dragging-equipment detectors are used to ensure that equipment (such as brake rods and air hoses) dragging along the track are identified. Dragging-equipment detectors lower the possibility of derailment caused by such equipment becoming lodged between wheels and rails. These detectors also lower the possibility of damage to turnout equipment at sidings (WESTPO, 1981).

The average number of trains per day passing along the mainline section through Las Vegas from 1978 to 1983 is given in Table 3-11. Table 3-11 also lists the average number of cars per train and the average number of tons per freight train. An analysis of the capacity of the principal Union Pacific mainlines that was prepared under the auspices of the Western Governors' Policy Office (WESTPO, 1981), estimated that centralized traffic controlled lines could accommodate between 25 and 54 trains daily. Because of its centralized traffic control system, good maintenance, and frequent sidings, the Salt Lake City to Barstow section of the Union Pacific line should be at the high end of this range.

A conservative estimate that the line could accommodate 30 trains per day would suggest the following:

1. The line has not operated at over 71-percent capacity in the past six years.

2. The line has operated at an average of 60-percent capacity over the past six years.

3. The line operated at 53 percent of capacity in 1983.

Table 3-11 to be inserted in.

Table 3-11. Recent railroad traffic patterns[a]

Year	Average number of trains[b] per day (both directions)		Average number of cars per freight train[c]		Average number of tons per freight train	
	Freight	Passenger	Eastbound	Westbound	Eastbound	Westbound
1978	14.4	2	68	65	3077	5599
1979	17.4	2	70	65	3000	6138
1980	16.7	2	73	65	3040	6279
1981	19.2	2	68	64	3042	6500
1982	13.2	2	NA[d]	NA	3206	5799
1983	13.9	2	70	61	3168	5908

[a] Source: Written communication from Ms. N. Nunn, Marketing Manager, Union Pacific Railroad Company, Omaha, Nebraska, 1983.

[b] Number of trains is equally distributed between eastbound and westbound traffic.

[c] Passenger trains average five cars in each direction.

[d] NA = not available.

3.6 SOCIOECONOMIC CONDITIONS

This section describes existing and expected future baseline social and economic conditions in the region surrounding the Yucca Mountain site. These conditions provide the basis for the evaluations in Chapters 4, 5, and 6.

If a repository were located at Yucca Mountain, social and economic impacts would occur in Nye County, where the site is located, and neighboring Clark County. Current settlement patterns of DOE and contractor employees working at the Nevada Test Site indicate that almost all the Yucca Mountain project work force would reside in this bicounty area, which is shown in Figure 3-21.

3.6.1 Economic conditions

Since World War II, Nevada's economy has rapidly expanded, especially the hotel and gaming industry, for which revenue increased more than 100 times between 1945 and 1982 (including inflation). The hotel, gaming, and recreation industry in Nevada directly employs over 121,000 persons, about 30 percent of the total jobs in the State, and as many other jobs indirectly depend on this industry. Other key employers include: other services; transportation, communications, and public utilities; construction; trade; finance; real estate and insurance; and government.

The Nevada economy is expected to rapidly expand well into the future. Combining real per-capita income projections from the OBERS forecast of the Bureau of Economic Analysis, U.S. Department of Commerce, with the most recent University of Nevada, Reno (UNR) population forecast shows that Nevada real personal income is expected to more than double between 1984 and 2000, growing at an average annual rate of 4.8 percent (DOC, 1981). The hotel, gaming, and recreation industry will continue to lead the expansion, although this sector's share of total income is expected to decline slightly over the forecast period (McBrien and Jones, 1984).

3.6.1.1 Nye County

In 1980, 6700 workers were employed in the Nye County public and private sectors (State of Nevada, Nevada Employment Security Department, 1981). In 1982, about 80 percent of the 7508 workers in Nye County were employed by the mining industry, the service industry, or government (McBrien and Jones, 1984).

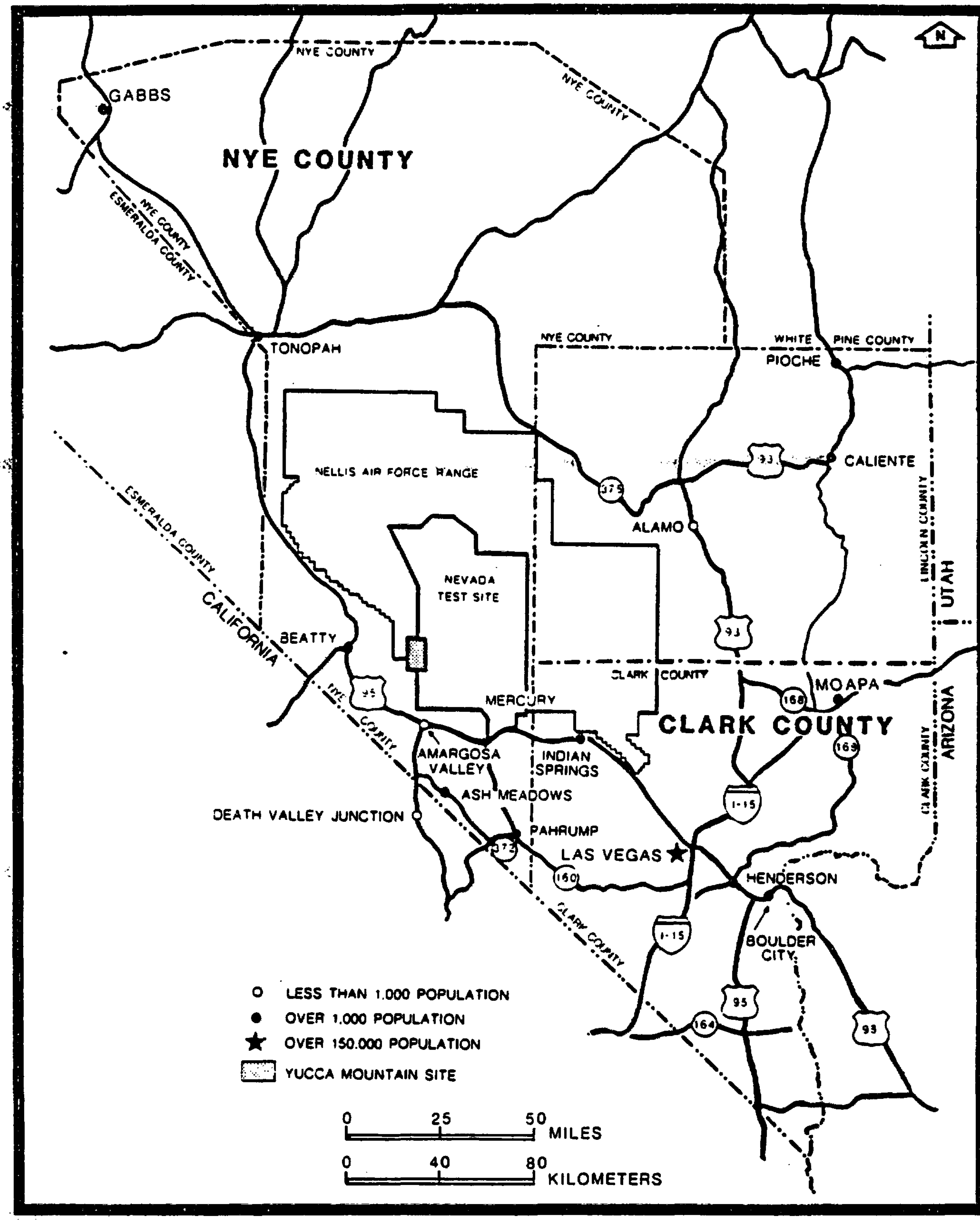

Figure 3-21. Bicounty area surrounding the Yucca Mountain site.

As in most of the U.S., the service industry is the largest employer in Nye County, but the area's character is better defined by its other large employers: mining, construction, and government. Baseline employment forecasts for each of these four economic sectors are shown in Table 3-12. Its entries are based on OBERS projections, adjusted to make them consistent with more recent University of Nevada, Reno (UNR) population growth forecasts for the county (written communication from L. Ryan, Director, State Office of Community Services, Carson City, Nevada, 1984). The forecasts indicate that, in the absence of the proposed repository project, mining employment is expected to decline slightly while construction is expected to grow at a very modest average annual rate of about 1.6 percent between 1984 and 2000 (1984 value determined by linear interpolation between 1978 and 1985).

[illegible]

The mining industry has played a major historical role in the economy of Nye County. Tonopah, the largest town in the county, was founded as a silver mining center, and the town and the county have experienced boom and bust periods fluctuating with mineral demand since that time. Mining employment increased 160 percent (an average of 17 percent per year) between 1975 and 1981, from 520 to 1340 workers (McBrien and Jones, 1984).

Table 3-12. Employment in selected industries in Nye County, 1978-2000[a]

Employment category and growth	Year 1978	1985	1990	2000
Mining	735	888	830	792
Average annual growth	NA[b]	1.5	0.3	-0.5
Construction	467	601	657	745
Average annual growth, percentage	NA	3.7	1.8	1.3
Government	785	994	1,125	1,331
Average annual growth, percentage	NA	3.4	2.5	1.7
Services	3,742	5,429	6,498	8,052
Average annual growth, percentage	NA	5.5	3.7	2.2
Total (includes other categories)	7,909	11,156	13,184	16,384
Average annual growth, percentage	NA	5.0	3.4	2.2

[a] Source: Estimates from 1980 OBERS regional projections, adjusted for difference between OBERS and recent UNR population growth forecasts (DOE, 1981; written communication from L. Ryan, Director, State Office of Community Services, Carson City, Nev., 1984).

[b] NA = not applicable.

In 1982, 9 percent of the Nye County work force was employed by the government sector. The primary Federal government activities in Nye County are located at the Nevada Test Site and the Nellis Air Force Range. However, most employees of these facilities reside in Clark County and commute to their jobs. Thirteen percent, or about 600, of Nevada Test Site workers live in Nye County. Nye County also has more than 500 County and State government employees providing education, police and fire protection, and other government services (McBrien and Jones, 1984).

In addition, while not among the largest employers in the county, agriculture is an important activity in the Pahrump and Amargosa valleys. Primary agricultural products of the Pahrump Valley include alfalfa, cotton, hay, and dairy products. In 1980 about 6000 ha (14,000 acres) of hay and alfalfa were under cultivation, and about 28,000 head of cattle were raised in Nye County (McBrien and Jones, 1984).

3.6.1.2 Clark County

More than half of the 1980 Nevada work force was employed in Clark County (State of Nevada, Employment Security Department, 1981). One-third of these workers, or more than 70,000 individuals, were directly employed by the hotels, gaming, and recreation industry. Major employers in Clark County are the service industries, which include hotels, gaming, and recreation (48 percent); trade industries (21 percent); government (12 percent); transportation and public utilities (6 percent); and construction (6 percent). The retail trade industry, a primary component of the wholesale and retail trade industry in the Las Vegas area, depends heavily on the hotel and gaming industry to bring buyers into the region. The mining industry employed 500 workers in 1980 (State of Nevada, Governor's Office of Planning Coordination, 1981).

As shown in Table 3-13, employment in the service sector, which includes the hotel/gaming industry, is projected to double between 1978 and 2000. In response to this growth and to forecasted rapid growth in manufacturing in Clark County, the trade industry is expected to increase its employment levels by 62 percent between 1984 and 2000. Table 3-13 shows projected growth in the construction and service industries through the year 2000. Its entries are based on OBERS projections, adjusted to make them consistent with more recent University of Nevada, Reno (UNR) population growth forecasts for the County. Specifically, OBERS employment forecasts for each sector have been scaled

(Table 3-13 to be dropped in)

upward by the ratio of UNR- to OBERS-forecasted population for each year. Just as in Nye County, baseline construction employment shows very modest growth of 1.6 percent per year between 1984 and 2000.

3.6.2 Population density and distribution

Population forecasts that form the basis of impact assessments in other chapters of this document are based on county population-growth projections produced by UNR. These forecasts are presented below, followed by a description of existing and likely future demographic conditions in Nye and Clark counties.

The prediction of future growth of Nevada's state and local populations, like any prediction, is subject to increasing uncertainty as the forecast period increases. The projections shown here rely implicitly and explicitly on many assumptions about future economic, demographic, and social conditions. Forecasts presented in this section were prepared by the Bureau of Business and Economic Research, University of Nevada, Reno (UNR) for the State of Nevada (written communication from L. Ryan, 1984). Although the UNR forecast does not extend beyond the year 2000 and has not yet been published in final form, it is the most recent available forecast for the area. Thus, it was used as the basis for estimates presented in Chapters 4, 5 and 6. Where the analysis requires population-growth forecasts for the post-2000 time period, population growth is assumed to continue past the year 2000 at rates projected for the 1990-2000 period.

Table 3-13. Employment in selected industries in Clark County, 1978-2000[a]

Employment category and growth	Year 1978	1985	1990	2000
Construction	15,323	21,041	22,359	26,145
Average annual growth, percentage	NA[b]	4.6	1.2	1.6
Services	92,392	143,013	166,510	212,473
Average annual growth, percentage	NA	6.4	3.1	2.5
Total (includes other categories)	215,758	322,096	370,221	472,851
Average annual growth, percentage	NA	5.9	2.8	2.5

[a] Source: Estimates from 1980 OBERS regional projections, adjusted for difference between OBERS and recent UNR population growth forecasts (DOC, 1981; written communication from L. Ryan).

[b] NA = not applicable.

3.6.2.1 Existing and future baseline population of the State of Nevada

Nevada's recent historical population growth has been the greatest of any of the 50 states: 63.8 percent, or an average annual increase of 4.9 percent between 1970 and 1980. Eighty-four percent of this growth came from net inmigration associated with growing job opportunities in the area (State of Nevada, Employment Security Department, 1981).

Nevada population growth forecasts appear in Table 3-14. According to these preliminary projections by UNR, the state population is expected to grow at an average annual rate of 3.5 percent from 1985-1990, with the growth rate declining to an average annual 2.6 percent per year between 1990 and 2000.

3.6.2.2 Existing and future baseline population of Nye County

Nye County is largely rural, with 1.9 percent of the state population: 17,750 persons, according to preliminary UNR 1984 estimates (written communication from L. Ryan, 1984). Approximately 30 percent of the county population lives in each of the three largest townships: Tonopah, Pahrump, and Beatty (McBrien and Jones, 1984). Tonopah, located 218 km (136 mi) from the proposed site, is the only community having a population greater than 2,500. The smaller communities of Amargosa Valley and Beatty are each within 26 km (16 mi) of the site (see Figure 3-21), Ash Meadows and Pahrump are farther to the south.

Table 3-14. Population of the State of Nevada, 1970-2000[a]

Population/growth	Year 1970	1980	1985	1990	2000
State of Nevada population	488,738[b]	800,493[b]	980,597	1,164,480	1,498,234
Average annual growth, percentage	NA[c]	5.1	4.1	3.5	2.6

[a] Source: Unless otherwise noted, written communication from L. Ryan.
[b] Source: Clark County Dept. of Comprehensive Planning, 1983a.
[c] NA = not applicable.

Population growth in Nye County had paralleled that of the State until 1980, when it increased significantly and Nye County's share of the State population rose from 1.1 percent in 1980 to 1.9 percent by 1984 (UNR, 1983; written communication, L. Ryan, 1984). The UNR forecast projects Nye County population using the assumption that the county's share of State population will increase to 3.0 percent by 1990, declining slightly to 2.8 percent by the year 2000. This population forecast appears in Table 3-15.

3.6.2.3 Existing and future baseline population of Clark County

The 1984 population of Clark County is about 549,800 (written communication, L. Ryan, 1984). Although 96 percent of Clark County's 1980 population resided in the Las Vegas valley, the county's rural population of 9767 exceeded Nye County's total population for that year (Clark County Department of Comprehensive Planning, 1983b). The Las Vegas valley includes the incorporated cities of Henderson, Las Vegas and North Las Vegas and the unincorporated towns of East Las Vegas Town, Enterprise, Grandview, Lone Mountain, Paradise Town, Spring Valley Town, Sunrise Manor Town, and Winchester Town. The Las Vegas Valley had a 1980 population of 443,730, covering about 760 square miles (585 persons per square mile). The remainder of Clark County, which makes up 90 percent of its geographic area, had a 1980 population density of about 2.7 persons per square mile (Clark County Department of Comprehensive Planning, 1983b).

Table 3-15. Population of Nye County, 1970-2000[a]

Population/growth	1970	1980	1985	1990	2000
Nye County population	5,599[b]	9,048[b]	20,190	34,790	42,408
Average annual growth, percentage	NA[c]	4.9	17.4	11.5	2.0

[a] Source: Unless otherwise noted, written communication from L. Ryan.
[b] Source: Clark County Dept. of Comprehensive Planning, 1983a.
[c] NA = not applicable.

Clark County population grew 69.5 percent between 1970 and 1980 (or an average annual rate of 5.4 percent) making it the second-fastest-growing metropolitan area in the nation for that decade. As the county population has grown, its rate of growth has declined over the past 30 years, from 163.0 percent between 1950 and 1960 (9.7 percent annual average growth) to 115.2 percent between 1960 and 1970 (7.7 percent annual average) to the 69.5 percent figure cited above between 1970 and 1980. This pattern follows that of the nation (Clark County Dept. of Comprehensive Planning, 1983a). As was the case for the State as a whole, net inmigration accounted for 84 percent of county population growth in the 1970's.

Baseline forecasts of Clark County's residential population growth are given in Table 3-16. As shown in Table 3-17, these forecasts lie within the range of other population forecasts developed for Clark County.

Table 3-16 dropped here

Table 3-16. Population of Clark County, 1970-2000[a]

	Year				
Population and growth	1970	1980	1985	1990	2000
Clark County population	273,288[b]	463,087[b]	567,150	661,700	889,269
Annual average growth, percentage	NA[c]	5.4	4.1	3.1	3.0

[a] Source: Unless otherwise noted, written communication from L. Ryan.
[b] Source: Clark County Department of Comprehensive Planning, 1983b.
[c] NA = not applicable.

Table 3-17. Population forecast comparisons (in thousands) for Clark County through year 2000

Year	UNR[a]	OBERS[b]	BEA[c]	CCRPC[d]			SWP[e]			McDonald & Grefe	State planning coordinator's office[g]
				Low	Medium	High	Low	Medium	High		
1980	463	463	403	420	435	460	473	483	500	461	411
1985	567	547	ND	495	520	555	568[a]	601	635	550	527
1990	662	634	524	560	600	650	662	715	770	664	660
1995	775	ND	ND	535	680	755	739*	810	885*	766	757
2000	889	823	628	700	750	850	816	894	1,000	891	867

[a] Bureau of Business and Economic Research, University of Nevada, Reno (UNR, 1983; written communication, L. Ryan).

[b] OBERS projection, series E population by the U.S. Department of Commerce (source: McBrien and Jones, 1984).

[c] Disaggregation by State Planning Coordinator's Office of state projections by the Bureau of Economic Analysis (1978).

[d] Clark County Regional Planning Council (CCRPC) (1973).

[e] State Water Plan (SWP). Forecasts for the Future - Population, Volume 5, Water for Nevada (* indicates projections were obtained from 1995 State Water Plan unpublished estimates) (1973).

[f] McDonald and Grefe, Inc. 1977 Unconstrained Estimates (1977).

[g] State of Nevada, Office of the Planning Coordinator (1978).

[h] ND = no data.

Source: All data except UNR data (footnote a) cited in Clark County Department of Comprehensive Planning, 1983b.

3.6.3 Community services

The services described in this section include housing, education, water supply, waste-water treatment, solid-waste disposal, energy, public safety services (police and fire), medical services, social services, and transportation and roads. Even though county-wide data are presented, the description emphasizes those portions of Clark and Nye counties that might experience impacts from project-induced population growth. As will be discussed in Chapter 5, future community services requirements were projected assuming that present ratios of services to population (e.g., police officers per 1000 persons) would be valid in future years. The current community services are described in the following sections.

3.6.3.1 Housing

Table 3-18 summarizes housing characteristics for Clark and Nye Counties. While the number of persons per unit is almost equal for the two counties, other characteristics differ significantly. Nye County has a higher percentage of mobile homes (44 vs. 11 percent), while Clark County has a higher percentage of multiple family units (29 vs. 9 percent). The vacancy rate in 1980 was 8.4 percent in Clark County and 17.9 percent in Nye County. Las Vegas is primarily an adult community; only two out of five households have children under 18 years of age.

3.6.3.2 Education

Statistics on public and private schools in Clark and Nye Counties are summarized in Table 3-19. In Nye county, two of the elementary schools, a junior high, and one of the high schools are located in Tonopah. Beatty, Gabbs, and Pahrump each support an elementary school and a high school. In addition to these schools, one one-room, seven-student contract school is operated at the Fallini Ranch for grades 1-8 (Davis and Cline, 1984). There are no private schools in the county. As seen in Table 3-21, ratios of schools per 1000 residents are much larger in Nye County than in Clark County because the schools in Nye County are smaller. The educational personnel/student ratio is slightly higher in Nye County.

Of the Clark County schools, 66 elementary, 17 junior high, 10 senior high, and 2 special education schools are located in the greater Las Vegas area. The student/teacher ratio in Clark County is about 19 to 1. Specific data on the number of private schools or their operating costs are not available. Enrollment estimates are included in Table 3-19. Also located in Clark County are the University of Nevada, Las Vegas (a four-year college) and Clark County Community College (a two-year college) with a combined 1980-81 enrollment of 18,972 (McBrien and Jones, 1984).

Table 3-18. Housing characteristics in Clark and Nye Counties, 1980-1983

Characteristic	Clark County[a] 1980	Clark County[a] 1983[c]	Nye County[b] 1980
Composition and housing types			
Total housing units	190,607	207,153	4,292
Occupied units	173,891	199,078	3,434
Vacant units	15,969		768
Seasonal and second homes	747		90
Units within urban areas	178,686		0
Units within rural areas	7,896		4,292
Owner occupied units	102,555		2,291
Renter occupied units	71,336		1,143
Year-round housing types			
Single family units	114,316		1,916
Multiple family units	54,815		393
Mobile homes	20,730		1,893
Persons per occupied unit	2.64		2.61
Housing values and rents			
Median value for single family and mobile home units	$67,800		$35,600
Median cash rent	$264/month		$155/month
Median value for condominiums	$73,000		0
Government assisted housing[d]			
Units receiving construction, operation, and/or rental payment assistance	12,732[e]		56
Units receiving home construction or purchase assistance or both (not including Federal Housing Authority loans)	4,700		7

[a] Source: Clark County Nevada Profile (State of Nevada, NOCS, 1982a), except where otherwise noted.
[b] Source: Nye County Nevada Profile (State of Nevada, NOCS, 1982b).
[c] Source: Clark County Department of Comprehensive Planning (1983a).
[d] Federal or State assistance during 1981.
[e] May include double counting.

Table 3-19. School facilities and enrollment in Clark and Nye Counties[a]

Characteristic	Clark County (1982-1983) Number	Clark County (1982-1983) Number per 1,000 residents[b]	Nye County (1983) Number	Nye County (1983) Number per 1,000 residents[c]
Number of public schools				
Elementary	78	0.151	11[d]	0.710
Junior high	18	0.035	4[e]	0.258
Senior high	15[e]	0.029		
Contract schools (K-8)	0	0	1	0.065
Total	111	0.215	16	1.033
Enrollment				
Elementary	44,100	85.6	1,653	106.7
Junior high	19,600	38.1	922[d]	59.5
Senior high	19,200	37.3		
Special education	6,800	13.2	130	8.4
Contract schools (K-8)	0	0	7	0.5
Total	89,700	174.2	2,712	175.1
Average daily attendance	86,500	166.7	ND[f]	ND
Educational personnel				
Administrative staff	174	0.338	8	0.516
Elementary school teachers	2,007	3.897	148	9.555
Secondary school teachers	1,945	3.777		
Special education	609	1.182	ND	ND
Total	4,735	9.194	156	10.071
Private school enrollment				
Kindergarten	454	0.882	0	0
Elementary	2,664	5.173	0	0
High school	1,020	1.981	0	0
Total	4,138	8.036	0	0

[a] Source: Clark County data obtained by McBrien and Jones (1984) from the 1982-1983 Clark County School District Budget. Nye County data from Nye County Nevada Profile (State of Nevada, NOCS, 1982b); Nye County Master Education Plan, Phase I (Davis and Cline, 1984); and Nye County School District (1984a, 1984b).

[b] Based on 1982 population estimate (UNR, 1983).

[c] Based upon 1983 population estimate by the University of Nevada (UNR, 1983).

[d] Includes some middle schools.

[e] Includes some combination junior/senior high schools.

[f] ND = No data.

3.6.3.3 Water supply

In Nye County, centralized water supply services are available only in Beatty, Tonopah, Mercury, and Gabbs (State of Nevada, NOCS, 1982b) and within parts of Pahrump. These utilities served about 64 percent of the County's population in 1980. A total of 3.408 million gallons per day (which does not include use at the Nevada Test Site) was used by the 5216 Nye County residents for which water data are available. Thus, the water demand is estimated to be 2472 m^3/day (0.653 million gallons per day) per 1000 persons. The remainder of the county's homes and industries depend on private wells. Table 3-20 summarizes available information on supply sources and amounts in those portions of Clark and Nye counties near the Nevada Test Site.

Beatty is currently experiencing a problem with its water supply according to the Beatty Water and Sanitation District (letter from M. Walker, Manager, Beatty Water and Sanitation District, to M. Rogozen, Science Applications, Inc., August 7, 1984), regarding information on water supply in Beatty). The Nye County Commission recently requested $150,000 in U.S. Housing and Urban Development block grant funds from the Nevada Office of Community Services so that new high-quality water sources could be found (Pahrump Valley Times-Star, 1984a).

The main areas of existing and potential future agricultural water use are in the Amargosa and Pahrump valleys south of the proposed repository site in Nye County. Actual water use in the Amargosa Valley is unknown, and the potential for future agricultural use is limited by marginal soil and meteorological conditions. Certified appropriations and development permits for ground water in the Pahrump valley totaled 112 x 10^6 m^3 (91,000 acre-feet) per year in 1970, although in recent years actual exploitation has averaged about 49 x 10^6 m^3 (40,000 acre-feet) per year. In the last ten years, real estate developers have purchased agricultural land (with appurtenant water rights) for constructing single-family homes in subdivisions and so water use has transferred from agricultural to domestic. An overdraft situation (i.e., long-term withdrawal exceeds replenishment) apparently exists, and the certification of new water use permits appears unlikely.

The Nevada Division of Water Resources estimates an average of 23,000 acre feet per year of pumping for irrigation. Since annual recharge is about 19,000 acre-feet per year (Harrill, 1982), agricultural uses "mine" about 4,000 acre-feet per year. Because there are over 6 million acre-feet of water in storage in the upper 100 feet of the valley-fill reservoir, the U.S. Geological Survey concludes that it will be "a long time before the valley-wide depletion of ground-water storage becomes critical" (Harrill, 1982).

Table 3-21 shows how water is provided to metropolitan areas of Clark County. Lake Mead on the Colorado River supplies 62 percent and wells supply 38 percent of the county's municipal and industrial water. Metropolitan areas are served by 7 water systems managed by 22 distribution companies (State of Nevada, NOCS, 1982a), while rural users rely upon private wells. The metropolitan water systems' aggregate capacity is about 2.12 x 10^6 m^3 (559 million gallons) per day. Peak demand in 1982 was 1770 m^3 (0.467 million gallons) per

Table 3-20. Current (1980-1984) water supply accounted for in nonmetropolitan areas of Clark and Nye Counties[a]

Community	Estimated population served	Water sources	Estimated water use[b]	
			acre-ft/yr	mgd
Amargosa Valley[c]	2300	Domestic wells 320 feet deep	1731	1.546
Beatty[d]	1200-1500	Four municipal wells	165	0.148
Crystal	42[e]	Domestic wells 160 feet deep	33	0.029
Indian Springs	912	Municipal well capable of supplying 0.8 mgd to 53 customers, plus approximately 80 domestic wells with unknown capacity	686	0.612
Indian Springs Air Force Base	500	Two wells supplying 0.2 mgd potable water	326	0.291
Johnnie	2[f]	No data	0.12	<0.001
Mercury	300	Three municipal wells coupled with a distribution system	237	0.212
Nevada Test Site	ND[g]	Six wells supplying 1.2 mgd	1344	1.2 .
Pahrump[h]	1260	Wells in valley-fill aquifer	1680	1.5
Rhyolite	4[i]	Served by pipeline from water tank at new Beatty well at Indian Springs; other family uses bottled water	2.4	0.002
Totals			6204.52	5.540

[a] Source: MITRE, 1983, Table 2-11, unless otherwise noted.
[b] 1 acre-ft = 1234 m^3; mgd = million gal/day.
[c] Includes Ash Meadows, Amargosa Farms and Lathrop Wells.
[d] Data from Beatty Water and Sanitation District (letter from M. Walker, Beatty Water and Sanitation District, to M. Rogozen, Science Applications, Inc., August 7, 1984, regarding water supply and wastewater treatment in the Beatty area). An undetermined amount of water is used by persons not served by the District.
[e] 20 families.
[f] 1 family.
[g] ND = no data.
[h] Data are for the Central Nevada Utilities Service area only (Carney, 1984). Total population and domestic water use are unknown.
[i] 2 families.

Table 3-21 dropped here

day per 1000 persons. Thus, peak demand represents about 43 percent of capacity.

Available rights to surface water (from Lake Mead) in the Las Vegas metropolitan area are currently about 320×10^6 m^3/yr or an average of about 878×10^3 m^3 (232 million gallons) per day (State of Nevada, NDCNR, 1982). The present use of ground water in Las Vegas Valley is about 88×10^6 m^3/yr (64 million gallons per day), but the State Engineer has adopted a goal to reduce this to 62×10^6 m^3/yr (45 million gallons per day) (State of Nevada, NDCNR, 1982). Present delivery systems are adequate for current needs, but, as will be discussed in Section 5.4.3, supply may not be sufficient for the demand projected for 2020 and later years.

Table 3-21. Water supply in metropolitan areas of Clark County[a]

Community	Suppliers	Sources	Maximum capacity (mgd)[b]	Peak demand (mgd)
Boulder City	Southern Nevada Water System, U.S. Bureau of Reclamation	Lake Mead	14.8	7.8
Henderson	Southern Nevada Water System, Las Vegas Valley Water District, BMI	Lake Mead	19.3	13.6
Las Vegas[c]	Las Vegas Valley Water District	Lake Mead (60%) Wells (40%)	479.0	195.1
North Las Vegas	City of North Las Vegas	Lake Mead (60%) Wells (40%)	45.9	23.3
Totals			559.0	239.8

[a] Source: Nevada Development Authority, 1982.
[b] mgd = million gallons per day; 1 gal = 0.0038 m^3.
[c] Includes unincorporated areas of Clark County.

3.6.3.4 Sewage treatment

Waste-water treatment facilities in Nye County operate in Beatty, Gabbs and Tonopah; the remainder of the county uses private waste-water treatment systems (e.g., septic tanks) (State of Nevada, NOCS, 1982b). Central Nevada Utilities operates two aerobic treatment plants for the Calvada housing subdivision in Pahrump. Approximately one third of the water consumed in Clark County enters the County's sewage system (McBrien and Jones, 1984). This waste water is treated in 11 facilities operated in Boulder City, Henderson, Las Vegas, Overton, and other sites throughout the County (State of Nevada, NOCS, 1982a). Table 3-22 summarizes waste-water treatment in Clark County and southern Nye County.

3.6.3.5 Solid waste

Trash collection in Nye County is handled by private contractors. County-owned, privately-operated landfills are located outside Amargosa Valley, Beatty, Pahrump, Tonopah, and Gabbs. Refuse in Las Vegas, North Las Vegas, Henderson, and the unincorporated portions of Clark County is collected by Clark Sanitation Company, Silver State Disposal, and Automated Transfer Services, which form one private collection service. Fees are collected from residents by these companies, who pay a percentage of the fees collected to the County and to the cities. The major landfill in the bicounty study area, Sunrise, is owned by the U.S. Bureau of Land Management, leased by Clark County, and operated and maintained by Clark Sanitation Company. The landfill's 130 ha (320 acres) are adequate for current needs. Other major landfills are located at Boulder City and Nellis Air Force Base.

3.6.3.6 Energy utilities

In Nye County, propane is supplied by four distributors and heating oil by three distributors. The main sources of electrical energy for Clark County are the hydroelectric plant at Hoover Dam, Nevada Power Company's fossil-fueled Clark Generating Station (near Las Vegas), and Reid Gardner Generating Station (near Moapa). Power in Nye County is distributed by the Sierra Pacific Power Company, the Valley Electric Association, and the Overton Power District. Piped natural gas is available only in Clark County. Table 3-23 summarizes electrical and natural gas supply services in the two counties.

3.6.3.7 Public safety services

The Nye County Sheriff's Office provides police protection for the entire county except for the City of Gabbs. The Sheriff's Office employs 44 deputies and 14 dispatchers to cover 5 million ha (12 million acres) of the county; the City of Gabbs employs an additional three deputies (State of Nevada, NOCS, 1982b). Thus there are about 3.53 commissioned police officers for every 1000 people in the county. This relatively high ratio is explained in large part by the large area of the county and the long distances between towns.

Table 3-22. Waste-water treatment facilities in Clark and Nye Counties[a]

Community	Type of facility	Maximum capacity[b] (mgd)	Peak demand (mgd)
Amargosa Valley (including Ash Meadows)	Septic tanks	ND[c]	ND
Beatty	Oxidation ponds	ND	ND
Boulder City	Facultative ponds	2.0	1.0
Clark County unincorporated	Advanced secondary treatment (trickling filter)	90.0	38.0
Crystal	Septic tanks	ND	ND
Henderson	Secondary treatment (trickling filters), Imhoff tanks, oxidation ponds, aerated lagoon system	6.4	2.5
Indian Springs	Evaporation ponds	ND	ND
Indian Springs AFB	Primary treatment (Imhoff tanks); sludge disposal in pits	ND	ND
Johnnie	ND	ND	ND
Las Vegas	Secondary treatment (trickling filters), chemical treatment for phosphorus removal	37.5	30.0
Mercury	Oxidation ponds	ND	ND
Nevada Test Site	ND	ND	ND
North Las Vegas	Uses City of Las Vegas plant	NA[d]	NA
Pahrump[d]	Aerobic package plants for Calvada development, septic tanks for rest	0.06	ND
Rhyolite	Septic tanks	ND	ND

[a] Source: MITRE (1983); Nevada Development Authority (1982).
[b] mgd = million gallons per day. 1 gallon = 0.0039 m^3.
[c] ND = no data.
[d] Data from Central Nevada Utilities (Carney, 1984).

Table 3-23. Energy distributors in Nye and Clark Counties[a]

Utility	Service area	Supplier	Capacity Total	Capacity Maximum daily
Boulder City Electrical Department	Boulder City	DOE and Colorado River Commission	28.3 MW[b]	27.2 MW
C.P. National	Henderson	El Paso National Gas Company	3.1 MMSCFD[c]	ND[d]
Nevada Power Company	Henderson, Las Vegas, N. Las Vegas, unincorporated areas	Nevada Power Company	1,792.0 MW	1,528.0 MW
Overton Power District	Bunkerville, Logandale, Mesquite, Overton	Colorado River Commission[e]	ND	13.735 MW[e]
Sierra Pacific Power Company	Nye County	ND	ND	ND
Southwest Gas Company	Boulder City, Las Vegas, N. Las Vegas, unincorporated areas	El Paso National Gas Company	160.0 MMSCFD	150.4 MMSCFD
Valley Electric Association	Beatty, Amargosa Valley, Pahrump, Scotty's Junction	Colorado River Commission[f]	ND	ND

[a] Source: Nevada Development Authority (1982), except where otherwise noted.
[b] MW = megawatts capacity.
[c] MMSCFD = million standard cubic feet per day of natural gas.
[d] ND = no data.
[e] Summer peak = combined capacities of Parker Dam and Colorado River Storage Project.
[f] Clark County Comprehensive Energy Plan (Clark County Department of Comprehension Planning, 1982a).

Nye County has 12 fire departments, which operate 14 fire stations, staffed by 128 firefighters, (all but 14 are volunteers). The largest stations are the Amargosa Volunteer Fire Department and the Tonopah Fire Department, which have 17 and 25 firefighters, respectively. The Tonopah Fire Department has four paid employees, and 10 of the 20 firefighters at the Anaconda Copper Corporation are paid. The 12 fire departments own a total of 36 major pieces of equipment (State of Nevada, NOCS, 1982b). As with police protection, the number of firefighters (9.68 per 1000 people) is relatively high. This large figure may be attributed to the nature of the volunteer fire departments and the regional geographic characteristics.

The Las Vegas Metropolitan Police Department, which is responsible for the City of Las Vegas and unincorporated portions of Clark County, employs 738 police officers, including 27 in its airport section (LVMPD, 1984). There are also 17 officers in Boulder City, 41 in Henderson, and 97 in North Las Vegas (data from interoffice memorandum from T. F. Fay, City of North Las Vegas Police Department regarding nuclear waste storage response, April 17, 1984). Thus, the County had 893 police officers for a total 1983 population of 535,150, or about 1.67 commissioned officers per 1000 residents. The four police departments operated about 430 vehicles in 1983 (McBrien and Jones, 1984). According to a recent study by the Las Vegas Metropolitan Police Department, sheriff stations, and detention facilities in many of the Clark County rural communities are inadequate, especially in those areas with rapid growth in tourism (LVMPD, 1983).

Clark County is served by 24 fire departments through 41 fire stations. Five fire departments are located on government facilities and at private industrial complexes. All but four of the remaining fire departments are manned by volunteers. There are 218 volunteer firefighters in the 15 Clark County volunteer fire departments and 525 paid firefighters at the 9 private and public stations. Thus, the County had 0.407 volunteer and 0.981 paid firefighters for every 1000 people in the county in 1983. Fire departments in Clark County use 105 major equipment pieces, including pumpers, tankers, security and emergency items, and squad cars. Most departments own one or two pieces of equipment, although the Clark County Fire Department has 33 major pieces of equipment and Nellis Air Force Base has 10 (State of Nevada, NOCS, 1982a).

3.6.3.8 Medical services

In 1982 there were 676 physicians in Clark County, or 1.31 per 1000 residents, and 6 in Nye County, or 0.450 per 1000 residents. At the end of 1982, Clark County had 215 dentists, or 0.417 per 1000 residents. All of Nye County has been ranked as a priority 1 health-manpower-shortage area by the U.S. Public Health service; i.e. it has the highest priority for allocating health manpower recruited by the Health Service Corps (State of Nevada, NSHCC, 1982). Health care services in the three communities nearest the proposed waste repository site are limited. Amargosa Valley has no resident doctors or dentist. Its clinic is staffed by a full-time physician's assistant provided by the Central Nevada Rural Health Consortium (McFarlane, 1984). The Beatty medical clinic is staffed by a part-time physician's assistant and visited by a dentist from time to time; there is no doctor in the town (letter from P. Thayer, Town Advisory Council, to M. Rogozen, Science Applications, Inc., June 18, 1984, regarding community services in Beatty). Pahrump has a county-owned and maintained medical clinic manned by a full-time physician's assistant. A doctor visits the clinic once a week from Las Vegas, and another doctor is in private practice in the town. All three communities have volunteer ambulance services and access to the "Flight for Life" helicopter service run by Valley Hospital in Las Vegas.

Areas of Clark County having a priority of 1 include Searchlight-Davis Dam-Southpoint, Indian Springs, Virgin Valley, Moapa Valley, Lake Mead, Jean-Goodsprings, Sandy Valley, Blue Diamond-Lee Canyon, Mount Charleston, and Central and North Central Las Vegas. The Paiute Indian colonies in Las Vegas Metropolitan area and Moapa Valley have a priority rating of 4 (Priority 4 means that the area does not have as great a health manpower shortage as Priority 1).

Acute care facilities in the two counties are listed in Table 3-24, along with the average number of beds in various service classes in 1982. In addition, Clark County has 11 long-term care facilities having a total of 1047 beds. Thus Clark County hospitals had, at the end of 1982, 2997 beds, or 5.82 per 1000 residents. Nye County has 22 acute care hospital beds and 24 long-term care beds (all at Nye General Hospital), for a total of 3.45 per 1000 residents. The Nye General Hospital in Tonopah has been operating at a deficit (Pahrump Valley Times-Star, 1983). In an effort to improve the situation, the Nye County Commission formed a special assessment district in March 1984 (Pahrump Valley Times-Star, 1984b). Since they had voted overwhelmingly to oppose a "health tax" for the hospital, the towns of Amargosa Valley and Pahrump were not included with the new district. According to the town councils of Beatty, Amargosa Valley, and Pahrump (P. Thayer, Beatty Town Advisory Council letter, 1984; McFarlane, 1984; Laute, 1984), very few people in these communities use Nye General.

An important factor in evaluating health care systems in the area is the impact of the large visitor population on health services. In 1980 the Las Vegas area had nearly 12 million visitors, who stayed an average of 4.3 nights. Therefore, there are about 141,000 visitors on any given day (more than 25 percent of the resident population) who may require some degree of health care, primarily emergency services. In 1982, about 130 acute-care hospital beds were allocated for use by out-of-area patients. The hospital admission rate for visitors to Clark County has been estimated at 0.5 per 1000 visitors. According to the Nevada State Health Coordinating Council (State of Nevada, NSHCC, 1982), 6.9 percent of the admissions to Clark County Hospitals are out-of-state residents.

3.6.3.9 Library facilities

Library services are provided by four library districts in Clark County. Boulder City, Henderson and North Las Vegas maintain municipal systems, while the Clark County Library District is responsible for the City of Las Vegas and unincorporated areas of the county. Branches are located in Blue Diamond, Bunkerville, Goodsprings, Indian Springs, Mesquite, Mount Charleston, Overton,

Table 3 24. Hospital facilities in Nye and Clark Counties, 1982: Average number of allocated hospital beds per classification[a]

Facility	Total beds[c]	Class[b] 1	2	3	4	5	6	7	8	9	10	11
						COMMUNITY HOSPITALS						
Boulder City	38	31.0	5.0	0	2.0	0	0	0	0	0	0	0
St. Rose de Lima	78	59.1	14.9	0	4.0	0	0	0	0	0	0	0
Desert Springs	222	179.5	0	0	18.8	22.8	0	0	0	0	0	0
Southern Nevada Memorial	356	152.4	26.8	33.0	35.9	22.0	0	0	30.0	30.0	11.6	8.0
Sunrise	670	459.4	56.0	42.0	72.0	0	5.0	35.0	0	0	0	0
Valley	298	210.0	0	12.0	20.0	25.0	0	0	31.0	0	0	0
Women's	61	40.0	21.0	0	0	0	0	0	0	0	0	0
North Las Vegas	131	115.0	0	6.0	16.0	0	0	0	0	31.0	0	0
Nye General	22	17.4	2.0	0	2.0	0	0	0	0	0	0	0
Subtotal	1876	1263.8	125.7	93.0	170.7	69.8	5.0	35.0	61.0	61.0	11.6	8.0
						SPECIAL HOSPITALS						
Raleigh Hills	34	0	0	0	0	0	0	0	0	0	33.5	0
Las Vegas Mental Health Center	40	0	0	0	0	0	0	0	40.0	0	0	0
Total	74	0	0	0	0	0	0	0	40.0	0	33.5	0
						FEDERAL HOSPITALS						
Nellis AFB	35	32.5	0.5	2.5	0	0	0	0	2.0	0	0	0
Total	1985	1296.3	126.2	95.5	170.7	69.8	10.0	35.0	103.0	61.0	45.1	8.0

[a] Source: State of Nevada, NSHCC, 1982.

[b] Bed classes are as follows: 1 = Medical/Surgical, 2 = Obstetrical, 3 = Pediatric, 4 = UCU/CCU, 5 = Intermediate care, 6 = pediatric intensive care unit, 7 - Neonatal intensive care unit, 8 = Psychiatric, 9 = Rehabilitation/physical medicine, 10 = Alcohol treatment, 11 = Jail (security).

[c] This column shows total licensed beds as of December 31, 1982. The sum of the average number of allocated beds in each bed class may differ from the total licensed beds for a given hospital, since more or fewer beds may have been available during the year.

and Searchlight. The four districts have a total of 565,909 books and employ the equivalent of 102 full-time staff members, including professional librarians and administrative staff (State of Nevada, NSL, 1984). Nye County does not have a county-wide library system. Individual libraries are located in Beatty, Gabbs, Amargosa Valley, Manhattan, Pahrump, Round Mountain, and Tonopah. The new library in Amargosa Valley is staffed by a full-time librarian and an assistant and is funded by the town and the Nye County School District. The Beatty Library, which is also new, has 12,000 books and a full-time librarian. About one third of the support for the library comes from the Nye County School District, and the remainder from local tax revenues (P. Thayer, Beatty Town Council letter, 1984). A library assessment district was recently formed in Pahrump (Pahrump Valley Times-Star, 1984c).

3.6.4 Social conditions

This section is a preliminary description of existing sociocultural characteristics of southern Nevada. The focus is on those communities which could be affected by inmigrating repository workers. Because transportation routes have not yet been identified, communities that could be affected by transportation have not yet been identified. The data provide the basis for the assessment of sociocultural impacts described in Chapter 5 that could be caused by locating a repository at Yucca Mountain. This type of description is sometimes classified as describing the quality of life in the affected area and involves measuring both objective and subjective components of community social life. A single index of the quality of life has not been determined for all residents in the study area because southern Nevada, which has experienced rapid and dynamic change, has a wide diversity of cultures and social organizations. The following sections describe (1) social organization and structure, (2) culture and lifestyle, (3) community attributes, and (4) a preliminary assessment of citizens' concerns about the repository.

3.6.4.1 Existing social organization and social structure

The terms "social structure" and "social organization," as used in the following sections, refer to the major social groupings and the network of social relationships that exist among residents in a given location.

In contrast to the social impacts documented in the traditional boom town literature (Wilkinson et al., 1982; Murdock and Leistritz, 1979; Cortese and Jones, 1977), the study area of southern Nevada comprises two distinct social settings: (1) a rural component, which includes all Nye County and the nonurban sections of Clark County, and (2) an urban component, which includes 96 percent of Clark County's population. Table 3-25 summarizes selected social characteristics of Nye and Clark counties that form the basis for the following discussion of social organization and structure.

Rural social organization and structure

As indicated in Table 3-25, Nye County exhibits a high rate of population growth and immigration, as compared with the national average. Between 1980

Table 3-25. Comparison of selected social characteristics by region[a]

Characteristic	U.S.	Western States	Mountain States	State of Nevada	Nye County	Clark County
Persons per square mile	64.0	24.6	13.3	7.3	0.5	58.8
Percent urban	73.7	83.9	76.4	85.3	0.0	95.5
Racial composition (percent)						
White	83.4	81.5	88.1	87.8	92.2	84.8
Black	11.7	5.2	2.4	6.4	0.3	10.0
American Indian, Eskimo, Aleut	0.7	1.8	3.3	1.8	4.7	0.8
other	4.2	11.5	6.2	4.0	2.8	4.4
Spanish origin	6.5	14.5	12.7	6.8	5.5	7.6
Males per 100 females	94.5	98.0	98.7	102.4	115.7	101.7
Percent aged 65+	11.3	10.0	9.3	8.2	9.0	7.6
Percent population increase 1970-80	11.4	23.9	37.2	63.8	61.6	69.5
Percent born in-state	63.9	45.3	44.1	21.4	24.9	18.5
Percent owner-occupied homes	64.5	60.3	67.2	59.6	66.7	59.0
Percent one person households	22.7	23.5	21.6	24.6	26.6	35.6
Crime rate[b]	5397	6923	6384	8485	2980	9075
Marriage rate[c]	10.4	24.1	29.6	148.8	11.7	116.0
Divorce rate[c]	5.2	7.6	8.0	16.	7.7	14.9
Suicide rate[c]	12.8	17.3	18.0	27.8	14.6	23.6
Homicide rate[c]	9.7	8.6	8.6	17.0	24.2	19.4

[a] Except where footnoted, data were obtained from DOC, 1983.

[b] Values were calculated from data obtained from the U.S. Department of Justice, 1977-1980, and from the State of Nevada, Department of Law Enforcement Assistance, 1980. Data are expressed as a rate per 100,000 inhabitants and averaged over a four-year period.

[c] Values were calculated from data obtained from the State of Nevada, Department of Human Resources, 1983. Marriage and divorce are expressed as a rate per 1000 inhabitants; suicide and homicide are expressed as a rate per 100,000 inhabitants. Rates were averaged over a four-year period.

and 1983, Nye County population grew at an average rate of 17.9 percent per year (UNR, 1983); and in 1980 only 25 percent of residents were born in the state. Historically, a high rate of inmigration and population turnover associated with boom and bust mining activities has occurred both in the State and in Nye County (Elliot, 1973; DOI, 1975). These data suggest the absence of community cohesion, defined as "social forces that draw and keep persons together" (Finsterbusch, 1980). Other indicators however, point to a greater degree of social cohesion in Nye than in Clark County. In Nye, home ownership rates are higher, divorce rates and crime rates are lower, and the population is fairly homogeneous in rural and racial composition (although it includes a relatively high percentage of Native Americans). In addition, Nye County has a relatively high ratio of males to females.

The most striking feature of the area surrounding the Yucca Mountain site is the sparseness of population. As shown in Table 3-25, Nye County has only 0.5 persons per square mile. The Yucca Mountain site is bounded entirely on one side by the Nevada Test Site; on the remaining sides, the population is dispersed over a wide geographical area. Forms of social organization include individual farms and ranches, settlements, and communities. Settlements include company housing complexes such as those established for workers at the American Borate Company, described later, and for Nevada Test Site workers at Mercury.

Data on settlement patterns of recent DOE and contractor employees at the Nevada Test Site indicate that some rural communities may be affected by inmigrating repository workers (see Table 5-30). Inmigrants would be most likely to settle in those rural communities that provide services and amenities. Three of the communities that lie closest to the proposed repository site are Amargosa Valley, Beatty, and Pahrump. The distinctive features of these communities may be discerned and are described in the following paragraphs.

Amargosa Valley - 26 km (16 mi) from Yucca Mountain - is the nearest population center to the proposed repository site. The U.S. Environmental Protection Agency estimates a population of 1500 in the Amargosa Farm Area which is approximately 18 km (11 mi) from U.S. Highway 95, and 280 at the American Borate Housing Complex on Nevada State Route 373 near the California state line (personal communication from S. Black, Environmental Protection Agency, 1983). The Valley has witnessed growth in recent years and has significant percentages of migrant, transient and Hispanic population groups. Both mining and agriculture are important in the area (Davis and Cline, 1984). Much of the land can be classified as "agriculturally marginal." Under irrigation, it produces some pasture, alfalfa, and small grains. Most of the farms are operated on a part-time basis with the owner working fulltime at another job (DOI, 1975).

Beatty, population 900 (McBrien and Jones, 1984), is located approximately 48 km (30 mi) north of the community of Amargosa Valley. Originally established during the mining boom of the early twentieth century, Beatty became an important supply center to several boomtowns after construction of the Tonopah and Tidewater railroad. It was the only town to survive after early mines were abandoned (Writer's Program, 1940; DOI, 1975). Mining is now of minor importance, and Beatty has been characterized as a retirement community, with little expectation of growth (Davis and Cline, 1984).

Pahrump, located about 80 km (55 mi) south and east from Yucca Mountain, has both the land and tax base to support expansion. Unlike most of Nevada, nearly 50 percent of the land is privately owned. Within the past decade, large areas of agricultural land have been subdivided, and some attractive permanent housing constructed. Between 1976 and 1982, the population grew at an average annual rate of 16 percent; the 1982 population was 3965 (Mooney, 1982). Current estimates show a population of 5000 (Davis and Cline, 1984). Surveys of community residents indicate that almost 50 percent view the optimum Pahrump population at between 10,000 and 20,000, and another 20 percent would like to see population at 20,000 to 40,000 (Mooney, 1982). The proportion of construction and mining employment relative to agricultural employment increased between 1976 and 1982, and the trend has been for more residents to work in Pahrump or at the Nevada Test Site rather than in Las Vegas. The proportion of retirees has also increased, while younger persons have been leaving the area (Mooney et al., 1976; Mooney, 1982).

Social organization and structure in urban Clark County

The most striking features of Clark County are its high population growth and inmigration rate (Table 3-25). While the total U.S. had a 1 percent average annual population growth rate in the decade between 1970 and 1980, Clark County grew at a 5.3 percent average annual growth rate. Also notable are the high percentage of one-person households, the heterogeneous racial and ethnic mix, and the relatively low percentage of homeowners. These data, when examined in light of the dependence of the economic base on the gaming and tourism industries, suggest a complex and transient social entity. Indicators of social stress, such as rates of suicide, homicide, divorce and crime, which are high relative to national and regional data (Table 3-25), also are affected by the tremendous influx of out-of-state vacationers. Considerable variations exist, however, among the governmental entities (outlined in Section 3.6.5) that form urban Clark County. Their histories have been different, and census tract data show that social characteristics and indicators of social problems vary (DOC, 1983).

Political and economic relationships in Clark County are more formal and bureaucratic that those in rural Nye County. Metropolitan Las Vegas is the most complex social grouping in the study area, with numerous subgroups including civic and social organizations. As might be expected, those groups having the greatest stake in the economic base play the greatest role in formulating the direction and development of the area (Greater Las Vegas Chamber of Commerce, 1981). Also significant are four Federal installations (Hoover Dam, Basic Magnesium Industries, Nellis Air Force Base, and the Nevada Test Site) in southern Nevada that have played an important role in Clark County's growth since 1930 (Clark County Department of Comprehensive Planning, 1982b).

3.6.4.2 Culture and lifestyle

Culture, as used in the following discussion, is defined as the enduring and deeply felt set of attitudes and beliefs held by an identifiable group of people. The overt part of culture is manifested in actual behavior in the institutions, associational life, artifacts, traditions, and overall lifestyle of the group. Essentially, however, these are the expressions of group ideas, values, and beliefs. The rich diversity of cultures and lifestyles exhibited in Nye and Clark counties is outlined in the following sections. The absence of a homogeneous culture, coupled with the large numbers of inmigrants who have been assimilated over the past few decades, are important features of the area. The heterogeneous culture suggests that a wide variety of subcultures can be easily assimilated and accepted and provides the basis for the assessment, presented in Chapter 5, of the potential impact of inmigrating repository workers on the existing cultural environment.

Rural culture

Available data for Nye County suggest an informal, personal organization and lifestyle. In 1982, the county supported 9 churches, 13 motels or hotels, 11 service organizations, and 5 fraternal organizations (State of Nevada, NOCS, 1982b). A rich social life exists based on less formal organizations. In addition, the Nye County government is relatively informal.

Noteworthy aspects of the rural culture include pride in a western heritage, "boom and bust" mining history, and religious, tribal, and ethnic influences. Pride in the western heritage is shown by the number of commemorative celebrations such as Jim Butler Days in Tonopah, Amargosa Valley Days, and the Harvest Festival Rodeo at Pahrump. There are frequent reminders of the boom and bust associated with the mining activities that figure so prominently in Nevada's history; these include railroads that have been removed and ghost towns such as Rhyolite, former population 6,000. Nevada has the lowest percentage of church adherents in the U.S. (26.2 percent in Nye County, 29.7 percent in Clark County) (Quinn et al., 1980). The communities of Bunkerville, Overton, and Logandale in eastern Clark County were settled by members of the Church of Jesus Christ of Latter Day Saints (Clark County Department of Comprehensive Planning, 1982b). Two Indian reservations, the Moapa River Paiute Reservation in eastern Clark County and the Duckwater Shoshone Reservation in northern Nye County, are distant from Yucca Mountain.

Urban culture

The most notable aspect of Las Vegas is its image as "the gaming capital of the world": the Strip, with its "high-rises, explosive colors of night-lighting, and reflective surface materials" is visually and culturally the most dominant feature of the area (Clark County Department of Comprehensive Planning, 1982b). Regardless of background, all citizens must reach some accommodation between gaming and other cultural values (Adams, 1978; Gottlieb and Wiley, 1980). A basic division, however, may be discerned between the lifestyles of the transients (associated with gaming and tourism) and relatively more settled population groups. In Nevada cities, such as Reno and Las Vegas, residents insist on separating the gaming city from the residential city of schools, homes, and churches with emphasis on family and neighborhood values thus creating cities with "two faces." (Elliott, 1973). Greater Las Vegas, with its many social and civic organizations, exhibits cultural characteristics common to cities of its size. In addition to many out-of-state visitors, only 18 percent of Clark County residents were born in Nevada, resulting in a marked cultural diversity.

3.6.4.3 Community attributes

An important component of the "quality of life" in any region or community is the subjective evaluation of persons who live there. Residents' opinions about their community indicate characteristics that could be negatively or positively affected by repository activities. From these attitudes it may be possible to anticipate public reaction to repository siting. No survey of Nevada citizens on repository siting has been made and so the following data are based on two attitudinal surveys recently undertaken for other activities.

The first survey was undertaken for the Governor of Nevada and published in Report of the Governor's Commission on the Future of Nevada (List, 1980). The survey was not systematically distributed; however, the number of forms returned was roughly proportional to the population of each county. The second survey was undertaken by Dr. James Frey of the University of Nevada, Las Vegas to assess citizens' perceptions of the proposed Department of the Air Force MX Missile System (Frey, 1981). In this survey, a proportionate stratified random sample of counties throughout the state was selected. The sample size permitted an overall rural-urban comparison only. The proposed MX Missile System would have been a significantly larger construction project than the proposed repository, employing as many as 22,000 workers at peak (Department of the Air Force, 1980).

Significant findings from the Governor's survey included (List, 1980):

1. More than 80 percent of Nye and Clark County residents would like their region to grow at a slow or moderate pace.

2. The three most valued features of Nevada life for Nye County residents were the open spaces, relaxed lifestyle and freedom, and clean air and lack of pollution. For Clark County residents, these values were climate, open spaces, and relaxed lifestyle and freedom.

3. The most serious problems for the Nye County residents were the housing availability, water and sewage facilities, and road conditions. For the Clark County residents, the problems were roads/transportation, crime, the environment, and unregulated growth.

4. Changes that Nye County residents would be most unwilling to accept are reduced access to open spaces, a deterioration in air quality, increased Federal regulation, and water scarcity. Clark County residents are most unwilling to accept a deterioration in air quality, water scarcity, reduced access to the outdoors, and increased traffic congestion.

From the University of Nevada, Las Vegas survey, findings included:

1. A majority of Nevadans are satisfied with their state as a place to live. Satisfaction is particularly pronounced among rural residents, 79 percent of whom rated Nevada as very desirable.

2. Urban counties rated drug abuse, crime, and road conditions as the most serious problems facing the area; rural counties rated the availability of housing, medical care, and recreational facilities as problems.

3. Urban areas rated the friendliness of other residents, medical care, and recreational facilities as nonproblems; rural areas rated air pollution.

4. Although both urban and rural groups welcomed the jobs that the MX project would bring, all other possible impacts of the proposed project were rated negatively. Rural groups were particularly opposed to the social disruption (crime and drug abuse, for example) they feared would accompany the project.

3.6.4.4 Attitudes and perceptions toward the repository

Attitudes and perceptions regarding the possible siting of the repository at Yucca Mountain are important for understanding social impacts because they form the basis from which social changes may occur. No definitive assessment of residents' attitudes has been undertaken to date. But in a very recent general survey, a majority of the 393 Clark County residents surveyed opposed locating a repository at Yucca Mountain (UNLV, 1984).

Citizens' views expressed during the Las Vegas and Reno public hearings on the potential repository held in March 1983 were reviewed as a means of discerning specific concerns of Nevada residents. A simple count of the number of times a particular topic was mentioned in the hearings suggests the witnesses' greatest concerns were (1) health and safety, (2) transportation, and (3) socioeconomic and community impact. Many witnesses also expressed distrust of the Federal government and a desire for public participation (DOE/NVO, 1983), concerns not restricted to the disposal of nuclear waste.

3.6.5 Fiscal and government structure

This section describes the fiscal and governmental structure of the region surrounding the Yucca Mountain site. Governmental entities lying within Nye and Clark counties include: unincorporated areas, both rural and urban; the incorporated cities of Las Vegas, North Las Vegas, Henderson, Boulder City, and newly incorporated Mesquite; and the unincorporated towns of Amargosa Valley, Beatty, Pahrump, and Tonopah. In 1983, more than half of Clark County residents and more than 90 percent of Nye County residents lived in unincorporated portions of those counties.

While the incorporated cities are responsible for providing public services within their boundaries, county commissions are responsible for providing services to residents in the unincorporated areas. In Nye County, three county commissioners are elected to 4-year terms from individual geographic districts. Day-to-day government operations are handled by a professional manager and staff. In Clark County, seven commissioners have jurisdiction over the unincorporated portions of the County. They are elected in even-numbered years from single-seat geographic districts, three in one election year and four the next. Clark County employs a professional manager and extensive staff to implement commission policy on a full-time basis.

Within the unincorporated towns, provision of services is administered by town councils and town advisory boards, who are either elected or appointed by the County Commission.

Some local government entities have been granted the power of taxation by the Nevada Legislature. For example, in Clark County, specific taxing authority is held by: the incorporated cities of Las Vegas, North Las Vegas, Henderson, Boulder City, and Mesquite, the Clark County School District, and a variety of special districts including library, water, and fire protection districts. In addition, several government entities receive taxes or other public monies but do not have specific taxing authority.

Revenue sources for some governmental entities in the region are shown in Tables 3-26 and 3-27. Fiscal year 1982-83 was chosen to represent the most recent fiscal data in light of substantial changes in Nevada tax law during the previous legislative sessions. The presence of legalized gaming in Nevada gives the state a unique fiscal structure. Gaming revenue contributed almost half--about $230 million--of the State's general fund in the 1982-83 fiscal year. Other major sources of state income included sales and insurance taxes (State of Nevada, 1983).

At the local level, revenue sources for the various governmental units are similar, although income from these sources varies widely. Local sources of revenue include: property taxes (ad valorem taxes on real property); other

Table 3-26. School revenue sources for Nye and Clark counties

Revenue source	Nye County[a]		Clark County[b]	
	Amount (dollars)	Percentage of Budget	Amount (millions of dollars)	Percentage of Budget
State	3,700,000	52.2	105,800,000	52.0
County	2,300,000	42.8	86,800,000	43.0
Federal	70,000	1.0	2,160,000	1.0
Other	27,500	4.0	7,800,000	4.0

[a] Source: Nye County, 1983.
[b] Source: Clark County School District, 1983.

Table 3-27. Local government revenue sources in southern Nevada, 1982-83[a]

Funding category	County: Nye	County: Clark	City: Las Vegas	City: North Las Vegas	City: Henderson	City: Boulder City
Property taxes	0.819 (7%)[b]	51.0 (14%)	9.17 (8%)	1.21 (4%)	0.382 (2%)	0.084 (7%)
Other taxes	2.34 (20%)	56.1 (16%)	6.85 (6%)	4.88 (16%)	0.616 (2.5%)	1.47 (20%)
Licenses and permits	0.237 (2%)	34.0 (9.5%)	7.07 (6.5%)	1.73 (5.5%)	0.783 (3.5%)	0.183 (2%)
Intergovernmental resources	2.42 (21%)	15.9 (4.5%)	62.6 (57%)	11.0 (36%)	5.16 (23%)	1.68 (21%)
Charges for services	4.74 (42%)	139.0 (40%)	19.3 (17.5%)	9.38 (31%)	0.240 (1%)	4.43 (41%)
Fines and forfeits	0.700 (<1%)	2.38 (<1%)	2.06 (2%)	0.964 (3%)	0.225 (1%)	0.056 (<1%)
Miscellaneous	0.838 (7%)	57.7 (16%)	3.47 (3%)	1.33 (4%)	14.8 (67%)	0.481 (7%)
Total	17.5	356.0	110.0	30.5	22.2	8.4

[a] Source: Schedule S-1, State of Nevada Taxation Department, Carson City, Nevada.

[b] All percentages are of total budget.

taxes (city and county relief taxes paid to local governments by the state and income from franchises granted by local governments); licenses and permit fees (business, liquor and local gaming licenses, etc.); intergovernmental resources (cigarette and liquor taxes, local gaming taxes, motor vehicle privilege taxes, etc.); charges for services (recreation, sewer, building inspections, etc.); fines and forfeits (court fines and forfeited bail); and miscellaneous revenues.

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Chapter 4

EVALUATION OF EFFECTS OF SITE-CHARACTERIZATION ACTIVITIES ON THE ENVIRONMENT

The purpose of this chapter is (1) to describe the proposed site-characterization activities at Yucca Mountain and (2) to evaluate the potential effects of those activities on the environment. Site characterization is required by the regulations promulgated by the Nuclear Regulatory Commission (10 CFR Part 60), the DOE siting guidelines (10 CFR 960 Subpart B), and the Nuclear Waste Policy Act of 1982 (NWPA) which defines "site characterization" as

> "activities, whether in the laboratory or in the field, undertaken to establish the geologic condition and the ranges of the parameters of a candidate site relevant to the location of a repository, including borings, surface excavations, excavations of exploratory shafts, limited subsurface lateral excavations and borings, and in situ testing needed to evaluate the suitability of a candidate site for the location of a repository, but not including preliminary borings and geophysical testing needed to assess whether site characterization should be undertaken."

During site characterization, studies will be conducted at the proposed depth of the repository using the exploratory shaft facility. At the same time, standard geophysical field tests and exploratory drilling from the surface will be continued. In parallel with these site-characterization studies, the DOE will also collect information about other aspects of the site, such as weather conditions, the plant and animal life of the area, and the socioeconomic characteristics of the region.

The data collected during site characterization will be used to determine compliance with many of the DOE siting guidelines and the applicable regulatory standards (10 CFR Part 60 and 40 CFR Part 191). Results of site-characterization studies will form the basis of the analyses submitted to the NRC in order to obtain a construction authorization for the repository.

4.1 SITE-CHARACTERIZATION ACTIVITIES

This section contains a description of the site-characterization activities currently planned for the Yucca Mountain site. The activities include conducting field studies, constructing the exploratory shaft facility and conducting tests from the facility, and other studies that have little or no potential for environmental impacts.

If Yucca Mountain is recommended for site characterization, the Department of Energy (DOE) would issue a Site Characterization Plan (SCP), describing the tests necessary to adequately characterize the site's potential for repository development. A progress report would be prepared at six-month intervals to update the information presented in the SCP. The Nuclear Regulatory Commission (NRC) would review the SCP and progress reports as a basis for their independent technical appraisal of the research and testing program.

4.1.1 Field studies

Since 1978, the DOE has been conducting tests and surveys in the vicinity of the Yucca Mountain site to obtain preliminary information on the geologic, hydrologic, and geophysical characteristics of the site and the surrounding area. These tests and surveys include exploratory drilling and testing, geomechanical testing of core samples, geophysical surveys, and geologic mapping. Similar tests and surveys would continue to be conducted if Yucca Mountain were to be recommended for site characterization.

4.1.1.1 Exploratory drilling

Exploratory drilling and testing activities provide data that allow three-dimensional characterization of the geologic, hydrologic, and geochemical characteristics of the site and the surrounding area. By core-drilling exploratory holes one can (1) collect cores, describe the geology of the cores, and analyze the geochemical and physical properties of the cores; (2) investigate geophysical properties below the surface (e.g., logging); (3) measure in-situ stress; (4) test hydraulic conditions beneath the water table; (5) test and monitor the unsaturated zone; and (6) collect water samples for chemical analysis.

Since 1978, the DOE has core-drilled several exploratory holes and conducted geohydrologic tests at Yucca Mountain. Because a Site Characterization Plan has not been completed for the Yucca Mountain site, the following assumptions, which represent the best estimates currently available, have been made for the purposes of assessing the type and magnitude of impact that might be expected from further exploratory drilling if Yucca Mountain is recommended for site characterization:

- Twenty new deep exploratory holes would be drilled from surface-based drill pads to complete characterization of the site's hydrology and geology.
- The new exploratory holes would be drilled within 8 km (5 mi) of the Yucca Mountain site.
- An access road 8 km (5 mi) long would be constructed to each drill location. This is a worst-case assumption used for calculating impacts.
- Access roads would be bladed smooth, boulders would be pushed aside, fill dirt would be added as required, hillside cuts would be made where required, and some roads would be graveled to achieve the desired grade.

- Road width, including shoulders, would average 15 m (50 ft).
- Roads would be sprinkled with water both to aid soil compaction and to provide dust control.

Each drill site must be prepared to accommodate a drill rig and crew. Site-preparation activities include clearing and grading the site and staging area, constructing a raised and leveled drill pad, constructing a parking area and equipment yard, excavating fill dirt from either adjacent or nearby areas, and constructing a mud and cuttings pit. It is assumed that an average of 1 ha (2.5 acres) per drill site would be disturbed by site-preparation activities.

Exploratory hole activities would include core-drilling to depth, geophysical logging, and hydrostatic testing. Equipment and facilities that would be used at the drill site include a diesel-powered drill rig, drilling-fluid circulation pumps, drill pipe, drilling and coring tools, two trailers for supervisory and laboratory space, an electric generator, and an air compressor. Solid waste would be hauled from the site to an existing landfill on the Nevada Test Site (NTS). The water that would be used for drilling, dust suppression, compaction, and human consumption would be trucked daily to the drill site. Waste drilling fluids and cuttings would be confined in mud and cuttings pits.

Downhole geophysical logging using a contained radiation source is a common practice in geologic characterization. Logging tools having radiation sources are used to remotely determine degree of water saturation, rock density, and other physical characteristics; the sources are licensed by the Nevada Division of Radiologic Health. The licensing of these sources requires that the contractor receive formal training in radiologic safety and in the use of the logging tool. In addition, the Nevada Test Site radiation safety program provides safety and use requirements that are comparable to those required by the State.

4.1.1.2 Geophysical surveys

Certain geophysical surveys provide a means by which to obtain information about the subsurface geology without drilling deep boreholes. The surveys can be used to map the geometry of geologic structures at depth and to recognize discontinuities in stratigraphic sequences. Some geophysical techniques are useful for detecting major changes in rock density at depth, magnetic or electrical properties which may indicate the presence of an igneous intrusive body (pluton), or a metallic ore body. The geophysical techniques described in this section include seismic reflection and refraction, gravity, magnetic, and electrical surveys. Each of these techniques may require land surveying and geologic reconnaissance either on foot or by using off-road vehicles or helicopters.

Seismic reflection and refraction surveys involve the generation of sound waves that travel through earth materials. Either seismometers or geophones are used to detect, amplify, and record the resulting motion of the ground at nearby points. Reflection and refraction of the sound waves are caused by changes in rock properties (e.g., density and sonic velocity) along the travel paths from the seismic source to the receiver. The resultant seismic reflection and refraction patterns are mathematically analyzed and are used to determine the types of rock materials and three-dimensional structures that would be expected to produce the observed patterns.

Seismic reflection surveys at Yucca Mountain have been conducted using dynamite charges set off in shot holes that have been drilled and arranged in a linear pattern. These holes did not require drill pads; however, it was necessary to clear some vegetation for vehicle access and geophone positioning. In addition, low-frequency sound waves for seismic reflection surveys were generated by use of large, specially designed four-wheel-drive trucks with a large plate attached to the truck bottom. Hydraulic jacks were used to press the plate against the ground while simultaneously lifting the truck and vibrating it on the plate. A full-scale test of this type was conducted in the eastern foothills of Yucca Mountain. Data were recorded from an array of geophones that were placed on the ground surface at specific distances from the trucks. Similar seismic reflection studies may be conducted during site characterization.

A seismic refraction survey was conducted as part of the preliminary investigations of Yucca Mountain. A north-south line approximately 80 km (50 mi) long was located in the eastern portion of Crater Flat. To emplace explosives, holes were drilled with a truck-mounted rig. The holes contained explosives that were detonated to generate sound waves. An array of geophones was deployed to collect the refraction data. Another refraction survey was conducted east of Yucca Mountain along the road to Drill Hole Wash. Small drill pads were constructed and holes were drilled for emplacement of explosives. Similar seismic refraction surveys may be conducted during site characterization.

Gravity surveys are conducted to measure small differences in the strength of the earth's gravitational field to detect subsurface geologic structures. Positive and negative gravity anomalies, which are the result of differences in the density of underlying rock materials, are recorded and interpreted. Gravity measurements are taken at discrete locations defined by a grid system consisting of cells that are typically 60 by 60 m (200 by 200 ft). Some gravity surveys have been made in the Yucca Mountain area, and additional surveys are planned during site characterization.

Magnetic surveys are conducted to measure differences in the earth's magnetic field from place to place and are used to determine the subsurface configuration of rocks having different magnetic properties. Magnetic surveys may be conducted from the ground, or airplanes may be equipped to conduct magnetic surveys. Both survey methods have been used at Yucca Mountain, and additional surveys are planned during site characterization.

A number of other geophysical techniques may be used to enhance the understanding of the position and characteristics of rock units in the subsurface. Electrical surveys that measure the response of earth materials to the passage of natural and induced electrical currents (e.g., resistivity, self-potential) have been made in the vicinity of Yucca Mountain. Another technique, commonly used in the petroleum industry, is vertical seismic profiling (VSP). This technique is useful for fracture mapping and for determining the extent of interconnection of the fractures. Attenuation of high-frequency electromagnetic waves by fluid-filled fractures has also been used successfully to map fractures.

4.1.1.3 Geologic mapping

Geologic mapping is conducted to record the surface features and characteristics of exposed rock in the area. This mapping uses aerial photography and requires detailed field observations on foot. Occasionally, the surface study is supplemented by shallow subsurface investigations requiring a limited amount of trenching. Typically, the trenches are approximately 2 m (8 ft) wide, range from 1 to 3 m (4 to 10 ft) deep, and are from 30 to 60 m (100 to 200 ft) long. The walls of shallow trenches are kept straight, smooth, and as nearly vertical as possible. Deeper trenches are terraced for safety reasons, and they may be as wide as 8 m (25 ft). Some trenching and additional geologic mapping would be done during site characterization.

4.1.1.4 Standard operating practices for reclamation of areas disturbed by field studies

When the DOE determines that an exploratory hole is no longer needed for gathering data, the exploratory hole would be sealed. State of Nevada requirements, as well as cooperative agreements with the BLM (BLM/DOE Cooperative Agreement FCA-N5-2-2) and the Department of the Air Force (Air Force Permit DACCA09-4-80-332), call for the proper sealing and capping of exploratory holes upon abandonment or termination of DOE activities at the site. All exploratory holes that are not currently being used are capped temporarily. If a decision were to be made to abandon an exploratory hole, it would be sealed according to accepted practice. If any specific sealing requirements are necessary, they would be determined using the data obtained during site characterization. In general, the exploratory hole would be sealed with a ground-matching grout that has a density that corresponds to the surrounding geologic medium. The grout would be injected in increments to prevent fracturing the surrounding medium. The formulation of the grout would be determined by using data from cores that were taken during drilling. Following the injection of ground-matching grout, the surface casing would be filled with concrete to the surface, and a concrete cap would be poured around the sealed hole. A permanent marker that gives pertinent data about the exploratory hole would be emplaced following surface restoration.

Standard operating practices for reclamation and habitat restoration include the following:

1. Removing and disposing of the surface debris and any concrete drill pads in the Nevada Test Site landfill.

2. Disking or ripping of the compacted, stabilized drill-pad area to relieve compaction and to cause mixing with the underlying soil.

3. Filling the mudpit with stockpiled topsoil after removal of drilling fluids or sludge, as appropriate.

4. Contouring disturbed areas to reestablish natural drainage patterns, to minimize erosion, and to blend with surrounding land contours.

5. Distributing available stockpiled topsoil over the recontoured area in a manner that minimizes erosion and encourages moisture retention.

6. Ripping or disking the compacted unpaved roads that are no longer used and recontouring and stabilizing the disturbed road area to minimize erosion and encourage revegetation.

Because reclamation and habitat restoration techniques in fragile, arid ecosystems are not completely understood and long periods of time are required to reestablish climax vegetation associations; the effectiveness of habitat restoration is not clear. Consequently, each practice previously identified would be individually evaluated and adjusted as an outgrowth of continuing restoration studies.

About 100 ha (247 acres) of surface disturbance would be associated with geophysical and geological surveys. The disturbed exploration areas and off-road vehicle paths would be disked to relieve compaction and to encourage revegetation. Geological trenches would be filled with the material removed during excavation and the land would be restored to its original contours. If appropriate, the recontoured surface would be treated to encourage moisture retention and to hasten revegetation, based upon the results of habitat restoration studies.

4.1.2 Exploratory shaft facility

If Yucca Mountain is approved for site characterization, the DOE will construct an exploratory shaft facility to provide access for detailed study of the potential host rock as well as the overlying and underlying strata. The excavation and construction of this exploratory shaft facility would be a major contributor to potential environmental impacts during site characterization. The exploratory shaft facility would consist of (1) an exploratory shaft large enough for the transport of people and equipment (inside finished diameter of 4 m, or 12 ft), (2) underground testing areas, (3) a secondary egress shaft (inside diameter of 1.8 m or 6 ft), and (4) the surface facilities needed is support construction and testing. Both of the shafts would extend slightly beyond the proposed depth of the repository. The underground testing areas would be excavated at three levels. A main test facility with drifts and rooms would be excavated into the host rock at the middle level. The secondary egress shaft would be used for ventilation and would provide another means of egress from the underground areas. It would be connected to the exploratory shaft by a drift. Figure 4-1 is an illustration of the proposed exploratory shaft facility showing the exploratory shaft, the secondary egress shaft, the underground test areas, and the associated surface facilities.

The exploratory shaft facility would be located in Coyote Wash on the eastern side of Yucca Mountain at an elevation of about 1300 m (4150 ft).

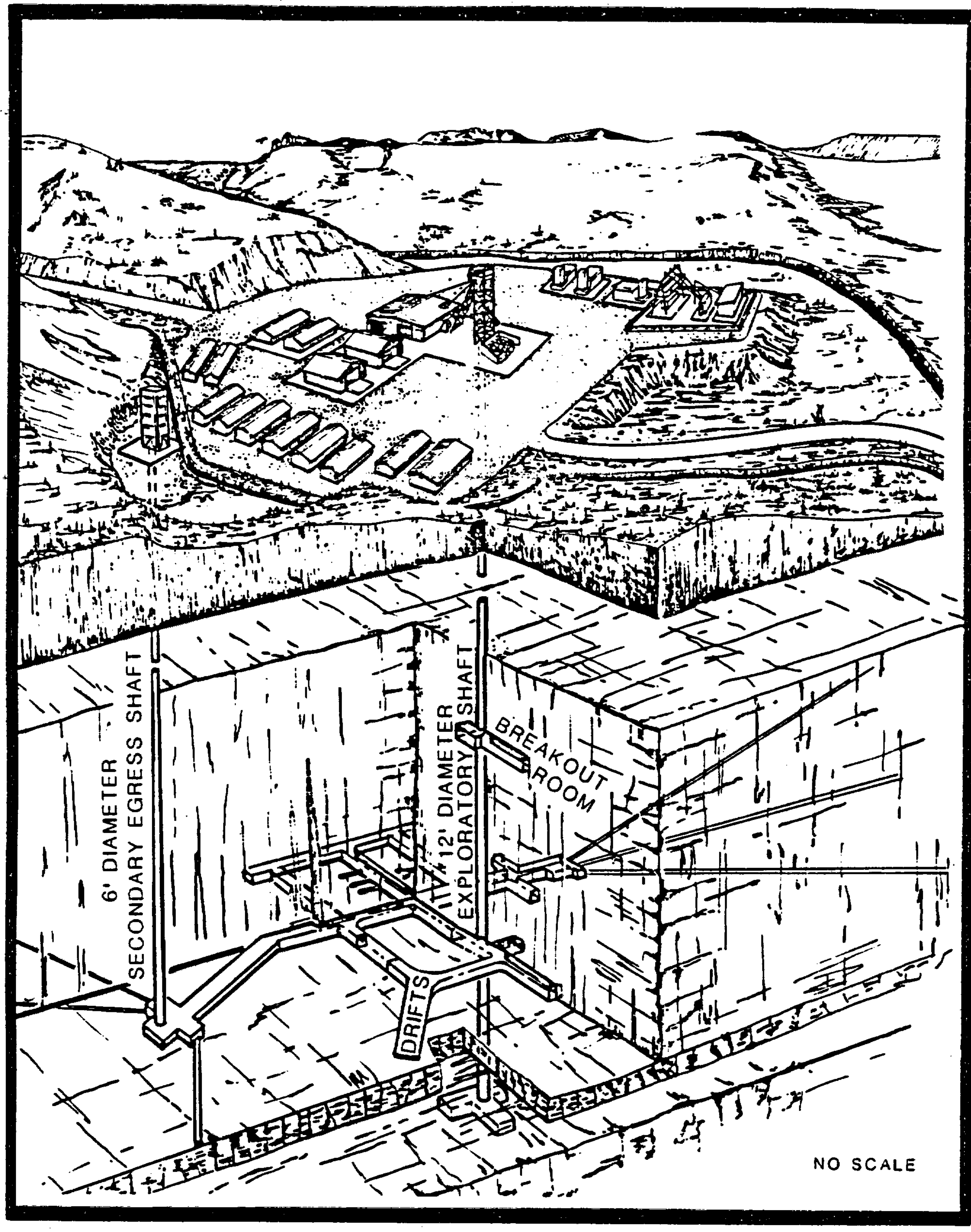

Figure 4-1. Three-dimensional illustration of exploratory shaft facility (no scale).

Figure 4-2 shows the proposed site, utility lines, and the access road. It also shows the administrative boundaries of the Nevada Test Site, the Nellis Air Force Range (NAFR), and the Bureau of Land Management (BLM). The site plan at Coyote Wash is shown in Figure 4-3.

Facility design and construction specifications require that equipment and systems meet the requirements set forth by the DOE (1983), and applicable local, State, and Federal regulations, and national standards. It is also required that construction disturb only the minimum amount of land necessary to accomplish the project. Design criteria include considerations of site restoration; the site would be restored to approximately its original condition if Yucca Mountain is eliminated from the list of potential repository locations. The following sections describe the exploratory shaft facility, the plans for testing, and the practices being considered to minimize environmental damage.

4.1.2.1 Surface facilities

Construction of the surface facilities is expected to take from six to seven months to complete. The site would first be cleared and graded; then it would be stabilized with 15 cm (6 in.) of gravel and a dust binder.

As shown on Figure 4-3, two existing natural drainage channels would be diverted to control potential runoff from a 100-year storm event. About 180 m (600 ft) of one channel was diverted in 1982 when the drill pad for the principal borehole, USW G-4, was constructed at the exploratory shaft location. Site preparation would require cut and fill to provide a level pad (exploratory shaft site pad) for the surface structures and for the parking area. About 57,000 m^3 (2,000,000 ft^3) of fill material would be removed from areas east and west of the pad. In addition, a 30 by 30 m (100 by 100 ft) pad would be required to support surface activities associated with the 1.8-m (6-ft) diameter secondary egress shaft. Approximately 280 m^3 (10,000 ft^3) of soil would be moved (cut and fill) to construct this pad. A small trailer may be located on the pad to support drilling activities there. The surface area that would be required for all of the exploratory shaft facilities is about 8 ha (20 acres).

The parking area and the access road would be paved with double oil-and-chip. Access to the exploratory shaft site pad from the east would be controlled by a chain-link fence and gates. The natural terrain provides a barrier to vehicle access elsewhere on the site. The access road from Jackass Flats has been improved to the edge of the NTS to accommodate heavy equipment. The road is 7 m (22 ft) wide, has 1-m (4-ft) shoulders, and is surfaced with double oil-and-chip. The remaining 400 m (1300 ft) of the road to the exploratory shaft site pad would be constructed on fill to maintain a grade that would not be greater than 10 percent. This road would disturb a path 50 m (160 ft) wide, including channel modification.

Prefabricated metal buildings, which would be assembled at the site on concrete foundations, would provide space for a shop, a warehouse, and a hoist house. All three buildings would be designed to withstand the maximum expected

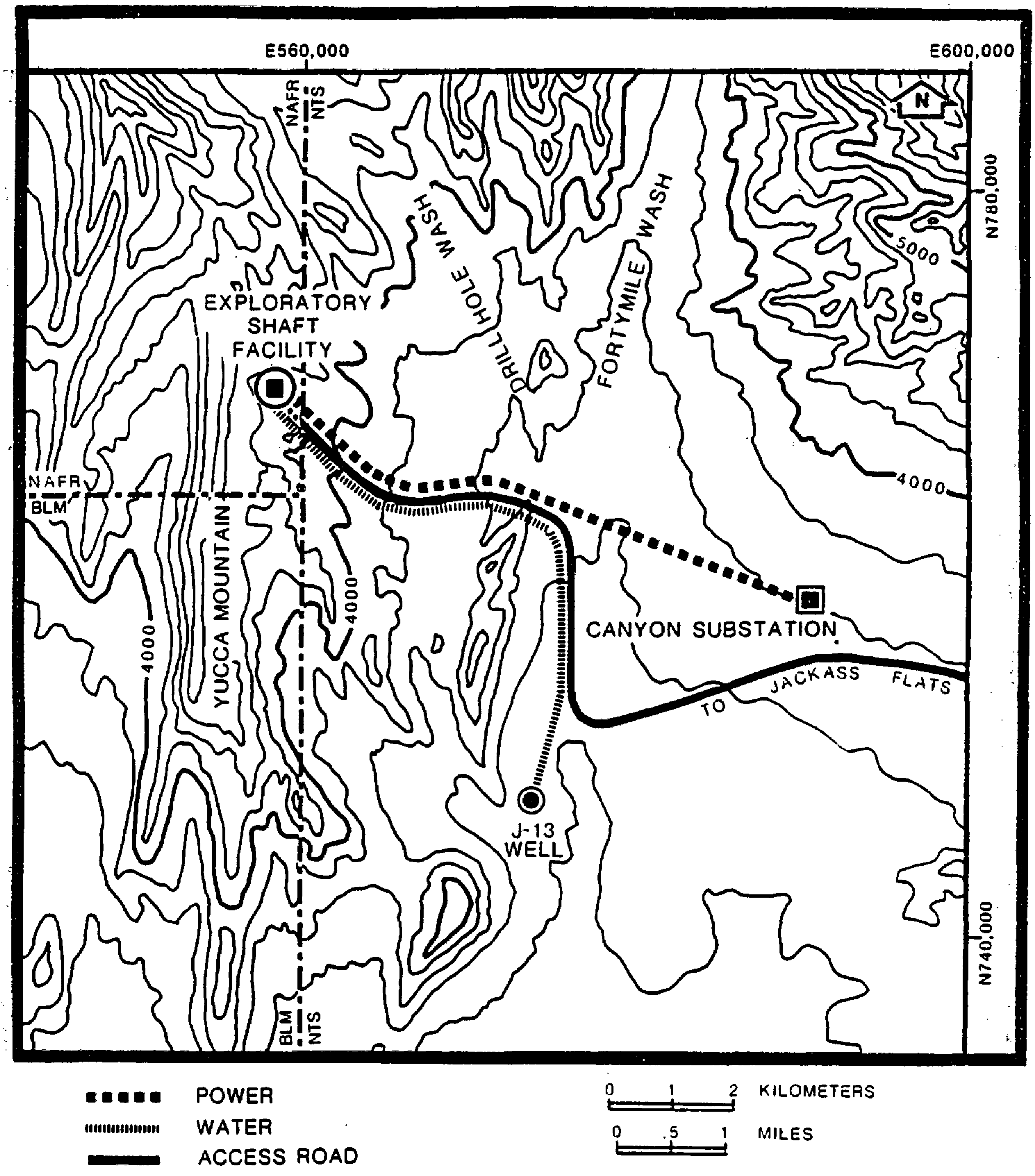

Figure 4-2. Location of proposed exploratory shaft facility and utilities.

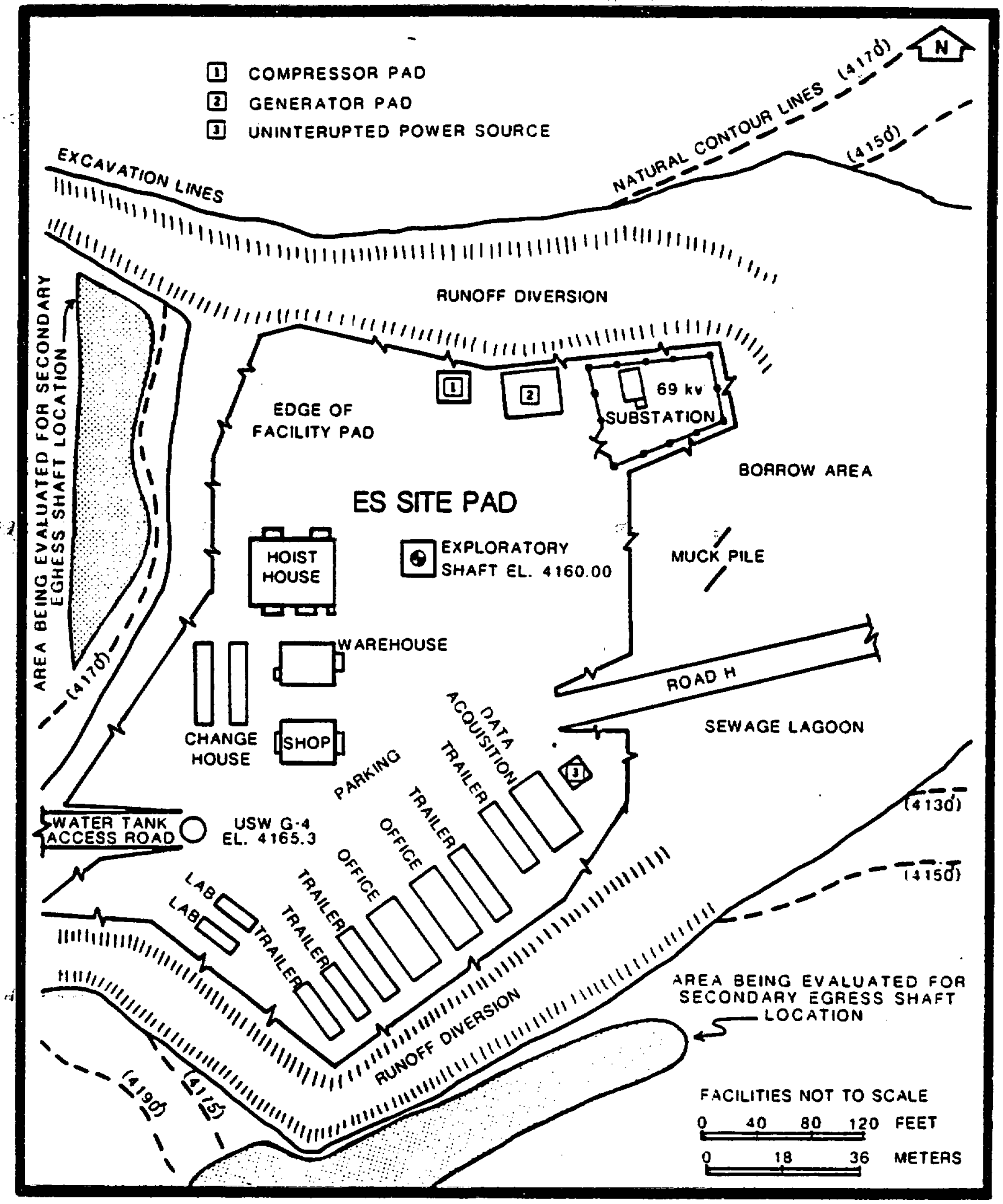

Figure 4-3. Site plan for exploratory shaft facility.

ground motion from either natural earthquakes or nuclear weapons testing. A 4.5-metric ton (5-ton) overhead crane would be installed in the shop area. The hoist house would accommodate two hoists. Fire protection would be provided. As many as twelve trailers would be located on the exploratory shaft pad and used for change rooms, office and laboratory space, data acquisition, first aid room, visitor's center, and overnight accommodations. Showers and lockers would be provided for the technical staff and for the mining crew, which is estimated to be 20 persons per shift. Each structure would have restrooms, electric space heating and water heating, and air conditioning.

Three magazines would be required for storage of explosives: one for powder, one for caps, and one for primer makeup. Two magazines would be located at least 600 m (2000 ft) from the shaft. The magazine for primer makeup would be located north of the pad and nearer the shaft. The size and location of the magazines would be determined by the maximum amount of powder to be stored at any time.

The utilities and communication systems include the following: (1) above-ground electrical supply and underground distribution; (2) emergency electrical supply; (3) water supply and distribution; (4) sanitary, industrial, and refuse waste collection and disposal; and (5) telephone communications. An overhead power line 10 km (5 mi) long has been constructed from Canyon Substation in Jackass Flats to the NTS boundary (Figure 4-2). This 69-kV transmission line would provide power to the site substation. The site substation would include both a 5 MW transformer to supply 4.16-kV power to the hoists, and secondary transformers to supply 480-V, 220-V, and 110-V power to the other surface facilities. The substation would require cutouts, distribution panels, conduit and wire, fencing, trenching, and some concrete work. Two distribution systems would supply the surface structures and the underground workings. A second power line would be placed on the same set of poles to supply 4.16 kV to a booster station to pump water to the site. Area floodlights on wood poles would provide night lighting. The emergency power generation system would have two 500-kVA diesel generators.

The water supply would be pumped from well J-13 on the NTS through a 10-km (6.2-mi) long, 15-cm (6-in.) diameter polyvinyl chloride pipe buried about 0.6 m (2 ft) below grade. The pipeline, which has been constructed in the old access roadbed to the NTS boundary, is adjacent to the new paved road. One pumping station is at J-13 and a booster pumping station is at about the half-way point. Water would be pumped to a 600-m^3 (150,000-gal) water tank located 500 m (1600 ft) west of the site at an elevation of 1320 m (4325 ft). The water distribution system from the tank would supply water for all needs at the exploratory shaft facility.

Waste disposal would be in either the sewage lagoon, on the muck pile, or in the Nevada Test Site landfill as noted in the following. The sewage lagoon, which is an area about 41 by 41 m (135 by 135 ft) located east of the site, would have a holding area capable of handling sewage for 75 persons in a 24-hour period. It would be connected to a collection system by an underground sewer line from all buildings and trailers. The lagoon would be constructed in alluvium, which has a high permeability. If the evaporation rate and the percolation rate are sufficiently higher than the sewage inflow rate, then the sewage lagoon will not function properly unless more water is added to maintain the sewage decomposition balance. Therefore, water would be added as necessary. Water and other fluids removed with the muck from the shaft and underground rooms would be disposed of on the muck pile, which also would be built on alluvium. Fluids that would be used for core drilling including air-water mist, bentonitic mud with water control agents, and polymer foam would be disposed of on the muck pile. Excess drilling water would be pumped to the sewage lagoon. Solid refuse from the site would be hauled to an existing landfill on the Nevada Test Site.

The ventilation fans located at the secondary egress shaft would be capable of providing 1,135 m^3/min (40,000 cubic ft per minute (cfm)) of air to the underground workings. The ventilation system would meet all Mine Safety and Health Administration (MSHA) requirements and would provide underground temperatures to allow a work regimen of 75 percent work and 25 percent rest with a rock temperature of 27°C (80°F) at the 370 m (1200 ft) depth. The fans would have reverse-flow capability to exhaust smoke, fumes, and dust from blasting in the underground workings. Backup fans and emergency power for operation of the ventilation system would also be provided. Two air compressors would supply primary and backup capability for air drilling of underground boreholes. Each would have a capacity to compress 40 m^3/min (1500 cfm) of free air to a gauge pressure of 860 kPa (125 psi) on a sustained basis. This system would include foundations and electrical supply controls, and distribution piping. The air compressors would be located near the power substation to provide noise separation from the shaft and buildings.

A mine-dewatering system would be available; however, it is not expected that large quantities of water would be encountered in the exploratory shaft or underground workings. It is possible that perched water zones and percolation seepages could release some water to the shaft or underground workings during construction and testing. Such water would be collected in a sump and then pumped to the surface and discharged on the muck pile. There would be a backup sump pump and emergency power. The quantity of water removed from the shaft would be measured and documented.

The muck pile would be located immediately off the site pad and east of the exploratory shaft. The muck removed from the construction of the shafts, from breakouts, from the drift connecting the two shafts, and from the main underground test facility would be transported to the surface and deposited adjacent to the exploratory shaft. From there, the muck would be collected and hauled to the edge of the pad where it would be dumped from the 9-m (30-ft) embankment. The 0.6-ha (1.6-acre) muck pile area would be sufficient to accommodate the 32,200 m^3 (1,144,000 ft^3) of muck that would be produced during shaft and drift mining. Dust from the dumping operation would be controlled by appropriate wet suppression techniques. A berm would be constructed between the muck pile and the drainage channel to contain any chemicals or muck leachates and to prevent them from reaching the drainage channel. This berm would be designed to contain a volume of 1400 m^3 (375,000 gal) of liquid.

4.1.2.2 Exploratory shaft and underground workings

The current plans are to mine the exploratory shaft to a total depth of about 450 m (1480 ft), which is about 23 m (75 ft) below the contact between the overlying Topopah Spring Member and the underlying tuffaceous beds of

Calico Hills. This total depth would provide about 15 m (50 ft) of penetration into the pervasively zeolitized interior of the Calico Hills unit and would leave undisturbed about 85 m (280 ft) of the Calico Hills unit above the water table. The design diameter of the excavated shaft is 4.3 m (14 ft) and the finished diameter is 4 m (12 ft).

The mining of the exploratory shaft would begin after the surface facility has been completed. The exploratory shaft would be constructed by a conventional drill-blast-muck mining technique. Explosives would be placed into small holes drilled in the rock. After the explosives have been detonated, the muck would be collected and hoisted from the shaft. Conventional mining, instead of drilling, was selected as the exploratory shaft construction technique because it would provide the capability to examine geologic and hydrologic conditions above, below, and within the candidate host rock during the exploratory shaft construction. Conventional mining would minimize the potential introduction of water and other contaminants into the unsaturated zone, thereby reducing the possibility of affecting some tests designed to assess ground-water flux and undisturbed moisture content of the rock.

The mucking operation may be somewhat dustier than it would be in a typical mine because minimal amounts of water would be used for dust suppression in the shaft. Normally, the rubble would be sprayed with water before mucking to provide additional dust control. However, in the exploratory shaft, water would be used sparingly so that certain tests would not be affected. All of the water used in shaft construction, including the water used for making liner concrete, would be tagged with a suitable tracer. The quantity of water entering the shaft, the humidity in the air supply, and the humidity in the exhaust ventilation air would be metered and recorded. Shaft ventilation after blasting (smoke-out) would normally be accomplished by sucking out the gases produced by the blasting before they have a chance to diffuse throughout the drift volume.

Breakout rooms would be excavated at the 160 and 370 m (520 and 1200 ft) levels during shaft construction. The shaft would be mined to 450 m (1480 ft). A test area would be excavated at the bottom of the shaft before the main underground test facility is constructed from the middle breakout room at 370 m (1200 ft). Current plans are to mine the underground test facility and drifts using conventional drill-blast-muck methods.

4.1.2.3 Secondary egress shaft

The locations being considered for the secondary egress shaft are noted in Figure 4-3. Detailed design has not been done on the secondary egress shaft, therefore, the information provided below is based on preliminary design work and is subject to change as design proceeds (letter from D. C. Nelson, Los Alamos National Laboratory, to J. H. Dryden, Department of Energy, August 1, 1984, regarding request for Title I and Title II engineering design for a second shaft for the exploratory shaft facility). Other locations for the proposed second shaft are also under consideration.

According to the current plans, a 200-mm (8-in.) pilot hole would be drilled from the surface using a down-hole compressed-air hammer drill.

Because this type of drill uses air in the drilling process instead of a water-based drilling fluid, it avoids introducing water into the host rock. The pilot hole will be drilled to a depth of 370 m (1200 ft), which is the depth of the main underground test facility. A dust-filtering system would be used to catch airborne dust.

The pilot hole would be expanded from 200 mm (8 in.) to 1.8 m (6 ft) by raise boring (a mining technique involving drilling upward) with the drilling rig at the surface. A 3.7 by 3.7 m (12 by 12 ft) drift would be mined from the exploratory shaft test level to the bottom of the pilot hole. From there, the secondary egress shaft would be raise bored along the pilot hole. The muck would be removed through the exploratory shaft and would be placed in the muck pile.

The quantity of water necessary for cooling and for dust suppression during the drilling operation is expected to be small. This water would be tagged with a suitable tracer. Most of the water would be removed along with the muck.

After drilling,the secondary egress shaft would be lined with a steel casing. The hoist, head frame, and hoist house would then be constructed.

4.1.2.4 Exploratory shaft testing program

The goal of the exploratory shaft testing program is to obtain information that is required to assess the intrinsic ability of the geologic setting at Yucca Mountain to isolate high-level waste (HLW). Information would be acquired also that would assist the design of engineered components such as drifts, emplacement holes, canisters, etc. The underground test program is being designed to provide information needed to address compliance with Federal regulations related to performance and siting criteria for high-level waste repositories. Engineering test plans would be prepared for individual exploratory shaft tests before beginning the tests.

A number of assumptions have been established to provide a consistent basis for planning the exploratory shaft testing program. These assumptions include:

1. The underground workings would be restricted to the unsaturated zone beneath Yucca Mountain.

2. The candidate host rock would be the densely welded Topopah Spring Member of the Paintbrush Tuff.

3. The tests that would be conducted would be focused on obtaining site-characterization information necessary for licensing.

4. The tests would be planned to provide timely input for the performance assessment analysis of the site.

All exploratory shaft construction, operations, and maintenance functions would be performed in accordance with established Federal, State, and Nevada Test Site safety codes and procedures.

The tests in the exploratory shaft facility that are being considered at this time can be grouped into two general categories:

1. Construction Phase Tests: Tests that would be initiated concurrently with shaft sinking (some construction phase tests would continue into the in-situ test phase).

2. In-Situ Phase Tests: Tests that would be initiated after shaft sinking is complete.

Ten construction-phase tests are planned. One of the ten tests--shaft wall mapping, photography, and hand specimen sampling--will be conducted routinely following each blast round as the shaft is being sunk. Three of the tests require large block samples that would be collected from 15 to 30 locations in the shaft. The pore waters that would be extracted from the large block samples would be chemically analyzed and dated by using chlorine-36 techniques. Laboratory measurements of geomechanical properties are also planned on these samples. The fifth test, unsaturated zone water sampling, would only occur if perched water were found during shaft sinking, which is not considered to be likely. The basic shaft wall mapping test is expected to require one to two hours after each blasting round. In those instances where large blocks or water samples are collected, an additional one to two hours is expected to be required. The remaining five tests would be at selected depths. These tests represent nonroutine operations and would require planned pauses in shaft sinking operations of from several hours to several days. The five tests include: (1) vertical coring; (2) lateral coring to confirm the adequacy of geologic and hydrologic conditions before constructing breakouts at the 160-m (520-ft) level, at the 370-m (1200-ft) level, and at the shaft bottom at 450 m (1480 ft); (3) overcore drilling to measure in-situ stress conditions; (4) the breakout room tests that would be performed to assess constructibility and stability of repository-sized drifts; and (5) shaft convergence tests between the 160-m (520-ft) and 370-m (1200-ft) breakouts.

Fifteen in-situ-phase tests are currently planned. These tests would begin after the shaft has been completed to the required depth. Most of the in-situ tests would be at the 370-m (1200-ft) level. The in-situ-phase tests can be grouped by the categories of site information that would be obtained. Geologic information on fracture frequency and orientation would be obtained by mapping the walls of the drifts in the testing area. Lateral coring would provide geologic information on the continuity and structure of the proposed host rock. Hydrologic data would be obtained from permeability and infiltration tests both in the Topopah Spring Member and in the underlying tuffaceous beds of Calico Hills. Geochemical tests would investigate the potential for retardation of radionuclide movement by various physical and chemical sorption processes. Geomechanical tests are planned that would simulate the effects of temperature increases on the host rock caused by heat from radioactive decay of emplaced waste. Tests are also planned to assess the stability of mined openings and to make other in-situ measurements required to design a safe repository. A final category of tests is planned that would investigate the physical and chemical characteristics of the emplacement environment to provide information necessary for proper design of waste canisters and engineered barriers.

4.1.2.5 Final disposition

The Nuclear Waste Policy Act (NWPA) (Section 113) requires that the site characterization plan for a candidate site contain provisions for the decontamination and decommissioning of the site. The current plans for site characterization at Yucca Mountain do not include the use of high-level radioactive waste; therefore, no decontamination of the site is expected to be required after site characterization. The final disposition of the exploratory shaft facility would depend upon whether or not Yucca Mountain is selected as a repository site. Potential Federal actions lead to the following three possible exploratory shaft dispositions:

1. The site-characterization program may show that Yucca Mountain is unsuitable for a radioactive waste repository. In this case, the exploratory shaft facility would be either decommissioned or preserved for other uses.

2. The site may be shown to be suitable, but the first repository may be built at another site. In this case, the exploratory shaft facility would not be decommissioned until a final decision was made as to whether or not the site is needed.

3. The site may be shown suitable and be selected for the first repository. The exploratory shaft facility would be incorporated into the repository design.

Because final decisions about techniques for shaft sealing may require data from site characterization, the following decommissioning strategies are only representative of those that might be implemented:

1. If an alternative use for the exploratory shaft facility is identified before decommissioning, a limited "standby decommissioning" would occur after site characterization. The utilities and ventilation system would be left in place and periodic maintenance would preserve the structural integrity of the facility. Adequate surface physical security would be retained to prevent unauthorized access and accidents.

2. A second strategy that would preserve the exploratory shaft facility for future use entails removing the utilities and any salvageable materials from the interior of the facility and welding steel covers over the openings to prevent accidents or unauthorized access. After reclamation and habitat restoration of the surface, the sealed facility would be marked to identify pertinent history and details of the excavation. This sealing option would require a minimum degree of security to protect the shafts from vandalism and accidents.

3. A third decommissioning strategy includes removing all utilities and salvageable material from the underground structure and closing both

shafts by backfilling with material removed during the initial excavation. Depending upon the backfill technique used, about 50 percent of the muck removed from the facility would be used for backfill. Horizontal and vertical boreholes in the exploratory shafts would be sealed with an appropriate cement-based grout as required. The composition of sealing grout and the need for it would be clarified during site characterization. After the closure of the shafts and of the restoration surface, a small concrete structure containing a marker would be installed that would detail the pertinent history and details of the excavation.

In the event that the Yucca Mountain site is eliminated from consideration as a potential repository site, decommissioning would begin as soon as possible after the decision. In addition to the shaft sealing previously described, decommissioning would include the removal of all buildings, fences, trailers, electrical distribution and communications equipment, explosives magazines, and standby electric generators either for reuse or salvage sale.

A variety of subsurface utilities such as the water supply line, water distribution and collection pipes, and electrical cables would be installed in conjunction with the construction of the exploratory shaft facility. The cost and environmental disturbance associated with the excavation and removal of these structures generally exceeds the cost and disturbance associated with leaving them buried in place. Consequently, if the site were to be abandoned, any portion of the structure that would extend above the ground would be cut off below grade, and the structures would be covered during the reclamation of the surface. Other subsurface structures would be backfilled and closed if no longer needed, using generally accepted procedures.

4.1.2.6 Standard operating practices that would minimize potential environmental damage

Reclamation and habitat restoration would follow the practices described in Section 4.1.1.5. In addition to these procedures, the sewage lagoon would be filled after complete evaporation, and the muck pile would be stabilized by reducing slope angles and applying either available topsoil or fill to encourage revegetation.

It is not likely that the 10 km (6.2 mi) of improved roads, which would be developed to provide access to the exploratory shaft site, would be reclaimed. Not only would restoration be more disruptive to the area than would abandoning the road, but future activities on the Nevada Test Site could benefit from the access provided by the improved roadways.

Other standard operating practices that would be implemented during site characterization include the following:

1. Containing of fluids and effluents generated during site characterization in either the muck pile or the sewage lagoon and establishing a muck leachate monitoring program.

2. Stockpiling of topsoil so that during later reclamation the seed bank and the beneficial soil microorganisms might be used advantageously.

3. Controlling slope angles to minimize erosion and to stabilize slopes.

4. Using scarification and microtopographic features to promote moisture retention on disturbed areas.

5. Siting borrow pits where the least damage would occur.

6. Avoiding sensitive biological species and habitats.

7. Minimizing dust by spraying with water, by using dust-binding agents, or by paving some roads.

8. Spacing of surface facilities and associated clearing of vegetation to reduce fire potential.

9. Conducting field studies before construction activities begin to identify and avoid Mojave fishhook cacti and desert tortoises.

10. Avoiding or salvaging archaeological sites and establishing a 50 m (160 ft) buffer zone around significant archaeological sites near construction locations. Restricting off-road travel and informing workers of policies regarding archaeological sites and of the penalties for unauthorized collection and excavation of these sites.

4.1.3 Other studies

Some ongoing activities, including both field and laboratory work, would be continued to support site characterization. These activities are perceived to have little or no potential for environmental impacts. Dry horizontal drilling techniques would be developed to provide that capability if it is required in the exploratory shaft. Studies would be conducted of paleohydrology, tectonics, seismicity, volcanism, ground motion induced by weapons testing, and field experiments would be conducted in the G-Tunnel facilities. Laboratory analyses of cores and water from boreholes would be conducted. Repository sealing technology developed in the laboratory would be tested in the field. Each of these studies are discussed in more detail in the following paragraphs.

4.1.3.1 Geodetic surveys

Geodetic surveys to monitor any tectonic movements that may occur in the Yucca Mountain area began in 1983 and would be continued during site characterization. The surveys use a 70-km (44-mi) level line that extends from the southwest corner of Crater Flat at U.S. Highway 95 along existing roads in Crater Flat, and crosses Yucca Mountain, Jackass Flats, and Skull Mountain, and finally ends in Rock Valley. In addition, a quadrilateral network has been installed across selected faults on Yucca Mountain. Both the installation of bench marks and the initial survey were completed in June 1983. A resurvey was made near the end of 1983, and yearly resurveys will be made to measure changes, if any, of the earth's crust in this area. Wherever possible, the required bench marks were installed along existing roadways. However, some were installed where no roads existed. Access to these bench marks will require the use of either an off-road vehicle or a helicopter.

4.1.3.2 Horizontal core drilling

Experimental horizontal core drilling from the surface was conducted at Fran Ridge in 1983 to develop prototype dry-drilling techniques for use in the exploratory shaft. Surface core drilling at Fran Ridge required a bladed road for access; a drill pad, about 30 by 46 m (100 by 150 ft), for emplacement of the horizontal boring machines; and a smaller pad, 18 by 6 m (60 by 20 ft), for electrical power generators. Additional prototype drilling activities may be conducted during site characterization.

4.1.3.3 Paleohydrology studies

Potential future changes in the regional ground-water system are being estimated based upon studies of past climates. These studies include investigation of the paleohydrology of the Amargosa Desert, coring of lake sediments in southern Nevada; and description of the late Quaternary climates based upon fossilized packrat middens. It is expected that these studies would continue during site characterization.

4.1.3.4 Tectonics, seismicity, and volcanism studies

The potential for faulting, earthquakes, volcanic activity, and accelerated erosion in the Yucca Mountain area is being assessed. These studies include investigating the rate, intensity, and distribution of faulting, monitoring and interpreting present seismicity, studying the history of volcanism, and evaluating past rates of erosion and deposition. Volcanic and tectonic studies focus on the history of Pliocene and Pleistocene activity within the southern Great Basin and particularly, the Yucca Mountain site. These studies use data from boreholes, trenches, mapping activities, geophysical surveys, and seismic-monitoring stations, and they would be continued during site characterization.

4.1.3.5 Weapons-test seismic studies

The purpose of the weapons-test seismic investigations is to measure the ground motion at Yucca Mountain caused by underground nuclear explosions at the Nevada Test Site. These investigations relate ground motion at Yucca Mountain to such parameters as the distance to the explosion site, the depth of burial, and the yield of the explosion. Measurements are made in boreholes and on the surface at Yucca Mountain. These investigations may be continued during site characterization.

4.1.3.6 Field experiments in G-Tunnel facilities

In-situ physical and mechanical properties of tuffaceous rocks similar to those at Yucca Mountain are currently being measured under simulated repository conditions in G-Tunnel, which is an existing test facility at the Nevada Test Site. G-Tunnel is being used for preliminary investigations because it is in a layer of welded tuff that has thermal and mechanical properties that are similar to some of the welded tuffs at Yucca Mountain. The completed and ongoing tests include small-diameter heater tests and a heated block experiment. The purpose of these experiments is to measure thermal and mechanical behavior of welded tuff in situ. Predictions can then be made of the rock's response to heat imposed during radioactive waste storage. The heated block experiment used an in-situ, 2-m (6-ft) square block of welded tuff bounded by vertical slots. Both stress and thermal loads were imposed on the block to achieve combinations of stress and temperature for evaluating the deformation, thermal conductivity, thermal expansion, and fracture permeability. Moisture changes within the block were examined with piezometers, ultrasonic instruments, and a neutron probe. These tests provide valuable experience for developing instrumentation and field techniques that can be used for in-situ testing during site characterization.

4.1.3.7 Laboratory studies

Laboratory activities necessary to characterize the tuff at Yucca Mountain include studies in geochemistry, mineralogy and petrology, mineral stability, and geochronology. In addition, development of shaft and borehole sealing methods are being conducted in the laboratory. Most of the laboratory work for site characterization and technology development would be done using existing offsite facilities and equipment. No new offsite buildings or facilities would be required.

4.2 EXPECTED EFFECTS OF SITE CHARACTERIZATION

The effects that might result from the site-characterization activities described in Section 4.1 have been divided into two categories: the effects on the physical environment and the effects on socioeconomic and transportation conditions. Both positive and negative effects have been considered. A brief discussion of resource commitments has also been provided and the activities and environmental effects have been summarized.

4.2.1 Expected effects on the environment

The expected effects of site-characterization activities on the environment include localized effects on geologic and hydrologic conditions, land use, surface soils, ecosystems, air quality, noise levels, aesthetic quality, and cultural, historical, and archaeological resources.

4.2.1.1 Geology, hydrology, land use, and surface soils

Geology

The activities scheduled for site characterization would have a negligible effect on the geology of Yucca Mountain. Rock would be removed physically during excavation of the exploratory shaft facility, and from several boreholes. Only minor spalling is expected to occur along the insides of these openings (see the discussion of rock-characteristics guidelines in Chapter 6). On the basis of the information now available, there are no site-characterization activities scheduled that would significantly impact the geology of the Yucca Mountain site.

Hydrology

There are no perennial sources of surface water at Yucca Mountain. However, heavy precipitation may form ephemeral pools which are commonly known as catch basins. Fugitive dust and other air emissions may adversely affect the quality of the water trapped in these basins. Catch basins are the only sources of water for wildlife at Yucca Mountain. None of the runoff from the mountain is used by humans for any purpose.

Heavy rains can cause locally accelerated erosion and gullying of dirt roads, especially on steep slopes. Proper engineering designs of new access roads and other facilities would be used to minimize accelerated erosion and gullying to the extent possible. A significant increase in erosion is not expected.

The water table is about 535 m (1765 ft) below the surface at the exploratory shaft location, and it is about 85 m (280 ft) below the bottom of the proposed exploratory shaft. The water table would not be significantly affected by the exploratory shaft. However, hydrologic exploratory boreholes would be drilled through the water table so that the water table could be mapped. These wells would be capped and sealed after completion of ground-water studies. Ground-water withdrawals for construction and operation activities during site characterization are not expected to impact the ground-water system. The planned site-characterization activities would not significantly impact the hydrologic conditions at Yucca Mountain.

Land use

The Yucca Mountain site is located entirely on Federally controlled lands that are not being actively used, and there is no plan for either private or public use of the lands during the time proposed for site characterization. The Department of the Air Force uses the airspace over Yucca Mountain to support occasional tactical air missions into and out of the Nellis Air Force Range (NAFR). The proposed site-characterization activities will not interfere with use of the airspace; therefore, no land use impacts are predicted.

Surface soils

Most field activities to be conducted during site characterization would occur within 8 km (5 mi) of the Yucca Mountain site, and only a small portion of this area would be disrupted. The soils would be disturbed during site preparation for boreholes, for the exploratory shaft facility, and during construction of access roads and surface facilities. Assuming construction of 20 borehole drilling access roads, each 8 km (5 mi) long and 15 m (50 ft) wide, a total of 246 ha (606 acres) of surface soils may be disturbed. Each of the 20 borehole drilling pads with its associated facilities and equipment may disturb an additional 1 ha (2.5 acres), for a total of 20 ha (50 acres). An estimated 8 ha (20 acres) of soil would be cleared and graded in preparation for construction of the exploratory shaft facilities. The above activities would disrupt a total of approximately 280 ha (700 acres) of surface soils. In addition, geophysical and geodetic surveys and geologic mapping would disturb an additional acreage, about 10 ha (25 acres), in the Yucca Mountain area from off-road driving, constructing small drill pads, clearing and grading areas for geophysical studies, and trenching for fault studies.

Removal and compaction of soils during site-characterization activities would disrupt the existing physical, chemical, and biotic soil processes. Disturbing the soil would temporarily accelerate wind and water erosion, although engineering measures can minimize these potential impacts to some extent. Reclamation of these disturbed lands would be undertaken; the effectiveness of reclamation in arid environments is being studied. The acreage that potentially would be disturbed is relatively small compared with the tens of thousands of acres of relatively undisturbed desert land surrounding the Yucca Mountain site.

4.2.1.2 Ecosystems

The major impact associated with site-characterization activities would be the removal of habitat. Drill pads, roads, utility lines, trenches, seismic lines, and off-road driving would result either in removal or compaction of soils and destruction of vegetation that subsequently would displace animals.

Approximately 280 ha (700 acres) of habitat would be disturbed throughout the study area. Wildlife displaced from activity areas because of noise and movement of heavy equipment would probably return to the area after the activity ceases.

As a standard operating practice, before beginning any activity that would disturb an area, field surveys would be conducted to assess impacts and to assure protection of the desert tortoise and the Mojave fishhook cactus. Construction activities would be sited to avoid populations of the cactus and desert tortoise when possible. When found, tortoises would be relocated from activity sites.

Wildlife may be adversely affected by the destruction or contamination of ephemeral water in natural catch basins. Physical destruction of catch basins could occur during construction and the water could be adversely affected by fugitive dust and other air emissions. Surrounding vegetation may be adversely affected if fluids escape from the bermed muck pile.

Increased human activity could contribute to an increased potential for range fires during site-characterization activities. The vegetation associations that are dominated by black brush are commonly considered to present the greatest fire hazard. In wet years, the annual grass (desert brome) also is a hazard. Range fires can be ignited by catalytic converters on off-road vehicles, especially in stands of dry grasses. Fire hazard would be reduced by spacing buildings, removing vegetation in work areas, and controlling off-road driving.

4.2.1.3 Air quality

Site-characterization activities would generate particulate and fossil-fuel combustion-related emissions. Particulates would be generated by drilling, blasting, muck removal and stockpiling, batch concrete plant operation, surface leveling, wind erosion, and traveling over unpaved roads. The main fossil-fuel combustion emissions would be from diesel-powered equipment. These emissions would consist of carbon monoxide (CO), nitrogen oxides (NO_x), particulates (TSP), and hydrocarbons (HC).

Fugitive particulate emissions and dust vented from mining and drilling operations are expected to have the greatest effect on the existing air quality. Regulations established to limit such emissions and their resultant concentration in the atmosphere (Chapter 5) would define the allowable impact of these particulate emissions. However, because of the uncertainties of exploratory shaft emissions at this time, no estimation of these emissions or the resultant air quality impact has been made.

Yucca Mountain is in an area where the existing air quality is considered to be better than State and Federal ambient air quality standards. As such, site-characterization activities may be subject to review under the Nevada Prevention of Significant Deterioration (PSD) regulations. Because the applicability of PSD regulations is based in part on emissions, however, a PSD determination cannot be made at this time. If applicable, PSD review would include an evaluation of project pollutant control strategies, and would limit project-related impacts to small incremental increases over existing pollutant concentrations. If project-related impacts are shown to exceed the applicable increments (e.g., through atmospheric dispersion modeling), then more stringent control methods than originally proposed could be required. Such controls (using particulate emissions as an example) might include enclosed conveyors, baghouse filters at conveyor transfer points, more frequent watering of unpaved roads, soil-stabilization chemicals, etc. In the case that PSD regulations did not apply, project impacts would be evauated against National and Nevada Ambient Air Quality Standards (see Chapter 5). These standards are absolute (project plus background) values that are not to be exceeded in areas where the general public has access.

In either case, compliance with these standards probably would be determined from atmospheric dispersion modeling. The meteorological data collected in the vicinity of the site and source and emission data (when available) would be used in this effort.

4.2.1.4 Noise

Wildlife is the only sensitive noise receptor in the vicinity of site-characterization activities. The effects of noise on wildlife are speculative. Laboratory experiments have shown both temporary and permanent physical and behavioral effects at levels in the 75 dBA to 95 dBA range (EPA, 1971; Ames, 1978; Brattstrom and Bondello, 1983). For purposes of this analysis, 75 dBA is assumed to be the level at which wildlife could be affected.

The construction of surface facilities in Coyote Wash would produce the maximum sustained noise levels associated with site-characterization activities. Other site-characterization activities would not contribute significantly to these noise levels because of their small magnitude and location. Construction techniques have yet to be specified. Therefore, it has been assumed that construction equipment requirements would be similar to the construction of other large facilities. Maximum instantaneous noise levels attributed to each piece of construction equipment assumed are listed in Table 4-1. This table also contains the resultant average noise levels at 150 m (500 ft) from the focal point of construction activities. Because the resultant level at 150 m (500 ft) is based on the loudest instantaneous levels possible, the analysis is conservative. Furthermore, the analysis assumes that geometric divergence of the sound waves provides the only attenuation. Again, this represents a conservative analysis because it excludes possible attenuation due to absorption and barrier effects. Based upon the resultant noise level of 88 dBA at 150 m (500 ft), wildlife may be impacted within 0.6 km (0.4 mi) of the construction site.

4.2.1.5 Aesthetics

The two access roads from Fortymile Canyon to the top of Yucca Mountain can be seen from eastern Jackass Flats and Skull Mountain, both of which are on the Nevada Test Site. From the ground, the site-characterization activities would only be visible from the Nevada Test Site. They would not be visible

Table 4-1. Noise from construction of the exploratory shaft facilities

Equipment		Noise level at 15.2 m (50 ft) (dBA)
Type	Number	
Air compressors	1	81[b]
Backhoes	1	85[b]
Boring machines	1	98[b]
Bulldozers	1	80[a]
Concrete mixers	1	85[b]
Cranes	6	83[b]
Drill rigs	1	101[a]
Dump trucks	6	88[a]
Earth movers	6	78[a]
Front-end loaders	6	76[a]
Grader scrapers	1	88[b]
Gravel elevators	1	88[b]
Service vehicles	30	88[b]
Shovels	1	82[b]
Steam rollers	1	75[a]
Truck handling conveyor	1	88[b]

Resultant noise level at 150 m (500 ft): 88 dBA

[a] Source: Henningson, Durham and Richardson Sciences, 1980.
[b] Source: EPA, 1974.

from major population centers, public recreation areas, or public highways. However, the entire project area can be seen from the commercial airline flight path that follows U.S. Highway 95 south of the Nevada Test Site. Considering this limited public visual exposure, the visual impact would not be significant.

4.2.1.6 Archaeological, cultural, and historical resources

During a cultural resources reconnaissance of the Yucca Mountain Area, 178 prehistoric and 6 historic sites were identified (Pippin et al., 1982). Direct impact to these sites may occur during construction of the exploratory shaft facility, site preparation for borehole drilling, geophysical surveys, or other surface-disturbing activities. Physical disturbance of archaeological sites by site-characterization activities could result in the loss of data that are important to archaeological research. Indirect impacts are those that result from either unauthorized excavation or collection of artifacts and can result from improved access to the area. Nonscientific excavation or collection can limit or reduce the research value of the sites. For example, the removal of just a few chronologically or functionally sensitive artifacts can reduce or distort the cultural value of small sites.

Before activities begin, archaeological sites would be identified in affected areas. These sites would then be avoided when possible. As part of the standard operating practices, if a site cannot be avoided it would be salvaged and the findings would be documented so that the artifacts and important knowledge about the site would not be lost.

4.2.2 Socioeconomic and transportation conditions

Evaluation of the expected socioeconomic effects of site-characterization activities include considerations of the potential economic, demographic, community services, social, fiscal and governmental, and transportation impacts. For this analysis, the affected region is defined as the bicounty area of Nye and Clark counties (Figure 3-21). Most site-characterization activities would take place at the Yucca Mountain site in southern Nye County, which is about 160 km (100 mi) by road from the Las Vegas urban area. Some other Nevada Nuclear Waste Storage Investigations (NNWSI) Project activities would take place in the Las Vegas area, including work that would be performed at the existing DOE offices in Las Vegas.

The social and economic impacts of site characterization are expected to be small and insignificant with the possible exception of the fiscal effect of State and local participation in the repository-related planning processes. Actions that would mitigate this potential effect are specified in the Nuclear Waste Policy Act.

4.2.2.1 Economic conditions

The assessment of the effect on economic conditions in the region is based upon an evaluation of site-characterization employment and materials requirements and related population effects. As described below, this effect is considered positive but insignificant.

Employment

Direct labor requirements for site characterization consist of onsite and offsite workers. Most offsite workers would be located at the DOE and contractor offices in the Las Vegas area. Other offsite workers include employees of national research organizations, such as the national laboratories, who would conduct brief visits to the area.

Table 4-2 shows the anticipated number of onsite and offsite workers directly required for site characterization. The table also indicates the level of indirect support employment that is likely to be associated with that direct employment. Indirect employment is a result of the services requirements of the direct employees and their families. The peak total site-characterization employment is estimated to be about 690 jobs. This represents about 0.20 percent of projected 1985 Nye and Clark County employment (Tables 3-12 and 3-13). Therefore, the employment impact of site characterization is considered to be insignificant.

It is estimated that about 60 percent of the direct work force shown in Table 4-2 would consist of individuals who are currently employed on DOE activities related to the NNWSI Project. Accordingly, only about 40 percent of the 273 workers employed during the peak employment period, or 109 workers, would represent new NNWSI Project employees. Using a multiplier of 1.54, the indirect employment effect would be about 168 jobs or a total of about 277 new jobs in Southern Nevada over the first two years of site characterization. This same increase could occur over a period as brief as six months under alternative budgetary scenarios being considered by the DOE. In either case, the employment impact would be positive and insignificant.

Materials

Most of the materials used in site characterization would be required to construct the exploratory shaft facility. Table 4-3 displays the estimated material requirements for the exploratory shaft facility. A substantial portion of these materials would be procured through contractors located in southern Nevada. Materials not available in southern Nevada would ultimately be obtained from outside the bicounty region. This includes most nonlabor resources, with the exception of fuel and power (McBrien and Jones, 1984).

Table 4-2. Peak regional employment effects of site characterization

Category of employment	Surface construction (3/85-8/85)	Subsurface construction and testing (8/85-6/87)	Testing only (6/87-7/89)
Direct			
Onsite	72	147[a]	96
Offsite	126	126	126
Total direct	198	273	222
Total indirect	305	420	342
Total direct and indirect	503	693	564

[a] Includes construction of the secondary egress shaft with a maximum of 9 employees, for a period estimated to be between three and four months (see Section 4.1.2).

Table 4-3. Resources committed to the exploratory shaft facility[a]

Resource	Surface construction	Shaft[b] construction	Drift construction and testing	Decommissioning
Energy				
Gasoline, l (gal)	3.8×10^5 (1.0×10^5)	3.8×10^5 (1.0×10^5)	15.2×10^5 (4.0×10^5)	3.8×10^5 (1.0×10^5)
Diesel fuel, l (gal)	9.0×10^5 (2.4×10^5)	4.9×10^5 (1.3×10^5)	4.5×10^5 (1.2×10^5)	4.5×10^5 (1.2×10^5
Electricity, MWh	140	4,500	14,000	140
Explosives, kg (lb)		3.9×10^4 (8.7×10^4)	2.2×10^4 (4.8×10^4)	
Materials				
Cement, kg (lb)	6.0×10^4 (1.3×10^5)	7.7×10^5 (1.7×10^6)		
Steel, kg (lb)	1.4×10^4 (3.0×10^4)	5.1×10^5 (11.2×10^5)		
Copper wire, kg (lb)	3.6×10^4 (8.0×10^4)	2.7×10^3 (6.0×10^3)		
Wood power poles, each	100			

[a] For calculating transportation effects in Section 4.2.2.5, the following assumptions were used:

1. Concrete: 11.5 m^3/truck; 23 m^3/railcar.
2. Structural steel: 18 metric tons/truck; 90 metric tons/railcar.
3. Fuel: 56,800 l/truck; 11,400 l/railcar.
4. Explosives: 6800 kg/truck.
5. Copper wire: 7300 kg/truck.
6. Wood poles: 100 per truck.

[b] Includes secondary egress shaft.

4.2.2.2 Population density and distribution

The estimated maximum population impact (worst case) of site-characterization activities would be to increase the bicounty population by 2000 residents, assuming that onsite and offsite employees would bring an average of 1.28 dependents and related indirect workers would bring an average of 2.47 dependents (McBrien and Jones, 1984). This is about 0.4 percent of the 1983 population of that area. Thus, the population impact is considered to be insignificant. Furthermore, because 60 percent of the workers that are required to conduct site-characterization activities are already either directly or indirectly employed on other DOE activities in the same area, the actual population increase due to site-characterization activities is expected to be only about 830 residents.

4.2.2.3 Community services

Effects on community services would result from significant changes in the service-area population. However, because no significant population changes are projected, no effects on community services are expected to result from site characterization.

4.2.2.4 Social conditions

Effects on social conditions can be caused by significant changes in population. Because no significant changes in either regional or local population levels would accompany Yucca Mountain site-characterization activities, the social impacts that are often associated with changes in community population levels would not occur. However, some social effects may result from an increase in the public's awareness of the NNWSI Project. This might result if a decision to select Yucca Mountain for site characterization were to create an increased local and regional controversy and dissent over the prospect of a high-level radioactive waste repository at Yucca Mountain. The effects might include changes in social organization that are associated with the formation of opposition and/or support groups, disputes within existing groups, and a focused attention on repository-related issues.

4.2.2.5 Fiscal and governmental structure

Effects on fiscal and government structure are related to employment, population, community services, and State and local government agency participation in site-characterization activities. Site-characterization activities at Yucca Mountain are not expected to have a significant effect either on regional and local employment or on population and community services. Therefore, no significant fiscal impacts are anticipated from either population or employment effects of site characterization. While the social effects of any changes in the level of controversy surrounding the NNWSI Project may affect the political organization and potentially the governmental structure of the area, such effects are expected to be insignificant.

A potentially significant effect of recommending Yucca Mountain for site characterization would be an increase in State and local participation in planning activities. The Nuclear Waste Policy Act explicitly recognizes the fiscal implications of State participation and provides a mechanism for financial assistance for the following purposes:

1. To review DOE activities undertaken to assess the potential social, public health and safety, and environmental impacts of a repository.
2. To develop a request for assistance to alleviate impacts associated with the development of a repository.
3. To engage in any monitoring, testing, or evaluation activities with respect to site-characterization programs.
4. To provide information to State residents about State and Federal actions concerning the potential repository.
5. To request information from, and to make comments and recommendations to, the Secretary of Energy regarding the siting of a repository.

4.2.2.6 Transportation

During site characterization, transportation effects would be concentrated along U.S. Highway 95 as workers and materials are transported to and from the site. Table 4-2 indicates that the maximum work force onsite is approximately 147 people. As stated in Section 4.2.2.1, about 60 percent of these workers currently are employed by the NNWSI Project. Therefore, little additional traffic is anticipated. Assuming a worst case in which each new worker would drive a private automobile, the resulting increment of approximately 60 vehicles during the evening peak hour from 5 P.M. to 6 P.M. would not cause the service levels to change on any segment of U.S. Highway 95.

The transportation of materials would occur during all phases of site characterization. Material requirements and time frames were listed in Table 4-3. The per-shipment quantities noted in Table 4-3, suggest that the maximum amount of daily shipments are expected to occur during exploratory shaft facility construction. Assuming 250 work days per year, approximately one truck shipment per day would be required. Peak shipments may require several additional trucks per day. This would not present any adverse effects on any part of U.S. Highway 95.

4.2.3 Irreversible and irretrievable commitment of resources

Most of the resources that would be committed to site characterization would be devoted to the exploratory-shaft facility. Therefore, this section will focus on resources committed to construction and operation of this facility (Table 4-3). The quantities listed in Table 4-3 are estimates. Items such as gasoline consumption are not customarily included as part of engineering construction design studies. The estimates in Table 4-3 were therefore obtained by consulting several experienced engineers, and these estimates may change as additional information becomes available. No adverse effects are expected to result from the commitment of these resources.

4.2.4 Summary of environmental effects

A summary of the characterization activities and their potential impacts is shown in Table 4-4. The table lists the activities and their impact-causing components, standard operating practices to minimize environmental effects, and the potential environmental impacts that could remain after standard operating practices have been implemented.

Land-surface disturbance would result in the most widespread and lasting impact on the physical environment. There would be virtually no aesthetic, surface-water, or ground-water impacts. Air quality impacts would be greatest for particulates (dust). Increased noise levels may disturb wildlife; noise impacts to humans are not expected. Wind and water erosion of disturbed soil would occur locally and would result in an insignificant loss of wildlife habitat. Impacts on protected species are possible but unlikely. Two species would be protected because they have been under review for listing as threatened and endangered species by the U.S. Fish and Wildlife Service. The Mojave fishhook cactus would be avoided where possible. Desert tortoises would be avoided, or they would be removed to a safe location. Tortoise burrows would be avoided where possible.

Much of the project area has been surveyed for archaeological sites, and the potentially significant sites that are threatened by either direct or indirect impact would be protected or salvaged. No significant socioeconomic or transportation impacts are expected.

Restoration of the disturbed areas would require recontouring and either ripping or disking. Topsoil would be added where necessary. The surface soil would be prepared to reduce water erosion and to facilitate revegetation.

Table 4-4. Standard operating practices for, and resultant impacts from, site characterization activities

Activity	Standard operating practices	Potential resultant impacts[a]
BOREHOLE DRILLING		
Clearing, cutting, and filling about 160 km (100 mi) of access roads (about 246 ha or 606 acres): roadbed, borrow pit, and cuts	• Perform preconstruction biological surveys for species of concern and archaeological surveys with site protection/salvage. Contain effluent, stockpile topsoil, suppress construction dust with water	• Contour change, topsoil loss, soil compaction, drilling mud residue, vegetation and burrowing wildlife destruction, increased erosion and sedimentation, engine exhausts, dust, possible loss of in-situ archaeological sites, accidental fire, water use, and noise
Disturbing about 20 ha (50 acres) for drilling sites to consist of: drill pad, mudpit, borrow area, staging area, and parking area. Traveling on unpaved roads	• When access is no longer required, rip or disk road surface, recontour to minimize erosion, reestablish natural drainage, and blend with natural landforms. Close and seal borehole, empty and fill in mudpit, regrade and contour drill pad, rip or disk disturbed surfaces to minimize erosion and enhance revegetation. Remove drill pad concrete, debris and drilling mud residue to NTS landfill. Distribute stockpiled topsoil over disturbed soil. Perform additional restoration, as appropriate	
GEOPHYSICAL SURVEYS		
Off-road driving, clearing of survey lines, shot-hole pad construction, clearing staging areas, seismic lines	• Before and during surveys: avoid sensitive biologic species and habitats and archaeologic sites identified in preactivity surveys. Enforce restriction on off road driving	• Erosion and gullying of off road vehicle trails, soil compaction of seismic lines, some vegetation loss, and accidental fire

Table 4-4. Standard operating practices for, and resultant impacts from, site characterization activities (continued)

Activity	Standard operating practices	Potential resultant impacts[a]
	• After survey completion: rip or disk vehicle trails, seismic lines, cleared areas, and pads. Perform additional restoration as appropriate	
GEOLOGICAL MAPPING		
Off-road vehicle driving, trenching, storing of trench material	• During mapping, same as for geophysical surveys • After completion of mapping, fill in trench, contour surface. Perform additional restoration as appropriate	• Soil excavation; mixing of topsoil and subsoil; destruction of vegetation in access trail, trench, and trench storage area; erosion and gullying of off-road trails; and accidental fire
ROCK MECHANICS FIELD EXPERIMENTS		
Excavating short drifts in G tunnel, disposing of muck	• During experiments suppress dust with water, establish muck disposal area	• Dust, possible flooding of muck pile causing effluent plume
EXPLORATORY SHAFT		
Site preparation Grading, filling, leveling, paving, stabilizing three acre pad. Disturbing 8 ha (20 acres) for access roads, power lines, water line, 57,000 m^3 (2,000,000 ft^3) borrow area. Constructing sewage lagoon, muck pile, diversion channel, water tank	• Perform preconstruction biological and archaeological surveys; ensure no sensitive species or archaeological sites in area. Minimize area disturbed. Truck debris and trash to landfill. Stockpile topsoil from borrow area, control surface runoff, suppress dust with water, avoid driving over flammable vegetation	• Change of contour, loss of top soil, soil compaction, destruction of vegetation and burrowing animals, displacement of wildlife, dust, engine exhaust, construction debris, water use, and noise

Table 4-4. Standard operating practices for, and resultant impacts from, site characterization activities (continued)

Activity	Standard operating practices	Potential resultant impacts[a]
	• After decommissioning, remove paving and concrete pads, surface debris, dispose in NTS landfill. Break up stabilized pad and mix with underlying soil. Fill in sewage lagoon. Recontour site and regrade to reduce erosion and enhance moisture retention. Distribute topsoil. Perform additional habitat restoration as appropriate	
Surface facility construction Installing concrete pads and foundations, erecting buildings and installing trailers, water tank, electrical substation, fans, compressors, fence, utilities revetments	• During construction, provide firebreak around site and building, replace topsoil on borrow area to start revegetation (see site preparation)	• Dust, accidental fire, engine exhaust, construction debris, water use, and noise
Exploratory shaft construction Mining out shaft and rooms, lining shaft and installing internals, installing head frame and structing muck pile, drilling exploratory boreholes	• During construction, suppress muck dust with water, cover zeolite muck pile (berm prevents dispersion on surface), monitor leachate and control further, if necessary, and truck construction and batch plant waste to landfill	• Muck dust, zeolite dust, blasting dust and gases, dewatering effluent, muck pile leaching, concrete batch plant dust and residue, construction debris, engine exhaust, water use, and noise

Table 4-4. Standard operating practices for, and resultant impacts from, site characterization activities (continued)

Activity	Standard operating practices	Potential resultant impacts[a]
<u>Secondary egress shaft construction</u> Establishing drilling pad, drilling pilot hole, mining 260 ft drift, upreaming shaft, lining shaft, installing hoist frame and house	• During construction, pneumatic drilling of pilot hole with a dust filtration system to reduce water usage and collect dust (see above three exploratory shaft categories)	• (See above three exploratory shaft categories except no blasting dust and gases)
<u>Exploratory shaft operation</u> Drilling in-situ test boreholes, traveling on unpaved roads	• During operation, dispose of drilling effluents on muck pile, truck trash and debris to NTS landfill, control fire on site, maintain sewage decomposition balance, control travel on unpaved roads	• Shaft effluent fluids, dust, operational trash and debris, accidental fire, engine exhaust, and noise
OTHER ACTIVITIES		
<u>Geodetic surveys, paleohydrology study, and weapons test seismic study</u> Off road driving	• Enforce restrictions on off road driving; use helicopter where appropriate	• Soil compaction and increased erosion potential
<u>Horizontal core drilling</u> Access road, drill pad, generator pad	• Same as for borehole drilling	• Same as for borehole drilling
<u>Tectonics, seismicity and volcanism study</u> Off-road driving, borehole drilling, trenching	• Same as for borehole drilling and geophysical surveys	• Same as for borehole drilling and geophysical surveys
<u>Laboratory studies</u>	• Not applicable since not in field	• None

Table 4-4. Standard operating practices for, and resultant impacts from, site characterization activities (continued)

Activity	Standard operating practices	Potential resultant impacts[a]
DECOMMISSIONING		
Final disposition of exploratory shaft (Strategy 3, Section 4.1.2.3) Removing internals, backfilling from muck pile, capping shaft; removing all buildings and equipment, water tank, utility stations, etc.	• During decommissioning, suppress dust from muck with water, truck debris to Nevada Test Site landfill • After decommissioning, same as for exploratory shaft site preparation	• Dust from backfilling, construction debris, engine exhaust, water use, and noise
Exploratory drill holes Either capping holes with a plate or seal with ground matching grout, installing markers	• Same as for final disposition of exploratory shaft	• Dust, engine exhaust, and noise

[a] Resultant impacts are the potential impacts that could remain after standard operating practices have been implemented.

4.3 ALTERNATIVE SITE-CHARACTERIZATION ACTIVITIES

At depth in-situ site characterization is mandated by the Nuclear Regulatory Commission (10 CFR 60, 1981). Therefore, alternatives to developing an exploratory shaft facility during site characterization have not been addressed. However, there are alternative methods to accomplish at depth in-situ site characterization. The major alternative is drilling (as opposed to mining) the exploratory shaft. Other alternatives include varying the number of boreholes and varying the size, number, and location of underground test facilities.

Some variations in the design of surface support facilities and in the degree of site disturbance would occur if the shaft were drilled. For example, preconstruction site disturbance for a drilled shaft would require sinking two confirmatory boreholes that would be used for geologic and hydrologic testing. Only one confirmatory hole would be required if the shaft were to be mined, and this would result in less surface disturbance. In addition, maintaining access to the additional borehole for future testing would reduce the area available to optimally site other surface support facilities.

Drilling of the exploratory shaft would require the inclusion of a lined mud pit in which to hold the cuttings and drilling fluid. The size of the mud pit would be constrained by the topography of the site. Therefore, it would be necessary to periodically dredge the mud pit by dragline or similar mechanical means and to transport the cuttings to a second lined pit located away from the immediate shaft vicinity.

During the drilling process, the shaft is partially filled with a drilling fluid consisting of water, clay, and polymer. This fluid provides hydrostatic support to the shaft wall, lubricates and cools the drill bits and reamers, and carries rock chips to the surface. These construction practices severely limit the ability to characterize the natural hydrologic setting of the unsaturated zone. The most important potential adverse impact of drilling would be potential alteration of existing in-situ moisture conditions due to introduced drilling fluids. Drilling the shaft would also preclude mapping the shaft wall which would be done if the mining technique is used.

In conclusion, the drilling alternative to shaft mining is not considered to be a viable alternative. Underground test facility alternatives would have either little or no impact on the environmental consequences of site characterization because most of the impacts would result from exploratory shaft construction and off-road driving.

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Chapter 5

REGIONAL AND LOCAL EFFECTS OF LOCATING A REPOSITORY AT YUCCA MOUNTAIN

If the Yucca Mountain site is recommended for site characterization, it could be found suitable for subsequent selection and development as a repository. A preliminary repository concepts report for Yucca Mountain has been completed (Jackson, 1984). Section 5.1 summarizes this design and constitutes a description of a proposed action for the subsequent sections, which assess the regional and local impacts of locating a repository at Yucca Mountain. Alternative repository designs have been proposed (DOE, 1984a; DOE 1984b; Sandia, 1984) which involve inclusion of temporary surface storage at the repository site, receipt of five-year old spent nuclear fuel elements, and repository construction and operation on a two-phase schedule that would be different than the schedule assumed in this chapter. Section 5.1.5 briefly describes the concept of the two-phase alternative and discusses possible impacts.

5.1 THE REPOSITORY

A repository consists of a surface facility, a subsurface facility, and a means of access from one to the other. An artist's rendition of a nuclear-waste repository is shown on Figure 5-1.

The function of a repository is the permanent isolation of spent fuel, of solidified high-level waste from reprocessing, and of other nuclear wastes associated with the commercial generation of nuclear power such as transuranic (TRU) waste. In addition, low-level waste generated at the repository from the handling of incoming wastes would also be emplaced in the repository. The total amount of waste to be emplaced at the repository is limited by the NWPA to the equivalent of 70,000 metric tons of uranium (MTU) until a second repository is in operation. Emplacement of 70,000 MTU is assumed for purposes of this analysis.

The Yucca Mountain site is located approximately 26 km (16 mi) due north of the town of Amargosa Valley. The surface facility would be along the eastern foothills of Yucca Mountain. The subsurface facility would be located approximately below the ridgeline of Yucca Mountain. The proposed highway and rail access routes to the site are shown on Figure 5-2. The proposed highway access would originate at U.S. Highway 95 approximately 1.0 km (0.5 mi) west of the town of Amargosa Valley and extend about 26 km (16 mi) northward to the site. The proposed rail line would originate at Dike Siding 18 km (11 mi) northeast of downtown Las Vegas and extend approximately 137 km (85 mi) to the site.

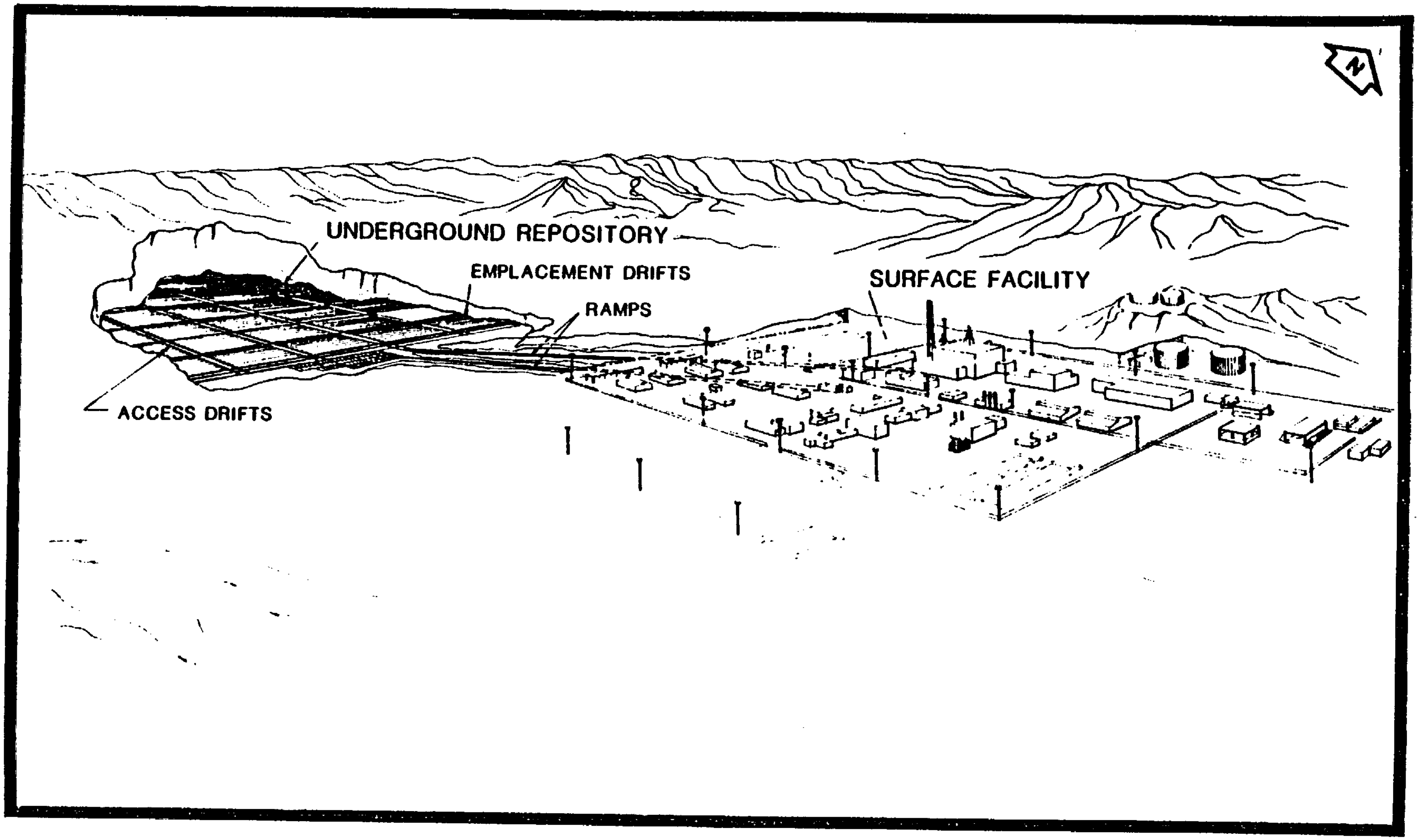

Figure 5-1. Artist's rendition of the proposed Yucca Mountain repository.

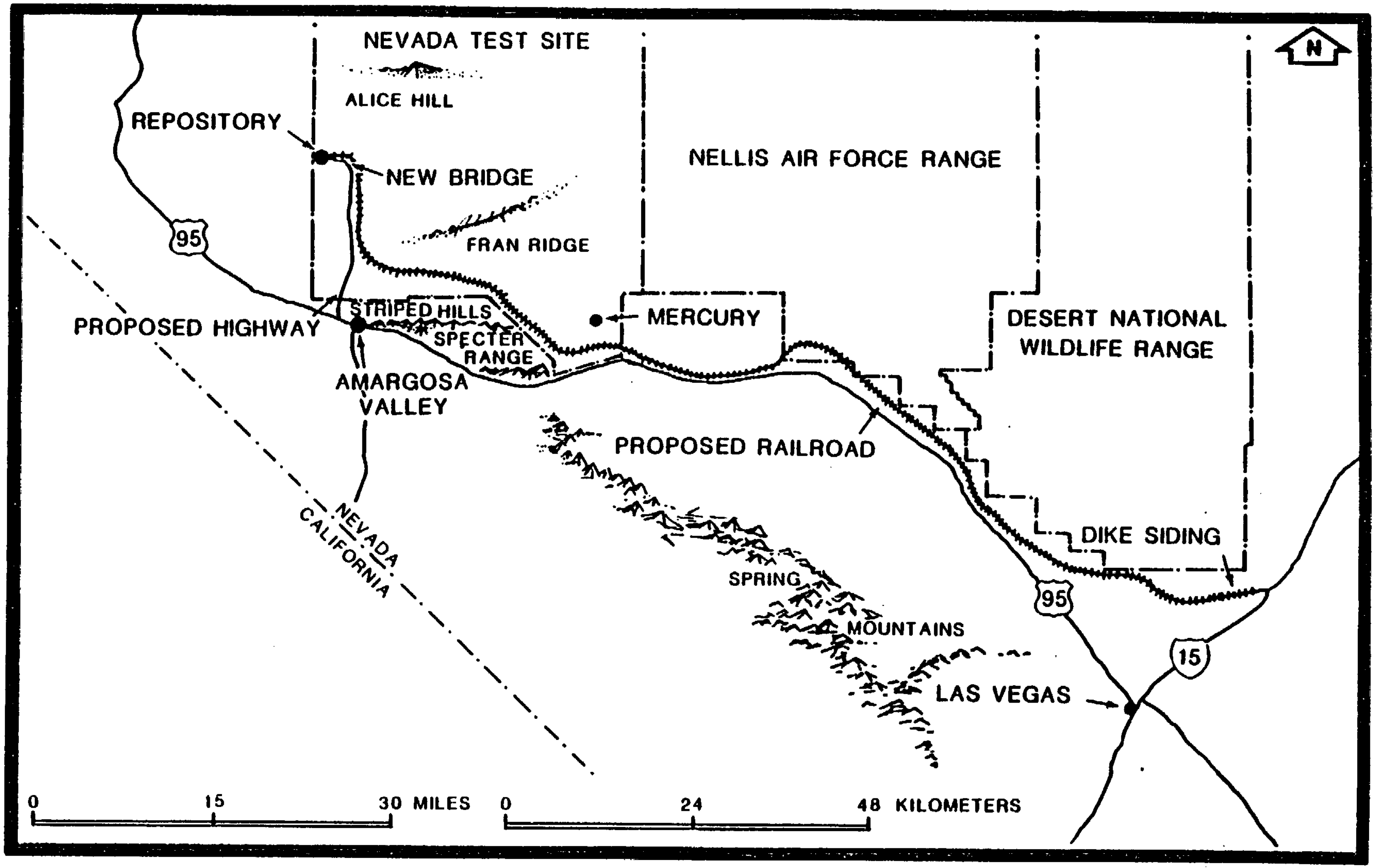

Figure 5-2. Proposed highway and rail access route to the Yucca Mountain repository.

Locating a repository at Yucca Mountain may result in regional and/or local impacts over a preclosure period of approximately 60 years. The preclosure period includes the construction, operation, retrievability, and decommissioning phases. Surface facilities would be constructed and some of the subsurface would be excavated during the 5-year construction phase. Nuclear waste would then be received and emplaced over the next 30 years during the operations phase. Excavation of subsurface facilities would continue in tandem with waste emplacement for the first 28 years of the operations phase. During the 20-year retrievability phase, the facilities as well as the surrounding environment would be monitored, and the surface and subsurface facilities would be maintained so that the emplaced wastes could be retrieved, if necessary. Although a decision to retrieve the emplaced wastes could be made at any time after wastes are emplaced, a 20-year retrievability phase is planned to ensure that the repository can be monitored for 50 years before decommissioning begins. If a decision to retrieve the waste were made during the last year of the retrievability phase, the lifetime of the project would be extended for up to 30 years. The repository would be decommissioned and closed during the 5-year decommissioning period. The following paragraphs describe the activities proposed during the construction, operation, retrievability, and decommissioning phases. The activities and design are based on preliminary repository concepts (Jackson, 1984) for Yucca Mountain; the preliminary nature of the design would suggest that changes should be expected.

5.1.1 Construction

Construction of the repository would include construction of utilities, buildings, and other structures on the surface, sinking of shafts and ramps to the subsurface, and the development of all underground areas. Most surface construction would occur at the main surface facility. Construction away from the main facility (other construction) would include construction of highways and railroad connections, mine ventilation buildings, and other ancillary facilities.

5.1.1.1 The surface facilities

The surface facilities at Yucca Mountain would encompass approximately 30 ha (75 acres) of land, all of which would be enclosed by a security fence. These facilities would be located along the gently sloping east side of Yucca Mountain, as shown on Figure 5-3.

The surface facilities would be used to conduct waste-handling, to support the underground operations, to handle mined material, and for general repository support services. The underlying material along the east side of Yucca Mountain is considered suitable for conventional foundations for construction of the surface facilities. A preliminary layout of the surface facilities at Yucca Mountain is shown on Figure 5-4.

The waste-handling and packaging facilities would include buildings and equipment that would receive and package all incoming wastes (see Section 5.1.2.2 for more details). A facility would also be constructed to process all

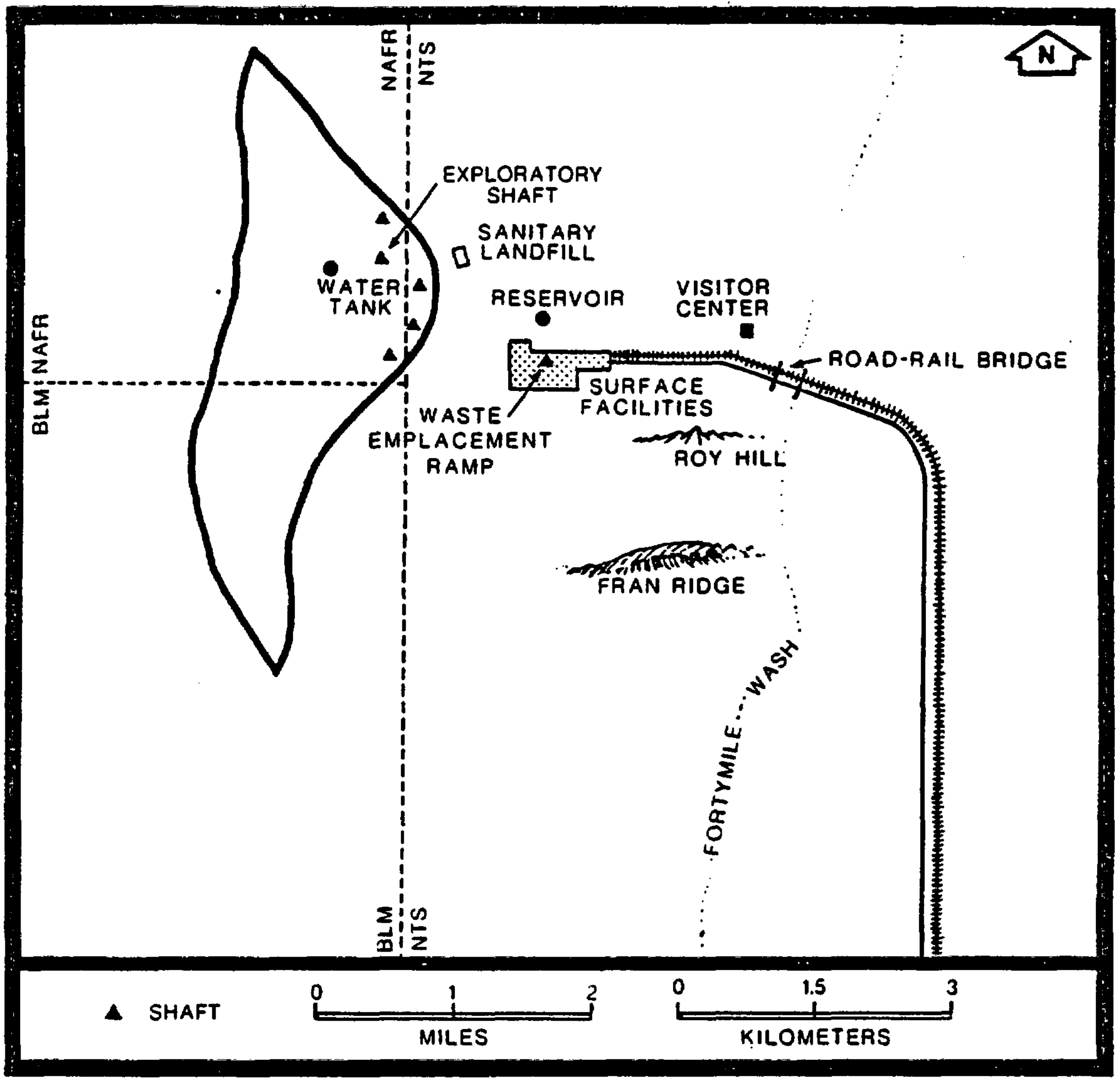

Figure 5-3. Location of surface facilities for the Yucca Mountain repository showing ramp and shaft locations. (Source: Jackson, 1984.)

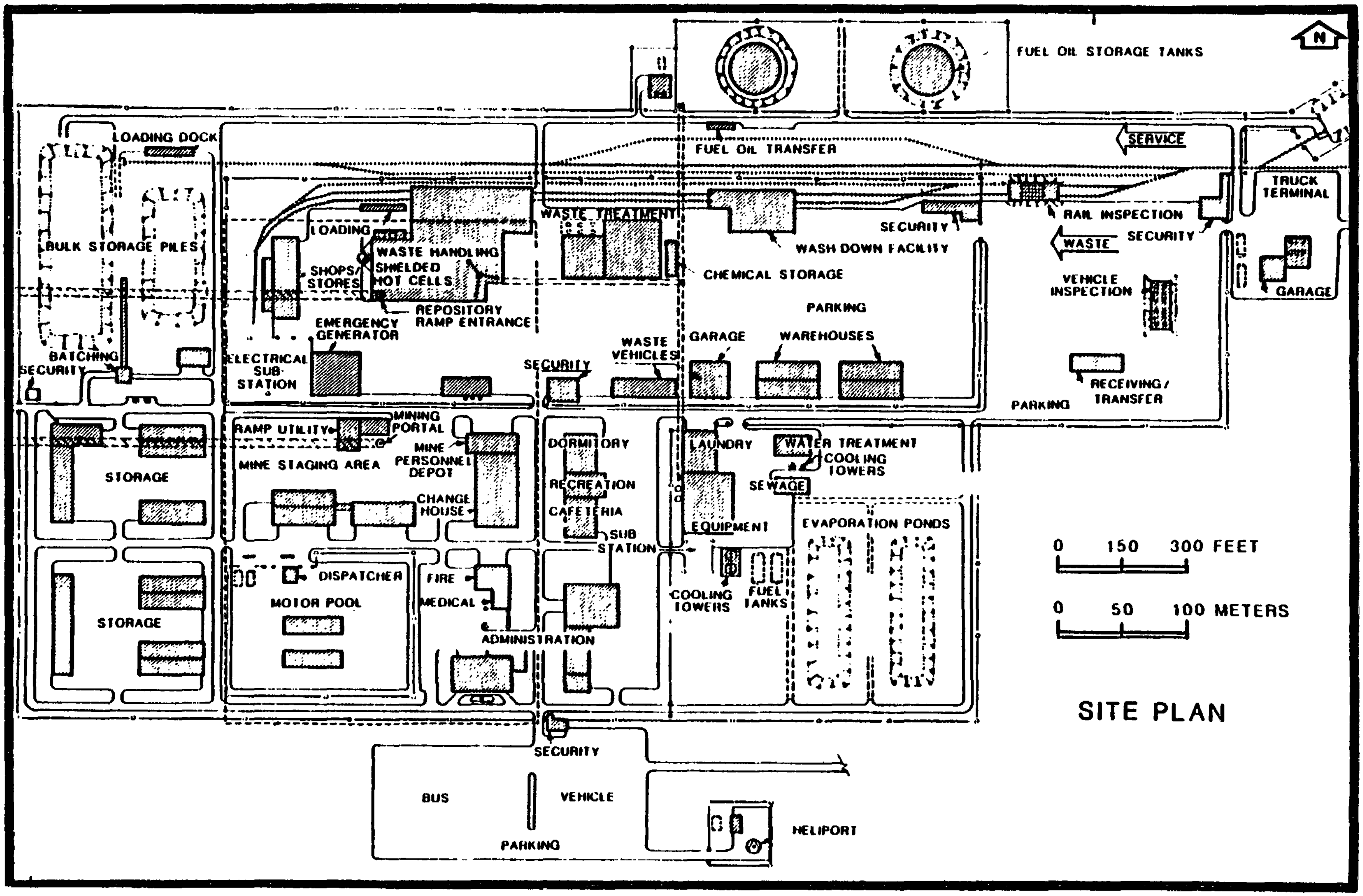

Figure 5-4. Preliminary site plan for the Yucca Mountain repository.

of the solid, liquid, and gaseous radioactive wastes that are produced onsite such as from protective clothing, decontamination streams, ventilation filters, etc. Similar, though smaller, facilities have been constructed elsewhere for remote handling activities, and the construction of these facilities at Yucca Mountain are not expected to present any technical difficulties.

Surface facilities in support of the underground operations include personnel change-rooms and showers as well as space to store mining equipment. Ventilation-supply shafts would also be constructed, and separate surface facilities would contain fans, filters, and other equipment needed for large-volume ventilation. Ventilation exhaust facilities would be located away from the main complex, and are described in Sections 5.1.1.2 and 5.1.1.4.

Surface facilities for receiving the rock that would be mined during construction of the underground openings include a surge bin for temporary storage and a conveyor system to move the crushed rock to the muck pile.

Facilities that would support the repository include buildings to house administrative, management, and engineering staff. Other support facilities would include a firehouse, a medical center, a training center, a computer center, a vehicle maintenance shop, a security building, a machine and sheet metal shop, and an electrical shop. Warehouses would be constructed to store bulk materials, equipment, spare parts, and supplies. Facilities for environmental and instrument laboratories would also be constructed.

Utilities which support the repository would include an electric power building with emergency electrical generating equipment. Electric transmission lines would be extended to Yucca Mountain from existing local utility lines. A new substation would be constructed at the site. Steam-generating equipment, compressor and chiller systems, and cooling towers with water treatment equipment would be included if needed. A system for treating and distributing potable water and for supplying a source of water for fighting fires would be required. Existing wells east of Yucca Mountain are expected to supply all the water required during construction and operation of the repository. A sewage treatment plant and evaporation ponds would also be constructed. Finally, fuel stations containing gasoline and diesel fuel would be required at the site.

5.1.1.2 Access to the subsurface

Two concepts for access to the subsurface at Yucca Mountain have been developed (Jackson, 1984). These concepts are as follows: (1) vertical shafts with appropriate hoisting mechanisms; or (2) gently sloping ramps through which wheeled vehicles are driven. Ramp access for waste transfer operations is the preferred concept and is assumed for the impact analyses in this chapter. Personnel, materials, and muck would be transported through either a shaft or a ramp. Ventilation intake and exhaust would occur through shafts.

Six openings for access to and from the emplacement horizon are included in the preliminary conceptual design (Figure 5-4). Table 5-1 lists these openings and indicates the opening size for each of two proposed emplacement methods. Future design studies will establish the number, function, type, and size of each opening.

Table 5-1. Subsurface access dimensions for vertical and horizontal waste emplacement[a]

Purpose of openings	Vertical emplacement	Horizontal emplacement
Men, materials, and muck		
Shaft diameter	7.6 m (25 ft)	6.1 m (20 ft)
Ramp height and width	4.6 m x 6.1 m (15 ft x 20 ft)	4.6 m x 6.1 m (15 ft x 20 ft)
Waste transfer ramp height and width	4.6 m x 6.1 m (15 ft x 20 ft)	4.6 m x 6.1 m (15 ft x 20 ft)
Ventilation intake shaft diameter	6.1 m (20 ft)	4.3 m (14 ft)
Ventilation exhaust shaft diameter	4.9 m (16 ft)	4.3 m (14 ft)
Mine development exhaust shaft diameter	4.9 m (16 ft)	3.0 m (10 ft)
Exploration shaft diameter	3.7 m (12 ft)	3.7 m (12 ft)

[a] Source: Jackson, 1984.

5.1.1.3 The subsurface facilities

The subsurface facilities would be located within Yucca Mountain, approximately one mile west of the proposed surface facilities location (Figure 5-4). This facility would encompass roughly 615 ha (1520 acres) of subsurface area. On the basis of the current understanding of the Yucca Mountain site, the repository horizon would be more than 200 m (650 ft) below the surface within the Topopah Springs Member of the Paintbrush Tuff. The water table in the vicinity of Yucca Mountain is approximately 200 to 400 m (650 to 1300 ft) below the level of the underground openings. Except for possible scattered pockets of perched water, the underground openings are expected to be dry. A profile of the subsurface facilities showing the ramp waste transfer configuration is shown on Figure 5-5.

The subsurface facilities consist of main access corridors to the emplacement areas, the emplacement drifts, and service areas near the shafts and ramps. The layout of the facilities is based upon the configuration of waste emplacement: either vertical or horizontal. For vertical emplacement, which is currently the preferred conceptual design, waste canisters are to be emplaced in vertical boreholes in the floors of the emplacement drifts. For horizontal emplacement, waste canisters are to be emplaced in horizontal boreholes in the drift pillars (walls).

Conceptual design work completed to date indicates that areal and geometric requirements, mine ventilation requirements, stability of the underground workings and retreivability considerations will be satisfied by conventional room and pillar mining techniques. Excavation may be conducted using either a drill-blast-mucking technique or a mobile mining machine.

An extraction ratio of 24 percent has been adopted for the vertical emplacement alternative (Dravo Engineers, Inc., 1984a). About 460 km (285 mi) of access corridors and emplacement drifts would be mined. Cross-sectional dimensions of these openings are listed in Table 5-2. The total amount of rock excavated for the facility would be about 7,878,400 m^3 (10,304,000 yd^3).

Table 5-2 to be supplied.

Table 5-2. Dimensions of underground openings for vertical and horizontal waste emplacement[a]

	Vertical Emplacement		Horizontal Emplacement	
Opening	Height	Width	Height	Width
Access corridors	3.7 m (12 ft)	6.1 m (20 ft)	3.7 m (12 ft)	6.1 m (20 ft)
Emplacement drifts	6.7 m (22 ft)	6.1 m (20 ft)	3.7 m (12 ft)	6.1 m (20 ft)

[a] Source: Jackson, 1984.Typed in text.

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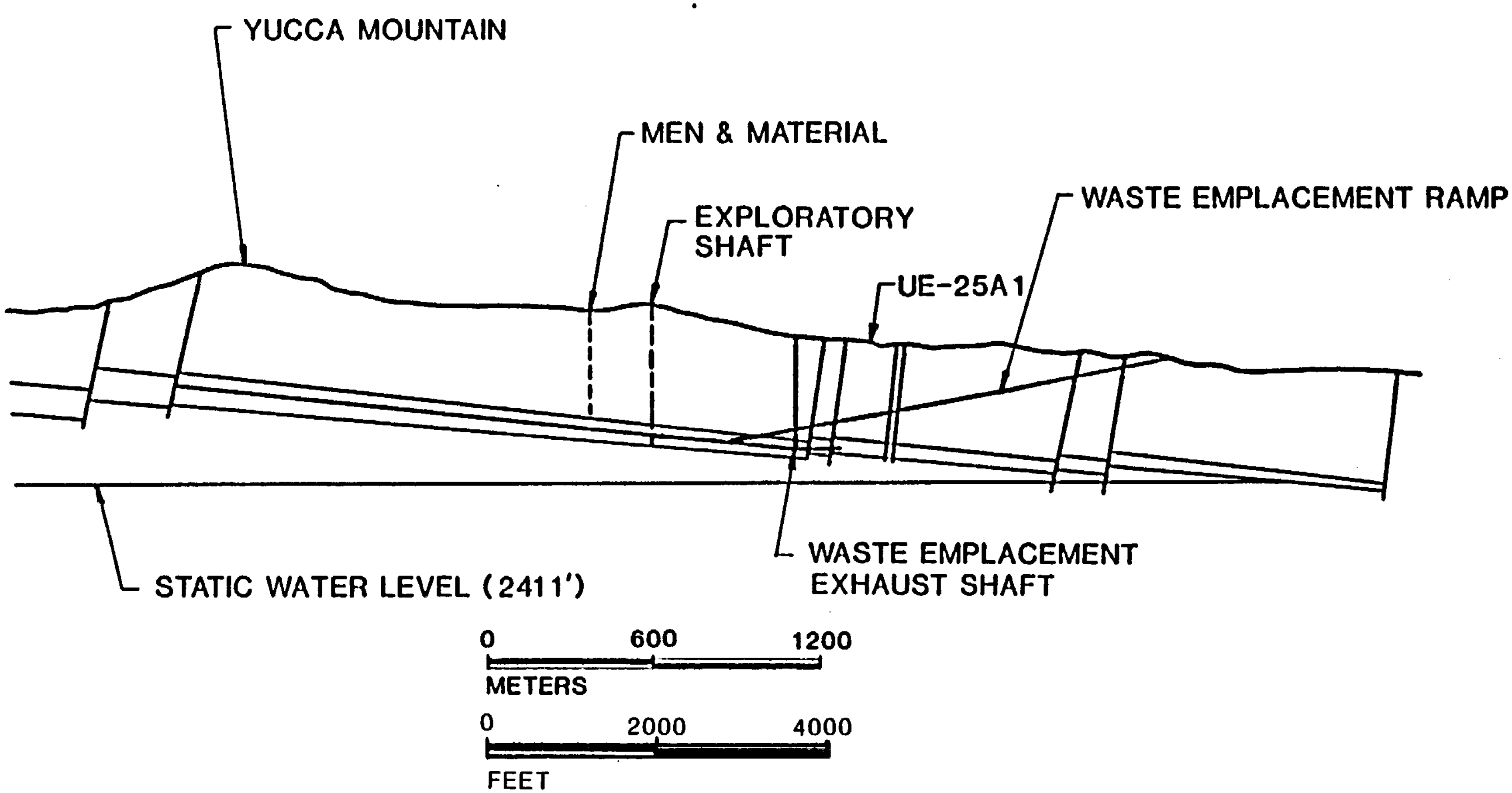

Figure 5-5. East-West Subsurface profile for the proposed Yucca Mountain Repository.

The subsurface layout for horizontal waste-emplacement requires considerably less excavation. With an extraction ratio of about 4.5 percent, about 133 km (40 mi) of corridors and drifts (Dravo Engineers, Inc., 1984a) would be mined. Table 5-2 lists the dimensions of the openings for horizontal waste-emplacement. Approximately 868,600 m^3 (1,136,000 yd^3) of rock would be excavated and stored on the site for the horizontal emplacement case.

Conventional mining equipment as well as machinery designed specifically to transport wastes to the emplacement locations would be required underground. The service areas required underground include medical facilities, warehouses, and maintenance areas.

The excavated rock would be stored on the surface at the site. Rock-storage piles would be constructed using conventional muck handling equipment, and dust would be suppressed with standard procedures such as water spray. Runoff from precipitation would be intercepted by dikes, ditches, and liquid-collection sumps. The present conceptual design does not require backfilling of the excavated access and emplacement drifts to maintain the structural integrity of the underground openings. If backfilling of a portion of the repository is required before closure and decommissioning, some of the excavated rock would be used for that purpose.

5.1.1.4 Other construction

Construction away from the main site would consist primarily of a highway connection from U.S. Highway 95, a rail line from Dike Siding, and facilities above each upcast shaft. The rail line would also require the construction of a railroad facility at Dike Siding and a bridge over Fortymile Wash. The highway connection leading northward from U.S. Highway 95 would also utilize a portion of the railroad bridge to traverse Fortymile Wash. Other areas of minor construction such as storage tanks, explosive material magazines, etc., would be required in the vicinity of the surface complex but at some distance outside of the fence. An additional 10 ha (25 acres) would be required for offsite structures, i.e., ventilation buildings, visitors center, landfill, and water tower.

Highway

A highway would be constructed between U.S. Highway 95 and the site for truck and automobile access (see Figure 5-2). The highway would originate approximately 1.0 km (0.5 mi) west of the town of Amargosa Valley. The road would be two lane, 9 m (30 ft) wide, 26 km (16 mi) long, and would be rated for 36 metric tons (80,000 lb) gross vehicle-weight trucks. Each roadway shoulder would be 2.5 m (8 ft) wide. The total required right-of-way would be about 15 m (50 ft), and the total land area needed would be about 36 ha (90 acres).

The highway would cross Fortymile Wash via a bridge. The preliminary repository concept calls for a single bridge carrying both highway and rail traffic, although construction of two separate bridges would be considered.

Railroad

For rail access to the site, a rail spur would be constructed from the Las Vegas area (see Figure 5-2). The rail line would originate in the vicinity of Dike Siding, approximately 18 km (11 mi) northeast of downtown Las Vegas. A railhead facility would be constructed at Yucca Mountain to provide railcar handling, and buffer storage. Details on this facility have not yet been formulated.

The rail connection from Dike Siding would require approximately 137 km (85 mi) of track (Jackson, 1984) and a bridge over Fortymile Wash. The route shown on Figure 5-2 is preliminary and could change as additional information is gathered. A right-of-way of 18 m (60 ft) would be required; thus, the land committed to the rail line would total about 250 ha (620 acres).

Upcast Shafts

Upcast shafts for ventilation would be located away from the surface complex. The exact location would depend on whether shaft entry or ramp entry for personnel and materials is used. The configuration for the ramp-entry is shown on Figure 5-3. At the surface, either ventilation-exhaust facilities or rock-transfer equipment would be installed. The ventilation facilities would be fenced and would require less than 1 ha (about 1 to 2 acres) each. Exhaust stacks at each site would extend about 10 m (35 ft) above the land surface. Improved roads would connect these sites to the surface complex. The rock-handling equipment would be used to construct the above-grade rock storage piles.

Other offsite facilities

Other facilities away from the surface complex include the rock storage pile, the visitors' center, the water tower, explosive magazines, and a sanitary landfill. The layout of these facilities is shown on Figure 5-4. Improved roads would connect these facilities to the main complex.

5.1.1.5 Schedule and labor force

The initial construction phase (preparation for waste emplacement) is scheduled for five years. During that time, all surface facilities are to be constructed, shafts (and ramps) would be excavated, and enough of the subsurface facilities would be excavated to permit waste transfer and emplacement to begin. During the next 28 years, the remainder of the subsurface facilities would be excavated concurrently with waste emplacement. Waste emplacement would continue for about 2 years after all subsurface areas have been excavated, which equals a total emplacement or operations period of 30 years. A 20-year retrievability phase (years 36-55) is planned following the operation phase. Retrieval of the emplaced wastes could be initiated, however, at any time from year 5 to year 55 (or up to 50 years after the first waste has been emplaced). If waste retrieval is necessary, the retrievability phase would continue for up to an additional 30 years. The retrievability phase would be followed by a 5-year decommissioning phase. The repository would be decommissioned and closed during years 56 to 60.

The size of the labor force during construction would depend on whether vertical or horizontal emplacement is used. Vertical emplacement would require more personnel. Estimates of the work force required at Yucca Mountain for both emplacement configurations are shown on Figure 5-6 (McBrien and Jones, 1984). Preliminary estimates of the labor-force requirements by skill level have been prepared by McBrien and Jones (1984) and are shown in Table 5-3 for vertical emplacement, and in Table 5-4 for horizontal emplacement.

The number of workers onsite at any one time would vary with the shift. Mining activities are to be conducted on a three-shift basis for 250 days per year. While most surface operations would be on a one-shift basis, some activities would require three shifts. In all cases, the day shift, which is to be from about 8 A.M. to 4 P.M., would be the most labor-intensive. The average day-shift onsite work force throughout the repository lifetime for the vertical emplacement case is estimated to be:

- Construction phase - 1568
- Operational phase - 778
- Retrievability phase - 243
- Decommissioning phase - 541

Construction of the highway and rail line is to begin during the first year of the construction phase and is to be completed during the initial five-year construction phase. To construct the rail-access route, approximately 70 workers would be required for two years (personal communication from T. Yellvington, Holmes and Narver, 1983). Construction of the highway would require 50 workers for one year, and construction of the bridge(s) would require about 40 workers for two years.

5.1.1.6 Material and resource requirements

Building materials and other resources would be delivered to the main site and to the sites of road and railroad construction. The amount and type of construction materials for the repository are only estimates at this time. Since concrete and steel represent the greatest quantities of construction materials, estimates of these are given as an indication of the quantities of materials that would be required. Estimated amounts of these construction materials and energy resources that would be required annually for the repository are listed on Table 5-5 for vertical emplacement and on Table 5-6 for horizontal emplacement. Requirements would decrease when the subsurface excavations are completed, which would occur around year 35.

Construction materials would be shipped to the repository via highway and rail. The estimated number of annual shipments of material over the repository lifetime is shown on Table 5-5 for vertical emplacement and on Table 5-6 for horizontal emplacement. During the first two years of construction, all shipments would be by truck while the rail line from Dike Siding is being constructed. Upon completion of the rail line, materials would be shipped to the site by train. Because of the volumes of construction materials required and the remoteness of the site, railroads would be an efficient means of material supply. Therefore, for the analysis of transportation impacts, it is

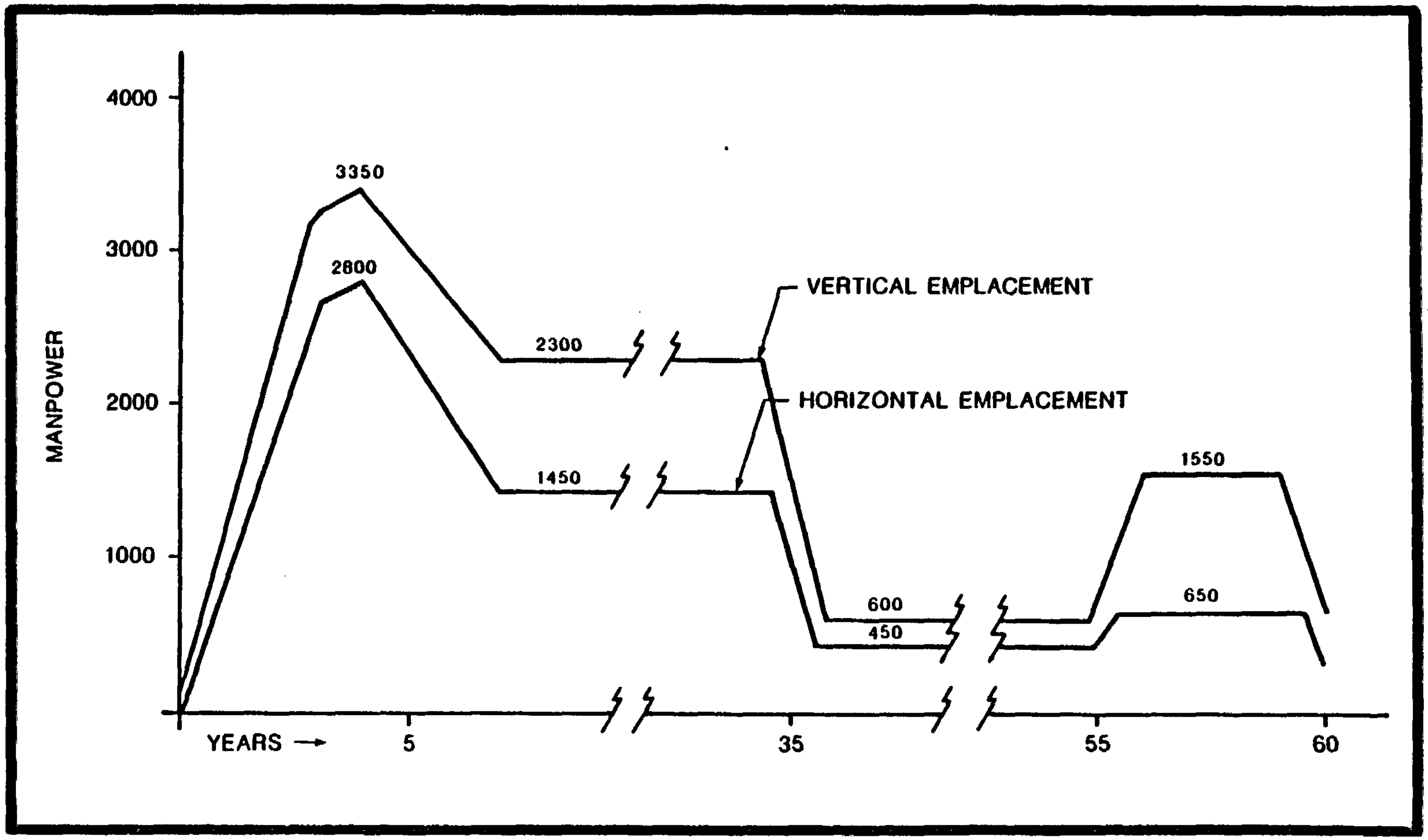

Figure 5-6. Estimated work force for the Yucca Mountain repository.

Table 5-3. Labor force size by skill for vertical emplacement[a]

	Phase and year							
	Construction					Operations	Retrieva-bility	Decommis-sioning
Location/skill	1	2	3	4	5	6-35	36-55	56-60
Surface								
Road and rail construction	160	110	NA[b]	NA	NA	NA	NA	NA
Surface facility construction	429	1287	1929	1287	427	NA	NA	NA
Equipment installers	0	0	0	765	765	NA	NA	NA
Engineers	18	51	77	81	46	NA	NA	NA
Supervisors	49	146	219	234	136	NA	NA	NA
QA staff	46	139	208	221	128	NA	NA	NA
Support personnel	NA	NA	NA	NA	NA	517	172	342
Service personnel	NA	NA	NA	NA	NA	193	90	104
Mining support	NA	NA	NA	NA	NA	354	185	478
Waste handling support	NA	NA	NA	NA	NA	313	32	152
Subsurface								
Mining/mine workers[c]	519	683	806	760	760	728	115	472
Waste emplacement personnel	NA	NA	NA	NA	NA	81	NA	NA
Emplacement support personel	NA	NA	NA	NA	127	127	NA	NA
Total employment								
Direct	1221	2416	3239	3348	2389	2313	594	1548
Indirect[d]	1880	3721	4988	5156	3679	3562	915	2384
Total project related	3101	6137	8227	8504	6068	5875	1509	3932

[a] Source: McBrien and Jones, 1984.
[b] NA = not applicable.
[c] Includes miners, mechanics, electricians, carpenters, pipefitters, engineers, supervisors.
[d] Assumes 1.54 indirect workers for each direct worker.

Table 5-4. Labor force size by skill for horizontal emplacement[a]

	Phase and year							
	Construction					Operations	Retrievability	Decommissioning
Location/skill	1	2	3	4	5	6-35	36-55	56-60
Surface								
Road and rail construction	160	110	NA[b]	NA	NA	NA	NA	NA
Surface facility construction	425	1276	1913	1276	425	NA	NA	NA
Equipment installers	NA	NA	NA	744	744	NA	NA	NA
Engineers	18	51	76	80	46	NA	NA	NA
Supervisors	49	144	216	228	132	NA	NA	NA
QA staff	43	130	193	204	119	NA	NA	NA
Support personnel	NA	NA	NA	NA	NA	355	118	235
Service personnel	NA	NA	NA	NA	NA	193	89	104
Mining support	NA	NA	NA	NA	NA	167	91	100
Waste handling support	NA	NA	NA	NA	NA	313	102	115
Subsurface								
Mining/mine workers[c]	162	211	269	268	268	252	56	99
Waste emplacement personnel	NA	NA	NA	NA	NA	42	NA	NA
Emplacement support personnel	NA	NA	NA	NA	120	120	NA	NA
Total employment								
Direct	857	1922	2667	2800	1854	1442	456	653
Indirect[d]	1320	2960	4107	4312	2855	2221	702	1006
Total project related	2177	4882	6774	7112	4709	3663	1158	1659

[a] Source: McBrien and Jones, 1984.
[b] NA = not applicable.
[c] Includes miners, mechanics, electricians, carpenters, pipefitters, engineers, supervisors.
[d] Assumes 1.54 indirect workers for each direct worker.

Table 5-5. Annual requirements for construction materials, fuel and power, and shipments to the repository for vertical emplacement[a,b]

	Years[c]					
	1-2	3-5	6-35	36-55	56-60	Total
Concrete[d]						
1,000 m^3	34	34	6.9	0.38	7.6	423
Railcars	NA[e]	630	130	7	140	NA
Trucks	3,000	900	180	10	200	NA
Steel[d]						
Metric tons	2,700	2,700	340	NA	NA	23,700
Railcars	NA	21	3	NA	NA	NA
Trucks	150	45	6	NA	NA	NA
Diesel fuel[d]						
1,000 liters	3,860	3,860	6,270	341	1,430	221,400
Railcars	NA	24	37	2	9	NA
Trucks	68	20	33	2	8	NA
Electrical power						
Million kWh	31	31	137	9	38	4,635
Total annual shipments						
Railcars	NA	675	170	9	149	NA
Trucks	3,218	965	219	12	208	NA

[a] Source: McBrien and Jones, 1984.
[b] The following assumptions were used for shipping loads:
(1) Concrete: raw materials (sand, gravel, and cement) shipped at 11.5 m^3/truck; 23 m^3/railcar
(2) Steel: 18 metric tons/truck; 90 metric tons/railcar
(3) Diesel fuel: 56,800 liters/truck; 113,600 liters/railcar.
[c] Years 1-2: shipment by truck only.
Years 3-60: 70 percent of materials and fuel are shipped by rail; the remainder by truck.
[d] Conversions: 1 m^3 = 1.31 yd^3; 1 metric ton = 1.1 ton; 1 U.S. gal = 3.79 l.
[e] NA = not applicable.

Table 5-6. Annual requirements for construction materials, fuel and power, and shipments to the repository for horizontal emplacement[a,b]

	Years[c]					
	1-2	3-5	6-35	36-55	56-60	Total
Concrete[d]						
1,000 m^3	21	21	2.8	0.19	1.9	202
Railcars	NA[e]	380	50	4	35	NA
Trucks	1,800	540	70	5	50	NA
Steel[d]						
Metric tons	2,500	2,500	180	NA	NA	17,900
Railcars	NA	20	2	NA	NA	NA
Trucks	140	40	3	NA	NA	NA
Diesel fuel[d]						
1,000 liters	1,760	1,760	3,580	151	691	122,700
Railcars	NA	11	22	1	4	NA
Trucks	31	9	19	1	4	NA
Electrical power						
Million kWh	19	19	82	9	17	2,820
Total annual shipments						
Railcars	NA	411	74	5	39	NA
Trucks	1,971	589	92	6	54	NA

[a] Source: McBrien and Jones, 1984.
[b] The following assumptions were used for shipping loads:
(1) Concrete: raw materials (sand, gravel, and cement) shipped at 11.5 m^3/truck; 23 m^3/railcar
(2) Steel: 18 metric tons/truck; 90 metric tons/railcar
(3) Diesel fuel: 56,800 liters/truck; 113,600 liters/railcar.
[c] Years 1-2: shipment by truck only.
Years 3-60: 70 percent of materials and fuel are shipped by rail; the remainder by truck.
[d] Conversions: 1 m^3 = 1.31 yd^3; 1 metric ton = 1.1 ton; 1 U.S. gal = 3.79 l.
[e] NA = not applicable.

assumed that 70 percent of construction materials would arrive by train and the remainder would arrive by truck.

Materials required for construction of the highway and rail line have been estimated (personal communication from T. Yellvington, Holmes and Narver, 1983) and are listed on Table 5-7. Materials for the bridge(s) over Fortymile Wash are included in these estimates. The number of shipments of these materials to the various sites along the routes are also indicated on Table 5-7.

Equipment requirements for the construction of the repository are shown on Table 5-8. Most of this equipment is to be removed after construction. Some equipment, however, would remain during the operation, retrievability, and decommissioning phases.

Over the lifetime of this project, various resources, such as water, electric, diesel fuel, etc., would be required at the repository. Estimates of the amount of these resources for vertical emplacement are listed on Table 5-9.

5.1.2 Operations

The operations phase of a nuclear-waste repository at Yucca Mountain would begin 5 years after construction of the facility begins and would continue for 30 years thereafter.

5.1.2.1 Waste receipt

Nuclear waste would be shipped to the repository by rail or by truck in Federally licensed casks. Waste emplaced at the repository would consist of either spent fuel that has been out of the reactor for a 10-year decay period that has been reprocessed. For purposes of this analysis, it was assumed that a reprocessing facility would be located at Barnwell, South Carolina. Reprocessing wastes are categorized as commercial high-level wastes (CHLW), which are fission products and actinides solidified in a borosilicate glass matrix; fuel cladding hulls (hulls); remote-handled transuranics (RHTRU); and contact-handled transuranics (CHTRU). The four bounding scenarios assessed herein assume that the repository would receive either 70,000 MTU of spent fuel, or the equivalent amount of reprocessing wastes, and that the waste is shipped either 100 percent by truck or 100 percent by rail. Details on the packaging of these wastes are included in Jackson (1984). Quantities of each type of waste for the four scenarios are shown in Table 5-10. In addition, onsite generated low-level waste would be disposed of in the repository, but the expected quantities of these wastes are small and not available at this time.

It is assumed that the wastes would arrive either entirely by rail or entirely by truck. Spent fuel would be shipped from reactor power plants, while the other wastes (described above) would be shipped from a reprocessing plant or from a fuel-fabrication plant. The average one-way shipping distance is assumed to be about 3300 km (2000 mi) (Appendix A).

Table 5-7. Highway and rail construction materials[a,b]

Material[c]	Highway[d]		Rail[e]	
	Quantity	No. Shipments	Quantity	No. Shipments
Limestone (m^3)	30,600	2,700	210,000	5,000
Asphalt (metric tons)	36,000	2,000	0	0
Prime Tar (liters)	359,000	6	0	0
Tar (liters)	359,000	6	0	0
Paint (liters)	946	1	0	0
Concrete (m^3)	3,000	275	3,000	80
Fencing (m)	48,200	80	0	0
Rails - steel (metric tons)	0	0	18,000	200
Railroad ties	0	0	255,000	500
Drain pipe (m)	0	0	1,400	10

[a] Source: personal communication from T. Yellvington, Holmes and Narver, 1983.

[b] Includes bridge(s) over Fortymile Wash.

[c] Conversions: 1 m = 3.28 ft; 1 metric ton = 1.1 ton; 1 U.S. gal = 3.785 liters; 1 m^3 = 1.31 yd^3.

[d] Assumes all shipments are via truck from U.S. Highway 95 and all are brought in during the first year. Each shipment is one truck load.

[e] Assumes all shipments are via rail to Dike Siding and all materials brought in during two years. From Dike Siding, materials are brought up along the right-of-way. These are numbers of railcar loads.

Table 5-8. Estimated construction equipment requirements[a]

Type	Quantity
Bulldozers	30
Earthmovers	30
Dump trucks	35
Drilling machines	8
Front-end loaders	40
Gravel elevators	4
Graders/scrapers	22
Backhoes	5
Shovels	20
Cranes	25
Earth compactors	15
Air compressors	5
Concrete mixers	30
Drill rigs	2
Mucking elevators	2
Scaling machines	5
Rockbolting machines	5
Boring machines	5
Truck cranes	10
Services vehicles	140

[a] Based on typical requirements for the construction of large facilities.

Table 5-9. Total (60 yr) resource requirements for vertical emplacement

Resource	Requirement (ha)	Requirement (acres)
Cleared land		
Surface facilities	30	75[a]
Offsite facilities	10	25[a]
Rock storage piles[b]	37	92
Railroad spur	250	620[c]
Highway construction	36	90[c]
Electric transmission line	(d)	(d)
Water pipeline	(d)	(d)
Undisturbed or little disturbed land commitment for controlled area	42,200[e]	104,000[e]
Water use	180 acre-ft/yr[a]	
Diesel fuel	221 million liters[a] (58.4 million gal)	
Electrical power	4635 million kWh[a]	
Labor	97,000 person-years[a]	

[a] Source: McBrien and Jones, 1984.

[b] Assumes that pile is 30 m (100 ft) high and varies according to emplacement concept. Stockpile consists of rock from excavation assuming no backfilling. Volume determined from McBrien and Jones, 1984.

[c] Calculated: Railroad right of way is 18 m (60 ft) wide by 137 km (85 mi) long. Road right of way is 15 m (50 ft) wide by 25 km (15 mi) long.

[d] These would already be in place for the exploratory shaft phase, but may have to be upgraded.

[e] Based on 10 CFR 60. A qualified controlled area extending 10 km from the outer boundary of the subsurface area.

Table 5-10. Waste quantities by waste category for each scenario[a]

Scenario[b]	Waste type[c]	Total quantity	Annual receipt	No. of shipments/yr[d] Truck	Rail
I	Spent fuel - PWR	98,600 assemblies	3,300 assemblies	1,650	0
	Spent fuel - BWR	136,000 assemblies	4,500 assemblies	900	0
			Total	2,550	0
II	Spent fuel - PWR	98,600 assemblies	3,300 assemblies	0	275
	Spent fuel - BWR	136,000 assemblies	4,500 assemblies	0	140
			Total	0	415
III	CHLW	30,900 canisters	1,030 canisters	1,030	0
	Hulls	10,500 canisters	350 canisters	350	0
	RHTRU	52,800 canisters	1,760 canisters	1,760	0
	CHTRU	375,000 drums	12,500 drums	780	0
			Total	3,920	0
IV	CHLW	30,900 canisters	1,030 canisters	0	85
	Hulls	10,500 canisters	350 canisters	0	90
	RHTRU	52,800 canisters	1,760 canisters	0	440
	CHTRU	375,000 drums	12,500 drums	0	240
			Total	0	855

[a] Reflects 70,000 metric tons of uranium (MTU) of either spent fuel or CHLW based on data in Appendix A.

[b] I - 100% spent fuel/100% truck; II - 100% spent fuel/100% rail; III - 100% CHLW/100% truck; IV - 100% CHLW/100% rail.

[c] PWR - pressurized water reactor; BWR - boiling water reactor; CHLW - commercial high-level waste; Hulls - cladding hulls; RHTRU - remote-handled transuranic waste; CHTRU - contact-handled transuranic waste.

[d] For 30 years.

For simplicity, it is assumed that an equal amount of waste would arrive at the site each year. The number of shipments by truck or rail per year required to fill the repository in 30 years are given for each scenario in Table 5-10. Assuming 250 working days per year, average daily shipments range from 2 to 16, depending on the scenario.

Upon arrival at the repository, the shipping casks would remain on their carrier in either a rail or a truck yard until space is available in the waste-handling building. A shipping cask is then brought into the building, lifted by crane from the railcar or truck, and placed in a shielded transfer-cell where the waste is removed by remotely operated machines. After inspection of the cask, the spent-fuel assemblies will be unloaded and packaged, or they may be disassembled and individual fuel rods packaged into specially designed waste packages. This description assumes that the facilities for packaging the spent-fuel assemblies would be located at the repository. The length of time a loaded shipping cask would remain in the yard would depend upon the number of transfer cells available for the incoming waste and the time required for the unloading operation.

5.1.2.2 Waste emplacement

Spent fuel and CHLW would be sealed in high-integrity packages prior to disposal. These waste packages would be designed to meet the minimum lifetime requirements set by the U.S. Nuclear Regulatory Commission (10 CFR Part 60). To meet this requirement, minimum waste package lifetimes would be between 300 and 1000 years under the expected subsurface environment of the repository. High-integrity packages are one component of a system of engineered barriers. Other engineered barriers may be used as part of the repository system. Such engineered barriers for this purpose include waste forms, overpacks, sleeves, and backfill materials.

The high-level and transuranic wastes that are shipped from reprocessing facilities and fuel-fabrication plants are assumed to arrive in canisters. These canisters are unloaded from the shipping casks in a shielded transfer-cell and sealed in a waste package.

When the waste packages have been determined to be suitable for emplacement, they would be held temporarily in a surge-storage area. This surge storage would allow incoming waste to be unloaded and prepared for disposal at a faster rate than the emplacement operation, thus it would reduce the yard-storage time. The design rate of waste emplacement, however, would also be determined to minimize the length of time required for surge storage. After surge storage, the waste packages are transported to the waste shaft or ramp by remotely operated machines and either lowered or driven into the underground facility. The waste packages arrive at subsurface transfer stations where they are placed in shielded transporters and carried to the waste-emplacement rooms. The waste packages are then placed either in vertical holes in the floors of the storage drifts (vertical emplacement) or in long horizontal holes in the pillars (horizontal emplacement). If placed horizontally, each borehole would contain 30 to 60 waste packages; if vertical, each hole would contain one waste package (Jackson, 1984).

Canisters of hulls and RHTRU would be handled remotely throughout the facility. Upon arrival, they would be inspected in shielded hot cells and, if accepted, they would be transferred to the subsurface facilities for emplacement. Provisions would be made for the upgrading of unacceptable canisters. Drums of CHTRU would be contact handled (i.e., using forklifts), inspected, and transferred to the subsurface for disposal.

The surface and subsurface facilities at the repository that handle radioactive wastes would be operated at less than atmospheric pressure. Exhaust air from these facilities would be processed through a high efficiency particulate filter train before being discharged into the atmosphere. Exhaust from the underground waste-storage rooms would be directed to a surface building where the exhausts will be filtered and then discharged into the atmosphere. Ventilation during underground construction would be physically separated from the waste-emplacement ventilation circuit.

The requirements for materials and other resources for the operation phase (years 6-35) are listed in Tables 5-5, 5-6, 5-7, and 5-9. The labor requirements are shown on Figure 5-6. This work force would be in place for the 30-year operational period. This force would work three shifts for 250 days per year. The size of the operational staff is dependent on the emplacement configuration used.

5.1.3 Retrievability

The Yucca Mountain repository would be designed to allow retrieval of all waste as required by the NRC (10 CFR Part 60). The requirements state that waste must be retrievable for a period of up to 50 years after waste emplacement begins. The requirements also state that if retrieval becomes necessary, the waste must be retrieved in about the same amount of time that was devoted to the initial emplacement of the waste (up to 30 years if the repository has reached capacity).

Designs for the subsurface facilities would incorporate features to insure that the openings would remain intact for at least 90 years (a 5-year construction phase, 30-year operations phase, a 20-year phase during which retrieval could be initiated, a 30-year retrieval phase, and a 5-year decommissioning phase). These features include minimizing the extraction ratio, optimizing rock temperatures through spacing of emplacement holes and ventilation, and using steel sleeves for horizontal emplacement holes. In addition, periodic inspections and maintenance programs would be used to monitor and verify stability of the subsurface openings throughout the retrievability period.

During the period when the retrievability phase is planned, which is years 35-55 as shown on Figure 5-6, a standby work force would be needed. This staff, would be onsite for security, surveillance, monitoring of repository performance, and maintenance.

5.1.4 Decommissioning

Following the planned 20-year retrievability phase, decommissioning and final closure is to begin. This phase is estimated to require five years to complete. To decommission the subsurface facilities, all subsurface access areas (shafts and ramps) would be sealed. These openings would be sealed using multiple materials and techniques to assure that the seal offers the same or improved isolation properties as the host rock (Fernandez and Freshley, 1984).

All surface structures would then be decontaminated and dismantled. Some contaminated material may be placed underground prior to the sealing of shafts. The surface areas would be reclaimed. Permanent markers would be erected to inform future generations about the presence of the repository. Development of such markers or a marking system is currently under way. All records concerning the repository would be maintained by appropriate Federal, State and local agencies. It is expected that the records and markers would be kept in perpetuity. The labor force for decommissioning activities is shown on Figure 5-6; materials and resources are listed in Tables 5-5, 5-6, 5-7, and 5-9.

5.1.5 Alternative repository concepts

Recent reports (DOE, 1984a; DOE 1984b) have proposed repository construction and operation on a schedule different from the schedule presented in earlier sections. In this alternative concept, the repository would be constructed and operated in two phases. In the first phase, surface and underground facilities would be constructed to receive and emplace a limited amount (400 MTU per year) of spent fuel 4-1/2 years after construction began. The phase 1 repository would be ready for operation in January 1998, and would be followed by a full capacity (phase 2) repository (3000 MTU per year), which would begin operation six years later (see Table 5-11).

The present preliminary repository concept assumes that spent fuel would be out of the reactor for at least 10 years at the time of emplacement; the mission plan currently indicates that some of the spent fuel could be out of the reactor for only 5 years. During phase 1, spent fuel would not be consolidated but would be packaged in canisters with each canister containing either 9 BWR (boiling water reactor) or 3 PWR (pressurized water reactor) fuel assemblies. During phase 2, spent fuel would be consolidated and packaged in canisters, which contain either 18 BWR or 6 PWR assemblies.

The phase 1 waste handling building (WHB-1) would be designed to receive and process 400 MTU per year of intact fuel assemblies requiring only packaging into canisters. Approximately 240 MTU of surface storage would be provided outside the building for canistered spent fuel in the transport casks and in a dry vault cooled by circulating air supplemented with evaporative cooling. Adequate rack storage of bare fuel assemblies in the hot cell in WHB-1 would also be provided for operational surge requirements.

(Table 5-11 to be dropped in)

The waste handling building for phase 2 (WHB-2) would provide the full 3000 MTU annual receipt and processing and storage capability based on 80 percent rail, 20 percent truck shipment. Fuel consolidation would be performed in two hot cells, each of which would have two parallel processing trains employing the dry consolidation concept. Surface storage of 750 MTU would be provided for canistered spent fuel in rail- and truck-mounted casks, a dry vault storage, and within WHB-1. Adequate surge storage of bare fuel elements in hot cell racks would also be provided. Figure 5-7 shows the conceptual site plan for a phased repository at Yucca Mountain. Figure 5-8 shows the site plan for the surface facilities.

In phase 1, all shipments would be made by a fleet of 82 trucks and an average of 4 trucks per day would arrive at the repository. Each truck would carry a cask that contains 2 PWR and 5 BWR assemblies (Appendix A). A parking lot for 82 trucks containing about 80 MTU of spent fuel would be provided during phase 1. As a contingency measure, a marshalling yard for 10 rail casks containing about 60 MTU would also be provided. Each rail cask carries 12 PWR or 32 BWR assemblies (Appendix A). An additional 100 MTU of surface storage would be provided within WHB-1 for operational continuity.

During phase 2, parking for the fleet of 82 trucks would be retained and marshalling facilities for 40 additional rail cars would be provided. An

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Table 5-11. Spent fuel waste receipts by year, MTU Equipment[a]

Year	Phase 1	Phase 2	Total
1	400	NA[b]	400
2	400	NA	400
3	400	NA	400
4	400	500	900
5	400	1400	1800
6	NA	3000	3000
7	NA	3000	3000
8	NA	3000	3000

[a] Source: Sandia, 1984.
[b] NA = not applicable.

(To be inserted on page 5-17)

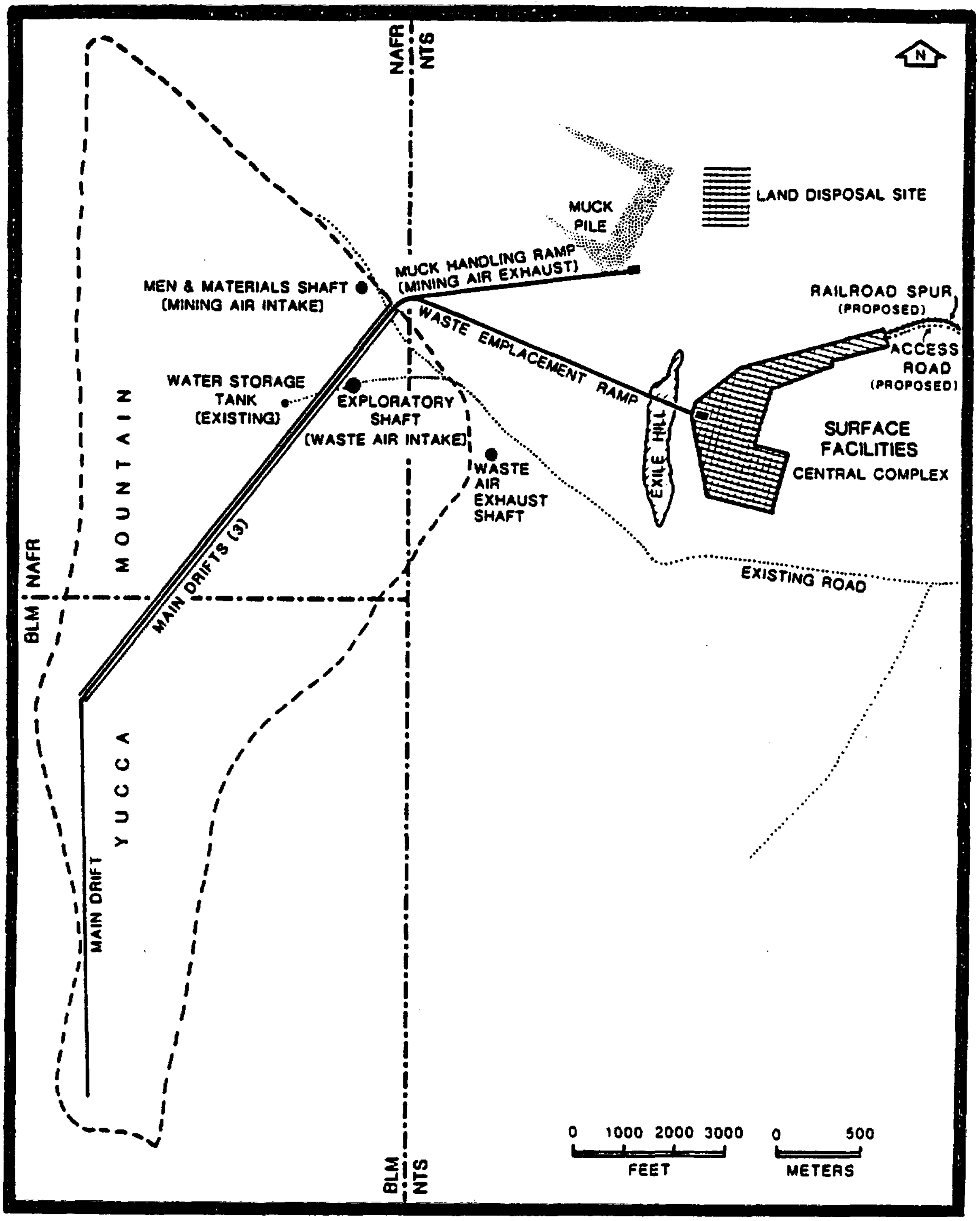

Figure 5-7. Phased repository site plan.

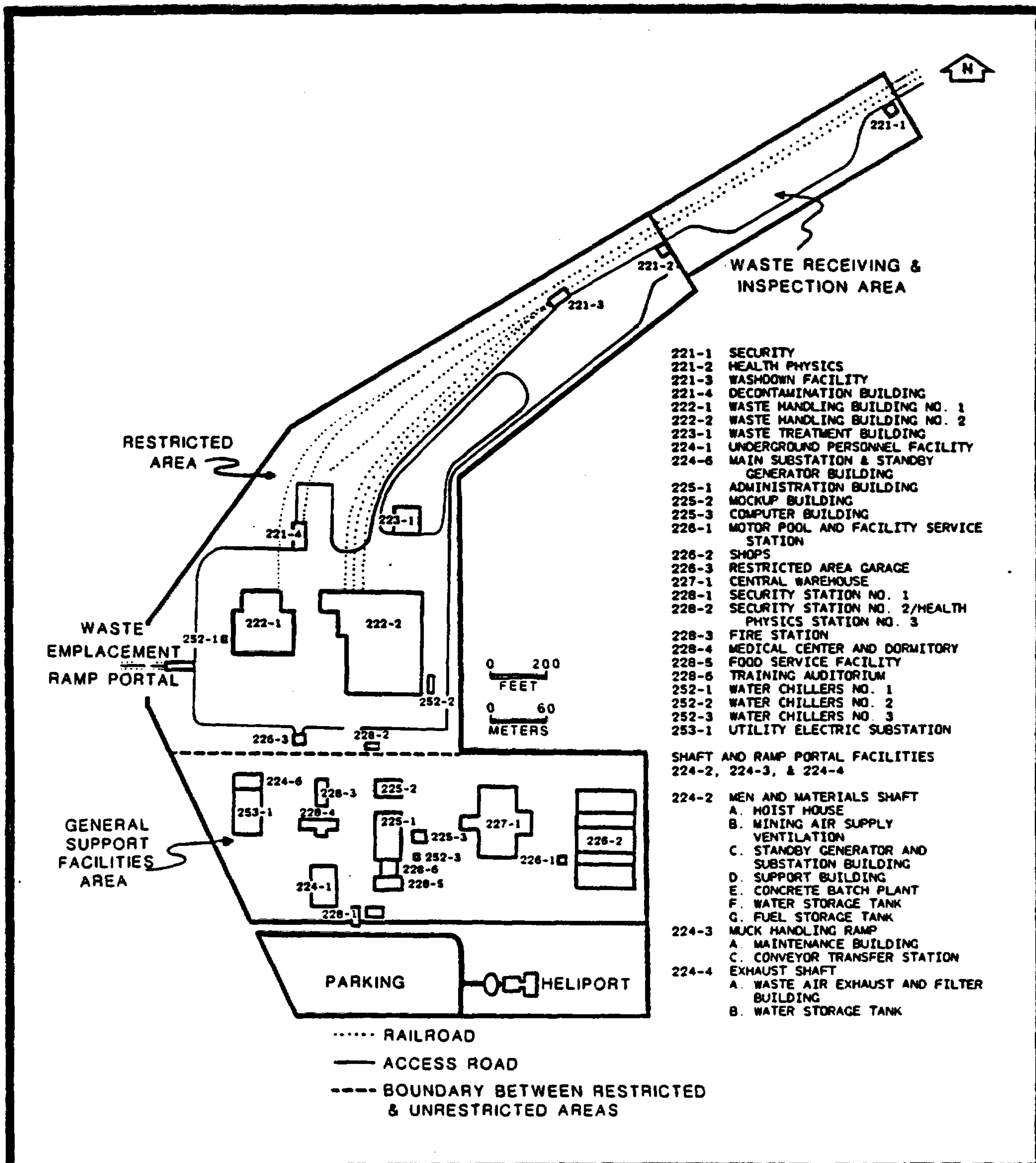

Figure 5-8. Surface facility plan for a phased repository. (Source: Sandia, 1984.)

additional 390 MTU of surface storage would be provided within WHB-2 for a total of 750 MTU surface storage.

If it is decided that solidified high-level radioactive waste from defense activities and from the West Valley processing plant may also be emplaced at the repository, this waste would supplant the MTU capacity provided for commercial waste. On a per canister basis, these wastes are lower in thermal output and have lower radiation levels than the assumed 10-year-old spent fuel; therefore, the radiation shielding and waste-loading design criteria based on spent fuel would be sufficient for these additional waste forms.

The impacts of phased repository development are not evaluated in this environmental assessment, but preliminary analyses indicate that impacts on the geology, and on aesthetic, archaeological, cultural, and historical resources should remain about the same as those described in the remainder of this chapter. Impacts on hydrology would be expected to be about the same with the exception of water use. Increased water use would be expected with the phased repository. Larger land use requirements and a protracted construction schedule would tend to increase impacts to land use, ecosystems, air quality and noise. The use of outside lag storage, and the receipt of 5-year old fuel would increase the potential for radiological effects. It is assumed that more workers would be needed to develop a phased repository. An increased work force is usually favorable to the economy, but may have adverse impacts on communities' services.

5.2 EXPECTED EFFECTS ON THE PHYSICAL ENVIRONMENT

This section describes the potential local and regional impacts that may result from locating a repository at Yucca Mountain. The topics that are discussed include possible impacts to the geologic and hydrologic environments, land use, ecosystems, air quality, noise, aesthetics, archaeological, cultural, and historical resources, and background radiation levels.

5.2.1 Geologic impacts

Locating a repository at Yucca Mountain is expected to have minimal impact on the geologic environment. Excavation of the repository represents an insignificant disturbance to the overall competence of the rock units at Yucca Mountain. Heat and radiation, which would be introduced into the rocks by decay of radioactive material in the repository, would affect only a small volume of rock and would neither result in loss of competence nor in loss of structural stability (see Chapter 6, Sections 6.3.1.3 and 6.3.3.2). Future exploration and development of any local mineral or energy resources would be excluded on approximately 42 ha (104 acres) of Federal land. A class I resource survey (Bell and Larson, 1982) found no evidence of significant mineral or energy resources in the region surrounding Yucca Mountain and therefore future exploration and development is not anticipated. The following paragraphs describe the potential impacts associated with the construction, operation, retrievability, and decommissioning phases of the repository.

5.2.1.1 Construction

Studies by Dravo Engineers, Inc. ((1984a, 1984b) and Hustrulid (1984), indicate that a repository can be built at Yucca Mountain using standard construction techniques (Section 6.3.3.2). Access drifts and underground openings can be supported by conventional rockbolts, wire mesh, and shotcrete. Intersections of fault zones and drifts could be supported, if necessary, by steel or by concrete.

The presence of lithophysae, small voids in the host rock, have been considered in the mining analyses (Section 6.3.3.2). The preliminary repository concepts assume that rocks with less than 15-20 percent lithophysae are preferable. On the basis of current information, there is an adequate thickness of host rock in which to locate the underground facility that contains less than 15-20 percent lithophysae. Conventional mining techniques in welded tuff have been demonstrated by construction of the G-Tunnel at Rainier Mesa north of Yucca Mountain. Both experience gained at the G-Tunnel and results of the engineering studies previously described indicate that the excavations at Yucca Mountain should remain serviceable for over 90 years with only routine maintenance.

5.2.1.2 Operation

To date, there are no identified physical or chemical characteristics of either the Topopah Spring tuff or of the geochemical environment to suggest that the isolation capability of the host rock could be reduced (see Chapter 6, Section 6.3.1.2) because of the heat and radiation generated by the emplaced wastes (Johnstone and Wolfsberg, 1980; Bish et al., 1984; Nimick and Williams, 1984; Tillerson and Nimick, 1984). Furthermore, there are no indications that the retrieval of wastes, if required, would be hampered because of the effects of heat and radiation on the rock. Calculations predict that only minor thermally induced fractures extending less than 10 cm (4 in.) into the rock may occur around the waste-emplacement boreholes. Any possible difficulty in retrieving the wastes due to thermally induced fracturing could be either reduced or avoided by using steel sleeves in the waste-emplacement boreholes. Chapter 6, in particular Sections 6.3.1.2, 6.3.1.3, 6.3.3.2 and 6.3.3.3, discusses the analyses that support the above observations.

5.2.2 Hydrologic impacts

Potential hydrologic impacts of locating a repository at Yucca Mountain are discussed in this section. These discussions include regional effects from ground-water withdrawals at Yucca Mountain (Section 5.2.2.1), the potential for release of radionuclides into the ground water (Section 5.2.2.2), the potential for flash floods at the repository (Section 5.2.2.3); and the possibility that future generations might consider Yucca Mountain to be a significant source of ground water (Section 5.2.2.4). The secondary effects on municipal water systems from population increases caused from locating a repository at Yucca Mountain are discussed in Section 5.4.3.

5.2.2.1 Water use

It has been estimated that the water requirements for a repository at Yucca Mountain would average 220,000 m^3 (180 acre-ft) per year over a 60-year period that includes the construction, operation, retrievability, and decommissioning phases (McBrien and Jones, 1984). This water can be adequately supplied by existing wells, primarily well J-13 located on the Nevada Test Site (Figure 4-2).

The regional effects of withdrawing ground water for a repository at Yucca Mountain are expected to be negligible. Thordarson (1983) reports that the water level in well J-13 has remained essentially constant after long periods of pumping between 1962 to 1980. The large volume of water produced from this well (approximately 400 acre-feet per year), along with the minor drawdown during pumping tests (Young, 1972), suggest the aquifers underlying Yucca Mountain can produce an abundant quantity of ground water for long periods of time without lowering the regional ground-water table (Chapter 6, Sections 6.3.1.1 and 6.3.3.3).

5.2.2.2 Potential contamination of ground water

Both preliminary assessments of the long-term performance of a repository at Yucca Mountain (Sinnock et al., 1984; Thompson et al., 1984) and a preliminary performance assessment described in Sections 6.3.2 and 6.4.2 of this Environmental Assessment indicate that a repository at Yucca Mountain would meet the proposed EPA standards for radionuclide releases to the accessible environment (40 CFR Part 191). The analyses indicate that the natural barriers to radionuclide migration at Yucca Mountain, which are inherent attributes of the geologic and hydrologic setting, would adequately limit exposure to the accessible ground water and to the public for the required period of 10,000 years.

The evidence compiled to date suggests that climatic changes during Quaternary time, the last 1.8 million years, had a negligible effect on the hydrologic system at Yucca Mountain. Furthermore, there is no evidence to suggest that during the next 10,000 years the water table will rise to a level that could flood the repository. The details in Section 6.3.1.4 support these conclusions.

5.2.2.3 Flooding

Part of the area that is being considered for construction of the surface facilities at Yucca Mountain could be inundated by the 500-year and regional maximum floods along Fortymile Wash (Squires and Young, 1984). During construction of the surface facilities, a combination of surface grading and construction of both flood barriers and diversion channels would be used to prevent flooding of the repository surface facilities (Chapter 6, Section 6.3.3.3).

5.2.2.4 Potential for future exploitation of ground water

It seems reasonable to expect that future generations will continue to consider the mountainous areas in the Great Basin as less desirable targets for ground-water withdrawal than the adjoining valleys. This assumption together with the results of a study of ground-water potential in this area by Sinnock and Fernandez (1982), indicate that future generations will probably view Yucca Mountain as a poor prospect for ground water as opposed to adjoining parts of Jackass Flats to the east of Yucca Mountain and Crater Flat to the west (Chapter 6, Section 6.3.1.8).

5.2.3 Land use

The Nevada Test Site and the Nellis Air Force Range have been withdrawn from public use for more than 30 years. Continued restriction of public access is not expected to affect either the current or the future economic and recreational requirements of the people in this region.

In addition to use of Nevada Test Site land, about 21,000 ha (50,000 acres) of public land that is administered by the Bureau of Land Management, U.S. Department of Interior, would be withdrawn from public use. Because Yucca Mountain is not a prime location for other uses, withdrawing this land should have essentially no effect on land use in the area. Construction of the rail line would require an additional withdrawal of 250 ha (620 acres) of public land. Assuming that access to lands north of the proposed rail line to the Sheep and Las Vegas ranges is neither restricted nor reduced, adverse impacts are not expected to occur to users of these areas. The proposed new access road would be located on the Nevada Test Site with the exception of a small segment from the Test Site to U.S. Highway 95 which would be on BLM land.

5.2.4 Ecosystems

This section describes the effects that locating a repository at Yucca Mountain may have on terrestrial and aquatic vegetation and wildlife. Possible adverse effects are greatest for the construction period and are a result of removing vegetation and increasing transportation activities in the vicinity of the site. Beneficial effects are anticipated during decommissioning and the postclosure period.

The primary ecological effect of repository construction would be the permanent removal of over 360 ha (900 acres) of vegetation. Table 5-9 itemizes the acreage that would be disturbed. Clearing this land is not expected to be ecologically significant because the affected areas are very small compared with surrounding undisturbed areas that have similar vegetation.

The ecological effects that may result from construction depend on the nature, the size, the location, and the duration of the disturbance. If the disturbance is restricted to the surface without removing the soil, then revegetation from an existing seed source or from root stock would occur in 10 to 20 years (Wallace et al., 1980). If the disturbance includes removing the soil, then natural revegetation may require hundreds of years (Wallace et al., 1980). The development of new vegetation is usually inhibited by the very low precipitation in the area and is influenced by soil characteristics and animal feeding habits.

A secondary ecological effect of removing the vegetation is the alteration of the habitats for wildlife. The vegetation provides wildlife with food, structures for nesting and with shelter from predators and from climatic extremes. When the vegetation of an area is destroyed, the wildlife that is dependent on that area is displaced into the surrounding, undisturbed areas. After displacement, the wildlife may die because of competition with other wildlife that live in the undisturbed areas. However, the net potential effect upon the animal community would probably not be significant because the areas that would be disturbed are not ecologically unusual, and because the potentially effected biota represents only a very small percentage of the surrounding, undisturbed biota in this region.

Indirect ecological effects may also be caused by combustion emissions, fugitive dust, sedimentation, and noise. The projected concentrations of the combustion emissions, which are described in Section 5.2.5. are not considered high enough to cause any significant adverse effects to the plants and animals in the region. However, fugitive dust deposition on the leaves of desert shrubs can increase the loss of leaves (Beatley, 1965). Over several years, deposition of dust could result in the death of shrubby vegetation near disturbed areas. Increased levels of fugitive dust would be minimized to the extent possible by mitigative measures such as wetting the surface of the disturbed areas. Also, erosion of disturbed areas and sedimentation both during and after storms could bury the vegetation surrounding the disturbed areas. However, erosion of the disturbed areas would be controlled to the extent possible by maintaining moderate slopes and by applying soil stabilizers, if necessary. Construction noise may affect some animal communities; but, a study by Ames (1978) indicated that the effects of noise on some species are temporary because individuals become acclimated to the noise. Potential noise impacts are discussed in Section 5.2.6.

Although there are no federally listed threatened or endangered species in the vicinity of Yucca Mountain, two species that occur in the area are being reviewed for inclusion on the Federal list (O'Farrell and Collins, 1983). These species are the Mojave fishhook cactus (Sclerocactus polyancistrus) and the desert tortoise (Gopherus agassizii). The distribution of these species is described in Section 3.4. Impacts on the Mojave fishhook cactus during construction are expected to be minimal because the densest populations are on the west side of Yucca Mountain, and the surface facilities are to be constructed on the east side of Yucca Mountain. The effects of construction on the desert tortoise would depend directly on the number of tortoises found in the construction zones. If a tortoise is encountered, it would be moved to a safe area. The density of desert tortoise in the project area (less than 8 per km^2 or 20 per mi^2) is lower than in other parts of its range (O'Farrell and Collins, 1983).

Riparian habitats do not exist on Yucca Mountain or in Fortymile Wash because of the absence of seasonal surface water. Therefore, impacts to aquatic ecosystems are not expected. Ash Meadows, which is located about 40 km (25 mi) south of Yucca Mountain, contains approximately 30 springs that have populations of rare pupfish and many unusual plants. Three endangered species of fish occur in this area: Devil's Hole pupfish (Cyrinodon diabolis), Amargosa pupfish (Cyprindon nevadensis pectoralis), and Pahrump killfish (Empetrichthys latos) (Collins et al., 1982). In addition, two endangered species of fish and their critical habitats were recently listed by the U.S. Fish and Wildlife Service (USFWS, 1983): Ash Meadows Amargosa pupfish (Cyprinodon nevadensis mionectes) and Ash Meadows speckled dace (Rhinichthys osculus nevadensis). Nine plant species in the Ash Meadows area are also under review for protection (Collins et al., 1982). As explained in Section 3.3.2, ground-water withdrawals for the repository are not expected to have any impact on maintenance of the water levels in the Ash Meadows area, and impacts to the ecosystems of the area are not expected.

The secondary effects of repository operations are similar to those discussed for construction, and include the loss of some plants and animals from combustion emissions, noise, fugitive dust, and sedimentation. During operations, the transportation of materials, equipment, and waste to the repository would result in an increased number of animals killed on the road.

Decommissioning of the repository would generally have positive ecological effects. Decommissioning would result in a reduced level of human activity and a reduction in all types of emissions. The presence of the repository may restrict the development of the region for other purposes. Therefore, the region would remain undisturbed for the foreseeable future.

Heat generated by the wastes would gradually increase the temperature at the surface (Johnstone et al., 1984). The maximum increase is expected to be less than 1°C (2°F) approximately 3000 years after waste emplacement, and the heat would dissipate slowly thereafter. The surface area that would be affected by the 1 C isotherm would probably be generally circular and will encompass approximately 800 ha (2000 acres), which includes the areal extent of the repository. The ecological consequences of increasing the surface and near-surface temperatures over the repository cannot be quantified with the information currently available. However, significant ecological impacts would not be expected because of the relatively small area to be affected.

5.2.5 Air quality

The development of Yucca Mountain as a repository would result in emissions of several substances into the atmosphere. This section will discuss the impacts associated with emissions from construction, operation, and subsequent decommissioning of the repository and the relationship of these impacts to applicable regulations. Only nonradiological emissions have been considered in this section. Section 5.2.9 discusses the potential for radiological emissions.

5.2.5.1 Ambient air quality regulations

Both the State of Nevada and the U.S. Environmental Protection Agency (EPA) have promulgated regulations that are designed to protect the air quality of Nevada, and they are expressed as ambient air quality standards. The standards that apply to the development of Yucca Mountain are outlined on Table 5-12. Before construction can begin, the State of Nevada requires a registration certificate that outlines limits on, and controls of, the emissions from facilities. After operation begins, an operating permit is required to verify that the source is operating within the limits of its registration certificate.

Particulate emissions are expected to be of the most concern in development of Yucca Mountain as a repository. The State of Nevada's regulatory intent concerning fugitive particulate emissions is that "no person shall cause or permit the handling, transporting, or storing of any material in a manner which allows, or may allow, controllable particulate matter to become airborne." Compliance with this mandate would be incorporated into the registration certificate. However, because of the preliminary stage of the repository concept at Yucca Mountain, only uncontrolled or minimally controlled (i.e., worst-case) particulate emissions have been assumed in this analyses.

Table 5-12. Ambient air quality standards[a]

Pollutant	Time period	Nevada standard $\mu g/m^3$ (ppb)[b]	Federal primary standard $\mu g/m^3$ (ppb)	Federal secondary standard $\mu g/m^3$ (ppb)
Sulfur dioxide	3 hour	1,300	---	1,300 (500)
	24 hour	365 (140)	365 (140)	---
	Annual arithmetic mean	80 (30)	80 (30)	80 (30)
Total suspended particulates	24 hour	150	260	150
	Annual geometric mean	75	75	60
Oxidant (ozone)	1 hour	235 (120)	235 (120)	235 (120)
Nitrogen dioxide	Annual arithmetic mean	100 (50)	100 (50)	100 (50)
Carbon monoxide	1 hour	40,000 (35,000)	40,000 (35,000)	40,000 (35,000)
	8 hour	10,000 (9,000)	10,000 (9,000)	10,000 (9,000)

[a] Source: State of Nevada, 1982.
[b] ppb = parts per billion.

In addition to these regulatory requirements, the project could be subject to review under the Prevention of Significant Deterioration (PSD) provisions of the Clean Air Act Amendments of 1977. Three classes of areas were established under the Clean Air Act to maintain specified levels of air quality. The classes allow for some industrial development by specifying incremental increases in ambient pollutant levels. These increments are small percentages of the National Ambient Air Quality Standards (NAAQS) and are outlined on Table 5-13. Class I areas are to remain pristine and allow only limited development, such as for national parks and wilderness areas. All other parts of the country that are subject to PSD regulations, including the Yucca Mountain site, were initially designated as Class II areas which allows for moderate industrial development. Class III areas are allowed to reach, but not to exceed, the NAAQS. At the present time, it is not clear whether or not the repository would be subject to PSD review. The applicability of PSD requirements is related to significant emission levels below which PSD review is not required. When specific details of repository emissions are known, the State of Nevada would be required to make a determination of applicability of PSD requirements. If review is required, it would entail a control technology review and could require either air quality or meteorological monitoring.

Table 5-13 to be dropped in

5.2.5.2 Potential impacts from construction

A preliminary assessment of the emissions and ambient air quality impacts of construction of the Yucca Mountain repository has been made by Bowen and Egami (1983). It was determined that emissions may result from site preparation, mine construction, movement of mined rock to storage piles, wind erosion of stored material, concrete preparation, and combustion of fossil fuels. Although Bowen and Egami (1983) assumed a seven-year construction period, these

Table 5-13. Maximum allowable pollutant increments assuming PSD requirements

Pollutant	Time period	Increments[a] ($\mu g/m^3$) Class I	Class II	Class III
Sulfur dioxide	3 hour	25	512	700
	24 hour	5	91	182
	1 year	2	20	40
Particulates	24 hour	5	19	37
	1 year	10	37	75

[a] For any period other than annual, increase may be exceeded not more than one day per year at any one location.

(To be inserted on page 5-38)

values have been corrected to reflect the five-year period now envisioned for Yucca Mountain. Table 5-14 presents estimated particulate emissions for the construction phase based upon three eight-hour shifts working 250 days per year, and Table 5-15 presents estimated gaseous emissions associated with construction of the project. These emission rates do not represent absolute values, however, and would need to be revised as more accurate information on specific construction practices becomes available.

Space to be closed, Tables 5-15 and 5-16 will be put on one page following Table 5-4.

Bowen and Egami (1983) attempted to quantify the ambient impact of project related emissions by applying the air-quality simulation model known as "Valley." Valley is an EPA-approved, complex-terrain model that is most frequently used as a screening-level model for 24-hour periods. Screening indicates that many physical parameters are not well known such as exact emission rates and locations, plume rise and velocity, and onsite meteorology. Thus, assumptions are made that result in worst-case ambient concentrations.

For modeling purposes, short-term worst-case meteorological conditions are defined as a very stable atmosphere and a constant wind speed of 2.5 m/s (8.2 ft/s) in one of 16 compass directions for 6 of 24 hours. These conditions would most likely occur during late evening and early morning, and they do not necessarily correspond to peak working hours at the repository. In fact, emissions during this stable period could be at a minimum.

Two possible locations for the exploratory shaft have been modeled: one is along the ridge of Yucca Mountain, and the other is on the eastern slope of Yucca Mountain. For modeling purposes, the repository was assumed to be a square area of 280 ha (700 acres) with a uniform emission rate over the entire area. Because the Valley model was developed for evaluating the impacts from a single, elevated-point source, this assumption is not entirely appropriate; however, it provides a screening-level assessment.

Table 5-14. Estimated particulate emissions from repository construction[a]

Source	Total (metric ton)[b]	Emission rate (g/s)[c]
Surface facilities[d]	1296	86.5
Mine construction[e]		
Shaft drilling/blasting	58	0.54
Subsurface[f]		
Drilling/blasting	4.4	0.04
Rockmoving		
Loading	13	0.12
Dumping	0.68	0.006
Surface rock transport		
Loading	1500	13.9
Hauling	2700	25.0
Dumping	77	0.7
Wind erosion	1000	6.5
Concrete		
Batching	20	0.19
Sand and gravel processing	17	0.15
Transportation related[g]	7.0	0.06

[a] Source: Bowen and Egami, 1983.
[b] 1 metric ton = 2.205×10^3 lb.
[c] 1 gram/sec = 2.205×10^{-3} lb/sec.
[d] Total emissions and emission rate for one-year assumed duration of this activity.
[e] Conventional drill/blast/muck-removal techniques have been assumed.
[f] Emissions calculated assuming conventional subsurface controls.
[g] Includes diesel fuel useage.

Table 5-15. Estimated total potential gaseous emissions during repository construction[a,b]

Pollutant	Total (metric ton)	Emission rate g/s[c] (5 years)
Carbon monoxide	22.0	0.20
Hydrocarbons	8.0	0.07
Nitrogen oxides	114.4	1.06
Sulfur dioxide	7.2	0.07

[a] Source: Bowen and Egami, 1983.
[b] From internal combustion engines.
[c] 1 g/s = 2.205 x 10^{-3} lb/sec.

Table 5-16. Estimated maximum 24-hour concentrations of pollutants from repository construction[a,b]

Pollutant	Emission rate (g/s)[c]	Predicted impact ($\mu g/m^3$)	
		Ridge location[d]	Valley location[e]
Total suspended particulate	133.7	130	132
Carbon monoxide	0.2	0.2	0.2
Hydrocarbons	0.1	0.1	0.1
Nitrogen oxides	1.1	1.1	1.1
Sulfur dioxide	0.1	0.1	0.1

[a] Source: Bowen and Egami, 1983.
[b] Modeled year includes surface facility construction that would not last the duration of the 5-year period.
[c] 1 gram/sec = 2.205×10^{-3} lb/sec.
[d] Maximum concentration occured 1.5 km (1 mi) SSW of the repository location.
[e] Maximum concentration occured 1.0 km (0.6 mi) ENE of the repository location.

(To be included on page 5-41)

For mathematically linear models such as Valley, ambient concentrations are directly proportional to emission rates. Thus, the modeled concentrations that had been obtained by assuming a 7-year construction period (Bowen and Egami, 1983) can be extrapolated to a 5-year construction period. The Valley-predicted maximum 24-hour concentrations are shown on Table 5-16. The worst-case emission scenario, in which all activities indicated in Tables 5-14 and 5-15 occur simultaneously, is also shown in Table 5-16.

A comparison can be made of the predicted construction impacts (Table 5-16) with the ambient air quality standards presented earlier (Table 5-13). Such a comparison indicates that none of the predicted pollutant concentrations would violate applicable standards.

If the project were subject to PSD requirements, these impacts would also have to be evaluated against applicable pollutant increment levels. Because of the uncertainties involved in many of the emission estimates and modeling assumptions, however, evaluation of PSD-related impacts have not been addressed.

In addition, the analyses described in the preceding section have assumed that fugitive-dust control measures would not be used. However, such measures are available, and could be used to further reduce emissions. For example, watering exposed surfaces twice daily would reduce emissions by about 50 percent, and chemical suppressants can reduce emissions by 80 percent on completed cuts and fills (EPA, 1974a). In general, by using proper techniques, emissions during construction of the repository could be reduced to a level less than one-half of that assumed in this conservative analysis.

Emissions from completed dirt roads can be reduced by traffic control. They can also be reduced 85 percent by paving, 50 percent by treating the surface with penetrating chemicals, and 50 percent by working soil-stabilization chemicals into the road bed (Bowen and Egami, 1983). Storage piles of waste rock could be treated with chemicals to inhibit resuspension, and the waste pile area could be revegetated.

In addition to potential impacts on ambient air quality, a potential health hazard to miners may exist because of the existence of zeolite mineral types that contain crystal habits similar to those of asbestos. The potential for health effects from exposure to minerals will be investigated further during site characterization.

5.2.5.3 Operation and transportation

Nonradiological emissions associated with operation of the repository include both dust from surface handling of mined materials and combustion products from burning diesel fuel. Dust emissions from surface handling of mined materials were discussed in Section 5.2.5.2 and were represented in Table 5-14. Based upon estimates of diesel-fuel usage (McBrien and Jones, 1984) and emission factors (URS, 1977), the total emissions from construction, operation, retrievability, and decommissioning are shown on Table 5-17.

Based upon the results of the preliminary Valley modeling, these emission rates do not indicate future violations of any ambient air standards. Furthermore, part of the diesel emissions would be underground and would be filtered before being released to the atmosphere; this would slightly reduce both the amount and the rate of emissions as listed on Table 5-17.

Emissions would also occur from commuter traffic to and from the site. Total emissions have been estimated on the basis of gasoline usage estimated in a report by URS (1977) for a 35-year emission duration, and they are shown on Table 5-18. Considering the diverse area over which emissions would occur and the long duration of the emissions, these emission levels should have no significant impact on ambient air quality.

Wind erosion from waste-rock storage piles would cause resuspension of some particles. Also, unpaved roads at the site would be a source of fugitive dust emissions during repository operation. The amount of fugitive dust that could be generated depends upon the extent of such roads and the control measures to be employed; neither factor is known at this time.

Transport of nuclear wastes to the repository would result in emissions from trucks and trains. Because the amount of waste to be transported by each mode is not known at this time, it was assumed that emissions would be generated either 100 percent by rail or 100 percent by truck. Using estimates of

Table 5-17. Estimated emissions during 60 years of repository construction, operation, retrievability, and decommissioning phases based upon diesel fuel use[a]

Years and phase	Pollutant[b] CO	HC	NO_x	SO_2	Particulates
1-5: Construction					
Total (metric tons)[c]	22.0	8.0	114.4	7.2	7.0
Emission rate[d] (g/s)[e]	0.20	0.07	1.06	0.07	0.06
6-35: Operation					
Total (metric tons)	214.5	78.3	1114.2	70.4	67.9
Emission rate (g/s)	0.33	0.12	1.72	0.11	0.10
36-55: Retrievability					
Total (metric tons)	7.8	2.8	40.4	2.6	2.5
Emission rate (g/s)	0.02	0.01	0.09	0.01	0.01
56-60: Decommissioning					
Total (metric tons)	8.1	3.0	42.3	2.7	2.6
Emission rate[f] (g/s)	0.11	0.04	0.60	0.04	0.04

[a] Source: McBrien and Jones, 1984.
[b] CO = carbon monoxide; HC = hydrocarbons; NO_x = nitrogen oxides; SO_2 = sulfur dioxide.
[c] 1 metric ton = 2.205×10^3 lb.
[d] Based on three 8-hour shifts, 250 days per year.
[e] 1 g/s = 2.205×10^{-3} lb/sec.
[f] Based on two 8-hour shifts, 250 days per year.

(Table 5-18 to be dropped in)

diesel fuel consumption (Table 5-9) and related emission factors (URS, 1977); EPA, 1981), emission estimates from transportation of waste to the site were calculated and are shown in Table 5-19.

Appendix A states that the total one-way shipping distance by rail is 55×10^6 km (34×10^6 mi) and 300×10^6 km (186×10^6 mi) for truck. The estimated emissions, when dispersed over this distance during the life of the project, should have a negligible effect on ambient air quality.

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Table 5-18. Estimated total emissions for 35 years from commuter traffic[a]

Pollutant	Total emissions (metric ton)[b]
Carbon monoxide	27,075
Hydrocarbons	946
Nitrogen oxides	804
Sulfur dioxides	36
Total suspended particulated	50

[a] Source: URS, 1977.
[b] 1 metric ton = 2.205×10^3 lb.

(To be included on page 5-45)

Table 5-19. Estimated emissions over 30 years from transportation of radioactive wastes[a]

Pollutant	100% rail transport (metric tons)[b]	100% truck transport (metric tons)
Carbon monoxide	3,290	8,630
Hydrocarbons	2,390	3,130
Nitrogen oxides	9,370	44,800
Sulfur oxides	1,440	2,830
Total suspended particulates	630	2,730

[a] Source: URS, 1977.
[b] 1 metric ton = 2.205×10^3 lb.

5.2.5.4 Decommissioning

Decommissioning could consist of partially backfilling the mined shafts and drifts with material from the storage piles closing the facility, and restoring the surface to a condition that would be similar to its original topography. This would cause fugitive dust emissions from loading, hauling, dumping, and surface restoration. Gaseous and particulate emissions would occur from construction equipment and commuter traffic (Bowen and Egami, 1983). No particulate emission rate other than for diesel fuel combustion (Table 5-17) can be determined at this time. In any case, the extent of these activities would be limited in comparison to construction activities and are not expected to create significant ambient impacts when spread over five years.

5.2.6 Noise

Wildlife is the only sensitive noise receptor in the uninhabited desert. The effects of noise on wildlife are speculative. Laboratory and field experiments have shown both permanent and temporary physical and behavioral effects at levels in the 75 dBA to 95 dBA range (EPA, 1971; Ames, 1978; Brattstrom and Bondello, 1983). For purposes of this analysis, continuous 75 dBA noise was assumed to be the level at which wildlife would be affected.

Investigators studying incremental noise levels that affect humans have concluded that an annual increment of 5 dBA should be considered significant (EPA, 1974b). Assuming that small towns in the vicinity of Yucca Mountain experience an annual average noise level of 50 dBA, this increment would increase the annual level to 55 dBA for the small towns characterized in Chapter 3. A composite annual day/night noise level (L_{dn}) of 55 dBA has been declared to be the level that will protect public health and welfare (EPA, 1974b). Therefore, this analysis will use an annual L_{dn} of 55 dBA as the level above which people in residential areas may begin to experience some annoyance.

5.2.6.1 Construction

Construction noise sources include the use of construction equipment and the transportation of workers and materials to the site. Construction activities that would produce noise include building the surface facilities, the rail line, the bridge over Fortymile Wash, an access road, and mining the repository shaft. All five of these activities are expected to occur simultaneously during the first two years of repository construction.

Neither construction techniques nor routes for the road(s) and the rail have been specified yet. In the absence of this information, it has been assumed that construction equipment and manpower requirements are similar to those required in the construction of other large facilities. Maximum noise levels attributed to each piece of construction equipment are listed in Tables 5-20 and 5-21. These tables also list the area to be affected, sensitive receptors, and the resultant noise levels at 150 m (500 ft) from the focal point of construction activities. Because the resultant levels at 150 m (500 ft) have been developed assuming the maximum transient noise level of each

Table 5-20. Noise sources during site-characterization construction

Equipment	Maximum Noise level (dBA at 15m)	Construction activity and number of equipment units					
		Surface facilities	Each shaft	Access road	Rail spur	Rail spur bridge	Transmission line[a]
Air compressors	81[c]	1	1	0	0	0	0
Backhoes	85[c]	1	1	0	0	0	0
Boring machines	98[c]	1	1	0	0	1	1
Bulldozers	80[b]	1	1	5	5	5	0
Concrete mixers	85[c]	1	1	5	5	2	0
Cranes	83[c]	1	1	2	5	2	1
Drill rigs	101[b]	1	1	0	0	0	0
Dump trucks	88[b]	6	1	5	5	5	0
Earthmovers	78[b]	6	1	5	5	5	0
Front-end loaders	76[b]	6	1	5	5	5	0
Graders	88[c]	0	0	5	5	2	0
Grader/scrapers	88[c]	1	1	0	0	0	0
Gravel elevators	88[c]	1	1	0	0	0	0
Pile drivers	101[c]	0	0	0	0	3	0
Rollers	80[c]	0	0	5	5	0	0
Service vehicles	88[c]	30	5	10	10	5	2
Shovels	82[c]	1	1	2	5	5	0
Steam rollers	75[b]	1	1	0	0	0	0
Truck handling conveyors	88[c]	1	1	0	0	0	0

[a] Assumes that the transmission line is placed along the right-of-way for the rail line and that construction follows clearing for the rail line.
[b] Henningson, Durham and Richardson Sciences, 1980.
[c] EPA, 1974b.

Table 5-21. Summary of noise impacts from construction activities

Location of activity	Resultant maximum dBA level at 150 m[a]	Radius required to affect humans (km)[a]	Radius required to affect wildlife (km)	Area affected	Receptor affected
Repository					
Surface facilities	85	NA[b]	0.5	uninhabited desert	wildlife
Shafts	84	NA	0.4	uninhabited desert	wildlife
Access road	82	1.4	0.3	uninhabited desert town of Amargosa Valley	wildlife humans
Rail spur	82	1.4	0.3	uninhabited desert Indian Springs, Mercury	wildlife humans
Rail spur bridge	86	NA	0.5	uninhabited desert	wildlife
Transmission line	79	1.3	0.2	uninhabited desert Indian Springs, Mercury	wildlife humans

[a] 1 m = 3.28 ft; 1 km = 0.621 mile.
[b] NA = not applicable.

piece of equipment is sustained throughout the construction day, the analysis is conservative. Furthermore, the analysis assumes that geometric divergence of the sound waves provides the only attenuation. Again, this represents a conservative analysis because it excludes possible attenuation due to absorption and barrier effects. Table 5-21 summarizes the noise levels from construction and indicates the radial distances required to attentuate the construction noise to below 75 dBA (the level assumed to affect wildlife) or 55 dBA (the level asumed to affect humans). In developing the radial distance required to achieve an annual L_{dn} of 55 dBA, it was assumed that construction would last 10 hours per day, 250 days per year, for all offsite construction activities. Repository-related construction activities are assumed to be 24 hours per day, 250 days per year.

The radial distances associated with reaching an annual L_{dn} level of 55 dBA suggests that impacts may occur. The access road is expected to pass within 0.8 km (0.5 mi) of the town of Amargosa Valley. The radial distance of 1.4 km (0.9 mi) for the access road suggests that some residents may experience noise-related annoyance while construction operations are within 1.4 km (0.9 mi) of town. Construction of the rail line also carries a 1.4 km (0.9 mi) impact radius. This would affect residents in Indian Springs. People in Mercury and users of Floyd R. Lamb (formerly Tule Springs) State Park should not be affected by noise because the rail line will probably not pass within 1.4 km (0.9 mi) of Mercury or of the park. Impacts to wildlife should be limited to the immediate vicinity of the construction sites.

Noise would also occur during transportation of workers to and from the site and from transportation of materials to the site. Based upon preliminary information on transportation, as is detailed in Section 5.3, worker transport during the night shift would have the greatest noise impacts. Incremental noise has been estimated and is based on the following:

1. Existing or baseline noise has been assumed using the 1996 projected traffic flows (see Section 5.3).

2. Off-peak traffic flow is evenly distributed throughout the remainder of the day.

3. The average speed of vehicles is 80 km per hour (50 mph).

4. Nevada Test Site traffic patterns would prevail.

Based upon these assumptions, incremental noise is anticipated to be approximately 4 dBA. It is generally accepted that 4 dBA is just over the value at which people begin to perceive a noise change. Assuming a 4 dBA increment during all three shifts, the annualized increment level would be approximately 2 dBA. This is below the EPA's significant level of 5 dBA. Therefore, no significant noise problems due to worker transport are anticipated at either the town of Amargosa Valley or at Indian Springs. It is estimated that wildlife that is farther than 240 m (800 ft) from the noise source would experience noise levels of 75 dBA or less when vehicles are passing by.

5.2.6.2 Operation

During operation of the repository, major noise sources would include underground rock-handling equipment, rail and truck waste transportation, and worker transport. Table 5-22 lists the type and number of vehicles expected to be used during operation, the equipment noise-levels, the area affected, the sensitive receptors, and the resultant noise levels at 150 m (500 ft).

(Table 5-22 to be dropped in)

Rail transport would average one train per day in each direction and would consist of a locomotive and approximately four to five cars carrying radioactive waste and construction material. Maximum noise levels at 30 m (100 ft) have been established by the EPA as 90 dBA for moving locomotives and 93 dBA for rail cars exceeding 72 km per hour (45 mph) (40 CFR Part 201). For a train with one locomotive and five cars, the noise level at a distance of 150 m (500 ft) would be approximately 86 dBA. This would result in maximum levels of approximately 67 dBA at Indian Springs, Floyd R. Lamb State Park, and Mercury. The level would begin to mask outdoor human communication where people were more than one meter apart (EPA, 1974b). Human indoor activities should not be disturbed by the resultant levels, however, if rail shipments occur at night when people are most sensitive to intrusive noise, more severe problems should be anticipated in nearby communities. The resultant radius at which there would be no impacts to wildlife would be approximately 610 m (2000 ft).

Truck transport of concrete, steel, and diesel fuel could average 13 vehicle trips per day in each direction during the first two years of repository construction. Given an average daily traffic count of 1450 in the town of Amargosa Valley, 247 of which are trucks (written communication from

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Table 5-22. Maximum noise levels from operation of the repository

Equipment	Maximum Noise level (dBA at 15 m)	Number of vehicles
Bulldozers	80[a]	2
Earthmovers	78[a]	5
Front-end loaders	76[a]	5
Rock elevators	88[b]	2
Service vehicles	88[b]	25

Resultant Noise Level at 150 m (500 ft): 82 dBA
Area affected: Uninhabited desert
Receptors affected: Wildlife

[a] Henningson, Durham and Richardson Sciences, 1980.
[b] EPA, 1974b.

(To be included on page 5-50)

State of Nevada Department of Transportation, Carson City, 1983, information on traffic flow, accidents, and traffic projections), no noise impacts are anticipated to the residents. The resultant radius to avoid impacts to wildlife along the access road is 47 m (150 ft) assuming a truck noise level of 85 dBA at 15 m (50 ft).

During the operational period, worker transport would be less than it would be during construction. Furthermore, background, or existing, traffic is expected to increase. Therefore, increased noise due to an incremental traffic increase would be less than that predicted for the construction period. As with the construction period, however, no significant impacts are expected either for the communities of Amargosa Valley or Indian Springs.

5.2.6.3 Decommissioning

Decommissioning and closure operations would result in elevated noise levels from operation of construction equipment and from worker transport. The postclosure period would not contribute to noise.

Construction equipment that would be used during this phase is listed in Table 5-23. This table also indicates the location and number of construction vehicles, noise levels of the equipment, resultant noise levels at 150 m (500 ft), and the areas and the sensitive receptors that could be affected. Based upon these values, the resultant impact radius is 300 m (1000 ft) for decommissioning and closure of surface facilities and 150 m (500 ft) for decommissioning of shafts.

Worker and material transport during this phase will be approximately one third of that previously analyzed for construction activities. Based on that analyses (Section 5.2.6.1), no impacts on the human population are predicted. Wildlife may experience noise levels above 75 dBA within about 240 m (800 ft) of the roadway when vehicles are passing by.

5.2.7 Aesthetic resources

The construction and operation of a repository and its supporting facilities would have an impact on the visual aesthetics of the area. However, this impact is not expected to be either significant or controversial.

During the construction of the railway and access road, equipment and construction crews would be visible along U.S. Highway 95. When they are in place, the rail line, the transmission lines, and the paved road would be visible to travelers along U.S. Highway 95. Most of the construction crews, and equipment at Dike Siding, would be far from population centers. In addition, the repository surface facilities would be constructed in a limited-access area and would not be visible from U.S. Highway 95. Overall, aesthetic impacts would be minimal.

(Table 5-23 to be dropped in)

5.2.8 Archaeological, cultural, and historical resources

Both direct and indirect impacts have been considered in evaluating the potential impacts to the archaeological resources. Direct impacts, including destruction of archaeological sites, may occur during repository construction, operation, closure, and decommissioning. Direct impacts can also result from road and railway construction, drilling, stockpiling of mined material, and construction of surface facilities.

Impacts from repository operation would be less than those associated with repository construction. No further construction is expected to take place during the operations phase, except for the possible installation of an additional transmission line. No additional impacts are expected during closure and decommissioning because no new areas would be disturbed.

The case-by-case preservation or data recovery approach developed for use during site characterization may not be continued. Instead, a representative and scientifically based sample of significant cultural resources has been recomended for use if a repository is constructed at Yucca Mountain. The recommended program would treat the project area as a whole, rather than as a series of unrelated sites. An integrated site recovery program would provide a better scientific data base than a case-by-case program and could be submitted to the Nevada Division of Historic Preservation and Archaeology and the Advisory Council for a single review and approval instead of review and

Table 5-23. Noise levels from decommissioning operations

Equipment	Noise level (dBA at 15 m)	Number and location of vehicles anticipated	
		Surface facilities	Each shaft
Bulldozers	80[a]	6	1
Concrete mixers	85[b]	1	1
Earth movers	78[a]	1	1
Graders	88[b]	1	1
Dump trucks	88[a]	6	1
Cranes	83[b]	1	1
Front-end loaders	76[a]	1	1
Shovels	82[b]	1	1
Service vehicles	88[b]	12	2

Resultant noise level at 150 m (500 ft):
Surface facilities: 81 dBA
Each shaft location: 75 dBA
Areas affected: Uninhabited desert
Receptors affected: Wildlife

[a] Henningson, Durham and Richardson Sciences, 1980.
[b] EPA, 1974b.

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approval on a case-by-case basis. Indirect impacts can result either from unauthorized excavation and collection of artifacts or from vandalism of cultural sites. To avoid indirect adverse impacts, off-road travel would be restricted. As is specified under the Archaeological Resource Protection Act of 1979, employees of the repository would be informed of policies regarding archaeological sites and the penalities for unauthorized collections and excavation at these sites.

Archaeological and historical sites located outside the Yucca Mountain site and the Nevada Test Site may also experience indirect impacts from construction and operation of the repository. However, it should be noted that these sites are accessible to residents of the Las Vegas area who are not affiliated with the repository. Therefore, it is impossible to differentiate the impact that the increased population associated with the repository would have, although it is reasonable to assume that a larger number of people could result in a greater impact to these resources.

5.2.9 Radiological effects

This section discusses the possible radiological effects from repository construction and operation. Since much of the following discussion focuses on radiological effects, a brief review of the relevant terminology is in order.

A curie (Ci) is a unit used to describe the number of atoms undergoing radioactive decay per unit time. One Ci is equal to 3.7×10^{10} disintegrations per second. The International System of Units (SI) unit for radioactivity is the Becquerel (Bq), where 1 Bq is equal to 1 disintegration per second. The mass of a 1-Ci amount of radioactive material can vary dramatically depending on the half-life (i.e., the time it takes for one-half of the atoms initially present to decay) of the isotope. For example, 1 Ci of Co-60 is equal to less than 1 mg, 1 Ci of Ra-226 is 1 g, and 1 Ci of U-238 is about 3000 kg (6600 lb). The measure of activity as a function of mass is referred to as specific activity, and the unit of specific activity is Ci/g.

Absorbed radiation dose is a measure of the amount of ionizing radiation that is deposited in a given mass of absorbing medium. The unit of absorbed radiation dose is the rad; 1 rad is equal to 100 erg/g. The SI unit for absorbed radiation dose is the Gray (Gy), where 1 Gy is defined as an amount of absorbed dose equal to 1 Joule per kilogram (J/kg). 1 Gy is equal to 100 rads.

Since the biological damage inflicted by different types of radiation can vary, the quality factor (Q) is used as a measure of the relative biological effectiveness of a given type of radiation. The quality factor is directly related to the linear energy transfer (LET) of the radiation, which is a measure of the energy deposited per unit of path length. The unit of LET is a thousand electron volts (keV) per micron. Densely ionizing (high LET) particles such as protons, neutrons, and alpha particles are assigned quality factors of ten to twenty, while sparsely ionizing (low LET) radiation such as beta particles, X rays, and gamma rays are assigned a quality factor of unity. In essence, this means that densely ionizing radiation is approximately ten to twenty times as effective at inflicting biological damage per rad as sparsely ionizing radiation.

The concept of dose equivalent is used to describe the effectiveness of a given unit of absorbed radiation dose. The unit of dose equivalent is the rem; 1 rem is the product of 1 rad and the quality factor for the radiation in question. Thus, an absorbed dose of 1 rad of gamma rays is equal to a dose equivalent of 1 rem, and a dose of 1 rad of alpha particles is equal to a dose equivalent of 10 rem. The SI unit of dose equivalent is the Sievert (Sv); 1 Sv is the product of 1 Gy and Q (i.e., 1 Sv = 100 rem). If radioactive material is taken into the body (e.g., by inhalation or ingestion), some fraction will be deposited in various organs or tissues depending on the chemical and physical nature of that material. The deposited material will be reduced by a combination of physical and biological mechanisms, and the time required to eliminate half of the deposited material is called the effective half-life. Effective half-lives may range from a few days (e.g., soluble forms of H-3) to many years (e.g., insoluble forms of uranium or plutonium isotopes). The cumulative radiation dose equivalent that an individual is committed to receive as a result of intake and subsequent deposition is referred to as the dose commitment. The unit of dose commitment is the rem, and the period of time over which the dose commitment is integrated is usually 50 years.

5.2.9.1 Repository construction

Two families of radioactive heavy elements (the uranium and thorium series) are found in most rocks and soils, and they account for about one-third of the natural background radiation to which humans are exposed. For example, the concentration of uranium in rocks ranges from more than 300 parts per million (ppm) in phosphatic rocks in South Carolina, to from 1 to 4 ppm in other sedimentary rocks. These radioactive heavy elements exist in rocks in equilibrium with their decay products, and some of them are gaseous. The breaking and crushing of rocks, such as that which occurs in mining operations, may release these decay products to the atmosphere in much larger quantities than those that escape naturally through the fractures and pores of the rocks. The estimated quantities of these decay products that are released annually to the atmosphere due to mining activities are listed in Table 5-24. The quantity released is directly proportional to the volume of rock that is mined annually. In the vertical waste-emplacment repository design, approximately 2.5 times as much rock is mined as in the horizontal waste-emplacement design. Values in Table 5-24 were estimated from those given for a repository constructed in granite (DOE, 1980), which has approximately the same uranium and thorium content as Yucca Mountain rocks, by scaling with the ratio of total mined volume.

The enhanced release of naturally occurring radionuclides is estimated to result in whole-body dose commitments of 5 man-rem to the regional population for the horizontal waste-emplacement design and 12 man-rem for the vertical waste-emplacement design. By comparison, a regional population of 19,908 people within an 80-km (50-mi) radius of Yucca Mountain will receive an annual dose of 1800 man-rem from natural background radiation (Jackson, 1984).

(Table 5-24 to be dropped in)

5.2.9.2 Repository operation

The operating life of the repository would span 30 years. During that period, workers would be exposed to radiation from receiving, handling and packaging, and emplacing of wastes. The permissible dose equivalent limit for worker exposure is 5 rem per year (10 CFR 20) with a prescribed design objective. The facilities would be designed to reduce the annual exposure to individual workers and to the total repository work force to the lowest levels reasonably achievable.

Two types of high-level wastes are assumed to be shipped to the Yucca Mountain repository: spent reactor fuel and commercial high-level waste (CHLW). The repository is being designed to accept the equivalent of 70,000 metric tons of heavy metal (MTHM). The occupational exposures that have been calculated and reported in the following paragraphs are for an assumed waste composition of 50 percent spent fuel and 50 percent CHLW. These dose estimates will not change substantially if other waste compositions (e.g., 100 percent spent fuel or 100 percent CHLW) are assumed.

Worker exposure during normal operation

Specific operations were identified, individual tasks were listed, and operation times were allocated so that estimates could be made of the radiation exposure to workers at the repository during the receipt, handling and emplacing of high-level wastes (Dennis et al., 1984). The number of individual workers assigned to crew positions was estimated from the annual waste receipts and anticipated facility operations time. The annual worker exposure for each task and each individual was calculated from the anticipated operations time, the estimated worker exposure times for each task, the radiation field in which

Table 5-24. Estimated releases of naturally occuring radionuclides to the atmosphere from repository construction

Nuclide	Releases (curies/yr)	
	Horizontal emplacement	Vertical emplacement
Radon-220	1.6	3.8
Radon-222	1.6	3.6
Lead-210	1.2×10^{-4}	8.0×10^{-4}
Lead-212	2.3×10^{-3}	5.7×10^{-3}
Lead-214	1.5	3.6
Bismuth-210	1.5	3.6

the operation was performed, and the annual receipt and handling rates of spent fuel and CHLW.

Gamma-ray and neutron source intensities were calculated using the isotope generation and depletion code ORIGEN2. Shipping cask designs were used in conjunction with the three-dimensional radiation transport code, PATH, to develop dose rate maps around spent fuel and CHLW shipping casks. The results of these analyses are presented in Table 5-25.

Table 5-25 dropped here

The total annual worker exposure at the repository is estimated to be about 79 man-rem during receipt, handling and emplacing high-level radioactive wastes. Over the 30-year life of the repository, the estimated collective worker radiation dose is 2365 man-rem.

Public exposure during normal operation

The two principal pathways by which the offsite population may be potentially exposed from normal (nonaccident) repository operation are external exposure to direct radiation during receipt, handling, and emplacing high-level wastes; and exposure to airborne effluents. The former pathway would result in insignificant public exposures both because of the shielding and packaging measures that would be taken to reduce occupational exposures and because of the large distance (several miles) that separates the source from the receptor. Exposure to airborne effluents is not significant because of the negligible quantities of these emissions coupled with the dilution of effluent concentrations over the transport distance. In light of these facts, a quantitative estimate of public exposures resulting from normal repository operation was not made.

Accidental exposure during operation

The potential causes of accidental releases to the general public and to repository operations personnel can be divided into three categories: natural phenomena, external man-made events, and operational accidents (Tables 5-26 and 5-27). Under natural phenomena, three scenarios are postulated that could cause radionuclide releases: flooding, tornadoes and earthquakes. The external man-made events which could cause a release are aircraft impact and underground nuclear weapons testing (Jackson, 1984). The five operational

Table 5-25. Summary of expected occupational exposures from repository operation[a,b]

Operation	Number of workers	Average worker dose (rem/yr)	Cumulative worker dose (man-rem/yr)[c]
Receiving	35	1.28	44.8
Handling and packaging	16	0.43	6.9
Surface storage to emplacement horizon	14	0.43	6.0
Emplacement			
Vertical	18	0.69	12.4
Horizontal	7	1.25	8.7

[a] Source: Dennis et al., 1984.
[b] See text for assumptions.
[c] Cumulative for all workers.

Table 5-26. Preliminary population dose commitments from postulated accidents[a]

Scenario[b]	Maximally exposed individual[c]: Whole-body equivalent dose (rem)	General population: Population exposed (number)	General population: Whole-body equivalent dose (man-rem)
<u>Natural phenomena</u>			
Flood	1.59×10^{-5}	29[d]	4.61×10^{-4}
Earthquake	2.34×10^{-4}	19,908	3.07×10^{-3}
Tornado	2.34×10^{-4}	19,908	3.07×10^{-3}
<u>Man-made external events</u>			
Underground nuclear explosives test	2.34×10^{-4}	19,908	3.07×10^{-3}
Aircraft impact	3.28×10^{-1}	19,900	1.21×10^{2}
<u>Operational accidents</u>			
Fuel assembly drop in hot cell	5.14×10^{-6}	19,908	8.21×10^{-5}
Transportation accident and fire at loading dock			
Spent fuel	2.42×10^{-4}	19,908	4.04×10^{-3}
CHLW	4.35×10^{-5}	19,908	4.76×10^{-4}
Transportation accident and fire on waste handling ramp	9.64×10^{-9}	19,908	1.32×10^{-7}
Transporation accident and fire in repository emplacement drift	9.64×10^{-9}	19,908	1.32×10^{-7}

[a] Source: Jackson, 1984.
[b] Except for the transportation accident outside facility where both spent fuel and CHLW are evaluated, all scenarios are based on spent fuel.
[c] Radiation safety levels in 10 CFR Part 60: 0.5 rem whole-body dose per accident.
[d] Only population in the zone directly south of Drillhole Wash is exposed.

Table 5-27. Preliminary worker dose commitments from postulated accidents[a]

Scenario[b]	Single worker whole-body equivalent dose[c] (rem)[c]
<u>Natural phenomena</u>	
Flood	[d] 1.80×10^{-11}
Earthquake	[d] 5.71×10^{-1}
Tornado	[d] 5.71×10^{-1}
<u>Man-made external events</u>	
Underground nuclear explosives test	[d] 5.71×10^{-1}
Aircraft impact	[e] 6.16×10^{0}
<u>Operational accidents</u>	
Fuel assembly drop in hot cell	[f] 1.25×10^{-2}
Transportation accident and fire at loading dock	
Spent fuel	[g] 4.00×10^{0}
	[g] 1.01×10^{-2}
CHLW	[g] 6.9×10^{-1}
	[g] 1.75×10^{-3}
Transportation accident and fire and fire on waste handling ramp	[h] 7.23×10^{1}
	[i,j] 4.98×10^{1}
	[i,j] 1.28×10^{1}
	[i] 7.50×10^{-2}
Transporation accident and fire in repository emplacement drift	[j,k] 1.86×10^{2}
	[j,k] 1.57×10^{1}
	[k] 7.50×10^{-2}

[a] Source: Jackson, 1984.

[b] Except for the transportation accident and fire at the loading dock where both spent fuel and CHLW are evaluated, all scenarios involve spent fuel.

[c] Worker exposure limit in 10 CFR Part 20: 5.0 rem/yr; 3 rem/qtr.

[d] Only waste-handling facility workers are assumed to be exposed.

[e] All waste-handling facility workers are assumed killed. Other surface and subsurface personnel are assumed to be exposed as a consequence of the accident.

[f] All surface and subsurface personnel are assumed to be exposed equally as a consequence of the accident.

[g] Workers at the waste-handling facility loading dock receive the maximum dose; remaining personnel receive the smaller dose.

[h] Workers in the waste-handling ramp area receive the maximum dose.

[i] Waste emplacement workers receive a smaller dose than workers in the ramp area. Remaining personnel aboveground receive the smallest dose.

[j] Horizontal emplacement of waste canisters requires an estimated 40 subsurface workers; vertical emplacement requires an estimated 60 subsurface workers.

[k] Waste emplacement workers receive a greater dose than aboveground operations personnel.

accidents considered to be potential sources of radionuclide release are: (1) a fuel assembly drop in a hot cell; (2) a transportation accident and fire outside the surface facility involving spent fuel; (3) a transportation accident outside the surface facility involving commercial high-level waste; (4) a transportation accident and fire on the waste handling ramp; and (5) a transportation accident and fire in an emplacement drift.

The principal exposure pathway for the accident scenarios analyzed is atmospheric transport. Immersion in contaminated flood water is an exposure mechanism only for workers in the flooding scenarios. No significant water ingestion pathway was identified. Ingestion of meat, milk, and crops grown on land contaminated by radionuclides is considered to be a minor exposure pathway for the general public because of the low level of agricultural activity in the surrounding area. Fifty-year dose commitments were calculated for the maximally exposed individual, for the general public, and for operations personnel for each of the 10 accident scenarios. The maximally exposed individual is a member of the public whose location and habits tend to maximize the radiation dose he receives from a postulated accident. In this analysis, this individual is located just outside the exclusion boundary, which is 4 km (2.5 mi) directly west of the surface facility. The results of this analysis (Jackson, 1984) are given in Table 5-26.

All exposures to the maximally exposed individual and to the general public are less than the radiation exposure limit set (0.5 rem/accident) by the NRC (10 CFR Part 20). The most severe exposure to the maximally exposed individual is 0.328 rem from the postulated aircraft impact scenario.

5.3 EXPECTED EFFECTS OF TRANSPORTATION ACTIVITIES

Transportation effects occur from (1) the use of the existing and projected transportation network to move people and materials to and from the proposed Yucca Mountain repository site and (2) the use of the projected transportation network to move high-level waste through the state to the site.

This section discusses the expected effects for these two activities for the repository construction, operation, and decommissioning phases. Because the retrievability phase would have the smallest effects, its effects are not analyzed.

5.3.1 Traffic volume impacts

The impacts of increased traffic volumes on highway and railroad transportation networks during the construction, operation, and decommissioning phases are discussed in the following sections.

5.3.1.1 Highway impacts

Effects on the highway infrastructure would be limited to those associated with increased traffic because no roads are planned to be improved for the sole purpose of transporting people and material to the repository site.

Construction

For purposes of this analysis, it is assumed that construction would begin in 1993 and would reach its peak in 1996 when approximately 1570 workers would be employed during the day shift (Section 5.1). This represents the peak work force that is expected for the most intensive scenario (i.e., vertical emplacement of waste); therefore, it represents the worst-case scenario. Impacts from both night-shift and swing-shift workers would be less than those from the day shift because there are fewer workers involved and there is less traffic during these hours.

The projected travel patterns of these day-shift workers are derived from current Nevada Test Site employee residence patterns as shown in Table 5-28. Figure 5-9 indicates that U.S. Highway 95 between the junction with the site access road and Las Vegas would be the most severely impacted. This highway would carry 98 percent of the day-shift employees. Seventy-six percent of the work force would terminate their trip in Las Vegas and another 6 percent would travel beyond Las Vegas.

The transport of material would peak during the first two years of construction (Table 5-5). However, the peak for workers would not occur until

(Table 5-28 to be dropped in)

the third year of construction (i.e., 1996). To conservatively estimate the impacts to U.S. Highway 95 traffic flow the following assumptions have been made:

1. All truck traffic would approach the site from Las Vegas along U.S. Highway 95;
2. Vertical emplacement of waste would occur; and
3. Peak transport of material would coincide with peak worker traffic.

These conservative assumptions should more than compensate for any material transport that was not accounted for in Section 5.1. By using these assumptions, the estimated material requirements (Table 5-5) and assuming 250 delivery days per year, it has been determined that during the first two years of construction there would be 13 round trips per day of trucks carrying material. Assuming that construction equipment is brought into the site over the first six months of construction, trucks carrying construction equipment would average four round trips per day. Assuming these trips would be spread evenly throughout the day shift, about 4 trucks per hour would pass any given point

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Table 5-28. Settlement patterns of Nevada Test Site employees[a]

Location	Percent of employee residences
Urban Clark County (Las Vegas)	66.1
North Las Vegas	9.5
Pahrump	6.0
Mercury	4.8
Indian Springs	4.0
Henderson	3.0
Tonopah	1.8
Alamo	0.6
Beatty	0.1
Boulder City	0.4
Town of Amargosa Valley	0.3
Other Nevada towns	1.6
California	0.7
Utah	0.5
Arizona	0.4
Other	0.2
Total	100

[a] Source: Preliminary information based on ZIP codes of NTS personnel and contractors, 1983.

(To be included on page 5-[illegible].

along the route. To be conservative, the following analysis assumes five trucks per hour.

The projected repository traffic must be evaluated against likely conditions in 1996. As noted in Section 3.5, evening peak-hour traffic flow is of critical importance. Table 5-29 compares 1996 traffic patterns on U.S. Highway 95 with and without the repository during the evening peak hour. In developing Table 5-29, several of the highway segments shown on Figure 5-9 were subdivided. This was done to account for traffic volumes that were not related to the repository and to account for varying road conditions, both of which would affect the level of service. (The level of service categories are discussed in Section 3.5.)

Table 5-29 indicates that the level of service would decline beginning 8 km (5 mi) east of Amargosa Valley to Las Vegas. The decline is moderate for the segment between the site access road and SR 160, but the level at the Mercury interchange approaches undesirable conditions. (See Table 3-10 for definitions of service levels). Baseline traffic for segment E has the lowest level of service for 1996 along any of the evaluated segments of U.S. Highway 95. Furthermore, the incremental traffic due to the repository would not be as great for this segment as for segments B and C. In segments B and C, traffic increases due to the repository are more than twice the baseline traffic; and for segment E the increase is from 1.5 to 1.8 times baseline traffic. This suggests that baseline traffic volumes and road conditions are prime factors contributing to a low service level. This two-lane road segment has very poor passing capabilities. However, this low service level is only expected to occur during the worst-case year (1996).

As can be seen from the preceding discussion, repository construction traffic would have its greatest impact on U.S. Highway 95 between the site access road and Las Vegas. Predicted accidents for 1996 along U.S. Highway 95 both with and without repository-related traffic are shown in Table 5-30. These predictions were calculated by assuming a linear relationship between vehicle-miles traveled and accident rate data (written communication from State of Nevada, Department of Transportation, Carson City, 1983, information on traffic flow, accidents, and traffic projections). Table 5-30 shows that under worst-case conditions approximately 13 additional accidents may be expected due to peak construction-related traffic. These additional accidents could result in six additional injuries and one additional death over a one-year period. The accident rates suggest that the most likely place for accidents is segment E which is between SR 160 and the Mercury interchange. This estimate is consistent with the results shown on Table 5-29, which indicates that this segment has the lowest level of service either with or without the repository. For this segment, peak repository-related construction traffic would be expected to cause an additional three accidents, which includes one injury over a one-year period.

Operation

It is assumed that operation of the repository would begin in 1998. During the 30 years the repository is to be in operation, traffic would be generated by workers and their families and by delivery of both construction and high-level radioactive waste material. The construction-related

Table 5-29. Projected traffic patterns on U.S. Highway 95 during evening peak hour (5-6 p.m.), 1996[a]

	Highway segment (see Figure 5-8)	Without repository (baseline)			With repository		
		Number of cars	Number of trucks	Service level obtained[b]	Number of cars	Number of trucks	Service level obtained[b]
B	Site access road to the town of Amargosa Valley	119	24	B	422	63	B
C	Town of Amargosa Valley to 5 mi east of the town of Amargosa Valley	153	30	B	454	68	B
C	5 mi east of the town of Amargosa Valley to SR 160	153	30	B	454	68	C
E	SR 160 to NRDA Road	156	30	B/C	438	66	D
E	NRDA Road to Mercury interchange	188	23	B/C	469	59	D
F	Mercury interchange to Indian Springs	319	81	B	585	116	C
G	Indian Springs to SR 156	336	86	B	590	119	C
G	SR 156 to northern city limits of Las Vegas	376	96	B	630	130	C

[a] Source: Written communication from State of Nevada, Department of Transportation, Carson City, 1983, information on traffic flow, accidents, and traffic projections.
[b] See Table 3-10 for definition of service levels.

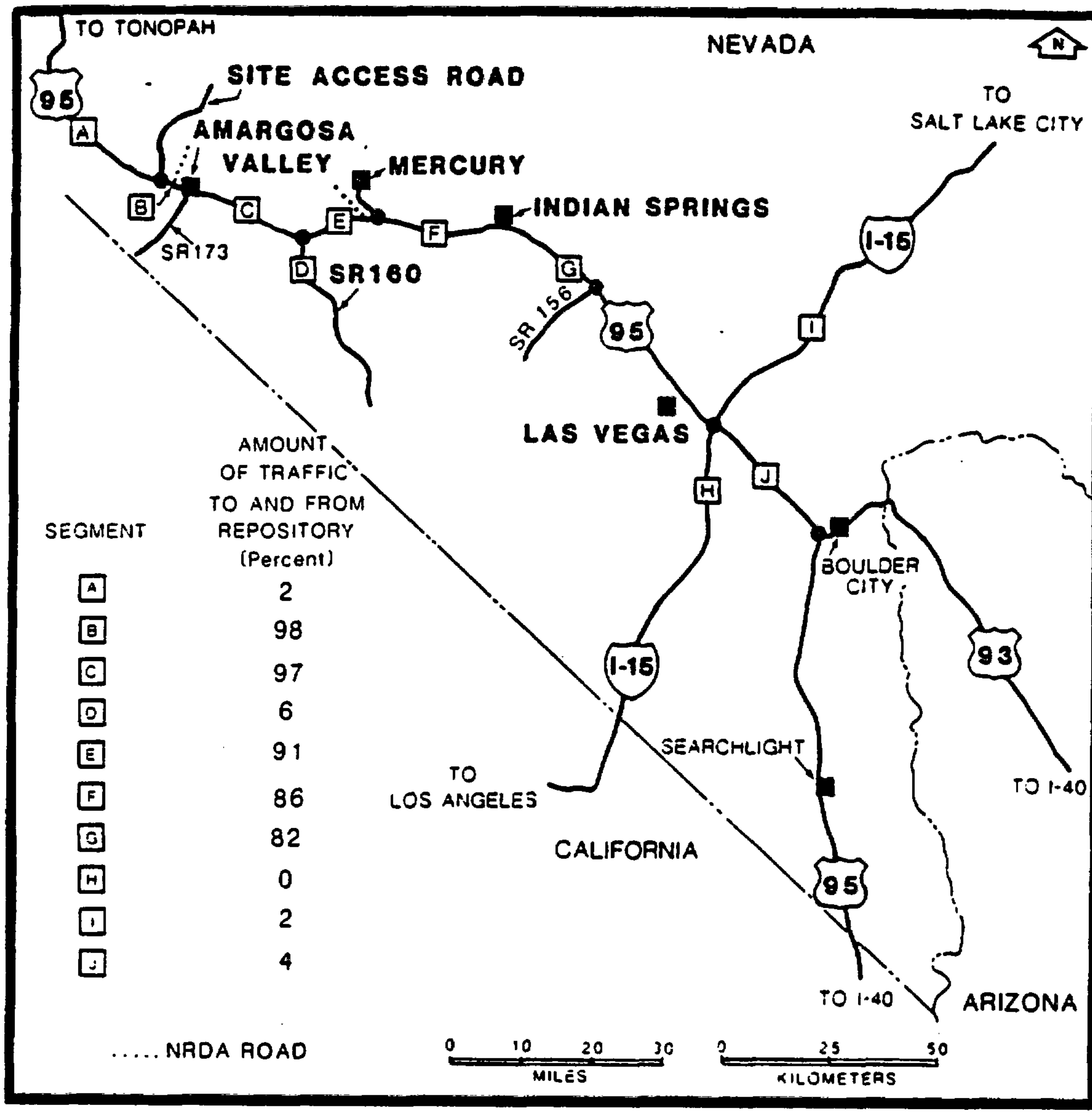

Figure 5-9. Employee travel patterns for the Yucca Mountain repository.

Table 5-30. Projected annual accidents on U.S. Highway 95, 1996[a]

	Highway segment (see Figure 5-8)	Without repository (baseline)				With repository			
		Vehicle mi x 10^3	Accidents	Injuries	Fatalities	Vehicle mi x 10^3	Accidents	Injuries	Fatalities
B	Site access road to the town of Amargosa Valley	442	0	0	0	530	1	0	0
C	The Town of Amargosa Valley to 5 mi east of the town of Amargosa Valley	5,651	5	3	1	6,526	5	3	1
C	5 mi east of the town of Amargosa Valley to SR 160	13,111	11	7	3	15,140	13	8	3
E	SR 160 to NRDA Road	5,532	9	5	6	6,322	11	6	6
E	NRDA Road to Mercury interchange	3,780	6	3	1	4,257	7	3	1
F	Mercury interchange to Indian Springs	34,318	32	16	1	37,172	35	17	1
G	Indian Springs to SR 156	25,905	23	18	3	27,858	25	20	3
G	SR 156 to northern city limits of Las Vegas	30,336	30	18	2	32,378	32	19	3
	Total		116	70	17		129	76	18

[a] Source: Written communication from State of Nevada, Department of Transportation, 1983.

transportation analysis showed U.S. Highway 95 evening peak-hour traffic would be most sensitive to increased traffic volume.

After operations have begun, assuming vertical emplacement, about 780 workers would be employed during the day shift (Section 5.1). Travel by these workers during the evening peak could coincide with that of the empty trucks leaving the repository. Assuming 250 delivery days per year, approximately one construction-related (Section 5.1) and up to 24 waste-related trucks (Section 5.3.2) could enter and leave the repository daily, resulting in 50 trucks passing a given point each day. Thus, an average of 6.25 trucks would pass a given point in any one-hour period (assuming an 8-hour delivery day). To be conservative, 7 trucks per hour has been used to predict resulting traffic. By using both these estimates and the same assumptions given previously for construction activities, Table 5-31 projects traffic for 1998, both with and without repository-related traffic. Values in this table indicate that incremental traffic due to operations of the repository would only cause a drop in the level of service achieved for segment E (between SR 160 and the Mercury interchange). This segment would drop to service level D, as it did during the peak of construction activities. However, the incremental repository-related traffic that would cause this drop in service is much less than that during construction. The increase is less than the amount attributable to the baseline traffic. This means that the baseline or nonrespository-related traffic is much more of a factor in the resultant level of service than is the repository traffic. As repository-related traffic remains constant over the 30-year operational period of the repository, the regional traffic along the segment would grow. Therefore, the incremental impacts due to repository operational traffic would diminish over time, which would make the first year a worst-case for the operations period.

Traffic accidents for this first year of repository operations are projected in Table 5-32. The incremental repository traffic is estimated to cause an additional seven accidents including four injuries over this one-year period. No additional deaths are predicted. The additional accidents and injuries would be less than those predicted during peak construction (Table 5-32). Furthermore, as was noted previously, these effects of increased traffic volume would become relatively smaller during the 30-year operational periods of the facility.

Decommissioning

Decommissioning of the repository would entail an estimated maximum employment of approximately 540 day-shift workers for vertical emplacement. Only about one truck per day of construction material would be required (Table 5-5). Traffic along U.S. Highway 95 will have increased due to regional growth. The increment of this work force on the local and regional highway network is not expected to create any significant effects as this increment is only one third of that which was previously analyzed for construction activities, in which the effects were minimal.

Table 5-31. Projected traffic patterns on U.S. Highway 95 during evening peak hour (5-6 p.m.), 1998[a]

	Highway segment (see Figure 5-8)	Without repository (baseline)			With repository		
		Number of cars	Number of trucks	Service level obtained[b]	Number of cars	Number of trucks	Service level obtained[a]
B	Site access road to the town of Amargosa Valley	125	26	B	276	49	B
C	The town of Amargosa Valley to 5 mi east of the town of Amargosa Valley	163	31	B	313	54	B
C	5 mi east of the town of Amargosa Valley to SR 160	163	31	B	313	54	B
E	SR 160 to NRDA Road	166	32	C	306	54	D
E	NRDA Road to Mercury interchange	200	25	C	339	47	D
F	Mercury interchanges to Indian Springs	339	87	B	471	108	B
G	Indian Springs to SR 156	357	92	B	483	112	B
G	SR 156 to northern city limits Las Vegas	399	102	B	525	123	B

[a] Source: Written communication from State of Nevada, Department of Transportation, 1983.
[b] See Table 3-9 for definition of service levels..

Table 5-32. Projected annual accidents on U.S. Highway 95, 1998[a]

Highway segment (see Figure 5-8)		Without repository (baseline)				With repository			
		Vehicle[a] mi x 10^3	Accidents	Injuries	Fatalities	Vehicle[a] mi x 10^3	Accidents	Injuries	Fatalities
B	Site access road to the town of Amargosa Valley	467	0	0	0	514	1	0	0
C	The town of Amargosa Valley to 5 mi east of the town of Amargos Valley	6,019	5	3	1	6,477	5	3	1
C	5 mi east of Amargosa Valley to SR 160	13,965	12	7	3	15,027	13	8	3
E	SR 160 to NRDA Road	5,876	10	5	6	6,290	11	6	6
E	NRDA Road to Mercury interchange	4,023	6	3	1	4,274	7	3	1
F	Mercury interchange to Indian Springs	36,529	34	17	1	38,033	36	18	1
G	Indian Springs to SR 156	27,536	25	19	3	28,567	26	20	3
G	SR 156 to northern city limits of Las Vegas	32,170	32	19	3	33,248	33	19	3
	Total		124	73	18		131	77	18

[a] Source: Written communication from State of Nevada Department of Transportation, 1983.

5.3.1.2 Railroad impacts

During the construction period, rail use would be zero during the first two years while the rail spur to the repository is being constructed. Maximum use of the rail line is expected to occur from year three to year five of construction. Projections of future Union Pacific rail use without the repository are unavailable. The incremental rail use due to repository requirements is evaluated against the maximum Union Pacific rail use over the past six years. During years three through five of construction, it is estimated that three rail cars per day would be required to supply the site with material (assuming vertical emplacement, see Table 5-5). As before, 250 delivery days per year have been assumed. In 1981, the Union Pacific line carried an average of 19.2 freight trains per day with an average of 66 cars per freight train (Section 3.5), or 1257 rail cars per day. The increment of 3 rail cars per day, or one 66-car train every 22 work days, equates to an increase of less than 0.2 percent of usage. In 1981, the line was operating at about 71 percent of capacity and could accommodate more use (Section 3.5). Therefore, no impacts on rail line capacity are predicted.

During the 30 years of repository operation, the railroad may be used to transport both construction materials and high-level radioactive waste. The maximum number of shipments of construction material is estimated to be approximately one railcar per day (Table 5-5). High-level radioactive waste shipments by rail are estimated to average 3-1/2 rail cars per day (Section 5.3.2). Including construction material shipments, the total could be from four to five cars per day. This is approximately the same increase as that estimated for the construction phase and little or no impact on rail line capacity is expected assuming current regulatory conditions.

During decommissioning, railroad usage is expected to drop to less than one car per day (Table 5-5). At that level, no impacts are predicted.

5.3.2 Transportation of nuclear wastes

Specific routing requirements apply to packages containing quantities of radioactive material designated as a highway route controlled quantity. These requirements (49 CFR Part 177) would apply if the wastes are shipped by truck to Yucca Mountain. Federal regulations specify driver training requirements (49 CFR 177.825) and require that a written route plan be submitted that lists specifics such as planned stops, estimated departure and arrival times, and telephone numbers for emergency assistance in each state traversed. Variations from the route plan are allowed only under certain circumstances, and they require 30 days notice.

The rationale underlying routing regulations and the role of State and local governments in selecting a route that maximizes safety are explained in a notice in the Federal Register (46 FR 5298, Monday, January 18, 1981). Basically, the overall goal is to reduce risk by reducing the amount of time the radioactive material is in transit. Therefore, interstate highways have been selected as preferred routes for truck transport. In addition to reducing the amount of time in transit, interstate highways also have lower accident rates than do the alternate routes that were considered. However, State routing agencies, which were established by the states and are defined in 49 CFR 171.8, may designate alternate routes in accordance with Department of Transportation (DOT) guidelines (DOT, 1981). The DOT guidelines require State routing agencies to consider all categories of risk, and not simply the high-consequence, low-probability categories. For example, travel through population centers should be considered if it can be demonstrated that the risks are lower in them than travel through less populated areas.

In Nevada, the State Routing Agency is composed of three members; all of whom are elected public officials. They include the Governor, the Attorney General, and the State Comptroller. To date, the State Routing Agency has not identified the preferred transportation routes within the State. Similarly, entry points into the State have not yet been identified. However, an examination of the locations of waste origination can be used with information regarding the current and projected status of regional highways and rail systems to identify the principal candidate routes into the area. Some assumptions (Section 5.3.2.1) regarding waste entry points are necessary to assess the regional impacts of waste transportation.

5.3.2.1 Radiological effects of nuclear waste transportation

This section addresses the radiological impacts associated with the transportation of high-level waste (HLW) on both a national and a regional scale. The HLW mixture for which these impacts are assessed consists both of spent fuel that has been out of the reactor for a 10-year decay period, and of wastes generated by the reprocessing of spent fuel. Reprocessing wastes are categorized as commercial high-level wastes (CHLW), which are fission products and actinides solidified in a borosilicate glass matrix; fuel cladding hulls (hulls); remote-handled transuranics (RHTRU); and contact-handled transuranics (CHTRU). The bounding scenarios assessed herein assume that the repository would receive 70,000 MTU of spent fuel, or the equivalent amount of reprocessing wastes, and that the waste is shipped either 100 percent by truck or 100 percent by rail.

Under accident-free operating circumstances, no radioactive material would be released from the shipping containers during transport. Nevertheless, because of the penetrating radiation emitted by certain components of the radioactive wastes, people in the vicinity of the shipping containers would be exposed to low levels of radiation. The radiological impacts of transporting the waste are expressed in terms of radiation dose to individuals and groups of individuals. The calculations shown in Tables 5-33 and 5-34 are for both transportation workers and the nearby population along the routes of shipment from the point of origin of the wastes to receipt at the Yucca Mountain repository. The radiation dose calculations are based upon the information in Appendix A.

Transportation accidents that are severe enough to release radioactive materials from a shipping container are extremely unlikely. However, because there is a small probability that some releases may occur that would expose people to radiation, the analysis in this section addresses the radiological impacts of transportation accidents.

Table 5-33. Estimated population radiation doses (man-rem) from the transportation of waste to Yucca Mountain

Transportation mode/ exposure category	Spent fuel		Reprocessing wastes	
	30 yr total (man-rem)	Annual (man-rem)	30 yr total (man-rem)	Annual (man-rem)
Truck				
Normal				
Occupational	2,550	85	8,500	283
Nonoccupational	13,000	433	40,000	1,333
Accident[a]	35	1.2	100	3.3
Total	15,585	519	48,600	1,619
Rail				
Normal				
Occupational	15	0.5	30	1
Nonoccupational	85,000	2,833	155,000	5,167
Accident[a]	100	3.3	200	6.7
Total	85,115	2,837	155,230	5,174

[a] The total exposed population in the accident scenarios includes both occupationally and nonoccupationally exposed individuals.

Table 5-34. Dose to maximally exposed individual from transportation of waste to Yucca Mountain

Transportation mode/ dose category	Spent fuel	Reprocessing wastes
Truck transportation		
Total (mrem)[a]	16	45
Annual (mrem/yr)	0.53	1.5
Rail transportation		
Total (mrem)[a]	6	7
Annual (mrem/yr)	0.2	0.23

[a] Total dose received over 30-yr period.

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Potential radiation doses from transporting spent fuel and reprocessing wastes are presented for each of the following categories: (1) transportation workers, (2) the general population along the transportation route, and (3) an individual in the public referred to as the maximally exposed individual and defined as a person standing about 30 m (100 ft) from either the rail or truck shipment route and is exposed to all shipments. The transportation work force consists of railroad workers for rail transport and truck drivers for truck transport. These workers would usually receive the highest individual radiation doses; however, it is not clear that they would be classified as radiation workers because the occupational standards for radiation exposure do not necessarily apply to them.

For purposes of this analysis, it has been assumed that the spent fuel would be shipped by the nuclear power reactor operators either directly to the repository or to Barnwell, South Carolina, for reprocessing. It has also been assumed that all of the reprocessing wastes would be shipped from Barnwell, South Carolina, to the repository. The distances of travel from each of the waste sources to the Yucca Mountain repository have been estimated by assuming 21 reactor centroid locations. Centroid locations have been designated to simulate the approximately 80 actual reactor locations. The number of shipments that are assumed to originate from these locations is presented in Table 5-35 according to waste category and transport mode. The distances used in this analysis were derived from the highway and rail routing models HIGHWAY (Joy et al., 1982) and INTERLINE (Joy et al., 1984), respectively, and are shown in Table 5-36. drop in Table 5-35

The amount of time that a shipment stops during transit is an important consideration in the calculation of the radiation dose to the population. In this analysis, the stop-time values are assumed to be 0.011 hours per kilometer

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Table 5-35. Number of shipments required over 30-year period by waste type and transport mode[a]

Waste type[b]	Number of shipments	
	100% trucks	100% rail
100% Spent fuel	173,229	22,465
100% Reprocessing wastes		
CHTRU	23,026	7,086
Hulls	10,525	2,632
CHLW	30,704	2,559
RHTRU	52,637	13,160

[a] Source: Appendix A.

[b] CHTRU = contact-handled transuranic wastes; Hulls = cladding hulls; CHLW = commercial high level waste; RHTRU = remote-handled transuranic waste.

[illegible] as included on page 5-72.

Table 5-36. Estimated highway and rail distances between waste origin locations and Yucca Mountain[a]

Origin	Highway		Rail	
	Yucca Mt. (km)[b]	Barnwell (km)	Yucca Mt. (km)	Barnwell (km)
Reactor centroid				
Indiana	3228	977	3447	1378
Ohio	3566	1003	3769	1608
Michigan	3315	1444	3570	1643
Texas	2316	1642	2926	2120
New Jersey	4200	1123	4519	1136
New York	4232	1382	4464	1524
Maine	4706	1551	4859	1872
Minnesota	2858	1996	2937	2253
Iowa	2326	1886	2412	2166
Illinois	2876	1524	2989	1772
Wisconsin	3203	1677	3304	1909
Tennessee	3206	612	3636	771
North Carolina	3795	248	4426	364
Georgia	3513	317	4253	391
Florida	4049	753	4942	834
Virginia	4060	682	4714	676
Louisiana	2599	1127	3639	1828
Kansas	2264	1662	2826	2023
So. California	595	3695	571	4347
No. California	970	4352	1138	5248
Washington	1608	4397	2081	4960
Reprocessing location				
Barnwell, SC	3681	NA[c]	4575	NA

[a] Source: Appendix A.
[b] 1 km = 0.621 mi.
[c] NA = not applicable.

close

travel for truck shipments and 0.086 hours per kilometer travel for rail shipment (Appendix A).

Table 5-33 presents the calculated values for cumulative radiological impacts. Although the number of shipments is reduced by using rail transport, the impact per MTU of rail transport is greater than that of truck transport because trains travel slower than trucks, stop for longer periods, and generally must travel longer distances to reach the same destination from the same origin. Accidents are not expected to contribute substantially to the radiological impact of transportation because it is unlikely that an accident resulting in a release of material would occur. Even if an accident should occur, experimental evidence suggests that the consequences would not be great (Wilmot et al., 1981; Sandoval and Newton, 1982). The greatest radiological risk of exposure of the public is from stops during shipment. However, the total radiological risk is very low when compared to the radiological and nonradiological risks that exist from natural background factors.

The estimated doses to the maximally exposed individual by HLW transportation are presented in Table 5-34. The doses are very low compared to variations in natural background doses for all categories of exposure and represent a minimal amount of incremental risk.

Regional radiological impacts

Additional assessments were performed to characterize the regional radiological impacts (i.e., those that may be incurred within the State of Nevada) of HLW transport. These assessments are necessarily based on a set of assumed conditions regarding both the number and type of shipments and the routes by which the shipments enter and travel about the State. The assumed routes of transport are used for purposes of analysis only, and their use neither presumes nor implies that these would be the actual routes. Also, the RADTRAN II risk analysis method, upon which these regional impacts are based, is not well-suited for fine-scale or region-specific analyses. These assessments were performed to characterize the general impacts on a regional scale and to determine whether or not these risks vary for different routing patterns.

Two routing scenarios, Scenarios I and II, are considered. Scenario I assumes entry points from I-15 south, I-15 north, U.S. Highway 93 north, and I-80 east for truck transport, and entry points from Utah, Arizona, and California for rail transport. Scenario II assumes entry points from I-15 north and south for truck transport, and from Utah and California for rail transport. For each scenario, Tables 5-37 and 5-38 present the number of shipments entering the State according to waste type, transport mode, and entry point. As in the national impact assessment, it is assumed that either 100 percent spent fuel or 100 percent reprocessing wastes are shipped either entirely by truck or entirely by rail.

The results of the regional impact assessments that are presented on Table 5-39 indicate the following: (1) the differences in assumed routing do not substantially affect the resultant doses, and (2) the magnitude of the total population dose (40 to 190 man-rem/year) for each category is low compared to the dose that would be received from natural background sources, which is approximately 1800 man-rem/year for 19,908 people within 80 km (50 mi) of Yucca Mountain (Black et al., 1983; Jackson, 1984). It should be noted that the regional impact estimates are probably higher than those that would actually occur because of the radiological unit factors used by the RADTRAN II method; for example, most of the transport within the State would be through rural environments and RADTRAN II assumes a mean density of six people/km^2 based on a national average. However, the actual mean density for Nevada is much lower than this value, and in many areas it is close to zero. Thus, the man-rem per kilometer of rural travel is probably significantly lower than the value shown in Table 5-39. There would actually be fewer stops in the regional case.

5.3.2.2 Nonradiological effects

Nonradiological effects are expressed in terms of latent cancer fatalities per kilometer that result from nonradiological pollutants emitted by the truck or train. The factors used to calculate these effects are presented in Table 5-40. These factors are categorized according to both normal and accident conditions of transport for either truck or rail mode. The unit

Table 5-37. Assumed regional transport conditions for Scenario I

Transportation mode/ entry point	Number of shipments					Distance/shipment (km)[b]		
		Reprocessing wastes[a]						
	Spent fuel	CHTRU	Hulls	CHLW	RHTRU	Rural	Suburban	Urban
Truck								
I-15S	103,066					344	13	13
I-15N	5,875					275	19	16
U.S. 93N	56,559	23,026	10,525	30,704	52,637	236	25	16
I-80E	7,729					512	92	6
Rail (Union Pacific)								
From Utah	14,438					250	5	0
From Arizona	6,656	7,086	2,632	2,559	13,160	150	27	16
From California	1,371					216	13	16

[a] CHTRU = contact-handled transuranic; Hulls = cladding hulls; CHLW = commercial high-level waste; RHTRU = remote-handled transuranic.
[b] 1 km = 0.621 mi.

Table 5-38. Assumed regional transport conditions for Scenario II

Transportation mode/ entry point	Number of shipments					Distance/shipment (km)[b]		
		Reprocessing wastes[a]						
	Spent fuel	CHTRU	Hulls	CHLW	RHTRU	Rural	Suburban	Urban
Truck								
I-15S	103,066					344	13	13
I-15N	70,163	23,026	10,525	30,704	52,637	275	19	16
Rail (Union Pacific)								
From Utah	14,438					250	5	0
From California	8,027	7,086	2,632	2,559	13,160	216	13	16

[a] CHTRU = contact-handled transuranic; Hulls = cladding hulls; CHLW = commercial high-level waste; RHTRU = remote-handled transuranic.
[b] 1 km = 0.621 mi.

Table 5-39. Estimated 30-year radiological impacts (man-rem) resulting from transportation of high-level waste within the State of Nevada for scenarios I and II[a]

Transportation mode/ exposure category	Spent fuel		Reprocessing waste	
	I	II	I	II
100% Truck				
Normal operation				
Occupational	180	170	510	550
Nonoccupational	1000	960	2400	2600
Accidents	3	3	8	7
Total	1200	1100	2900	3200
100% Rail				
Normal operation				
Occupational	1	1	1	1
Nonoccupational	4500	4800	4500	5700
Accidents	2	2	23	22
Total	4500	4800	4500	5700

[a] Estimated on the basis of results contained in Appendix A (see text for assumptions). Results are whole numbers rounded to two significant figures.

Table 5-40. Nonradiological unit factors for transportation impact analysis[a]

Transportation mode/ exposure category	Rural	Suburban	Urban
	NORMAL (NONOCCUPATIONAL)		
Truck			
Latent cancers/km[b]	ND[c]	ND	1.0×10^{-7}
Rail[d]			
Latent cancers/km	ND	ND	1.3×10^{-7}
	ACCIDENT		
Truck			
Nonoccupational			
Fatalities/km	5.3×10^{-8}	1.3×10^{-8}	7.5×10^{-9}
Injuries/km	8.0×10^{-7}	3.8×10^{-7}	3.7×10^{-7}
Occupational			
Fatalities/km	1.5×10^{-8}	3.7×10^{-9}	2.1×10^{-9}
Injuries/km	2.8×10^{-8}	1.3×10^{-8}	1.3×10^{-8}
Rail[d]			
Nonoccupational			
Fatalities/km	1.7×10^{-8}	1.7×10^{-8}	1.7×10^{-8}
Injuries/km	3.3×10^{-8}	3.3×10^{-8}	3.3×10^{-8}
Occupational			
Fatalities/km	1.4×10^{-9}	1.4×10^{-9}	1.4×10^{-9}
Injuries/km	1.9×10^{-7}	1.9×10^{-7}	1.9×10^{-7}

[a] Source: Appendix A.
[b] 1 km = 0.621 mi.
[c] ND = no data.
[d] Based on railcar kilometers.

factors for normal transport are for urban areas only and are for nonoccupationally exposed people. Table 5-41 presents values for the assumed percentage of travel in rural, suburban, and urban population zones along truck and rail routes.

(Table 5-41 to be dropped in)

The accident factors are for both fatalities and injuries. The nonoccupationally exposed population includes all people except those that comprise the truck and train crews, which are included in the occupationally exposed group.

The results of the nonradiological impact assessments for transportation of high-level waste that are presented in Table 5-42 indicate the following: (1) nonradiological transportation risk is substantially greater than the corresponding radiological risk; (2) members of the general public are subjected to the highest level of risk; (3) the nonradiological risk associated with truck transport is much greater than that associated with rail transport; and (4) the total nonradiological impact is small relative to that associated with general commercial transportation activities. Accidents are the dominant factor for nonradiological fatalities. The primary reason that fatalities associated with truck transport are greater than those associated with rail transport is because trucks have a much greater accident rate. For instance in 1980, truck-related accidents resulted in 2528 fatalities, whereas rail transport resulted in only 1242 fatalities (Appendix A). When they are projected for 30 years, these values become 75,800 for truck travel and 37,300 for rail travel.

Since nonradiological health impacts on the regional population are impossible to assess without knowing the number of waste shipments for specific routes, it has been assumed that waste shipments would enter the State as

Table 5-41. Percentage of travel in various population zones along routes from reactor centroid to Barnwell and to Yucca Mountain[a]

Transportation mode/ destination	Population zone[b]		
	Rural (percent)	Suburban (percent)	Urban (percent)
~~Truck~~			
Barnwell, South Carolina	70.7	27.7	2.2
Yucca Mountain	83.7	15.2	1.1
Rail			
Barnwell, South Carolina	69.5	28.1	2.4
Yucca Mountain	83.1	15.5	1.4

[a] Source: Appendix A.

[b] Rural corresponds to 6 people/km^2 (mean density). Suburban corresponds to 719 people/km^2 (mean density). Urban corresponds to 3816 people/km^2 (mean density).

Table 5-42. Nonradiological impacts associated with truck or rail transport of nuclear wastes over 30-year operational ~~period~~[a] phase[a]

Transportation mode/ impact category	Spent fuel	Reprocessing wastes
Truck		
Normal		
Nonoccupational[b]	1.4	2.5
Accident - fatalities		
Occupational	16	17
Nonoccupational	55	60
Total fatalities	72	80
Accident - injuries		
Occupational	30	34
Nonoccupational	870	970
Rail		
Normal		
Nonoccupational[b]	0.35	0.8
Accident - fatalities		
Occupational	0.25	0.5
Nonoccupational	3.0	5.4
Total fatalities	3.6	6.7
Accident - injuries		
Occupational	33	61
Nonoccupational	5.8	11

[a] Source: Appendix A.
[b] Nonoccupational impacts from normal transport are latent cancer fatalities resulting from pollutants emitted by the truck or train.

described in either of the two scenarios discussed previously. The results of this assessment are presented in Table 5-43. These impacts are minor and follow the same general pattern as that for nonradiological impacts on a national scale.

5.3.2.3 Costs of nuclear waste transportation

This section assesses the total costs associated with the transportation of nuclear waste over the life of the repository. The cost results presented here are based on the methods and data which are presented in detail in Appendix A.

The total transportation cost associated with each fuel cycle scenario, 100 percent spent fuel and 100 percent reprocessing, is the sum of costs incurred for each of the following items:

1. Capital costs, which are the costs of the transportation packaging and associated trailer or railcar.
2. Maintenance costs, which are costs associated with maintenance and licensing activities.
3. Shipping costs, which are based on studies of published tariffs or conservative estimates of actual shipping rates.

The results of these assessments (Table 5-44) indicate that the total transportation cost for the spent fuel scenario would be about $2.9 billion for truck or $2.6 billion for rail. For the reprocessing fuel scenario, these costs would be $3.4 and $3.9 billion, respectively. These costs are for a repository of 70,000 MTU capacity at Yucca Mountain and are expressed as 1981 dollars. Other transportation-related costs such as the costs of constructing access roads, are not included in these estimates.

5.3.2.4 Emergency preparedness

Traditionally, it has been the responsibility of State and local government to respond to transportation accidents; the role of the Federal government in the event of civilian radioactive-waste transportation accidents is usually one of supporting the State's lead role. In Nevada, the State Health Division is designated by law (Nevada Revised Statute 459) as the state radiation control agency. Consequently, the Health Division is the agency with primary responsibility in the event of a radiological emergency. Assistance should be requested, as needed, from other government agencies and coordinated by the department. A State Radiological Emergency Plan is in place.

The Department of Energy Nevada Operations Office has a unique capability in the area of radiological response. The Department of Energy maintains a 24-hour manned emergency telephone station in Las Vegas that serves as the initial notification contact for emergencies and response coordination for radiological assitance. Under a Memorandum of Understanding with the State of Nevada (revised, July 1982), the Department of Energy Nevada Operations Office will immediately notify the Health Division and the Division of Emergency

Table 5-43. Nonradiological impacts associated with truck or rail transport of nuclear wastes within the State of Nevada, for Scenarios I and II for 30-year operational ~~period~~ phase

Transportation mode/ impact category	Spent fuel		Reprocessing wastes	
	I	II	I	II
Truck				
Normal				
Nonoccupational[a]	0.24	0.24	0.19	0.19
Accident - fatalities				
Occupational	0.86	0.86	0.42	0.49
Nonoccupational	3.1	2.9	1.6	1.7
Total fatalities	4.2	4.0	2.2	2.4
Accident - injuries				
Occupational	1.7	1.6	0.83	0.95
Nonoccupational	46	46	24	28
Rail				
Normal				
Nonoccupational[a]	0.018	0.017	0.053	0.053
Accident - fatalities				
Occupational	0.0077	0.0078	0.0069	0.0087
Nonoccupational	0.094	0.095	0.083	0.11
Total fatalities	0.12	0.12	0.14	0.17
Accident - injuries				
Occupational	1.0	1.1	0.93	1.2
Nonoccupational	0.18	0.19	0.16	0.21

[a] Nonoccupational impacts from normal transport are latent cancer fatalities.

Table 5-44. Summary of total transportation costs to Yucca Mountain by waste type, transportation mode, and cost category[a]

Waste type and mode	Cost (millions of dollars)
100% Spent fuel scenario	
100% Truck	
Capital	432
Maintenance	356
Shipping	2154
Total	2942
100% Rail	
Capital	1092
Maintenance	311
Shipping	1204
Total	2607
100% Reprocessing wastes scenario	
100% Truck	
Capital	559
Maintenance	442
Shipping	2411
Total	3412
100% Rail	
Capital	1168
Maintenance	609
Shipping	2104
Total	3881

[a] Source: Appendix A.

Management of any emergency and will respond until state personnel take action. In southern Nevada, a Radiological Assistance Team, with a 24-hour rotating duty officer and a specially equipped vehicle, can be called upon immediately. In northern Nevada, the State of Nevada Emergency Response Team, composed of qualified State and university personnel, is available. The Department of Energy's response capability is exceptionally well developed. In addition, first-on-the-scene training courses have been developed and conducted for ambulance operators, fire departments and Nevada State law enforcement personnel by the Reynolds Electrical and Engineering Co., Inc. Environmental Sciences Department. Civil defense radiation monitoring kits have been given to each state highway patrolman who completes the course and the kits are maintained on a regular basis.

5.4 EXPECTED EFFECTS ON SOCIOECONOMIC CONDITIONS

This section describes the potential economic, demographic, and social impacts of locating a repository at Yucca Mountain. There are several important factors to consider when determining potential social and economic effects and the subsequent development of a mitigation plan. These factors include the local availability of workers, the extent of inmigration, and the public's perceptions and attitudes about the safety of waste transportation and disposal. For this analysis, it has been assumed that safety questions about waste transportation and disposal would be resolved before the repository would be constructed. In the absence of detailed information about work force skill mix, a worst-case analysis of demographic effects assumes that all project workers would come from outside the bicounty region (i.e., Clark and Nye counties). This assumption has been modified in the economic impact section, which provides a preliminary evaluation of local labor availability. Although fiscal impacts have not yet been quantified, preliminary estimates of the potential effects on community services are presented that suggest the magnitudes of potential fiscal effects. Section 5.4.5 presents an overview of the Federal government's commitments for fiscal impact mitigation under the Nuclear Waste Policy Act of 1982. Other types of impact mitigation, such as mitigation by avoidance, would be identified as part of the ongoing studies. Further information on the expected effects of locating a repository at Yucca Mountain is contained in Chapter 6, Sections 6.2.1.2 and 6.2.2.2.

5.4.1 Economic conditions

The potential economic impacts that relate to labor, materials, income, land use, and tourism are described in this section. Only private-sector activity will be considered here (Public-sector implications are discussed in Sections 5.4.3 and 5.4.5). This analysis is based both on preliminary estimates of the demand for project labor and materials and on preliminary studies of future baseline market conditions. It has been assumed that construction would begin in 1993. In 1993, the bicounty region would experience significant increases in demand for mine workers, construction workers, and other skilled workers and materials. This demand would decline sharply at three different points in the 60-year project schedule: at the end of construction in 1997, at the end of the operations period in 2027, and at the end of the retrievability period in 2047. Unless southern Nevada were to be experiencing rapid growth during these years, these periods would probably resemble similar periods of slower economic growth that the bicounty region experienced during previous fluctuations in the mining and construction industries.

5.4.1.1 Labor

Table 5-3 presents preliminary estimates of the project's labor requirements by skill for the vertical emplacement option. Table 5-4 presents the same information, but assumes the horizontal-emplacement alternative. Local purchases of repository materials and expenditures by repository workers would result in increased demands for local goods and services. Indirect employment is defined as the increase in trade, service, and other employment that can be attributed to the increased demand for goods and services. The project's total employment effect is the sum of the repository labor force (direct employment) and indirect project employment. Tables 5-3 and 5-4 provide estimates of the indirect employment effect based on the assumption that 1.54 indirect jobs would be created for each direct job (Nevada Development Authority, 1982; McBrien and Jones, 1984).

Assuming vertical emplacement, the project would employ 1200 workers in its first year, 1993. This number would increase to a peak of 3350 workers in 1996. Mining employment would increase from a 1993 level of 500 to a peak of about 800 workers in 1995. Between the construction and operation phases of the project in 1997 and 1998, employment would decline markedly to a level of 2300 workers by 1999. This number, which includes about 700 mining employees, would be sustained throughout the operations period of about 30 years.

At the start of the retrievability phase, which would cover the period from 2028 to 2047, project employment would decline by about 1700 to a total of approximately 600 workers. At the end of this 20-year period, project employment would increase by an additional 900 workers who would be required to decommission the repository. Decommissioning would occur between 2048 and 2053. No workers would remain at the site on a regular basis after 2053.

Total direct and indirect employment induced by the project would increase and decline over time in relation to the size of the direct project work force. The total annual employment impact would reach a peak of about 8500 jobs in 1996. At the end of the construction period in 1997, this number would decline markedly to 5900 employees in 1999. This level of employment would be supported for about 30 years until 2027. Although it is not reflected in Tables 5-3 and 5-4, the project also would employ workers during the operation period for traffic escort and control, emergency preparedness, road and rail maintenance, and operation of locomotives, trucks, and other vehicles. Estimates of employment levels for these activities are not available yet.

Data on the recent settlement patterns of the Nevada Test Site work force suggest that some project employees could choose to reside in communities in Nye and Clark counties. Settlement patterns of the 1983 Nevada Test Site work force are shown in Table 5-28. These data suggest that about 80 percent of the repository labor force would reside in the Las Vegas metropolitan area, and about 20 percent of the labor force would locate in the smaller communities of Indian Springs, Pahrump, Tonopah, Amargosa Valley, and other communities surrounding the site. The current settlement patterns of Nevada Test Site employees also indicate that workers have been drawn from a labor market that includes residents of Clark, Nye, and other Nevada counties, as well as from California, Arizona, and Utah.

Potential labor-market implications of the project would include inmigration of workers that have the required skills such as mining and construction skills. There might be an increase of wages and salaries to induce these workers to relocate to the area. Labor-market impacts would depend upon the local and regional availability of workers and at various phases of the project, especially during the construction period from 1993 to 1997 in which direct work-force requirements would reach their peak. Based upon the linear interpolation of the forecasts presented in Tables 3-12 and 3-13, peak labor demand would be less than one percent of the baseline bicounty employment in 1996.

Estimates of project labor requirements indicate that the greatest demand would be for construction and mining workers. The peak requirement for surface facility construction workers would be about 2000 workers as indicated on Table 5-3, representing an 8 percent increase over baseline construction employment levels in the bicounty area as shown on Tables 3-12 and 3-13. Mining employment in the area would increase by almost 100 percent over the projected future baseline. This level would be maintained for over thirty years under the vertical emplacement scenario. This projection indicates that the development of a repository at Yucca Mountain would be a project of significant size for the local construction and mining sectors. Although the horizontal emplacement method would reduce the number of mining jobs generated by the project by about two-thirds, the construction work-force requirement would be about the same as for vertical emplacement.

Thus, many mining and construction workers would come from outside the bicounty area. The extent to which this would occur depends upon the presence in the area of other large projects in the early 1990s, the state of the national economy at that time, and the unemployment rates in those skill areas.

In summary, the project would affect significantly the total demand for construction and mining workers in the bicounty area. Potential increases in wages and salaries in the bicounty area could be mitigated by the inmigration of skilled workers from other areas such as California and Utah. Another mitigating factor would be the long duration of the project, especially of the underground activities. If the decision to construct a repository at Yucca Mountain were to be announced publicly in advance, inmigrating workers might anticipate employment opportunities and move into the area before the project begins.

5.4.1.2 Materials and resources

The average annual requirements for some construction materials and resources are shown in Tables 5-5 and 5-6. In addition to electrical power, a preliminary analysis of materials supplies in southern Nevada indicates that it is reasonable to assume that concrete and fuel would be purchased in the area (McBrien and Jones, 1984). However, many of the materials that eventually would be required may not be available in southern Nevada. The retrievability phase would generate only a small requirement for materials. During the decommissioning phase, the project would require heavy equipment and materials both to seal the shafts and tunnels and to dismantle surface facilities. Materials required to decommission the surface facilities may be shipped to the site from outside the area (McBrien and Jones, 1984).

5.4.1.3 Cost

Preliminary cost estimates for the construction, operation, and decommissioning of a repository at Yucca Mountain are summarized in Table 5-45. The cost of maintaining the repository during the retrievability period has not been determined. The cost estimates in Table 5-45 are preliminary and are useful for this analysis, but they are not appropriate for budget projections. In particular, the costs for operation and decommissiong should not be used for purposes other than comparison with similar costs for other repositories from the same source. Conceptual cost estimates cannot be completed until engineering designs have been developed further and until construction, operating, and decommissioning requirements have been assessed in greater detail. All costs are shown in 1983 dollars and include allowances for engineering, design, and inspection; contingency; construction management; and quality assurance.

The cost estimates are based on the emplacement of single canisters of spent fuel in vertical holes in the floor of the emplacement drifts. The cost of horizontal emplacement would be less. For horizontal emplacement, the costs for underground workings and rock handling would be less; other costs would be about the same as for vertical emplacement. However, the total savings that

Table 5-45. Preliminary cost estimate for the Yucca Mountain repository assuming vertical emplacement[a]

Category	Cost estimate (millions of 1983 dollars)			
	Construction	Operations	Decom-missioning	Total
Waste preparation	510	1629	70	2209
Repository system				
Site	369	83	49	501
Waste handling and emplacement	195	570	13	778
Underground workings and rock handling	399	398	87	884
Ventilation	310	514	43	867
Support/utilities	193	568	92	853
Totals	1976	3762	354	6092

[a] Data from Repository Life Cycle Estimates for Basalt, Salt, Tuff, and Granite Geologies, Roy F. Weston, Inc., 1984.

could be realized have not been determined yet for horizontal emplacement. Facility operations costs are based upon receiving a total of 70,000 metric tons of heavy metal (MTHM) as spent fuel during a 30-year emplacement period. It has been assumed that the maximum annual receipt rate would be 3000 MTHM per year.

5.4.1.4 Income

Increases in Department of Energy spending on labor and materials during the construction and operation of a repository at Yucca Mountain would contribute to growth in the region. Labor and materials suppliers would experience a direct increase in demand for their resources. Also, increased Department of Energy spending would generate growth in support sectors, such as the trade and services industries.

Table 5-46 shows the total increase in wage spending impacts to the southern Nevada area that might result from project employment assuming vertical emplacement of the waste. The same information is shown in Table 5-47 for horizontal waste emplacement. These projections are based on preliminary studies that project an annual wage of $25,400 for both construction and operations workers and $14,000 for secondary workers in 1983 dollars (McBrien and Jones, 1984). The peak annual economic stimulus of repository spending on wages alone would be $157.2 million during the five-year construction period under the vertical emplacement scenario and $131.5 million under the horizontal emplacement scenario.

5.4.1.5 Land Use

Land-use requirements for a repository at Yucca Mountain would involve the withdrawal of public land along with the associated surface and subsurface rights. It is not likely that the land would be used for grazing were it not to be withdrawn for a repository. This is because approximately 255 ha (630 acres) are required to support one cow in the Yucca Mountain area (Collins et al., 1982).

The area immediately surrounding the site has very limited, if any, potential for energy and mineral resource development. It is not realistic to assume that prices could increase sufficiently to make these geologic resources, which have no current economic value, economically significant. According to the Level 1 Resource Appraisal (Bell and Larson, 1982), any geothermal, metal, industrial rock, and mineral resources that may occur in the Yucca Mountain area are available elsewhere in greater abundance. Thus, it would appear that withdrawing mineral rights would not result in loss of significant resources (see Section 3.2.4).

Table 5-46. Potential annual wage expenditures associated with vertical emplacement (millions of 1983 dollars)

	Phase and year							
	Construction					Operations	Retrieva-bility	Decommis-sioning
Category	1	2	3	4	5	6-35	36-55	56-60
Direct project employees[a]	31.01	61.37	82.27	85.04	60.68	58.75	15.09	39.32
Indirect workers[b]	26.32	52.09	69.83	72.18	51.51	49.87	12.81	33.38
Total	57.33	113.46	152.10	157.22	112.19	108.62	27.90	72.70

[a] Includes wages of both construction and operation workers. Assumes an average annual wage of $25,400 (McBrien and Jones, 1984).

[b] Assumes an average annual salary of $14,000, the average annual wage of persons in the trade industry in southern Nevada (McBrien and Jones, 1984).

Table 5-47. Potential annual wage expenditures associated with horizontal emplacement (millions of 1983 dollars)

	Phase and year							
	Construction					Operations	Retrievability	Decommissioning
Category	1	2	3	4	5	6-35	36-55	56-60
Direct project employees[a]	21.77	48.82	67.74	71.12	47.09	36.63	11.58	16.59
Indirect workers[b]	18.48	41.44	57.50	60.37	39.97	31.09	9.83	14.08
Total	40.25	90.26	125.24	131.49	87.06	67.72	21.41	30.67

[a] Includes wages of both construction and operation workers. Assumes an average annual wage of $25,400 (McBrien and Jones, 1984).

[b] Assumes an average annual salary of $14,000, the average annual wage of persons in the trade industry in southern Nevada (McBrien and Jones, 1984).

5.4.1.6 Tourism

Because of the importance of the tourism industry to the State and local economies, even small changes in tourism levels could have a significant economic impact. Public comments indicate a concern that the potential for adverse public perception of a repository and its associated waste transportation could adversely affect the growth of this industry. The importance of public perception lies in the attractiveness of Las Vegas' image to potential visitors. Research to date concerning the potential effect of repository operation on tourism is inconclusive; therefore, further investigation has been planned. The results of past investigations are summarized below in the following discussion.

According to preliminary descriptions, the Yucca Mountain repository itself would not be visible to tourists. The site is far from major population centers and public recreation areas, and it is not visible from public highways. However, in the early 1990s, construction of a road that would lead from the site to a point one-half mile west of the town of Amargosa Valley would be visible from the highway and from the town of Amargosa Valley. Construction of a rail line from Dike Siding to Yucca Mountain would be visible from highways, residences, and from Floyd Lamb State Park which is located outside Las Vegas.

In addition, waste transportation activities would be visible to tourists. The truck routes that would be used to transport radioactive waste to Yucca Mountain are not known (Section 5.3); however, it is possible that waste could be routed through Las Vegas. Spent-fuel shipments would be escorted, and all shipments would be placarded radioactive. Such shipments on local highways would be visible in the area while they were in transit.

Visitors may become further aware of the repository from extensive media coverage of the waste-disposal program. Preliminary research on the potential effects of the potential increased awareness of the waste-disposal program on local tourism levels has identified several theories on the nature of a possible link between tourism and the repository. First, tourism levels could decline because of safety concerns, even if the DOE design studies were to indicate that a repository would not present a credible safety threat to visitors or to residents. Second, tourism could decrease because of an adverse effect on the aesthetic appeal of Las Vegas and surrounding tourist attractions that extend beyond safety concerns. However, the presence of nuclear-weapons testing at the Nevada Test Site does not appear to have had a significant effect on tourism, and this suggests that the repository would not change the total aesthetic appeal of the Las Vegas area. In addition, preliminary studies of the effects of safety concerns following well-publicized accidents, such as the 1980-1981 Las Vegas hotel fires and the Three Mile Island incident, have not yielded evidence of any long-term effect on tourism levels from publicized safety concerns (SAI, 1983).

5.4.2 Population density and distribution

Table 5-48 shows a preliminary forecast of the maximum regional population influx that could be associated with locating a repository at Yucca Mountain, assuming vertical waste emplacement. Table 5-49 summarizes the horizontal

Table 5-48. Projected maximum total population increase for Clark and Nye Counties for vertical emplacement[a]

	Phase and year							
	Construction					Operations	Retrievability	Decommissioning
Category	1	2	3	4	5	6-35	36-55	56-60
SOUTHERN NEVADA AREA								
Direct project employees	1,221	2,416	3,239	3,348	2,389	2,313	594	1,548
Direct project employee dependents	1,563	3,092	4,146	4,285	3,058	5,713	1,467	1,981
Indirect employees	1,880	3,721	4,988	5,156	3,679	3,562	915	2,384
Indirect employee dependents	4,644	9,190	12,321	12,735	9,087	8,798	2,259	5,888
Maximum population impact of project	9,308	18,419	24,694	25,524	18,213	20,386	5,235	11,801
NYE AND CLARK COUNTIES[b]								
Total population projection with project[c]	775,982	808,247	837,790	862,105	878,605			
Annual growth rate, %	4.4	4.2	3.7	2.9	1.9			
Baseline population projection without project[c]	767,046	790,565	814,084	837,602	861,121			
Annual growth rate, %	3.2	3.1	3.0	2.9	2.8			

[a] Assumptions: 2.47 dependents per operations, retrievability, or indirect worker;
1.28 dependents per construction or decommissioning worker;
1.54 indirect jobs generated by each direct job;
All workers come from outside the area.
Construction begins in 1993.

[b] Assumes that 13 and 83 percent of inmigrants would settle in Nye and Clark counties, respectively (see Table 5-28).

[c] Projected 1992 population without repository is 743,528.

Table 5-49. Projected maximum total population increase for Clark and Nye Counties for horizontal emplacement[a]

Category	Construction 1	Construction 2	Construction 3	Construction 4	Construction 5	Operations 6-35	Retrievability 36-55	Decommissioning 56-60
SOUTHERN NEVADA AREA								
Direct project employees	857	1,922	2,667	2,800	1,854	1,442	456	653
Direct project employee dependents	1,097	2,460	3,414	3,584	2,373	3,562	1,126	836
Indirect employees	1,320	2,960	4,107	4,312	2,855	2,221	702	1,006
Indirect employee dependents	3,260	7,311	10,145	10,651	7,052	5,485	1,735	2,484
Maximum population impact of project	5,634	14,653	20,333	21,347	14,134	12,710	4,019	4,979
NYE AND CLARK COUNTIES[b]								
Total population projection with project[c]	772,455	804,632	833,604	858,095	874,690			
Annual growth rate, %	3.9	4.2	3.6	2.9	1.9			
Baseline population projection without project[c]	767,046	790,565	814,084	837,602	861,121			
Annual growth rate, %	3.2	3.1	3.0	2.9	2.8			

[a] Assumptions: 2.47 dependents per operations, retrievability, or indirect worker;
1.28 dependents per construction or deocommissioning worker;
1.54 indirect jobs generated by each direct job;
All workers come from outside the area.
Construction begins in 1993.

[c] Assumes that 13 and 83 percent of inmigrants would settle in Nye and Clark Counties, respectively (see Table 5-28).

[b] Projected 1992 population without repository is 743,528.

emplacement scenario. This forecast is based on the conservative assumption that all workers would come from and return to areas other than Nye and Clark counties and that each household has only one labor-market participant. Thus, it overstates the likely upward (or downward) responses of bicounty population to changes in project labor requirements. These conservative assumptions are used in Section 5.4.3 to estimate the worst-case impacts on community services.

During the peak employment period in 1996, the project could cause a worst-case population increase of 25,500 over baseline projections, which is 3 percent of the baseline bicounty population. If primary and secondary employees follow the settlement patterns of workers currently employed by the DOE and its contractors at the Nevada Test Site, Clark County would receive 83 percent of the project-related population increase during construction, or a maximum of about 21,200 people. Nye County, which would receive about 13 percent of the total, could experience a maximum influx of about 3318 people. Assuming vertical waste emplacement, during the 1998 to 2027 period the project related population increment would decline to about 20,400 people: 16,900 would reside in Clark County and 2,700 would reside in Nye County. The population growth rate during the first year of construction would be 4.3 percent for Clark County; and 5.4 percent for Nye County. Without the project, the population growth rate in these counties is projected to be 2.7 percent for Clark County and 2.1 percent for Nye County; this projection is based on a bicounty population increment of 9308 persons and interpolation of forecasts shown in Tables 3-15 and 3-16.

5.4.3 <u>Effects on community services</u>

5.4.3.1 Summary

Increased population growth typically results in an increase in the demand for local, state, and regional public services. These increases are of particular concern to public planners either because of a corresponding requirement for new facilities or because existing capacity must be expanded earlier than anticipated. Preliminary studies indicate that some potentially significant impacts on community services may accompany project-related population growth in the sparsely populated areas of Nye and Clark counties and that impacts in urban areas, such as the Las Vegas metropolitan area, would most probably be insignificant. Although the impacts that have been evaluated so far appear to vary between urban and rural areas, insufficient data were available to quantify them at the level of the urban or rural service provider (e.g., municipal police department or local water district). Instead, because of better access to county-wide data, separate analyses were performed for Nye and Clark counties as a whole.

To assess potential impacts on community services, it was necessary to define service levels in terms of readily quantifiable measures such as the number of police officers and the millions of gallons per day of water supply capacity. It is recognized that this wholly quantitative approach addresses only part of the question of the adequacy of existing and future services; however, it does help identify significant issues. Per-capita service ratios were calculated for each type of service in Nye and Clark counties. These ratios, along with the references upon which they are based, are summarized in Table 5-50.

It was assumed also that existing service ratios would be valid in future years; that is, that service providers, such as police departments, school districts, etc., would increase their services in proportion to the population increases in their service areas. No assumptions were made as to the timing of the service expansion, except that the necessary number of facilities and personnel would be available during each phase. Two types of future service requirements have been estimated. First, future baseline service requirements have been calculated by multiplying per-capita service ratios by the forecast baseline population. Second, incremental service requirements have been calculated by multiplying the same ratios by the forecast increments in Nye and Clark county population that would be induced by the project. Thus, the second calculation provides a set of service requirements that would be over and above those that are due to normal projected growth.

The size and probable settlement patterns of the inmigrant population are uncertain; thus, the impact on community services is also uncertain. Inmigrants could become a burden to small communities because they could adversely effect budgets for housing, schools, and other services. In a larger community in which the inmigrants would represent a smaller proportion of a growing population, there would be a less significant effect on public services. This analysis assumes that 100 percent of the jobs created by repository construction and operation would be filled by inmigrating workers. This extreme assumption permits the identification of maximum impacts on all community services in the region.

The following discussion summarizes service impacts under the assumption that 83 percent of the inmigrating population that would be associated with the project would settle in Clark County, and that 13 percent would settle in Nye County. Projections of incremental service demand during each of the four project phases are shown in Tables 5-51 and 5-52. Ranges of demand during Phase I reflect the fact that the inmigrating population is projected to vary from year to year.

The incremental service requirements shown in Tables 5-51 and 5-52 are cumulative. For example, the one additional elementary school that would be required for Clark County during Phase II also would meet the county's service requirements during Phase III; i.e., it would not be necessary to build a new school during that phase.

Service requirements in Nye County would be greater for the vertical emplacement method. During the construction phase these requirements would increase by about 6 to 15 percent over those projected for the future baseline. During operations, service requirements would be about 7 percent higher than the projected baseline levels. These incremental percentages are higher than those for Clark County, mainly because the projected inmigrating population represents a higher percentage of the projected baseline population.

It is not expected that the requirements for increased services in Clark County would exceed forecast baseline service levels by more than 3 percent during the period of greatest impact, which is the construction phase from 1993

Table 5-50. Ratios used to forecast community service requirements

Type of service	Clark County			Nye County		
	Ratio[a]	Base year	Source[b]	Ratio[a]	Base year	Source[b]
Elementary schools	0.151	1982	1	0.775	1983	8
Secondary schools	0.064	1982	1	0.258	1983	8
Teachers and staff	9.194	1982	1	10.071	1983	2
Police officers	1.669	1983	3	3.529	1982	2
Police vehicles	0.804	1983	4	ND[c]	ND	ND
Voluntary firefighters	0.407	1983	4	8.558	1982	2
Paid firefighters	0.981	1983	4	1.051	1982	2
Fire equipment pieces	0.196	1983	4	2.703	1982	2
Physicians	1.313	1982	4	0.450	1982	5
Hospital beds	5.819	1982	5	3.453	1982	6
Water (million gallons per day)	0.467	1982	6	0.653	(d)	(d)
Library books (1000)	1.507	1983	7	ND	ND	ND
Library staff	0.191	1983	7	ND	ND	ND

[a] Number per 1000 residents.

[b] Sources:
1. McBrien and Jones (1984) from the 1982-1983 Clark County School District Budget
2. Nye County Nevada Profile, (State of Nevada, NOCS, 1982)
3. LVMPD (1983); North Las Vegas Police Department (Fay, 1984)
4. McBrien and Jones (1984)
5. 1982-1983 Nevada State Health Plan (State of Nevada, NSHCC, 1982)
6. Nevada Development Authority (1982)
7. Nevada Library Directory and Statistics - 1984 (State of Nevada, NSL, 1984)
8. Nye County Master Education Plan, Phase I (Davis and Cline, 1984)
9. Nye County School District (1984a, 1984b).

[c] ND = no data on which to compute a ratio.

[d] Based upon ratio between reported use and number of people served by public and private water systems.

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Table 5-51. Incremental service requirements associated with the location of a repository at Yucca Mountain (vertical emplacement)[a]

Service	Incremental service requirements							
	Clark County				Nye County			
	Construction	Operation	Retrievability	Decommissioning	Construction	Operation	Retrievability	Decommissioning
Expected population increments	7,726-21,185[b]	16,920	4,345	9,795	1,210-3,318	2,650	681	1,534
Education								
Schools								
Elementary	1-3	3	1	1	1-3	2	1	1
Secondary	0-1	1	0	1	0-1	1	0	0
Teachers	71-193	156	40	90	12-33	27	7	15
Police								
Officers	13-35	28	7	16	4-12	9	2	5
Vehicles	6-17	14	3	8	1-3	2	1	1
Fire								
Volunteer fire fighters	3-9	7	2	4	11-28	23	6	13
Paid fire fighters	8-21	17	4	10	1-3	3	1	2
Trucks and other equipment	2-4	3	1	2	3-9	7	2	4
Medical services								
Doctors	10-28	22	6	13	1-1	1	0	1
Hospital beds	45-123	98	25	57	4-11	9	2	5
Water (millions of gallons)	4-10	8	2	5	1-2	2	0	1
Library services								
Books (thousands)	8-22	18	5	10	1-4	3	1	2
Staff	1-4	3	1	2	0-1	1	0	0

[a] Construction is assumed to begin in 1993, operation in 1998, retrievability in 2028, and decommissioning in 2048.

[b] Range indicates range of impacts over years of project shown in table heading.

Table 5-52. Incremental service requirements associated with the location of a repository at Yucca Mountain (horizontal emplacement)[a]

Service	Incremental service requirements							
	Clark County				Nye County			
	Construction	Operation	Retrievability	Decommissioning	Construction	Operation	Retrievability	Decommissioning
Expected population increments	4,676-17,718[b]	10,549	3,336	4,133	732-2,775	1,652	522	647
Education								
Schools								
Elementary	1-3	2	1	1	1-2	1	0	1
Secondary	0-1	1	0	0	0-1	0	0	0
Teachers	43-163	97	31	38	7-28	17	5	7
Police								
Officers	8-30	18	6	7	3-10	6	2	2
Vehicles	4-14	8	3	3	1-2	1	0	1
Fire								
Volunteer fire fighters	2-7	4	1	2	6-24	14	4	6
Paid fire fighters	5-17	10	3	4	1-3	2	1	1
Trucks and other equipment	1-3	2	1	1	2-8	4	1	2
Medical services								
Doctors	6-23	14	4	5	0-1	1	0	0
Hospital beds	27-103	61	19	24	3-10	6	2	2
Water (millions of gallons)	2-8	5	2	2	0-2	1	0	0
Library services								
Books (thousands)	5-19	11	4	4	1-3	2	1	1
Staff	1-3	2	1	1	0-1	0	0	0

[a] Construction is assumed to begin in 1993, operation in 1998, retrievability in 2028, and decommissioning in 2048.

[b] Range indicates range of impacts over years of project shown in table heading.

to 1997. In subsequent phases, the incremental service requirements associated with the repository in Clark County would range from about 0.1 to 2.2 percent over that which would be due to projected baseline growth.

5.4.3.2 Potentially significant community service effects

Based upon the assumed population impacts described in Section 5.4.2, the following discussion describes some of the potentially significant impacts on community services that could result from the repository project. Impacts which, in light of the information available at this writing, do not appear to be of concern will not be discussed. For example, both Nye and Clark counties appear to have ample near- and long-term future capacity to accommodate disposal of increased solid waste.

Housing

Housing impacts are qualitatively different from other community services impacts because housing services typically are provided by the private sector. Therefore, the issue is whether or not the market would be able to accommodate increased housing demand. Future baseline housing demand in Clark and Nye counties is shown in Table 5-53. Repository-related impacts on projected housing demand in the area would follow forecast population changes associated with the project. During the initial construction phase, housing demand would increase with the influx of workers and dependents. The outmigration of workers at the beginning of the operation phase would produce a slight bust period. During the decommissioning phase, the incremental impact would be small enough to allow the forecast housing units to absorb easily the additional repository-related population.

This qualitative analysis reflects preliminary assessments of effects on the housing market, which are related directly either to the growth or decline of population and to the overall level of economic activity in the study region. The current uncertainty as to the location, price, and quality of available housing, and the locational and other preferences of individuals who would be moving into the area, make estimates of housing effects uncertain. As this uncertainty becomes resolved, mitigative measures, such as temporary housing during the construction phase, may be identified that would avoid potentially significant housing effects.

Education

The potential effects on the Nye County education system may be substantial. For example, the additional three schools that could be required in Nye County during the construction phase would represent a 20 percent increase in the baseline requirement in the year 2000. On the other hand, the effect upon Clark County educational services could be small. For example, repository construction could require a 2.9 percent increase over the presently forecast requirement for teachers between 1990 and 2000. If there were to be no additional teachers hired above the baseline forecast requirements, then an average of one student per class could be added to existing classrooms.

Table 5-53. Projected future baseline (without repository) housing demand in Clark and Nye Counties, 1980-2000[a,b]

	Housing units							
	Clark County				Nye County			
Type of housing	1980	1985	1990	2000	1980	1985	1990	2000
Single family units	114,315	140,003	163,343	219,520	1,916	4,275	7,367	8,980
Multiple family units	54,815	67,133	78,325	105,262	393	877	1,511	1,842
Mobile homes	20,730	25,388	29,621	39,808	1,893	4,222	7,279	8,872
Totals	189,860	232,524	271,289	364,590	4,202	9,376	16,157	19,694

[a] Source: McBrien and Jones, 1984.
[b] 1980 housing demand based upon Nye County Nevada Profile (State of Nevada, NOCS, 1982).

Water supply

At present, the size of municipal and private utility systems in most communities near Yucca Mountain appears to be adequate for current and future population levels, although some water systems need to be expanded. For example, Beatty's high-quality water source is inadequate for the present population (letter from M. Walker, Beatty Water and Sanitation District, to M. Rogozen, Science Applications International Corporation, August 7, 1984, regarding water supply and waste-water treatment in the Beatty area). There are plans to improve many systems that would require several years to complete. The plans include improvements such as new wells, water distribution lines, and sewer lines that are designed to accommodate projected baseline growth in the immediate vicinity of these communities. The major problems presently associated with this expansion are identifying additional potable water sources (e.g., from within the lower carbonate aquifer) and obtaining adequate development capital from revenues because many areas have large mobile home populations and few permanent dwellings. However, water supply impacts because of the project generally do not appear to be significant.

According to an investigation sponsored by the State of Nevada, NDCNR (Nevada Department of Conservation and Natural Resources, 1982), if present rates of water use continue, then there is both legal and technical uncertainty as to the ability of existing sources to meet the water supply needs of the Las Vegas valley beyond the year 2020, or when the population would reach about 1 million people. Several recommendations have been made that are designed to extend and increase the water supply, which include increased conservation, reliance upon ground water for peak demand, and the use of aquifers for storage of temporary surface water surpluses.

Sewage treatment

Additional treatment facilities may be necessary in the smaller communities to accommodate the increased water use associated with repository construction. In Nye County, sewage is either disposed of through private septic tanks and package plants or it is discharged from sewage-collection systems to evaporation pits in the desert. The capacity for wastewater treatment is not likely to be affected more severely than that of water-supply systems. However, extensive settlement close to the work site in Nye County could require additional facilities.

Public safety services

Special training and other assistance, which is discussed in Section 6.2.1.8, would be necessary to prepare local police and fire departments to respond to potential accidents involving nuclear waste transportation. However, the quality of law enforcement and fire protection would not be affected significantly by the population increase associated with construction of a repository. Such increases in police and fire-service personnel are likely to be accommodated by normal expansion plans that are commensurate with anticipated growth. However, as was noted in Section 3.6.3, present service levels in rapidly growing nonurban areas of Clark County may be inadequate. Additional personnel may be required if the project work force were responsible either for greater numbers or for different types of crimes than that which would accompany similar growth in the existing population. Both during repository operation and subsequent phases of the project, the demand for services would be less than would be anticipated in the construction phase.

Medical services

A small increase in the demand for health-care facilities and personnel would result from repository construction. Projected inmigration would probably generate an increase in the need for doctors and hospital beds that would range from less than 1 percent to about 3 percent over future baseline requirements in 1998 to 2053; this projection assumes that the mix of health care needs of the repository workers and their dependents would be similar to those of the present residents. The significance of these demand increases would probably be greatest in smaller communities in which relatively few medical facilities are available. Nye County residents might turn to Las Vegas area facilities for major health care services.

Transportation

Major improvements to existing highway systems are planned for U.S. Highway 95 through metropolitan Las Vegas. This highway will be rebuilt completely from Railroad Pass to I-15 and will become I-515 along one section. By 1992, the new freeway is scheduled to be completed to Russell Road. By the year 2000, the entire freeway should be completed to Railroad Pass. Despite improvements, it is projected that a number of streets, including sections of I-15 and U.S. Highway 95, would be either at or over capacity during peak-hour use for the baseline population levels expected by the year 2000 (Clark County Transportation Study Policy Committee, 1980).

To estimate the effects of repository-related traffic in Las Vegas, the annual average daily traffic levels for the in-town portions of U.S. Highway 95 and I-15 have been compared both with and without the repository. Repository-related population increases, as discussed in Section 5.4.2, have been used to project 1996 traffic volumes on various segments of these highways. These projections are shown in Tables 5-54 and 5-55 along with State of Nevada, Department of Transportation baseline projections. These projections indicate a 2.6 percent increase due to repository-related population growth. This increment is not considered to be significant. Rail capacity would be adequate to meet additional demands for service caused by baseline and project-related growth.

5.4.4 Effects on sociocultural conditions

The following is a preliminary assessment of potential sociocultural effects that may be expected in communities near Yucca Mountain. The assessment is preliminary because of the limited data base (see Chapter 3) and because of the uncertainty about the number and location of expected inmigrants.

A distinction is made between standard and special sociocultural effects that may accompany nuclear projects (Murdock and Leistritz, 1983). Standard effects result from the influx of population that typically accompanies the construction of large projects in rural areas. Special effects stem from

Table 5-54. Projected annual average daily traffic on U.S. 95 in Las Vegas, 1996

Highway segment	Without repository (baseline)			With repository		
	Number of cars	Number of trucks	Total vehicles	Number of cars	Number of trucks	Total vehicles
Decatur - Valley View	77,414	2,394	79,808	79,410	2,456	81,865
Valley View - Rancho	80,578	2,492	83,070	82,655	2,556	85,211
Rancho - Highland	94,294	2,916	97,211	96,725	2,991	99,716
Highland - I 15 Int.	111,914	3,461	115,375	114,799	3,550	118,349
I 15 Int. - Casino Ctr.	91,058	1,858	92,917	93,405	1,906	95,311
Casino Ctr. - D Town Exp.	64,794	1,322	66,117	66,464	1,356	67,820
D Town Exp. - L.V. Blvd.	64,947	1,325	66,272	66,621	1,359	67,980
L.V. Blvd. - Charleston	75,091	1,532	76,624	77,027	1,571	78,598
Charleston - Sahara	92,801	2,870	95,671	95,193	2,944	98,137
Sahara - Lamb	92,758	2,869	95,627	95,149	2,943	98,092
Lamb - Flamingo	90,126	2,787	92,913	92,449	2,859	95,308
Flamingo - Nellis	100,703	3,115	103,818	103,299	3,195	106,494
Nellis - Tropicana	98,384	3,043	101,427	100,920	3,121	104,042
Tropicana - L.V. NLV[a]	70,479	2,180	72,658	72,296	2,236	74,532
L.V. NLV - NUL[b] Henderson	66,527	2,058	68,585	68,242	2,111	70,353
NUL Henderson - Sunset Rd.	66,527	2,058	68,585	68,242	2,111	70,353
Sunset Rd. - SR 146	64,023	2,668	66,691	65,673	2,737	68,410
SR 146 - Henderson	31,135	---	31,135	31,938	---	31,398

[a] NLV = North Las Vegas.
[b] NUL - Northern Urban Limits.

Table 5-55. Projected annual average daily traffic on I-15 in Las Vegas, 1996

Highway segment	Without repository (baseline)			With repository		
	Number of cars	Number of trucks	Total vehicles	Number of cars	Number of trucks	Total vehicles
Craig - Northern city limits of Las Vegas	11,091	2,948	14,039	11,377	3,024	14,401
Craig - Cheyenne	25,841	4,560	30,401	26,507	4,678	31,185
Cheyenne - Lake Mead	39,442	4,382	43,824	40,459	4,495	44,954
Lake Mead - D & Washington	64,320	5,593	69,913	65,978	5,737	71,715
D & Washington - D. Town Exp.	70,274	6,111	76,385	72,085	6,269	78,354
D. Town Exp. - Charleston	101,595	6,485	108,079	104,214	6,652	110,866
Charleston - Sahara	111,348	7,107	118,456	114,218	7,290	121,508
Sahara - Spring Mountain	109,379	6,982	116,361	112,198	7,162	119,360
Spring Mountain - Dunes Flamingo	93,930	7,070	101,000	96,351	7,252	103,603
Dunes Flamingo - Tropicana	77,031	7,618	84,649	79,017	7,814	86,831
Tropicana - Las Vegas Blvd.	42,549	10,637	53,187	43,646	10,911	54,557

concerns about radioactive material. Because radioactive materials would be transported through the region, these special effects may occur in both rural and urban areas. The concerns include the following: (1) the effects on health and safety; (2) the fairness of the site selection process; (3) the institutional issues related to security, handling, and transportation; and (4) public participation and monitoring (Hebert et al., 1979; DOE/NVO, 1983; Murdock and Leistritz, 1983).

5.4.4.1 Effects on social structure and social organization

Standard effects on social structure and organization typically involve conflicts between inmigrating workers and existing residents; changes from an informal, neighborly lifestyle to a more formal bureaucratic mode; and social disruption during the transition. Special effects may be evident in the form of mobilization (that is, commitment of resources), and formation of opposing and supporting groups.

Standard effects on social structure and social organization

If current Nevada Test Site settlement patterns are followed, much of the population influx would be absorbed by urban Clark County. In light of the small size of the increment relative to the projected baseline population and the complex nature of the existing social structure in urban Clark County, the effects would not be significant. Further study is required to assess whether the net effect would be adverse or beneficial. Inmigration could aggravate existing social stress; conversely, the project may provide an opportunity to diversify the area's economic base and offer a stable source of employment.

Nye County is a rural area in which previous experience indicates that significant standard effects could occur. However, preliminary assessment suggests that inmigrating construction workers would become assimilated within the existing county structure. Relevant factors in this assessment include the compatibility between inmigrating workers and the communities of Nye County and the long lead-time that permits adequate planning.

Certain characteristics of the existing rural structure, which would reduce the possibility of conflict between existing and inmigrating groups, appear to be compatible with inmigration. Historically, Nye County communities have had large percentages of miners, and mining continues to be important in the area. A recent trend in Pahrump has been an increase in construction and mining work relative to agricultural employment. Some residents of the town of Amargosa Valley depend upon employment outside of the immediate area to supplement their farm income. In addition, separate employee housing complexes such as housing at Mercury for Nevada Test Site workers and the American Borate Housing Complex, which is south of the town of Amargosa Valley, appear to be accepted features of the existing social structure.

Increasingly formal relationships, which can occur as rural communities expand, may be more likely if growth is concentrated in any one rural community. The possibility of growth being accompanied by an increase in social problems is a valid concern in a region that has had negative effects from rapid growth cycles. However, the possibility may be reduced by the nature of the project itself. A long lead-time, combined with an impact mitigation process, should allow adequate time to plan for initial population and for changes that may occur over the entire repository lifecycle. Moreover, it is likely that repository operation would provide employment stability. As noted in Chapter 3, at least one rural Nye County community appears to seek expansion. The degree to which each community is prepared for and willing to accept inmigration is a critical factor in determining the potential for standard effects (Cortese, 1979).

Special effects on social structure and social organization

Concerns about radioactive material provide the basis for possible changes in existing social structure and social organization. Special effects may include the mobilization and formation of groups that either oppose or support the repository and may also include increased controversy in the community. These effects have been occurring since the State of Nevada was notified of the potential siting of the repository and the hearings were held (DOE/NVO, 1983). Opposition groups have formed, and several area organizations have made public statements either supporting or opposing the repository. Networks exist through which mobilization of groups could occur, such as those formed to oppose siting the MX Missile System in Nevada and Utah (Albrecht, 1983).

5.4.4.2 Effects on culture and lifestyle

Because of the diversity of the existing cultural environment, inmigrating workers would be able to select a compatible cultural environment and are likely to be readily assimilated into the community. Those construction workers who continue to be employed during the operation phase would be the most completely assimilated. However, it is possible that repository activities could affect certain cultures in the area. For example, Native Americans, who interpret threats to their land as threatening their cultural identity, may be affected if routes traverse their communities (Knack, 1980; Stoffle et al., 1982). Further assessment may be required following identification of specific routes within the state.

5.4.4.3 Effects on attitudes and perceptions

Attitudes and perceptions are an integral part of the social impact process and are factors in the social group mobilization that was previously discussed. The following preliminary assessment identifies conditions that are unique to southern Nevada and that may interact with the specific concerns outlined in Chapter 3 to affect the development of attitudes on the repository issue. These conditions include past experience, the salience of the issue to an individual or to a group, and the issue's relationship to other issues about which an attitude has already been formed.

Several experiences may be particularly relevant to the formation of attitudes on the repository issue. The MX siting process and the publicity surrounding the Beatty low-level waste site have sensitized southern Nevada residents to the subjects of waste transportation and disposal as well as to governmental procedure. In addition, the legal action and the publicity from early atmospheric testing may either introduce or reinforce apprehension of both civilian and military uses of nuclear material. Conversely, the identification of familiar and voluntarily accepted activities are important elements in the perception of risk and, by extension, of nuclear risk. For citizens who have lived alongside the Test Site for many years, nuclear technology may be viewed as more familiar and be more likely to be accepted (Starr, 1969; Slovic, 1976; Slovic et al., 1977; Wildavsky and Douglas, 1983; see also Crouch and Wilson, 1983 for a succinct summary and updated bibliography).

Economic considerations and the potential for changes in lifestyle also contribute to the formation of public attitudes; for further discussion, see Section 3.6.4.3. Preliminary analysis suggests that the repository could be considered more economically beneficial by Nye County communities than by Clark County communities; however, there may be varied reactions within either county. Towns such as Amargosa Valley and Pahrump could welcome the potential for growth and increased employment, particularly for the skilled workers and young persons who might otherwise leave the area. It should be noted, however, that indications of Nye County support should be tempered by the survey findings, which were cited in Chapter 3, that demonstrate a desire for growth without social disruption. This support may depend on the extent to which Nye County residents are convinced that growth can be managed and that problems can be mitigated.

In contrast, urban Clark County residents could view the repository, especially waste transportation, as negatively affecting the tourism image on which the economy is based. Moreover, it is possible that repository-related traffic (other than waste) could aggravate the transportation problems that have been cited already by residents (List, 1980; Frey, 1981). Las Vegas newspapers and the 1984 UNLV survey suggest that many Clark County residents may oppose locating a repository at Yucca Mountain.

The following issues may contribute to the formation of public attitude about the repository: (1) resentment of the high percentage of Federal land ownership, which is symbolized by the Sagebrush rebellion (Brodhead, 1980); (2) the belief, which is evident in the public hearings, that Nevadans have "done their share" by giving land for Nevada Test Site activities and should not have to accept waste from other states when Nevada produces none; (3) distrust of the Federal government, which is also evident in the hearings and is reinforced by the perception of a dual role played by the government in managing both the development of nuclear power and radioactive-waste disposal. This last issue may be particularly important because of the role that credibility plays in the formation of attitudes.

5.4.5 Fiscal conditions and government structure

The location of a repository at Yucca Mountain would increase both the revenues and the expenditures of State and local government entities in the affected area. Although no quantitative estimates of potential net fiscal effects are presently available, this section will describe some of the qualitative revenue and expenditure implications. A description of key fiscal impact mitigation provisions of the Nuclear Waste Policy Act (the Act) is also provided.

The earliest expenditure would result from the increased planning activity required at the State, county, and local government levels to enable affected government entities to prepare for and participate in a decision to locate a repository at Yucca Mountain. At the onset of construction in 1993, an influx of workers from outside the area would increase the demand for community services, as described in Section 5.4.3. During repository operation, additional outlays would be associated with road maintenance, traffic escort and control, and emergency preparedness. This would be offset, at least partially, by increases in government revenues at the State level through increased sales and use taxes, motor fuels taxes, and other highway use and general fund revenues; and it would be offset at the local level through increased sales, property and other tax revenues, and user fees.

In addition, to ensure mitigation of any potential adverse net fiscal effects of a repository, the Act explicitly provides a number of different ways for state and local governments and Indian tribes to obtain financial assistance. The Act recognizes the fiscal implications of preconstruction planning activities as well as the fiscal effects of the physical presence of the repository and its related work force. Under the Act, the Secretary of Energy must make grants to a State that has been notified that a repository may be located within its boundaries so that the State can participate in the review of assessments of the economic, social, public health and safety, and environmental implications of a repository (Sections 116 and 117). Similar provisions for financial assistance to affected Indian tribes appear in Section 118. Also, states that have sites that have been approved for site characterization and Indian tribes that have been designated as "affected" will receive Federal grants in accordance with the NWPA. Those provisions (i.e., Sections 117 and 118) have been paraphrased below:

1. To review activities undertaken to assess potential social, public health and safety, and environmental impacts of a repository.
2. To develop a request for impact assistance associated with the development of a repository.
3. To engage in monitoring, testing, or evaluation activities with respect to site characterization programs.
4. To provide information to residents about actions concerning the potential repository.
5. To request information from and to make comments and recommendations to the Secretary of Energy regarding the siting of a repository.

Finally, the Act provides for financial and technical assistance to the state in which repository construction is authorized for purposes of mitigating the impacts of repository development (Section 116(c)(2)(A)). Additional studies will be performed by the DOE as part of the site selection environmental impact statement. In addition to this financial assistance, the Act requires that the Federal government make payments in lieu of real property taxes to State and local governments in the affected area. These payments must be equal to the amounts that would be paid if the State and local government entities were authorized to tax site-characterization development and operation activities as they would any other real property and industrial activities occurring the in area.

In addition, Section 117(c)(5) requires that, pursuant to a Consultation and Cooperation Agreement negotiated with States selected for characterization, DOE is to assist both the state and "units of general local government" in resolving a number of concerns such as state liability arising from accidents; necessary road upgrading and access to the site; ongoing emergency preparedness and emergency response; monitoring of transportation of high-level waste and spent nuclear fuel through such state, the conduct of baseline health studies of inhabitants in neighboring communities, and reasonable periodic monitoring thereafter; and monitoring of the repository site upon decommissioning and closure.

As in the case of community services impacts, the significance of potential fiscal impacts of the project would depend upon the extent to which workers would be obtained from outside the southern Nevada area and the settlement patterns of those inmigrating workers. While the assessment of community services impacts in Section 5.4.3 suggests that the fiscal effects might be observable yet insignificant for the urban areas of Clark County, the influx of inmigrants to the rural communities of Clark and Nye counties could have a potentially significant effect on the fiscal and governmental structure of those communities. Further information of inmigration and settlement patterns will be required to accurately quantify these impacts for purposes of identifying a detailed approach to fiscal and governmental impact mitigation.

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