DOE/RW-0198

Nuclear Waste Policy Act
(Section 113)

Site Characterization Plan

Overview

Yucca Mountain Site, Nevada Research and Development Area, Nevada

December 1988

U.S. Department of Energy
Office of Civilian Radioactive Waste Management
Washington, DC 20585

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FOREWORD

The Yucca Mountain site in Nevada has been designated by law for detailed study as the candidate site for the first U.S. geologic repository for spent nuclear fuel and high-level waste. The detailed study--called "site characterization"--will be conducted to obtain the information necessary to determine the suitability of the site for a repository and, if the site is suitable, to obtain from the Nuclear Regulatory Commission authorization to construct the repository.

As part of the site-characterization process, the Department of Energy (DOE) has prepared a site characterization plan (SCP) for the Yucca Mountain site. The SCP is a nine-volume document, more than 6,000 pages long, that describes in considerable detail the activities that will be conducted to characterize the geologic, hydrologic, and other conditions relevant to the suitability of a site for a repository. To ensure that the SCP is available to the public, the DOE has placed copies of the SCP in its public reading rooms around the country and in public libraries in Nevada. Individual copies are available upon request. Persons wishing to comment on the SCP during the 90-day comment period beginning January 15, 1989, should either review the document at one of the public libraries or reading rooms or request an individual copy from the DOE's Yucca Mountain Project Office, whose address is given below.

To help the public better understand both the SCP and the site-characterization program, the DOE has prepared this overview and the SCP Public Handbook. The overview presents summaries of selected topics covered in the SCP; it is not a substitute for the SCP. The organization of the overview is similar to that of the SCP itself, with brief descriptions of the Yucca Mountain site, the repository, and the containers in which the waste would be packaged, followed by a discussion of the characterization program to be carried out at the Yucca Mountain site.

This overview is intended primarily for those persons who want to understand the general scope and basis of the site-characterization program, the activities to be conducted, and the facilities to be constructed without spending the time necessary to become familiar with all of the technical details presented in the SCP. For the readers of the SCP, the overview will be useful as a general guide to the plan.

The SCP Public Handbook is a short document that contains brief descriptions of the SCP process and the contents of the SCP. It also explains how the public can submit comments on the SCP and lists the libraries and reading rooms at which the SCP is available.

Copies of the SCP, the SCP Overview, and the SCP Public Handbook can be obtained by contacting the Yucca Mountain Project Office, U.S. Department of Energy, Box 98518, Las Vegas, Nevada 89193.

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Chapter 1

INTRODUCTION

As directed by the U.S. Congress, the U.S. Department of Energy (DOE) has been conducting a program for siting the nation's first geologic repository for radioactive waste.* The process and the schedule for this program were specified in the Nuclear Waste Policy Act of 1982. One of the sites included in that program is Yucca Mountain, Nevada, which the DOE has been studying for about 10 years. In May 1986, the DOE recommended and the President approved the Yucca Mountain site as one of three candidate sites for detailed study. In December 1987, in the Nuclear Waste Policy Amendments Act, the Yucca Mountain site was designated by the Congress for characterization as the single candidate site for a geologic repository.

The Yucca Mountain site has not been selected for a repository; rather, it has been designated as the only "candidate site" to be characterized at this time. A comprehensive program of detailed investigations will be conducted at Yucca Mountain to determine whether it is suitable for a repository. If the site is suitable, then the DOE must demonstrate to the Nuclear Regulatory Commission (NRC) that the site meets regulations intended to protect the health and safety of the public both during repository operations and after the repository has been permanently closed. In order to demonstrate to the NRC that the repository system--that is, the site, the repository, and the waste package--would perform as required, the DOE must also develop designs for the repository and the waste package (i.e., the waste and the container in which it is packaged for disposal) and conduct scientific assessments to determine that the performance of the repository system would meet all applicable regulations.

The comprehensive program referred to above is known as the "site-characterization program" and is described in a multivolume document called the "site characterization plan," or the "SCP." The site-characterization program and the SCP are explained in this overview.

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*The radioactive waste emplaced in a repository will consist of spent fuel from commercial nuclear reactors, high-level waste from defense activities, and a small quantity of commercial high-level waste. For convenience, the words "radioactive waste" and "waste" are often used in this overview to mean spent nuclear fuel or high-level waste.

The remainder of this chapter briefly discusses the purposes of, and the requirements for, site characterization (Section 1.1); the purposes of the SCP, the requirements for the SCP, and the organization and level of detail in the SCP (Section 1.2); the process established for participation by the NRC, the State of Nevada, and the public, as well as the purpose of the consultation draft of the SCP (Section 1.3); the siting process after site characterization (Section 1.4); and the organization of this overview (Section 1.5).

1.1 SITE CHARACTERIZATION

Purpose of site characterization

The purpose of site characterization is to obtain the information necessary to determine whether the Yucca Mountain site is suitable for a repository and, if so, to obtain from the NRC authorization to construct a repository. The information to be collected will serve to establish (1) whether a repository can be constructed and operated at that site without adversely affecting the health and safety of the public during repository operations and (2) whether the waste emplaced in the repository will remain isolated from the general environment for thousands of years.

Legislative and regulatory requirements

Requirements for site suitability and licensing are specified in two sets of regulations:

- The general guidelines for the recommendation of suitable sites that were developed pursuant to Section 112 of the Nuclear Waste Policy Act and issued by the DOE as Part 960 of Title 10 of the Code of Federal Regulations (10 CFR Part 960).

- The regulations promulgated for the licensing of geologic repositories by the NRC in Part 60 of Title 10 of the Code of Federal Regulations (10 CFR Part 60).

The NRC regulations implement and enforce the environmental standards issued for the management and disposal of radioactive waste by the Environmental Protection Agency in Part 191 of Title 40 of the Code of Federal Regulations (40 CFR Part 191).

A site-characterization program that will provide the information needed to address these requirements is mandated by Section 113 of the Nuclear Waste Policy Act, as amended. It is also required by the DOE's general siting guidelines in 10 CFR Part 960 and the NRC's regulations in 10 CFR Part 60.

Activities conducted during site characterization

In order to determine the suitability of the site, information is needed on the geologic, geoengineering, hydrologic, geochemical, climatological, and meteorological conditions at the site. This information is obtained by investigations conducted both from the surface and underground.

The surface-based investigations will include tests performed at the surface of the ground and tests performed in boreholes and trenches. The underground investigations will be made in special facilities to be constructed at Yucca Mountain. These facilities will consist of two exploratory shafts excavated to the depth of the proposed repository and underground rooms and tunnels for testing. To support these facilities, the DOE will provide various structures and buildings on the surface, such as a hoisthouse for the shafts and temporary buildings used for offices and laboratories.

Although no significant adverse impacts are expected to result from site characterization, the DOE will monitor activities that might have significant environmental and socioeconomic effects and will implement appropriate mitigation measures that may be necessary.

The DOE does not currently plan to use any radioactive materials in site characterization with the exception of well-logging tools that contain short-lived radioactive materials and are commonly used in geologic and hydrologic exploration. After these tools have been removed, no radioactive material will be left behind at the site.

1.2 THE SITE CHARACTERIZATION PLAN

Purpose of the SCP

The basic purpose of the SCP is threefold:

1. To describe the site, the preliminary designs of the repository and the waste package, and the waste-emplacement environment in sufficient detail so that the basis for the site-characterization program can be understood.

2. To identify the issues to be resolved during site characterization, including the issues related to site suitability; to present the strategy for resolving the issues; and to identify the information needed to resolve the issues.

3. To describe general plans for the work needed to obtain the information deemed necessary and to resolve outstanding issues.

The information deemed necessary includes the information needed to prepare the environmental impact statement required under Section 114(f) of the Nuclear Waste Policy Act, as amended.

In the context of items 2 and 3, "issues" are defined as questions related to the performance of the repository system that must be resolved to demonstrate compliance with the applicable Federal regulations.

Requirements for the contents of the SCP

The Nuclear Waste Policy Act, as amended, specifies that the SCP include a description of the Yucca Mountain site, a description of the planned site-characterization activities, a description of the packaging to be used for the waste, a conceptual design of the repository, and any other information that the NRC may specify. The requirements of the Act are repeated by the NRC in its regulations (10 CFR Part 60), which include some additional specifications (e.g., requirements for a quality-assurance program).

In preparing the SCP, the DOE has met both sets of requirements. (A complete list of the requirements is given in the introduction to the SCP, which also explains how the requirements are met.) In addition, the DOE has followed NRC guidance for the format and the organization of the SCP. Furthermore, as explained in Section 5.2 of this overview, the preparation of the SCP was guided by an issue-resolution strategy whose objective was to ensure that site characterization would provide the information needed for determining whether the Yucca Mountain site is suitable for a repository and for obtaining a construction authorization from the NRC.

Organization of the SCP

The SCP is divided into two parts: Part A, which describes the site and the conceptual designs of the repository and the waste package, and Part B, which presents the DOE's rationale and plans for the site-characterization program. In addition, a comprehensive index is provided to help readers find the various sections of the SCP in which topics of interest to them are addressed.

Part A consists of seven chapters. Chapters 1 through 5 discuss the available information on the natural conditions at the site. In particular, Chapter 1 presents the available data on the geologic conditions of the site and the region; Chapter 2 discusses the geoengineering properties of the rock units at the site; Chapters 3 and 4 discuss the hydrologic and geochemical conditions, respectively; and Chapter 5 is concerned with climate and meteorology. In all of these chapters, the available information is evaluated in terms of the regulatory requirements and the data needed in order to have confidence that the information is sufficient to describe a particular condition or characteristic. The results of these evaluations were considered in developing the plans presented in Part B. Each of the first five chapters in Part A concludes with a summary that links the data and analyses presented in that chapter with the strategies and plans presented in Part B.

The last two chapters in Part A are concerned with the conceptual design of the repository (Chapter 6) and the waste package (Chapter 7). Like the preceding chapters, Chapters 6 and 7 conclude with a summary that links the design of the repository and the waste package to Part B by summarizing design issues and related information needs.

Part B, which consists of one large chapter (Chapter 8), describes the site-characterization program and the issue-resolution strategies that are the basis for this program. It begins by presenting, in Section 8.0, the top-level strategy for determining whether the repository will perform satisfactorily. Section 8.1 discusses the overall rationale for the program, the site-specific hierarchy of issues that must be resolved during site characterization, and the general issue-resolution strategy that the DOE has adopted. Section 8.2 presents the site-specific issues hierarchy. Detailed descriptions of the issue-resolution strategies are given in Section 8.3, which also discusses the investigations planned for the site, the repository, the seal system, the waste package, and the assessment of repository performance. The rest of Chapter 8 discusses the activities that will be carried out during site characterization, including the tests to be performed, the construction and design of the exploratory shafts, and the potential impacts of site characterization on the waste-isolation capabilities of the site (Section 8.4); the schedule for site-characterization activities (Section 8.5); the quality-assurance program for site characterization (Section 8.6); and the decommissioning of the facilities used for characterization if Yucca Mountain is not found to be suitable as a repository site (Section 8.7).

Level of detail

The contents of the SCP and its level of detail reflect earlier consultations with the NRC staff and the State of Nevada. The SCP presents general information on the activities to be conducted, the sequence of activities, the priorities assigned to activities, and general schedules for the site-characterization program. The detailed descriptions of site-characterization studies and activities will be given in study plans. Each study plan will be made available before the start of new onsite activities, in accordance with previous agreements with the staff of the NRC.

Not included in the SCP are the activities that will be performed to collect data on environmental and socioeconomic conditions. Plans for these activities are described in other documents, principally the Environmental Monitoring and Mitigation Plan and the Socioeconomic Monitoring and Mitigation Plan.

1.3 THE SCP PROCESS

Legislative requirements for the SCP process

Section 113 of the Nuclear Waste Policy Act, as amended, specifies that, before starting to construct exploratory shafts at Yucca Mountain, the DOE must meet the following two requirements:

1. Submit to the NRC and to the Governor and the Legislature of the State of Nevada a site characterization plan (SCP) for their review and comment.

2. Make the SCP available to the public and hold public hearings to inform the residents of the Yucca Mountain area of the SCP and to receive their comments.

To meet both of these requirements, the DOE is submitting copies of the SCP to the NRC and to the Governor and the Legislature of Nevada.

To ensure that the SCP is available to the public, the DOE has placed copies of the SCP in its public reading rooms around the country and in public libraries in Nevada. Individual copies are available upon request.* To help the public understand the SCP, the DOE has prepared this overview and the SCP Public Handbook and has widely circulated both of these documents. In addition, the DOE has informed the public through its regular Project Update Meetings and briefed Federal, State, and local officials as requested.

During site characterization, the DOE is required by the Nuclear Waste Policy Act, as amended, and by NRC regulations to report not less than once every 6 months to the NRC and to the Governor and the Legislature of Nevada on the nature and extent of site-characterization activities and the information that is collected.

To comply with this requirement, the DOE will issue semiannual progress reports during characterization at Yucca Mountain. These reports will summarize the results of site-characterization activities and will explain any changes that may be made in the test program as information is collected and evaluated or as comments from the State of Nevada and the NRC are received and evaluated. In addition to the NRC and the Governor and the Legislature of Nevada, these reports will also be submitted to the affected units of local government, and they will be available to the public.

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*Copies of the SCP may be requested from the Yucca Mountain Project Office, U.S. Department of Energy, Box 98518, Las Vegas, Nevada 89193.

Participation by the State of Nevada and affected units of local government

The Nuclear Waste Policy Act of 1982 (the Act), as amended, gives the State of Nevada and affected units of local government* a specific role in the repository-siting process. This role includes review of the DOE's technical activities, including the SCP, the periodic progress reports that the DOE will issue during site characterization, the results of site characterization, the designs for the repository and the waste package, and the results of performance assessments. The Act also requires the DOE to provide the State and the affected units of local government with financial assistance to perform these review activities.

The consultation draft of the SCP

On January 8, 1988, the DOE issued a consultation draft of the SCP for the Yucca Mountain site to the State of Nevada and the NRC. The purpose of the consultation draft of the SCP was to facilitate a consultation process that was expected to improve the quality of the SCP and to assist in defining a site-characterization program that will generate the information necessary for siting, designing, and licensing a geologic repository. In addition, the consultation process was intended to accomplish the following:

1. Provide an advance forum for the DOE to explain the organization and the content of the SCP.

2. Provide an advance forum for consulting with the State of Nevada and the NRC staff on concerns they may have and, if possible, for resolving those concerns.

Preliminary comments on the consultation draft were submitted to the DOE by the NRC staff in March 1988, and final comments were submitted in May 1988. In addition, comments were received from the U.S. Geological Survey in April 1988 and from the Edison Electric Institute and the Utility Nuclear Waste Management Group in August 1988. The State of Nevada submitted comments in September 1988. (Copies of all the comments are available for inspection in all of the DOE's public

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*An affected unit of local government is defined in the Nuclear Waste Policy Act, as amended, as "the unit of local government with jurisdiction over the site of a repository or a monitored retrievable storage facility. Such term may, at the discretion of the Secretary (of Energy), include units of local government that are contiguous with such unit." In the State of Nevada, Nye County is an affected unit by definition because it contains the Yucca Mountain site. Clark County and Lincoln County have applied for, and have been granted, the status of affected unit of local government.

reading rooms and in the NRC's public document rooms in Washington, D.C., and at the University of Nevada in Las Vegas.)

The SCP, as issued, represents a significant revision of the consultation draft of the SCP. The revision reflects the comments received before the end of the comment period designated for the consultation process (June 1988). (Comments received after that date will be considered in preparing the semiannual progress reports.) During the consultation period, the DOE held several technical meetings and workshops with the NRC and the State of Nevada. During the first half of this consultation period, the purpose of these interactions was to discuss the NRC's comments on the consultation draft; during the last half, the purpose was to discuss with the NRC and the State of Nevada the DOE's approach to addressing some of the NRC's major concerns. Interactions with the NRC and the State are expected to continue on selected topics during the site-characterization period.

In addition to providing an opportunity to obtain and address external comments on the consultation draft of the SCP, the consultation period served another useful purpose: it allowed the DOE to review and reevaluate the plans and schedules for the site-characterization program described in the consultation draft. In defining this program initially, the DOE placed primary emphasis on the technical sufficiency of the proposed investigations to ensure that all the needed information would be obtained. During the consultation period, the DOE carefully evaluated the planned activities to ensure that the tests included in the SCP are not only sufficient but also necessary; in the process, the program and the SCP were revised and an integrated schedule for the various site, design, and performance-assessment programs was developed.

The consultation period also provided the DOE with the opportunity to continue the development and implementation of a qualified quality-assurance program for site characterization.

1.4 THE SITING PROCESS AFTER SITE CHARACTERIZATION

In addition to its requirements for the process of site characterization, the Nuclear Waste Policy Act, as amended, specifies other steps in the process for siting and licensing a repository.

At any point in the site-characterization process, the DOE could uncover a major disqualifying flaw at the Yucca Mountain site. The discovery and confirmation of such a flaw would bring site-characterization activities to a halt; similarly, at the end of the site-characterization process, the DOE could reach the conclusion that the site is unsuitable. In either case, if the Yucca Mountain site is determined to be unsuitable for a repository, then the DOE must stop all site-characterization activities at the site, notify the Congress and the Governor and the

Legislature of Nevada of the termination, and recommend further action to the Congress to provide for the permanent disposal of the waste. This recommendation for further action is to be made not later than 6 months after the determination of unsuitability.

If, after site characterization, the site is found to be suitable, the Secretary of Energy will submit a report to the President to recommend Yucca Mountain for development as a repository. This report will be accompanied by an environmental impact statement. If the President approves, the recommendation will go to the Congress.

Within 60 days after the Congress has received this recommendation, the State of Nevada may submit a notice of disapproval to the Congress. This will prevent the development of the site as a repository unless the Congress passes a joint resolution of repository-siting approval within the next 90 days of continuous session. If no notice of disapproval is submitted or if a notice of disapproval is overturned by a joint resolution, then the site designation will become effective. At that time, the Secretary will submit an application to the NRC for authorization to construct the repository.

This application will contain a description of the site, a description of the design of the repository and the waste package, and the results of assessments performed to demonstrate that the repository complies with the applicable regulations. The NRC will review the application and decide whether to authorize the construction of the repository. If NRC authorization is received, construction may begin.

When the repository is ready for operation, the DOE will submit an updated license application to the NRC, seeking a license to receive and possess waste at the site. If this license is received, the DOE can begin to receive and emplace waste in the repository.

If, however, the State's notice of disapproval is not overturned by the Congress, the site cannot be used for developing a repository.

1.5 ORGANIZATION OF THE SCP OVERVIEW

This SCP overview is structured somewhat differently from the SCP itself. After this introduction, Chapter 2 briefly describes the Yucca Mountain site, including a history of the process by which the site was selected for characterization and the characteristics that are pertinent to a geologic repository, as determined by investigations performed to date. Chapter 3 presents information about preliminary designs for the repository and the containers in which the waste would be packaged for disposal.

Chapter 4 of this overview discusses the various activities that will be conducted at the Yucca Mountain site during characterization and describes the facilities that will be constructed for that purpose. It also discusses the analyses that have been conducted to determine that the activities conducted during site characterization will not significantly affect the ability of the site to provide waste isolation.

Chapter 5, the longest and most detailed of the overview chapters, explains the basis for the site-characterization program. It begins by discussing the top-level strategy for determining whether a repository would perform satisfactorily at Yucca Mountain. Next it discusses the hierarchy of issues that must be addressed by the site-characterization program and summarizes the DOE's preliminary strategies for resolving the issues. Chapter 5 then briefly describes the investigations that will be conducted to obtain the information needed to support these strategies and the programs in which this information will be used. These include (1) refining the designs of the repository, the system to seal the repository, and the waste package and (2) assessing the performance of the repository. Chapter 5 is followed by a glossary.

Included in this overview is an appendix that presents the issues and information needs for the Yucca Mountain site.

Chapter 2

THE YUCCA MOUNTAIN SITE

This chapter briefly describes the Yucca Mountain site--its location, the host rock that would be used for the repository, and the features that are pertinent to the performance of a repository. It starts with a brief summary of the process that led to the selection of Yucca Mountain for characterization as a candidate site for a repository.

2.1 THE HISTORY OF SITE SCREENING AND SELECTION

The screening process that led to the selection of Yucca Mountain for characterization started in 1977, when the U.S. Government decided to investigate the possibility of siting a repository at the Nevada Test Site (NTS). The NTS was selected for this investigation because it was used for nuclear operations, its land was withdrawn from public use, and the land was committed to long-term institutional control. Furthermore, the U.S. Geological Survey proposed that the NTS be considered for a number of geologic reasons, including the following:

- In southern Nevada, ground water does not discharge into rivers that flow to major bodies of surface water.

- Many of the rocks at the NTS have geochemical characteristics that are favorable for waste isolation (i.e., they would retard the migration of radionuclides).

- The paths of ground-water flow between potential sites for a repository and the points of ground-water discharge are long.

- Because the region is arid, the rate at which ground water is recharged is very low and therefore the amount of moving ground water is also very low, especially in the unsaturated rocks.

To be compatible with weapons testing at the NTS, site screening was eventually limited to the southwestern part of the NTS and the adjacent land. Three locations in this area were identified as the most attractive for preliminary testing.

One of these locations was Yucca Mountain, which contained a block of tuff (see Section 2.2.3) that seemed to be large and thick enough for a repository. Because tuff had not previously been considered as a potential host rock for a repository, the government solicited the views of the National Academy of Sciences on investigating tuff as a host rock and received a favorable response. At about the same time, Yucca Mountain was recommended by the U.S. Geological Survey, which had compared the results of preliminary explorations at all three locations. In 1980, a formal analysis of 15 potential locations showed that Yucca Mountain was preferred, with several potentially suitable horizons. In February 1983, after the enactment of the Nuclear Waste Policy Act of 1982, Yucca Mountain was formally identified as one of nine potentially acceptable sites.

In May 1986, after preparing an environmental assessment,* the Secretary of Energy nominated the Yucca Mountain site as one of five sites suitable for characterization and recommended that it be characterized as one of three candidate sites for a repository; the Secretary's recommendation was approved by the President. The Secretary also made the preliminary determination, required by the Nuclear Waste Policy Act of 1982, that the Yucca Mountain site is suitable for development as a repository. On December 21, 1987, the Congress enacted the Nuclear Waste Policy Amendments Act of 1987, which directed the DOE to characterize only one site as a candidate for the first repository, and that site was identified as Yucca Mountain. The Amendments Act was signed into law by the President on December 22, 1987.

2.2 GENERAL DESCRIPTION OF THE SITE

2.2.1 Location and land ownership

The Yucca Mountain site is in southern Nevada, in Nye County, about 100 miles by road northwest of Las Vegas (Figure 2-1). As shown in Figure 2-2, the Yucca Mountain site is on various Federal lands: public lands managed by the Bureau of Land Management (BLM) of the Department of the Interior; the Nellis Air Force Range, withdrawn from the public domain for use by the Air Force (the Department of Defense), but managed by the BLM; and the Nevada Test Site, withdrawn from the public domain and reserved for use by the DOE.

2.2.2 General description

The site lies in the southern part of the Great Basin--an arid region with linear mountain ranges and intervening valleys, very little rainfall, sparse vegetation, and a sparse population. Northern Yucca Mountain is about 5,000 feet above sea level, more than 1,200 feet above the western edge of Jackass Flats to the east, and more than 1,000 feet above the eastern edge of Crater Flat to the west.

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*U.S. Department of Energy, Environmental Assessment, Yucca Mountain Site, Nevada Research and Development Area, DOE/RW-0073, Washington, D.C., 1986.

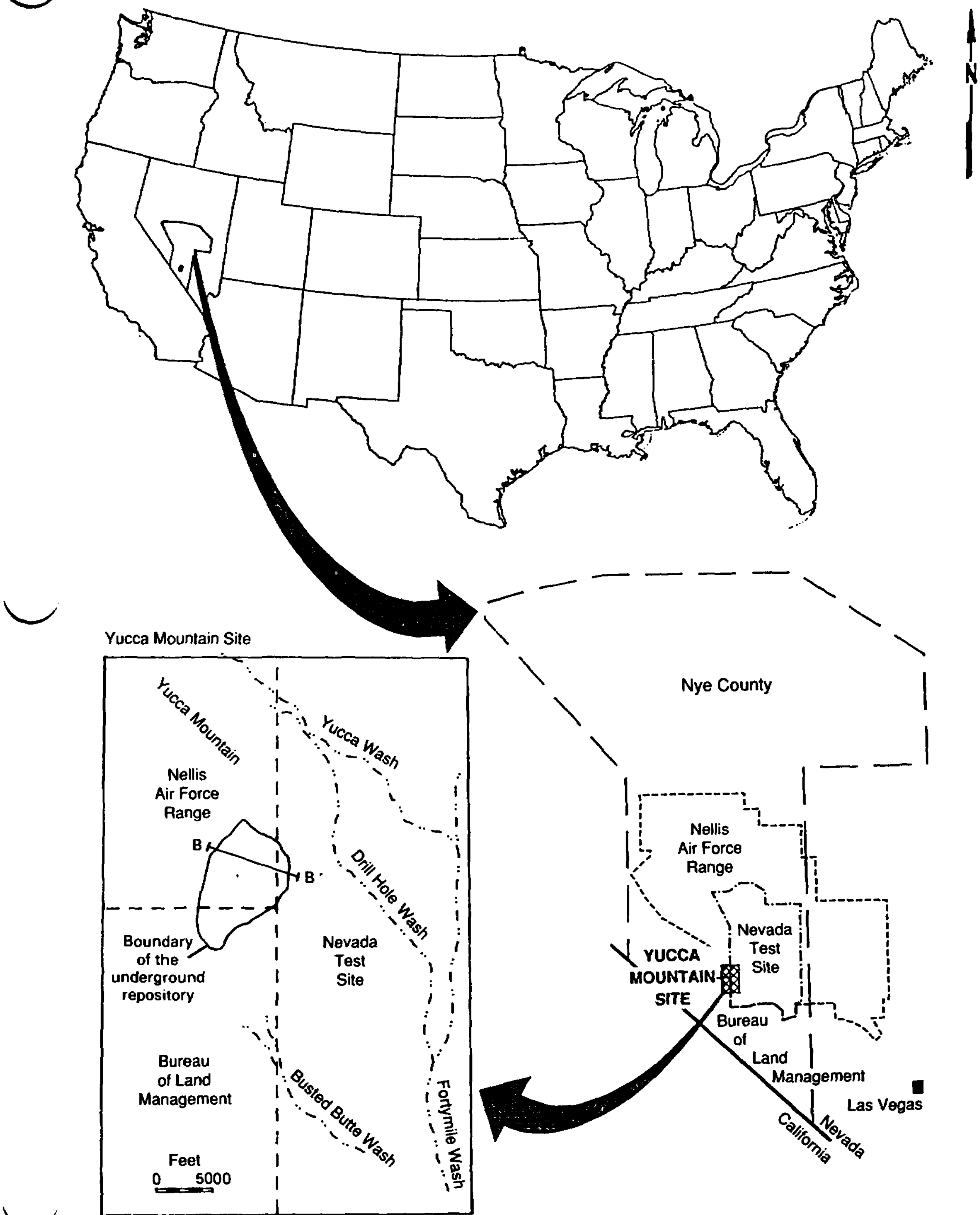

Figure 2-1. Location of the Yucca Mountain site in southern Nevada. The line labeled B-B' marks the location of the cross section shown in Figure 2-3.

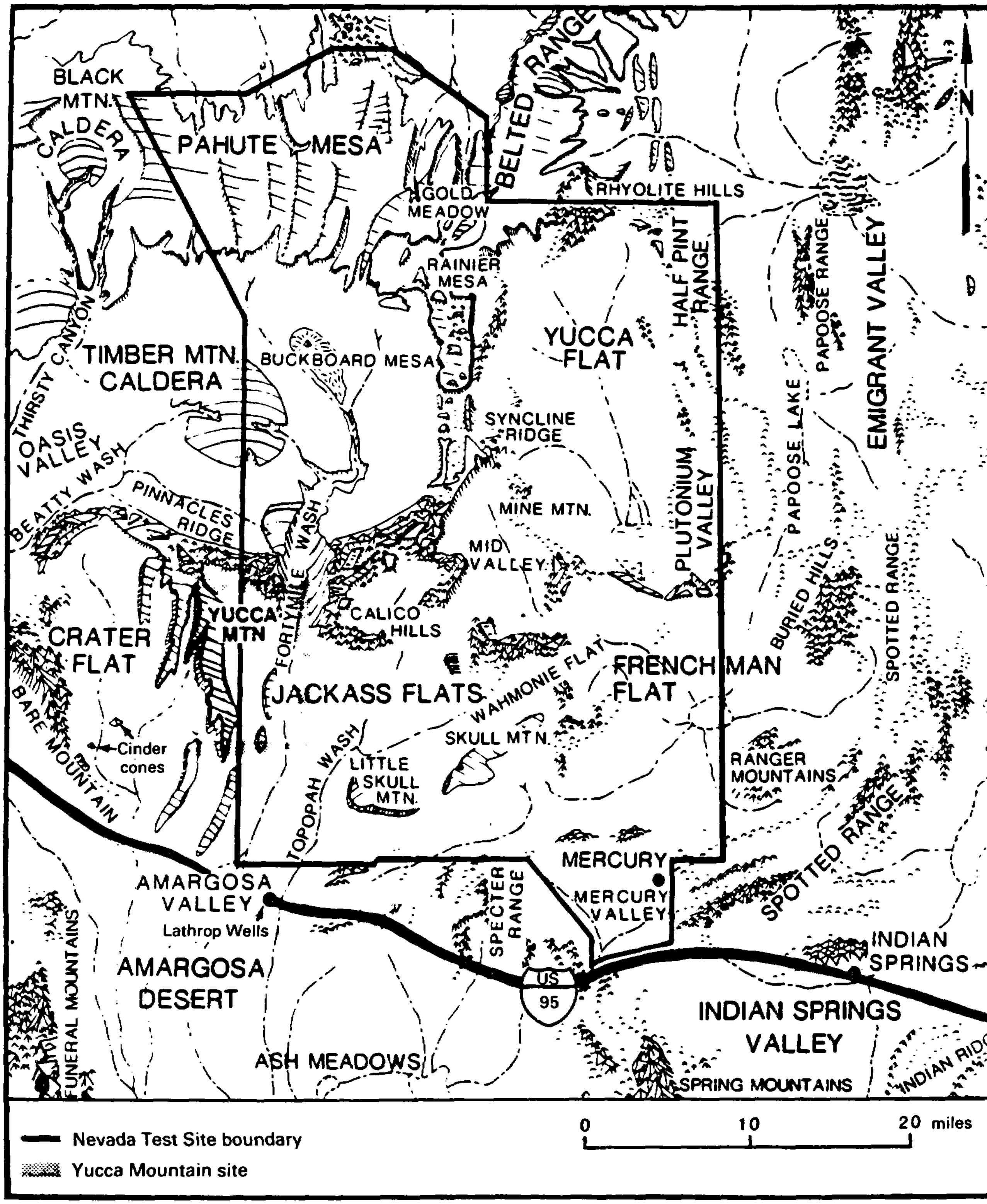

Figure 2-2. Physiographic features of Yucca Mountain and the surrounding region.

Yucca Mountain is part of a prominent group of north-trending ridges that extend southward from Beatty Wash on the northwest to U.S. Highway 95 in the Amargosa Desert (Figure 2-2). Steep slopes (15 to 30 degrees) are found on the west-facing side of Yucca Mountain and along some of the valleys that cut into the more gently sloping (5 to 10 degrees) east side of Yucca Mountain. North of Yucca Mountain is the high terrain of Timber Mountain. To the west, along the west side of Crater Flat, fans of stream-deposited sediments extend from valleys that have been cut into Bare Mountain. A few basalt cones and small lava flows are present on the surface of the southern half of Crater Flat.

At Yucca Mountain, the water table is very deep, lying as much as 2,500 feet below the land surface. Because rainfall is very low and the evaporation rate is very high, it is believed that there is little percolation of water downward through the unsaturated rocks above the water table.

2.2.3 The origin and formation of tuff

The tuff in the Yucca Mountain region was formed from volcanic eruptions occurring between 8 and 16 million years ago. At Yucca Mountain, the volcanic rocks are at least 6,500 feet thick. Their source was magma rising through the earth's crust, which resulted in explosive eruptions that produced ash flows and gases. Because of rapidly decreasing pressure and cooling, the molten material explosively expanded upon eruption and broke up into particles of hot glass shards and crystals. These particles spread across the surrounding land. After coming to rest, the glass shards and crystals were subjected to various degrees of compaction and fusion, depending on temperature and pressure. If the heat and the pressure were high enough, a rock known as "welded tuff" was formed. Eventually, the glassy shards tended to devitrify and develop crystals, but some of the rocks remained glassy and are called "vitric tuffs." A glassy unit often occurs at the base or the top of an ash flow, where rapid cooling was caused by contact with the earth or the air.

If a single ash flow was completely cooled before being covered by another hot flow, it formed a single cooling unit with a densely welded, fractured center. The central parts of thick, densely welded zones may contain cavities called "lithophysae." The densely welded interior parts also generally contain closely spaced fractures. On the other hand, if several eruptions occurred close together and the ash flow did not cool completely between eruptions, the result is a sequence called a "compound cooling unit."

Air-fall tuffs commonly occur between the ash-flow tuffs. They came from ash that cooled in the air before falling to the ground. The resulting rock, known as bedded tuff, is nonwelded. It is more porous than welded tuff and generally contains fewer fractures.

2.3 CHARACTERISTICS AND CONDITIONS PERTINENT TO A GEOLOGIC REPOSITORY

This section presents brief descriptions of the characteristics and conditions of the Yucca Mountain site that are pertinent to a geologic repository and that will be given special attention in the site-characterization program discussed in Chapter 5. The descriptions cover geologic, geoengineering, hydrologic, geochemical, and climatic conditions.

2.3.1 Geology

Geologic conditions are intrinsic to the performance of a repository, and it was the geologic stability of certain rock formations that led to the selection of geologic repositories as the preferred means for the disposal of radioactive waste. Furthermore, geologic conditions are important to the design of a repository. To judge whether a site is geologically suitable, all significant processes and events important to waste isolation must be considered, including the natural processes and events that are expected to occur at the site over the next 10,000 years and the potentially disruptive processes and events that are not expected but are sufficiently credible to warrant consideration. The likelihood that disruptive phenomena or processes will occur during the period required for waste isolation can be assessed from the geologic history of approximately the past 2 million years (the Quaternary Period in geologic time).

The geologic history of Yucca Mountain suggests that the phenomena of special interest in regard to the long-term stability of the region are the effects of faulting, seismicity, and volcanic activity. The design of the repository requires information on stratigraphy, lithology, and seismicity. The assessment of past faulting and volcanic activity will provide a basis for determining the potential for disruptive tectonic events both before and after the closure of the repository. Information on the seismicity of the region and the site will be a primary source of data in developing the design of the surface facilities of the repository; this information will also be used in estimating the probabilities of disruptive events for the assessment of long-term performance after closure. Also of interest is the occurrence of natural resources because exploration for resources in the future could lead to inadvertent human intrusion into the repository. Brief descriptions of these phenomena are given below; they are based on the detailed discussions presented in Chapter 1 of the SCP.

Sources of available data

Information about the geologic history and conditions in the region surrounding Yucca Mountain has been collected since the early 1900s, first to support exploration for mineral and energy resources and later to support government activities at the Nevada Test Site. Since late

1977, information about the region and the site has been collected specifically for the repository program. This information has been obtained by reviewing published data, performing detailed geologic mapping of the Yucca Mountain area, conducting regional geophysical investigations, recording seismic-monitoring data, and conducting other field studies. To date, more than 180 holes have been drilled (with about 40 holes being more than 300 feet deep) and more than 20 trenches have been excavated within about 6 miles of the site to investigate the geologic conditions of Yucca Mountain. Since 1978, more than 50 seismic-monitoring stations have been installed within 100 miles of the site. Six of these stations were installed in 1981 at the site itself.

Stratigraphy and lithology

Yucca Mountain is underlain by a sequence of silicic volcanic rocks from more than 3,000 to about 10,000 feet thick and dipping 5 to 10 degrees to the east at the location of the proposed repository. These rocks consist mainly of welded and nonwelded ash-flow and air-fall tuffs (see Section 2.2.3). Volcanic flows and breccias (rock consisting of sharp, angular fragments cemented together or embedded in a fine-grained matrix) commonly occur underground in the northern part of Yucca Mountain but are rare in the southern part. The rocks beneath the volcanic sequence of Yucca Mountain are known from only one of the boreholes in the Yucca Mountain area. This hole, which is on the eastern flank of the mountain, has penetrated rocks of Silurian age (about 400 million years old) in a unit known as the lower carbonate aquifer, which lies at a depth of about 4,000 feet. Data from gravity surveys suggest that the volcanic rocks may extend to a depth of about 10,000 feet below the ground surface under much of Yucca Mountain. In the northern part of Yucca Mountain, the Eleana Formation, which was deposited in Mississippian time (345 to 310 million years ago), may occur at a depth of 7,200 to 7,900 feet. It has been postulated that in the northern part of the mountain, the basement rocks that lie beneath the volcanic rocks contain a deep-seated granitic body.

At Yucca Mountain, the repository would be constructed in an ash-flow unit called the "Topopah Spring Member," which is part of the rock formation known as the "Paintbrush Tuff. Of the four members of the Paintbrush Tuff, the Topopah Spring is the lowermost, thickest, and most extensive in the Yucca Mountain area. At Yucca Mountain, the Topopah Spring unit is about 1,100 feet thick, but it thins abruptly to the south and apparently also to the north. The Topopah Spring unit was formed approximately 12 to 13 million years ago; it consists of a multiple-flow, compound cooling unit, and most of it is moderately to densely welded, devitrified tuff. Lying below the Paintbrush Tuff are the tuffaceous beds of Calico Hills, the Crater Flat Tuff, and older tuffs.

Although the available data have allowed the selection of the Topopah Spring tuff as the horizon for the proposed repository, additional data are needed for the final engineering design.

Volcanic activity

In the region of the Yucca Mountain site, volcanic activity started about 16 million years ago, forming the southwestern Nevada volcanic field. In the area of the site, it produced several large caldera complexes associated chiefly with the explosive eruptions of silicic tuffs, the rock that makes up Yucca Mountain. By 6 to 8 million years ago, the volcanic activity had changed into the more-quiescent basaltic-flow type. Basalt-type volcanic activity in the region is characterized by low-volume eruptions of short duration, with the rate of magma production apparently declining over the past 4 million years. The youngest basalt-type volcanic feature in the area, located at the southern edge of Crater Flat, is the Lathrop Wells cinder cone. The age of the Lathrop Wells cone is not certain, but this cone may have been formed as little as 20,000 years ago or less. Several other relatively young (less than 2 million years old) cinder cones are being investigated in the region of Yucca Mountain.

The explosive silicic volcanism that occurred in the southern Great Basin during Cenozoic time (the last 66 million years) is well documented through geologic and geophysical studies. The data suggest that the probability of silicic volcanism is negligible, but the possibility of new basaltic volcanism at Yucca Mountain may be higher. Basalt has been the predominant product of volcanism in the southern Great Basin over the past 8 to 9 million years and is therefore more likely to be the product over the next 10,000 years.

Faulting

In southern Nevada, the development of geologic structures has been complex. An expression of this complex development is the faulting at Yucca Mountain, which can be seen from the cross section shown in Figure 2-3. This faulting occurred mainly in response to the tectonic activity that has occurred in the Basin and Range Province for about the last 15 million years. Two overlapping phases have been identified: (1) older extensional faulting associated with silicic volcanism from about 11 to about 7 million years ago and (2) basin-and-range faulting for about the past 7 million years.

The basin-and-range structures in the southern Great Basin have been attributed, in part, to right-lateral faulting along the western edge of North America. Western North America lies within a broad belt of right-lateral movement caused by differences in motion between the North American and the Pacific crustal plates. Some of the right-lateral movement occurs along the San Andreas fault and other similarly oriented faults in California. Such motion may have occurred at an earlier time in southern Nevada along the Walker Lane and the Las Vegas Valley shear zones in close proximity to the site (Figure 2-4). This motion and the related extensional faulting caused the crust to fragment into basins and ranges oriented along northerly trends oblique to the right-lateral fault zones.

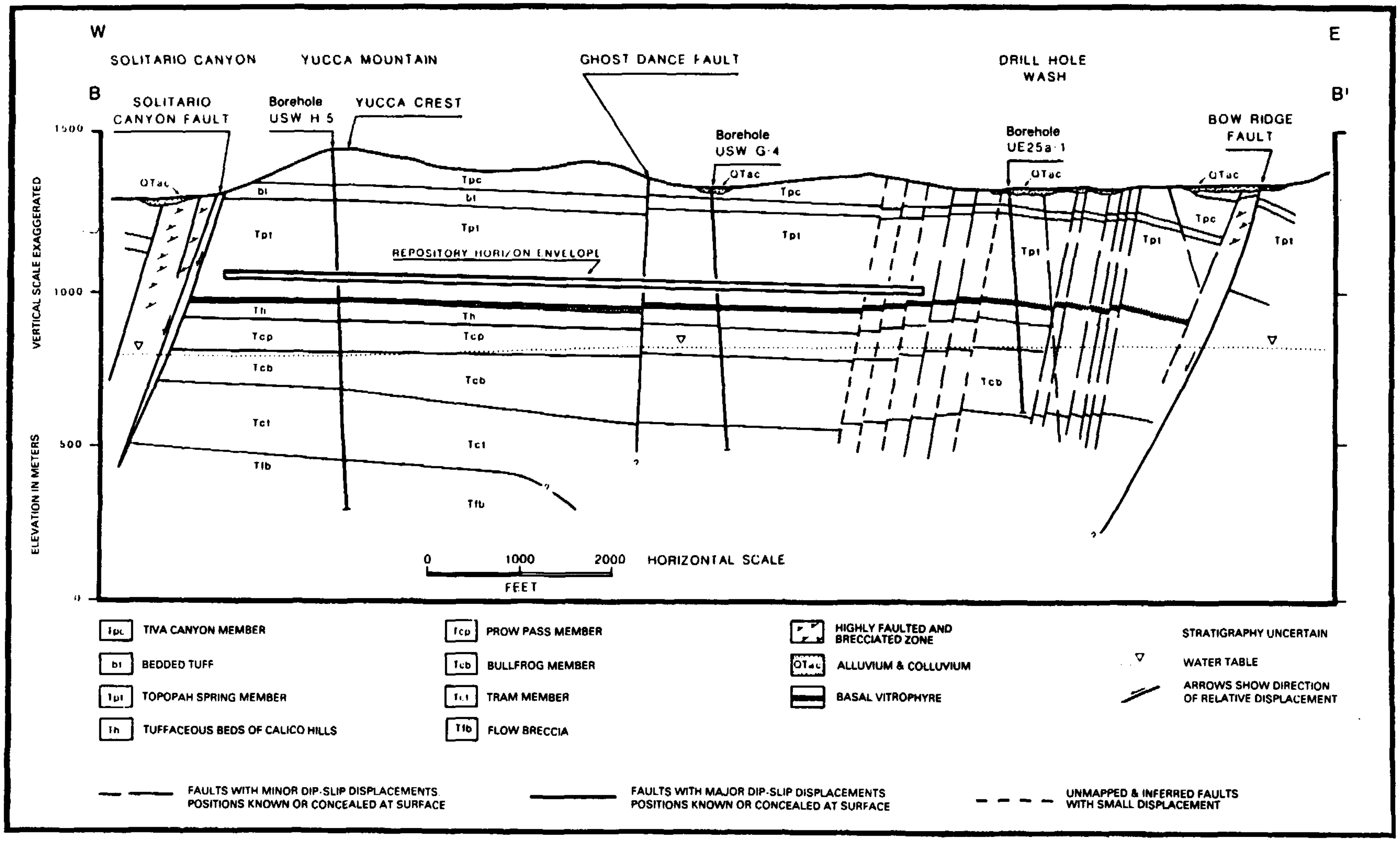

Figure 2-3. East-west geologic cross section for the Yucca Mountain site (see Figure 2-1 for the location of B-B'). This figure shows the relative positions of various tuff units at the site, including the unit proposed for the repository, and the fault zones that are closest to the site.

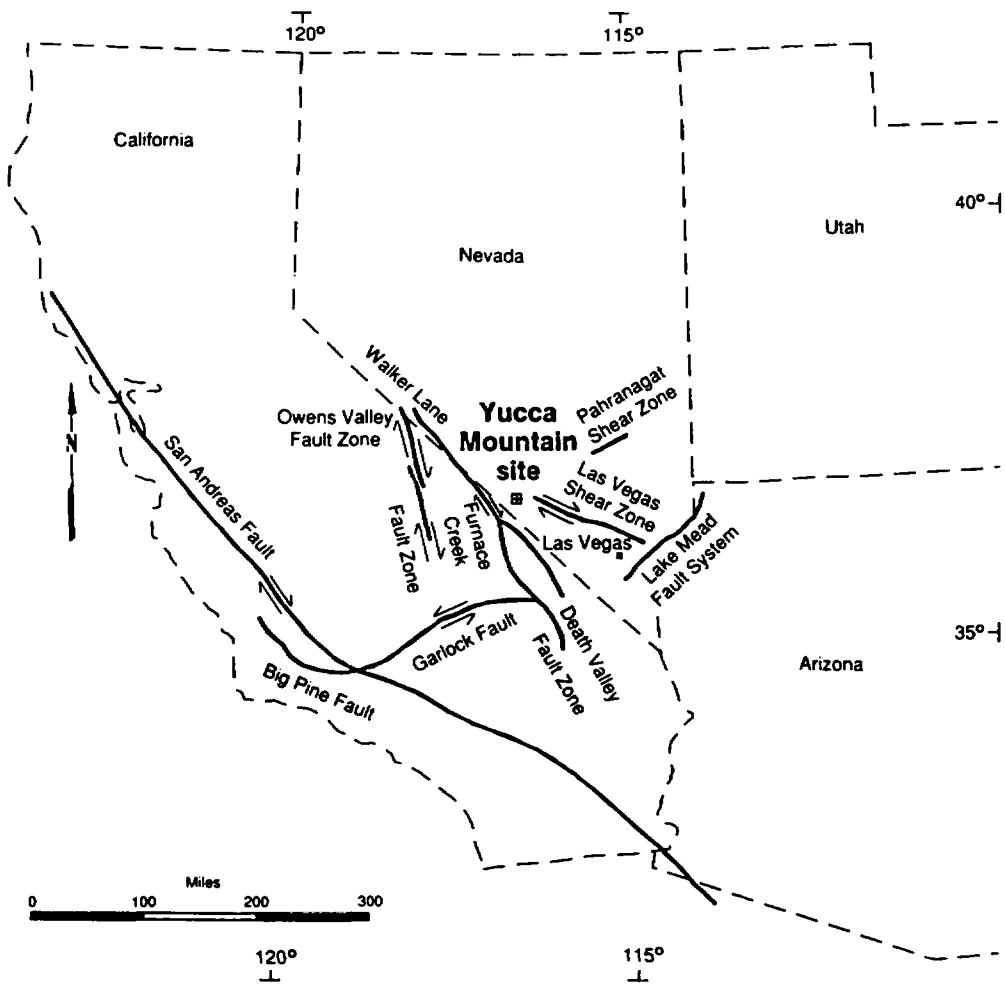

Figure 2-4. Major strike-slip faults of the southern Great Basin and vicinity. Strike-slip faults are faults along which there has been horizontal movement in opposite directions on either side, as shown by the arrows.

Yucca Mountain is a series of north-trending structural blocks that have been tilted eastward along west-dipping, high-angle normal faults. The underground facilities for the proposed repository would be excavated in a rock unit dipping eastward at about 5 to 10 degrees in a relatively unfaulted part of one of these structural blocks. This block is bounded on the west by the Solitario Canyon fault, on the northeast by the Drill Hole Wash structure, and on the east and southeast by the western edge of an imbricate normal fault zone. One fault, the Ghost Dance fault, transects the underground repository. The faults that have been interpreted from geologic mapping are shown in Figure 2-5.

The faults at Yucca Mountain include local faults related to the formation of calderas (collapses of volcanic centers) and longer faults of the basin-and-range type. The strata are gently tilted to the east and are offset by several north-trending high-angle faults, dipping chiefly to the west, that created several large north-trending structural blocks. Another fault system trends northwest in the northern

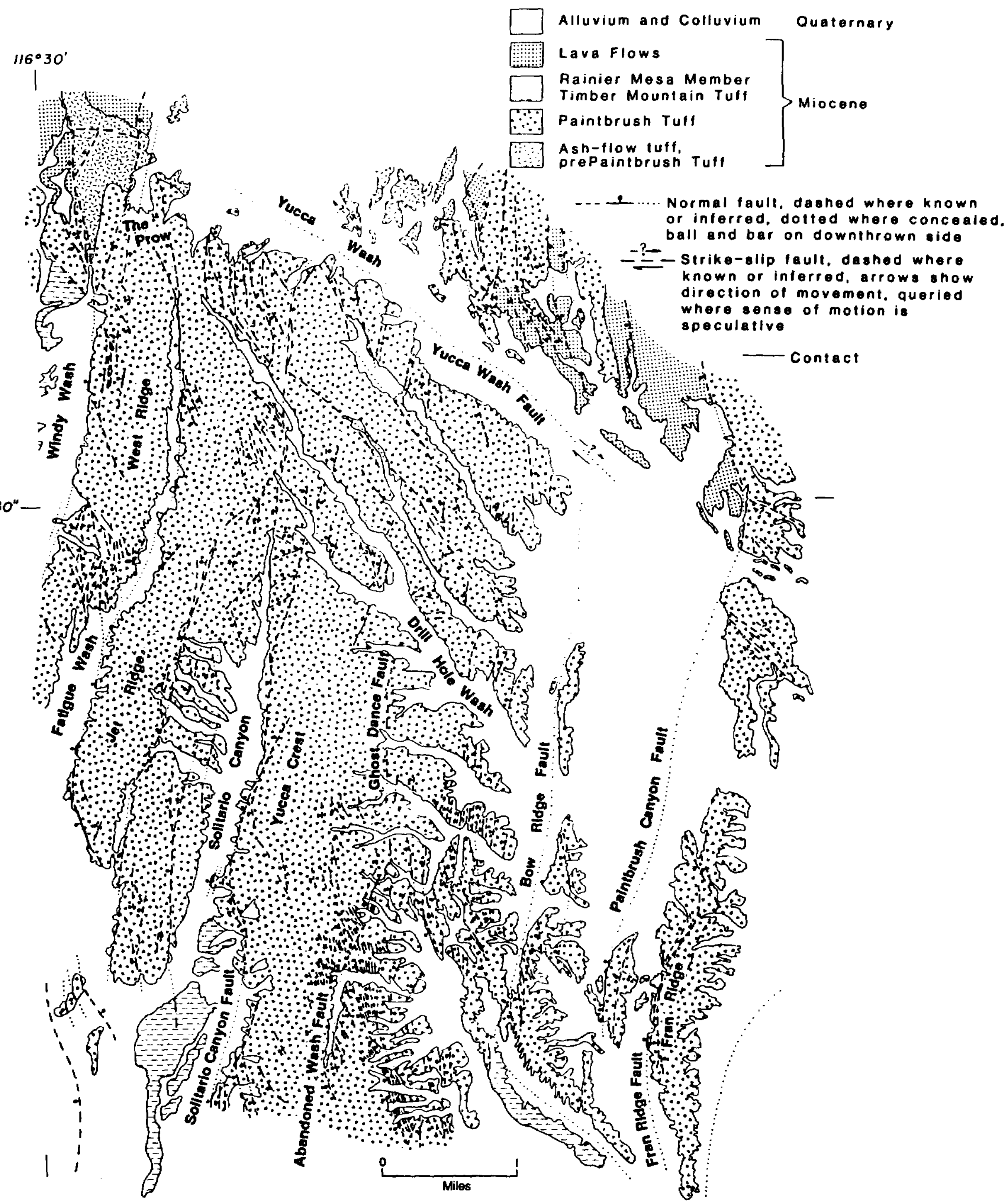

Figure 2-5. Faults in the vicinity of Yucca Mountain.

part of Yucca Mountain. Recognized vertical offsets on faults within the area proposed for the underground facilities of the repository are about 15 feet or less, except for the Ghost Dance fault, which is offset about 125 feet at the southeast end of the proposed underground facilities. Vertical displacement along the Solitario Canyon fault diminishes from about 700 feet at the southern end to about 70 feet at the northwestern corner. For assessing the suitability of the site and obtaining data for the design of the surface facilities of the repository, fault movement since the start of the Quaternary Period, about 2 million years ago, is of primary interest. There is evidence of some movement during Quaternary time at four of the normal faults shown in Figure 2-5--the Windy Wash, Solitario Canyon, Bow Ridge, and Paintbrush Canyon faults--and the Bare Mountain fault, which is some 11 miles to the west of the site.

Seismicity

The Yucca Mountain site is about 100 miles to the east of the Nevada-California seismic belt and about 150 miles to the northwest of the Intermountain seismic belt. As shown in Figure 2-6, the site is in a region of diffuse seismicity (earthquake activity). During the time for which records are available (the past 150 years), eight major earthquakes (with magnitudes M of 6.5 or more) have occurred within about 250 miles of Yucca Mountain: six in the Nevada-California seismic belt and two on or near the San Andreas fault. The nearest recorded major earthquake was the 1872 Owens Valley event (with an estimated magnitude of about 8-1/4) about 90 miles west of Yucca Mountain. However, the area surrounding Yucca Mountain (including the eastern Mojave Desert and the southwest quadrant of the Nevada Test Site) has been relatively quiet seismically during the past 150 years.

In some instances, earthquake epicenters in the southern Great Basin are apparently clustered on north- to northeast-trending mapped faults and regional structures. However, in the vicinity of Yucca Mountain, it has not, in general, been possible to correlate earthquakes with specific faults or tectonic structures.

Geologic field evidence suggests that in terms of major tectonic activity Yucca Mountain has been relatively stable for the past 11 million years. Recent seismic data are available from a 47-station seismic network that was installed within 100 miles of the site in 1978 and 1979 and a supplemental 6-station network that was installed at Yucca Mountain in 1981. Measurements made since 1978 show that within about 6 miles from the proposed repository the release of seismic energy has been 100 or 1,000 times lower than that in the surrounding region.

Estimates of vibratory ground motion for proposed repository facilities are currently based on a full-length rupture on the Bare Mountain fault. If an earthquake with a magnitude of 6.8 occurred on this fault, the peak ground acceleration would be expected to be 0.4g. This acceleration value has been used for preliminary designs of the repository, but it may change as additional data are collected during site characterization.

The Yucca Mountain area is tectonically quiet in comparison with adjacent parts of the Great Basin. However, its faults could experience periods of above-average slip rates within the next 10,000 years. Some of the major faults in the area of Yucca Mountain have repeatedly experienced small-scale movement during the Quaternary Period. The stress configuration at Yucca Mountain favors right-lateral strike-slip on north-striking faults, normal slip on northeast-striking faults, and left-lateral strike-slip on east-northeast-striking faults. Relatively high seismic activity continues today along some right-lateral fault zones northwest and southwest of Yucca Mountain, and there is some evi-

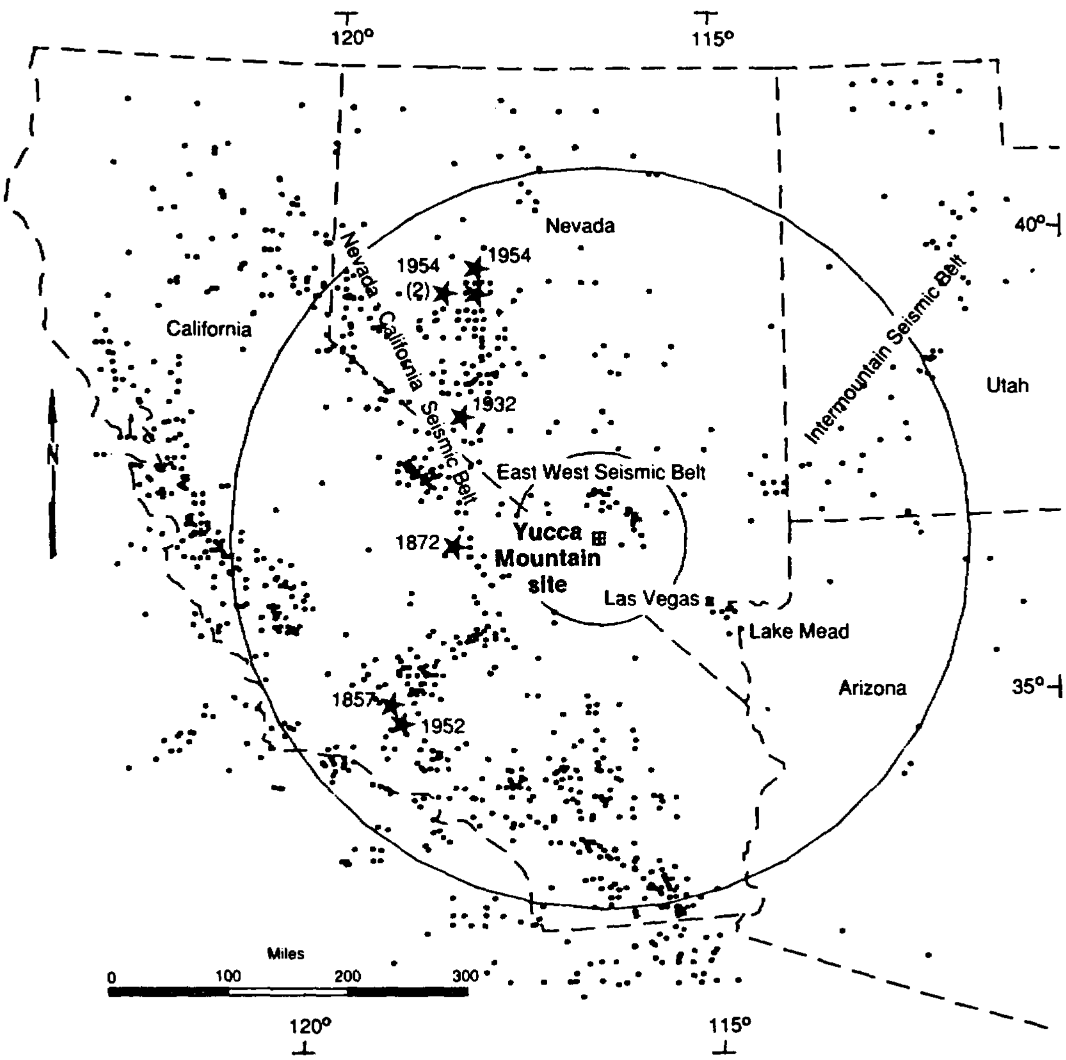

Figure 2-6. Seismicity of the southwestern United States, 1969 through 1978, showing earthquakes with a magnitude of 4 or more. The circles centered on the Yucca Mountain site have radii of about 60 and 250 miles. The stars show the locations of major (M = 6.5 or more) historical earthquakes.

dence that moderate seismic activity and surface fault displacements have occurred during this century in the Walker Lane shear zone.

Natural resources

In evaluating a candidate site for a repository, it is necessary to consider the possibility that future generations might inadvertently intrude into the repository in search of natural resources. Such an intrusion could result in a direct release of radionuclides or it could interfere with the performance of the repository in other ways, such as shortening travel paths to the accessible environment. There is general agreement that the potential for human intrusion depends mainly on the presence of natural resources (e.g., minerals, oil and gas, geothermal resources, and ground water) or geologic conditions that are favorable for the occurrence of natural resources.

The information currently available for the Yucca Mountain site does not indicate that the site is attractive for exploration because the rocks on the surface do not show evidence of mineralization; past mining or exploration; and the alterations characteristic of economic deposits of precious metals (e.g., gold and silver) and base metals. The geophysical surveys conducted to date have not indicated the presence of any geophysical anomalies that would suggest the presence of minerals. In comparison, many of these features are present at Bare Mountain, north-northwestern Yucca Mountain, the Calico Hills, and the Wahmonie District, and these areas are considered likely prospects for exploration. On the basis of present knowledge, gold, silver, mercury, uranium, and base metals are considered to be speculative, undiscovered resources at the site.

The oil-and-gas (hydrocarbon) potential at the Yucca Mountain site is considered to be low in the case of oil and somewhat greater in the case of gas, depending on the location. To the north, the potential hydrocarbon-source rocks beneath the volcanic rocks at Yucca Mountain appear to be relatively mature, which indicates that a high thermal gradient was present in this area, and the thermal gradient would have driven off the bulk of hydrocarbons. To the south, the thermal gradients were lower, and hence some gas may have been preserved in the rocks.

The site does have geothermal resources that are classified as low-temperature (less than 190°F) resources. The site's potential for exploration is considered to be very low because shallow resources of this type are widely available throughout Nevada. The geothermal resources that are more likely to be exploited are those classified as moderate- or high-temperature resources.

Ground water of good quality is present deep below the site, but more easily accessible sources of good-quality water are present elsewhere in the region. Nonetheless, the potential for water supply and demand in the future will be evaluated.

2.3.2 Geoengineering

The behavior of tuff as an engineering material must be understood to design, construct, operate, and close a repository at Yucca Mountain. A repository is different from ordinary mines and tunnels because the waste emplaced in it adds heat and radiation to the rock mass and because of the need for long-time stability. The heat changes the temperature field, which in turn changes the state of stress and possibly the distribution and flow of moisture in the unsaturated-rock mass. In addition to potential effects on the flow of moisture in the unsaturated zone, geoengineering properties are important in the construction and operation of the repository because they control, among other things, the stability of the waste-emplacement holes. The latter affects both near-term performance (e.g., worker safety, waste retrievability) and long-term performance (the integrity of the disposal container). A detailed discussion of the geoengineering properties of the Yucca Mountain site can be found in Chapter 2 of the SCP.

The current data base for the geoengineering properties of the tuffs at Yucca Mountain is derived from two sources: (1) the results of laboratory tests on small-diameter (2.5 inches) core samples from Yucca Mountain and outcrop samples from the vicinity of the site and (2) both field and laboratory tests on similar tuff units in the region. In particular, a field testing program in G-Tunnel at Rainier Mesa on the Nevada Test Site (see Figure 2-2) has provided valuable information. The G-Tunnel data came from a tuff that is considered a reasonable analog for the proposed repository horizon at Yucca Mountain in many aspects, including similar bulk, thermal, and mechanical properties.

The volcanic section of the rocks at Yucca Mountain is composed of a sequence of welded and nonwelded tuffs. Some units are devitrified, and some are vitric. The part of the Topopah Spring Member that has been selected as the potential host rock is moderately to densely welded and devitrified, with minor amounts of cavities. The results of laboratory experiments show that saturated and dehydrated rock samples have different thermal conductivities that are dependent on variations in the porosity of the rock and the mineral composition.

The characteristics that affect thermal and mechanical properties, such as porosity, degree of saturation, and stress state are known to vary both laterally and vertically. Consequently, the thermal and mechanical properties are also likely to vary spatially. This variability must be taken into account in designing the underground repository and the seals for shafts and boreholes (see Chapter 3).

Because the tuffs at Yucca Mountain are similar to those of Rainier Mesa, the site of the G-Tunnel, the mining experience of the G-Tunnel should be applicable to the Yucca Mountain site. This experience indicates that controlled-blasting techniques can be used to excavate the welded tuff. In addition, roof bolts and wire mesh should be sufficient to stabilize the openings, and the available data indicate that no unusual support systems will be required during the excavations of the exploratory shafts or the repository.

2.3.3 Hydrology

The hydrologic conditions at the site are critical to the long-term performance of the repository because hydrologic conditions may affect the behavior of the waste package and because the movement of ground water is the principal mechanism for transporting radionuclides to the accessible environment. In addition, hydrologic conditions must be considered for the preclosure period because they may affect the construction and operation of the repository and the safety of workers.

An important feature of a repository at Yucca Mountain is its location in the unsaturated zone. The unsaturated zone is the rock mass (and the fluids contained in this rock mass) between the surface of the land and the water table. In the unsaturated zone, most of the pores in the rock matrix are not completely filled with water (i.e., the rocks are unsaturated). The percentage of pore space that is filled with water is expressed as the degree of saturation. Saturation generally varies spatially within and between rock units. Water within the partially saturated pores of the unsaturated zone is held under tension, which in effect produces a net negative "pressure," or potential. In contrast, in the saturated zone the interconnected pores are completely filled with water, the water is under hydrostatic compression, and the pressure in the water-filled pores is positive. The boundary between the two zones defines the water table, which is the surface at which liquid-water is at atmospheric pressure. At Yucca Mountain, the unsaturated zone is thick enough to allow the construction of a repository about 660 to 1300 feet above the top of the water table.

Hydrologic investigations of the region surrounding the Yucca Mountain site were begun in the late 1950s to evaluate the hydrologic system at the Nevada Test Site, and in the 1960s studies directed at appraising the ground-water resource were begun. Hydrologic studies for the repository project were started in 1978. Since 1981, hydrogeologic test holes more than 1 mile deep have been drilled into the saturated zone, and tests have been performed to determine such parameters as the depth to the water table, total water yield, hydraulic conductivity, transmissivity, and water chemistry. Multiple-well tests to determine the effective porosity and the nature and extent of the contribution of fractures to permeability are continuing.

When the advantages of locating the proposed repository in the unsaturated zone became apparent, the emphasis of the studies shifted from the saturated zone to the unsaturated zone. Beginning in 1983, test holes deeper than 1,000 feet were drilled into the unsaturated zone, and these holes have been used to monitor the ambient water saturation, potential, and flux in the rocks above, below, and in the proposed repository horizon. Ambient water potentials have been monitored in one test well since 1983. The data from rock samples show a wide variation in hydrologic properties among the various hydrogeologic units in the unsaturated zone. The mechanisms of water flow and storage (as liquid water, water vapor, or both) at any location in the system depend largely on the amount of water entering the system as net infiltration. A detailed discussion of the hydrologic data pertinent to the Yucca Mountain site is given in Chapter 3 of the SCP.

Because little is known about the occurrence and movement of water deep within unsaturated, fractured tuffs, an extensive program of field investigations and theoretically based studies is planned during site characterization to provide a comprehensive understanding of the hydrologic conditions in the unsaturated zone at Yucca Mountain.

The unsaturated zone at Yucca Mountain consists of the tuffs described in Section 2.2.3. The proposed horizon for the repository is a moderately to densely welded tuff of relatively high fracture density. Current estimates are that only a small part of the rain that falls on Yucca Mountain (probably less than 0.02 inch of the approximately 6 inches that falls annually) percolates to the deeper units of the unsaturated zone, and only a small vertical ground-water flux is expected in the Topopah Spring tuff.

The water table under Yucca Mountain occurs in the fractured tuffs of the Calico Hills and the Crater Flat units; it slopes to the southeast from an elevation of 2,600 to 2,400 feet above sea level. The water table forms the upper boundary of a tuff aquifer that is a part of the Alkali Flats-Furnace Creek ground-water subbasin. This basin discharges by evapotranspiration through the Franklin Lake Playa at Alkali Flats in California and may discharge at springs in Death Valley near Furnace Creek Ranch. Together with two adjoining subbasins, this ground-water basin is part of the Death Valley ground-water system. The principal source of recharge for the tuff aquifer is probably Pahute Mesa to the north and northwest of Yucca Mountain. The recharge and discharge areas for the hydrogeologic study area of the repository project are shown in Figure 2-7. The regional direction of ground-water flow is south and southwest (Figure 2-8). As elsewhere in the southern Great Basin, the ground-water basins tend to be closed, with no external drainage into rivers or major bodies of surface water.

In the unsaturated zone, ground water moves by percolating through the rock matrix and by flowing within the fractures of the welded tuff. There is evidence that, under current saturation conditions in the host rock, matrix flow is the dominant mechanism for vertical flow.* The velocity of the flow depends on the degree of saturation. The variability in rock properties can lead to localized zones of higher saturation, where fracture flow may occur. The exact nature of the transition between matrix and fracture flow in partially saturated, fractured rocks is uncertain. There is also uncertainty about the potential for, and the extent of, flow along the interfaces between zones of different per-

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*However, as noted in Section 5.4.2, alternative hypotheses about flow mechanisms are possible, and these hypotheses will be tested during site characterization.

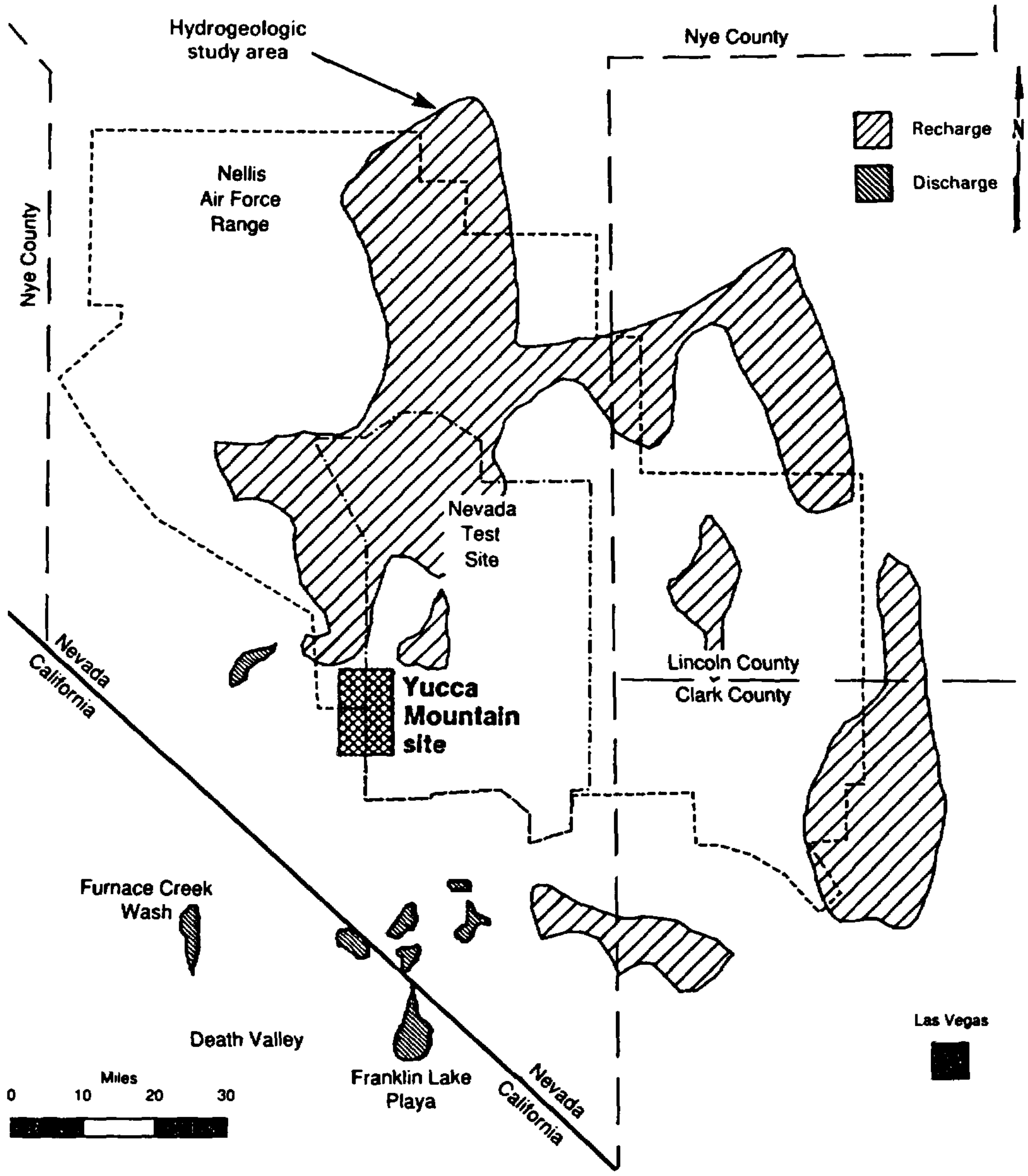

Figure 2-7. Ground-water recharge and discharge areas.

meabilities. Present estimates of the time of ground-water travel from the proposed repository to the underlying water table range from about 9,000 to 80,000 years. The conceptual ground-water-flow system in the unsaturated zone is shown in Figure 2-9.

In the saturated zone, water will tend to flow laterally, downgradient. The flow is likely to occur in fractures and therefore to be more rapid than flow that is confined within the rock matrix. The pattern of ground-water movement is likely to be to the southeast of the site, although the general direction of movement in the Alkali Flat-Furnace Creek ground-water basin is to the southwest. The hydraulic gradient near the site appears to be steep, while southeast of the repository it is nearly flat.

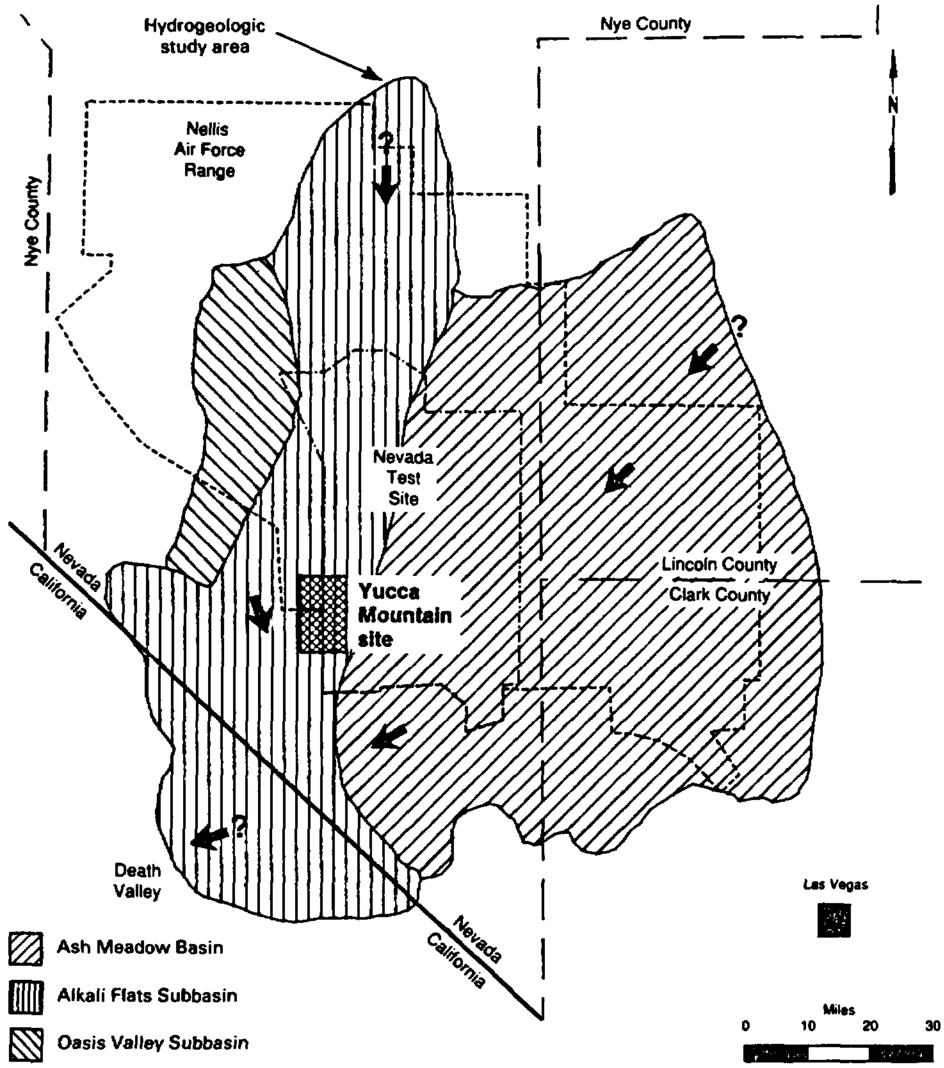

Figure 2-8. Regional direction of ground-water flow. Questionmarks indicate uncertainty.

No perennial 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 (see Figure 2-8). Because of the aridity of the region, most of the water discharged by the springs travels only a short distance before evaporating or infiltrating into the ground. During heavy rains, however, transient floods do occasionally occur in the arroyos.

2.3.4 Geochemistry

The geochemical environment of the host rock may affect the long-term performance of the repository by affecting the behavior of the engineered-barrier system (mainly the waste package) and by retarding the transport of radionuclides. To characterize this geochemical envi-

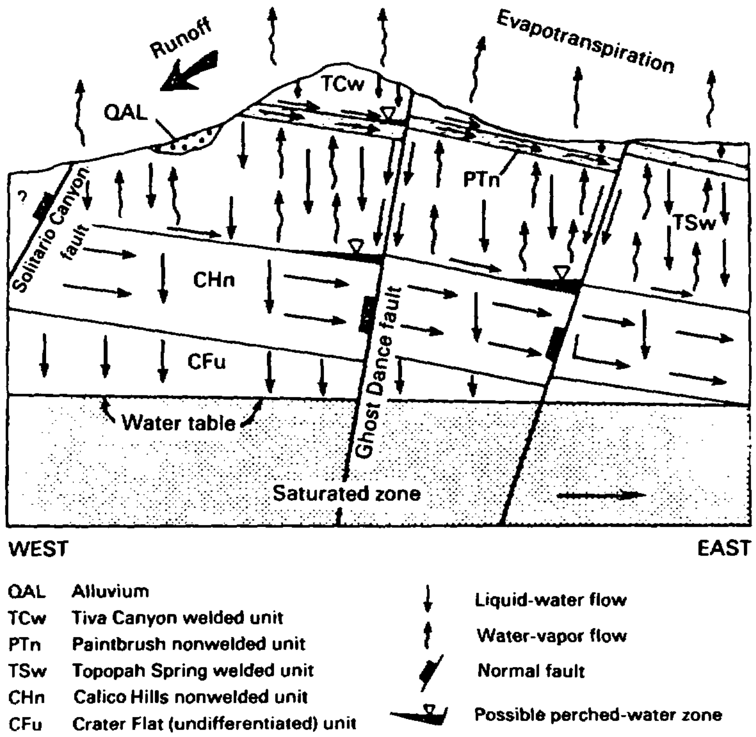

Figure 2-9. Generalized east-west section through Yucca Mountain showing conceptual moisture-flow system under natural conditions.

ronment, geochemical data have been collected since late 1977. Current knowledge of the geochemical conditions at Yucca Mountain is summarized in Chapter 4 of the SCP.

The geochemical data have been obtained from samples taken at Yucca Mountain or its vicinity. Samples for mineralogic and petrologic studies have been taken from drill cores, sidewall samples, drill cuttings, and surface outcrops. Data on water chemistry have been obtained from ground-water samples taken from wells. Information on the stability of geochemical conditions has been obtained from laboratory experiments.

The ground water sampled from boreholes that penetrate the host rock and the surrounding units in the area proposed for the repository is of the sodium bicarbonate type, with a low concentration of total dissolved solids (200 to 400 milligrams per liter). The dominant cations in the Yucca Mountain ground water are sodium, calcium, potassium, and magnesium. Sodium is the most abundant cation, accounting for 65 to 95 percent of the cations present. Measurements of the oxidation-reduction potential and the dissolved-oxygen content of the ground water that have been analyzed indicate that most of the waters are oxidizing. (This characteristic must be considered in designing the waste package.) Overall, only minor variations in the composition of ground water have been observed in and adjacent to Yucca Mountain, and variations over time are also minor. However, the only water available to date for chemical analysis has come from boreholes in the saturated zone. When the exploratory shafts are constructed, water from the voids in unsaturated tuff, any water flowing in fractures in unsaturated tuff, and water from any perched-water zones in Yucca Mountain will be sampled, where possible, and analyzed.

The characteristics of the ash-flow tuffs at Yucca Mountain, especially those of the nonwelded tuffs lying above and below the potential repository horizon, would allow several types of radionuclide retardation. For example, the chemical conditions are such that some of the key radionuclides (the actinides) are more likely to precipitate than to remain in solution in any available liquid water. Another retardation mechanism is the matrix diffusion that is expected to occur in fractured rocks with a low matrix permeability: the radionuclides that are carried by flow in a fracture will diffuse into the matrix and back into the fracture, thus requiring a longer time for travel than does the water traveling through the fracture. In addition, minerals with a high sorption capacity--zeolites and clays--are present along potential paths of ground-water flow below the repository and in the saturated zone.

2.3.5 Climate and meteorology

Climatic changes that may occur in the distant future--in the next 10,000 years and more--are important to the long-term performance of a repository because a change from the current arid conditions might affect hydrologic conditions. At Yucca Mountain, the potential for a change in the amount of ground-water flux through the unsaturated zone and a rise in the water-table level is important because the thickness of the unsaturated zone below the repository could be decreased and the amount of water available for contact with the waste could be increased.

The climatic trend that can be expected in the next 10,000 to 100,000 years will be predicted from the changes in climate that occurred during the Quaternary Period in geologic time (approximately the past 2 million years). The climates of the past can be deduced from the plant remains left thousands of years ago in the middens of pack rats, fossilized plant pollens, evidence of past lake positions preserved in deposits formed along their shorelines, and any glaciation that may have occurred in the Great Basin. The influences of climate on the elevation of the water table can also be estimated by identifying spring deposits that represent the locations of ground-water discharges in the past. As described in Chapters 3 and 5 of the SCP, such data are being collected and analyzed for the Yucca Mountain site.

The evidence accumulated to date suggests that the region of the Yucca Mountain site has been arid to semiarid during the past 2 million years. The average annual precipitation during the last glacial maximum about 18,000 years ago was probably 30 to 40 percent higher than the precipitation occurring at the present time. As discussed in Chapter 3 of the SCP, some experts suggest that the general climate in southern Nevada became progressively more arid during the Quaternary Period. This change is attributed to the uplift of the Sierra Nevada and the Transverse mountain ranges: the rising mountain ranges are thought to have produced a rainshadow that affected the distribution and the amount of precipitation in Nevada.

Data on meteorological conditions in the Yucca Mountain region have been collected since 1922 at Beatty, Nevada, since 1949 at the Town of Amargosa Valley, and since the 1950s at the Nevada Test Site. In 1983, meteorological stations were installed at several elevations on Yucca Mountain to collect data on wind speed and direction, temperatures and temperature differences due to elevation, the standard deviation of vertical wind speed, precipitation, relative humidity, and dew point.

The existing climate in the vicinity of Yucca Mountain is classified as a midlatitude-desert climate. The most notable general meteorological characteristics of such a climate are temperature extremes, particularly during the summer months, approaching 120°F; large ranges in the maximum and minimum temperatures; and an annual precipitation of less than 6 inches. Skies are mostly clear throughout the year, and the average relative humidity is low. Winds from the north dominate in the fall, in the winter, and into early spring but shift to a predominantly south to southwesterly direction in late spring and early summer. This annual average cycle is affected by the terrain, with upgradient winds occurring during daylight hours in almost all months.

Chapter 3

THE DESIGN OF THE REPOSITORY AND THE WASTE PACKAGE

This chapter briefly describes the design of the engineered elements of the repository system--the repository and the waste package. The description is based on the SCP conceptual designs for the repository and the waste package. These designs were completed in 1987 and are to be followed by three more-advanced design steps: the advanced conceptual design, the license-application design, and the final procurement and construction design. The purpose of the SCP conceptual designs was to concentrate on the design components that require site-characterization data and to identify the design-related information that must be collected during site characterization. The SCP conceptual designs, therefore, were developed in sufficient detail to identify the needed site data, but these are early conceptual designs and can be expected to change as data from site characterization are collected and more-detailed designs are developed. Furthermore, as discussed in the Sections 3.1.1, 3.1.3, and 3.2 of this overview, the designs may be affected by other factors, such as changes in the waste-management system resulting from the 1987 amendments to the Nuclear Waste Policy Act.

3.1 THE REPOSITORY

A geologic repository will consist of surface facilities, underground facilities, and shafts and ramps connecting the surface and the underground facilities. In addition, when the repository is prepared for permanent closure, seals will be constructed for the shafts, ramps, and exploratory boreholes. The repository facilities will be designed to meet various functional and regulatory requirements, including those of the Nuclear Regulatory Commission (NRC).

The description given here of the surface facilities of the repository is based on the SCP and on the SCP conceptual-design report;* this design was completed before the enactment of the Nuclear Waste Policy Amendments Act of 1987, which has authorized changes in the waste-management program that may affect the design of the repository and especially the surface facilities. The SCP conceptual design is based on a waste-management system that was assumed to consist of a geologic repository and waste-transportation system. Furthermore, the design is based on the assumption that the repository will perform all of the waste preparation before emplacement underground, including the consol-

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*Sandia National Laboratories, Site Characterization Plan Conceptual Design Report, SAND-84-2641, Albuquerque, N.M., 1987.

idation of spent fuel into more-compact arrays. Finally, it was assumed that the repository will be developed in two phases to allow the earliest possible acceptance of spent fuel at the repository and will therefore contain two waste-handling buildings, as described below in Section 3.1.1.

As explained in the draft 1988 Mission Plan Amendment,* the DOE has reevaluated the phased-development approach because the Nuclear Waste Policy Act, as amended, authorizes the construction and operation of a facility for monitored retrievable storage (MRS) subject to certain conditions. This reevaluation took into consideration the schedule and the capabilities of the MRS facility, which could perform some or all of the waste-preparation functions allocated to the repository in the SCP conceptual design. The results indicate that, with an MRS facility in the system, it is preferable to develop the repository in a single phase, with only one waste-handling building, and that such one-phased development would not entail a delay in the schedule for waste acceptance. Moreover, the DOE is performing system studies to determine whether spent fuel should be consolidated and, if so, where the consolidation should be performed. Thus, the more-advanced designs of the repository may be significantly different from those described here and in the SCP, but the design differences are not expected to require changes in plans for site characterization.

A sketch of the proposed repository at Yucca Mountain is shown in Figure 3-1. A map of the site, showing the locations of the underground repository and the central surface facilities, is presented in Figure 3-2. An overall plan for the site is given in Figure 3-3. A detailed discussion of the conceptual design of the repository can be found in Chapter 6 of the SCP.

3.1.1 Surface facilities

The purpose of the surface facilities of the repository is to receive the waste and to prepare it for permanent disposal underground. These facilities would be built to the east of Yucca Mountain, on ground that is relatively flat. They would consist of central surface facilities, various outlying support facilities, and facilities that would provide access and ventilation for the underground repository. A railspur would be constructed for the waste that is shipped by rail, and a road would be built for waste shipped by truck.

The central surface-facilities area would be divided into three distinct functional areas used for waste receiving and inspection, waste

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*U.S. Department of Energy, Draft 1988 Mission Plan Amendment, DOE/RW-0187, Washington, D.C., 1988.

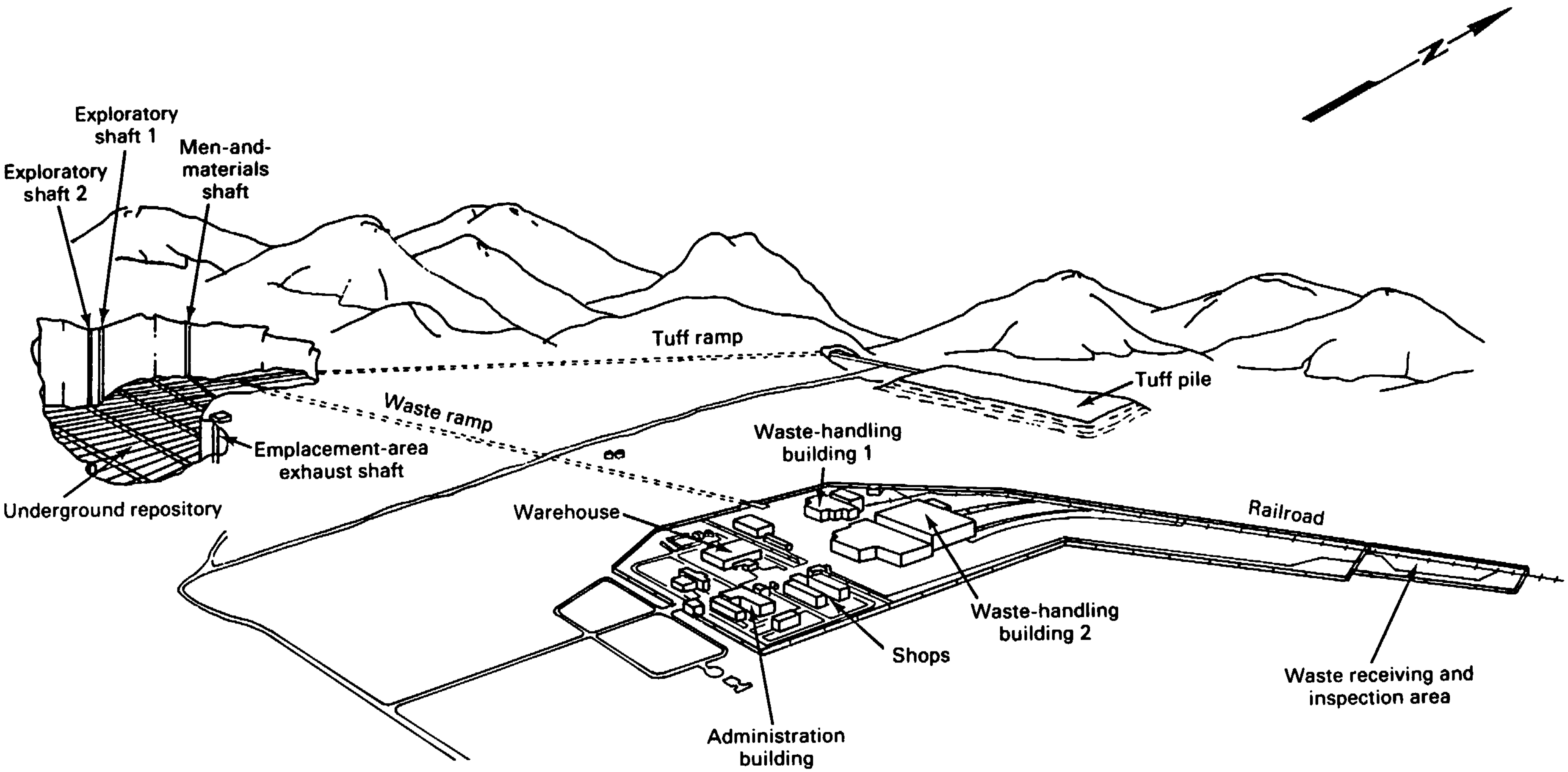


Figure 3-1. Perspective of the proposed repository at Yucca Mountain.

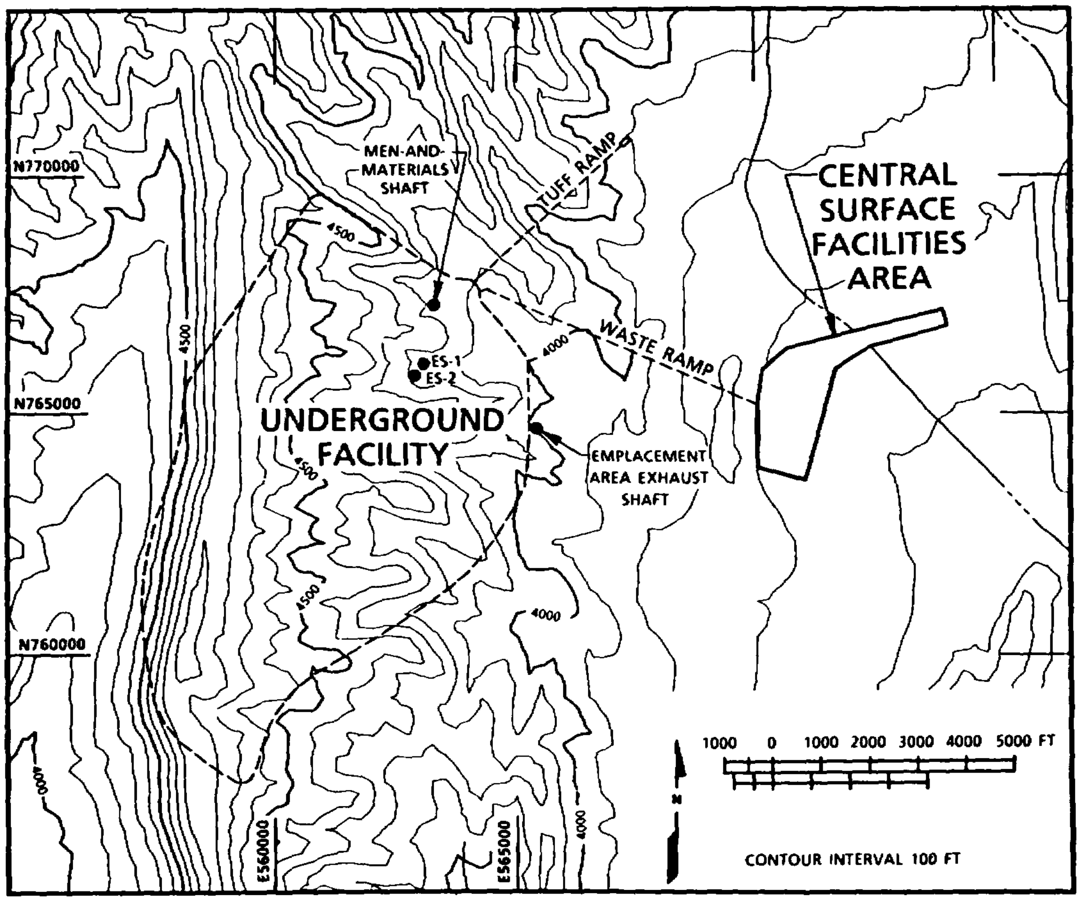


Figure 3-2. Topographic map showing the locations of the underground and the central surface facilities of the repository. The locations of the exploratory shafts are indicated by ES-1 and ES-2.

operations, and general support facilities. The waste-operations area would include two waste-handling buildings and other facilities where radioactive material is handled and prepared for emplacement in the underground repository.

Two waste-handling buildings are included in the SCP conceptual design because it was assumed that the repository would be constructed and operated in two phases. During phase 1, only waste-handling building 1, the smaller building, would be available, and the repository would receive only spent fuel. In waste-handling building 1, spent fuel would be unloaded from the shipping cask it arrived in and loaded into disposal containers (see Section 3.2 for a description of these containers). The containers would be filled with an inert gas to protect the spent fuel from oxidation, sealed by welding, inspected for leaks, and loaded into transfer casks. These casks would be used to move the containers to the waste-handling ramp (see Section 3.1.2) and then to the

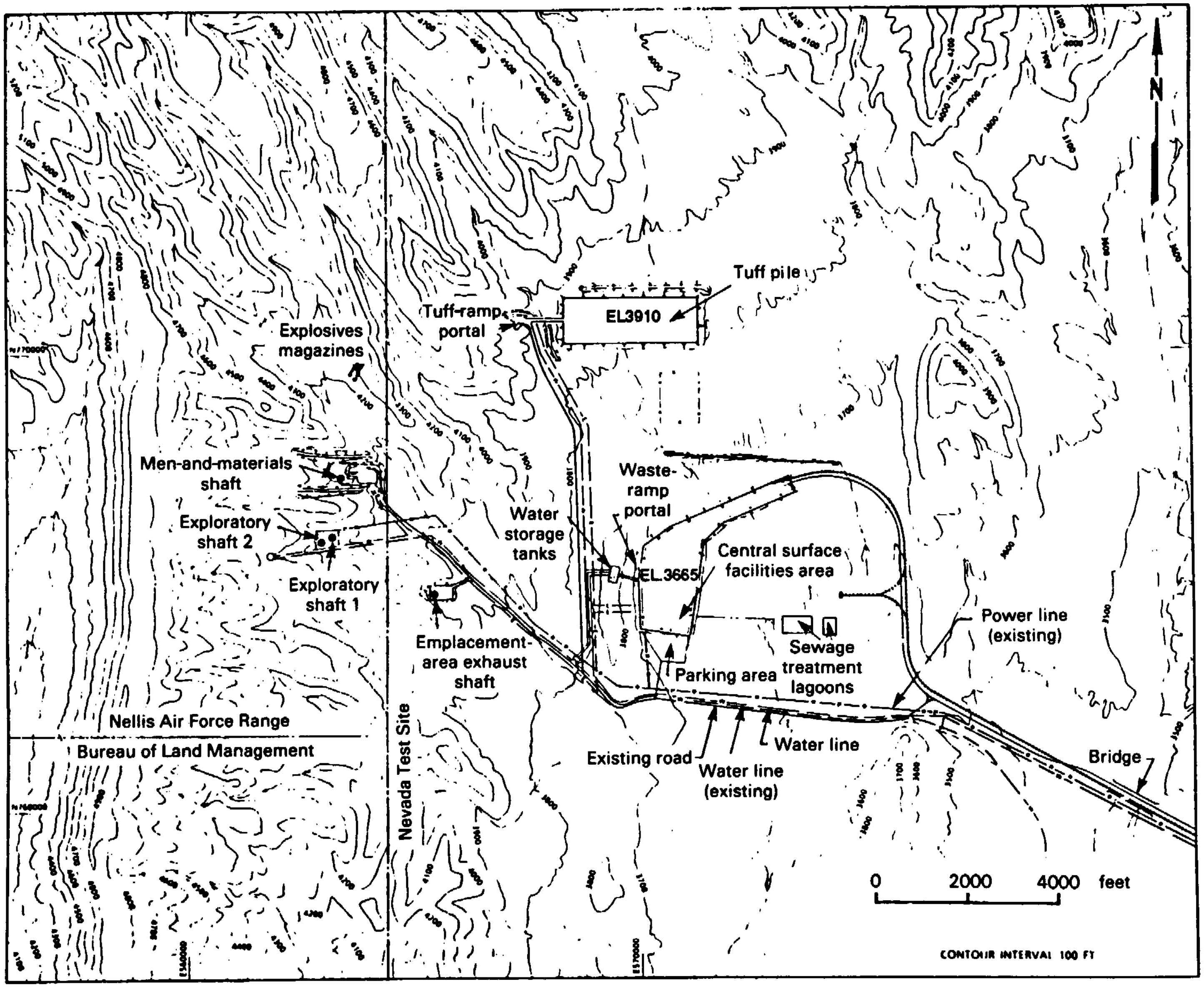


Figure 3-3. Overall site plan showing surface facilities and shafts.

underground repository. During phase 1, the repository would be operated at a limited capacity, receiving spent fuel at a rate of 400 metric tons of heavy metal (MTHM) per year. Full-capacity operation at 3,000 MTHM per year would be reached during phase 2, when the larger waste-handling building would be completed.

During phase 2, both of the waste-handling buildings would be available. Waste-handling building 2 would be used for handling most of the spent fuel received by the repository; it would have facilities for consolidating the spent fuel into more-compact arrays than those used in the spent-fuel assemblies. Waste-handling building 1 would be used for preparing waste that does not require consolidation--that is, defense high-level waste, commercial high-level waste, spent fuel that cannot be consolidated, and spent fuel consolidated at the reactor site or another waste-management facility. The types of waste handled at the repository and their preparation for disposal are discussed in more detail in Section 3.2.

In waste-handling building 2, the spent fuel would be unloaded from the shipping cask it arrives in and transferred to an encapsulation, or packaging, station in a "hot" cell--a room provided with shielding from radiation and equipped with remotely controlled equipment for cutting the spent-fuel assemblies, consolidating the spent-fuel rods into more-compact arrays, and loading the consolidated fuel into disposal containers. The loaded containers would then be transferred to another station, where they would be filled with an inert gas, sealed by welding, and inspected for leaks. The sealed containers would be moved to a surface vault for temporary storage before transfer underground and emplacement in the disposal rooms. The storage vault in waste-handling building 2 would be large enough to hold about 130 containers of consolidated spent fuel. A small storage vault would also be provided in waste-handling building 1. All waste-transfer operations would be performed with transfer casks and transporters specially designed to provide shielding against radiation (see Figure 3-4).

Other planned surface facilities include those used for testing the performance of waste packages; the decontamination building, which would be used to receive, decontaminate, and return to service any contaminated components and equipment (including casks and transport vehicles); and the waste-treatment building, which would be used to prepare for disposal the radioactive waste that is produced at the repository. Support facilities would provide such services as security, fire protection, administration, maintenance, and laboratories. The layout of the central surface-facilities area is shown in Figure 3-5.

3.1.2 Shafts and ramps

The surface facilities would be connected to the underground repository through two ramps and four shafts. One of the ramps, the waste ramp, would be used to transport the waste containers from the

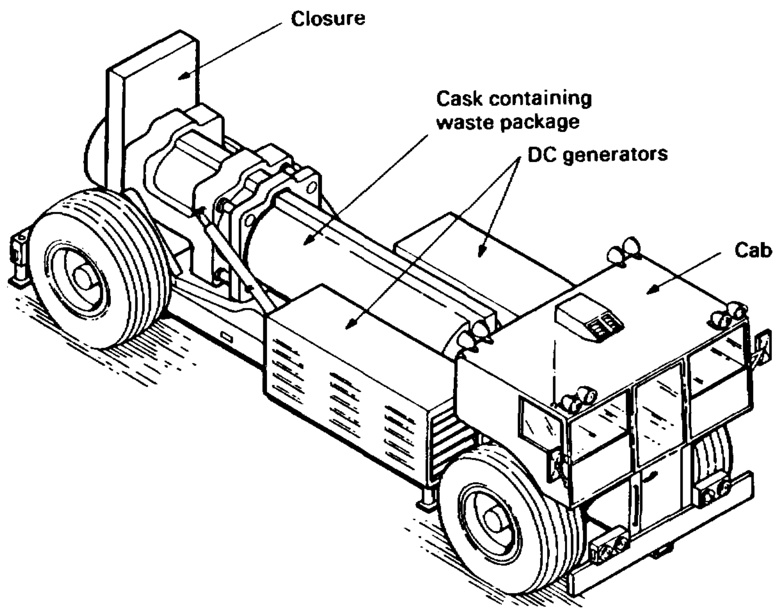
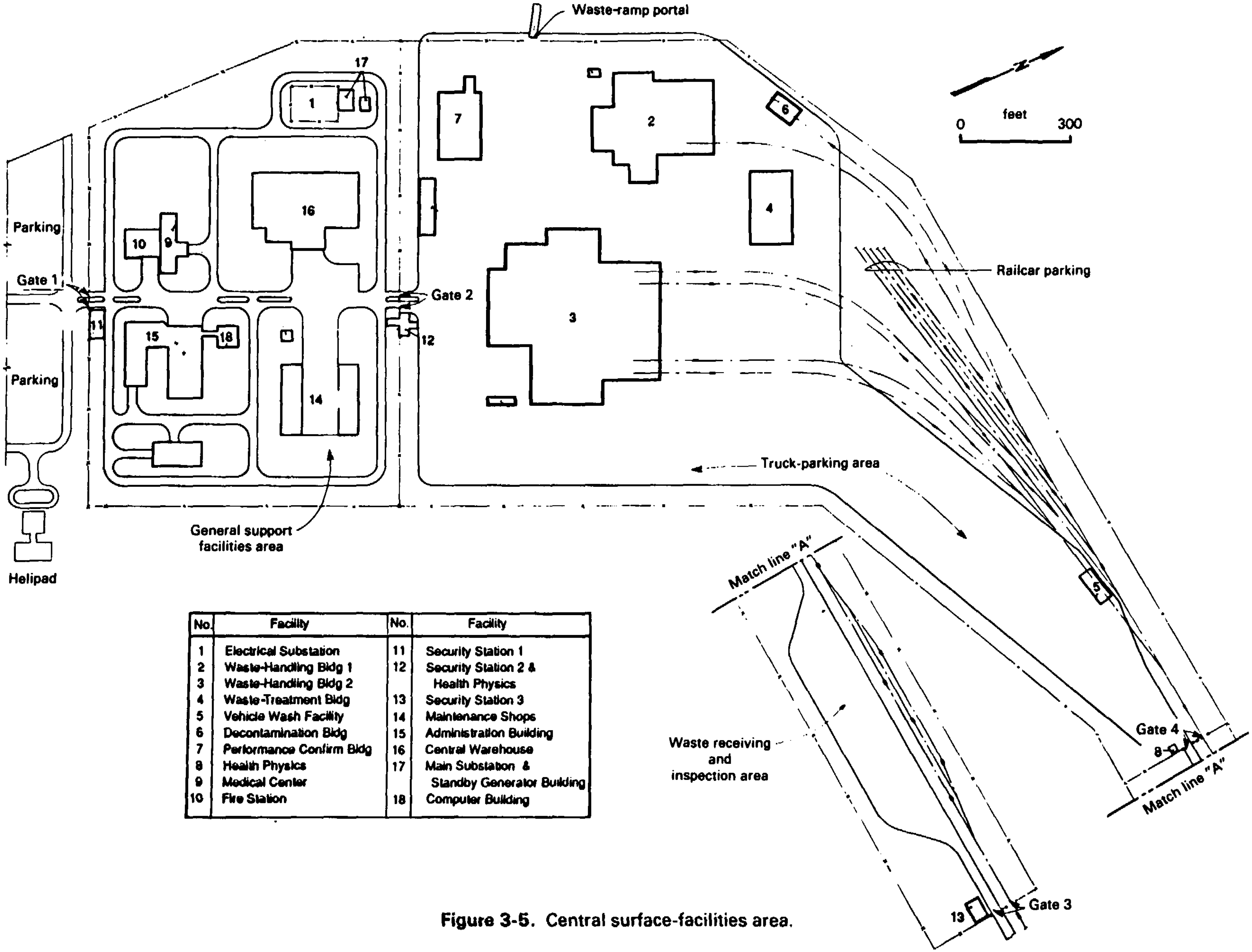


Figure 3-4. Waste transporter in the transport mode. At the emplacement borehole, the cask is raised to the vertical position and the waste package is lowered into the borehole.

surface to the underground and to provide a fresh-air intake for the waste-emplacement area. This ramp would have a length of about 6,600 feet, a slope of nearly 9 percent, and an excavated diameter of about 20 feet. Its portal would be in solid rock inside the central surface-facilities area. The second ramp, known as the tuff ramp, would be needed for the excavation and construction of the underground repository because it would be used to move mined rock from the underground areas to the surface. In addition, this ramp would house the main electrical feeder for the underground facilities and also serve as the primary exhaust airway for the underground-development area, which is discussed in the next section. The tuff ramp would extend close to the tuff pile, on which the mined rock will be stored. Equipped with a belt conveyor, this ramp would have a length of approximately 4,630 feet, a slope of nearly 18 percent, and an excavation diameter of about 20 feet. The locations of both ramps can be seen in Figures 3-1 and 3-2, and the locations of the portals for the ramps can be seen in Figure 3-3.

All four shafts would be located 1 to 1.5 miles west of the central surface-facilities area (see Figures 3-1 and 3-2). Two of the shafts would be the exploratory shafts constructed for site characterization (see Chapter 4). Both of these shafts would be used as fresh-air intakes for the waste-emplacement area, which is described in the next section. Both would have a depth of about 1,100 feet and a finished inside diameter of 12 feet. The second shaft would provide ventilation air and also provide an emergency exit from the underground. A more detailed description of the exploratory shafts and their construction is given in Chapter 4 of this overview and in Section 8.4 of the SCP.

The other two shafts would be the men-and-materials shaft and the emplacement-area exhaust shaft; both would have an inside finished diameter of 20 feet. The men-and-materials shaft, 1,090 feet deep,



No.	Facility	No.	Facility
1	Electrical Substation	11	Security Station 1
2	Waste-Handling Bldg 1	12	Security Station 2 & Health Physics
3	Waste-Handling Bldg 2		
4	Waste-Treatment Bldg	13	Security Station 3
5	Vehicle Wash Facility	14	Maintenance Shops
6	Decontamination Bldg	15	Administration Building
7	Performance Confirm Bldg	16	Central Warehouse
8	Health Physics	17	Main Substation & Standby Generator Building
9	Medical Center		
10	Fire Station	18	Computer Building

Figure 3-5. Central surface-facilities area.

would contain a service elevator and a cage for moving people and materials between the surface and the underground. It would also serve as an air intake for the areas being excavated. The fourth shaft, with a depth of 1,030 feet, would exhaust air from the underground waste-emplacement area.

3.1.3 Underground facilities

The underground repository, where the final emplacement of the waste would occur, would be constructed at a depth of about 1,000 feet below the eastern flank of Yucca Mountain. The primary area for the underground repository is in the welded tuff of the Topopah Spring Member (see Chapter 2). The boundaries of this area are shown in Figure 3-2. The host rock in the primary area is sufficiently thick over a sufficiently large area to accommodate the equivalent of 70,000 metric tons of heavy metal. Existing information about the site indicates that an area of 2,095 acres would be available underground for waste emplacement; current plans call for using 1,380 acres.

Layout

Three parallel main entry drifts would extend southwest through the underground facility to provide access to the waste-emplacement areas, called "emplacement panels." One of the mains would be dedicated to transporting waste, another would be used for moving mined rock and bulk materials, and the third would be a service main for the ventilation and electrical distribution systems.

The main component of the underground layout is the emplacement panel--a volume of rock in which the waste would be emplaced. The panels would be about 1,400 feet wide and 1,500 to 3,200 feet long. Each emplacement panel would contain a number of emplacement drifts, in which boreholes would be drilled for the emplacement of waste. The emplacement panels would be reached through panel-access drifts (see Figure 3-6). The preliminary layout calls for 18 emplacement panels; this layout was based on the heat expected to be emitted from the waste (an areal power density of 57 kilowatts per acre).

The development of the panels would begin in the northeast corner and progress in a clockwise direction.

Waste emplacement

Waste-emplacement operations would follow the order used for developing the waste-emplacement panels in the rock. Waste emplacement would not begin until two panels have been completely developed, to allow separation between development mining and waste-emplacement operations and thus protect the development workers from exposure to radiation.

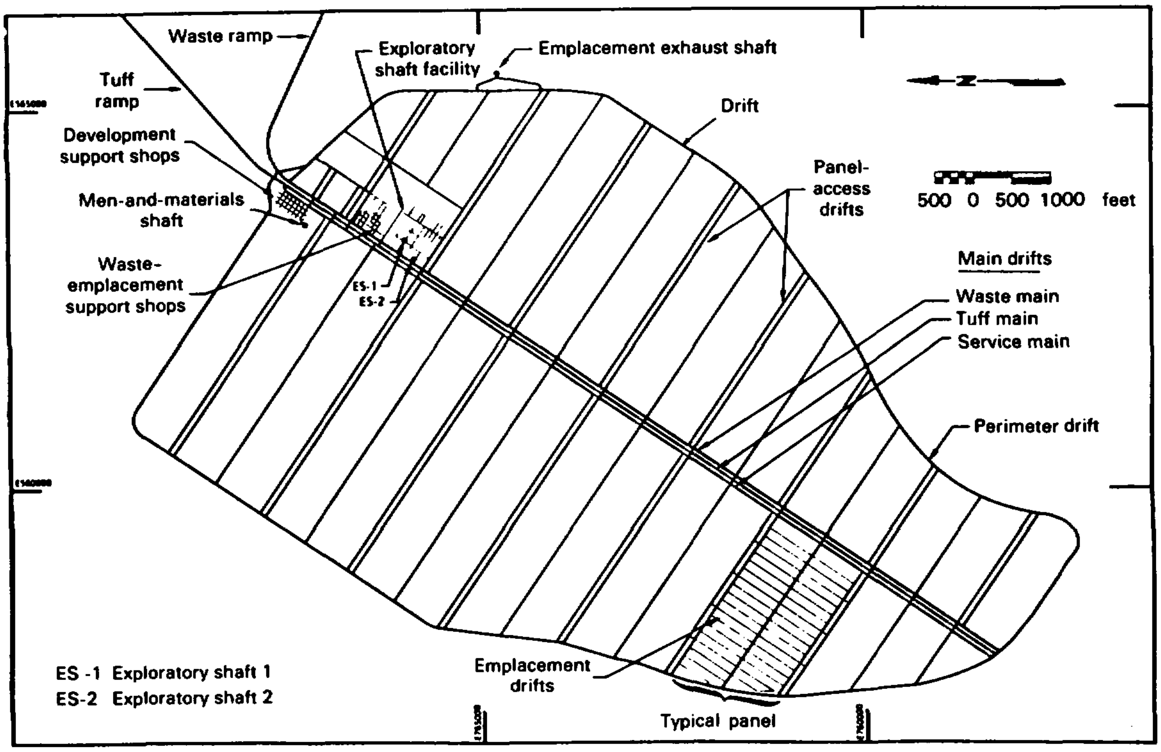


Figure 3-6. Underground repository layout for vertical waste emplacement.

In the SCP conceptual design, it was assumed that the containers of waste would be emplaced in vertical boreholes drilled into the floors of the waste-emplacement panels. However, the use of horizontal boreholes is also being considered, and the final decision on the mode to be used has not been made. In the vertical emplacement mode (Figure 3-6), the boreholes, about 25 feet deep and about 30 inches in diameter, would be drilled vertically into the floor of the emplacement drifts, and a single container of waste would be emplaced in each borehole; a container of spent fuel would be 15.5 feet long and 26 inches in diameter (see Section 3.2). In the horizontal emplacement mode, boreholes would be drilled horizontally into the walls of the emplacement drifts. In either mode, the waste-emplacement panels would be roughly the same size.

A vertical borehole with an emplaced waste package is shown in Figure 3-7. To protect the disposal container in vertical emplacement, a support plate would be inserted into the bottom of a vertical borehole and the borehole would be lined with a metal casing starting at the top of the hole and extending past the top of the container. After the container was placed in the borehole, a metal plug several inches thick would be inserted to provide shielding from radiation, crushed tuff would be packed around or on top of this shielding, and the borehole would be closed with a metal cover (see Figure 3-7).