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Consultation Draft

Site Characterization Plan
Overview

Deaf Smith County Site, Texas

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U.S. Department of Energy
Office of Civilian Radioactive Waste Management
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DISCLAIMER

NOTE TO THE READER

Since the printing of this overview and the consultation draft of the site characterization plan (SCP/CD) that it represents, the Congress has enacted legislation that changes the process for siting the nation's first geologic repository. The Nuclear Waste Policy Amendments Act of 1987, signed by the President on December 22, 1987, directs the Department of Energy (DOE) to characterize the Yucca Mountain site in the State of Nevada and to terminate site-specific activities for the Hanford site in the State of Washington and the Deaf Smith County site in the State of Texas.

As a result of these changes in the repository-siting process, this overview contains, in the Foreword and the Introduction, statements about site selection that are no longer applicable. However, the DOE expects that the changes in the siting process will not affect the plans for site-characterization activities that are described in the SCP/CD and the overview. The Yucca Mountain site will remain subject to previously established regulatory requirements, and the objectives of site characterization will remain the same.

FOREWORD

As part of the process for siting the nation's first geologic repository for radioactive waste, the Department of Energy (DOE) is preparing a site characterization plan for the candidate site in Deaf Smith County, Texas. As a step in the preparation of that plan, the DOE has provided, for information and review, a consultation draft of the plan to the State of Texas and the U.S. Nuclear Regulatory Commission. The site characterization plan is a lengthy document that describes in considerable detail the program that will be conducted to characterize the geologic, hydrologic, and other conditions relevant to the suitability of the site for a repository.

The Deaf Smith County site is one of three sites that the DOE currently plans to characterize; the other sites are the Hanford site in the State of Washington and the Yucca Mountain site in Nevada. After site characterization has been completed and its results evaluated, the DOE will identify from among the three characterized sites the site that is preferred for the repository.

The overview presented here consists of brief summaries of important topics covered in the consultation draft of the site characterization plan; it is not a substitute for the site characterization plan. The arrangement of the overview is similar to that of the plan itself, with brief descriptions of the repository system--the site, the repository, and the waste package--preceding the discussion of the characterization program to be carried out at the Deaf Smith County site. It is intended primarily for the management staff of organizations involved in the DOE's repository program or other persons who might wish to understand the general scope of the site-characterization program, the activities to be conducted, and the facilities to be constructed rather than the technical details of site characterization.

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1. INTRODUCTION

The Deaf Smith County site is one of three candidate sites for the first geologic repository for radioactive waste.* On May 28, 1986, it was approved by the President for detailed study in a program of site characterization, which will be conducted by the Department of Energy (DOE). The purpose of this program is to obtain the information necessary to select a site for the repository and to obtain from the U.S. Nuclear Regulatory Commission (NRC) authorization to construct a repository. This necessary information describes the geologic, geoengineering, hydrologic, geochemical, climatological, and meteorological conditions at the site.

The DOE's plans for conducting the site-characterization program at the Deaf Smith County site are described in the consultation draft of the site characterization plan (SCP/CD); brief summaries of important topics covered in the SCP/CD are presented in this overview.

1.1 THE SITING AND THE LICENSING OF A REPOSITORY

The process of siting a repository, as specified by the Nuclear Waste Policy Act of 1982 (the Act), consists of several steps.** For the first repository, several of the steps have been completed, the most recent being the following:

1. The Secretary of Energy has nominated five sites as suitable for characterization and has issued environmental assessments to accompany each nomination.

2. The Secretary has recommended three of the nominated sites for characterization as candidate sites for the first repository, and the President has approved the recommendation. The three sites are the Hanford site in basalt in the State of Washington, the Deaf Smith County site in salt in the State of Texas, and the Yucca Mountain site in tuff in the State of Nevada.

3. The Secretary has made the preliminary determination that the recommended candidate sites are suitable for development as repositories.

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*The radioactive waste emplaced in the 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 from the West Valley Demonstration Project. For convenience, the term "radioactive waste" or simply "waste" is often used in this overview to mean spent nuclear fuel or high-level waste.

**The process specified by the Act may be changed by legislation now pending before the Congress.

When site characterization is completed, the Secretary of Energy is to recommend to the President one of the three sites for the development of the first repository. This recommendation is to be accompanied by an environmental impact statement. The President is then to submit the recommendation to the Congress.

After the President's recommendation, the affected State and Indian Tribes may submit, within 60 days, a notice of disapproval to the Congress. This disapproval prevents the use of the site for 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 is overturned by the joint resolution, the site designation becomes effective. If the notice is not overturned, the disapproval stands, and the President must recommend another site not later than 1 year after the disapproval. When the site designation becomes effective, the DOE will submit an application to the NRC; the application is submitted to obtain authorization to construct the repository. The Act requires that this application be submitted not later than 90 days after the effective date of the site designation. The application will contain a description of the site, a description of the design of the repository and the waste package, and the results of an assessment performed to demonstrate that the disposal system--that is, the site and the natural barriers at the site, the repository, and the waste package--complies with the applicable regulations. The NRC will review the application and decide whether to authorize the construction of the repository. When an authorization has been received from the NRC, construction will begin.

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

1.2 REGULATIONS FOR GEOLOGIC DISPOSAL

A repository for radioactive waste must meet some unprecedented requirements. It will have to keep highly radioactive material safely separated from the environment for very long periods of time. And it must require no human maintenance, because future generations cannot be expected to take on the burden of caring for the waste through times longer than recorded history. These requirements can be met in a geologic repository by emplacing the waste deep underground in rock that is isolated from the surface environment. The waste emplaced in such rock can reasonably be expected to remain isolated for as long as necessary.

To provide the required containment and isolation for the waste, the DOE will rely on a repository system that will provide multiple barriers, both natural and engineered, to the transport of radionuclides. The natural barriers will consist of various geologic, hydrologic, and geochemical conditions present at the site; the engineered barriers will consist of the waste package, the seals for shafts and boreholes, and the underground facility.

Recognizing the hazard posed by the radioactive waste, the Congress directed in the Act that regulations designed to protect the health and safety of the public be promulgated by the U.S. Environmental Protection Agency (EPA) and the NRC and that guidelines for siting repositories be developed by the DOE. The regulations promulgated by these agencies are briefly discussed here, and, for the convenience of the reader, excerpts are reprinted in Appendix A.

Primary standards and technical criteria

The primary standards for geologic repositories are concerned with protecting the health and safety of the public from the hazards of the waste to be emplaced in the repository; they have been promulgated by the EPA in 40 CFR Part 191. The key provisions of these standards are (1) a limit on the amount of radioactivity that may enter the environment for 10,000 years after disposal, (2) limits on the radiation dose that can be delivered to any member of the public for 1000 years after disposal, and (3) requirements for the protection of ground water.*

The EPA standards are implemented and enforced by the NRC regulations in 10 CFR Part 60. These regulations consist of (1) procedures for the licensing of geologic repositories and (2) technical criteria to be used in the evaluation of license applications under those procedural rules. The procedural portion of 10 CFR Part 60 specifies requirements for a site-characterization program and the associated site characterization plan. In addition to requiring that the EPA standards be met, the technical criteria of 10 CFR Part 60 specify a number of additional requirements: the NRC radiation-protection standards contained in 10 CFR Part 20, design criteria for the surface and the underground facilities of the repository, and three separate performance objectives for each of the three subsystems of the geologic disposal system: a minimum lifetime for the waste package, a limit on the release rate from the engineered barriers of the repository, and, for the natural system at the site, a minimum pre-waste-emplacement time of ground-water travel from the disturbed zone to the accessible environment.

DOE siting guidelines

As required by the Act, the DOE has developed guidelines for nominating and recommending sites for characterization and selecting sites for the development of repositories. Promulgated as 10 CFR Part 960, they are referred to here as the "siting guidelines." The siting guidelines are based on both the EPA and the NRC regulations.

The siting guidelines are divided into three groups: implementation, postclosure, and preclosure. The implementation guidelines are not directly used in the evaluation of sites; their purpose is to specify how the postclosure and preclosure guidelines are to be applied. The postclosure guidelines govern the siting considerations that deal with the long-term perform-

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*A decision on July 17, 1987, by the U.S. Court of Appeals for the First Circuit has vacated and remanded to the EPA for further proceedings the postclosure standards (Subpart B) in 40 CFR Part 191. (See also the footnote in Section 4.2 of this overview.)

ance of a repository--that is, performance after waste emplacement and repository closure. The preclosure guidelines govern the siting considerations that deal with the siting, construction, operation, and closure of the repository.

Both the postclosure and the preclosure guidelines are divided into system and technical guidelines. The postclosure system guideline defines general requirements for the performance of the total repository system after closure. The postclosure technical guidelines specify requirements for one or more elements of the system--the physical properties and physical phenomena at the site. The preclosure system guidelines address three different systems involving (1) preclosure radiological safety; (2) environment, socioeconomics, and transportation; and (3) the ease and cost of repository siting, construction, operation, and closure. Each preclosure system guideline is associated with a set of technical guidelines specifying requirements on various components of the system (e.g., population density and distribution, meteorology, surface characteristics).

Both the postclosure and the preclosure technical guidelines specify conditions that would disqualify or qualify sites, and they also specify conditions that would be considered favorable or potentially adverse.

Any disqualifying condition constitutes sufficient evidence to conclude, without further consideration, that the site is disqualified, and the presence or absence of almost all of these conditions may be verifiable without extensive data gathering or complex analysis. In the case of the qualifying conditions, on the other hand, no single condition is sufficient to qualify a site. In order to be qualified, a site must meet all of the qualifying conditions, and failure to meet any one of these conditions will disqualify the site. Failure to meet a qualifying condition can usually be determined only after site characterization or the concurrent investigations of environmental and socioeconomic conditions. The favorable and potentially adverse conditions are intended to be used primarily in the screening phase of site selection, during the search for potentially acceptable sites.

Most of the evaluations in the final environmental assessment led to preliminary findings, which are defined as lower-level findings in Appendix III of the siting guidelines. Final evaluations will be performed after site characterization is completed. These final evaluations will be used to make the higher-level findings necessary to demonstrate compliance with the system guidelines and each technical guideline; they will also be used in the comparative evaluation that will be performed to identify which of the characterized sites is to be recommended for the development of a repository.

1.3 THE SITE CHARACTERIZATION PLAN

Purpose and objectives

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, to identify the information needed to resolve the issues, and to present the strategy for resolving the issues; and (3) to describe general plans for the work needed to resolve outstanding issues. In this context, "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.

The SCP will be issued before the construction of the exploratory shafts, and thus the NRC, the State of Texas, and the public will be able to comment on the site-characterization program at an early phase of the program. This early review of the SCP will allow the DOE to make any program adjustments that may be necessary to accommodate the comments. This interactive process will continue throughout the program and will be documented in periodic progress reports, which are mentioned on the next page.

Contents and organization

Both the Act and the NRC's regulations in 10 CFR Part 60 specify requirements for the content of the SCP. In preparing the SCP/CD, the DOE has met both sets of requirements. (These requirements are given in the introduction to the SCP/CD, which also explains how the requirements are met.) The DOE has followed the guidance given by the NRC in Regulatory Guide 4.17 for the format and the organization of the plan. Furthermore, as explained in Section 4.2, the preparation of the SCP/CD was guided by an issue-resolution strategy whose objective was to ensure that site characterization would provide the information needed for site selection and a construction authorization from the NRC.

The SCP/CD is divided into two parts: Part A, which provides descriptions of the site and of the conceptual designs of the repository and the waste package, and Part B, which presents the DOE's plans for the site-characterization program.

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. The uncertainties in the data presented in these chapters were used in identifying the information needed to resolve the issues and in developing the plans presented in Part B. Each chapter concludes with a summary that links the data and analyses presented in the 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 is thus the most important part of the SCP. It begins by presenting, in Section 8.0, the top-level strategy for ensuring that the repository will perform satisfactorily and then, in Section 8.1, discusses the rationale for the program, the 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 issues hierarchy and the strategy for resolving each issue. Section 8.3 discusses the investigations planned for the site, the repository, the seal system, the waste package, and the assessment of repository performance. Also included in Chapter 8 are discussions of the activities that will be carried out during site characterization; schedules; quality assurance; and the decommissioning of the facilities used for characterization if the Deaf Smith County site is not selected as the site for a repository.

Periodic progress reports

To report the results of site characterization at the Deaf Smith County site, the DOE will issue progress reports, as required by the Act. These reports will also explain any changes that may be made in the DOE's plans for site characterization as information is collected and evaluated and comments from the State of Texas and the NRC are received. The reports will be submitted every 6 months to the NRC and to the Governor and the legislature of the State of Texas; they will also be made available to the public.

1.4 THE SCP/CD OVERVIEW

This overview of the SCP/CD is structured somewhat differently from the SCP/CD itself. After this introduction, Chapter 2 briefly describes the important characteristics of the Deaf Smith County site, as determined by the investigations performed to date. Chapter 3 summarizes the current site-specific design of the repository and the waste packages. Chapter 4 addresses the site-characterization program; it begins with an explanation of the top-level strategy for ensuring that the repository will perform satisfactorily. Next it discusses the hierarchy of issues that must be addressed by the site-characterization program and summarizes the strategy for resolving the issues. Chapter 4 then briefly describes the investigations, dictated by these strategies, that will be conducted to obtain the needed information as well as the programs in which this information will be used to refine the design of the repository, the seal system, and the waste package and to assess the performance of the repository. Chapter 5 summarizes the various activities that will be carried out at the Deaf Smith County site during characterization, discusses the facilities that will be constructed for that purpose, and describes how these facilities will be decommissioned if the Deaf Smith County site is not selected for the development of a repository.

Two appendixes are included in this overview. Appendix A presents excerpts from the regulations governing repositories--namely, the environmental standards from 40 CFR Part 191, the technical criteria from 10 CFR Part 60, and the preclosure and postclosure siting guidelines from 10 CFR Part 960. Appendix B presents the issues and information needs for the Deaf Smith County site.

2. THE DEAF SMITH COUNTY SITE

This chapter presents a brief description of the Deaf Smith County 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. Also included is a brief discussion of how the Deaf Smith County site was selected for characterization as a candidate site for a repository.

2.1 GENERAL DESCRIPTION

The Deaf Smith County site is in the north-central part of Deaf Smith County, in the Southern High Plains of the Texas Panhandle (Figure 2-1). The surface of the High Plains is nearly flat, sloping gently to the southeast.

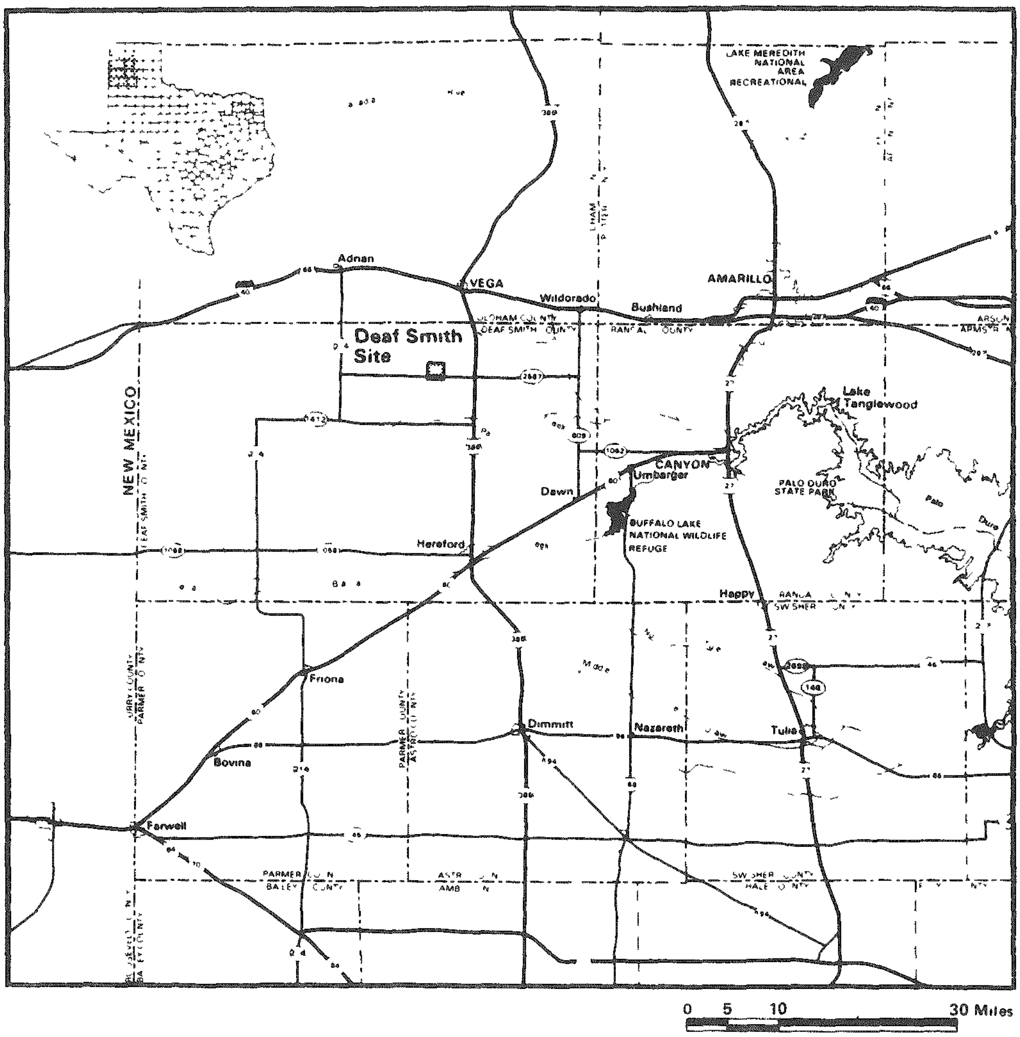

Figure 2-1. The location of the Deaf Smith County site.

Drainage in the Southern High Plains is largely internal into thousands of shallow-lake basins (playas) and into approximately 40 larger alkaline lake basins. The terrain at the site is typical of the High Plains: it is essentially flat except for the playas.

The site covers 9 square miles, or 5760 acres. More than 85 percent of the site area contains soils classified as prime farmland by the U.S. Soil Conservation Service. Part of this area is irrigated. Nearly all of the land at the site and in its vicinity is privately owned. A Texas farm-to-market road (FM 2587) passes through the southern part of the site and connects with U.S. Interstate I-40 via U.S. Highway 385. The closest railroad passes within 19 miles of the site.

The site is located in a rural setting where the population density averages about four persons per square mile. The incorporated communities that are within approximately 60 miles of the site are Hereford (1980 population of 15,853), Canyon (10,724), Vega (900) and Amarillo (149,230).

The site lies in the Palo Duro Basin, a structural basin in the larger Permian Basin. In its deepest part, the Palo Duro contains 10,000 to 11,000 feet of accumulated sediments. Most of this deposition occurred during the Paleozoic Era, from about 600 million to 230 million years ago, when the Permian Basin was an inland sea that experienced changes in water levels. Massive depositions of clastics (sands, silts, and clays) and carbonates occurred during the Pennsylvanian Period, 310 to 280 million years ago. Later, during Permian time (280 to 230 million years ago), the sea became briny, forming deposits of clastics, evaporites, and carbonates up to 7000 feet thick.

The candidate host rock, Unit 4 of the Lower San Andres Formation (LSA-4), is a sequence of bedded salt about 160 feet thick (Figure 2-2) and about 2500 feet below the surface. The San Andres Formation is a 1300-foot-thick evaporite unit composed of cyclic sequences that can be correlated throughout the Palo Duro Basin and exhibit only minor changes in thickness or lithology in the basin. The formation consists of an upper and a lower division, the latter containing five units based on depositional cycles. Unit 1, the basal unit, is a thin dolomite with interbeds of shale, anhydrite, and salt. Units 2 and 3 are thin cycles composed of carbonate, anhydrite, and salt. The base of Unit 4 is composed of microcrystalline dolomite, dolomitic sandstone, and limestone. Above the carbonate is a sequence of the cleanest and thickest San Andres salt recognized in the Palo Duro Basin, although, like other salt beds in the basin, it contains impurities and interbeds. This part of Unit 4 is the proposed host rock. The overlying unit, Unit 5, consists of a lower interval of anhydrite with minor dolomite and shale overlain by salt, interbedded shale, and anhydrite.

The ground-water regime at the site consists of three major units. The uppermost is an unconfined aquifer consisting of the Ogallala Formation and the Dockum Group--hydrostratigraphic unit A (HSU-A); it is often called the "High Plains aquifer." This aquifer is the principal source of fresh water in the Southern High Plains. The other two units include HSU-B--the shale and evaporite aquitard, and HSU-C--the deep-basin brine system.

The climate in Deaf Smith County and the surrounding area is semiarid, with warm temperatures and periods of little precipitation.

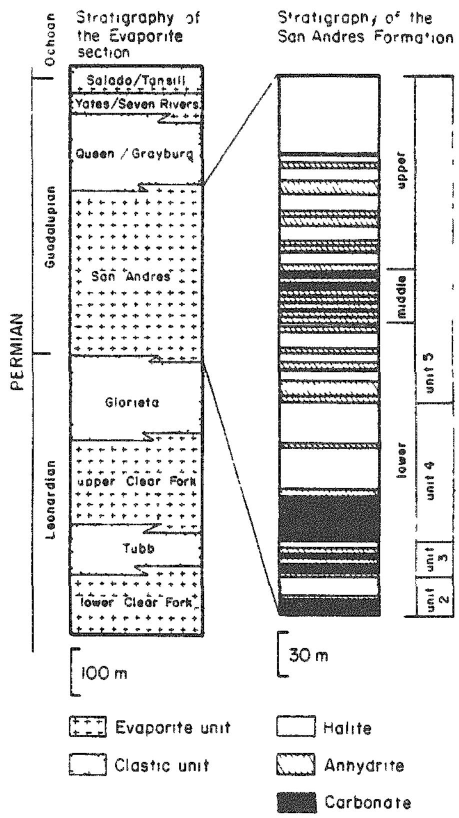

Figure 2-2. The stratigraphy of the San Andres Formation.

2.2 THE HISTORY OF SITE SCREENING AND SELECTION

Salt was first recommended as a potentially suitable host rock for waste disposal in 1955 by the National Research Council of the National Academy of Sciences. Rock salt has several characteristics that are favorable for isolating radioactive waste, including the following:

- Many salt bodies have remained undisturbed and water-free for tens of millions to several hundred million years.
- Because of its high thermal conductivity, rock salt can dissipate the heat that will be generated by the waste.
- Since salt is relatively plastic under high confining pressure, the fractures that might develop at repository depth would tend to close and seal themselves.
- Rock salt undergoes only minor, highly local change as a result of exposure to radiation.
- Rock salt has excellent radiation-shielding properties.

Screening of the entire United States in the 1960s and 1970s resulted in the identification of four large regions that are underlain by rock salt of sufficient depth and thickness for a geologic repository. One of these regions was the Permian Basin, which includes parts of Kansas, Texas, Oklahoma, and New Mexico.

In 1976, the Permian bedded-salt deposits in the Texas Panhandle and western Oklahoma were evaluated to determine whether they contained any areas that might be suitable for a geologic repository. This screening focused on five subbasins and identified two as preferable for more-detailed study: the Palo Duro Basin and the Dalhart Basin. These basins were considered preferable because they contain salt beds of adequate thickness and depth for a repository, have low levels of historical seismicity, do not contain any known major petroleum deposits or any significant economic mineral deposits, have relatively few boreholes that penetrate through all of the salt units, and show no evidence of ongoing peripheral salt dissolution at depths greater than 1400 feet.

Geologic and environmental studies of the Palo Duro and Dalhart Basins were begun in 1977. They led to the identification of six locations, all in the Palo Duro Basin, that warranted further consideration. Further screening against various geologic, hydrologic, environmental, and socioeconomic criteria identified two locations, one in Deaf Smith and Oldham Counties and the other in Swisher County. In February 1983, these locations were identified as potentially acceptable sites, and later that year the area of these sites was reduced to 9 square miles. Both sites passed an evaluation against the disqualifying conditions of the DOE siting guidelines, but a comparative evaluation concluded that, by a small margin, the Deaf Smith County site was the preferred site.

In May 1986, the Secretary of Energy nominated the Deaf Smith County site as one of five sites suitable for characterization and recommended that it be characterized as one of three candidate sites for the first repository; this recommendation was approved by the President. The Secretary also made the preliminary determination, required by the Nuclear Waste Policy Act, that the Deaf Smith County site is suitable for development as a repository.

The nomination of the Deaf Smith County site as suitable for characterization was accompanied by an environmental assessment (EA)* that included an evaluation against the DOE's siting guidelines (10 CFR Part 960). When the evaluation reported in the environmental assessment was made, only preliminary findings of compliance with the guidelines could be made because site characterization had not been performed. To make the higher-level findings necessary to show that the site meets the guidelines requires data from site characterization and the environmental and socioeconomic studies that will be

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*U.S. Department of Energy, Environmental Assessment--Deaf Smith County Site, Texas, DOE/RW-0069, May 1986.

carried out concurrently with characterization. The collection of data for the higher-level findings will be accomplished as a part of the site-characterization program.

2.3 CHARACTERISTICS AND CONDITIONS PERTINENT TO A GEOLOGIC REPOSITORY

This section presents brief descriptions of the characteristics and conditions of the Deaf Smith County site that are pertinent to a geologic repository and will be given special attention in the site-characterization program discussed in Chapter 4. The descriptions cover geology, geoengineering, hydrology, geochemistry, and climate. They are based on currently available information and are derived from the detailed descriptions in Chapters 1 through 5 of the SCP/CD.

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. To judge whether a site is geologically suitable, it is necessary to know which phenomena or processes can be expected at the site over the 10,000-year period of waste isolation and which other processes, although not expected, 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 the Deaf Smith County site indicates little likelihood of any phenomena that may affect the long-term stability of the region. Salt dissolution, though not expected to affect the host rock during the period of waste isolation, is a process that must be carefully evaluated. Also to be considered is the presence of natural resources that may attract exploration by future generations.

Geologic data pertinent to a repository in the Palo Duro Basin have been collected since 1977. Geologic field studies have included stratigraphy, structure, geomorphology, tectonics, seismicity, salt dissolution, and natural resources. These studies have been documented in published reports that are referenced in the SCP/CD. Most of the raw data used in Chapter 1 of the SCP/CD are derived from drilling, geophysical surveys, field studies, mapping, and remote sensing. During site screening, 10 boreholes were drilled for the DOE through the repository horizon in the Palo Duro Basin. The data thus obtained are supplemented by records from several thousand boreholes drilled in the area and region for oil and gas. Seismic data are available from about 150 line-miles of seismic-reflection surveys conducted by the DOE and proprietary information purchased by the DOE; the latter includes 440 line-miles of seismic data. Portions of the area of the site are covered by aerial photographs, Landsat satellite imagery, and imagery from a side-looking airborne radar.

Included in the discussion that follows is a description of the stratigraphy at the site because it is important to the design and performance of the repository. The principal methods used in the investigation of the stratigraphy of the Palo Duro Basin are correlation and interpretation of commercially available geophysical logs and interpretation of cores and geophysical logs from the 10 DOE wells in the northern part of the basin. Sample logs have been used to constrain the interpretation of geophysical logs in areas distant from cored wells, and seismic-reflection surveys have been useful in understanding the deep-basin stratigraphy and structure in areas where borehole data are unavailable.

The deep stratigraphic borehole closest to the Deaf Smith County site is the DOE's J. Friemel No. 1 well, which is approximately 3 miles to the south. On the basis of regional relationships, the formation lithologies and thicknesses in the J. Friemel No. 1 well are thought to be representative of the conditions at the site. The well was drilled and selectively cored to a depth of 8281 feet and terminates in rocks approximately 300 million years old (Pennsylvanian age). The generalized stratigraphic column developed from the J. Friemel well correlates well with geophysical logs of the closest wildcat wells and is considered to be generally representative of the stratigraphy at the site.

There are three stratigraphic units that are of interest to the repository: the San Andres Formation, the Dockum Group, and the Ogallala Formation. The San Andres Formation contains the host rock for the repository (Figure 2-2), as described in Section 2.1. The other two units, which are fresh-water aquifers, generally occur within 1000 feet of the surface in the vicinity of the site and lie at least 1500 feet above the host-rock horizon. The Dockum Group consists of sandstone, conglomerate, siltstone, and mudstone deposited late in the Triassic Period, which ended about 180 million years ago. The Ogallala Formation consists of fluvial sands, gravels, and eolian sediments deposited in Late Tertiary time, beginning about 24 million years ago. The thickness of the Ogallala averages approximately 300 feet in Deaf Smith County, but is highly variable owing to relief on the pre-Ogallala erosional surface.

Tectonic uplift or subsidence and seismicity have little potential for affecting the long-term stability of the region, but they should nonetheless be considered. The possible existence of faults is important because they could act as pathways for ground-water flow. The Palo Duro Basin is tectonically stable in comparison with other regions of the United States. No active surface faults have been identified in the immediate vicinity of the Deaf Smith County site, and no evidence of Quaternary tectonic deformation has been observed.

A 16-station microearthquake-monitoring network operated for the DOE detected 34 microearthquakes in the Texas Panhandle from 1984 through 1986. These low-magnitude earthquakes occurred along the Amarillo Uplift, the Oldham Nose, and the intervening saddle more than 20 miles to the north and east of the site. Although minor, such activity indicates some degree of tectonic adjustment. Most of the microearthquake activity in the Texas Panhandle occurs along the Amarillo Uplift, and therefore this area is considered a seismic source zone for estimating seismic hazards.

Salt dissolution

To evaluate the salt-dissolution history of the Palo Duro Basin, it is necessary to distinguish the dissolution episodes that occurred during the deposition of the salt from those that occurred subsequently. Also, it is necessary to distinguish between the absence of salt due to nondeposition (facies change) and dissolution. The DOE has used various investigative methods to locate and date salt dissolution: (1) lithologic examination of core samples from DOE wells, (2) stratigraphic and structural analyses using geophysical well logs and core data, (3) field mapping of outcrop and surficial features, and (4) hydrochemical analyses of ground water and surface discharge.

Salt dissolution can be either peripheral dissolution, which occurs laterally along the margins of the salt beds, or interior dissolution, which takes place in the uppermost salt bed in the geologic section as a result of contact with ground water. Along the margins of the salt beds in the Palo Duro Basin, the combined processes of erosion, peripheral dissolution, and subsidence are active but extremely slow. The result is a slow horizontal slope retreat on the east side of the basin, essentially parallel to the Caprock Escarpment, which is one of the physiographic features shown in Figure 2-3. As shown in Figure 2-4, the Deaf Smith County site is approximately

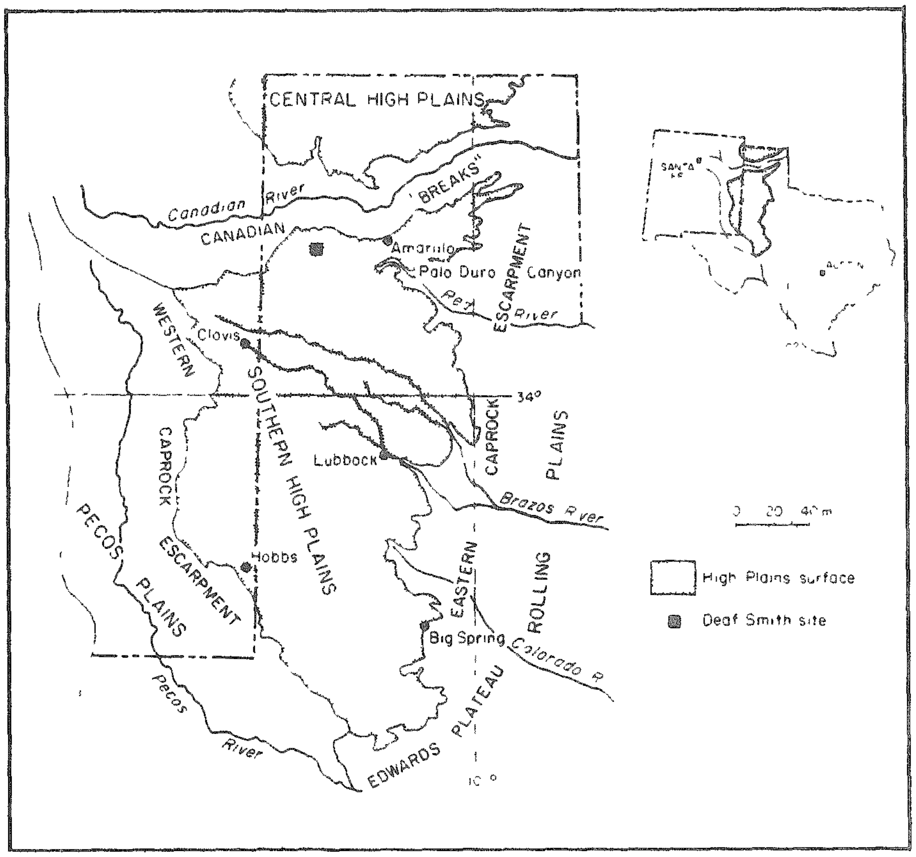

Figure 2-3. Major physiographic elements in the area of the Deaf Smith County site.

60 miles from the eastern extent of the Lower San Andres salt units, 20 miles from the northern extent, and 100 miles from the westernmost extent.

The greatest known salt-dissolution rate in the region is approximately 3 feet per year; this rate is measured at the North Fork of the Wichita River subbasin in the Rolling Plains. This rate has been used to make extremely conservative estimates of the time required to dissolve the salt in the Lower San Andres Unit 4 from its current margins to the Deaf Smith County site; the results show that approximately 100,000 years would be required for dissolution from the Eastern Escarpment to reach the site, and dissolution from the northern margin along the Canadian Breaks would take approximately 37,000 years to reach the site. It should be noted that these conservative estimates may be applicable only to the areas near the Caprock Escarpment, where the

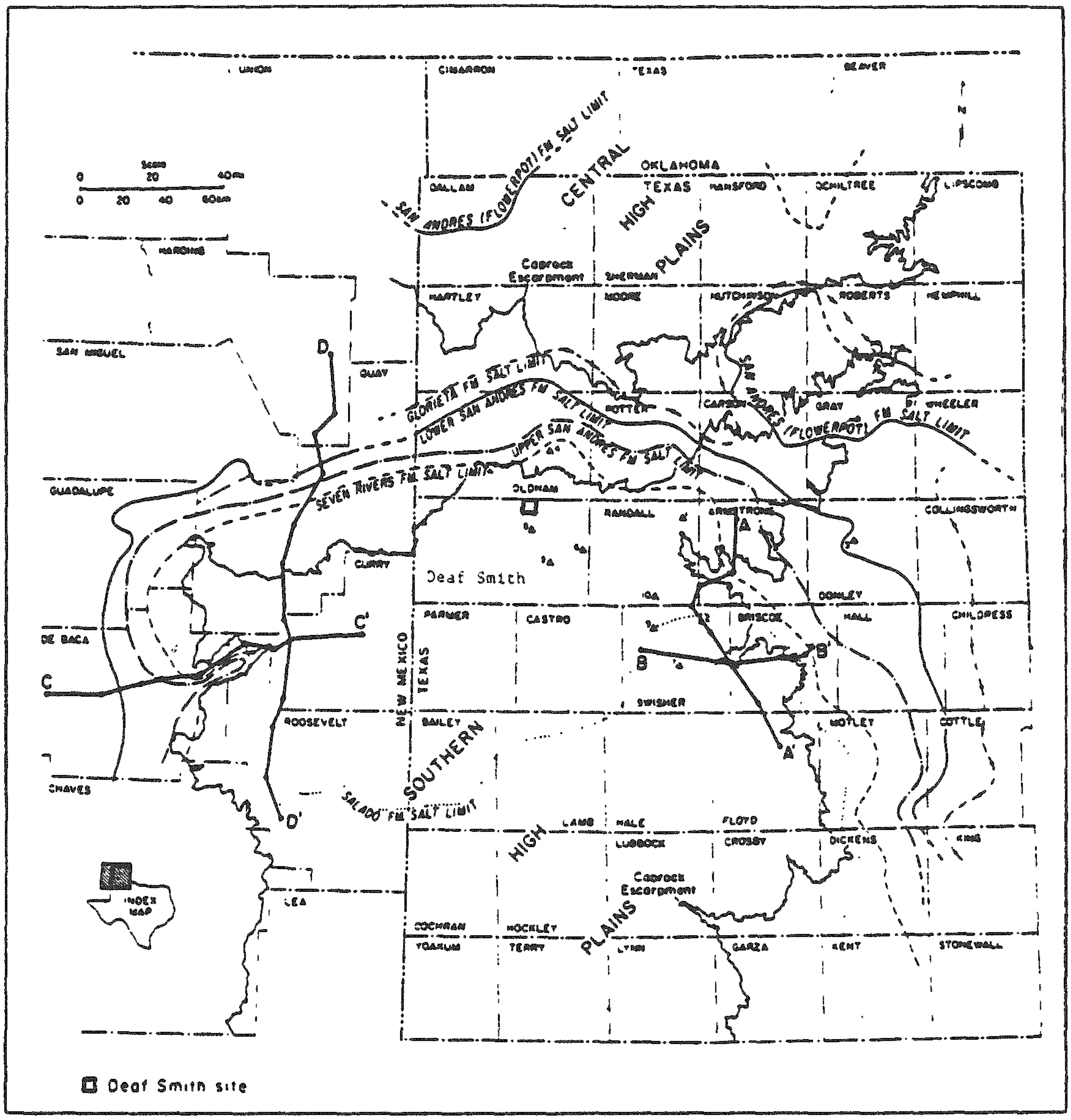

Figure 2-4. The present extent of salt beds for the Seven Rivers, the San Andres, and the Glorieta Formations.

unique hydrogeologic conditions may allow the continuous inflow of fresh water that is necessary for salt removal. Away from the topographic escarpment, toward the center of the Palo Duro Basin, the fresh water follows the regional dip into the interior of the basin, where it may become saturated with salt and therefore unable to dissolve more salt.

Postdepositional interior dissolution in the Palo Duro Basin has been recognized in all DOE wells from the presence of breccias overlying the Upper Seven Rivers and the Salado Formations--the uppermost salts above the San Andres Formation. If interior dissolution is occurring, the current rate in the basin at the site is not known because the original thicknesses of the salt units are not known, and it is not known conclusively whether the interior dissolution occurred a long time ago, possibly during the deposition of the salt, or whether it is the result of a more recent or current process. Some investigators have related numerous Quaternary alkaline lake basins and recent subsidence on the High Plains to the dissolution of the underlying Permian salt beds. The degree and the stratigraphic horizon of interior dissolution presently active beneath the Southern High Plains are not resolved.

Natural resources

In evaluating a candidate site for a repository, it is also necessary to consider the possibility that future generations might inadvertently intrude into the repository. The potential for such human interference depends largely on the potential for natural resources. Aside from salt, including its potential use as a storage medium, and hydrocarbons, there appear to be no resources present in the vicinity of the site with development potential.

Commercial production of brine is presently active in the Panhandle (approximately 3 miles north of Amarillo) from one well in bedded salt at a depth of 2205 to 2750 feet. This well has produced more than 250,000 barrels of saturated brine, from which some 30,000 barrels of rock salt has been extracted. No rock salt is being mined in the Palo Duro Basin, but a brine well near Hereford in Deaf Smith County was productive until abandoned in 1981. Salt deposits in parts of the Panhandle have also been commercially exploited for underground storage. The salt is mined by injecting low-salinity water into salt beds, thereby dissolving the salt, and the resulting brine is pumped out. Mined salt caverns can be used to store light hydrocarbons and are generally constructed near areas of petroleum refineries. However, bedded-salt deposits are abundant throughout the Permian Basin, and this abundance reduces the chance of human interference at the candidate site.

Through 1984, the Palo Duro Basin has produced approximately 177 million barrels of oil and 100 billion cubic feet of gas. Most of the oil and gas production has come from the margins of the basin, with only very little, noncommercial production from the interior of the basin. The quantities of oil and gas produced in 1979 are shown in Figure 2-5. The reason for the relative scarcity of major hydrocarbon discoveries in the center of the basin is not clear. The primary requirements for hydrocarbon occurrence--such as porosity, traps, and source rocks--are present; however, there is an apparent lack of thermal maturity in the source rocks. Hydrocarbons have not been found in wells near the site, and the probability of their presence in commercial quantities is low.

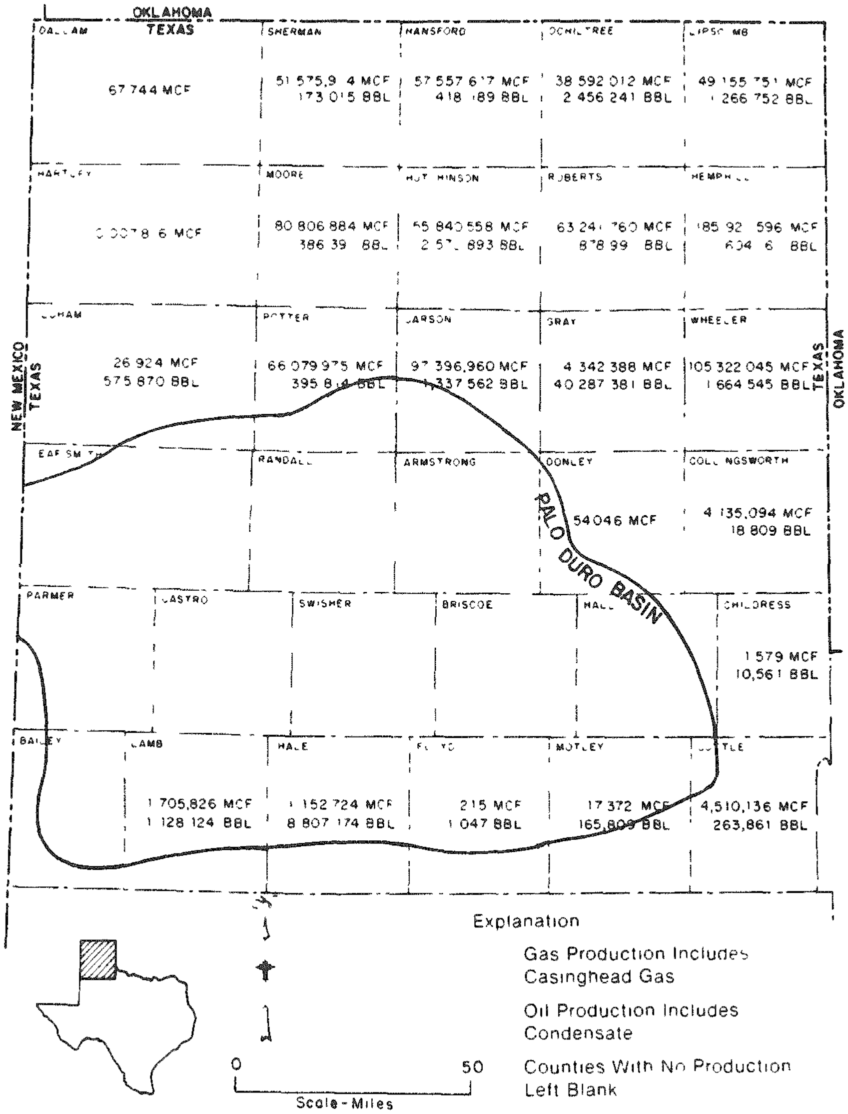

Figure 2-5. Oil and gas production in the Texas Panhandle in 1979. Oil in barrels (BBL) and gas in thousands of cubic feet (MCF).

2.3.2 Geoengineering

Geoengineering properties are important in predicting the mechanical and thermal behavior of the host rock and surrounding strata both before and after the closure of the repository; they include strength and deformability, density, thermal properties, and in-situ stress. A detailed discussion of currently available data on the geoengineering properties of the rock at the Deaf Smith County site can be found in Chapter 2 of the SCP/CD.

No samples from the site itself have been available for tests of geoengineering properties. However, tests have been performed on rock and salt samples from the 10 DOE wells mentioned in the preceding section, other wells representative of the site, another bedded-salt site in the Permian Basin (the site of the Waste Isolation Pilot Plant in New Mexico), and the Avery Island salt dome in Louisiana.

The mechanical properties on samples taken from test holes drilled in the site area (strength and deformation characteristics) can be grouped under intact rock, discontinuities, and rock mass. The intact-rock properties for salt, anhydrite, clastics, and carbonates have been tested for an area that includes the Deaf Smith County site. Strength tests indicate that the carbonates and anhydrites are strong to very strong in compression, whereas the clastics vary from very weak to strong. The older clastics (below the Dockum Group) are generally more competent.

Few tests have been possible on the mechanical properties of discontinuities, because only the smaller, natural discontinuities, such as those occurring along bedding planes and interbed contacts, were observed in the drill core. There is little evidence of discontinuities in the host rock salt. Aside from interpretations from geophysical logs and seismic data, no projections can be made concerning the large-scale mechanical properties of nonsalt rocks at the Deaf Smith County site, since direct access to the strata in question is not available.

The thermal properties of the host rock will determine how heat will be dissipated away from the waste packages, which in turn would control the rise in temperature of the rock mass over time. For the repository, the thermal properties of interest are thermal conductivity, thermal diffusivity, specific heat, and the coefficient of thermal expansion. The average thermal conductivity of Palo Duro salts tested under confining pressure decreases by about 35 percent over the temperature range of 30 to 200°C. Thermal diffusivity is unaffected by pressure and decreases by about 35 percent over the same temperature range.

Thermomechanical properties are the mechanical properties that are significantly temperature dependent. Salt from the Lower San Andres Formation has been tested at elevated temperatures to determine its thermomechanical properties. Three types of tests were performed on the salt in unconfined and triaxial compression: constant-strain-rate tests, constant-stress-rate tests, and constant-stress (creep) tests.

In salt, it appears that the existing stresses are approximately equal in all directions and equal to the overburden pressure. Within the nonsalt rocks of the Palo Duro Basin, the major principal stress is vertical; the other principal stresses are horizontal and approximately equal.

2.3.3 Hydrology

The hydrologic data base for the candidate site and its region consists of data from the literature and from DOE test wells in the Palo Duro Basin. Primary sources of data include the U.S. Geological Survey, the U.S. Army Corps of Engineers, the Texas Water Commission, the Texas Department of Water Resources, and the Texas Bureau of Economic Geology. A comprehensive summary of the information collected to date is presented in Chapter 3 of the SCP/CD.

Surface-water hydrology

The Deaf Smith County site is in the drainage basin of the Palo Duro Creek, which is a tributary of the Prairie Dog Town Fork of the Red River; the Red River flows through the Rolling Plains to the east (Figure 2-3). The terrain at the site is nearly flat, with a regional slope to the southeast. Because the area is semiarid, the annual evaporation potential greatly exceeds the precipitation. The flat terrain has poorly developed drainage patterns, and runoff occurs in ephemeral streams; approximately 90 percent of the runoff is impounded in playas. While most of the water collected in the playas evaporates, 10 to 15 percent is believed to infiltrate as recharge to the Ogallala Formation.

The candidate site is bounded on the north by a series of playas connected by swales that form a tributary of North Palo Duro Creek. The site has no stream channels, but it does have two playas, one to the southeast and the other to the southwest. No detailed hydrographic data for the playa basins are available.

There are no dams or large bodies of water upstream from the Deaf Smith County site, and most of the site is outside the floodplain of the 500-year and the probable maximum floods.

Ground-water hydrology

An understanding of the ground-water hydrology is necessary for assessing the long-term performance of the repository. Hydrologic data are also needed for the design of the underground repository, the shafts, the waste package, and the permanent seals for shafts and boreholes. Information that is particularly important to the assessment of performance is the estimated time of ground-water travel from the proposed repository to the accessible environment as well as the likely paths of ground-water flow. Descriptions of the regionwide ground-water flow system have been developed from interpretations of geophysical logs, drill-stem tests in oil and gas wells, the results of drilling and testing conducted by the DOE, and numerical modeling.

The geohydrologic framework. The Palo Duro Basin is bounded on the north and the northeast by the Amarillo Uplift and on the northwest by an eastern extension of the Sierra Grande Uplift (the Oldham Nose). The volcanic and granitic rocks of these uplifts are believed to act as barriers to regional ground-water flow in rocks that predate the salt deposits. The Matador Uplift to the south separates the Palo Duro Basin from the Midland Basin; however, the granitic rocks of this uplift do not act as a barrier to regional ground-water flow.

The geologic units of the site are conceptually divided into three separate hydrostratigraphic units (HSUs) on the basis of their hydraulic characteristics. HSU-A consists of the shallow fresh-water system, HSU-B includes the shale and evaporite aquitard, and HSU-C is the deep-basin brine system.

HSU-A consists of the High Plains aquifer and the Dockum Group. In the area of the site, the High Plains aquifer is predominantly the Ogallala Formation (Ogallala aquifer). This unconfined aquifer is made up of consolidated to unconsolidated sand, gravel, siltstone, shale, and clay; it is the principal source of water for the High Plains of Texas. The saturated thickness of the Ogallala aquifer is from less than about 200 to over 290 feet. The Dockum Group consists of clastics and is quite variable in thickness (between 600 and 1900 feet in the Palo Duro Basin). Because of the inhomogeneous distribution of the Ogallala, the Dockum Group is used locally as a supplement to the Ogallala.

HSU-B consists of the upper shale-and-evaporite aquitard, the basal carbonate in Unit 4 of the Lower San Andres salt (LSA-4), and the lower shale-and-evaporite aquitard. The LSA-4 carbonate was singled out because of its relatively high permeability and regional extent. The lower shale-and-evaporite aquitard extends from the base of the LSA-4 carbonate to the top of HSU-C (brine aquifer). Because HSU-B does not produce potable water, the information about its hydrologic properties was derived from oil test wells and the 10 DOE wells.

HSU-C consists of two brine aquifers and older strata. The upper aquifer, in strata up to 280 million years old (the Wolfcampian Series), is made up of thick fan-delta ("granite-wash") deposits and may be more than 2000 feet thick in the Palo Duro Basin; granite-wash deposits have moderate to high hydraulic conductivities. The second brine aquifer is also made up of thick fan-delta sediments that include coarse clastics (granite wash), finer clastics, and shallow marine carbonates up to 3000 feet thick. Pre-Pennsylvanian strata are discontinuous within the area and are made up of carbonates and arkosic (feldspar-rich) sandstones.

There is no direct evidence that regional ground-water flow in the Palo Duro Basin in Deaf Smith County is controlled by vertical fractures. The presence of vertical fractures is of great concern because vertical fractures might have higher permeabilities and could provide a faster flow path to the accessible environment.

<u>Conceptual model of regional ground-water flow</u>. As already mentioned, the Palo Duro Basin is conceptually divided into three hydrostratigraphic units. HSU-A is a fresh-water aquifer and is recharged by infiltration from precipitation; discharge is primarily from pumping for agricultural purposes. Ground-water flow is predominantly horizontal and is to the east and southeast. HSU-B has two zones with permeabilities higher than those in most of the units that make up the aquitard. The relatively permeable units are the salt-dissolution zone around the perimeter of the Southern High Plains and the carbonate bed in Unit 4 of the Lower San Andres salt. Water is believed to flow predominantly downward in the aquitard, with a horizontal component in the two permeable units. HSU-C is believed to have been recharged by infiltration from New Mexico shortly after the deposition of the formations and by leakage from overlying strata. Ground water flows horizontally and predominantly from the southwest to the northeast. From hydrologic data, the ground-water residence time in the deep-basin brine aquifer is estimated to be typically longer than 1 million years, and flow is predominantly in the permeable granite-wash deposits. Ground-water chemistry (e.g., stable-isotope data) tends to support an equally long residence time (i.e., more than 1 million years).

<u>Pathways to the accessible environment</u>. The most likely pathways for radionuclides to travel from the disturbed zone to the accessible environment

are either laterally through the carbonate bed in Unit 4 of the Lower San Andres salt or downward to the HSU-C "brown dolomite" and then laterally to the boundary.

Time of ground-water travel. Estimates for both porous flow and fracture flow indicate median ground-water travel times of 500,000 and 76,000 years, respectively, from the disturbed zone to the accessible environment. The distributions of these travel times span several orders of magnitude, which is a reflection of the uncertainties associated with the input parameters.

Ground-water uses. Ground water is the primary source of water in the Southern High Plains, and HSU-A (the Ogallala Formation and the Dockum Group) is the major supplier. The water is of good quality, although the Ogallala generally yields fresher water than does the Dockum. Water use in Deaf Smith County is more than 99 percent from ground-water sources, and 96 percent of the ground water is used for irrigation. Throughout the Southern High Plains ground water is being removed from the HSU-A aquifer at a rate far greater than recharge (about 70 times greater in Deaf Smith County). These overdrafts have resulted in the removal of ground water from recoverable storage and a measurable lowering of the potentiometric surface. In the past 40 years the potentiometric level of the Ogallala has declined by 85 feet at the candidate site, at a rate of slightly more than 2 feet per year.

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 in ground water. To study this geochemical environment and to develop a preliminary geochemical data base for the Palo Duro Basin, core and ground-water samples have been analyzed from the 10 DOE boreholes drilled in the basin as well as some outcrop samples. As discussed in Chapter 4 of the SCP/CD, the types of data collected include the amounts and compositions of brines, including their pH and oxidation-reduction potential; the isotope data for stable and radiogenic isotopes and activity ratios; and the mineral and chemical composition of rocks. The sampling and analysis of brines require specialized methods, some of which were developed for this program. The activity-ratio data were compared with data obtained from a natural analog (the Salton Sea geothermal field).

An understanding of the pre-waste-emplacement geochemical environment of the Deaf Smith County site requires assessing the mineral composition of the host rock, the chemistry of the formation fluids, and rock-water equilibrium relationships. The available data base is sufficient to develop several preliminary working hypotheses and models for the geochemical environment.

The host rock is a mixture of halite with lesser amounts of anhydrite, silt, and clay. The mineral composition appears to have been relatively stable since soon after deposition. Chemical analyses of the host rock, LSA-4, indicate that sodium and chloride predominate, with lesser amounts of calcium, potassium, magnesium, and sulfate.

The volume of fluids in the candidate host rock and the chemistry of those fluids are not well known. Fluids are assumed to be primarily associated with the mudstone-rich zones of LSA-4 and, to a lesser degree, occur as inclusions in the LSA-4 halite. Both of these fluids are magnesium-rich and are potentially quite corrosive, with mean total-dissolved-solids levels of 240,000 ppm. The temperature, pressure, pH, and oxidation-reduction conditions of the fluids remain uncertain. Isotope data indicate that fluids in the LSA-4 halite appear to have been isolated during the primary deposition of the evaporites and are thought to be concentrated seawater of Permian age, possibly mixed with Permian-age water from precipitation. Stable-isotope data combined with fluid-inclusion chemistry and depositional features indicate that the host rock has probably remained hydrologically isolated since shortly after its deposition. Rough estimates of the amount and distribution of brine in the host rock and the chemical concentration ranges in brine have been developed from preliminary data.

The geochemical factors potentially influencing radionuclide speciation and concentration in Palo Duro Basin ground water include the oxidation-reduction potential, pH, ionic strength, and the concentrations of selected ligands (radionuclide-complexing species). Indications are that the host rock-fluid geochemical environment is somewhat reducing, with a pH of 4 to 5 and a temperature of 25 to 35°C. Results based on limited data from the Palo Duro Basin indicate that there may be significant retardation for most key radionuclides along certain flow paths, even when transported in brine.

The ground water in the Ogallala aquifer is recharged by infiltration from precipitation; it has a low total-dissolved-solids concentration and a pH of 7 to 9. Ground water in the Dockum Group has higher levels of total dissolved solids and is also recharged from precipitation. The hydrochemistry of ground waters in HSU-C below the repository horizon indicates that they may have remained hydrologically isolated since shortly after deposition. However, hydrologic models suggest other possible origins for HSU-C waters.

2.3.5 Climate and meteorology

Climatic conditions at a repository site may affect the surface facilities and operations, and future climatic changes--10,000 and even 100,000 years from now--may affect the long-term performance of the repository. Chapter 5 of the SCP/CD summarizes available data on the current climate and assesses the potential for climatic changes over the long term from evidence about the climates that prevailed at the site in Quaternary time.

Recent climatological data have been collected at the National Weather Service (NWS) station at Amarillo, Texas, and at several climatologic substations in the vicinity of the site, including one at Hereford, Texas. The data collected cover a 30-year period and are considered to be reasonably representative of the climatologic conditions at the site because of the proximity of these stations to the site and the nearly flat terrain across the region. The area is characterized by high average wind speeds (mean annual wind speed of 13.7 mph), warm temperatures (an annual average of approximately 55°F), and little precipitation (about 17 inches per year). Severe weather is typical of the Southern High Plains; for instance, rapid and large temperature changes can occur during winter months (temperature drops of 50 to 60°F within 12 hours).

To reconstruct the regional climate of the past, with emphasis on the Quaternary Period, and to project conditions at least 10,000 years into the future, it is necessary to consider (1) late Cenozoic regional climatic variations, (2) long-term global trends, and (3) climatic changes induced by human activities. Through the use of evidence, including fossil pollen, found in lacustrine deposits from the end of the last glacial period, investigators have described the Quaternary climate of the Southern High Plains. Beginning approximately 11,000 years ago, there was a gradual change from cool, wet conditions to a warmer, more arid climate. Progressive warming and drying continued until almost 6000 years before the present, by which time conditions approximated those of the modern climate. Climate predictions based on global trends or human activities are not yet sufficiently detailed to allow meaningful long-term analyses and planning.

3. THE DESIGN OF THE REPOSITORY AND THE WASTE PACKAGE

This chapter briefly describes the design of the engineered elements of the disposal system--the repository and the waste package. The description is based on the SCP conceptual design, which is 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 design 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 design, therefore, was developed in sufficient detail to identify the site data that are needed, but it is an early conceptual design, and it is likely that the designs of both the repository and the waste package will change as site-characterization data are collected and more-detailed designs are developed.

3.1 THE REPOSITORY

A geologic repository will consist of surface facilities, underground facilities, and shafts connecting the surface and the underground facilities. In addition, when the repository is prepared for permanent closure, seals will be constructed for the shafts and exploratory boreholes. The repository will be designed to meet various functional and regulatory requirements, including the NRC's requirements in 10 CFR 60.111-113, 10 CFR 60.131-134, and 10 CFR 60.137 (see Appendix A).

A conceptual illustration of the proposed repository at the Deaf Smith County site is shown in Figure 3-1, and a topographic map of the site layout is shown in Figure 3-2. A detailed discussion of the conceptual design of the repository can be found in Chapter 6 of the SCP/CD. The data base for the conceptual design was derived from sources outside the repository site boundary and therefore is not site specific. In order to proceed with the design in spite of the absence of site-specific data, a body of synthetic data was compiled and baselined. This was accomplished by considering whatever non-site-specific data were available at the time and making the best estimates of the parameters needed for design.

3.1.1 <u>Surface facilities</u>

The principal purpose of the surface facilities of the repository is to receive the waste and to prepare it for permanent disposal underground. The surface facilities would be constructed on flat terrain in the north-central and northeastern part of the Deaf Smith County site. They would consist of a central surface-facilities area, various outlying support facilities, and facilities that would provide access and ventilation for the underground repository. Both rail and highway access to the site would be provided.

The surface facilities would be grouped into the following categories related to their functions: (1) waste-processing buildings, (2) underground-

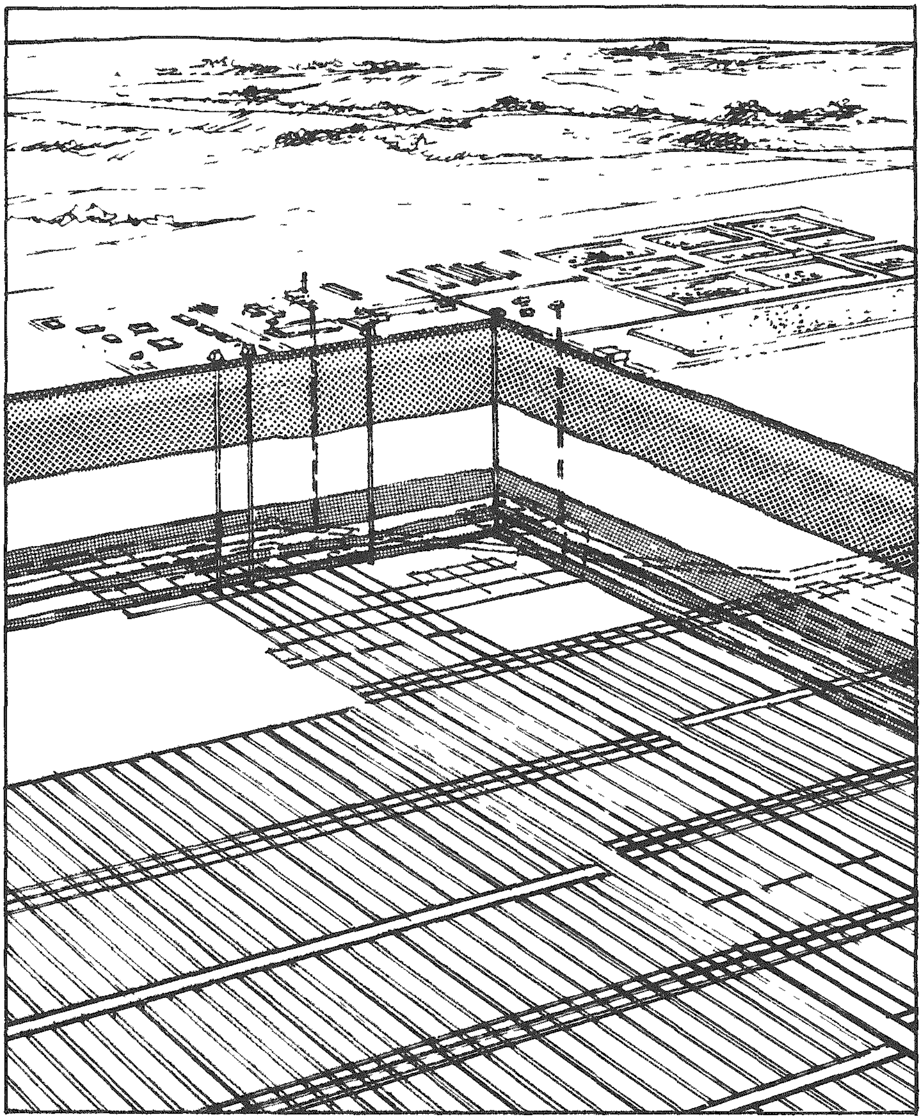

Figure 3-1. Conceptual illustration of a repository at the Deaf Smith County site, showing surface facilities, shafts, and the underground repository.

support buildings and structures, (3) administration buildings, (4) maintenance building, (5) storage and warehouse buildings, (6) utility buildings and facilities, and (7) miscellaneous buildings and structures.

The waste-processing area would be divided into functional areas used for waste receiving and inspection, waste preparation for disposal, and general support facilities. Two waste-handling buildings are included in the design because the repository would be constructed and operated in two phases. During phase 1, only waste-handling building 1, the smaller building, would be available; it would be used to receive spent fuel and to encapsulate it in disposal containers. During this phase, the repository would operate at a design receipt rate of 400 MTU per year. Full-capacity operation at 3000 MTU per year of spent fuel would be reached in phase 2, when the larger waste-

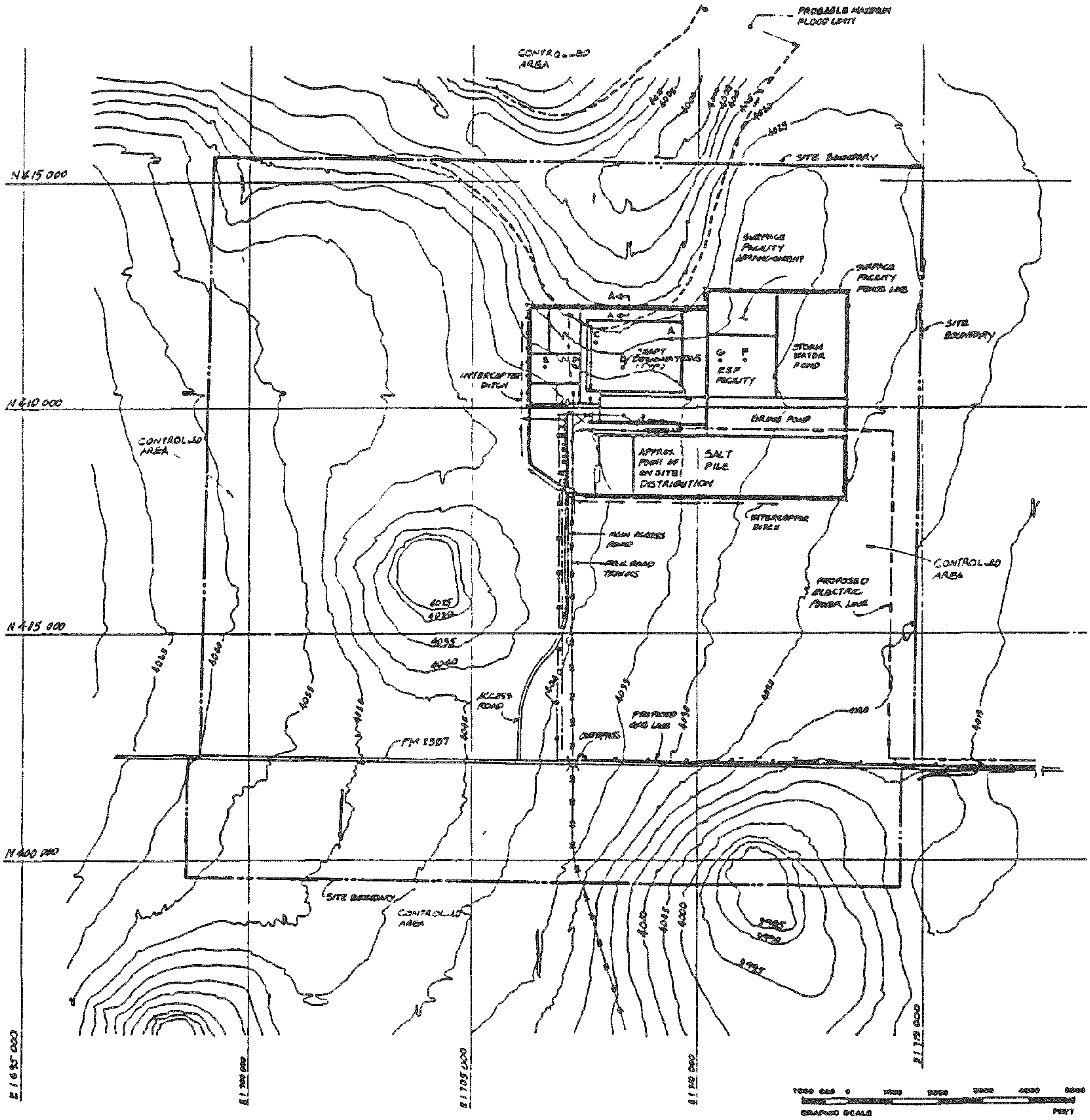

Figure 3-2. Topographic map showing the general layout of the repository. The layout of the surface facilities is shown in Figure 3-3. The letters A through G denote the locations of shafts.

handling building is completed. At that time, the repository would also receive high-level waste at a rate of 400 MTU per year.

During phase 2, waste-handling building 2 would have facilities for consolidating 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 and West Valley high-level waste. 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 against radiation and equipped with remotely controlled equipment for cutting the spent-fuel assemblies and loading the spent-fuel rods into disposal containers. The loaded containers would then be transferred to another station, sealed by welding, inspected for leaktightness, and moved to a shaft for transfer underground. If necessary, disposal containers might be temporarily stored in a dedicated storage cell. The transfer and emplacement operations would be performed with specially designed transfer casks and transporters.

Many of the other surface facilities would support waste-preparation, underground-development, and waste-emplacement operations. Support operations would include salt handling and storage; these operations would require special precautions, such as minimizing the possibility of salt contaminating the creek at the north of the site. Other support functions would include equipment maintenance and warehousing; utilities; and personnel services (change houses, cafeterias, offices, etc.). The layout of the surface-facilities area is shown in Figure 3-3.

3.1.2 Shafts

The surface facilities would be connected to the underground repository through six vertical shafts, including two exploratory shafts. The two exploratory shafts (F and G) would be sunk during site characterization as part of the exploratory-shaft facility (see Chapter 5). The remaining four shafts (A, B, D, E) would be sunk simultaneously after a construction authorization for the repository is received from the NRC. (Shaft C is an alternative shaft that would be constructed only if the ESF shafts are not used for repository operations.) The locations of shafts A through E are shown in Figure 3-2.

Shaft A would serve as the exhaust shaft for the emplacement ventilation system (see Section 3.1.3). It would not serve a hoisting function for the repository. Shaft B would be used to transport the waste to the repository horizon. Downcast airflow in shaft B would be sufficient to ensure adequate ventilation in the shaft and in the underground waste-transfer area. In the event of an accident in the shaft involving the waste, the airflow can be directed through an underground system of high-efficiency particulate air filters to prevent the release of radionuclides to the repository or the surface.

Shaft D would serve as the main exhaust shaft for ventilating the development side of the repository, and it would also be used for hoisting mined salt to the surface. The hoisting of mined salt would cease 22 years after the start of waste emplacement, at which time shaft D would be converted to transferring salt from the surface to the underground for backfilling.

Shaft E would be equipped for moving personnel, equipment, and materials. It would also serve as the intake airway for the development ventilation system.

It is proposed that exploratory shafts F and G be used for the pre-waste-emplacement development of the repository. After site characterization, the

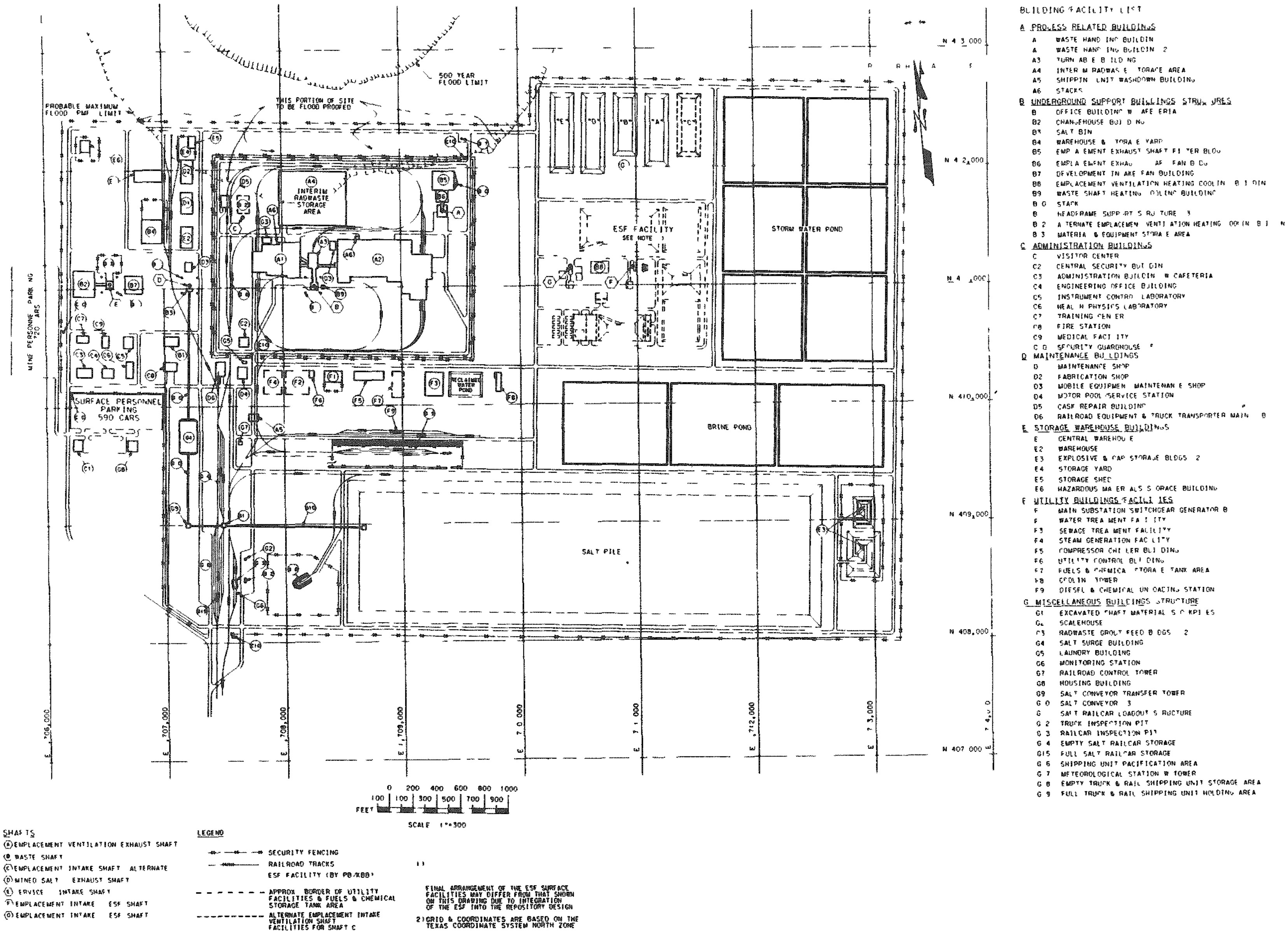

Figure 3-3. Surface facility arrangement.

two shafts would be reequipped with larger conveyances to handle increased salt tonnages and service requirements. Both headframes would require modification or replacement, and larger hoists would be installed. After the pre-waste-emplacement development is completed, shafts F and G would be converted to repository-ventilation shafts. This would be done by stripping all hoisting equipment from the shafts, removing the headframes and hoists, and installing the ventilation ductwork on the surface. At this point, personnel and equipment access to the underground facilities would be through shaft E.

Emergency, inspection, and maintenance hoisting systems would operate independently from the main hoisting systems. An emergency hoist would be installed at shaft E to evacuate personnel and provide access to the underground repository when the main service hoist is out of commission.

The shafts would be excavated by using conventional drilling and blasting as the primary excavation method. Pneumatic rock breakers and controlled blasting techniques would be employed as required to minimize ground disturbance beyond the perimeter of the shaft excavation. The proposed excavation methods were selected on the basis of experience in shaft construction under similar conditions.

The repository shafts would pass through the Ogallala and Dockum aquifers (see Section 2.3.3). Ground freezing would be used to construct the shafts through these aquifers. The freezing technique, which has been widely used by the mining industry in shaft sinking for over 100 years, would prevent groundwater flow into the shaft excavation and would provide additional ground control during excavation. These techniques are suitable over a wide range of hydrogeologic conditions and have been successfully used with ground conditions similar to those present in the Ogallala and Dockum Formations.

Shaft construction below 1000 feet would not require ground freezing since ground-water inflows below this depth are expected to be significantly smaller than those encountered in the Ogallala and Dockum Formations. Water inflow in this lower shaft area would be reduced to acceptable levels for shaft excavation by grouting from the shaft bottom if necessary. Any remaining water inflows encountered during construction would be handled by pumping from the shaft bottom to the surface.

Two arrangements for lining shafts have been developed. In both arrangements, the shaft lining between the surface and a depth of 1147 feet would include a primary concrete lining, with a final lining surrounded by an annulus filled with an asphaltic sealant. The final lining would consist of a single steel membrane with reinforced concrete from the surface to 400 feet and a double steel membrane with reinforced concrete from 400 to 1147 feet. Two lining options are also available for the shaft section from 1147 to 2051 feet. Lining option 1 consists of a nonwatertight concrete lining in the dry zone and a double steel and concrete watertight lining surrounded by grout in any water-bearing zones. Chemical seals would be installed at the top and the bottom of this watertight lining section. Option 2 consists of ductile-cast-iron tubing and concrete. The tubing, although a watertight lining, would not be required to function as such in the dry zone, but it would be a watertight lining in the water-bearing zone.

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 2500 feet below the surface. The primary area for the underground repository is in the Lower San Andres Unit 4 (see Chapter 2). The host rock in this area is expected to be sufficiently thick and large to easily accommodate the repository; an area of about 4000 acres would be used for waste emplacement. No significant geologic discontinuities are expected in the repository horizon.

Layout

The general arrangement of the underground repository would consist of a set of nine main entries extending south from the shaft locations through the center of the layout; a set of two main exhaust entries on the repository perimeter on the west, north, and east sides; and nine waste-emplacement panels. The general layout and the sequence of underground development are shown in Figure 3-4.

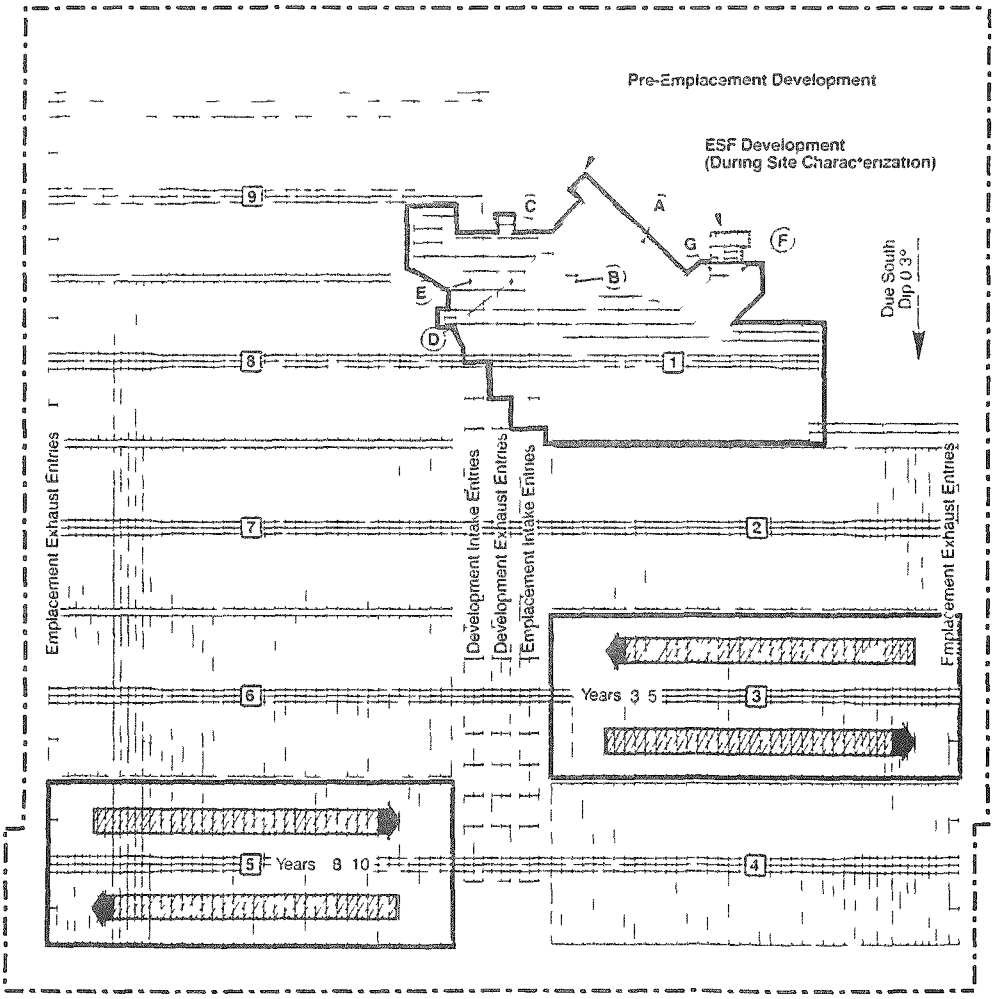

Figure 3-4. The layout of the underground repository and the sequence of underground development. The large arrows show the direction of development, and the thin lines show the centerlines of entries. The letters A through G designate shafts (see Section 3.1.2 for descriptions).

The shafts would be located within a "shaft pillar," where salt extraction would be very low (approximately 10 percent) in order to protect the shafts from damage by ground movement. All permanent underground facilities, including shops, warehouses, and refueling areas, would be located in the shaft pillar.

The main entries would provide access to the development and waste-emplacement areas for personnel and equipment, and ventilation air would be directed through them to the working areas. The mains would also be used as travelways for service and waste-transportation vehicles, and they would be equipped with conveyor-belt systems for moving mined salt and salt backfill. The sizes and the numbers of the mains depend on the need to accommodate equipment and the maximum airflow requirements of the ventilation systems.

Waste emplacement

In the SCP conceptual design, the reference waste-emplacement mode is vertical emplacement. In this mode, the boreholes would be drilled vertically into the floor of the emplacement drifts, and a single container of waste would be emplaced in each borehole. The alternative mode is horizontal; in this mode, boreholes would be drilled horizontally into the walls of the emplacement drifts, with a single waste container emplaced in each hole.

For either mode of emplacement, the waste would be placed in nine emplacement panels. Typically, three submains would be located in the center of a panel to provide access to the emplacement entries. Approximately 80 waste-emplacement entries would be located along both sides of the submains, and a ventilation-exhaust entry would be located along both edges of the panel. Waste would be emplaced only in the emplacement entries; these entries would be backfilled with crushed salt as each entry is filled with waste (see Section 3.1.5). This arrangement would provide access routes if retrieval of the waste is required.

Ventilation

Two independent ventilation systems would serve the underground repository. One would provide air for the development of the repository, while the other would provide air for the waste-emplacement operations. Connections between the systems would be sealed with bulkheads or airlocks. A positive-pressure system would be used for the development-area air circuit to prevent the in-leakage of air from the waste-emplacement area. The quantity of air circulated by the two ventilation systems would vary over the operating life of the repository. The maximum flow rate would occur near the end of active waste-emplacement activities.

Although designed to meet gassy-mine regulations, the repository is not expected to be a gassy mine as defined in the regulations. Only the potential for the presence of methane has been identified. If methane is found at the Deaf Smith County site, it is expected to be associated with water in fluid inclusions within the salt bed. Under these conditions, some of the methane would be released when mining breaks open the inclusions. The amount of methane that might be encountered is expected to be small, but it is prudent at present to design the repository to meet the gassy-mine regulations.

Construction method and equipment

For repository excavation, a boom-type mechanical miner is being considered. The miner is track mounted and mobile; it uses a milling-type head mounted on a movable boom for cutting salt from the mining face. The miner is equipped with a mechanism for gathering the broken salt and an elevating conveyor for loading the salt into a shuttle car.

Ground support

The walls and roof of the repository excavations are expected to be self-supporting throughout their operating life. Some areas, such as facilities in the shaft-pillar area that are needed throughout the life of the repository or areas in which there are geologic anomalies, may require auxiliary support or reinforcement.

3.1.4 Waste retrievability and closure

The emplaced waste would be retrievable for 50 years after the start of emplacement. Thus, after the waste-emplacement period, which is scheduled to last 26 years, a "caretaker" period of 24 years would begin. During both of these periods, various tests would be conducted to confirm that the repository is performing as expected. At the end of the caretaker period, the repository would be prepared for permanent closure by completing the backfilling of the underground areas and permanently sealing the shafts (current plans for sealing and backfilling are discussed in the next section). The surface facilities would be decontaminated and decommissioned, and the site would be returned to its natural state to the extent practicable. Permanent site markers would be erected to warn future generations of the presence of a repository.

3.1.5 Seals

The permanent closure of the repository would require the sealing of all shafts, exploratory boreholes, and underground openings. The design objective for seals is to reduce, to the extent practicable, the potential for creating preferential pathways for ground-water flow or radionuclide migration.

Sealing of shafts

The basic components of the shaft-seal system are concrete bulkheads, a structural backfill, a dense earthen backfill, a swelling clayfill, a general earthen backfill, and the shaft caps. Figure 3-5 shows the schematic layout of these seal components.

The shaft-seals system would include components to provide short-term and long-term sealing. Concrete bulkheads would be the primary source of short-term sealing. These bulkheads would be large, relatively impermeable structures that inhibit ground-water flow through the bulkhead, along the seal interface with the host rock, and through the "construction-affected zone" that surrounds the underground openings. The precise locations of the bulkheads

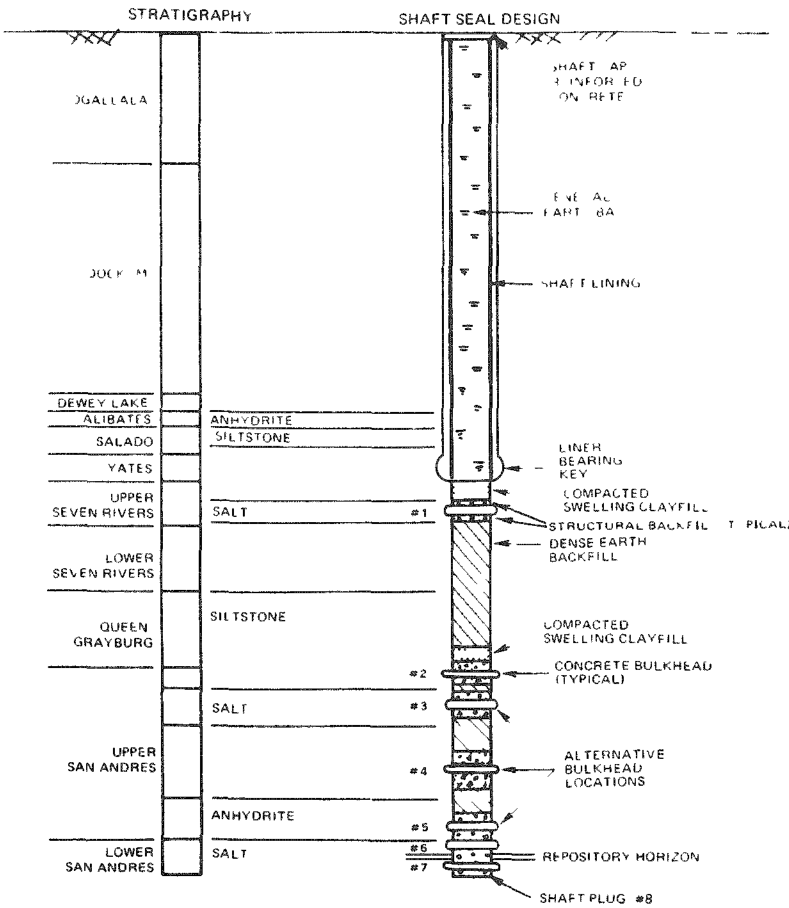

Figure 3-5. Design for sealing shafts.
The liner and bulkheads are not to scale.

would depend on such factors as the characteristics of the rock, local groundwater conditions, and the location of shaft lining components (e.g., bearing keys, operational seals, and type of lining).

Backfill sections would provide for long-term sealing. The objective is to provide backfill material that is as similar to the surrounding rock as possible, recognizing, of course, that the material is expected to consolidate nearly to initial in-situ conditions and that the material must be compatible with the local geochemical and hydrochemical environments. Seal materials would be engineered to restore the construction-affected zone to near its undisturbed state via swelling pressure. Critical long-term seal sections would be in the lower salt strata, where backfill would have a very low permeability and the fracture-healing behavior of the salt would restore the low hydraulic conductivity of the salt in the construction-affected zone. The short-term seals between the aquifer and the lower salt strata must remain effective until the critical long-term seals become effective. Redundancy in the short-term seal design should prevent the failure of one seal component from compromising the entire sealing system.

The shaft-seal system is designed to ensure that system performance is not dependent on the reliability of only one type of seal component or seal material. This redundancy is provided by the use of multiple bulkheads and multiple types of backfill. This multiplicity of components and materials leads to a very low probability of system failure because the failure of one type of seal component or the shrinkage of one type of seal material would not compromise the integrity of the overall sealing system.

Sealing of boreholes

In general, all boreholes would be backfilled and sealed by one of the techniques discussed below. The primary purposes for sealing boreholes are to retard the movement of ground water down the borehole to the repository horizon and to prevent the migration of radionuclides to the accessible environment. Sealing requirements would depend on the location and the depth of each borehole.

The basic components of the borehole-seal system are cement-grout sections and clay sections. Figure 3-6 shows the schematic design of a sealed borehole.

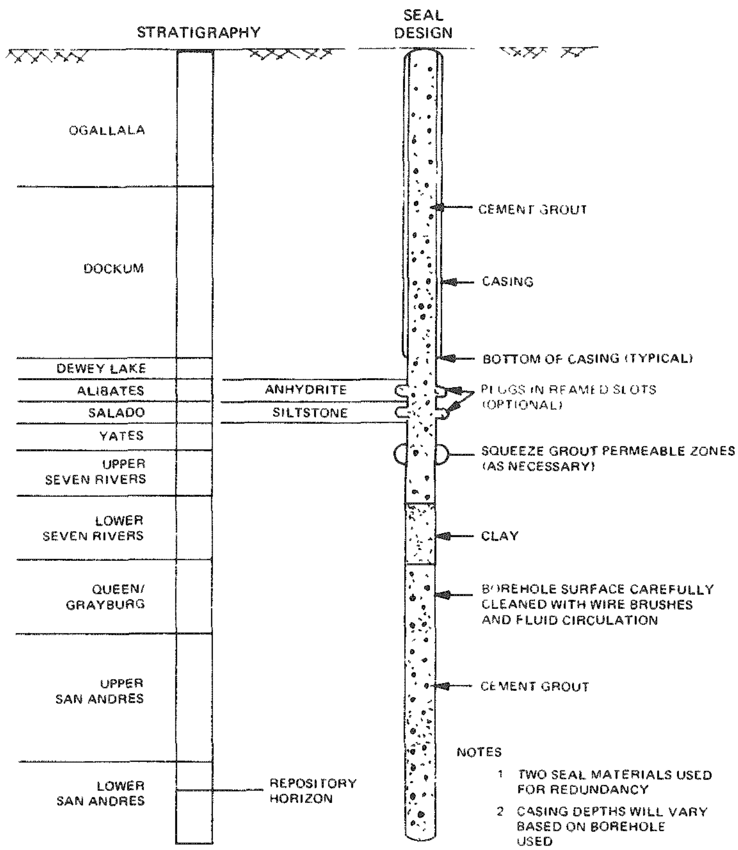

Figure 3-6. Design for a typical borehole seal.

Cement grout would be used as the general sealing material because it is relatively easy to place, structurally competent, and highly resistant to ground-water flow. Pressure grouting would be used to squeeze grout into highly permeable rock zones, as necessary, to retard water inflow from less-competent, water-bearing strata. Provisions can be made to install reamed slots of cement grout in low-permeability, competent rock strata immediately below the major aquifers to intercept flow along the borehole-rock interface. This concept is similar to the use of bulkheads in the shafts. The exact locations of each of these components would depend mainly on the locations of the stratigraphic units in the borehole.

The borehole-seal system is designed to ensure that the performance of the system does not depend on only one type of seal component or seal material. The required redundancy is provided by the use of multiple-pressure grout and reamed, slotted sections for sealing the wall-rock interface and the disturbed rock around the borehole. Different seal materials of cement grout and clayfill provide another degree of sealing redundancy by accounting for uncertainties in the material characteristics. (The uncertainties include the permeabilities and swelling potential of cement grout and clayfill and the consolidation rate of crushed salt.) The component redundancy should ensure a very low probability of borehole-seal failure because the failure of one type of seal component or the shrinkage of one type of seal material would not compromise the overall integrity of the sealed borehole.

Backfilling of the repository

Included in the category of seals is backfilling of the underground repository facilities. The emplacement entries would be backfilled as each entry is filled with waste. Other entries would be backfilled at the time of closure.

Crushed salt is proposed as the primary constituent backfill material for the underground drifts. The crushed salt would be modified, if necessary, to provide favorable mechanical parameters. The modifications may simply be grading to produce a specified size distribution, adding materials, or adding moisture to improve backfill effectiveness. As backfill in a salt repository, crushed salt would recrystallize under the pressure resulting from the closure of underground openings and elevated temperatures, forming a homogeneous and relatively impermeable mass.

3.2 THE WASTE PACKAGE

The waste package is defined in 10 CFR 60.2 and 10 CFR 960.2 as "the waste form and any containers, shielding, packing, and other absorbent materials immediately surrounding an individual waste container." For the Deaf Smith County site, the waste package includes the waste form, a canister in which the waste would be placed, a thick-walled, low-carbon-steel disposal container in which the canister of waste would be sealed, and packing material placed around the containers inside the emplacement borehole. The waste package would be the principal engineered barrier in the overall system.

The waste package would be designed to meet various functional and regulatory requirements, including those specified by the NRC in 10 CFR 60.113 and

60.135 (see Appendix A). Among these are the preclosure requirements that the production and the emplacement of the waste package must be feasible with reasonably available technology, that the design of the waste package cannot make the application of reasonably available technology impractical for other portions of the repository system or operations, and that cost effectiveness must be considered. For the postclosure period, the requirements include providing substantially complete containment for the waste for a period of 300 to 1000 years after repository closure and thereafter limiting the rate of radionuclide release from the engineered-barrier system.

A detailed discussion of current concepts for the waste package is given in Chapter 7 of the SCP/CD. These concepts are based on the current design phase for the waste package--the SCP conceptual design shown in Figure 3-7. The design would continue to evolve as data from site characterization are obtained and the later, more-detailed phases of design are conducted.

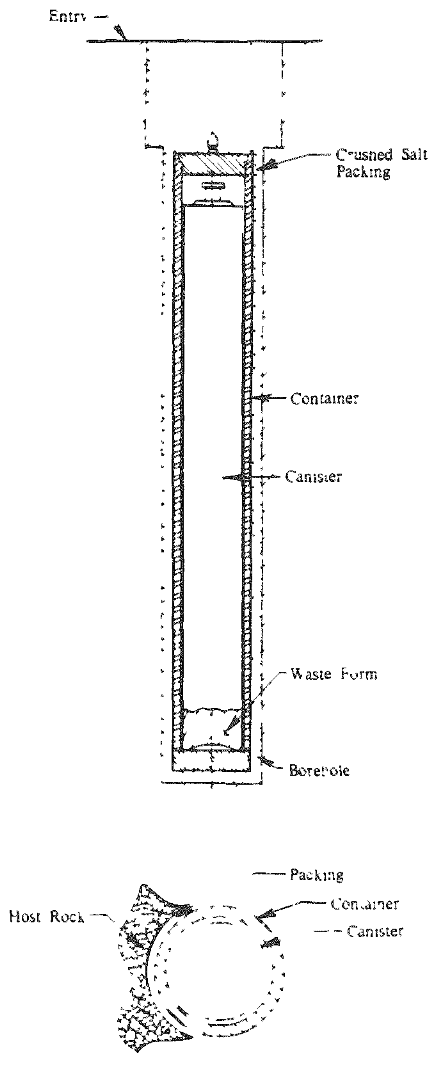

Figure 3-7. Conceptual design for the waste package.

The waste forms that would be emplaced are spent fuel from commercial reactors and solidified high-level waste. Most of the spent fuel would consist of spent-fuel rods consolidated at the repository or before shipment to the repository; the remainder would be disposed of as intact assemblies. The high-level waste, from both defense and commercial sources, would be in the form of borosilicate glass in stainless-steel canisters.

The reference spent fuel is 10-year-old fuel from pressurized-water reactors (about two-thirds of all spent fuel) and boiling-water reactors (about one-third of the spent fuel). With a nominal burnup and consolidated fuel at least 10 years old, the heat-generation rate is as much as 6.6 kilowatts per package. The reference high-level-waste package has a heat-generation rate of 0.47 kilowatt. For both types of waste, the actual heat-generation rate at emplacement could be somewhat different.

The canister would be a thin-walled metal receptacle. Its major purpose is to hold the waste during operations that occur before the canister is inserted into the container.

The reference disposal container is a thick-walled vessel designed to protect the waste against any water that may come into contact with the waste packages and to contain the waste for 1000 years after emplacement. The size of the disposal container depends on the waste form. The length of the reference spent-fuel container is between 14.8 and 15.7 feet, depending on the type of spent fuel; the length of the reference high-level-waste containers is 11.2 feet. The thickness of the wall is chosen to withstand both the expected lithostatic pressure from the salt and general corrosion through the first 1000 years after emplacement; the reference wall thickness ranges from 4.2 to 5.0 inches.

The material selected for the reference container is a cast low-carbon steel. This steel has a predictable general-corrosion behavior and is strong, easily formed, and weldable.

The packing is the material that fills the space around the container in the emplacement hole. The packing would serve primarily to control the release of radionuclides from breached containers. The packing may consist of crushed salt or an alternative material.

Alternatives to the reference design are being considered. For example, corrosion-resistant containers are being evaluated along with cathodically protected containers and containers made of other materials, including nonmetallic materials. These evaluations provide for alternatives if the reference design concept does not meet design or performance requirements.

The performance of the waste packages would depend on the fluid, chemical, mechanical, thermal, and radiation conditions in the repository. The amount of water that would contact the waste package under these conditions is expected to be small, but cannot be quantified with available information. It is unlikely that any significant amount of water would flow from the overlying High Plains aquifer through the thick sedimentary-rock aquitard to the repository; however, some water may be available from interbeds in the host rock close to the repository horizon or from intercrystalline or intracrystalline brine in the host salt. The heat generated by the waste may cause brine to migrate toward the waste packages. Tests and analyses will be conducted to evaluate the amount of water that might be available and the possible effects of this water on the performance of the waste package, taking into account the effects of heat and radiation generated by the waste. Similarly, the chemistry of the brine would be evaluated, taking the same factors into account. The waste packages would be subject to high lithostatic loads because of the creep and the thermal expansion of the host salt, and the design would take these stresses into account as well. A detailed discussion of the expected waste-package environment is given in Section 7.1 of the SCP/CD.

4. THE SITE-CHARACTERIZATION PROGRAM

Before any site can be judged suitable for development as a repository, it will be necessary to demonstrate that the performance of a repository at that site is likely to meet or exceed regulatory requirements. In order to do this, extensive information describing the site must be collected; designs for the repository, the seals, and the waste package must be developed; and the performance of the disposal system must be assessed. To collect the needed information, a carefully planned site-characterization program will be conducted. Such a program is required by the Act, by the NRC in 10 CFR Part 60, and by the siting guidelines (10 CFR Part 960).

The details of the site-characterization program planned for the Deaf Smith County site are presented in Chapter 8 of the SCP, including the strategies for demonstrating regulatory compliance, the data needed for carrying out the strategies, the programs that will collect and analyze the needed data, and the field activities that will take place at and near the site. This chapter of the overview summarizes the strategies and reviews the programs that will collect and analyze the needed data. The field activities to be carried out during site characterization are briefly described in Chapter 5 of this overview.

This chapter begins, in Section 4.1, with a "top-level strategy" that identifies the general objectives for the disposal system and provides a simple explanation of the role the principal features of the Deaf Smith County site are expected to play in meeting these general objectives. This top-level strategy provides the framework by which to understand the detailed strategies for demonstrating regulatory compliance.

Section 4.2 briefly explains the two organizing principles for the SCP--a hierarchy of issues, which embody the regulations that govern the disposal system, and a general strategy for resolving those issues. This explanation is needed for understanding the discussion in Section 4.3, which is a highly compressed summary of the detailed strategies for resolving the issues and thereby demonstrating compliance with the regulations. The remaining sections of Chapter 4 then proceed to summarize the principal parts of the program. Section 4.4 reviews the plans for gathering and interpreting data describing the properties of the site. Organized by technical discipline, it discusses both the collection of data and the models in which these data will be used. Section 4.5 reviews plans for the development of the design for the repository and for the analyses that will support the design. Section 4.6 reviews plans for designing the seals for the repository; it also reviews the tests needed for developing the designs. Section 4.7 reviews the activities planned for designing the waste package and for the supporting analyses, including the tests needed to define the environmental conditions in which the waste package will reside after emplacement in the host rock.

The last section in this chapter, Section 4.8, reviews the analyses that will assess the performance of the disposal system, both for the period preceding permanent closure and for the much longer time after closure.

4.1 TOP-LEVEL STRATEGY FOR THE DEAF SMITH COUNTY SITE

This section presents the "top-level strategy"--a brief explanation of the role the features of the Deaf Smith County site are expected to play in achieving the general objectives for the disposal system. As a consequence of this role, as will be explained, the program for characterizing this site focuses principally on the limited amount of water and its slow movement in the thick evaporite aquitard in which the waste would be emplaced. The program will also investigate the regional and local hydrology of the aquifers at the site, the performance of the waste packages, geochemical conditions, the performance of shaft and borehole seals, and the quality and the thermomechanical properties of the host rock. This section explains the basis for the emphasis on these areas in the site-characterization program.

The principal role of the disposal system would be to isolate waste for a long period into the future. Therefore, the general objective for the system is to limit any radionuclide releases to the accessible environment. This general objective will be achieved by selecting a site with suitable natural barriers to radionuclide migration and by providing an appropriate system of engineered barriers. To provide additional assurance that the system will perform adequately, individual objectives have also been defined for these engineered and natural barriers and for the design of the disposal system. The general objective for the engineered barriers is that they be effective in limiting the release of radionuclides to the system of natural barriers. The general objective for the natural barriers is that the time of radionuclide travel through these barriers should be very long. In particular, since ground-water movement is the most important mechanism for transporting radionuclides, the time of ground-water travel should be very long. The general objectives for the design of the disposal system are that the operation of the repository should be safe and that its construction should not compromise its ability to meet the other general objectives.

These general objectives are compatible with the regulations promulgated by the NRC in 10 CFR Part 60. In those regulations the NRC specifies postclosure performance objectives, including the environmental standards set by the Environmental Protection Agency for releases to the accessible environment, individual protection, and ground-water protection; requirements on the containment to be provided by the set of waste packages and on the rate of radionuclide release from the engineered-barrier system; and an objective for the pre-waste-emplacement time of ground-water travel. The regulations also specify design criteria for ensuring that the postclosure-performance objectives would be met and specify preclosure-performance objectives for radiation protection. The detailed strategies for addressing these regulations are presented in Section 8.2 of the SCP/CD. The remainder of this section describes the top-level strategy for addressing general objectives for the disposal system and its elements.

4.1.1 <u>General objective for the disposal system</u>

The major system elements that are expected to affect waste isolation at the Deaf Smith County site can be seen in Figure 4-1, which schematically shows the repository in the geologic setting. The geologic setting at the site consists of more than 6000 feet of sedimentary rock deposited rather

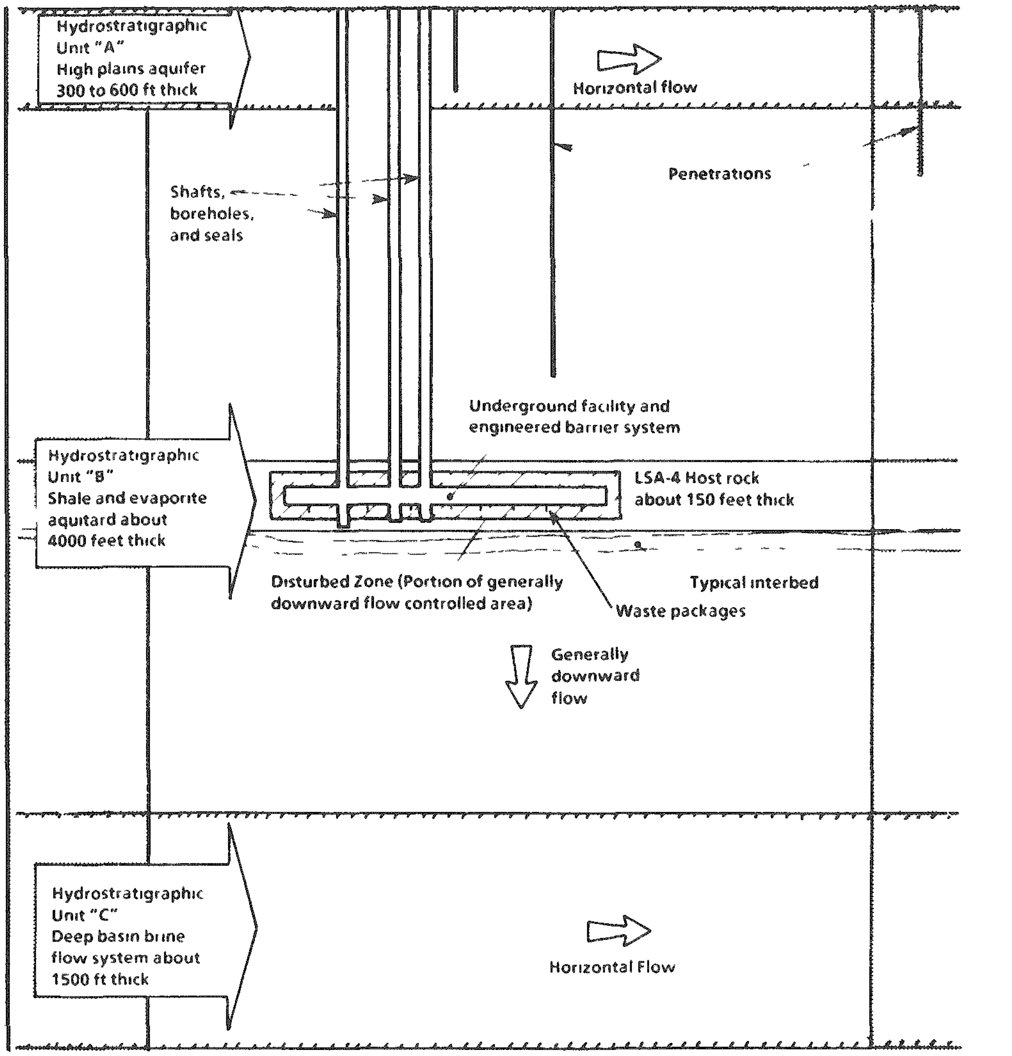

Figure 4-1. Schematic diagram of the disposal system at the Deaf Smith County site.

homogeneously across the Palo Duro Basin. The candidate host rock is a thick (about 150 feet) sequence of bedded salt and interbeds in Unit 4 of the Lower San Andres Formation (LSA-4) in the basin.

As explained in Section 2.3.3 of this overview and Section 3.9 of the SCP/CD, the ground-water regime consists of three major hydrostratigraphic units. The uppermost hydrostratigraphic unit, HSU-A, is the High Plains aquifer (i.e., the Ogallala Formation and the Dockum Group). The thickness of HSU-A ranges up to 1000 feet. The second hydrostratigraphic unit, HSU-B, is about 4000 feet thick and is an aquitard consisting of Upper Permian shales and evaporites underlying the High Plains aquifer. The candidate host salt, LSA-4, occurs near the middle of this unit. The third hydrostratigraphic unit, HSU-C, is primarily carbonate and clastic rock of Permian and Pennsylvanian age and includes brine aquifers, such as the Wolfcampian Group and the Granite Wash. Pre-Pennsylvanian basement rock, including granitic and clastic units, underlies the entire region. Regional geohydrologic information suggests that ground-water flow in HSU-A and HSU-C is predominantly horizontal. The present data on hydrologic gradients further indicate that HSU-A is at a higher potentiometric level than the units in HSU-B; and these are, in turn, higher than those in HSU-C. Therefore, the potential for vertical flow is downward; however, because of the low vertical permeability of the evaporites and shales in HSU-B, there is very little hydraulic communication between HSU-A, HSU-B, and HSU-C.

Because of this lack of hydraulic communication, water that can reach the waste package is likely to be of local origin--that is, intracrystalline brine inclusions in the host salt, intercrystalline brine at grain boundaries, and water associated with interbeds (shale, mudstone, anhydrite, or carbonate materials). Such water may be driven toward the waste packages because of gradients in the temperature, fluid pressure, rock stress, or moisture content or because of changes in hydraulic properties induced by the existence of the emplacement borehole or the heat generated by the waste. It is assumed that the influence of the regional hydrologic system in HSU-A or HSU-C on the local water is negligible; however, connections between the underground facility and HSU-A through boreholes or the shafts could provide an additional source of water. Therefore, the borehole and shaft seals may play an important role in the performance of the disposal system.

Water that reaches the waste packages may contribute to the corrosion of the disposal container. The current information suggests that the amount of water that could reach the waste package would be limited. Furthermore, much, if not all, of this water could be consumed during the corrosion of the container surface.

If any waste packages are breached because of damage or corrosion, water that reaches the container and is not consumed in the corrosion process may be able to reach the waste form and dissolve radionuclides, depending on the dissolution rates of the waste form. Radionuclides released from the waste form could migrate from the disposal container into the host rock by diffusion through the packing around the containers. Radionuclides that reach the salt could migrate by molecular diffusion or by advective transport in any downward flow of water in HSU-B. Radionuclides that reach an interbed in HSU-B may be transported advectively by any flow in this interbed. Such transport is expected to be extremely slow and would be controlled by the rate of ground-water flow and by the retardation of radionuclides by geochemical and physical processes in the interbed.

In this conceptual model it is unlikely that any radionuclides could migrate to the upper aquifer system in HSU-A because of the distance involved and because HSU-A is at a higher potentiometric level. However, the possibility that some radionuclides could reach the brine aquifers in HSU-C cannot be precluded at present. Radionuclides that reach HSU-C could conceivably be transported to the accessible environment in this case. The hydrologic and geochemical conditions in the deep brine-flow system may therefore be important.

In this conceptual model it is likely that, even under hypothetical disruptive conditions, the disposal system could continue to isolate the waste. Nevertheless, the DOE will consider events and processes that could disturb expected conditions to the extent that a connection would be established between HSU-A and HSU-B or HSU-C and under which flow could occur to transport radionuclides to aquifers in HSU-A or HSU-C. The DOE will also assess the possible penetration of the site by exploratory drilling. Therefore, the factors controlling such conditions, such as the effectiveness of institutional barriers in preventing exploratory drilling, may be important. The institutional barriers include engineered markers at the site and permanent records.

The DOE believes that this sequence of events--some inflow of brine to corrode the disposal container and dissolve the waste form and the radionuclides, slow diffusion of radionuclides out of the containers and through the packing to the host rock, transport to an interbed in HSU-B or, possibly, to brine aquifers in HSU-C, and advective transport to the accessible environment--provides a representation of the set of processes that should be evaluated when assessing the potential for release to the accessible environment.

From these considerations, the DOE has selected the elements that will be evaluated in the site-characterization program with respect to the general objective for the system. These elements are

- HSU-B, including the host rock (LSA-4) and interbeds in which radionuclides could be transported to the accessible environment.

- The brine aquifers in HSU-C.

- The waste package, including the waste form, the container, and the packing.

- The shaft and borehole seals.

- The institutional barriers.

HSU-B will be examined to determine the rate of movement of water in and through it. For example, the contention that flow is downward will be evaluated. The units in HSU-B and HSU-C will be evaluated with regard to the characteristics that control the rate of flow in these units and with regard to radionuclide transport, including the geochemical retardation properties of these units. The waste package will be evaluated with regard to the features that alter the rate of radionuclide release from the waste packages. The ability of the seals to control the flow of water into the underground facility and the transport of radionuclides out of the underground facility will be evaluated. Institutional barriers will be evaluated with regard to their effectiveness in preventing inadvertent human intrusion into the underground facility.

Concentrating on only one of these features, such as the slow movement of water down through HSU-B, could reduce the cost of the site-characterization program. The DOE has decided, however, that it is prudent to consider each of these features initially. Future evidence may, for example, be insufficient to confirm that the movement of the water is slow. If so, the DOE's strategy may need to focus on other features to ensure that the general objectives for the system would be met. Choosing all of these features is a way of dealing with the uncertainties in each of them; it ensures that site characterization will collect the data needed to evaluate the system with respect to the general objective. Analyses conducted during site characterization may indicate that other features may need to be considered. Conversely, data obtained during site characterization may show that fewer features may need to be taken into account; in either case, the top-level strategy can be revised appropriately.

4.1.2 General objective for the performance of the engineered-barrier system

The general objective for the engineered-barrier system is to limit the release of radionuclides to the natural barriers. In the top-level strategy the DOE has chosen to focus on three particular elements of the waste package to evaluate the release of radionuclides from the engineered-barrier system:

- The disposal container.
- The packing around the disposal container.
- The waste form.

The disposal container is expected to provide the principal containment barrier during the early period, when the heat and radiation emitted by the waste are at their peak. Waste-package materials will be chosen to limit container degradation in the repository environment.

The packing around the disposal container (e.g., crushed salt) fills the space between the wall of the container and the wall of the emplacement borehole. The packing is expected to limit the transport of radionuclides away from the containers by providing a diffusion barrier. As a result, the rate of radionuclide release from the waste package would be limited.

The waste form is chosen as an additional barrier to limit the rate of radionuclide release from the engineered-barrier system. Because of the low probability of early container failure and because of the small quantities of water available for waste-form dissolution and the leaching of radionuclides, the spent fuel or glass matrix is expected to be effective in providing containment and limiting the rate of release.

4.1.3 General objective for the performance of the natural barriers

As explained above, the geologic setting can contribute to the isolation of the waste and to the overall performance of the system by providing for a long time of ground-water travel to the accessible environment. The DOE has chosen to focus on two natural barriers to determine the time of ground-water travel:

- HSU B, in particular its interbeds.
- HSU C, in particular the Wolfcampian Group and the Granite Wash.

The current evidence suggests that the travel time to the accessible environment in interbeds in HSU-B is much longer than 10,000 years. Therefore, these units are expected to provide an effective barrier to radionuclide transport. According to the available evidence, the travel time in the Wolfcampian Group and in the Granite Wash in HSU-C is also much longer than 10,000 years. It is unlikely that these brine aquifers would be involved in the transport of radionuclides under undisturbed conditions; nevertheless, these units will be investigated to provide additional information pertaining to the objective for the time of ground-water travel.

4.1.4 General objectives for the design of the disposal system

The general design objectives for ensuring safe operation and not compromising the ability to meet the other general objectives have a number of implications for the site-characterization program. The most important of these for the Deaf Smith County site are related to the nature of the host salt. In particular, the quality and the thermomechanical creep properties of the host salt will be investigated to determine the engineering measures needed to excavate and maintain the openings needed in the underground repository. These properties will also be examined to evaluate whether the design preserves the option of retrieving the emplaced waste.

There are a number of other considerations for design and operation as well, such as the evaluation of the preclosure radiation safety of the surface and the underground facilities. Standard techniques and methods should be adequate to assess preclosure radiation safety. Although these assessments will not rely heavily on the features of the site, some investigations will be conducted during site characterization to support them.

4.1.5 Priorities for the site-characterization program

Priorities for the testing program can be inferred from the choices made for the top-level strategy; that is, the elements identified and the expected role of these elements with regard to the general objectives suggest the priorities for the site-characterization program. The top-level strategy for addressing these objectives at the Deaf Smith County site leads to the following areas of emphasis:

- The movement of water through and in HSU-B.
- The regional and local hydrology of HSU-C and HSU-A.
- The performance of waste-package components.
- The geochemical conditions in HSU-B and HSU-C.
- The performance of shaft and borehole seals.
- The quality and thermomechanical properties of the host salt.

The top-level strategy relies heavily on the current view that the flow of water through the evaporites in HSU-B is very limited and would be generally downward. Therefore, studies that investigate the nature of the movement of water through HSU-B are very important. In addition, the potential for intracrystalline and intercrystalline brine movement in the host salt will be investigated. The flow of water in interbeds in HSU-B will also be studied.

At a lower level of priority, the regional and local hydrology of the brine-aquifer systems in HSU-C will be evaluated. Furthermore, although considerable information about the High Plains aquifer (HSU-A) is available, additional information will be acquired for the Deaf Smith County site.

At a priority similar to that of the hydrology of HSU-C, the performance of the components of the waste packages will be tested. In particular, studies of container corrosion and studies of alternative waste-package designs will be conducted. In addition, the role of the packing in limiting the transport of radionuclides will be investigated.

At a priority lower than that for the regional hydrology or the performance of waste-package components, the geochemical conditions in HSU-B and HSU-C will be evaluated. Retardation due to geochemical conditions in HSU-B will be studied. Likewise the retardation in the Wolfcampian Group and the Granite Wash will be investigated. The geochemical conditions affecting waste-package containment and potential dissolution of the waste form and the radionuclides will also be studied.

At a still lower level of priority, the shaft and borehole seals will be investigated. The longevity of the seals as well as their properties with respect to limiting flow down to the host salt and the transport of radionuclides away from the repository will be studied. These studies will focus on the seal materials, the interfaces between these seal materials and the host rock, and the disturbed rock around the seals.

The ability to construct the repository is an important consideration for the Deaf Smith County site, and a high priority exists on the determination of the quality and thermomechanical properties of the host salt. The investigations of these properties will also help to evaluate whether the design preserves the option of retrieving the emplaced waste.

Additional studies will be conducted to support the investigations in the above areas. For example, the likelihood that valuable natural resources are present at the site will be examined to evaluate the likelihood of exploratory drilling at the site. The likelihood of dissolution of the host rock or of the overlying layers and the impact of any such dissolution will also be investigated.

The investigations to address these areas are discussed in Section 8.3 of the SCP/CD. The organization, focus, and logic for these investigations are defined in specific issue-resolution strategies derived from the top-level strategy in Section 8.2 of the SCP/CD.

4.2 THE ISSUES HIERARCHY AND ISSUE-RESOLUTION STRATEGY

To ensure that all the required information will be available when needed, the DOE has developed two organizing principles for site characterization--the issues hierarchy and a general issue-resolution strategy. This section briefly discusses these principles; a more detailed discussion is given in Section 8.1 of the SCP/CD. The next section explains how these principles have been applied to planning site characterization at the Deaf Smith County site.

4.2.1 The issues hierarchy

The issues hierarchy is a three-tiered framework that lays out what must be known before a site can be selected and licensed. The highest tier consists of four "key issues," which are derived from the system guidelines in the DOE siting guidelines (see Appendix A); since the system guidelines are based on the EPA and NRC regulations in 40 CFR Part 191* and 10 CFR Part 60, respectively, the key issues embody the principal requirements of the regulations governing repositories.

There are four key issues. The first addresses the postclosure performance of the disposal system. The second key issue addresses the radiation safety of repository operations before closure. The third key issue addresses environmental, socioeconomic, and transportation concerns. The third key issue is not considered in the SCP; plans for its resolution will be included in other planning documents. The fourth key issue addresses the ease and cost of repository siting, construction, operation, closure, and decommissioning.

Each key issue is followed, in the second tier, by a group of issues in the form of specific questions about compliance with regulatory requirements. In constructing each group of issues, an effort was made to include all the questions that must be answered to resolve the key issue. Each group contains issues of two kinds: performance issues and design issues. The performance issues are questions that will be resolved by analyzing the performance of the disposal system and comparing the results of the analyses with regulatory criteria. The design issues are questions that will be resolved through the design of the repository, the shaft and borehole seals, and the waste package in the area defined by the key issue.

The third tier consists of "information needs," which identify the technical information needed to answer the questions posed by the performance and the design issues. In developing the information needs, the DOE attempted to identify all the important information necessary for resolving the issues.

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*The U.S. Court of Appeals for the First Circuit has vacated and remanded to the EPA for further proceedings the environmental standards for the disposal of spent fuel, high-level waste, and transuranic waste (Subpart B of 40 CFR Part 191). Some of the plans described in the consultation draft of the SCP were specifically designed to furnish data needed for demonstrating compliance with those standards as promulgated by the EPA in 1985. The basic information needed to demonstrate compliance with any disposal standards eventually promulgated by the EPA is expected to remain substantially the same, and therefore the approach to testing set forth in the SCP is expected to remain substantially the same. Nevertheless, any changes that may be made by the EPA to its standards will be evaluated by the DOE to ensure that the planned testing program will be adequate.

The issues hierarchy provides a framework for the site-characterization program and for explaining why the program is adequate and necessary. It also provides a forum for interactions between the DOE, the NRC, the State of Texas, and the public on critical questions about the design and the performance of the disposal system.

Full statements of the three key issues that are addressed in the SCP, the associated issues, and the site-specific information needs that have been identified for the Deaf Smith County site are given in Appendix B.

4.2.2 The issue-resolution strategy

To resolve the issues in the issues hierarchy, the DOE has adopted a general strategy that guides the development of specific plans for resolving each issue. This strategy is a procedure consisting of three principal parts: issue identification, performance allocation, and investigations.

Issue identification

Issue resolution begins with the identification of regulatory requirements, and from the requirements the issues are derived. A detailed description of the disposal system is also necessary.

Performance allocation

The second part of the general approach, called "performance allocation," provides the rationale for establishing particular site-characterization activities. It starts by using available information to develop a "licensing strategy"--a statement of the site features, engineered features, conceptual models, and analyses that the DOE expects to use in resolving the issue. The statement is called a "licensing strategy" because the combined statements developed for all the issues are the basis for current plans to show compliance with regulations. At present, the licensing strategy is preliminary: not enough information is available for a definitive plan, because site characterization is only beginning. But the strategy is sufficiently developed to guide planning for the tests and the analyses that are at present deemed to be necessary. Further development of the licensing strategy will take place after the DOE has received and considered comments from the NRC and the State of Texas and completed its own internal review.

The principal product of this licensing-strategy step is a statement of the disposal-system elements that the DOE currently intends to rely on in resolving the issue. This statement addresses the expected functions of these elements and the processes or factors that could affect those functions. The site-characterization program will investigate these elements to determine whether the disposal system will comply with the applicable regulations.

To guide the site-characterization program more explicitly, "performance measures" are established for the elements identified in the preceding step. These measures are system variables that describe the performance of the elements in the licensing strategy. Each performance measure is assigned a value called a "tentative goal." This tentative goal is not a "goal" in the sense that it must be met; it is simply a guide for developing a testing program, and it can be changed or even discarded once the testing program has been established. The goal is a conservative estimate that is consistent with a favorable resolution of the issue and the available information about the site.

Performance allocation then develops specific "information needs," which are the types of information needed to resolve the issue. The information needs include sets of parameters that will be used to evaluate the performance measures, the models needed for the evaluation, and other information needed to understand the characteristics of the site in terms of the issue.

Investigations

After plans have been developed for supplying the information needs, the next step is to proceed with the investigations called for in the plans. As soon as data become available from the investigations, analyses of the results begin; as more data are collected, the analyses continue, throughout site characterization and beyond. These analyses include the evaluations needed to resolve the issues. The collection of information continues until all of the information needs defined in the performance allocation have been satisfied. The information is then used in a concluding set of analyses to resolve the issues, and the resolution is documented.

Application

The entire issue-resolution procedure is intended to be iterative. For example, the licensing strategy or the goals for some performance measures may be changed in response to comments from the NRC and the State of Texas or as new information becomes available or internal reviews provide new insights; if they are changed, the steps that follow will also be reexamined and their products revised. The analyses of the results of the investigations may produce new understandings that require the rethinking of earlier steps. Any of the steps may lead to revisions of earlier steps.

Dealing with uncertainty during performance allocation

An important objective of the planning for the site-characterization program is to identify and reduce uncertainties in the information about the disposal system. During performance allocation these uncertainties are addressed, in part, through the application of the multiple-barrier concept, the use of conservatism, and the consideration of alternative interpretations of existing information.

The use of multiple barriers to protect the public against the hazards posed by radioactive waste is embodied in the regulations governing separate elements of the disposal system. Since the issues hierarchy and the issue-resolution strategy address these individual requirements, the plans for site characterization do as well. In addition, the performance allocation for individual issues generally relies on multiple elements of the disposal system and on multiple processes operating within the elements.

Decisions about the reliance to be placed on elements of the system have been made conservatively. In other words, the decisions generally rest on underestimates of the performance of the elements. This practice provides additional assurance that the performance of the system is likely to meet or exceed the regulatory requirements.

In considering alternative interpretations of the existing information about the site, the DOE has used alternative conceptual models of systems and processes that are not well understood. For some issues this practice has led to alternative performance allocations. Alternative design considerations have also been part of planning site characterization.

4.3 STRATEGIES FOR THE DEAF SMITH COUNTY SITE

The DOE's general issue-resolution strategy has been applied to each issue in the issues hierarchy, and site-specific information needs have been developed for the Deaf Smith County site. An overview of these strategies and the key information to be provided by the site-characterization program is given below, first for performance issues and then for design issues. This overview provides a general summary of the strategies; detailed information about the strategies and performance allocation for each issue is given in Section 8.2 of the SCP/CD. A complete listing of issues and information needs for the Deaf Smith County site is presented in Appendix B.

4.3.1 Postclosure strategies

Postclosure performance

The postclosure-performance issues address the regulations that directly relate to the postclosure performance of the disposal system--that is, the regulations that are directly related to the ability of the disposal system to isolate the waste from the accessible environment. Issues 1.1 through 1.6 (see Appendix B) address the postclosure-performance objectives of 10 CFR 60.112 and 60.113, issue 1.7 addresses the NRC's requirements in 10 CFR 60.137 for a performance-confirmation program, and issue 1.8 addresses the siting criteria of 10 CFR 60.122. Issue 1.9 addresses the postclosure siting guidelines of 10 CFR Part 960. (For the convenience of the reader, the NRC's technical criteria and the siting guidelines are reproduced in Appendix A.)

The DOE's general strategy for ensuring satisfactory postclosure performance for a repository in Deaf Smith County has been described in Section 4.1. Using this general strategy as a foundation, the DOE has developed strategies for the resolution of the individual postclosure-performance issues.

To isolate the waste from the accessible environment, the top-level strategy described in Section 4.1 relies on the limited amount and flow of water through the evaporites in HSU-B, on the shaft and borehole seals, and on the waste package. These elements will be relied on because the current information suggests that they will (1) ensure that the loss of containment by the set of waste packages will be limited, (2) ensure that virtually all radionuclides released from the waste packages will remain confined within the evaporite section, and (3) limit the migration of any radionuclides to the accessible environment.

The issue-resolution strategies identify performance measures for the disposal system and for the elements mentioned above. The system performance measures are the ratios of radionuclide releases to the EPA release limits, radionuclide concentrations in ground water, and the radiation doses received by members of the public in the accessible environment. The performance measures for individual elements of the system include the time of ground-water travel to the accessible environment, the fraction of disposal containers that are breached, and the rate of radionuclide release from the breached containers.

The information that is needed to evaluate the performance measures has been defined and organized in the issue-resolution strategies as information needs. It includes the geohydrologic and geochemical conditions in HSU-B, the regional hydrologic conditions in HSU-A and HSU-C, the performance of the shaft and borehole seals, and the characteristics and performance of the disposal containers and the waste form.

The DOE has also identified the information needed to evaluate possible future changes in the conditions at the site. These information needs address possible changes in the geohydrologic and geochemical conditions important to waste isolation and in the performance of the engineered-barrier system. In particular, the DOE has identified information needs that address possible future changes in climate, the potential for flooding the repository, the dissolution of the host rock, and inadvertent human intrusion to the degree that these phenomena or events could affect the performance of the repository. Finally, the DOE has identified the information needed to evaluate the potential direct radionuclide releases that might result from inadvertent human intrusion into the repository.

Postclosure design

There are three postclosure design issues under key issue 1 (see Appendix B for a complete statements of the issues): issue 1.10, which addresses the design criteria in 10 CFR 60.135 for the waste package; issue 1.11, which addresses the design criteria in 10 CFR 60.133 for the repository; and issue 1.12, which addresses the design criteria in 10 CFR 60.134 for shaft and borehole seals.

The strategy for waste-package design is directed at meeting the performance goals of providing radionuclide containment for a limited period and limiting the rate of radionuclide release for the full 10,000-year period of isolation. Performance goals for the waste package address the concentration of chemical species in the brine that could come in contact with the waste package, the quantity of such brine over time, the maximum stresses that the host rock imposes on the waste packages over time, and the temperature over time. The site information that is needed for waste-package design includes the geochemical characteristics of the host rock and the brine within the host rock, the changes in host-rock and brine geochemical properties expected to be induced by waste emplacement, the hydrologic characteristics of the host rock, and the host-rock thermal and mechanical properties that control the behavior of the emplacement holes over time.

The design strategy for the repository after closure is directed at providing a repository that does not adversely affect those characteristics of the site that provide favorable performance and, to the extent possible, contributes to the containment and the isolation of the waste. The strategy requires a repository orientation, layout, geometric configuration, and depth that provide a sufficiently long time of radionuclide transport to the accessible environment; flexibility in the layout of the underground repository so that local geologic features and anomalies, if any, can be accommodated during the construction of the repository and the emplacement of the waste packages; limiting the introduction of water to the repository; using engineered barriers (structural backfill) to limit flow within the openings created for the repository; limiting the extent of the rock that is affected by construction; and, in setting a design heat load for the repository, considering the potentially detrimental effects of heat on waste isolation. Needed information about the site includes the local stratigraphic sequence and the structure of the host rock in the areas proposed for waste emplacement; special geologic features in the host rock (e.g., folds, brine pockets); the hydraulic properties of the host rock and the brine; the thermal and mechanical properties of the host rock; and the response of the host rock to stress changes induced by excavation and heat.

The strategy for the design of the repository seals system is to limit the amount of ground water that can reach the waste-emplacement area and to limit any transport of radionuclides through the shafts. Among the information needed for design are data on the thermal, mechanical, and hydraulic properties of potential materials for seals. Needed information about the site includes stratigraphy; the presence of major anomalies; flow boundary conditions; the hydraulic, thermal, and mechanical properties of the host rock; and the geochemical properties of the host rock and ground water.

4.3.2 Preclosure strategies

Preclosure performance

The DOE has also developed strategies for resolving the issues that are related to the preclosure performance of the repository: radiation safety before closure (issues 2.1, 2.2, and 2.3), the retrievability of the waste (issue 2.4), and compliance with the preclosure siting guidelines (issues 2.5 and 4.1).

Radiation safety requires limiting the radiation doses that could be received by members of the public or by repository workers under normal operating conditions or after accidents. The strategy for limiting radiation doses is to rely on engineered systems that provide confinement and shielding for radiation (including the waste package) as well as operating procedures for waste handling.

In the radiation-safety strategies, performance goals are related directly to the requirements of the applicable Federal regulations (10 CFR Part 20, 40 CFR Part 191, and 10 CFR Part 960) for limiting doses. Since the strategy for protection from radiation relies mainly on the design, the role of geologic information is largely to support the design. The information required from site characterization includes the atmospheric-dispersion characteristics of the site, which would affect the radiation exposure of the public after airborne releases of radioactive material; the shielding properties of the host rock, which are needed to characterize the radiation environment in the underground facilities; and information on the likelihood and magnitudes of natural phenomena (e.g., rockfalls) that could imperil structures, systems, and components important to safety.

To meet the regulatory requirement for retrievability (10 CFR 60.111), the ability to retrieve the waste from the repository will be maintained for 50 years from the start of waste emplacement. The design strategy for retrievability is to maintain access to the shafts and nonbackfilled drifts (e.g., pillar entries, main entries, return-air entries) during the retrievability period and during the additional period of time that would be required for the actual retrieval of the waste, to ensure the capability to remine emplacement entries, to ensure the capability to locate and remove the disposal containers, to ensure the capability to transport the containers to the surface, and to ensure the capability to provide an acceptable working environment. The goal for the waste-emplacement design for a repository at the Deaf Smith County site is to allow the retrieval of waste packages under any credible conditions.

The primary concerns for retrieval are related to the thermomechanical properties of salt. The heat-induced increase in the rate of salt creep could cause closure of the annulus between the surface of the disposal container and the wall of the borehole, locking the container to the rock mass; closure of the main entries and emplacement entries; and weakening of the rock mass around entries. Unexpected but credible events that could affect retrievability are flooding and earthquakes. Key information includes the characteristics and behavior of the host rock in the immediate area of the emplacement boreholes as well as the potential for significant changes in the hydraulic properties of the rock units.

The evidence needed to support the higher-level findings for the preclosure siting guidelines (issues 2.5 and 4.1) will be obtained from data and analyses conducted for the resolution of other performance issues. (A complete list of the preclosure siting guidelines can be found in Appendix A.) Issue 2.5 covers the preclosure system guideline on radiological safety and the qualifying and disqualifying conditions of the associated technical guidelines (population density and distribution, site ownership and control, meteorology, and offsite installations and operations). The evidence for this issue will be made available through the information and analyses that support the resolution of issues 2.1 and 2.2. Issue 4.1 covers the preclosure system guideline on the ease and cost of siting, construction, operation, and closure and the associated technical guidelines on surface characteristics, rock characteristics, hydrology, and tectonics. The evidence needed for these guidelines will be obtained through the information and analyses that support the resolution of design issues 4.2 through 4.5.

Preclosure design

The preclosure design issues are related to performance requirements for radiation safety, retrievability, technical feasibility, and cost. In particular, they address the design and production of waste packages (issues 2.6 and 4.3), the design of the repository (issues 2.7, 4.2, and 4.4), and the total costs of repository development (issue 4.5).

The strategy for the resolution of the preclosure design issues is constrained by the waste-package design and the postclosure design requirements discussed above. Within these requirements and constraints, the strategy for the design is based on adapting available nuclear and mining technology to maintain a safe environment for the workers and the nearby public while providing cost-effective waste handling, waste emplacement, and repository closure. The strategies for the design issues set safety and functionality goals for radiation protection, the stability and longevity of mined openings, working environments (e.g., temperature, humidity), water control, and functional layout. The resolution of the repository-design issues requires information about the characteristics of the host rock, including the existing stress and temperature conditions, thermal properties, strength and deformation properties, and hydraulic properties.

4.3.3 Link to the site-characterization program

The issue-resolution strategies developed for the Deaf Smith County site have been used to identify the information to be obtained by the various parts of the site-characterization program--that is, the site program; the repository, seals, and waste-package design programs; and the performance-assessment program.

The various activities conducted in the site program will be documented in topical reports. These reports will continue to update and extend the data base available for use in design and performance-assessment activities. When designs and calculations are sufficiently mature, reports will document the preliminary basis for seeking the NRC's concurrence that various regulatory and technical requirements can be met. Thus, by acquiring the site data and other information necessary for the resolution of performance and design issues, the DOE will systematically establish the basis for demonstrating compliance with the major technical and regulatory requirements.

4.4 SITE PROGRAM

The site program consists of all the investigations planned to obtain information about the characteristics of the site; it is described in Section 8.3.1 of the SCP/CD. The rationale for identifying the needed information has been described in Section 4.2. The site program is divided into six characterization programs that consist of one or more associated investigations (Table 4-1).

Table 4-1. Investigations to be conducted in the site program

Program	Investigation
Geology	Geomorphology Stratigraphy Tectonics and structural geology Seismology Dissolution Drilling and mining
Hydrology	Surface-based hydrology
Geochemistry	Baseline geochemical characteristics of the fluids and rocks in the repository horizon and the surrounding units Geochemical confirmation of groundwater behavior Radionuclide geochemistry
Climatology	Climatology and meteorology Design- and operating-basis severe weather Long-term climate
Resource potential	Resource potential
Soil and rock-mechanics properties	Soil mechanics Non-host-rock rock mechanics

4.4.1 Geology

The geology program, described in Section 8.3.1.2 of the SCP/CD, consists of six investigations. Its objectives are to provide the information needed for the resolution of performance and design issues. To this end, the investigations and studies will collect information describing the present and expected geologic conditions of the region, the site, and, in some cases, the exploratory-shaft facility (ESF).

Geomorphology

The geomorphology investigation addresses preclosure issues related to surface-facility design and performance as well as postclosure issues concerning the potential effects of changes in climate, the potential for the dissolution of the repository host rock, and the location of surface markers. The geomorphology investigation will produce geologic data that will be used as input to the investigations of stratigraphy and tectonics and structural geology. It consists of two studies: descriptive geomorphology and geomorphic processes.

The descriptive geomorphology study will collect data on surficial landforms; these data will be used in the layout of surface facilities, the layout of shafts, and the location of access roads. The collected information will include descriptions of playas; descriptions and locations of dissolution and collapse features; paleotopography; the location of streams during the Quaternary Period; evidence of extreme erosion during the Quaternary Period; maps of the surficial geology of the site and selected offsite locations; evidence of the effects of climate changes, tectonic processes, and salt dissolution on the formation and modification of landforms; paleontologic and stratigraphic data; and soil maps.

The geomorphic-process study will address postclosure rates of erosion, the potential for salt dissolution, and the potential for changes in climate. This study is designed to test and refine existing conceptual models; link geomorphic processes with information on stratigraphy, tectonic activity, dissolution events, and climatic changes; evaluate the likely origins of playas; and confirm or refine estimated rates of erosion and dissolution.

Stratigraphy

The primary objectives of the stratigraphy investigation are to determine the sequence, lithology, thickness, depth, porosity, depositional facies, lateral extent, spatial variations, and discontinuities for the major stratigraphic units and to construct a conceptual three-dimensional stratigraphic model of the candidate site and the surrounding area. This investigation consists of three studies: regional, site, and ESF stratigraphy. These studies will provide information on potential radionuclide pathways; on stratigraphic units that could be potential hydrocarbon reservoirs or could host potential mineral deposits; information about geologic structures; information on climate during Cenozoic time; data on heterogeneity, thickness, and the presence of channels in the Ogallala Formation and the Dockum Group; and data on the stratigraphic and facies framework of samples obtained for geochemical analyses.

Tectonics and structural geology

The investigation of tectonics and structural geology will describe the past and present tectonic environment as a basis for predicting future tectonic conditions that may affect radionuclide releases to the environment. It consists of a study of geologic and tectonic structures and the development of a conceptual tectonics model. The structures study will identify the distribution, attitude, and relative displacement of buried and surface faults and fracture systems and collect information on possible karst development. The conceptual tectonic model will address both preclosure and postclosure concerns. The preclosure concerns include the potential for faulting in the region and the site and the orientation of in-situ stress as it relates to repository design, whereas the postclosure concerns pertain to permeable fault or fracture zones with potential to act as pathways for ground-water flow and radionuclide transport and the potential for future tectonic events that could affect the hydrologic system at the site.

Seismology

The purposes of this investigation are to (1) develop a seismic-design basis for repository facilities that are important to safety and (2) provide other information that will facilitate assessing the adequacy of the seismic-design basis and identifying credible accidents that might be initiated by seismic events and lead to radionuclide releases. One objective of this study is to describe the current seismic environment of the area so that the seismicity and seismologic data can be integrated with the geologic and tectonic data to predict preclosure and postclosure earthquake hazards.

Eight studies are planned: the seismotectonic zone; the seismicity of the area; the seismicity of the site; the correlation of earthquakes with geologic structures; regional attenuation of ground motion; the effects of site geology on ground motion; the design-basis earthquake; and a probabilistic seismic-hazard analysis. The analyses that are part of these studies will be used to estimate long-term tectonic stability, magnitude of maximum earthquakes, design levels for strong ground motion at the repository site, and the potential for future faulting at the site.

The results of the seismology investigation will be integrated with data and models from the investigation of tectonics and structural geology and the hydrology program to evaluate the potential effects of future tectonic activity on the hydrology of the site and radionuclide transport to the accessible environment.

Dissolution

Salt dissolution has occurred or is occurring in the vicinity of the Caprock Escarpment bordering the Southern High Plains (peripheral dissolution) and in the subsurface beneath the Southern High Plains (interior dissolution). The dissolution investigation is designed to address the rates and effects of salt dissolution in both areas. The overall purpose of the dissolution investigation is to make long-term assessments of salt dissolution and its potential effects on the postclosure performance of the repository for use in performance assessments.

The dissolution investigation consists of three studies: regional dissolution, dissolution at the Deaf Smith County site, and dissolution at the exploratory-shaft facility. These studies will synthesize data from several other investigations--including stratigraphy, structural geology, geomorphology, geochemistry, and hydrology--to develop and refine conceptual models of salt dissolution. The conceptual dissolution model will be used to derive numerical models for estimating the locations, rates, and directions of salt dissolution.

Drilling and mining

The objectives of this investigation are to locate and provide information on active and abandoned wells and excavations--information needed to assess the presence of potential hydrologic pathways and gradients created by such penetrations at or near the site and to resolve concerns about drilling and mining in the area and at the site. The collected information will be used to identify potential ground-water pathways, to estimate any effects of boreholes on site hydrology, to predict the potential for future human interference, and to define the properties of injection or withdrawal wells. Since no evidence of abandoned mines has been found to date, the investigation consists of a borehole search and characterization study.

4.4.2 Hydrology

The hydrology testing program consists of a single surface-based hydrologic investigation directed at supporting performance and design issues. This investigation is designated "surfaced-based" in Section 8.3.1.3 of the SCP/CD to distinguish it from investigations and studies to be conducted underground in the exploratory-shaft facility.

The investigation will assist in resolving several principal hydrologic concerns, including (1) determining the time of ground-water travel through the host evaporite horizon and the underlying deep-basin brine aquifer--that is, the extent to which the repository would be hydrologically isolated; (2) safeguarding the water resources of the Ogallala Formation and the Dockum Group; and (3) estimating the likelihood that salt dissolution may affect the performance of shaft and borehole seals.

In order to provide parameters, information, and interpretive results needed for issue resolution, the surface-based hydrology investigation has been subdivided into three studies: (1) regional hydrology, (2) site hydrology, and (3) ESF hydrology.

The regional hydrologic study will examine the following aspects of the hydrologic system: precipitation and surface waters, water in the unsaturated zone, shallow fresh-water aquifers (HSU-A), the evaporite confining system (HSU-B), and the deep-basin brine aquifer (HSU-C). The scope of the regional study includes areas where recharge and discharge occur for the hydrologic system of the Palo Duro Basin.

The data collected during the regional ground-water study will be integrated with existing data to develop a conceptual model that will be used as the basis for a numerical model of the regional ground-water flow system. This model will assist in predicting the characteristics associated with ground-water flow, recharge, and discharge areas. The numerical model will assist in defining the site hydrologic boundaries and in predicting the effects of man-induced, climatic, and tectonic stresses on the regional ground-water system.

The study of the site hydrology will examine precipitation and surface waters, water in the unsaturated zone, shallow fresh-water aquifers, the evaporite confining system, and the deep-basin brine aquifer. The scope of this study is limited to an area that will include the 9-square-mile site and the immediately adjacent areas (within approximately 10 miles of the exploratory-shaft facility).

The data of site hydrology will be used to refine the conceptual model developed during the regional study and to construct a site-scale numerical model for describing the local ground-water flow system. The site-scale model will also provide boundary conditions for numerical modeling at the ESF scale.

The study of the ESF hydrology will obtain information through the installation of a series of ESF monitoring wells that will be screened at various depths. Its main purpose is to (1) provide quantitative information on ground-water flow to the freeze walls of the shafts and (2) to evaluate the influence of repository construction on ground-water quality and levels.

4.4.3 Geochemistry

As described in Section 8.3.1.4 of the SCP/CD, the geochemistry program consists of three investigations: (1) baseline geochemical characteristics of the fluids and rocks in the repository horizon and the surrounding units, (2) geochemical confirmation of ground-water behavior, and (3) radionuclide geochemistry. The results will be used in designing the waste package and the repository and assessing the performance of the disposal system. In particular, the results will have the greatest bearing on the period of waste containment, the rate of radionuclide release from the engineered-barrier system, and the rate of radionuclide transport to the accessible environment.

The geochemical baseline investigation emphasizes the geochemical characteristics of the host rock, the surrounding units, and the associated brines in their natural state. There are three studies, delineated by the three hydrostratigraphic units HSU-A, HSU-B, and HSU-C (the upper aquifer system, the evaporite aquitard, and the deep-basin brine aquifer, respectively). Data from these studies will be used to assess the performance and design of engineered barriers, the location and rates of salt dissolution, the potential for petroleum and mineral resources, and the transport capabilities of ground water with respect to radionuclides.

The investigation of ground-water behavior deals with the geochemical data that would increase the understanding of the overall hydrodynamics of the site and, to an extent, the Palo Duro Basin. It is needed because of the complexities involved in ground-water hydrology and the need for additional information to resolve questions about ground-water flow paths and travel times. There are two studies in this investigation: (1) ground-water origin, evolution, age, and residence time and (2) ground-water leakage through the evaporite aquitard. The first study will focus on the water-bearing units of the evaporite aquitard and the deep-basin brine aquifer. The second study will provide data to determine whether there is leakage through the aquitard, which would indicate an interconnection between the upper aquifers (e.g., the Ogallala Formation) and the lower aquifer (e.g., the carbonate unit in Unit 4 of the Lower San Andres salt).

The radionuclide-geochemistry investigation consists of two studies, one that addresses radionuclide solubilities in brines and another that addresses radionuclide retardation along credible pathways to the accessible environment. These studies will draw on the baseline geochemistry investigation and an investigation that will define the geochemical environment of the waste package. Two system-performance requirements will be addressed by the studies described above: (1) the requirement for limiting the radionuclide-release rate from the engineered-barrier system to less than one part in 10^5 per year of the 1000-year inventory of radionuclides and (2) limits on the cumulative release of radionuclides to the accessible environment for 10,000 years after the closure of the repository.

4.4.4 Climatology

The climatology program is described in detail in Section 8.3.1.5 of the SCP/CD. It consists of investigations on (1) climatology and meteorology, (2) design- and operating-basis severe weather, and (3) long-term climate. The objective of these investigations is to support the resolution of performance and design issues.

This investigation consists of four studies: the onsite measurement program, the evaluation of data representativeness, the development of atmospheric dispersion models, and the development of information input to repository design. The purpose is to obtain information about the state of the atmosphere in terms of normal, mean, and extreme conditions, to describe the atmospheric-dispersion characteristics that are needed for assessments of preclosure radiation safety, and to develop climatological input for the design of the repository.

Design- and operating-basis severe weather

This investigation will establish a data base of design-basis wind, tornado, and snow-load parameters for use in the structural design of repository surface facilities and in quantifying accidental preclosure radionuclide releases. The investigation will also establish a data base on severe-weather phenomena that may affect routine repository operations. The data base will be used in developing repository operating procedures. This investigation consists of two studies: the development of design-basis severe-weather parameters and the evaluation of the potential for severe weather to significantly disrupt routine repository operations.

Long-term climate

The investigation of long-term climatic trends in the candidate area consists of two studies that will refine available reconstructions of Quaternary climates and predict the climates of the future. The reconstruction of Quaternary climates is needed for the geohydrologic and geomorphic programs, for modeling the potential effects of future climate changes on the hydrology of the site, and for evaluating geomorphic processes that could affect the performance of the repository.

The study of Quaternary climates will relate the climatological and environmental conditions of the past to geomorphic and geohydrologic processes (including erosion, deposition, ground-water flow, salt dissolution, and subsidence). It will focus on conditions and processes identified through previous studies in the area, as well as expected new findings related to regional geomorphic evolution and subsidence history.

4.4.5 Resource potential

The resource-potential program, described in Section 8.3.1.6 of the SCP/CD, consists of a single investigation that is divided into three studies. These studies are directed at describing the present and expected hydrocarbon, nonhydrocarbon mineral, and ground-water resource potential of the candidate area and the site. This program will provide the data and analyses needed for assessing the potential for human intrusion into the repository through exploratory drilling or the exploitation of hydrocarbon, mineral, and ground-water resources at the site.

The study of hydrocarbon resources will incorporate data from the investigations on stratigraphy, tectonics-structural geology, surface-based hydrology, and baseline geochemical characteristics. Geochemical indicators will be used to evaluate organic-source rock potential and thermal maturity. Borehole testing will be conducted on any prospective reservoirs for possible direct detection of hydrocarbons.

The study of ground-water resources will consider surface waters and waters in HSU-A (the Ogallala-Dockum aquifer) and HSU-C (the deep-basin brine aquifer). The development of HSU-C for potable and irrigation water would require desalinization. Data will be acquired through the investigations on stratigraphy, surface-based hydrology, and baseline geochemical characteristics. In addition, an economic analysis will be conducted to evaluate the likelihood of developing the deep-basin brines.

The study of nonhydrocarbon mineral resources will assess near-surface industrial minerals, subsurface industrial minerals, metal resources (base-metal and uranium deposits), and helium.

4.4.6 Soil and rock mechanics

The soil and rock-mechanics program is described in Section 8.3.1.7 of the SCP/CD. It consists of two investigations that will address soil mechanics and non-host-rock rock mechanics.

The purpose of the soil-mechanics investigation is to explore and characterize the soils at the site and to gather data to be used in performance assessment and the design of surface facilities. To satisfy this purpose it will be necessary to define and locate the different soils at the site using surface and borehole geologic data. It will be necessary to characterize the engineering nature of soils including mechanical and thermal properties. The investigation is composed of three studies--laboratory soil mechanics, transportation routes, and boreholes for the design of foundations for the surface facilities of the exploratory-shaft facility.

The investigation of non-host-rock rock mechanics will provide data for the design of the shafts, the characterization of the nonhost rocks at the site, and performance assessment for the overall disposal system. The mechanical and thermal properties data will be required primarily (1) to evaluate the structural stability of the components of the shaft under thermal and mechanical loads and (2) to evaluate the integrity of the stratigraphic units in the aquitard over the life of the repository. This investigation will be conducted under three studies--a routine laboratory rock-mechanics study, a nonroutine laboratory rock-mechanics study, and a shaft study.

4.5 REPOSITORY PROGRAM

The SCP repository program for the Deaf Smith County site, described in Section 8.3.2 of the SCP/CD, consists of the site-characterization activities that are associated with designing the repository. The repository program is based on the strategies for resolving the four repository-design issues in the issues hierarchy: issues 1.11 (compliance with the postclosure criteria of 10 CFR 60.133), 2.7 (compliance with the preclosure design criteria of 10 CFR 60.130-133), 4.2 (nonradiological worker safety), and 4.4 (adequacy of technology). It will also provide data needed for the resolution of design issues 1.10 and 1.12, which address the waste package and the shaft and borehole seals, respectively. (See Appendix B for full statements of the issues and the associated information needs.) In addition, the program is tied to seven issues that address both postclosure and preclosure performance: issue 1.1 (overall long-term performance objective), 1.4 (containment objective for the waste package), 1.5 (postclosure control of radionuclide release from the engineered barriers), 2.4 (waste retrievability), and 2.1, 2.2, and 2.3 (preclosure radiation safety).

As indicated by the issues mentioned above, the design of the repository must meet the requirements of two different phases: preclosure and postclosure. For the preclosure phase, the design is concerned mainly with providing the facilities and equipment that will permit the emplacement of waste while protecting the health and safety of the public and of the workers at the repository. Included in the preclosure phase is the requirement for waste retrievability. For the postclosure phase, the repository design is concerned with providing engineered barriers that contribute to the containment and isolation of radionuclides and with minimizing adverse effects of construction and operation on the waste-isolation ability of the site.

The SCP repository program for the Deaf Smith County site consists of four specific programs: (1) the verification or measurement of the host-rock environment, (2) repository coupled interactions, (3) repository-design optimization, and (4) repository modeling.

Verification or measurement of the host-rock environment

As discussed in Section 8.3.2.2 of the SCP/CD, the verification or measurement of the host-rock environment is directed at obtaining data needed for the resolution of design issues 1.11, 1.12, 2.7, and 4.2 as well as performance issues 1.1, 1.4, 1.5, 1.8, and 2.4. Its objectives are (1) to measure the engineering parameters that describe the mechanical, thermal, and thermomechanical behavior of the host rock and are needed for the numerical models used in design and performance assessment and (2) to gather the information needed to validate the models with tests simulating repository conditions. This program consists of four investigations that will address geologic conditions, rock mechanics, thermal conditions, and hydrologic conditions.

The investigation of the host-rock geologic environment will study stratigraphy, lithology, and geologic structure. It will be carried out by direct observation of the rock mass in at-depth testing, detailed studies of salt stratigraphy, direct observation and laboratory analyses of core samples, and geophysical studies of structural features (e.g., gravity and seismic surveys). This study will provide a geologic description of the host rock at the scales needed to support various studies.

The investigation of the host-rock rock-mechanics environment will consist of two studies. The first, conducted in the laboratory, will measure (1) the strength of the host rock (e.g., compressive and tensile strength, effects of temperature and strain rate), (2) rock deformation (e.g., the effects of stress and temperature on creep in salt), (3) dynamic properties, (4) physical properties (e.g., density, porosity, water content, grain density, and hardness), and the special properties of bedded salt (e.g., thermal decrepitation, fracture healing). These special properties will require the development of site-specific tests for their measurement. The second study in the rock-mechanics investigation will consist of in-situ stress tests, using methods that will include hydrofracturing and overcoring.

The investigation of the host-rock thermal environment will measure ambient rock temperatures, thermal expansion coefficients, thermal conductivities, and specific heats. It will consist of three studies--laboratory testing, in-situ measurements of thermal conductivity, and in-situ tests with heaters in a full-size repository room; the latter will simulate the effects of emplaced waste on the host salt.

The investigation of the host-rock hydrologic environment will consist of (1) laboratory measurements of rock permeability, rock porosity, and the density and viscosity of brines; (2) in-situ testing of permeability, diffusion, and hydraulic pressures; and (3) an underground borehole-seal test.

Repository interactions

The repository coupled-interactions program, described in Section 8.3.2.3 of the SCP/CD, addresses the interactions of thermal, mechanical, and other effects in the host-rock environment. Its objective is to identify the coupled interactions that are significant to design or to performance and to quantify their effects. The program consists of four investigations covering thermal-mechanical, thermal-hydrologic, mechanical-hydrologic, and geochemical interactions. Each investigation is limited to two processes because meaningful experiments involving three or more coupled parameters are difficult to design, and in most cases coupled interactions can be effectively studied by superimposing the effects of two-way coupling. Each investigation consists of studies to be performed in the laboratory and in the exploratory-shaft facility. The results will be used in performance assessments to predict the responses of the host rock to the conditions expected in a repository in bedded salt.

The investigation of thermal-mechanical interactions will provide heat-transfer data for both the preclosure and the postclosure periods. For the preclosure period, this includes the data needed for determining ventilation requirements; the mechanical response of underground openings (rooms and drifts) and the attendant requirements for operational safety, waste retrievability, and maintenance; and the thermomechanical responses of underground openings to the emplaced waste (i.e., thermal effects on stresses, deformations, and fracturing and healing), especially in relation to stability and waste retrievability. For the postclosure period, these studies will supply data on heat transfer, the thermomechanical response of underground openings to the heat generated by the waste and to the presence of repository backfill.

The investigation of thermal-hydrologic interactions will address the preclosure and postclosure thermohydrologic responses of the underground openings. For the postclosure period, parameters like hydraulic pressure and inflow will be determined. The postclosure studies will attempt to determine the thermohydrologic response of underground openings to changing hydrologic conditions (e.g., termination of dewatering) and the heat emitted by the waste, especially as it relates to the resaturation of the underground repository.

The investigation of mechanical-hydrologic interactions will collect data on the preclosure and postclosure hydrologic response of the underground openings. For the postclosure period, this investigation will emphasize the hydrologic response of underground openings to changing hydrologic conditions (e.g., the termination of dewatering), the mechanical loading caused by the thermal expansion of the rock (as a result of the heat generated by the waste), and deformation related to room closure. Of particular importance are the resaturation of the underground facility and the subsequent radionuclide transport through the engineered-barrier system.

The investigation of chemical-geochemical interactions will address the effects of repository construction and operation on the geochemical conditions in the repository. It will study effects on brine content and composition, gas content and composition, acid-base indicators and buffers, oxidation-reduction indicators and buffers, and the composition of near-surface rock.

Repository-design optimization

Repository-design optimization is the process of selecting the optimum design from several alternatives; it will be accomplished by performing various tradeoff studies that will consider performance, safety, cost, and schedules while recognizing the constraints imposed by constructibility, operation, maintenance, and reliability requirements. The tradeoff studies will cover rock-excavation and mining techniques, waste-package emplacement, and waste retrieval. For the Deaf Smith County site, the design-optimization program, described in Section 8.3.2.4 of the SCP/CD, is linked to the resolution of issues 1.11 (repository configuration and postclosure performance), 2.4 (waste retrievability), 2.7 (repository design), 4.2 (nonradiological worker safety), 4.4 (adequacy of technology), and 4.5 (costs). It consists of investigations on (1) the natural underground environment, (2) the thermal and thermomechanical conditions in the repository, and (3) the performance of underground equipment.

The investigation of the underground natural environment will collect data for use in the the design and construction of shaft and repository ventilation systems, including data on at-depth air temperatures, humidity, and air quality.

The investigation of thermal and thermomechanical conditions in the repository will consist of studies on (1) temperature distribution, (2) stress distribution, (3) opening displacements, and (4) requirements for heating, ventilation, and air conditioning. The results of these studies will be used to evaluate the performance of underground openings, including the excavation-affected zones around the openings; to validate the rock-response predictions of numerical models; and to evaluate the responses of the excavations to variations in geologic conditions throughout the repository horizon, identifying possible constraints to the configuration and size of openings.

The investigation of shaft and underground equipment performance will consist of six studies on (1) the performance of various types of ground-support devices (e.g., mechanically anchored rock bolts, resin-grouted bolts), (2) the durability of monitoring instruments and data-storage devices in an underground salt environment, (3) the effectiveness and stability of operational seal materials, (4) the performance of underground equipment in the emplacement of waste packages and under waste-retrieval conditions, (5) alternative procedures for excavating through the shaft sections where ground freezing must be used for ground control and water control, and (6) repository backfill, including pneumatic techniques for stowing the crushed-salt backfill.

Repository modeling

The repository-modeling program is described in Section 8.3.2.5 of the SCP/CD. It will provide the models needed for selecting the appropriate alternatives in design optimization and hence will contribute to the resolution of issues 1.11, 2.4, 2.7, 4.2, 4.4, and 4.5. The models developed in this program will be verified and validated in accordance with the approach described in Section 4.8.3.

The repository-modeling program for the Deaf Smith County site consists of two investigations, one for preclosure modeling and the other for postclosure modeling. The preclosure modeling is designed to provide a supportable basis for estimating the responses of repository components to the construction and operation of the repository, with primary emphasis on the response of the host rock. Three studies are planned for this investigation. The first study, geomechanical modeling, will develop constitutive models and use them in evaluating the stability of shafts and underground entries (e.g., access entries, emplacement boreholes). The second study is concerned with the development of models needed for the design of surface and underground facilities and equipment, scheduling, and cost estimating. The third study will address the nonradiological health and safety of workers.

The postclosure modeling investigation consists of two studies directed at demonstrating compliance with regulatory requirements. The results will be used in assessing the long-term performance of the natural barriers (the site), the waste package, and the total disposal system. The objective of the first study is to predict the total fluid flow into, through, and in the vicinity of the repository. The second study will develop models for predicting the release and transport of radionuclides from the engineered-barrier system and the disturbed zone.

4.6 SEAL-SYSTEM PROGRAM

The SCP program for the seal system is based on the strategy for resolving design issue 1.12, which is concerned with the characteristics and configurations of shaft and borehole seals, and also performance issue 1.1, which is concerned with the overall system performance after closure. A detailed description of this program can be found in Section 8.3.3 of the SCP/CD. Since the postclosure seals will generally not be installed until the underground repository is closed, the design, development, and testing of seals will extend far beyond site characterization. Plans for work during site characterization are aimed at developing design concepts and evaluating seal materials for consideration after site characterization and before repository closure.

The SCP seal-system program for the Deaf Smith County site consists of four specific programs: (1) seal-system environment, (2) seal-system components and interaction, (3) seal-system design optimization, and (4) seal-system modeling.

Seal-system environment

As described in Section 8.3.3.2 of the SCP/CD, the program for the seal-system environment consists of four investigations that will evaluate the pertinent geologic, rock-mechanics, thermal, and hydrologic conditions in the host rock at potential seal locations in shafts and in the underground excavations. These investigations will be conducted in the laboratory, in the exploratory shafts, and in the underground area of the exploratory-shaft facility.

The purpose of the investigation of the seal-system geologic environment is to develop a geologic description of the rock at the various locations where seals will be emplaced, with particular emphasis on discontinuities and other features that are potential paths for ground-water flow. The studies in this investigation will provide detailed information on stratigraphy, petrology, and small-scale structures.

The investigation of the seal-system rock-mechanics environment will determine the mechanical properties of, and the stresses existing in, the host rock at various seal locations. Of particular interest is the complex deformation behavior of salt. Since this complex behavior requires precisely controlled test conditions, the deformation tests will be conducted in the laboratory.

The investigation of the seal-system thermal environment will determine the thermal characteristics of the host rock--that is, thermal expansion coefficient, thermal conductivity, and specific heat. To verify the thermal conductivity of the rock mass at a relatively large scale, a room heater test will be conducted.

The investigation of the seal-system hydrologic environment will determine in-situ hydraulic pressures, rock-mass permeability, and the nature of ground-water flow in the disturbed zone around underground openings. Included in this investigation will be a borehole-seal test that will provide direct measurements of the permeability of the rock mass and will allow the selection of the most appropriate conceptual model for analyzing flow around and through borehole seals.

The seal-system environment program will provide a basis for the specific program described below--seal-system components and interaction.

Seal-system components and interaction

The objectives of the seal-components program are to identify and recommend appropriate materials for seals, to determine the responses of these materials to the repository environment, to develop models for performance assessment, and to assist in the development of seal designs. As described in Section 8.3.3.3 of the SCP/CD, this program consists of four investigations: seal-system components, the interactions of shaft seals, the interactions of underground-entry seals, and the interactions of underground-borehole seals.

The investigation of seal-system components will consist of two studies. The first will be laboratory studies of the properties of three types of seal materials: crushed salt, cementitious materials, and earthen materials. In addition to physical and mechanical properties, the laboratory tests will include such properties as ease of handling (mixing, emplacement, curing), the potential for chemical reactions with the host rock and ground water, electrochemical properties, and long-term durability. The second study will be dedicated to model development.

The other three investigations in this program will assess the mechanical, hydrologic, and geochemical interactions between the rock mass and the shaft, underground-entry, or borehole seals. Of special concern are geochemical processes in the interfaces between seal materials and the host rock as well as responses to ground-water flow. The critical geochemical parameters for both geologic substrates and formation fluids include mineral composition, trace elements, organic-matter content, oxidation-reduction potential, and pH. Each investigation will include tests of materials performance, geochemical studies, model development, and performance assessment. The investigation of underground-entry seals will also include a room-backfill test and a room-seal test, whereas the borehole-seals investigation will include the borehole-sealing test mentioned in the discussion of the SCP repository program (Section 4.5).

Seal-system design optimization

The specific program on the optimization of the seal-system design will proceed through three steps: (1) laboratory studies, site studies, and performance studies will be conducted to select seal-system materials, locations, and configurations; (2) engineering studies will be conducted to develop construction methods; and (3) the results of further performance analyses and materials testing will be used to optimize the design of seals. The design-optimization program, described in Section 8.3.3.4 of the SCP/CD, consists of two investigations, one directed at selecting seal-system materials, configuration, and location and the other concerned with developing construction methods. Both investigations will interface closely with those field-testing and materials-testing investigations that will provide the data needed for seal design.

Seal-system modeling

The final component in the seals-system program is the development of conceptual and numerical models to be used in design optimization and performance assessment. These models will be applied in the resolution of issue 1.12, which will require demonstrating that the flow of water through the seal system into the waste package is not significantly greater than flow through undisturbed rock at the site and demonstrating that radionuclide transport through the seal system is not significantly greater than transport through undisturbed rock.

The seal-system models will be of two types: component models and system models. The component models will be used to study the detailed thermal, mechanical, hydrologic, and geochemical responses of the seal system to the host rock. The system models will be constructed from the results of the component models and will be used in the performance-assessment program described in Section 4.8.

4.7 WASTE-PACKAGE PROGRAM

The SCP waste-package program is based on the strategies developed for the resolution of five issues. Two of the issues are postclosure-performance issues: issue 1.4 (substantially complete containment of radionuclides within the set of waste packages for up to 1000 years) and issue 1.5 (controlled release of radionuclides from the engineered-barrier system for 10,000 years). The other three issues pertain to waste-package design: issue 1.10 (the postclosure characteristics of the waste package), issue 2.6 (the preclosure characteristics of the waste package), and issue 4.3 (the fabricability of the waste package).

As described in Section 8.3.4 of the SCP/CD, the SCP waste-package program consists of four specific programs: (1) the waste-package environment, (2) waste-package components and interaction, (3) waste-package design development, and (4) waste-package modeling.

Waste-package environment

The overall objective of this program, as described in Section 8.3.4.2 of the SCP/CD, is to characterize the physical and geochemical environment in which the waste package is emplaced and to provide the data needed to predict how this environment will be changed by interactions with the waste-package materials and the effects of heat and radiation during the first 10,000 years after repository closure. This will be accomplished by conducting investigations of (1) the waste-package thermal and radiation field environment, (2) the waste-package rock-mechanics environment, (3) brine movement, and (4) the waste-package geochemical environment.

The investigation of the waste-package thermal and radiation fields environment around the waste package will consist of a thermal study and a radiation study; both studies will use information compiled in other waste-package and site investigations. The thermal study will calculate the temperatures expected in the various components of the waste package and the surrounding host rock for the period from emplacement to the end of the containment period (300 to 1000 years). The radiation study will calculate the gamma and neutron dose rates in and around the waste packages.

The investigation of the waste-package rock-mechanics environment will model and analyze the closure of the emplacement borehole around the waste package and determine the pressure on the waste package. To obtain the data needed for this modeling and analytical study, two other studies will be performed. The first will be a laboratory study to establish a constitutive model for salt; it will include tests of creep, stress relaxation, stress rate, strain rate, cyclic loading, and deformation. The second study will conduct at-depth in-situ tests to monitor borehole closure and the thermomechanical response of salt.

The brine-movement investigation will identify and quantify the various sources of water in the host rock, identify the potential for the migration of water from these sources, investigate the processes involved in water migration, develop bounding models to describe the flux of brine to the waste package, and conduct in-situ tests to validate the predictions of the models. It will consist of two studies, one conducted in the laboratory and the other in situ.

The investigation of the waste-package geochemical environment will consist of three laboratory studies that will determine how the geochemical environment and the associated fluids will be affected by (1) the thermal pulse from the emplaced waste, (2) radiation, and (3) waste-package degradation products.

Waste-package components and interaction

As described in Section 8.3.4.3 of the SCP/CD, the waste-package components and interaction program consists of four investigations: (1) waste-form materials, (2) container materials, (3) packing materials, and (4) component interactions. The objective is to obtain sufficient data on the waste-form material characteristics and radionuclide-release properties for the development of models of radionuclide release and transport. These models will in turn be used in design and in performance assessments, including the generation of source terms for radionuclide-transport analyses.

The investigation of waste-form materials consists of four studies. The first, waste selection and characterization, will use data from the literature and materials tests performed at the Materials Characterization Center of the Pacific Northwest Laboratory. The other three will be laboratory studies of radionuclide solubility and speciation behavior, the dissolution of spent fuel, and the dissolution of borosilicate glass.

The investigation of container materials is directed at gaining a mechanistic understanding of the corrosion behavior of candidate materials for the disposal container and to develop corrosion models. As mentioned in Section 3.2 of this overview, the reference material currently is A216 Grade WCA mild steel. Other candidate materials include three nickel- and copper-base alloys. The investigation will consist of laboratory studies on a variety of degradation modes, including general corrosion, nonuniform corrosion (pitting, crevice), stress-corrosion cracking, degradation by hydrogen, and degradation induced by microbes.

The packing-materials investigation will characterize candidate packing materials and evaluate their effects on the waste-package environment, with emphasis on the ability to retard the migration of corrosive agents toward the disposal container and the migration of radionuclides from the waste package.

The studies in this investigation will be conducted in the laboratory and will address (1) packing consolidation, (2) physical properties, (3) thermal properties, (4) chemical properties, and (5) compatibility with the other components of the waste package (see Section 3.2).

The component-interaction investigation consists of a laboratory analog study and an in-situ interactions study. The objective of the laboratory study is to quantify the effects of the waste-package environment on the corrosion of the disposal container as well as on the release and transport of radionuclides from the waste package, whereas the objective of the in-situ study is to verify the results of the laboratory study.

Waste-package design development

The third part of the waste-package program is described in 8.3.4.4 of the SCP/CD as the waste-package design investigation. Its objective is to develop engineering information for the specification of waste-package component materials; fabrication methods; methods for the preparation, storage, and shipment of waste-package components; methods for canister and container closure welding; and techniques for inspecting closure welds. This investigation will consist of two activities: (1) fabrication and assembly and (2) design. The latter will include the development of the advanced conceptual design and the license-application design for the waste package. These design activities will be preceded by studies of alternative waste-package design concepts and materials, an evaluation of the benefits to be derived from reducing the heat emitted by the waste package (i.e., reducing the quantity of spent fuel that is loaded into a waste package), and evaluating the potential for nuclear criticality after repository closure.

Waste-package modeling

The waste-package modeling program will develop and use models for assesssing the performance of the waste package. It will consist of three studies that will develop or select waste-package development models (i.e., models used to analyze the performance of specific waste-package components), standard models, and performance models. The objective of this program is to describe the waste packages and the waste-emplacement environment by numerical models, to use these models to analyze the phenomena occurring in and around the waste packages, and to predict the preclosure and postclosure performance of specific waste-package designs. A detailed description of this program is given in Section 8.3.4.5 of the SCP/CD.

4.8 PERFORMANCE ASSESSMENT

The performance-assessment program will develop analytical techniques and provide the analytical evaluations for the resolution of the performance issues. In particular, the purpose of the program is to calculate performance measures for each of these issues and to compare the results with the goals set for them. This section presents brief summaries of plans for the assessment of preclosure safety, the assessment of postclosure performance, and the development, validation, and verification of models. Detailed plans for the performance-assessment program for the Deaf Smith County site are given in Section 8.3.5 of the SCP/CD.

4.8.1 Preclosure safety

Three issues are addressed by the preclosure-safety assessment program: issues 2.1, 2.2, and 2.3. These issues are concerned with the preclosure radiation safety of the repository.

Assessment of preclosure safety

The assessment of preclosure safety will be conducted for the phases of repository construction, operation, waste retrieval (if necessary), closure, and decommissioning. It is directed mainly at the resolution of key issue 2 (preclosure radiation safety) and the following related performance issues:

- Radiation safety of the general public under normal conditions (issue 2.1).
- Radiation safety of the repository workers under normal conditions (issue 2.2).
- Radiation safety of the general public and the repository workers under accident conditions (issue 2.3).

Complete statements of these issues and the information needs can be found in Appendix B. The strategy for the assessment of preclosure safety is described in Section 8.3.5.1 of the SCP/CD.

The DOE is developing a preclosure-risk assessment methodology that will establish the procedures, computer codes, assumptions, and data bases to be used in these safety assessments. This methodology will be used to analyze the radiation-exposure risks of both routine operations and accidents at the repository; it will also be used to analyze accidents that do not lead to releases of radioactive material but may be hazardous for other reasons.

The general analytical approach to the resolution of issues 2.1 and 2.2 (radiation-exposure risks of routine operations) consists of four steps:

1. The evaluation of the design of the repository and the waste package, including the thickness of barriers and radiation shields, the characteristics of the ventilation system, and the containment characteristics of the waste form.

2. The identification of radiation-source characteristics, which depend on the design of the repository and the waste package, operating procedures, relevant environmental conditions, radionuclide transport, potential releases from offsite facilities, and radon releases from the excavation of the underground repository.

3. The development of dispersion and pathway models.

4. Calculation of the radiation exposures that might be received by the general public or by the workers at the repository.

The general analytical approach to assessing the radiation-exposure risks of accidents at the repository (issue 2.3) will employ techniques of probabilistic risk assessment in addition to deterministic, conservative methods of analysis.

The results of the preclosure-safety assessment will be used to guide the design of the repository and the development of operating procedures, to demonstrate compliance with regulatory requirements, to identify items important to safety, and to support the site-selection process.

4.8.2 Postclosure performance

The program for postclosure-performance assessment addresses issues 1.1 through 1.8. Issues 1.1 through 1.6 are concerned with the postclosure-performance objectives of 10 CFR Part 60, issue 1.7 addresses the need to develop a performance-confirmation program, and issue 1.8 addresses the siting criteria of 10 CFR Part 60.

The six postclosure-performance issues address the following performance objectives of 10 CFR Part 60:

- Environmental standards for the cumulative radionuclide release to the accessible environment (issue 1.1).
- Radiation protection for members of the general public in the accessible environment (issue 1.2).
- Ground-water protection (issue 1.3).
- Substantially complete containment of radionuclides by the set of waste packages (issue 1.4).
- Limiting the rates of radionuclide release from the engineered-barrier system (issue 1.5).
- The pre-waste-emplacement time of ground-water travel (issue 1.6).

The current plans for resolving these issues for a repository at the Deaf Smith County site are based on the current conceptual models of the site characteristics and the current understanding of the processes and events that could or may occur at the site in the future. Preliminary analyses of the behavior of this system have been conducted; they have contributed heavily to the planning. The general strategy for resolving issues 1.1 through 1.6 has been given in Section 4.1. Detailed strategies for each issue are presented in Section 8.2.2 of the SCP/CD.

The performance-assessment activities that will be planned for the resolution of issue 1.1 include the following:

1. The definition of the disposal-system elements and of the repository design.
2. The identification and development of scenarios for the release of radionuclides, taking into account significant processes and events.

3. The development of conceptual and numerical models for the performance of the system and its elements.

4. The performance of bounding and probabilistic analyses, including sensitivity and uncertainty analyses.

5. The calculation of performance measures (including a complementary cumulative distribution function for releases to the accessible environment) and comparison with criteria.

The performance-assessment activities that are planned for the resolution of issues 1.2 and 1.3 are closely related to those for issue 1.1. In these cases, the analysis will focus on the undisturbed performance of the disposal system--that is, the behavior that would be predicted if the system is not disrupted by inadvertent human intrusion or the occurrence of unlikely natural processes or events. For issue 1.2, the assessments will evaluate the radiation doses that could be received by any member of the public in the accessible environment. For issue 1.3, the assessments will evaluate the potential radionuclide contamination of any special sources of ground water.

The performance-assessment activities planned for issue 1.4 include the following:

1. Evaluation of the waste-package environment, including the thermal, radiation, chemical, mechanical, and hydraulic conditions in the vicinity of the waste packages.

2. Evaluation of the performance of the disposal container under these conditions, taking into account the properties of container materials, the nature of welds, the presence of mechanical defects, and potential modes of degradation.

3. Evaluation of the performance of the waste form, including the potential rate of radionuclide release from the waste-form matrix.

Issue 1.5 is concerned with the rate of release from the engineered-barrier system. The planned activities include compiling and integrating data on the waste form (spent fuel and vitrified high-level waste) and the design of the waste package, determining the sets of parameter values to be used in assessing the performance of the waste package, developing geochemical models to analyze the release of radionuclides from the waste form and their behavior after release, developing models for determining mechanism for radionuclide releases from spent fuel and vitrified waste, developing models for assessing waste-package performance, and calculating the rates of radionuclide releases from the waste package and the engineered-barrier system by both deterministic and probabilistic methods.

Issue 1.6 is concerned with the performance of the site in terms of the ground-water travel time. The performance-assessment activities planned for resolving this issue include the following:

1. The development and validation of computational models for predicting the ground-water travel time.

2. The determination of the extent of the disturbances of the flow system due to repository construction and waste emplacement.

3. The identification of paths of likely radionuclide travel from the disturbed zone to the accessible environment.

4. The calculation of the pre-waste-emplacement ground-water travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment.

The performance-assessment activities for performance issues 1.7 and 1.8 are essentially the same as those for performance issues 1.1 through 1.6, which directly address the postclosure performance objectives of 10 CFR Part 60. Performance issue 1.7 addresses the requirements for a performance-confirmation program as defined in 10 CFR 60.137.

Performance issue 1.8 addresses the siting criteria of 10 CFR 60.122. The detailed strategy for its resolution defines the DOE's approach to the evaluation of favorable and potentially adverse conditions at the site and the determination that an appropriate combination of these conditions together with the engineered-barrier system will allow the performance objectives related to waste isolation to be met.

The types of information needs and strategies discussed above are also applicable to the resolution of performance issue 1.9, higher-level findings for the postclosure siting guidelines of 10 CFR Part 960 and the comparison of sites. However, the specific analyses will be somewhat different in this case; that is, the analyses for issues 1.1 through 1.6 involve evaluations of the system for 10,000 years or less after permanent closure. The siting guidelines, on the other hand, require evaluations for longer periods in some cases. In particular, the comparison of sites will involve calculations of system performance for 100,000 years after closure. Therefore, although the types of performance-assessment activities are the same as those described above, specific analyses will be somewhat different.

4.8.3 Performance-assessment modeling

The analyses that will be conducted in assessing the performance of the disposal system will rely heavily on numerical models. For example, a particular performance measure will be calculated by using appropriate models that take into account the processes and events that may significantly affect the measure. The numerical models will be based on conceptual models for the system and on empirical or theoretical relationships for the processes considered to be important in these conceptual models.

The numerical models that will be used in the performance assessments for licensing will be verified and validated. That is, the analytic techniques for performing the calculations will be tested to ensure that they correctly perform the operations, and the conceptual models and the empirical and theoretical relationships will be evaluated to ensure that they adequately represent the physical system to be analyzed.

Verification that the analytic techniques correctly perform the operations will involve quality control and quality assurance in the development of the technique, the benchmarking of the techniques against other related techniques, and the evaluation of carefully chosen examples, including those with analytic solutions. The verification of a particular analytic technique may require substantial effort but is a relatively straightforward process.

The validation of the conceptual models and empirical and theoretical relationships, on the other hand, is expected to be more difficult because the validation process must address in a fundamental way the uncertainties in the description of the system itself. Such uncertainties include those in the specifications of the input parameters for the system and those in the conceptual model itself (e.g., in its geometrical configuration, major features, and boundary and initial conditions).

The DOE will attempt to address parameter uncertainty by considering bounding values for parameters or by taking parameter variations explicitly into account through stochastic modeling. Since parameter uncertainties to some extent reflect uncertainties in the conceptual model of the system, the bounding-modeling or stochastic-modeling approaches will also be useful in resolving the conceptual uncertainties. However, the validation of conceptual models is also expected to involve additional activities, including (1) explicit treatment of alternative conceptual models, (2) study of the sensitivity of performance-measure values to uncertainties in the conceptual model and in the specifications of parameters, and (3) peer review by qualified experts. Plans for specific verification and validation activities will be made during the planning of model development and application.

5. SITE CHARACTERIZATION

In order to carry out the site-characterization program described in Chapter 4, the DOE will conduct various activities at the Deaf Smith County site. These activities will consist of surface-based tests and tests conducted in an exploratory-shaft facility. Various laboratory tests and analyses will also be performed. In conducting the site-characterization activities, care will be taken to avoid adverse environmental and socioeconomic impacts. If the Deaf Smith County site is found to be unsuitable for a repository, the facilities at the site will be decommissioned.

The drilling of boreholes, the construction of the exploratory shafts in the exploratory-shaft facility, and any underground excavations will be performed in such a way that the integrity of the site is not compromised. These activities will be controlled to avoid or mitigate any significant adverse impacts that might affect the safety of the repository during preclosure operations or the waste-isolation capability of the site after closure.

5.1 SURFACE-BASED TESTS

The surface-based tests to be conducted during site characterization will consist of two general types of activities: tests performed at the ground surface (e.g., geophysical surveys and field mapping) and tests performed in boreholes and trenches.

These studies are described in Section 8.3.1 of the SCP/CD; the following description of them briefly summarizes information from the detailed discussions in those sections. The proposed activities may be augmented or modified to answer questions that arise during evaluation of data obtained from early phases of this program.

5.1.1 Tests performed at the surface

The tests performed at the surface will include activities related to mapping and visual inspection and activities related to geophysical surveying.

Several mapping activities are planned. Geologic and topographic maps will be produced of the surface-facilities area and site-access routes to provide data for grading, site-drainage planning, and access-road design. In addition, a search will be conducted to identify any unrecorded wells or boreholes that may be within the vicinity of the site and could affect hydrologic investigations or the design, construction, or operation of the exploratory shafts and underground workings.

Geophysical surveying and field mapping will be conducted on a regional basis. Seismographic records provide ground motion data that will be used in the design of the repository surface and underground facilities as well as for assessing the tectonic stability of the site. A regional seismic-reflection survey, a seismic-reflection survey in the engineering-design boreholes (EDBH), a three-dimensional seismic-reflection survey, and a potential-field survey will be used to investigate and evaluate subsurface structural and stratigraphic features for characterization and design purposes. The EDBH seismic-reflection survey (see Section 5.1.2) will be concentrated in the area of the exploratory-shaft facility and the repository surface facilities.

5.1.2 Drilling and trenching

Groups of boreholes, called "hydrology clusters," will be drilled to investigate hydrologic conditions at various depths. Hydrology clusters will be drilled in the upper aquifer (three boreholes at each of five sites) to obtain the data necessary for modeling ground-water flow in the Ogallala Formation and the Dockum Group and to collect samples for analyzing water quality. Hydrologic and fluid geochemical data from all strata from the Dewey Lake through the Queen-Grayburg are needed for performance assessment and for the design of the exploratory shafts; these data will be obtained from six intermediate clusters (totaling 16 boreholes) drilled to the top of the Upper San Andres Formation. Six hydrology clusters (totaling 18 holes) will be drilled into hydrostratigraphic unit C (HSU-C) to define and model the deep-basin saline ground-water flow regime.

Four types of boreholes are planned for design purposes. Four stratigraphic boreholes penetrating 200 feet below the proposed repository horizon will be drilled outside the perimeter of the repository. Two engineering-design boreholes will be drilled, one at the site of each shaft, and the stratigraphic and structural data obtained from these holes will be used to determine the layout and the design of the shafts and underground facilities. Approximately 50 borings will be made at the site of the exploratory-shaft surface facilities to provide information for their design, and approximately 400 shallow boreholes will be made at the site of the repository surface facilities to provide subsurface information for designing foundations.

Two types of monitoring wells are planned. Twelve wells penetrating the upper hydrostratigraphic unit (HSU-A) will be drilled within 500 feet of the two exploratory shafts. These wells will be used to establish preconstruction ground-water levels and water quality and to detect changes in these conditions during and after construction. Approximately 30 wells will be drilled to monitor ground-water quality and levels near the surface facilities. These wells, about 360 feet deep, will be installed around the salt-storage pile, refuse pits, onsite retention ponds, and similar facilities.

Several activities will be conducted to study playa-related conditions. Two deep-playa boreholes will be drilled to investigate the potential for anomalous fracture conditions or stratigraphic thinning beneath a playa. Nine shallow boreholes will be drilled to various depths at each of three playa sites. Some of these boreholes will be drilled to the base of the Upper Seven Rivers Formation to investigate the potential influence of shallow salt dissolution; others will be drilled to the base of the Ogallala Formation to investigate the possible influence of caliche dissolution on playa development.

Trenching activities are also planned for the study of playas. Shallow trenches near three playas in the vicinity of the exploratory-shaft facility may be excavated to explore near-surface evidence of fractures in caliche and for possible correlation with surface lineament trends.

Numerous surface-based activities will be conducted in the region outside the 9-square-mile site. Regional hydrologic sampling and monitoring activities will help define hydrogeologic processes controlling ground-water flow and chemical composition and will provide a framework for evaluating the hydrologic setting of the site. The activities will include water-sample collection at existing wells, lakes, and springs; deep-brine sampling from 30 to 50 oil and gas wells; and the drilling of ten wells 50 to 100 feet deep in playas for core sampling and moisture monitoring with neutron probes. In addition, a number of borings will be made along alternative access corridors to evaluate near-surface soils and geologic structure for selecting a preferred repository access corridor.

5.2 TESTS IN THE EXPLORATORY-SHAFT FACILITY

This section describes the exploratory-shaft facility and the tests to be performed there. A more complete description is provided in Section 8.4 of the SCP/CD.

5.2.1 The exploratory-shaft facility

The ESF (shown in Figure 5-1) will be located at the Deaf Smith County site and will consist of support facilities on the surface, two exploratory shafts, and underground testing rooms and drifts.

Surface facilities

The exploratory-shaft surface facilities will occupy approximately 65 acres of land in the southwestern corner of Section 9 in Deaf Smith County. The surface facilities include access roads, buildings and trailers, shaft-hoist houses, construction support facilities, utilities, and fire-protection and life-support facilities.

The development of access and roads to the exploratory-shaft facility will involve the construction of approximately 0.10 mile of new asphalt-paved access road, 1.6 acres of offsite parking area, and the upgrading of approximately 1.7 miles of existing earthen county road.

The surface facilities will include a security building; an administration building; electrical and mechanical transformer buildings; a shop, warehouse, and service building; chlorination and sewage-treatment plants; and a building for use by the underground testing contractor. The preferred structures for the buildings are preengineered metal buildings because they are easy to erect and provide flexibility. The transformer buildings and a section of the underground-contractor building, however, will be constructed

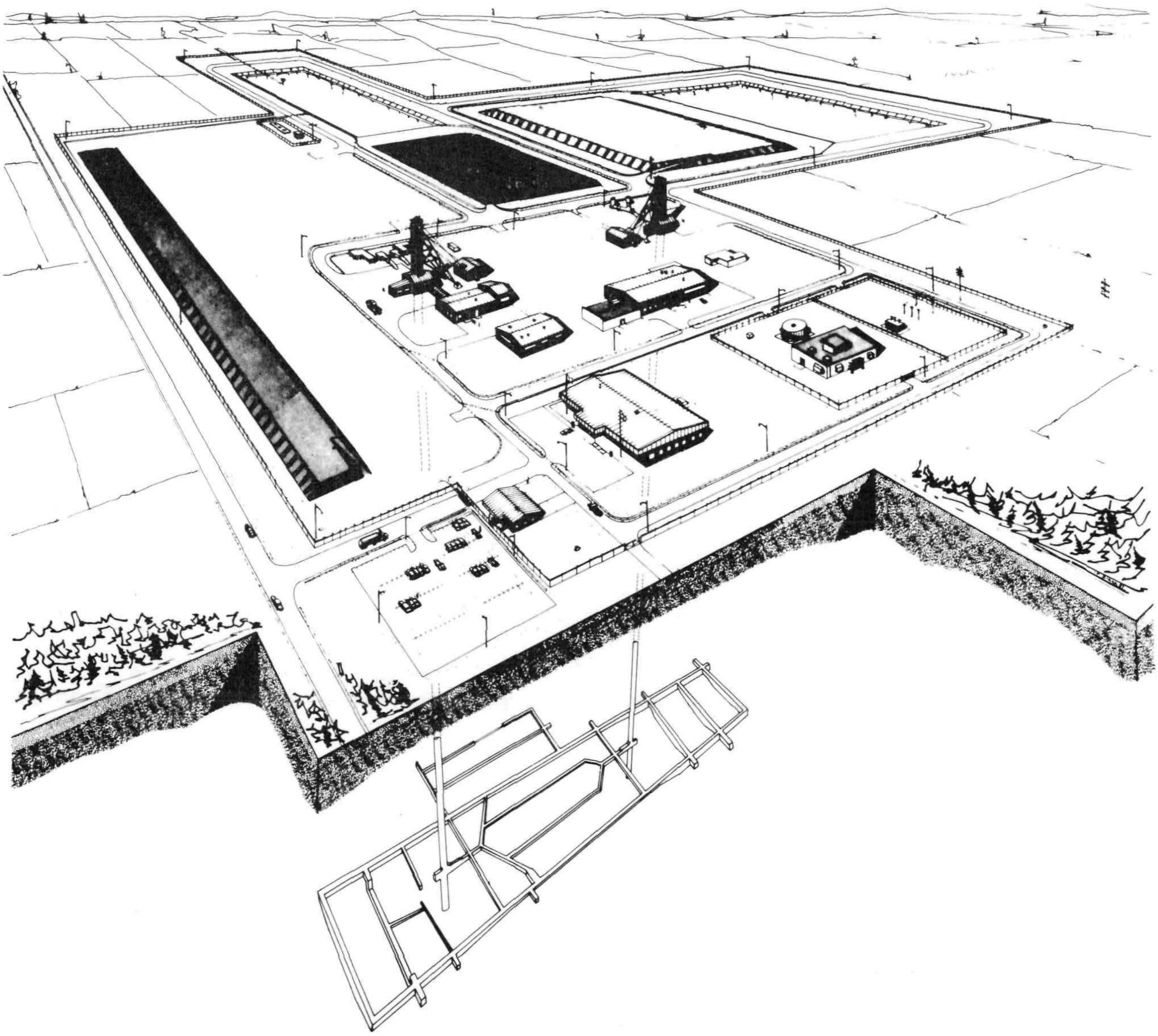

Figure 5-1. The exploratory-shaft facility.

of reinforced concrete to be tornado resistant. This will safeguard against the loss of electrical power for shaft facilities or critical testing equipment and the interruption of test-data transmission from the underground facility.

In addition to the buildings mentioned above, there will be two identical hoist houses. Each hoist house will provide a control room for the hoist operator, an electrical control center, and a hoist. The hoist for shaft 1, designed as the principal service hoist, will operate a personnel-and-materials cage. The hoist for shaft 2 is designed for emergency personnel evacuation and the occasional removal of materials and equipment. The shafts will also be equipped for underground ventilation: shaft 1 will be used for the heating and cooling intake, and shaft 2 will be used for the exhaust.

Commercial utility services that will be used for the construction and operation of the exploratory-shaft facility are electricity, gas, and telephone. Water may also be supplied to the site from remote wells because of concern over the influence of onsite wells on the development of the freeze wall and site ground-water monitoring wells (discussed below). To minimize the disruption of land use and other impacts, all utilities to the exploratory-shaft facility will be routed through the rights-of-way of State or county roads.

Additional surface facilities needed to support facility construction and operation, surface drainage, and waste disposal include tanks for potable water and fire-protection water, a sewage-treatment plant, a topsoil stockpile, a stockpile for mined rock other than salt, a salt stockpile, a sedimentation pond with pipe and riser spillway, and an evaporation and retention pond.

Shafts and underground test facilities

Exploratory shafts. There will be two exploratory shafts at the Deaf Smith County site. Both will have an inside diameter of 12 feet. Shaft 1, approximately 2550 feet deep, will serve as the ventilation intake shaft and as the primary means for moving personnel, equipment, and materials to and from the underground. Shaft 2, approximately 2600 feet deep, will be used for ventilation exhaust, for emergency evacuation, and as a limited-capacity muck-hoisting shaft during underground development.

The shafts will be excavated by conventional drilling-and-blasting methods. Extreme importance is placed on the structural integrity of the shafts and on constructing them in a safe and pratical manner with minimal disturbance of the penetrated aquifers and the surrounding rock mass. The excavation process, therefore, will be more carefully controlled than is usual for a commercial mine shaft. Methods for controlled blasting and mechanical excavation will be used to minimize the disturbance of the rock, especially in the frozen sections of the shaft.

After the excavation of each section of shaft, the shaft wall will be mapped in detail and photographed. Also, at various stages during shaft sinking, instrument arrays will be imbedded in the shaft wall at preselected horizons, as discussed below. A preliminary liner will then be installed and excavation will resume. The preliminary liner will be either cast-in-place concrete, for sections where the penetrated strata is relatively competent, or concrete blocks, where swelling ground conditions require a more yieldable support. A final liner will be installed in stages to finish the shafts to the finished 12-foot diameter. The final-liner type will vary throughout the shaft length. One of four types of final liners will be used, depending on the nature of the strata in the vicinity of a particular section of shaft.

Certain expected natural conditions will require the use of special methods during shaft construction. Since the shafts will intersect the unconsolidated sediments of the Ogallala and Dockum aquifers, ground-stabilizing techniques will be required. This will involve freezing the uppermost 1000 feet of strata before excavation and then sinking the shafts to a horizon below the aquifers (approximately 1400 feet deep). Upon installation of a watertight final liner of reinforced concrete, a welded-steel membrane, and an asphalt annulus in the excavated shaft section, the frozen ground will be thawed and shaft sinking will resume.

Underground facilities. The overall requirements and layout for the underground facility, referred to as the at-depth facility (ADF), are based on the testing and monitoring requirements for characterizing the site. These requirements are discussed in Section 8.3 of the SCP/CD.

The at-depth facility, shown in Figure 5-2, will consist of two shaft stations, a number of large rooms, and connecting drifts. The large rooms include those required for mine-by tests, room-seal tests, room-scale heater tests, brine-migration tests, borehole-seal tests, and canister-scale heater tests. The layout, including room sizes and spacing, allows for adequate ventilation, a safe working environment, noninterference between the tests, and adequate monitoring and testing locations.

Almost all of the at-depth facility will be excavated by mechanical means (i.e., roadheaders). Except for certain isolated areas, drilling and blasting will not be used, thus minimizing damage to the surrounding rock strata. Excavation will first connect shaft 1 with shaft 2 to establish adequate ventilation for the at-depth facility. The large rooms and connecting drifts will then be excavated. The excavation schedule will provide for planned delays for the installation of instrumentation, geologic mapping, fluid sampling, and other testing activities. The construction activities and testing activities will be coordinated to ensure that both can be performed with the minimum possible effect on either type of activity.

The at-depth facility will be outfitted with permanent utilities, including those required for power distribution, pumping, and refueling. The utility stations will be centrally located in the at-depth facility, along with a shop area for the maintenance of the equipment used for drift excavation and operations support. Adequate flexibility has been provided in the design to accommodate an expansion of the facility for additional testing, if necessary, or to accommodate alternative configurations before the excavation of the at-depth facility.

5.2.2 Tests in the exploratory-shaft facility

The tests planned for the exploratory shaft facility will collect information regarding the geologic, hydrologic, geoengineering, and geochemical environment in the host rock and overlying strata. They are divided into two categories: construction-phase tests and in-situ-phase tests.

Construction-phase tests

The construction-phase tests include all test activities that begin during the construction of the exploratory shafts. The purpose of testing in the exploratory shafts is to provide data for the characterization of the geology, geomechanics, thermomechanics, geohydrology, and geochemistry of the strata penetrated by the shafts. The data, which will be correlated with surface characterization data, will supplement the laboratory data base and aid in the validation of the design rationale for the exploratory-shaft facility. The data will be used to evaluate both undisturbed conditions and construction-induced conditions.

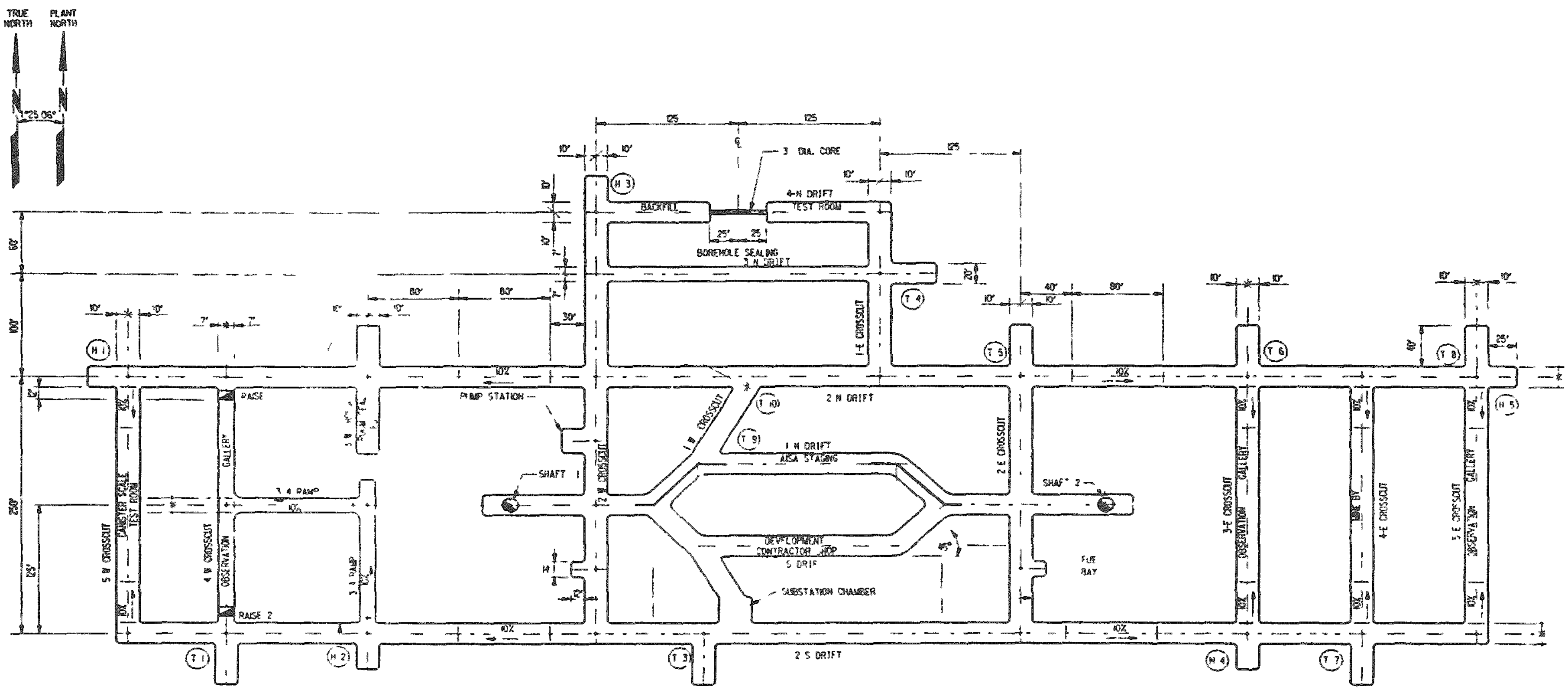

Figure 5-2. The layout of the at-depth facility.

Both shafts will be fully mapped and photographed during excavation, since the construction method affords an opportunity for directly examining the penetrated geologic units. During shaft sinking, rock and ground-water samples will also be collected from the excavation to obtain information on mineral composition, fluid chemistry and age, and other related information.

Instrumentation arrays will be installed at certain elevations during shaft sinking. The elevations will relate either to geologic horizons and conditions or to critical shaft-design elements. Arrays installed in the Ogallala and the Dockum Formations will monitor the hydrologic conditions in these aquifers to evaluate the potential effects of shaft construction and operation on them over the shaft design life. At the locations proposed for the operational and decommissioning seals, arrays will be installed to measure the hydraulic integrity of both natural materials and engineered structures. At other locations, instrument arrays will monitor such conditions as the mechanical response characteristics of the shafts (e.g., liner stress, salt creep, rock/liner temperature), various mechanical and thermal properties, and conditions relevant to shaft-construction support (e.g., blast vibration monitoring, rock-bolt testing).

The instruments installed in the shafts will be monitored with data-collection units that will be connected to the automatic data-acquisition system on the surface.

In-situ-phase tests

The tests started on the main level of the at-depth facility after the shafts have been connected are referred to as "in-situ-phase" tests. The at-depth facility has been designed to meet the requirements for implementing the at-depth testing program described in Section 8.3 of the SCP/CD. The objectives of the testing program are to determine the suitability of the site for a repository and to provide information for repository design and performance assessments.

The at-depth facility will be constructed in the proposed repository horizon--salt strata of very low permeability at a depth of about 2500 feet below the surface. The monitoring and testing conducted in or from the at-depth facility will be restricted for the most part to strata in the vicinity of the facility--Unit 4 of the Lower San Andres bedded salt--and in the adjacent salt and nonsalt layers of the Lower San Andres Formation. (Overlying and underlying strata will be characterized mainly through surface-based drilling and testing programs and during shaft construction.)

The construction of the at-depth facility will provide an opportunity for a detailed evaluation of the stratigraphy and structure over an area of the candidate repository horizon. Geologic characterization from the facility will complement surface-based studies by providing information on the continuity and character that is relevant to the dimensions of repository-sized openings. The geologic conditions at the site will be documented and evaluated primarily by means of (1) geologic mapping of exposures in underground openings; (2) the core logging of borings drilled into strata that are adjacent to the at-depth facility and, to some extent, the overlying and underlying strata; (3) the geophysical logging of borings drilled from the facility; (4) geophysical surveys (electrical, gravity, seismic reflection, and seismic refraction) performed from within the facility, and (5) the monitoring of seismic activity that is detectable in the at-depth facility.

A program of in-situ testing from the at-depth facility will be used to measure in-situ stresses and to characterize the important mechanical and thermal properties of the strata in the vicinity of the facility. Estimates of in-situ stresses and rock-mass deformability are required for the design of excavation and support systems and for evaluating the stability and deformation of underground openings. Knowledge of in-situ mechanical and thermal properties is necessary for the realistic modeling and evaluation of the thermomechanical response of the rock mass to the construction of, and waste emplacement in, a repository. The program will consist of in-situ stress measurement, strength and deformability testing, and thermal conductivity testing.

The monitoring of mechanical and thermal responses will provide a quantitative measure of the response of the rock mass to the development and operation of the at-depth facility. Because the excavation sizes, facility layout, and excavation and support methods incorporate significant features of the candidate repository design, the performance of the at-depth facility will also be important in confirming aspects of the repository design. Monitoring stations and arrays will be located throughout the facility to provide a broad areal coverage of the changing displacements, stresses, and ground-support loads that develop after excavation.

A program of hydrologic testing will be performed from within the at-depth facility to develop information on the in-situ hydraulic properties of the host horizon and adjacent hydrologically significant strata. Ten hydrologic profiling boreholes will be cored vertically from test alcoves to examine Units 2 through 5 of the Lower San Andres Formation. The tests to be conducted will include permeability and the sampling of formation fluids.

The excavation of the exploratory-shaft facility will affect the hydrologic conditions in the vicinity of the at-depth facility. The responses of these units will be monitored from within the at-depth facility, using two basic methods of repository-scale monitoring. The monitoring of ground-water inflow will measure the inflow of ground water into the at-depth facility, and piezometers will be used to measure ground-water pressures and monitor any changes in pressure resulting from ESF construction and operation. In addition, borehole permeability testing will be used to measure the changes in permeability in the construction-affected zone around excavations.

5.3 QUALITY ASSURANCE

Quality assurance consists of all planned and systematic actions necessary to ensure that the geologic repository will perform satisfactorily. All organizations participating in the site-characterization program will develop and implement a documented quality-assurance program that meets the quality-assurance requirements of the Nuclear Regulatory Commission.

Each item and activity during site characterization is assigned a level of quality assurance, which determines what requirements for control and documentation need to be followed. The level of quality assurance is consistent with the relative importance of the item or activity to public health and safety.

5.4 ENVIRONMENTAL AND SOCIOECONOMIC IMPACTS

In conducting the site-characterization program, care will be taken to minimize adverse environmental and socioeconomic impacts. As reported in the environmental assessment for the Deaf Smith County site, only the noise heard by people on adjoining lands was identified as a potentiallly significant impact of site characterization. The DOE will monitor site-characterization activities that might have significant environmental and socioeconomic impacts and, to the extent practicable, will implement mitigation measures if necessary. Plans for monitoring and mitigating those impacts will be developed in consultation with the State of Texas before starting the particular site-characterization activites.

5.5 DECOMMISSIONING

If the Deaf Smith County site is found to be unsuitable for a repository, the exploratory-shaft facility will be decommissioned. If no alternative use for the exploratory-shaft facility is identified by the responsible State and Federal agencies, the decommissioning of the surface and underground facilities will begin as soon as possible to restore the site as closely as possible to its original condition.

Equipment will be removed from the shaft stations, underground drifts, and test rooms. The shaft liners will be left in place, and the underground excavations and shafts will be backfilled with the stored salt and other rock removed during excavation. Backfilling with salt or salt-contaminated material will be limited to layers below potable-water-bearing strata to protect water quality. Concrete, polymer seals, clay plugs, or some combination will be placed at required intervals to prevent the vertical migration of water; one plug will be located at the bottom of the lined portion of each shaft. Excess salt will be removed from the site.

Surface buildings, temporary pipelines, and other suface facilities will be removed, including electricity and communication lines. The site will be returned as closely as possible to its approximate original contour, including the access road. The topsoil stockpiled on site will be used to prepare the disturbed areas for reseeding and revegetation.

Trenches will be backfilled with the material that was originally excavated, and drillholes will be sealed with a ground-matching grout.

Since no radioactive-waste materials will be introduced into the site during site characterization, no decontamination will be required after site characterization. (The radioactive materials in the geophysical tools used to investigate the movement of ground water during exploratory drilling are fully contained and retrievable; they are routinely used in geologic investigations and do not require any decontamination.)

Appendix A

EXCERPTS FROM REGULATIONS:

ENVIRONMENTAL STANDARDS FROM 40 CFR PART 191, TECHNICAL CRITERIA FROM 10 CFR PART 60, AND POSTCLOSURE AND PRECLOSURE GUIDELINES FROM 10 CFR PART 960

Subpart A—Environmental Standards for Management and Storage

§ 191.03 Standards.

(a) Management and storage of spent nuclear fuel or high-level or transuranic radioactive wastes at all facilities regulated by the Commission or by Agreement States shall be conducted in such a manner as to provide reasonable assurance that the combined annual dose equivalent to any member of the public in the general environment resulting from: (1) Discharges of radioactive material and direct radiation from such management and storage and (2) all operations covered by Part 190; shall not exceed 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other critical organ.

(b) Management and storage of spent nuclear fuel or high-level or transuranic radioactive wastes at all facilities for the disposal of such fuel or waste that are operated by the Department and that are not regulated by the Commission or Agreement States shall be conducted in such a manner as to provide reasonable assurance that the combined annual dose equivalent to any member of the public in the general environment resulting from discharges of radioactive material and direct radiation from such management and storage shall not exceed 25 millirems to the whole body and 75 millirems to any critical organ.

§ 191.04 Alternative standards.

(a) The Administrator may issue alternative standards from those standards established in 191.03(b) for waste management and storage activities at facilities that are not regulated by the Commission or Agreement States if, upon review of an application for such alternative standards:

(1) The Administrator determines that such alternative standards will prevent any member of the public from receiving a continuous exposure of more than 100 millirems per year dose equivalent and an infrequent exposure of more than 500 millirems dose equivalent in a year from all sources, excluding natural background and medical procedures; and

(2) The Administrator promptly makes a matter of public record the degree to which continued operation of the facility is expected to result in levels in excess of the standards specified in 191.03(b).

(b) An application for alternative standards shall be submitted as soon as possible after the Department determines that continued operation of a facility will exceed the levels specified in 191.03(b) and shall include all information necessary for the Administrator to make the determinations called for in 191.04(a).

(c) Requests for alternative standards shall be submitted to the Administrator, U.S. Environmental Protection Agency, 401 M Street, SW., Washington, DC 20460.

Subpart B—Environmental Standards for Disposal

§ 191.13 Containment requirements.

(a) Disposal systems for spent nuclear fuel or high-level or transuranic radioactive wastes shall be designed to provide a reasonable expectation, based upon performance assessments, that the cumulative releases of radionuclides to the accessible environment for 10,000 years after disposal from all significant processes and events that may affect the disposal system shall:

(1) Have a likelihood of less than one chance in 10 of exceeding the quantities calculated according to Table 1 (Appendix A); and

(2) Have a likelihood of less than one chance in 1,000 of exceeding ten times the quantities calculated according to Table 1 (Appendix A).

(b) Performance assessments need not provide complete assurance that the requirements of 191.13(a) will be met. Because of the long time period involved and the nature of the events and processes of interest, there will inevitably be substantial uncertainties in projecting disposal system performance. Proof of the future performance of a disposal system is not to be had in the ordinary sense of the word in situations that deal with much shorter time frames. Instead, what is required is a reasonable expectation, on the basis of the record before the implementing agency, that compliance with 191.13 (a) will be achieved.

§ 191.14 Assurance requirements.

To provide the confidence needed for long-term compliance with the requirements of 191.13, disposal of spent nuclear fuel or high-level or transuranic wastes shall be conducted in accordance with the following provisions, except that these provisions do not apply to facilities regulated by the Commission (see 10 CFR Part 60 for comparable provisions applicable to facilities regulated by the Commission):

(a) Active institutional controls over disposal sites should be maintained for as long a period of time as is practicable after disposal; however, performance assessments that assess isolation of the wastes from the accessible environment shall not consider any contributions from active institutional controls for more than 100 years after disposal.

(b) Disposal systems shall be monitored after disposal to detect substantial and detrimental deviations from expected performance. This monitoring shall be done with techniques that do not jeopardize the isolation of the wastes and shall be conducted until there are no significant concerns to be addressed by further monitoring.

(c) Disposal sites shall be designated by the most permanent markers, records, and other passive institutional controls practicable to indicate the dangers of the wastes and their location.

(d) Disposal systems shall use different types of barriers to isolate the wastes from the accessible environment. Both engineered and natural barriers shall be included.

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*A decision on July 17, 1987, by the U.S. Court of Appeals for the First Circuit has required the Environmental Protection Agency to reconsider its postclosure standards (Subpart B) in 40 CFR Part 191.

(e) Places where there has been mining for resources, or where there is a reasonable expectation of exploration for scarce or easily accessible resources, or where there is a significant concentration of any material that is not widely available from other sources, should be avoided in selecting disposal sites. Resources to be considered shall include minerals, petroleum or natural gas, valuable geologic formations, and ground waters that are either irreplaceable because there is no reasonable alternative source of drinking water available for substantial populations or that are vital to the preservation of unique and sensitive ecosystems. Such places shall not be used for disposal of the wastes covered by this Part unless the favorable characteristics of such places compensate for their greater likelihood of being disturbed in the future.

(f) Disposal systems shall be selected so that removal of most of the wastes is not precluded for a reasonable period of time after disposal.

§ 191.15 Individual protection requirements.

Disposal systems for spent nuclear fuel or high level or transuranic radioactive wastes shall be designed to provide a reasonable expectation that, for 1 000 years after disposal, undisturbed performance of the disposal system shall not cause the annual dose equivalent from the disposal system to any member of the public in the accessible environment to exceed 25 millirems to the whole body or 75 millirems to any critical organ. All potential pathways (associated with undisturbed performance) from the disposal system to people shall be considered, including the assumption that individuals consume 2 liters per day of drinking water from any significant source of ground water outside of the controlled area.

§ 191.16 Ground water protection requirements.

(a) Disposal systems for spent nuclear fuel or high-level or transuranic radioactive wastes shall be designed to provide a reasonable expectation that, for 1,000 years after disposal, undisturbed performance of the disposal system shall not cause the radionuclide concentrations averaged over any year in water withdrawn from any portion of a special source of ground water to exceed:

(1) 5 picocuries per liter of radium-226 and radium-228;

(2) 15 picocuries per liter of alpha-emitting radionuclides (including radium-226 and radium-228 but excluding radon); or

(3) The combined concentrations of radionuclides that emit either beta or gamma radiation that would produce an annual dose equivalent to the total body or any internal organ greater than 4 millirems per year if an individual consumed 2 liters per day of drinking water from such a source of ground water.

(b) If any of the average annual radionuclide concentrations existing in a special source of ground water before construction of the disposal system already exceed the limits in 191.16(a), the disposal system shall be designed to provide a reasonable expectation that, for 1,000 years after disposal, undisturbed performance of the disposal system shall not increase the existing average annual radionuclide concentrations in water withdrawn from that special source of ground water by more than the limits established in 191.16(a).

§ 191.17 Alternative provisions for disposal.

The Administrator may, by rule, substitute for any of the provisions of Subpart B alternative provisions chosen after:

(a) The alternative provisions have been proposed for public comment in the **Federal Register** together with information describing the costs, risks, and benefits of disposal in accordance with the alternative provisions and the reasons why compliance with the existing provisions of Subpart B appears inappropriate;

(b) A public comment period of at least 90 days has been completed, during which an opportunity for public hearings in affected areas of the country has been provided; and

(c) The public comments received have been fully considered in developing the final version of such alternative provisions.

Appendix A—Table for Subpart B

TABLE 1.—RELEASE LIMITS FOR CONTAINMENT REQUIREMENTS

[Cumulative releases to the accessible environment for 10 000 years after disposal]

Radionuclide	Release limit per 1 000 MTHM or other unit of waste (see notes) (curies)
Americium 241 or 243	100
Carbon 14	100
Cesium-135 or 137	1 000
Iodine-129	100
Neptunium-237	100
Plutonium 238, 239, 240, or 242	100
Radium 226	100
Strontium 90	1 000
Technetium 99	10 000
Thorium 230 or 232	10
Tin-126	1 000
Uranium 233, 234, 235, 236 or 238	100
Any other alpha-emitting radionuclide with a half life greater than 20 years	100
Any other radionuclide with a half life greater than 20 years that does not emit alpha particles	1 000

Application of Table 1

Note 1: *Units of Waste.* The Release Limits in Table 1 apply to the amount of wastes in any one of the following:

(a) An amount of spent nuclear fuel containing 1,000 metric tons of heavy metal (MTHM) exposed to a burnup between 25 000 megawatt-days per metric ton of heavy metal (MWd/MTHM) and 40 000 MWd/MTHM,

(b) The high-level radioactive wastes generated from reprocessing each 1 000 MTHM exposed to a burnup between 25 000 MWd/MTHM and 40,000 MWd/MTHM,

(c) Each 100,000,000 curies of gamma or beta-emitting radionuclides with half lives greater than 20 years but less than 100 years (for use as discussed in Note 5 or with materials that are identified by the Commission as high-level radioactive waste in accordance with part B of the definition of high-level waste in the NWPA),

(d) Each 1 000,000 curies of other radionuclides (i.e., gamma or beta emitters with half-lives greater than 100 years or any alpha emitters with half lives greater than 20 years) (for use as discussed in Note 5 or with materials that are identified by the Commission as high-level radioactive waste in accordance with part B of the definition of high level waste in the NWPA), or

(e) An amount of transuranic (TRU) wastes containing one million curies of alpha-emitting transuranic radionuclides with half-lives greater than 20 years.

Note 2: *Release Limits for Specific Disposal Systems.* To develop Release Limits for a particular disposal system, the quantities in Table 1 shall be adjusted for the amount of waste included in the disposal system compared to the various units of waste defined in Note 1. For example:

(a) If a particular disposal system contained the high-level wastes from 50 000 MTHM, the Release Limits for that system would be the quantities in Table 1 multiplied by 50 (50 000 MTHM divided by 1 000 MTHM).

(b) If a particular disposal system contained three million curies of alpha-emitting transuranic wastes, the Release Limits for that system would be the quantities in Table 1 multiplied by three (three million curies divided by one million curies).

(c) If a particular disposal system contained both the high-level wastes from 50 000 MTHM *and* 5 million curies of alpha-emitting transuranic wastes, the Release Limits for that system would be the quantities in Table 1 multiplied by 55:

$$\frac{50{,}000\ \text{MTHM}}{1\,000\ \text{MTHM}} + \frac{5{,}000\,000\ \text{curies TRU}}{1\,000{,}000\ \text{curies TRU}} = 55$$

Note 3: *Adjustments for Reactor Fuels with Different Burnup.* For disposal systems containing reactor fuels (or the high-level wastes from reactor fuels) exposed to an average burnup of less than 25,000 MWd/MTHM or greater than 40,000 MWd/MTHM, the units of waste defined in (a) and (b) of Note 1 shall be adjusted. The unit shall be multiplied by the ratio of 30,000 MWd/MTHM divided by the fuel's actual average burnup, except that a value of 5 000 MWd/MTHM may be used when the average fuel burnup is below 5,000 MWd/MTHM and a value of 100,000 MWd/MTHM shall be used when the average fuel burnup is above 100,000 MWd/MTHM. This adjusted unit of waste shall then be used in determining the Release Limits for the disposal system.

For example, if a particular disposal system contained only high-level wastes with an average burnup of 3,000 MWd/MTHM, the unit of waste for that disposal system would be:

$$1{,}000 \text{ MTHM} \times \frac{(30{,}000)}{(5{,}000)} = 6{,}000 \text{ MTHM}$$

If that disposal system contained the high-level wastes from 60,000 MTHM (with an average burnup of 3,000 MWd/MTHM), then the Release Limits for that system would be the quantities in Table 1 multiplied by ten:

$$\frac{60{,}000 \text{ MTHM}}{6{,}000 \text{ MTHM}} = 10$$

which is the same as:

$$\frac{60{,}000 \text{ MTHM}}{1{,}000 \text{ MTHM}} \times \frac{(5{,}000 \text{ MWd/MTHM})}{(30{,}000 \text{ MWd/MTHM})} \quad 10$$

Note 4: *Treatment of Fractionated High-Level Wastes.* In some cases, a high-level waste stream from reprocessing spent nuclear fuel may have been (or will be) separated into two or more high-level waste components destined for different disposal systems. In such cases, the implementing agency may allocate the Release Limit multiplier (based upon the original MTHM and the average fuel burnup of the high-level waste stream) among the various disposal systems as it chooses, provided that the total Release Limit multiplier used for that waste stream at all of its disposal systems may not exceed the Release Limit multiplier that would be used if the entire waste stream were disposed of in one disposal system.

Note 5: *Treatment of Wastes with Poorly Known Burnups or Original MTHM.* In some cases, the records associated with particular high-level waste streams may not be adequate to accurately determine the original metric tons of heavy metal in the reactor fuel that created the waste, or to determine the average burnup that the fuel was exposed to. If the uncertainties are such that the original amount of heavy metal or the average fuel burnup for particular high-level waste streams cannot be quantified, the units of waste derived from (a) and (b) of Note 1 shall no longer be used. Instead, the units of waste defined in (c) and (d) of Note 1 shall be used for such high-level waste streams. If the uncertainties in such information allow a range of values to be associated with the original amount of heavy metal or the average fuel burnup, then the calculations described in previous Notes will be conducted using the values that result in the smallest Release Limits, except that the Release Limits need not be smaller than those that would be calculated using the units of waste defined in (c) and (d) of Note 1.

Note 6: *Uses of Release Limits to Determine Compliance with 191.13* Once release limits for a particular disposal system have been determined in accordance with Notes 1 through 5, these release limits shall be used to determine compliance with the requirements of 191.13 as follows. In cases where a mixture of radionuclides is projected to be released to the accessible environment, the limiting values shall be determined as follows: For each radionuclide in the mixture, determine the ratio between the cumulative release quantity projected over 10,000 years and the limit for that radionuclide as determined from Table 1 and Notes 1 through 5. The sum of such ratios for all the radionuclides in the mixture may not exceed one with regard to 191.13(a)(1) and may not exceed ten with regard to 191.13(a)(2).

For example, if radionuclides A, B, and C are projected to be released in amounts Q_a, Q_b, and Q_c, and if the applicable Release Limits are RL_a, RL_b, and RL_c, then the cumulative releases over 10,000 years shall be limited so that the following relationship exists:

$$\frac{Q_a}{RL_a} + \frac{Q_b}{RL_b} + \frac{Q_c}{RL_c} \leq 1$$

Appendix B—Guidance for Implementation of Subpart B

[**Note:** *The supplemental information in this appendix is not an integral part of 40 CFR Part 191. Therefore, the implementing agencies are not bound to follow this guidance. However, it is included because it describes the Agency's assumptions regarding the implementation of Subpart B. This appendix will appear in the Code of Federal Regulations.*]

The Agency believes that the implementing agencies must determine compliance with §§ 191.13, 191.15, and 191.16 of Subpart B by evaluating long-term predictions of disposal system performance. Determining compliance with § 191.13 will also involve predicting the likelihood of events and processes that may disturb the disposal system. In making these various predictions, it will be appropriate for the implementing agencies to make use of rather complex computational models, analytical theories, and prevalent expert judgment relevant to the numerical predictions. Substantial uncertainties are likely to be encountered in making these predictions. In fact, sole reliance on these numerical predictions to determine compliance may not be appropriate; the implementing agencies may choose to supplement such predictions with qualitative judgments as well. Because the procedures for determining compliance with Subpart B have not been formulated and tested yet, this appendix to the rule indicates the Agency's assumptions regarding certain issues that may arise when implementing §§ 191.13, 191.15, and 191.16. Most of this guidance applies to any type of disposal system for the wastes covered by this rule. However, several sections apply only to disposal in mined geologic repositories and would be inappropriate for other types of disposal systems.

Consideration of Total Disposal System. When predicting disposal system performance, the Agency assumes that reasonable projections of the protection expected from all of the engineered and natural barriers of a disposal system will be considered. Portions of the disposal system should not be disregarded, even if projected performance is uncertain, except for portions of the system that make negligible contributions to the overall isolation provided by the disposal system.

Scope of Performance Assessments. Section 191.13 requires the implementing agencies to evaluate compliance through performance assessments as defined in § 191.12(q). The Agency assumes that such performance assessments need not consider categories of events or processes that are estimated to have less than one chance in 10,000 of occurring over 10,000 years. Furthermore, the performance assessments need not evaluate in detail the releases from all events and processes estimated to have a greater likelihood of occurrence. Some of these events and processes may be omitted from the performance assessments if there is a reasonable expectation that the remaining probability distribution of cumulative releases would not be significantly changed by such omissions.

Compliance with Section 191.13. The Agency assumes that, whenever practicable, the implementing agency will assemble all of the results of the performance assessments to determine compliance with § 191.13 into a "complementary cumulative distribution function" that indicates the probability of exceeding various levels of cumulative release. When the uncertainties in parameters are considered in a performance assessment, the effects of the uncertainties considered can be incorporated into a single such distribution function for each disposal system considered. The Agency assumes that a disposal system can be considered to be in compliance with § 191.13 if this single distribution function meets the requirements of § 191.13(a).

Compliance with Sections 191.15 and 191.16. When the uncertainties in undisturbed performance of a disposal system are considered, the implementing agencies need not require that a very large percentage of the range of estimated radiation exposures or radionuclide concentrations fall below limits established in §§ 191.15 and 191.16, respectively. The Agency assumes that compliance can be determined based upon "best estimate" predictions (e.g., the mean or the median of the appropriate distribution, whichever is higher).

Institutional Controls. To comply with § 191.14(a), the implementing agency will assume that none of the active institutional controls prevent or reduce radionuclide releases for more than 100 years after disposal. However, the Federal Government is committed to retaining ownership of all disposal sites for spent nuclear fuel and high-level and transuranic radioactive wastes and will establish appropriate markers and records, consistent with § 191.14(c). The Agency assumes that, as long as such passive institutional controls endure and are understood, they: (1) can be effective in deterring systematic or persistent exploitation of these disposal sites; and (2) can reduce the likelihood of inadvertent, intermittent human intrusion to a degree to be determined by the implementing agency. However, the Agency believes that passive institutional controls can never be assumed to eliminate the chance of inadvertent and intermittent human intrusion into these disposal sites.

Consideration of Inadvertent Human Intrusion into Geologic Repositories. The most speculative potential disruptions of a mined geologic repository are those associated with inadvertent human intrusion. Some types of intrusion would have virtually no effect on a repository's containment of waste. On the other hand, it is possible to conceive of intrusions (involving widespread societal loss of knowledge regarding radioactive wastes) that could result in major disruptions that no reasonable repository selection or design precautions could alleviate. The Agency believes that the most productive consideration of inadvertent intrusion concerns those realistic possibilities that may be usefully mitigated by repository design, site selection, or use of passive controls (although passive institutional controls should not be assumed to completely rule out the possibility of intrusion). Therefore, inadvertent and intermittent intrusion by exploratory drilling for resources (other than any provided by the disposal system itself) can be the most severe intrusion scenario assumed by the implementing agencies. Furthermore, the implementing agencies can assume that passive institutional controls or the intruders' own exploratory procedures are adequate for the intruders to soon detect, or be warned of, the incompatibility of the area with their activities.

Frequency and Severity of Inadvertent Human Intrusion into Geologic Repositories. The implementing agencies should consider the effects of each particular disposal system's site, design, and passive institutional controls in judging the likelihood and consequences of such inadvertent exploratory drilling. However, the Agency assumes that the likelihood of such inadvertent and intermittent drilling need not be taken to be greater than 30 boreholes per square kilometer of repository area per 10,000 years for geologic repositories in proximity to sedimentary rock formations, or more than 3 boreholes per square kilometer per 10,000 years for repositories in other geologic formations. Furthermore, the Agency assumes that the consequences of such inadvertent drilling need not be assumed to be more severe than: (1) Direct release to the land surface of all the ground water in the repository horizon that would promptly flow through the newly created borehole to the surface due to natural lithostatic pressure—or (if pumping would be required to raise water to the surface) release of 200 cubic meters of ground water pumped to the surface if that much water is readily available to be pumped; and (2) creation of a ground water flow path with a permeability typical of a borehole filled by the soil or gravel that would normally settle into an open hole over time—not the permeability of a carefully sealed borehole.

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Performance Objectives

§ 60.111 Performance of the geologic repository operations area through permanent closure.

(a) *Protection against radiation exposures and releases of radioactive material.* The geologic repository operations area shall be designed so that until permanent closure has been completed, radiation exposures and radiation levels, and releases of radioactive materials to unrestricted areas, will at all times be maintained within the limits specified in Part 20 of this chapter and such generally applicable environmental standards for radioactivity as may have been established by the Environmental Protection Agency.

(b) *Retrievability of waste.* (1) The geologic repository operations area shall be designed to preserve the option of waste retrieval throughout the period during which wastes are being emplaced and, thereafter, until the completion of a preformance confirmation program and Commission review of the information obtained from such a program. To satisfy this objective, the geologic repository operations area shall be designed so that any or all of the emplaced waste could be retrieved on a reasonable schedule starting at any time up to 50 years after waste emplacement operations are initiated, unless a different time period is approved or specified by the Commission. This different time period may be established on a case-by-case basis consistent with the emplacement schedule and the planned performance confirmation program.

(2) This requirement shall not preclude decisions by the Commission to allow backfilling part or all of, or permanent closure of, the geologic repository operations area prior to the end of the period of design for retrievability.

(3) For purposes of this paragraph, a reasonable schedule for retrieval is one that would permit retrieval in about the same time as that devoted to construction of the geologic repository operations area and the emplacement of wastes.

§ 60.112 Overall system performance objective for the geologic repository after permanent closure.

The geologic setting shall be selected and the engineered barrier system and the shafts, boreholes and their seals shall be designed to assure that releases of radioactive materials to the accessible environment following permanent closure conform to such generally applicable environmental standards for radioactivity as may have been established by the Environmental Protection Agency with respect to both anticipated processes and events and unanticipated processes and events.

§ 60.113 Performance of particular barriers after permanent closure.

(a) *General provisions.* (1) *Engineered barrier system.* (i) The engineered barrier system shall be designed so that assuming anticipated processes and events: (A) Containment of HLW will be substantially complete during the period when radiation and thermal conditions in the engineered barrier system are dominated by fission product decay; and (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long times. For disposal in the saturated zone, both the partial and complete filling with groundwater of available void spaces in the underground facility shall be appropriately considered and analysed among the anticipated processes and events in designing the engineered barrier system.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that:

(A) Containment of HLW within the waste packages will be substantially complete for a period to be determined by the Commission taking into account the factors specified in § 60.113(b) provided, that such period shall be not less than 300 years nor more than 1,000 years after permanent closure of the geologic repository; and

(B) The release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the underground facility, that remains after 1,000 years of radioactive decay.

(2) *Geologic setting.* The geologic repository shall be located so that pre-waste-emplacement groundwater travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment shall be at least 1,000 years or such other travel time as may be approved or specified by the Commission.

(b) On a case-by-case basis, the Commission may approve or specify some other radionuclide release rate, designed containment period or pre-waste-emplacement groundwater travel time, provided that the overall system performance objective, as it relates to anticipated processes and events, is satisfied. Among the factors that the Commission may take into account are—

(1) Any generally applicable environmental standard for radioactivity established by the Environmental Protection Agency;

(2) The age and nature of the waste, and the design of the underground facility, particularly as these factors bear upon the time during which the thermal pulse is dominated by the decay heat from the fission products;

(3) The geochemical characteristics of the host rock, surrounding strata and groundwater; and

(4) Particular sources of uncertainty in predicting the performance of the geologic repository.

(c) Additional requirements may be found to be necessary to satisfy the overall system performance objective as it relates to unanticipated processes and events.

Land Ownership and Control

§ 60.121 Requirements for ownership and control of interests in land.

(a) *Ownership of land.* (1) Both the geologic repository operations area and the controlled area shall be located in and on lands that are either acquired lands under the jurisdiction and control of DOE, or lands permanently withdrawn and reserved for its use.

(2) These lands shall be held free and clear of all encumbrances, if significant, such as: (i) Rights arising under the general mining laws; (ii) easements for right-of-way; and (iii) all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise.

(b) *Additional controls.* Appropriate controls shall be established outside of the controlled area. DOE shall exercise any jurisdiction and control over surface and subsurface estates necessary to prevent adverse human actions that could significantly reduce the geologic repository's ability to achieve isolation. The rights of DOE may take the form of appropriate possessory interests, servitudes, or withdrawals from location or patent under the general mining laws.

(c) *Water rights.* (1) DOE shall also have obtained such water rights as may be needed to accomplish the purpose of the geologic repository operations area

(2) Water rights are included in the additional controls to be established under paragraph (b) of this section.

Siting Criteria

§ 60.122 Siting criteria.

(a)(1) A geologic setting shall exhibit an appropriate combination of the conditions specified in paragraph (b) of this section so that, together with the engineered barriers system, the favorable conditions present are sufficient to provide reasonable assurance that the performance objectives relating to isolation of the waste will be met.

(2) If any of the potentially adverse conditions specified in paragraph (c) of this section is present, it may compromise the ability of the geologic repository to meet the performance objectives relating to isolation of the waste In order to show that a potentially adverse condition does not so compromise the performance of the geologic repository the following must be demonstrated:

(i) The potentially adverse human activity or natural condition has been adequately investigated, including the extent to which the condition may be present and still be undetected taking into account the degree of resolution achieved by the investigations, and

(ii) The effect of the potentially adverse human activity or natural condition on the site has been adequately evaluated using analyses which are sensitive to the potentially adverse human activity or natural condition and assumptions which are not likely to underestimate its effect, and

(iii)(A) The potentially adverse human activity or natural condition is shown by analysis pursuant to paragraph (a)(2)(ii) of this section not to affect significantly the ability of the geologic repository to meet the performance objectives relating to isolation of the waste, or

(B) The effect of the potentially adverse human activity or natural condition is compensated by the presence of a combination of the favorable characteristics so that the performance objectives relating to isolation of the waste are met, or

(C) The potentially adverse human activity or natural condition can be remedied.

(b) *Favorable conditions.* (1) The nature and rates of tectonic, hydrogeologic, geochemical, and geomorphic processes (or any of such processes) operating within the geologic setting during the Quaternary Period, when projected, would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(2) For disposal in the saturated zone, hydrogeologic conditions that provide—

(i) A host rock with low horizontal and vertical permeability;

(ii) Downward or dominantly horizontal hydraulic gradient in the host rock and immediately surrounding hydrogeologic units; and

(iii) Low vertical permeability and low hydraulic gradient between the host rock and the surrounding hydrogeologic units

(3) Geochemical conditions that—(i) Promote precipitation or sorption of radionuclides; (ii) Inhibit the formation of particulates, colloids, and inorganic and organic complexes that increase the mobility of radionuclides; or (iii) Inhibit the transport of radionuclides by particulates, colloids, and complexes

(4) Mineral assemblages that, when subjected to anticipated thermal loading, will remain unaltered or alter to mineral assemblages having equal or increased capacity to inhibit radionuclide migration

(5) Conditions that permit the emplacement of waste at a minimum depth of 300 meters from the ground surface. (The ground surface shall be deemed to be the elevation of the lowest point on the surface above the disturbed zone)

(6) A low population density within the geologic setting and a controlled area that is remote from population centers

(7) Pre-waste-emplacement groundwater travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment that substantially exceeds 1,000 years

(8) For disposal in the unsaturated zone, hydrogeologic conditions that provide—

(i) Low moisture flux in the host rock and in the overlying and underlying hydrogeologic units,

(ii) A water table sufficiently below the underground facility such that fully saturated voids contiguous with the water table do not encounter the underground facility;

(iii) A laterally extensive low-permeability hydrogeologic unit above the host rock that would inhibit the downward movement of water or divert downward moving water to a location beyond the limits of the underground facility,

(iv) A host rock that provides for free drainage, or

(v) A climatic regime in which the average annual historic precipitation is a small percentage of the average annual potential evapotranspiration

(c) *Potentially adverse conditions.* The following conditions are potentially adverse conditions if they are characteristic of the controlled area or may affect isolation within the controlled area.

(1) Potential for flooding of the underground facility, whether resulting from the occupancy and modification of floodplains or from the failure of existing or planned man-made surface water impoundments.

(2) Potential for foreseeable human activity to adversely affect the groundwater flow system, such as groundwater withdrawal, extensive irrigation, subsurface injection of fluids, underground pumped storage, military activity or construction of large scale surface water impoundments.

(3) Potential for natural phenomena such as landslides, subsidence, or volcanic activity of such a magnitude that large-scale surface water impoundments could be created that could change the regional groundwater flow system and thereby adversely affect the performance of the geologic repository.

(4) Structural deformation, such as uplift, subsidence, folding, or faulting that may adversely affect the regional groundwater flow system.

(5) Potential for changes in hydrologic conditions that would affect the migration of radionuclides to the accessible environment, such as changes in hydraulic gradient, average interstitial velocity, storage coefficient, hydraulic conductivity, natural recharge, potentiometric levels, and discharge points.

(6) Potential for changes in hydrologic conditions resulting from reasonably foreseeable climatic changes.

(7) Groundwater conditions in the host rock, including chemical composition, high ionic strength or ranges of Eh-pH, that could increase the solubility or chemical reactivity of the engineered barrier system.

(8) Geochemical processes that would reduce sorption of radionuclides, result in degradation of the rock strength, or adversely affect the performance of the engineered barrier system.

(9) Groundwater conditions in the host rock that are not reducing

(10) Evidence of dissolutioning such as breccia pipes, dissolution cavities, or brine pockets.

(11) Structural deformation such as uplift, subsidence, folding, and faulting during the Quaternary Period.

(12) Earthquakes which have occurred historically that if they were to be repeated could affect the site significantly.

(13) Indications, based on correlations of earthquakes with tectonic processes and features, that either the frequency of occurrence or magnitude of earthquakes may increase.

(14) More frequent occurrence of earthquakes or earthquakes of higher magnitude than is typical of the area in which the geologic setting is located.

(15) Evidence of igneous activity since the start of the Quaternary Period.

(16) Evidence of extreme erosion during the Quaternary Period.

(17) The presence of naturally

occurring materials, whether identified or undiscovered, within the site, in such form that:

(i) Economic extraction is currently feasible or potentially feasible during the foreseeable future; or

(ii) Such materials have greater gross value or net value than the average for other areas of similar size that are representative of and located within the geologic setting.

(18) Evidence of subsurface mining for resources within the site.

(19) Evidence of drilling for any purpose within the site.

(20) Rock or groundwater conditions that would require complex engineering measures in the design and construction of the underground facility or in the sealing of boreholes and shafts.

(21) Geomechanical properties that do not permit design of underground opening that will remain stable through permanent closure.

(22) Potential for the water table to rise sufficiently so as to cause saturation of an underground facility located in the unsaturated zone.

(23) Potential for existing or future perched water bodies that may saturate portions of the underground facility or provide a faster flow path from an underground facility located in the unsaturated zone to the accessible environment.

(24) Potential for the movement of radionuclides in a gaseous state through air-filled pore spaces of an unsaturated geologic medium to the accessible environment.

Design Criteria for the Geologic Repository Operations Area

§ 60.130 Scope of design criteria for the geologic repository operations area.

Sections 60.131 through 60.134 specify minimum criteria for the design of the geologic repository operations area. These design criteria are not intended to be exhaustive, however. Omissions in §§ 60.131 through 60.134 do not relieve DOE from any obligation to provide such safety features in a specific facility needed to achieve the performance objectives. All design bases must be consistent with the results of site characterization activities.

§ 60.131 General design criteria for the geologic repository operations area.

(a) *Radiological protection.* The geologic repository operations area shall be designed to maintain radiation doses, levels, and concentrations of radioactive material in air in restricted areas within the limits specified in Part 20 of this chapter. Design shall include—

(1) Means to limit concentrations of radioactive material in air;

(2) Means to limit the time required to perform work in the vicinity of radioactive materials, including, as appropriate, designing equipment for ease of repair and replacement and providing adequate space for ease of operation;

(3) Suitable shielding;

(4) Means to monitor and control the dispersal of radioactive contamination;

(5) Means to control access to high radiation areas or airborne radioactivity areas; and

(6) A radiation alarm system to warn of significant increases in radiation levels, concentrations of radioactive material in air, and of increased radioactivity released in effluents. The alarm system shall be designed with provisions for calibration and for testing its operability.

(b) *Structures, systems, and components important to safety. (1) Protection against natural phenomena and environmental conditions.* The structures, systems, and components important to safety shall be designed so that natural phenomena and environmental conditions anticipated at the geologic repository operations area will not interfere with necessary safety functions.

(2) *Protection against dynamic effects of equipment failure and similar events.* The structures, systems, and components important to safety shall be designed to withstand dynamic effects such as missile impacts, that could result from equipment failure, and similar events and conditions that could lead to loss of their safety functions.

(3) *Protection against fires and explosions.* (i) The structures, systems, and components important to safety shall be designed to perform their safety fuctions during and after credible fires or explosions in the geologic repository operations area.

(ii) To the extent practicable, the geologic repository operations area shall be designed to incorporate the use of noncombustible and heat resistant materials.

(iii) The geologic repository operations area shall be designed to include explosion and fire detection alarm systems and appropriate suppression systems with sufficient capacity and capability to reduce the adverse effects of fires and explosions on structures, systems, and components important to safety.

(iv) The geologic repository operations area shall be designed to include means to protect systems, structures, and components important to safety against the adverse effects of either the operation or failure of the fire suppression systems.

(4) *Emergency capability.* (i) The structures, systems, and components important to safety shall be designed to maintain control of radioactive waste and radioactive effluents, and permit prompt termination of operations and evacuation of personnel during an emergency.

(ii) The geologic repository operations area shall be designed to include onsite facilities and services that ensure a safe and timely response to emergency conditions and that facilitate the use of available offsite services (such as fire, police, medical and ambulance service) that may aid in recovery from emergencies.

(5) *Utility services.* (i) Each utility service system that is important to safety shall be designed so that essential safety functions can be performed under both normal and accident conditions.

(ii) The utility services important to safety shall include redundant systems to the extent necessary to maintain, with adequate capacity, the ability to perform their safety functions.

(iii) Provisions shall be made so that, if there is a loss of the primary electric power source or circuit, reliable and timely emergency power can be provided to instruments, utility service systems, and operating systems, including alarm systems, important to safety.

(6) *Inspection, testing, and maintenance.* The structures, systems, and components important to safety shall be designed to permit periodic inspection, testing, and maintenance, as necessary, to ensure their continued functioning and readiness.

(7) *Criticality control.* All systems for processing, transporting, handling, storage, retrieval, emplacement, and isolation of radioactive waste shall be designed to ensure that a nuclear criticality accident is not possible unless at least two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety. Each system shall be designed for criticality safety under normal and accident conditions. The calculated effective multiplication factor (k_{eff}) must be sufficiently below unity to show at least a 5% margin, after allowance for the bias in the method of calculation and the uncertainty in the experiments used to validate the method of calculation.

(8) *Instrumentation and control systems.* The design shall include provisions for instrumentation and control systems to monitor and control the behavior of systems important to safety over anticipated ranges for normal operation and for accident conditions.

(9) *Compliance with mining regulations.* To the extent that DOE is not subject to the Federal Mine Safety and Health Act of 1977, as to the construction and operation of the geologic repository operations area, the design of the geologic repository operations area shall nevertheless include such provisions for worker protection as may be necessary to provide reasonable assurance that all structures, systems, and components important to safety can perform their intended functions. Any deviation from relevant design requirements in 30 CFR, Chapter I, Subchapters D, E, and N will give rise to a rebuttable presumption that this requirement has not been met.

(10) *Shaft conveyances used in radioactive waste handling.* (i) Hoists important to safety shall be designed to preclude cage free fall.

(ii) Hoists important to safety shall be designed with a reliable cage location system.

(iii) Loading and unloading systems for hoists important to safety shall be designed with a reliable system of interlocks that will fail safely upon malfunction.

(iv) Hoists important to safety shall be designed to include two independent indicators to indicate when waste packages are in place and ready for transfer.

§ 60.132 Additional design criteria for surface facilities in the geologic repository operations area.

(a) *Facilities for receipt and retrieval of waste.* Surface facilities in the geologic repository operations area shall be designed to allow safe handling and storage of wastes at the geologic repository operations area, whether these wastes are on the surface before emplacement or as a result of retrieval from the underground facility.

(b) *Surface facility ventilation.* Surface facility ventilation systems supporting waste transfer, inspection, decontamination, processing, or packaging shall be designed to provide protection against radiation exposures and offsite releases as provided in § 60.111(a).

(c) *Radiation control and monitoring.* (1) *Effluent control.* The surface facilities shall be designed to control the release of radioactive materials in effluents during normal operations so as to meet the performance objections of § 60.111(a).

(2) *Effluent monitoring.* The effluent monitoring systems shall be designed to measure the amount and concentration of radionuclides in any effluent with sufficient precision to determine whether releases conform to the design requirement for effluent control. The monitoring systems shall be designed to include alarms that can be periodically tested.

(d) *Waste treatment.* Radioactive waste treatment facilities shall be designed to process any radioactive wastes generated at the geologic repository operations area into a form suitable to permit safe disposal at the geologic repository operations area or to permit safe transportation and conversion to a form suitable for disposal at an alternative site in accordance with any regulations that are applicable.

(e) *Consideration of decommissioning.* The surface facility shall be designed to facilitate decontamination or dismantlement to the same extent as would be required, under other parts of this chapter, with respect to equivalent activities licensed thereunder.

§ 60.133 Additional design criteria for the underground facility.

(a) *General criteria for the underground facility.* (1) The orientation, geometry, layout, and depth of the underground facility, and the design of any engineered barriers that are part of the underground facility shall contribute to the containment and isolation of radionuclides.

(2) The underground facility shall be designed so that the effects of credible disruptive events during the period of operations, such as flooding, fires and explosions, will not spread through the facility.

(b) *Flexibility of design.* The underground facility shall be designed with sufficient flexibility to allow adjustments where necessary to accommodate specific site conditions identified through in situ monitoring, testing, or excavation.

(c) *Retrieval of waste.* The underground facility shall be designed to permit retrieval of waste in accordance with the performance objectives of § 60.111.

(d) *Control of water and gas.* The design of the underground facility shall provide for control of water or gas intrusion.

(e) *Underground openings.* (1) Openings in the underground facility shall be designed so that operations can be carried out safely and the retrievability option maintained.

(2) Openings in the underground facility shall be designed to reduce the potential for deleterious rock movement or fracturing of overlying or surrounding rock.

(f) Rock excavation. The design of the underground facility shall incorporate excavation methods that will limit the potential for creating a preferential pathway for groundwater to contact the waste packages or radionuclide migration to the accessible environment.

(g) *Underground facility ventilation.* The ventilation system shall be designed to—(1) Control the transport of radioactive particulates and gases within and releases from the underground facility in accordance with the performance objectives of § 60.111(a).

(2) Assure continued function during normal operations and under accident conditions; and

(3) Separate the ventilation of excavation and waste emplacement areas.

(h) *Engineered barriers.* Engineered barriers shall be designed to assist the geologic setting in meeting the performance objectives for the period following permanent closure.

(i) *Thermal loads.* The underground facility shall be designed so that the performance objectives will be met taking into account the predicted thermal and thermomechanical response of the host rock, and surrounding strata, groundwater system.

§ 60.134 Design of seals for shafts and boreholes.

(a) *General design criterion.* Seals for shafts and boreholes shall be designed so that following permanent closure they do not become pathways that compromise the geologic repository's ability to meet the performance objectives or the period following permanent closure.

(b) *Selection of materials and placement methods.* Materials and placement methods for seals shall be selected to reduce, to the extent practicable:

(1) The potential for creating a preferential pathway for groundwater to contact the waste packages or (2) for radionuclide migration through existing pathways.

Design Criteria for the Waste Package

§ 60.135 Criteria for the waste package and its components.

(a) *High-level-waste package design in general.* (1) Packages for HLW shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages or the performance of the underground facility or the geologic setting.

(2) The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

(b) *Specific criteria for HLW package design. (1) Explosive, pyrophoric, and chemically reactive materials.* The waste package shall not contain explosive or pyrophoric materials or chemically reactive materials in an amount that could compromise the ability of the underground facility to contribute to waste isolation or the ability of the geologic repository to satisfy the performance objectives.

(2) *Free liquids.* The waste package shall not contain free liquids in an amount that could compromise the ability of the waste packages to achieve the performance objectives relating to containment of HLW (because of chemical interactions or formation of pressurized vapor) or result in spillage and spread of contamination in the event of waste package perforation during the period through permanent closure.

(3) *Handling.* Waste packages shall be designed to maintain waste containment during transportation, emplacement, and retrieval.

(4) *Unique identification.* A label or other means of identification shall be

provided for each waste package. The identification shall not impair the integrity of the waste package and shall be applied in such a way that the information shall be legible at least to the end of the period of retrievability. Each waste package identification shall be consistent with the waste package's permanent written records.

(c) *Waste form criteria for HLW. High-level radioactive waste that is emplaced in the underground facility shall be designed to meet the following criteria:*

(1) *Solidification.* All such radioactive wastes shall be in solid form and placed in sealed containers.

(2) *Consolidation.* Particulate waste forms shall be consolidated (for example, by incorporation into an encapsulating matrix) to limit the availability and generation of particulates.

(3) *Combustibles.* All combustible radioactive wastes shall be reduced to a noncombustible form unless it can be demonstrated that a fire involving the waste packages containing combustibles will not compromise the integrity of other waste packages, adversely affect any structures, systems, or components important to safety, or compromise the ability of the underground facility to contribute to waste isolation.

(d) *Design criteria for other radioactive wastes.* Design criteria for waste types other than HLW will be addressed on an individual basis if and when they are proposed for disposal in a geologic repository.

Performance Confirmation Requirements

§ 60.137 General requirements for performance confirmation.

The geologic repository operations area shall be designed so as to permit implementation of a performance confirmation program that meets the requirements of Subpart F of this part.

Subpart C—Postclosure Guidelines

§ 960.4 Postclosure guidelines.

The guidelines in this Subpart specify the factors to be considered in evaluating and comparing sites on the basis of expected repository performance after closure. The postclosure guidelines are separated into a system guideline and eight technical guidelines. The system guideline establishes waste containment and isolation requirements that are based on NRC and EPA regulations. These requirements must be met by the repository system, which contains natural barriers and engineered barriers. The engineered barriers will be designed to complement the natural barriers, which provide the primary means for waste isolation.

§ 960.4-1 System guideline.

(a) *Qualifying Condition.* The geologic setting at the site shall allow for the physical separation of radioactive waste from the accessible environment after closure in accordance with the requirements of 40 CFR Part 191, Subpart B, as implemented by the provisions of 10 CFR Part 60. The geologic setting at the site will allow for the use of engineered barriers to ensure compliance with the requirements of 40 CFR Part 191 and 10 CFR Part 60 (see Appendix I of this Part).

§ 960.4-2 Technical guidelines.

The technical guidelines in this Subpart set forth qualifying, favorable, potentially adverse, and, in five guidelines, disqualifying conditions on the characteristics, processes, and events that may influence the performance of a repository system after closure. The favorable conditions and the potentially adverse conditions under each guideline are *not* listed in any assumed order of importance.

§ 960.4-2-1 Geohydrology.

(a) *Qualifying Condition.* The present and expected geohydrologic setting of a site shall be compatible with waste containment and isolation. The geohydrologic setting, considering the characteristics of and the processes operating within the geologic setting, shall permit compliance with (1) the requirements specified in § 960.4-1 for radionuclide releases to the accessible environment and (2) the requirements specified in 10 CFR 60.113 for radionuclide releases from the engineered-barrier system using reasonably available technology.

(b) *Favorable Conditions.* (1) Site conditions such that the pre-waste-emplacement ground-water travel time along any path of likely radionuclide travel from the disturbed zone to the accessible environment would be more than 10,000 years.

(2) The nature and rates of hydrologic processes operating within the geologic setting during the Quaternary Period would, if continued into the future, not affect or would favorably affect the ability of the geologic repository to isolate the waste during the next 100,000 years.

(3) Sites that have stratigraphic, structural, and hydrologic features such that the geohydrologic system can be readily characterized and modeled with reasonable certainty.

(4) For disposal in the saturated zone, at least one of the following pre-waste-emplacement conditions exists:

(i) A host rock and immediately surrounding geohydrologic units with low hydraulic conductivities.

(ii) A downward or predominantly horizontal hydraulic gradient in the host rock and in the immediately surrounding geohydrologic units.

(iii) A low hydraulic gradient in and between the host rock and the immediately surrounding geohydrologic units.

(iv) High effective porosity together with low hydraulic conductivity in rock units along paths of likely radionuclide travel between the host rock and the accessible environment.

(5) For disposal in the unsaturated zone, at least one of the following pre-waste-emplacement conditions exists:

(i) A low and nearly constant degree of saturation in the host rock and in the immediately surrounding geohydrologic units.

(ii) A water table sufficiently below the underground facility such that the fully saturated voids continuous with the water table do not encounter the host rock.

(iii) A geohydrologic unit above the host rock that would divert the downward infiltration of water beyond the limits of the emplaced waste.

(iv) A host rock that provides for free drainage.

(v) A climatic regime in which the average annual historical precipitation is a small fraction of the average annual potential evapotranspiration.

Note.—The DOE will, in accordance with the general principles set forth in § 960.1 of these regulations, revise the guidelines as necessary, to ensure consistency with the final NRC regulations on the unsaturated zone, which were published as a proposed rule on February 16, 1984, in 49 FR 5934.

(c) *Potentially Adverse Conditions.* (1) Expected changes in geohydrologic conditions—such as changes in the hydraulic gradient, the hydraulic conductivity, the effective porosity, and the ground-water flux through the host rock and the surrounding geohydrologic units—sufficient to significantly increase the transport of radionuclides to the accessible environment as compared with pre-waste-emplacement conditions.

(2) The presence of ground-water sources, suitable for crop irrigation or human consumption without treatment, along ground-water flow paths from the host rock to the accessible environment.

(3) The presence in the geologic setting of stratigraphic or structural features—such as dikes, sills, faults, shear zones, folds, dissolution effects, or brine pockets—if their presence could significantly contribute to the difficulty of characterizing or modeling the geohydrologic system.

(d) *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.

§ 960.4-2-2 Geochemistry.

(a) *Qualifying Condition.* The present and expected geochemical characteristics of a site shall be compatible with waste containment and isolation. Considering the likely chemical interactions among radionuclides, the host rock, and the ground water, the characteristics of and the processes operating within the geologic setting shall permit compliance with (1) the requirements specified in § 960.4-1 for radionuclide releases to the accessible environment and (2) the requirements specified in 10 CFR 60.113 for radionuclide releases from the engineered-barrier system using reasonably available technology.

(b) *Favorable Conditions.* (1) The nature and rates of the geochemical processes operating within the geologic setting during the Quaternary Period would, if continued into the future, not affect or would favorably affect the ability of the geologic repository to isolate the waste during the next 100,000 years.

(2) Geochemical conditions that promote the precipitation, diffusion into the rock matrix, or sorption of radionuclides; inhibit the formation of particulates, colloids, inorganic complexes, or organic complexes that increase the mobility of radionuclides; or inhibit the transport of radionuclides by particulates, colloids, or complexes.

(3) Mineral assemblages that, when subjected to expected repository conditions, would remain unaltered or would alter to mineral assemblages with equal or increased capability to retard radionuclide transport.

(4) A combination of expected geochemical conditions and a volumetric flow rate of water in the host rock that would allow less than 0.001 percent per year of the total radionuclide inventory in the repository at 1,000 years to be dissolved.

(5) Any combination of geochemical and physical retardation processes that would decrease the predicted peak cumulative releases of radionuclides to the accessible environment by a factor of 10 as compared to those predicted on the basis of ground-water travel time without such retardation.

(c) *Potentially Adverse Conditions.* (1) Ground-water conditions in the host rock that could affect the solubility or the chemical reactivity of the engineered-barrier system to the extent that the expected repository performance could be compromised.

(2) Geochemical processes or conditions that could reduce the sorption of radionuclides or degrade the rock strength.

(3) Pre-waste-emplacement ground-water conditions in the host rock that are chemically oxidizing.

§ 960.4-2-3 Rock characteristics.

(a) *Qualifying condition.* The present and expected characteristics of the host rock and surrounding units shall be capable of accommodating the thermal, chemical, mechanical, and radiation stresses expected to be induced by repository construction, operation, and closure and by expected interactions among the waste, host rock, ground water, and engineered components. The characteristics of and the processes operating within the geologic setting shall permit compliance with (1) the requirements specified in § 960.4-1 for radionuclide releases to the accessible environment and (2) the requirements set forth in 10 CFR 60.113 for radionuclide releases from the engineered-barrier system using reasonably available technology.

(b) *Favorable Conditions.* (1) A host rock that is sufficiently thick and laterally extensive to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation.

(2) A host rock with a high thermal conductivity, a low coefficient of thermal expansion, or sufficient ductility to seal fractures induced by repository construction, operation, or closure or by interactions among the waste, host rock, ground water, and engineered components.

(c) *Potentially Adverse Conditions.* (1) Rock conditions that could require engineering measures beyond reasonably available technology for the construction, operation, and closure of the repository, if such measures are necessary to ensure waste containment or isolation.

(2) Potential for such phenomena as thermally induced fractures, the hydration or dehydration of mineral components, brine migration, or other physical, chemical, or radiation-related phenomena that could be expected to affect waste containment or isolation.

(3) A combination of geologic structure, geochemical and thermal properties, and hydrologic conditions in the host rock and surrounding units such that the heat generated by the waste could significantly decrease the isolation provided by the host rock as compared with pre-waste-emplacement conditions.

§ 960.4-2-4 Climatic changes.

(a) *Qualifying Condition.* The site shall be located where future climatic conditions will not be likely to lead to radionuclide releases greater than those allowable under the requirements specified in § 960.4-1. In predicting the likely future climatic conditions at a site, the DOE will consider the global, regional, and site climatic patterns during the Quaternary Period, considering the geomorphic evidence of the climatic conditions in the geologic setting.

(b) *Favorable Conditions.* (1) A surface-water system such that expected climatic cycles over the next 100,000 years would not adversely affect waste isolation.

(2) A geologic setting in which climatic changes have had little effect on the hydrologic system throughout the Quaternary Period.

(c) *Potentially Adverse Conditions.* (1) Evidence that the water table could rise sufficiently over the next 10,000 years to saturate the underground facility in a previously unsaturated host rock.

(2) Evidence that climatic changes over the next 10,000 years could cause perturbations in the hydraulic gradient, the hydraulic conductivity, the effective porosity, or the ground-water flux through the host rock and the surrounding geohydrologic units, sufficient to significantly increase the transport of radionuclides to the accessible environment.

§ 960.4-2-5 Erosion.

(a) *Qualifying Condition.* The site shall allow the underground facility to be placed at a depth such that erosional processes acting upon the surface will not be likely to lead to radionuclide releases greater than those allowable under the requirements specified in § 960.4-1. In predicting the likelihood of potentially disruptive erosional processes, the DOE will consider the climatic, tectonic, and geomorphic evidence of rates and patterns of erosion in the geologic setting during the Quaternary Period.

(b) *Favorable Conditions.* (1) Site conditions that permit the emplacement of waste at a depth of at least 300 meters below the directly overlying ground surface.

(2) A geologic setting where the nature and rates of the erosional processes that have been operating during the Quaternary Period are predicted to have less than one chance in 10,000 over the next 10,000 years of leading to releases of radionuclides to the accessible environment.

(3) Site conditions such that waste exhumation would not be expected to occur during the first one million years after repository closure.

(c) *Potentially Adverse Conditions.* (1) A geologic setting that shows evidence of extreme erosion during the Quaternary Period.

(2) A geologic setting where the nature and rates of geomorphic processes that have been operating during the Quaternary Period could, during the first 10,000 years after closure, adversely affect the ability of the geologic repository to isolate the waste.

(d) *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.

§ 960.4-2-6 Dissolution.

(a) *Qualifying Condition.* The site shall be located such that any subsurface rock dissolution will not be likely to lead to radionuclide releases greater than those allowable under the requirements specified in § 960.4-1. In predicting the likelihood of dissolution within the geologic setting at a site, the DOE will consider the evidence of dissolution within that setting during the Quaternary Period, including the locations and characteristics of dissolution fronts or other dissolution features, if identified.

(b) *Favorable Condition.* No evidence that the host rock within the site was subject to significant dissolution during the Quaternary Period.

(c) *Potentially Adverse Condition.* Evidence of dissolution within the geologic setting—such as breccia pipes, dissolution cavities, significant volumetric reduction of the host rock or surrounding strata, or any structural collapse—such that a hydraulic interconnection leading to a loss of waste isolation could occur.

(d) *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.

§ 960.4-2-7 Tectonics.

(a) *Qualifying Condition.* The site shall be located in a geologic setting where future tectonic processes or events will not be likely to lead to radionuclide releases greater than those allowable under the requirements specified in § 960.4-1. In predicting the likelihood of potentially disruptive tectonic processes or events, the DOE will consider the structural, stratigraphic, geophysical, and seismic evidence for the nature and rates of tectonic processes and events in the geologic setting during the Quaternary Period.

(b) *Favorable Condition.* The nature and rates of igneous activity and tectonic processes (such as uplift, subsidence, faulting, or folding), if any, operating within the geologic setting during the Quaternary Period would, if continued into the future, have less than one chance in 10,000 over the first 10,000 years after closure of leading to releases of radionuclides to the accessible environment.

(c) *Potentially Adverse Conditions.* (1) Evidence of active folding, faulting, diapirism, uplift, subsidence, or other tectonic processes or igneous activity within the geologic setting during the Quaternary Period.

(2) Historical earthquakes within the geologic setting of such magnitude and intensity that, if they recurred, could affect waste containment or isolation.

(2) Indications, based on correlations of earthquakes with tectonic processes and features, that either the frequency of occurrence or the magnitude of earthquakes within the geologic setting may increase.

(4) More-frequent occurrences of earthquakes or earthquakes of higher magnitude than are representative of the region in which the geologic setting is located.

(5) Potential for natural phenomena such as landslides, subsidence, or volcanic activity of such magnitudes that they could create large-scale surface-water impoundments that could change the regional ground-water flow system.

(6) Potential for tectonic deformations—such as uplift, subsidence, folding, or faulting—that could adversely affect the regional ground-water flow system.

(d) *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.

§ 960.4-2-8 Human interference.

The site shall be located such that activities by future generations at or near the site will not be likely to affect waste containment and isolation. In assessing the likelihood of such activities, the DOE will consider the estimated effectiveness of the permanent markers and records required by 10 CFR Part 60, taking into account site-specific factors, as stated in §§ 960.4-2-8-1 and 960.4-2-8-2, that could compromise their continued effectiveness.

§ 960.4-2-8-1 Natural resource.

(a) *Qualifying Condition.* This site shall be located such that—considering permanent markers and records and reasonable projections of value, scarcity, and technology—the natural resources, including ground water suitable for crop irrigation or human consumption without treatment, present at or near the site will not be likely to give rise to interference activities that would lead to radionuclide releases greater than those allowable under the requirements specified in § 960.4–1.

(b) *Favorable Conditions.* (1) No known natural resources that have or are projected to have in the foreseeable future a value great enough to be considered a commercially extractable resource.

(2) Ground water with 10,000 parts per million or more of total dissolved solids along any path of likely radionuclide travel from the host rock to the accessible environment.

(c) *Potentially Adverse Conditions.* (1) Indications that the site contains naturally occurring materials, whether or not actually identified in such form that (i) economic extraction is potentially feasible during the foreseeable future or (ii) such materials have a greater gross value, net value, or commercial potential than the average for other areas of similar size that are representative of, and located in, the geologic setting.

(2) Evidence of subsurface mining or extraction for resources within the site if it could affect waste containment or isolation.

(3) Evidence of drilling within the site for any purpose other than repository-site evaluation to a depth sufficient to affect waste containment and isolation.

(4) Evidence of a significant concentration of any naturally occurring material that is not widely available from other sources.

(5) Potential for foreseeable human activities—such as ground-water withdrawal, extensive irrigation, subsurface injection of fluids, underground pumped storage, military activities, or the construction of large-scale surface-water impoundments—that could adversely change portions of the ground-water flow system important to waste isolation.

(d) *Disqualifying Conditions.* 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.

§ 960.4-2-8-2 Site ownership and control.

(a) *Qualifying Condition.* The site shall be located on land for which the DOE can obtain, in accordance with the requirements of 10 CFR Part 60, ownership, surface and subsurface rights, and control of access that are required in order that potential surface and subsurface activities as the site will not be likely to lead to radionuclide releases greater than those allowable under the requirements specified in § 960.4–1.

(b) *Favorable Condition.* Present ownership and control of land and all surface and subsurface rights by the DOE.

(c) *Potentially Adverse Condition.* Projected land-ownership conflicts that cannot be successfully resolved through voluntary purchase-sell agreements, nondisputed agency-to-agency transfers of title, or Federal condemnation proceedings.

Subpart D—Preclosure Guidelines

§ 960.5 Preclosure guidelines.

The guidelines in this Subpart specify the factors to be considered in evaluating and comparing sites on the basis of expected repository performance before closure. The preclosure guidelines are separated into three system guidelines and eleven technical guidelines.

§ 960.5-1 System guidelines.

(a) *Qualifying Conditions*—(1) *Preclosure Radiological Safety.* Any projected radiological exposures of the general public and any projected releases of radioactive materials to restricted and unrestricted areas during repository operation and closure shall meet the applicable safety requirements set forth in 10 CFR Part 20, 10 CFR Part 60, and 40 CFR 191, Subpart A (see Appendix II of this part).

(2) *Environment, Socioeconomics, and Transportation.* During repository siting, construction, operation, closure, and decommissioning the public and the environment shall be adequately protected from the hazards posed by the disposal of radioactive waste.

(3) *Ease and Cost of Siting, Construction, Operation, and Closure.* Repository siting, construction, operation, and closure shall be demonstrated to be technically feasible on the basis of reasonably available technology, and the associated costs shall be demonstrated to be reasonable relative to other available and comparable siting options.

§ 960.5-2 Technical guidelines.

The technical guidelines in this Subpart set forth qualifying, favorable, potentially adverse, and, in seven guidelines, disqualifying conditions for the characteristics, processes, and events that influence the suitability of a site relative to the preclosure system guidelines. These conditions are separated into three main groups: Preclosure radiological safety; environment, socioeconomics, and transportation; and ease and cost of siting, construction, operation, and closure. The first group includes conditions on population density and distribution, site ownership and control, meteorology, and offsite installations and operations. The second group includes conditions related to environmental quality and socioeconomic impacts in areas potentially affected by a repository and to the transportation of waste to a repository site. The third group includes conditions on the surface characteristics of the site, the characteristics of the host rock and surrounding strata, hydrology, and tectonics. The individual technical guidelines within each group, as well as the favorable conditions and the potentially adverse conditions under each guideline, are not listed in any assumed order of importance. The technical guidelines that follow establish conditions that shall be considered in determining compliance with the qualifying conditions of the preclosure system guidelines. For each technical guideline, an evaluation of qualification or disqualification shall be made in accordance with the requirements specified in Subpart B.

Preclosure Radiological Safety

§ 960.5-2-1 Population Density and Distribution.

(a) *Qualifying Condition.* The site shall be located such that, during repository operation and closure, (1) the expected average radiation dose to members of the public within any highly populated area will not be likely to exceed a small fraction of the limits allowable under the requirements specified in § 960.5–1(a)(1), and (2) the expected radiation dose to any member of the public in an unrestricted area will not be likely to exceed the limit allowable under the requirements specified in § 960.5–1(a)(1).

(b) *Favorable Conditions.* (1) A low population density in the general region of the site.

(2) Remoteness of site from highly populated areas.

(c) *Potentially Adverse Conditions.* (1) High residential, seasonal, or daytime population density within the projected site boundaries.

(2) Proximity of the site to highly populated areas, or to areas having at least 1,000 individuals in an area 1 mile

by 1 mile as defined by the most recent decennial count of the U.S. census.

(d) *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 Part 60, Subpart I, "Emergency Planning Criteria."

§ 960.5-2-2 Site Ownership and Control.

(a) *Qualifying Condition.* The site shall be located on land for which the DOE can obtain, in accordance with the requirements of 10 CFR 60.121, ownership, surface and subsurface rights, and control of access that are required in order that surface and subsurface activities during repository operation and closure will not be likely to lead to radionuclide releases to an unrestricted area greater than those allowable under the requirements specified in § 960.5-1(a)(1).

(b) *Favorable Condition.* Present ownership and control of land and all surface and subsurface mineral and water rights by the DOE.

(c) *Potentially Adverse Condition.* Projected land-ownership conflicts that cannot be successfully resolved through voluntary purchase-sell agreements, nondisputed agency-to-agency transfers of title, or Federal condemnation proceedings.

§ 960.5-2-3 Meteorology.

(a) *Qualifying Condition.* The site shall be located such that expected meteorological conditions during repository operation and closure will not be likely to lead to radionuclide releases to an unrestricted area greater than those allowable under the requirements specified in § 960.5-1(a)(1).

(b) *Favorable Condition.* Prevailing meteorological conditions such that any radioactive releases to the atmosphere during repository operation and closure would be effectively dispersed, thereby reducing significantly the likelihood of unacceptable exposure to any member of the public in the vicinity of the repository.

(c) *Potentially Adverse Conditions.* (1) Prevailing meteorological conditions such that radioactive emissions from repository operation of closure could be preferentially transported toward localities in the vicinity of the repository with higher population densities than are the average for the region.

(2) History of extreme weather phenomena—such as hurricanes, tornadoes, severe floods, or severe and frequent winter storms—that could significantly affect repository operation or closure.

§ 960.5-2-4 Offsite installations and operations.

(a) *Qualifying Condition.* The site shall be located such that present projected effects from nearby industrial, transportation, and military installations and operations, including atomic energy defense activities, (1) will not significantly affect repository siting, construction, operation, closure, or decommissioning or can be accommodated by engineering measures and (2), when considered together with emissions from repository operation and closure, will not be likely to lead to radionuclide releases to an unrestricted area greater than those allowable under the requirements specified in § 960.5-1(a)(1).

(b) *Favorable Condition.* Absence of contributing radioactive releases from other nuclear installations and operations that must be considered under the requirements of 40 CFR 191, Subpart A.

(c) *Potentially Adverse Conditions.* (1) The presence of nearby potentially hazardous installations or operations that could adversely affect repository operation or closure.

(2) Presence of other nuclear installations and operations, subject to the requirements of 40 CFR Part 190 or 40 CFR 191, Subpart A, with actual or projected releases near the maximum value permissible under those standards.

(d) *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.

Environment, Socioeconomics, and Transportation

§ 960.5-2-5 Environmental quality.

(a) *Qualifying Condition.* The site shall be located such that (1) the quality of the environment in the affected area during this and future generations will be adequately protected during repository siting, construction, operation, closure, and decommissioning, and projected environmental impacts in the affected area can be mitigated to an acceptable degree, taking into account programmatic, technical, social, economic, and environmental factors; and (2) the requirements specified in § 960.5-1(a)(2) can be met.

(b) *Favorable Conditions.* (1) Projected ability to meet, within time constraints, all Federal, State, and local procedural and substantive environmental requirements applicable to the site and the activities proposed to take place thereon.

(2) Potential significant adverse environmental impacts to present and future generations can be mitigated to an insignificant level through the application of reasonable measures, taking into account programmatic, technical, social, economic, and environmental factors.

(c) *Potentially Adverse Conditions.* (1) Projected major conflict with applicable Federal, State, or local environmental requirements.

(2) Projected significant adverse environmental impacts that cannot be avoided or mitigated.

(3) Proximity to, or projected significant adverse environmental impacts of the repository or its support facilities on, a component 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 Land.

(4) Proximity to, and projected significant adverse environmental impacts of the repository or its support facilities on, a significant State or regional protected resource area, such as a State park, a wildlife area, or a historical area.

(5) Proximity to, and projected significant adverse environmental impacts of the repository and its support facilities on, a significant Native American resource, such as a major Indian religious site, or other sites of unique cultural interest.

(6) Presence of critical habitats for threatened or endangered species that may be compromised by the repository or its support facilities.

(d) *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 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.

(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.

§ 960.5-2-6 Socioeconomic impacts.

(a) *Qualifying Condition.* The site shall be located such that (1) any significant adverse social and/or economic impacts induced in communities and surrounding regions by repository siting, construction, operation, closure, and decommissioning can be offset by reasonable mitigation or compensation, as determined by a process of analysis, planning, and consultation among the DOE, affected State and local government jurisdictions, and affected Indian tribes; and (2) the requirements specified in § 960.5-1(a)(2) can be met.

(b) *Favorable Conditions.* (1) Ability of an affected area to absorb the project-related population changes without significant disruptions of community services and without significant impacts on housing supply and demand.

(2) Availability of an adequate labor force in the affected area.

(3) Projected net increases in employment and business sales, improved community services, and increased government revenues in the affected area.

(4) No projected substantial disruption of primary sectors of the economy of the affected area.

(c) *Potentially Adverse Conditions.* (1) Potential for significant repository-related impacts on community services, housing supply and demand, and the finances of State and local government agencies in the affected area.

(2) Lack of an adequate labor force in the affected area.

(3) Need for repository-related purchase or acquisition of water rights, if such rights could have significant adverse impacts on the present or future development of the affected area.

(4) Potential for major disruptions of primary sectors of the economy of the affected area.

(d) *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.

§ 960.5-2-7 Transportation.

(a) *Qualifying Condition.* The site shall be located such that (1) the access routes constructed from existing local highways and railroads to the site (i) will not conflict irreconcilably with the previously designated use of any resource listed in § 960.5-2-5(d) (2) and (3); (ii) can be designed and constructed using reasonably available technology; (iii) will not require transportation system components to meet performance standards more stringent than those specified in the applicable DOT and NRC regulations, nor require the development of new packaging containment technology; (iv) will allow transportation operations to be conducted without causing an unacceptable risk to the public or unacceptable environmental impacts, taking into account programmatic, technical, social, economic, and environmental factors; and (2) the requirements of § 960.5-1(a)(2) can be met.

(b) *Favorable Conditions.* (1) Availability of access routes from local existing highways and railroads to the site which have any of the following characteristics:

(i) Such routes are relatively short and economical to construct as compared to access routes for other comparable siting options.

(ii) Federal condemnation is not required to acquire rights-of-way for the access routes.

(iii) Cuts, fills, tunnels, or bridges are not required.

(iv) Such routes are free of sharp curves or steep grades and are not likely to be affected by landslides or rock slides.

(v) Such routes bypass local cities and towns.

(2) Proximity to local highways and railroads that provide access to regional highways and railroads and are adequate to serve the repository without significant upgrading or reconstruction.

(3) Proximity to regional highways, mainline railroads, or inland waterways that provide access to the national transportation system.

(4) Availability of a regional railroad system with a minimum number of interchange points at which train crew and equipment changes would be required.

(5) Total projected life-cycle cost and risk for transportation of all wastes designated for the repository site which are significantly lower than those for comparable siting options, considering locations of present and potential sources of waste, interim storage facilities, and other repositories.

(6) Availability of regional and local carriers—truck, rail, and water—which have the capability and are willing to handle waste shipments to the repository.

(7) Absence of legal impediment with regard to compliance with Federal regulations for the transportation of waste in or through the affected State and adjoining States.

(8) Plans, procedures, and capabilities for response to radioactive waste transportation accidents in the affected State that are completed or being developed.

(9) A regional meteorological history indicating that significant transportation disruptions would not be routine seasonal occurrences.

(c) *Potentially Adverse Conditions.* (1) Access routes to existing local highways and railroads that are expensive to construct relative to comparable siting options.

(2) Terrain between the site and existing local highways and railroads such that steep grades, sharp switchbacks, rivers, lakes, landslides, rock slides, or potential sources of hazard to incoming waste shipments will be encountered along access routes to the site.

(3) Existing local highways and railroads that could require significant reconstruction or upgrading to provide adequate routes to the regional and national transportation system.

(4) Any local condition that could cause the transportation-related costs, environmental impacts, or risk to public health and safety from waste transportation operations to be significantly greater than those projected for other comparable siting options.

Ease and Cost of Siting, Construction, Operation, and Closure

§ 960.5-2-8 Surface characteristics.

(a) *Qualifying Condition.* The site shall be located such that, considering the surface characteristics and conditions of the site and surrounding area, including surface-water systems and the terrain, the requirements specified in § 960.5–1(a)(3) can be met during repository siting, construction, operation, and closure.

(b) *Favorable Conditions.* (1) Generally flat terrain.

(2) Generally well-drained terrain.

(c) *Potentially Adverse Condition.* Surface characteristics that could lead to the flooding of surface or underground facilities by the occupancy and modification of flood plains, the failure of existing or planned man-made surface-water impoundments, or the failure of engineered components of the repository.

§ 960.5–2–9 Rock characteristics.

(a) *Qualifying Condition.* The site shall be located such that (1) the thickness and lateral extent and the characteristics and composition of the host rock will be suitable for accommodation of the underground facility; (2) repository construction, operation, and closure will not cause undue hazard to personnel; and (3) the requirements specified in § 960.5–1(a)(3) can be met.

(b) *Favorable Conditions.* (1) A host rock that is sufficiently thick and laterally extensive to allow significant flexibility in selecting the depth, configuration, and location of the underground facility.

(2) A host rock with characteristics that would require minimal or no artificial support for underground openings to ensure safe repository construction, operation, and closure.

(c) *Potentially Adverse Conditions.* (1) A host rock that is suitable for repository construction, operation, and closure, but is so thin or laterally restricted that little flexibility is available for selecting the depth, configuration, or location of an underground facility.

(2) In situ characteristics and conditions that could require engineering measures beyond reasonably available technology in the construction of the shafts and underground facility.

(3) Geomechanical properties that could necessitate extensive maintenance of the underground openings during repository operation and closure.

(4) Potential for such phenomena as thermally induced fracturing, the hydration and dehydration of mineral components, or other physical, chemical, or radiation-related phenomena that could lead to safety hazards or difficulty in retrieval du 'ng repository operation.

(5) Existing faults, shear zones, pressurized brine pockets, dissolution effects, or other stratigraphic or structural features that could compromise the safety of repository personnel because of water inflow or construction problems.

(d) *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.

§ 960.5–2–10 Hydrology.

(a) *Qualifying Condition.* The site shall be located such that the geohydrologic setting of the site will (1) be compatible with the activities required for repository construction, operation, and closure; (2) not compromise the intended functions of the shaft liners and seals; and (3) permit the requirements specified in § 960.5–1(a)(3) to be met.

(b) *Favorable Conditions.* (1) Absence of aquifers between the host rock and the land surface.

(2) Absence of surfacé-water systems that could potentially cause flooding of the repository.

(3) Availability of the water required for repository construction, operation, and closure.

(c) *Potentially Adverse Condition.* Ground-water conditions that could require complex engineering measures that are beyond reasonably available technology for repository construction, operation, and closure.

(d) *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.

§ 960.5–2–11 Tectonics.

(a) *Qualifying Conditions.* The site shall be located in a geologic setting in which any projected effects of expected tectonic phenomena or igneous activity on repository construction, operation, or closure will be such that the requirements specified in § 960.5–1(a)(3) can be met.

(b) *Favorable Condition.* The nature and rates of faulting, if any, within the geologic setting are such that the magnitude and intensity of the associated seismicity are significantly less than those generally allowable for the construction and operation of nuclear facilities.

(c) *Potentially Adverse Conditions.* (1) Evidence of active faulting within the geologic setting.

(2) Historical earthquakes or past man-induced seismicity that, if either were to recur, could produce ground motion at the site in excess of reasonable design limits.

(3) Evidence, based on correlations of earthquakes with tectonic processes and features, (e.g., faults) within the geologic setting, that the magnitude of earthquakes at the site during repository construction, operation, and closure may be larger then predicted from historical seismicity.

(d) *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.

Appendix B

ISSUES AND INFORMATION NEEDS FOR THE DEAF SMITH COUNTY SITE

Issue	Information need
Key issue 1 Will the mined geologic disposal system at the Deaf Smith County site isolate the radioactive waste from the accessible environment after closure in accordance with the requirements set forth in 40 CFR Part 191, 10 CFR Part 60, and 10 CFR Part 960?	
PERFORMANCE ISSUES	
Issue 1.1: Will the mined geologic disposal system meet the system performance objective for limiting radionuclide releases to the accessible environment as required by 10 CFR 60.112 and 40 CFR 191.13?	Ambient geochemical conditions Analogs of radionuclide mobility Characteristics of undetected features Chemical and radiological properties Chemical properties Chemical response Climatological normals, means and extremes Construction procedures Defense glass waste form performance measures Design parameters Earthquake characteristics Effect of borehole and shaft construction and sealing on baseline site geochemistry Effects of repository construction, operation, and decommissioning on host rock and fluid geochemistry Effects of waste emplacement on host rock and fluid geochemistry General climatology Geochemical characteristics of ground-water that serve as indicators of hydraulic interconnections Geochemical evidence relating to residence time, age or origin Geologic structure - stratigraphy Hydraulic properties Hydraulic properties of backfill and seals materials Hydraulic properties of fluid Hydraulic properties of rock Hydraulic properties of seal materials and surrounding rock Hydraulic response Hydrostratigraphic framework Inventory Leaching Mechanical properties Mechanical properties of backfill and seals materials Near field performance measures (applicable for all waste types) Packing performance measures (applicable for all waste types) Paleoclimatology Past or existing injection or withdrawal wells and mining activity Performance measures for bounding scenario analyses

Issue	Information need
	Key issue 1 (continued)
PERFORMANCE ISSUES	
Issue 1.1 (continued)	Performance measures for bounding scenario analyses - effectiveness of intrusion controls Performance measures for engineered-barrier system Performance measures for isolation system performance Physical extent of construction-affected zone Potential evidence of fracture flow causing dissolution Prediction of future climate Projected future human interference Radiation field Radionuclide retardation along credible pathways to the accessible environment Radionuclide solubilities in host media Radionuclide transport Radionuclide transport through packing material Radionuclide transport to accessible environment Recent climate Release rate from packages - aggregate Repository underground - location and structure Scenarios Seismic/tectonic history Special geologic features Spent-fuel waste form performance measures Surface-water characteristics Surface-water quality in surface-water bodies that receive runoff from site Thermal properties Thermal response Thermomechanical response Waste and backfill emplacement procedures
Issue 1.2: Will the mined geologic disposal system meet the requirements for limiting individual doses in the accessible environment as required by 40 CFR 191.15?	Atmospheric release scenarios Concentrations of radionuclides in ground water Geochemistry of formation Geologic structure - stratigraphy Hydraulic properties Hydraulic properties of fluid Hydraulic properties of rock Hydraulic properties of seal materials and surrounding rock Hydrostratigraphic framework Mechanical and thermomechanical properties

Issue	Information need
	Key issue 1 (continued)
PERFORMANCE ISSUES	
Issue 1.2 (continued)	Meteorology - atmospheric dispersion Performance measure for ground-water flow Performance measure for releases from controlled area Plume dimensions Prediction of future climate Releases to the accessible environment Residual contamination after decommissioning - reserve strategy Special geologic features Surface-water characteristics
Issue 1.3: Will the mined geologic disposal system meet the requirements for the protection of special sources of ground water as required by 40 CFR 191.16?	Background radionuclide concentrations Current ground-water use for drinking water within 5 km Geochemical characteristics of formation fluids Hydraulic properties of fluid Hydraulic properties of seal materials and surrounding rock Hydrostratigraphic framework Past or existing injection or withdrawal wells and mining activity Performance measures for ground-water classification Performance measures for radionuclide contamination Performance measures for radionuclide retardation Prediction of future climate Special geologic features
Issue 1.4: Will the waste package meet the performance objective for containment as required by 10 CFR 60.113?	Canister performance measures Chemical and radiological properties Chemical properties Chemical response Construction procedures Consumption by chemical processes Creep rate vs. temperature Defense glass waste form performance measures Design parameters Dewatering of packing material Evaporation into room Flow from interbeds Fluid within emplacement hole (quantity of fluid vs. time) General corrosion rate vs. time Geochemical effects of contaminants introduced Geochemical response to heat Geochemical response to radiation Hydraulic properties

Issue	Information need
	Key issue 1 (continued)
PERFORMANCE ISSUES	
Issue 1.4 (continued)	Hydraulic properties of backfill and seals materials Hydraulic properties of fluid Hydraulic response Inventory Leaching Mechanical properties Mineral dehydration Near field performance measures (applicable for all waste types) Packing performance measures (applicable for all waste types) Performance measure to address acceptable waste form temperatures Pitting and crevice corrosion susceptibility Quantity of fluid vs. time Radiation field Radionuclide solubility in host rock brines Radionuclide transport Radionuclide transport through packing material Rate of brine inclusion flow into emplacement hole Release rate from packages - aggregate Repository underground - location and structure Spent-fuel waste form performance measures Stress corrosion cracking susceptibility Thermal properties Thermal response Thermomechanical response Waste and backfill emplacement procedures
Issue 1.5: Will the waste package and repository engineered barriers meet the performance objective for limiting radionuclide release rates as required by 10 CFR 60.113?	Characteristics of undetected features Chemical and radiological properties Chemical properties Chemical response Construction procedures Consumption by chemical processes Container performance measures (applicable for all waste package types) Creep rate vs. temperature Defense glass waste form performance measures Design parameters Dewatering of packing material Evaporation into room Flow from interbeds

Issues and information needs for the Deaf Smith County site (Page 5 of 17)

Issue	Information need
	Key issue 1 (continued)
PERFORMANCE ISSUES	
Issue 1.5 (continued)	Fluid flow into repository vs. time Fluid within emplacement hole (quantity of fluid vs. time) General corrosion rate vs. time Geochemical effects of contaminants introduced Geochemical response to heat Geochemical response to radiation Hydraulic properties Hydraulic properties of backfill and seals materials Hydraulic properties of fluid in seals and surrounding rock Hydraulic response Inventory Leaching Mechanical properties Mineral dehydration Packing performance measures (applicable for all waste package types) Performance measures for waste package environment (applicable for all packages having glass waste form) Pitting corrosion rate Quantity of fluid vs. time Radiation field Radionuclide solubility in host rock brines Radionuclide transport Radionuclide transport through packing material Rate of brine inclusion flow into emplacement hole Release rate from packages - aggregate Repository underground - location and structure Spent-fuel waste form performance measures Stress corrosion cracking susceptibility Thermal properties Thermal response Thermomechanical response Waste and backfill emplacement procedures
Issue 1.6: Will the site meet the performance objective for pre-waste-emplacement ground-water travel time as required by 10 CFR 60.113?	Geochemical characteristics of ground water that serve as indicators of hydraulic interconnections Geochemical evidence relating to residence time, age or origin Hydraulic properties of fluid Hydraulic properties of rock Hydrostratigraphic framework

Issues and information needs for the Deaf Smith County site (Page 6 of 17)

Issue	Information need
Key issue 1 (continued)	
PERFORMANCE ISSUES	
Issue 1.6 (continued)	Natural recharge-discharge areas, rates, and composition Performance measure for ground-water travel time Potential evidence of fracture flow causing dissolution Special geologic features
Issue 1.7: Will the performance-confirmation program meet the requirements of 10 CFR 60.137?	No additional information needs identified at this time
Issue 1.8: Can the demonstrations for favorable and potentially adverse conditions be made as required by 10 CFR 60.122?	Ambient geochemical conditions Characteristics of undetected features Current and foreseeable future value of naturally occurring minerals Effects of repository construction, operation, and closure on host rock and fluid geochemistry Geochemical characteristics of ground water that serve as indicators of hydraulic interconnections Geochemical evidence relating to residence time, age, or origin Geochemical sensitivity to waste emplacement in host rock Geologic structure - stratigraphy Hydraulic properties of fluid Hydraulic properties of rock Hydraulic response from foreseeable human activities Hydrologic response Hydrostratigraphic framework Past or existing injection or withdrawal wells and mining activity Population distribution in vicinity of site Potential evidence of fracture flow causing dissolution Prediction of future climate Projected future erosion potential Projected future human interference Radionuclide retardation along credible pathways to the accessible environment Radionuclide solubilities in host media Radionuclide transport to accessible environment Recent climate Seismic-tectonic history Special geologic features Surface water and soil characteristics Surface-water characteristics Thermomechanical response

Issues and information needs for the Deaf Smith County site (Page 7 of 17)

Issue	Information need
	Key issue 1 (continued)
PERFORMANCE ISSUES	
Issue 1.9: (a) Can the higher-level findings required by 10 CFR Part 960 be made for the qualifying condition of the postclosure system guideline and the disqualifying and qualifying conditions of the technical guidelines for geohydrology, geochemistry, rock characteristics, climate changes, erosion, dissolution, tectonics, and human interference; and (b) can the comparative evaluations required by 10 CFR 960.3-1-5 be made?	No additional information needs identified
DESIGN ISSUES	
Issue 1.10: Have the characteristics and configurations of the waste packages been adequately established to (a) show compliance with the postclosure design criteria of 10 CFR 60.135 and (b) provide information for the resolution of the performance issues?	Canister performance measures Characteristics of undetected features Chemical and radiological properties Chemical properties Chemical response Construction procedures Consumption by chemical processes Container performance measures (applicable for all waste package types) Creep rate vs. temperature Defense glass waste form performance measures Design parameters Dewatering of packing material Evaporation into room Flow from interbeds Fluid flow into repository vs. time Fluid within emplacement hole (quantity of fluid vs. time) General corrosion rate vs. time Geochemical effects of contaminants introduced Geochemical response to heat Geochemical response to radiation Hydraulic properties Hydraulic properties of backfill and seals materials Hydraulic properties of fluid

Issue	Information need
Key issue 1 (continued)	
DESIGN ISSUES	
Issue 1.10 (continued)	Hydraulic response Inventory Leaching Mechanical properties Mineral dehydration Near field performance measures (applicable for all waste types) Packing performance measures (applicable for all waste package types) Packing performance measures (applicable for all waste types) Performance measure to address acceptable waste form temperatures Performance measures for waste package environment (applicable for all packages having glass waste form) Pitting and crevice corrosion susceptibility Quantity of fluid vs. time Radiation field Radionuclide solubility in host rock brines Radionuclide transport Radionuclide transport through packing material Rate of brine inclusion flow into emplacement hole Release rate from packages - aggregate Repository underground - location and structure Spent-fuel waste form performance measures Stress corrosion cracking susceptibility Thermal properties Thermal response Thermomechanical response Waste and backfill emplacement procedures
Issue 1.11: Have the characteristics and configurations of the repository and the repository engineered barriers been adequately established to (a) show compliance with the postclosure design criteria of 10 CFR 60.133 and (b) provide information to support resolution of the performance issues?	Chemical properties Construction procedures Geochemical properties Hydraulic properties Hydraulic properties of backfill and seals materials Hydraulic properties of fluid Hydraulic properties of rock Hydraulic response Hydrostratigraphic framework Mechanical properties Past or existing injection or withdrawal wells and mining activity Performance measures for entries and pillars Performance measures for excavation

Issue	Information need
	Key issue 1 (continued)
DESIGN ISSUES	
Issue 1.11 (continued)	Performance measures for placement of repository horizon Performance measures for placement of the repository within the region Performance measures for placement of waste in repository horizon Performance measures for repository Performance measures for repository horizon backfill Performance measures for repository shafts Performance measures for waste package Performance measures for waste retrieval systems Radionuclide transport Radionuclide transport to accessible environment Repository underground - location and structure Scenarios Special geologic features Thermal properties Thermal response Thermomechanical response Waste and backfill emplacement procedures
Issue 1.12: Have the characteristics and configurations of the shaft and borehole seals been adequately established to (1) show compliance with the postclosure design criteria of 10 CFR 60.134 and (2) provide information to support resolution of the performance issues?	Chemical properties Chemical response Construction procedures Earthquake characteristics Effects of repository construction, operation, and closure on host rock and fluid geochemistry Geochemical properties Hydraulic properties Hydraulic properties of rock Hydraulic response Hydrostratigraphic framework Mechanical and thermomechanical properties Mechanical properties Performance measures for assessing shaft seal performance Performance measures for borehole seals Performance measures for host rock horizon Performance measures for repository horizon construction-affected zone Performance measures for repository horizon seal and backfill material

Issue	Information need
	Key issue 1 (continued)
DESIGN ISSUES	
Issue 1.12 (continued)	Performance measures for seal performance Performance measures for seal system Performance measures for shaft seal material Performance measures for shaft seal zone Performance measures for underground excavation seals and backfill Performance parameters for repository horizon and backfill seal interface zone Performance parameters for shaft seal interface zone Physical extent of construction-affected zone Radionuclide transport Repository underground - location and structure Special geologic features Thermal properties Thermal response Thermomechanical response

Issue	Information need

Key issue 2

Will the projected releases of radioactive materials to restricted and unrestricted areas and the resulting radiation exposures of the general public and workers during repository operation, closure, and decommissioning at the Deaf Smith County site meet applicable safety requirements set forth in 10 CFR Part 20 10 CFR Part 60, 10 CFR 960, and 40 CFR Part 191?

PERFORMANCE ISSUES

Issue	Information need
Issue 2.1: During repository operation, closure, and decommissioning (a) will the expected average radiation dose received by members of the public within any highly populated area be less than a small fraction of the allowable limits and (b) will the expected radiation dose received by any member of the public in an unrestricted area be less than the allowable limits as required by 10 CFR 60.111; 40 CFR part 191, Subpart A; and 10 CFR Part 20?	Agricultural characteristics of region Airborne release parameters Atmospheric release scenarios Background radionuclide concentrations Baseline individual and population dose Characteristics of system governing potential occupational exposure - design elements Characteristics of system governing potential occupational exposures - HEPA filters Characteristics of system governing potential occupational exposures - waste container parameters Characteristics of system governing potential occupational exposures - normal radiological releases Characteristics of system governing potential occupational exposures - repository operations Characteristics of system governing potential occupational exposures - waste treatment Characteristics of system governing potential occupational exposures - waterborne release parameters, if any Chemical and radiological properties Current ground-water use for drinking water within 5 km Local terrain Health baseline for surrounding population Hydraulic characteristics of aquifers at shaft Performance measures for design to minimize radionuclide release Performance measures for offsite dose estimation Performance measures for offsite radionuclide transport via water Performance measures for radionuclide release Performance measures for radionuclide transport via air Performance measures related to population distribution in vicinity of site Performance parameters related to worker safety during accidents Plume dimensions Population distribution in vicinity of site

Issue	Information need
	Key issue 2 (continued)
PERFORMANCE ISSUES	
Issue 2.1 (continued)	Radiological emission characteristics, strengths of each radiation source Relative concentration Relative deposition Release scenarios - normal operations Severe weather design parameters Surface-water use Waterborne release parameters
Issue 2.2: Can the repository be designed, constructed, operated, closed, and decommissioned in a manner that ensures the radiological safety of workers under normal operations, as required by 10 CFR 60.111 and 10 CFR Part 20?	Characteristics of system governing potential occupational exposures - design elements Characteristics of system governing potential occupational exposures - HEPA filters Characteristics of system governing potential occupational exposures - waste container parameters Characteristics of system governing potential occupational exposures - normal radiological releases Characteristics of system governing potential occupational exposures - repository operations Characteristics of system governing potential occupational exposures - waste treatment Characteristics of system governing potential occupational exposures - waterborne release parameters, if any Characteristics of system governing potential occupational exposures - airborne release parameters Demographic profiles of onsite population Performance measures related to repository design affecting worker dose Plume dimensions Relative concentration Relative deposition Subsurface facility radiation design considerations Surface facility radiation design considerations
Issue 2.3: Can the repository be designed, constructed, operated, closed, and decommissioned in such a way that credible accidents do not result in projected radiological exposures of the general public at the nearest boundary of the unrestricted area, or workers in the restricted area, in excess of applicable limiting values?	Demographic profiles of onsite population Local terrain Performance measures for air transport of releases Performance measures related to offsite radiological accidents Performance measures related to public exposure from accidental releases Performance measures related to worker exposure

Issues and information needs for the Deaf Smith County site (Page 13 of 17)

Issue	Information need
Key issue 2 (continued)	
PERFORMANCE ISSUES	
Issue 2.3 (continued)	Performance parameters related to public exposure during accidents
	Plume dimensions
	Population distribution in vicinity of site
	Relative concentration
	Relative deposition
	Release scenarios - accidents
	Severe weather design parameters
	Surface-water use
Issue 2.4: Can the repository be designed, constructed, operated, closed, and decommissioned so that the option of waste retrieval will be preserved as required by 10 CFR 60.111?	Characteristics of system governing potential occupational exposures - waste container parameters
	Chemical properties
	Construction procedures
	Creep rate vs. temperature
	Defense glass waste form performance measures
	Design parameters
	Earthquake characteristics
	Effect of borehole and shaft construction and sealing on baseline site geochemistry
	Effects of repository construction, operation, and closure on host rock and fluid geochemistry
	Effects of waste emplacement on host rock and fluid geochemistry
	Fluid flow into repository vs. time
	Fluid within emplacement hole (quantity of fluid vs. time)
	General corrosion rate vs. time
	Geochemical response to heat
	Geochemical sensitivity to waste emplacement in host rock
	Hydraulic properties
	Hydraulic properties of backfill and seals materials
	Hydraulic properties of fluid in seals and surrounding rock
	Hydraulic properties of rock
	Hydraulic properties of seal materials and surrounding rock
	Hydraulic response
	Mechanical properties
	Performance measure for repository
	Performance measure for repository horizon
	Performance measure for repository horizon disturbed zone
	Performance measure for retrieval
	Performance measures for safe access
	Performance measures for shaft

Issue	Information need
Key issue 2 (continued)	
PERFORMANCE ISSUES	
Issue 2.4 (continued)	Performance measures for testing program Performance measures for the host rock Performance measures for the remaining systems Performance measures for the repository horizon construction-affected zone Performance measures for the shaft construction-affected zone Physical extent of construction-affected zone Pitting and crevice corrosion susceptibility Pitting corrosion rate Radiation field Rate of brine inclusion flow into emplacement hole Repository underground - location and structure Scenarios Special geologic features Stress corrosion cracking susceptibility Subsurface facility radiation design considerations Thermal properties Thermal response Thermomechanical response Underground performance observations and measurements
Issue 2.5: Can the higher-level findings required by 10 CFR Part 960 be made for the qualifying condition of the preclosure system guideline and the disqualifying and qualifying conditions of the technical guidelines for population density and distribution, site ownership and control, meteorology, and offsite installations and operations?	No additional information needs identified
DESIGN ISSUES	
Issue 2.6: Have the characteristics and configurations of the waste packages been adequately established to (a) show compliance with the preclosure design criteria of 10 CFR 60.135 and (b) provide information for the resolution of the performance issues?	All waste-package information needs are identified under issue 1.10

Issue	Information need
Key issue 2 (continued)	
DESIGN ISSUES	
Issue 2.7: Have the characteristics and configurations of the repository been adequately established to (a) show compliance with the preclosure design criteria of 10 CFR 60.130 through 60.133, and (b) provide information for the resolution of the performance issues?Issue 2.7 (continued)	Agricultural characteristics of region Airborne release parameters Characteristics of system governing potential occupational exposure - design elements Characteristics of system governing potential occupational exposure - repository operations Characteristics of system governing potential occupational exposure - waste treatment Climatological normals, means, and extremes Construction procedures Current ground-water use for drinking water within 5 km Demographic profiles of onsite population Local terrain Design dry and wet bulb temperatures Design verification of exploratory shaft construction Earthquake characteristics General climatology Hydrostratigraphic framework Mechanical properties for soil Meteorology - atmospheric dispersion Performance measures for atmospheric transport of radioactive releases Performance measures for control of releases Performance measures for establishing boundary for unrestricted access Performance measures for offsite exposure Performance measures for population exposure Performance measures for underground handling of radioactive materials Plume dimensions Population distribution in vicinity of site Relative deposition Release scenarios - accidents Repository underground - location and structure Residual contamination after decommissioning - reserve strategy Severe weather design parameters Special geologic features Subsurface facility radiation design considerations Surface facility radiation design considerations Surface-water characteristics Surface-water use Thermal properties of soils Thermal response Topographic and surface characteristics Waste and backfill emplacement procedures

Issues and information needs for the Deaf Smith County site (page 16 of 17)

Issue	Information need
Key issue 4	
Will the construction, operation (including retrieval), closure, and decommissioning of the mined geologic disposal system be feasible at the Deaf Smith County site on the basis of reasonable available technology and will the associated costs be reasonable in accordance with the requirements set forth in 10 CFR Part 960?	
PERFORMANCE ISSUES	
Issue 4.1: Can the higher-level findings required by 10 CFR Part 960 be made for the qualifying condition of the preclosure system guideline and the disqualifying and qualifying conditions of the technical guidelines for surface characteristics, rock characteristics, hydrology, and tectonics?	No additional information needs identified
DESIGN ISSUES	
Issue 4.2: Are the repository design and operating procedures developed to ensure the nonradiological health and safety of workers adequately established for the resolution of the performance issues?	Chemical properties Climatological normals, means, and extremes Design dry and wet bulb temperatures Design verification of exploratory shaft construction General climatology Mechanical properties Meteorology - atmospheric dispersion Performance measures for air quality Performance measures for safe access Performance measures for safe access to emplaced waste packages for retrieval Performance measures for safe access, protection against flooding Performance measures to maintain safe access to working locations Performance parameters for monitoring safety from airborne contaminants Plume dimensions Special geologic features Thermal properties Thermomechanical response

Issues and information needs for the Deaf Smith County site (Page 17 of 17)

Issue	Information need
Key issue 4 (continued)	
DESIGN ISSUES	
Issue 4.3: Are the waste package production technologies adequately established for the resolution of the performance issues?	All waste-package information needs have been identified under Issue 1.10
Issue 4.4: Are the technologies of construction, operation, closure, and decommissioning adequately established for the resolution of the performance issues?	No additional information needs identified
Issue 4.5: Are the costs of the waste packages and the repository adequately established for the resolution of the performance issues?	No additional information needs identified