U.S. NUCLEAR REGULATORY COMMISSION
OFFICE OF STANDARDS DEVELOPMENT

April 1981
Division 4

DRAFT REGULATORY GUIDE AND VALUE/IMPACT STATEMENT Task GS 027-4

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STANDARD FORMAT AND CONTENT OF SITE CHARACTERIZATION REPORTS FOR HIGH-LEVEL-WASTE GEOLOGIC REPOSITORIES

FOR COMMENT

This regulatory guide and the associated value/impact statement are being issued in draft form to involve the public in the early stages of the development of a regulatory position in this area. They have not received complete staff review and do not represent an official NRC staff position.

Public comments are being solicited on both drafts, the guide (including any implementation schedule) and the value/impact statement. Comments on the value/impact statement should be accompanied by supporting data. Comments on both drafts should be sent to the Secretary of the Commission, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, Attention: Docketing and Service Branch, by JUN 30 1981

Requests for single copies of draft guides (which may be reproduced) or for placement on an automatic distribution list for single copies of future draft guides in specific divisions should be made in writing to the U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, Attention: Director, Division of Technical Information and Document Control.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

INTRODUCTION

Paragraph 60.11(a) of 10 CFR Part 60, "Disposal of High-Level Radioactive Wastes in Geologic Repositories" (46 FR 13971), requires the Department of Energy (DOE) to submit to the NRC a site characterization report (SCR) as early as possible after commencement of planning for a particular geologic repository operations area. It is anticipated that DOE will perform site screening investigations at a number of alternative sites in the same geologic medium prior to selecting one site for site characterization. It is also anticipated that submittal of an SCR will coincide with the selection of this site and with commencement of planning for the particular geologic repository at the site.

The objectives of site characterization are:

1. To collect geological information so that the construction application will be complete and a meaningful evaluation can be made about the suitability of the site and the compatibility of the design aspects of the repository for the particular site.

2. To collect necessary data from alternative sites and media to permit the NRC to make a National Environmental Policy Act (NEPA) finding on the site advanced in the DOE's license application for construction authorization.

The objectives of the SCR are:

1. To provide a vehicle for early NRC, State and public input on the data gathering and development work so as to avoid postponing issues to the point where modifications in the program would involve major delays or disruptions in the program.

2. To summarize (either in the SCR or by reference):

   a. Screening work and criteria that led to selection of the candidate area and site to be characterized,

b. The decision process by which the site was selected for characterization, and

c. Plans for screening work and characterization on alternative sites in different geologic media.

3. To describe the site, repository design, waste form, waste packages, emplacement environment, and performance analysis in sufficient detail so as to understand the site screening and selection process and the site characterization program.

4. To identify the uncertainties and limitations on site- and design-related information developed during site screening, including issues that need further investigation or for which additional assurance is needed to fully determine compliance with 10 CFR Part 60.

5. To describe the detailed programs for additional work to resolve outstanding issues and to reduce uncertainties in the data.

The objectives of both site characterization and the SCR are more fully and completely described in the supplementary information to, and in the licensing procedures described in, 10 CFR Part 60.

The objectives of the Standard Format and Content of Site Characterization Reports for High-Level-Waste Geologic Repositories (hereinafter Standard Format) are to suggest the information to be provided in the SCR by DOE and to establish a uniform format for presenting the information so that the SCR will meet the objectives listed above. Use of this format will help ensure the completeness of the information provided, will assist the NRC staff and others in locating the information, and will aid in shortening the time needed for the review process. The Standard Format represents a format for SCRs that is acceptable to the NRC staff. Conformance with the Standard Format, however, is not required. SCRs with different formats will be acceptable to the staff if the information they contain provides an adequate basis for the analysis of the Director of the Office of Nuclear Material Safety and Safeguards (NMSS). How-

ever, because it may be more difficult to determine the adequacy of the information contained, the staff review time for such reports may be longer, and there is a greater likelihood that the staff may request additional information.

The Standard Format is divided into four parts.

1. Part A is designed to provide guidance to DOE on the information needed in the introduction and the information needed in describing the screening work, criteria, and decision process of selecting candidate areas and sites.

2. Part B is designed to provide guidance on the information needed in describing the site, the waste form, the waste package and emplacement environment, and the conceptual design. The level of detail that will be available at the time of the submittal of the SCR will be imbalanced owing to the varying degrees to which the required information can be collected by the site screening investigations. Some studies that do not require subsurface investigations such as surface-water hydrology or climatology may be reasonably complete. Other studies that rely primarily on in situ testing such as geomechanics and geochemistry may be substantially incomplete.

Listed below is guidance as to the types of methods of gathering information that the NRC anticipates will be used during site screening and will therefore provide the basis for the information in the SCR.

a. Methods that can be performed from the surface (e.g., geologic mapping, surface-water sampling).

b. Methods that are indirect and require no subsurface penetration (e.g., seismic surveying, earthquake monitoring, and measurement of potential fields).

c. Methods requiring a limited number of boreholes (e.g., borehole geophysics, water pressure testing, hydrofracturing).

d. Information that can be obtained from the literature and from the results of investigations for other purposes such as oil and gas exploration or mineral exploration.

Since the SCR is to be submitted as early as possible after the DOE begins planning for a particular geologic repository, the submittal of the SCR need not be delayed in order to complete all the investigations suggested in Part B. Therefore, it is expected that many of the studies will be incomplete and that most of the results of the investigation will be in the form of preliminary results or estimates. DOE should clearly indicate the bases of the descriptions and should discuss limitations and uncertainties in the data. Sufficient investigations should have been performed and the data should be sufficiently representative to clearly demonstrate that the site should be selected for characterization and to provide a sound basis for a thorough plan for site characterization.

3. Part C is designed to provide guidance on the information required in identifying and describing issues that remain to be resolved. The term "issues" includes all characteristics of a site that may affect the ability of a site to host a geologic repository, favorable conditions[1] and potentially adverse conditions,[2] and potential problems on the site or surrounding region.

4. Part D is designed to provide guidance to DOE for presenting the site characterization program that will resolve the outstanding questions and firm up uncertainties and limitations on site- and design-related data.

In its review of the SCR, the NRC will look for answers to the following questions:

1. Have the important issues been identified?

[1]Favorable conditions: Human activities or natural conditions that enhance the ability of a geologic repository to remain stable, decrease the migration of radionuclides from the repository, or decrease pathways to the accessible environment.

[2]Potentially adverse conditions: Human activities or natural conditions that can adversely affect the stability of the repository site, increase migration of radionuclides from the repository, or provide pathways to the accessible environment.

2. Does the SCR specifically address and lead to resolution of each issue?

3. Are the methods of testing and analysis appropriate?

4. Have alternative methods of testing and analysis been identified and evaluated, and has an adequate basis been provided for the selection of the methods to be used?

5. Will the data generated by testing and used in the analyses be of adequate quality?

The DOE should submit to the NRC semiannual progress reports during the period of site characterization. These progress reports should incorporate new data and information collected since the last report; update the repository design, the description of the waste form, the waste package and environment, and the methods of performance analysis; identify changes in the site characterization program from that described in the SCR; identify any new favorable or adverse issues or characteristics discovered since the last report; and present plans to characterize these new issues or characteristics. A Standard Format and Content for the Semiannual Progress Reports will be issued as a separate document.

It is essential that data acquisition and analysis be of high quality and controlled and documented in such fashion that uncertainties and limitations associated with it can be fully understood and quantified. Therefore, DOE should describe in the SCR the quality assurance (QA) programs that have been and will be implemented following the appropriately modified and supplemented criteria of Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities." The description should include all QA measures applicable to all technical programs in Parts A, B, C, and D of this guide. The QA methods should be described in sufficient detail to allow NRC to make an independent evaluation of the reliability, reproducibility, uncertainty limits, analytic sensitivity, and limitation of data acquisition and analysis methods that have been used during site screening and will be used during site characterization.

Style and Composition

Present information clearly and concisely. Avoid confusing or ambiguous statements and unnecessarily verbose descriptions. Support claims of adequacy of designs or design methods with technical bases.

Give units of measurement, both fundamental and derived, in the International System of Units (SI). If common industrial usage is in other units and the use of SI would be confusing, give the measurement in accepted units with SI units in parentheses.

Follow the numbering system and headings of the Standard Format at least to the headings with three digits, e.g., 3.6.8 Borehole Geophysics.

Use appendices to the SCR to provide supplemental information not explicitly identified in the Standard Format. Examples of such information are (1) summaries of how the DOE has treated matters addressed in NRC regulatory guides or proposed regulations and (2) supplementary information regarding calculational methods or design approaches used by the DOE.

Avoid duplication of information. Similar or identical information may be requested in various sections of the Standard Format because it is relevant to more than one portion of the proposed repository; however, present this information in the principal section and reference it appropriately in the other applicable sections.

Where numerical values are stated, the number of significant figures given should reflect the accuracy or precision to which the number is known. Where possible, give estimated limits of error or uncertainty.

Use consistent, generally accepted abbreviations throughout the SCR. Define in each chapter any abbreviations, symbols, or special terms not in general usage.

Employ drawings, maps, diagrams, sketches, and charts where the information can be presented more adequately or conveniently by such means. All

information presented in drawings should be legible, symbols defined, and drawings not reduced to the extent that visual aids are necessary to interpret pertinent items of information presented in the drawings.

List reports or other documents that are referenced in the text of the SCR at the end of the section in which they are referenced. In cases where proprietary documents are referenced, reference a nonproprietary summary of the document. List in Chapter 1 material incorporated into the SCR by reference (see Section 1.3 of the Standard Format).

Physical Specifications

All material submitted as part of the SCR should conform to specific standards as to the physical dimensions of page size, quality of paper and inks, and number of pages, exhibits, and attachments. More specifically:

1. Paper Size (not to exceed)

   Text pages: 8-1/2 x 11 inches.

   Drawings and graphics: 8-1/2 x 11 inches preferred; however, a larger size is acceptable provided:

   a. The bound side does not exceed 11 inches except where required for legibility, and
   b. The finished copy when folded does not exceed 8-1/2 x 11 inches.

2. Paper Stock

   Weight or substance: 20 pound for printing on both sides.
   16 to 20 pound for printing on one side only.

   Composition: wood chemical sulphite (no groundwood) and a pH of 5.5.

   Color: white is preferred, but pastel colors are acceptable provided the combination of paper stock and ink is suitable for microfilming.

3. Ink

Color sufficiently dense to record on microfilm or image-copying equipment.

4. Page Margins

A margin of no less than 1 inch should be maintained on the top, bottom, and binding side of all pages.

5. Printing

Composition: single space text pages.

Type font and style: must be suitable for microfilming.

Reproduction: may be mechanically or photographically reproduced. Text pages should preferably be printed on two sides with the image printed head to head.

6. Binding

Pages should be punched for standard 3-hole loose-leaf binder.

7. Page Numbering

Number pages with the two digits corresponding to the chapter and first-level section numbers followed by a hyphen and a sequential number within the section, i.e., the third page in Section 4.1 of Chapter 4 should be numered 4.1-3. Do not number the entire report sequentially. (Note that because of the small number of pages in many sections, this Standard Format is numbered sequentially within each chapter.)

PART A

STANDARD FORMAT AND CONTENT GUIDANCE FOR DESCRIBING THE CRITERIA AND DECISION PROCESS OF SELECTING CANDIDATE AREAS AND SITES

1. INTRODUCTION

1.1 National Site Screening Program

Briefly summarize how the site chosen for site characterization in this report fits into the national program for identifying alternative sites in different geologic media.

1.2 Identification of Agents and Contractors

Identify the DOE project organization, management, and technical projects and tasks. Prime agents or contractors for site investigations, design, waste form and packaging, and performance analysis should also be identified. In addition, principal consultants, outside service organizations, and key research groups involved with site characterization should be listed. If these parties have not been selected, indicate the qualifications that will be required and the selection process that will be used.

The division of responsibility and lines of communication among these various parties should be described.

1.3 Material Incorporated by Reference

Provide a tabulation of all reports that are incorporated by reference as part of the SCR. In this context, "reports" are defined as documents that have been prepared and filed separately with the NRC. For each report, this tabulation should include the title, the report number, the date submitted to the NRC, and the sections of the SCR in which the report is referenced. For any reports that have been withheld from public disclosure in accordance with § 2.790(b) of 10 CFR Part 2, "Rules of Practice for Domestic Licensing Proceedings," as proprietary documents, nonproprietary summary descriptions of the general content of such reports should also be referenced. Also include a tabulation of any documents submitted to the Commission in other applications that are incorporated by reference in whole or in part in this SCR. Summaries of such information should be included in appropriate sections of this SCR.

Results of tests and analyses may be submitted as separate reports. In such cases, these reports should be referenced in this section and summarized in the appropriate section of the SCR.

2. DECISION PROCESS FOR CHOOSING CANDIDATE AREA AND SITE

This chapter should describe the decision process through which a particular area and site were selected for characterization. This description should include the criteria used to arrive at the selection of candidate areas, the method by which the site was selected for characterization, the identification of alternative sites, and a description of the decision mechanism used to evaluate the technical, environmental, and institutional criteria.

2.1 Technical Factors

Using the criteria contained in 10 CFR Part 60, discuss the application of the following technical criteria used in screening and selecting the site.

1. Geologic and Tectonic.
2. Hydrologic.
3. Meteorologic.
4. Geochemical.
5. Geomechanical.
6. Resource Evaluation. Discuss how resource evaluation criteria for the disturbed zone were applied to the site screening and selection process.
7. Human Activity. Identify past and present mining and other human activities and structures that affected the site selection process.
6. Other. Identify any other factors such as waste form and retrievability that affected the site selection process.

2.2 Environmental Factors

Describe how the following potential impacts of the repository influenced site selection, including any possible ways to mitigate adverse impacts.

1. Radiological.

2. Ecological.
3. Air Quality.
4. Water Quality.
5. Land Resources and Use.
6. Esthetics.
7. Historic, Archeological, and Cultural Resources.
8. Socioeconomic Impacts
    a. Demographic Change
    b. Economic Impact
    c. Public Service Impact.
    d. Government.

2.3 Legal and Institutional Factors

1. State and Local Laws. Discuss the extent to which State and local laws and regulations have entered into the site selection process, including any specific State constitutional provisions, statutes, referenda, administrative regulations, or local ordinances that are relevant to site selection.

2. Federal Legal Framework. To the extent that other Federal agencies have statutory responsibilities for repository site selection, discuss how these responsibilities have entered into the site selection process. Also, discuss any other Federal statutes, treaties, and administrative regulations that affect site selection.

3. Public Involvement.

a. State, Local, and Indian Tribal Government Participation in the Decisionmaking Process. Identify the government units affected by the proposed site, the methods used to solicit and accommodate their viewpoints, and the provisions made for their continuing involvement in the site selection process.

b. Public Participation. Identify the provisions made for public input into the site selection process, the nature of public involvement, and how public attitudes affected the site selection process.

2.4 Decisionmaking Analysis

For the selected area and for each alternative site considered, describe the method by which the site was evaluated against the criteria in Sections 2.1, 2.2, and 2.3. Include a discussion of any quantitative methods used, problems associated with the availability and reliability of data, any value judgments made, and an explicit identification of the tradeoffs made among the various criteria.

PART B

STANDARD FORMAT AND CONTENT GUIDANCE FOR DESCRIBING THE SITE, WASTE FORM, WASTE PACKAGING AND ENVIRONMENT, AND CONCEPTUAL DESIGN

The main purpose of describing the site (including a description of the waste form, waste packaging and environment, and conceptual design) will be to provide information to support the site screening and selection process, to provide information to allow issues to be identified, and to provide information to support the site characterization program for resolving the issues. The results of investigations to provide the data necessary to describe the site should be presented in the form of preliminary results. The descriptions should include the method of investigation used to obtain the information, the method of evaluation used, and the limitations on either the method of investigation or the data used in the evaluation.

3. GEOLOGIC DESCRIPTION OF CANDIDATE AREA AND SITE

3.1 Introduction

The extent of the area for which the preliminary geologic investigation has to be conducted will vary with the particular study. The general area can be roughly broken down into two parts: (1) the candidate area and (2) the site in which a geologic repository may be constructed.

For phenomena such as seismicity, volcanism, tectonism (or defining tectonic provinces), and regional geology and geophysics, the candidate area is the proper area to study. As a general guideline, the candidate area would have a radius of about 100 km around a particular site. But, depending on the regional geology, this figure may vary and may have to be enlarged in order to study the effects of regional phenomena on a particular site.

The site includes that area (or volume of rock in three dimensions) that has to be studied in order to identify and understand all credible pathways from the geologic repository operations area to the accessible environment along which radionuclides may migrate and where waste/rock/water interaction may occur and where effects on the site may result from the emplacement of the waste. Depending on the parameter or process being studied, the distances from the geologic repository operations area to the boundary of the volume of rock may vary. It is thought that for most parameters and processes the distance will vary from 2 km up to 20 km.

3.2 Subsurface Penetrations at Site

Provide a tabulation of all active and abandoned wells, boreholes, and excavations; distinguish between those that preceded DOE site screening investigations and those that were made as part of the DOE site screening. The tabulation should describe the location, depth, diameter, drilling method, casing left in the hole, and method of plugging or sealing. Include a map showing the location of active and abandoned wells, boreholes, and excavations and the plan view of the underground parts of the geologic repository. Describe the methods used to investigate the extent of previous drilling and excavation, and discuss

the adequacy of the historical record in determining the likelihood of undiscovered wells, boreholes, and excavations in the volume of rock and their possible effect on the repository site.

Provide information on the effects of the active and abandoned wells, boreholes, and excavations on the principal hydrogeologic units. The presence of potential pathways should be indicated and the net flux and hydraulic gradients created by them should be assessed. The information should be compatible with Chapter 12, "Performance Analysis."

3.3 Physiography and Topography

Identify and describe the physiographic province(s) and section(s) in the candidate area and site.

Briefly describe each physiographic province and each section within the province. Included in the description should be province and section names, areal extent, relationships to surrounding provinces or sections, and distinguishing characteristics such as elevation, relief, slope, landforms, structure, rock type, and major active processes modifying the present-day topography. This information should be provided by means of topographic maps of the candidate area and site using appropriate scales and contour intervals needed to support other studies (i.e., repository design). Include representative ground-level photographs, vertical and oblique aerial photographs, and satellite imagery.

Define and justify the area of investigation for physiography and topography. A description of the sources of information and investigations conducted to obtain the above descriptions should be given.

3.4 Geomorphology

Identify and describe the geomorphology of the candidate area by (1) discussing the application of the information from other studies, (2) describing the geomorphic units, geomorphic processes, and geomorphic effects, and (3) describing the investigation program used to obtain the data given in this section.

3.4.1 Application of Geomorphic Information to Site Screening and Selection Process

Describe the uses of geomorphology by itself (geomorphic units, geomorphic processes, and geomorphic effects) and with respect to other studies such as structural geology, hydrogeology, repository isolation, and stability. This description should include the usefulness, significance, and application of geomorphic information to the other geologic investigations.

3.4.2 Geomorphology of Area of Geologic Repository Study

This section should (1) define the geomorphic units, (2) describe major geomorphic processes, and (3) describe the geomorphic effects for each geomorphic unit.

3.4.2.1 Geomorphic Units. Describe each geomorphic unit by giving it name, areal extent, distinguishing characteristics, and any other pertinent information. All units should be shown on a topographic map. Geomorphic units should be defined using a combination of factors controlling geomorphic processes such as near-surface geology and soil, landform morphology, and biota.

3.4.2.2 Geomorphic Processes. Describe any geomorphic process that is relevant to either repository isolation or stability. Each process should be discussed from the perspective of past, present, and future activity. Emphasis should be placed on present processes and past processes occurring during the Quaternary since these are the most useful for estimating future activity. However, information on older processes should also be given where it is useful for understanding present ground-water systems or predicting future changes (e.g., salt dissolution or collapse breccias) or where it can contribute to estimating the potential occurrence of future processes.

Each geomorphic process (past, present, or future) should be described. Such description should include (1) rates of activity, (2) frequency of occurrence and cycles, and (3) controlling mechanisms or factors.

3.4.2.3 Geomorphic Effects. Describe and illustrate any geomorphic effects, especially those that indicate the presence of geologic or tectonic processes relevant to repository isolation or stability. For each geomorphic effect, include (1) spatial extent and relationship to geomorphic units, (2) age, (3) origin and histor (4) landforms produced, (5) effects on geology and hydrology, and (6) relevance to the site screening and selection process. One example is drainage patterns or anomalies that can reflect major structures, faulting, or uplift. Reference should be made to other chapters of the SCR for additional discussions.

3.5 Stratigraphy and Lithology

Describe the stratigraphy and lithology of the candidate area and site by (1) describing the regional stratigraphic framework, (2) describing the relationships of the site to the regional framework, (3) describing the surface geology, (4) describing the stratigraphic and lithologic framework of the area of the geologic repository study, and (5) forecasting future rock genesis and alteration. Also describe the investigation program used to obtain the data given in this section, including methods, limits, and confidence in data and interpretation.

From the above information, generate a model of both the candidate area and site so that site selection, site suitability, and plans for site characterization can be assessed. These models should be developed to a level of detail and spatial extent needed to give a basic geologic understanding, to form a basis or framework for other investigations such as hydrogeology, geochemistry, structural geology, and geotechnical engineering, and to provide information for the decision on whether site characterization should be undertaken. Estimates of the uncertainty of extrapolation of stratigraphic sections should be given.

Descriptions and illustrations (e.g., maps, columns, cross sections) should be given in sufficient detail, style, and quality to permit an evaluation by independent reviewers. Conventional illustration format and symbols used in the publication of geologic literature should be used. Data and interpretive maps should be displayed on transparent stock in order to permit their being superimposed on base maps, and map or cross-section scales should

be standardized as much as possible to permit easy comparison or overlay of related information. Vertical exaggeration should be avoided to the extent practicable and should be clearly identified when used.

3.5.1 Regional Stratigraphic Framework

A regional framework for stratigraphy and lithology should be provided in the following manner:

1. The region should be defined and shown on a map. The regional boundary should have a technical basis such as a sedimentary basin, intrusive complex, or the extent of an extrusive flow, and it should include all areas relevant to studies supported by stratigraphy.

2. Regional stratigraphy and lithology should be described and illustrated. Lithostratigraphic sequences should be characterized in three dimensions in sufficient detail to give clear orientation and order to the detailed descriptions of rock units in the candidate area. The focus should be on defining sequences of similar rock units. For each sequence, the age, range of thickness, spatial extent, major rock units, rock types, vertical and lateral variations, and major unconformities should be given. An overall time sequence should be given by fitting the rock units into a time sequence (eras, periods, epochs, and ages). The regional stratigraphy should be clearly illustrated by showing information on illustrations such as geologic maps, representative columns, and cross sections.

3. A structural and tectonic framework that is relevant to stratigraphic interpretation should be given. Major tectonic features such as basins and arches should be described to the extent needed to understand the mechanisms that control the formation of existing rock units.

4. A genetic model giving the origins and development of the rock sequences should be developed. A general geologic history through time of the rock sequence and the processes that formed and altered the sequence should be given. This should include subjects such as sedimentary tectonics, source

area, depositional and diagenetic environments, volcanism, plutonism, and metamorphism.

3.5.2 Relationship of Candidate Area to Regional Framework

Define and give the basis for the chosen candidate area, and relate it to the region previously described. The study boundaries should not be limited arbitrarily; they should be based on the technical needs arising from the support that stratigraphy gives to studies of hydrogeology, geochemistry, structural geology, geotechnical engineering, and repository design and construction, isolation, and stability.

3.5.3 Surface Geology

Briefly describe the various lithostratigraphic units exposed. Outcrops should be described and mapped together with structural features. Representative measured sections should be given. The relationship of the surface rock units to those in the subsurface should be described and illustrated. Where feasible, nationally recognized symbols should be used.[1]

3.5.4 Stratigraphic and Lithologic Framework of Proposed Site of Geologic Repository

Describe the stratigraphy of the candidate area and site. Each unit as well as the sequence and spatial extent of units should be defined and described by combining both surface and subsurface information. This information should be obtained from the literature, observation, field and laboratory testing, analysis, and interpretation of outcrops, cores, remotely sensed data, and geophysical data. The sequence and spatial extent of the stratigraphic units should be appropriately shown on illustrations such as geologic maps, lithofacies maps, isopach maps, geologic columns, cross sections, fence or block diagrams, and diagrammatic stratigraphic models. Provide representative photographs and geophysical logs for the units. For wells that have been

[1]See Data Sheets Numbers 1-4, American Geological Institute, 5205 Leesburg Pike, Falls Church, Virginia 22041.

cored, driller logs, lithologic and geophysical logs, and core photographs should be provided.

The defined lithostratigraphic units can be formal (groups, formations, or members) or informal (sequences or lithofacies) and should represent the degree of subdivision of the rock mass necessary to support other studies such as hydrology and to determine if site characterization should be undertaken.

Definition of these units should depend on rock properties resulting from sedimentary origin and alteration, such as diagenesis, weathering, metamorphism, and strain. For the degree of subdivision chosen for the units, a rationale indicating what use the subdivision will eventually serve should be given.

Each lithostratigraphic rock unit should be described and mapped as needed to support other studies such as hydrology and to determine if site characterization should be undertaken. Descriptions should include but not be limited to:

1. The name, using established nomenclature,

2. Lithologic and mineralogic composition,

3. Diagnostic physical and paleontological characteristics useful for identification and correlation (i.e., color, sedimentary structures, texture, fabric, trace elements content, fossil content, etc.),

4. Physical characteristics significant to isolation such as bedding, mineralogy, grain size, intergranular fillings, cement, secondary mineralization,

5. Geophysical characteristics or signatures (surface and down hole),

6. Vertical and lateral variation of composition and characteristics and comparison to surrounding units (lithofacies maps),

7. Thickness and spatial extent (isopach maps),

8. Structure (specific dip measurements or inferred structure from geophysical data) and its variation (reference other SCR chapters as needed for detail),

9. Vertical and lateral relationships to surrounding rock units (contacts and unconformities),

10. Age in a manner suitable to needs (reference columns giving time units, and give general ages by time unit and years or specific ages for units involved with studies of the age and rates of processes), and

11. The genesis or origin of the unit to include rock formation processes and models (deposition, intrusion, extrusion) and rock alteration processes and models (metamorphism and diagenesis).

3.5.5 Future Rock Formation and Alteration

Discuss any credible future formation of new rock or natural alteration of existing rock during the next 10,000 years. This discussion should be based on all active processes that can be expected to occur during the next 10,000 years.

3.6 Geophysics of Candidate Area and Site

The geophysical information presented should provide a description of the geophysical data and their relationship to the geologic and tectonic conditions of the candidate area and site. An assessment of natural or man-made events that might change the geophysical and related tectonic conditions should be provided. Geophysical and related tectonic conditions that may influence the site characterization program should be identified. The rationale for using geophysical parameters as bases for the design of any portion of the facility should be explained. Sufficient information should be provided to permit an independent evaluation of the geophysical characteristics of the candidate area. Sources of information and data should be identified. Information

needs for which sufficient data are not currently available should be identified, and the site characterization program to obtain the information should be described in Part C of the SCR.

3.6.1 Seismicity of Candidate Area

A description of the earthquake history of the candidate area should be provided.

Relate historic earthquakes to seismic and tectonic zones. Whenever it is available, the following information should be provided: epicenter coordinates, origin time, total dislocation, source mechanism, and depth to hypocenter. A regional scale map of all the listed earthquake epicenters should be provided. Earthquakes should be differentiated on the basis of focal depth, where applicable.

Whenever applicable, the precise location of hypocenters of small earthquakes should be defined and used to map zones where relief of crustal stress is occurring. Precision estimates should accompany the hypocenter locations whenever possible. Seismic conditions that influence the design and operation of the facility should be identified. All information should be fully documented.

A listing of historic earthquakes should be provided of all earthquakes of magnitude greater than 3 or MM intensity greater than IV that have been reported for the candidate area.[2] The probability of future major earthquakes within the candidate area should be discussed. Where available information is adequate, intervals of recurrence, maximum probable and credible earthquake magnitudes, and a preliminary design earthquake for the proposed repository should also be discussed. Effects of such an earthquake on the proposed structures at the surface and at the proposed repository depth should be evaluated. Available information on focal mechanisms should be evaluated with respect to regional tectonics and stress distribution. The evaluation of the preliminary design earthquake should include an evaluation of the

[2]Comment is especially sought on these magnitude and intensity values.

active faults in the area and the relationship between fault length and earthquake magnitude. Where available information is inadequate, the portions of the site characterization program that will address these informational needs should be referenced.

To ensure the accuracy of seismic risk assessment for a particular site, redeterminations of historic seismicity of the area should be made. Parameters that should be recalculated for each historic earthquake include, but are not limited to, magnitude, epicentral and hypocentral coordinates, and ground motion displacement. Confidence ellipses should accompany hypocentral and epicentral coordinates whenever available.

When earthquakes are located on the basis of arrival times of seismic waves, the particular seismic wave should be identified. This is particularly necessary in the case of poorly recorded earthquakes when arrival times of later phases may be used to better locate the earthquake. If an earthquake cannot be accurately located by arrival time data, additional data should be derived from seismic observatories near the site or from original seismograms. The source of data used in all redeterminations should be identified and documented.

Revised locations of earthquake epicenters or hypocenters that differ substantially from original locations should be especially noted. Whenever a revised location is adopted in place of an original location, an explanation for the preference should accompany the revised location. Fault plane solutions should be provided for earthquakes located near the site. Fault plane solutions that differ significantly from the majority derived for the region should be specifically noted.

3.6.2 Seismicity of Site

The seismicity of the proposed site should be described. The relationship between the seismicity of the proposed site and local faults, fracture systems, and any other geologic features should be discussed. Where available information is inadequate, the portions of the site characterization program that will address these informational needs should be referenced.

3.6.3 Regional Seismic Reflection and Refraction Surveys

Seismic reflection and refraction information should be provided to adequately characterize the geologic subsurface structure and stratigraphy of the region. Subsurface structural and stratigraphic discontinuities should be noted and mapped. The rationale used in choosing the seismic techniques should be provided. Seismic data obtained from private or commercial sources such as surveys for oil, gas, or water should be fully documented.

High-resolution seismic reflection surveys along with modern processing techniques should be used where applicable. Results of seismic surveys should be correlated with borehole information wherever possible. The type of survey chosen and its resolution capabilities should be commensurate with the objective of the survey and its location with respect to the proposed site.

3.6.4 Regional Magnetics

A description of the regional magnetics for the candidate area should be provided and the source of the magnetic data (e.g., airborne and/or ground surveys) identified. The following information should be provided whenever available: contoured magnetic anomaly maps and magnetic profiles; interpretations of the magnetic maps and profiles; correlations of regional geological structural features with magnetic features, depth estimates of strongly magnetic layers, and, if applicable, daily and short-term fluctuations of the regional magnetic field. Local magnetic surveys may be performed to trace buried faults or other geologic structures. The precision of airborne magnetic data and survey line spacing should be commensurate with the objective of the survey.

3.6.5 Regional Gravity

Regional gravity studies should be used in conjunction with magnetic data. Station spacing should be commensurate with the purpose of the gravity survey. A description of the available gravity information should be provided and documented. These gravity data may include, but are not limited to, regional gravity contour maps, residual gravity contour maps, total Bouguer and Free air

anomaly contour maps, interpretations of the gravity maps and profiles, elevation contour maps, and latitudes of each station. Sharp gravity gradients in the candidate area should be identified. Any correlation of gravity gradients with areas of earthquake activity or geologic feature should be noted. Geologic and geophysical information used in conjunction with the interpretation of regional gravity should be referenced.

3.6.6 Regional Heat Flow

Provide heat flow data and heat flow maps that will permit the determination of the geothermal gradient and areas of anomalous heat flow in the candidate area. Terrestrial heat flow information derived from subsurface well-logging records should be documented. Candidate areas characterized by rock types containing radioactive elements (e.g., granitic rocks) should be identified. Terrestrial heat flow conditions that influence the ability of heat to be dissipated from the repository should be identified.

3.6.7 Remote Sensing

The geophysical and geological information obtained from remote-sensing studies of the candidate area should be described and documented. Structural lineaments, offsets of geomorphic and structural features, and regional (including anomalous) drainage patterns should be identified. Regional heat flow patterns derived from remote sensing (e.g., infrared) may be used in conjunction with regional heat flow studies whenever available.

3.6.8 Borehole Geophysics

Describe the results obtained from geophysical methods used in boreholes drilled to study the candidate area and site. Copies of all data, logs, and interpretations should be included.

3.7 Structural Geology and Tectonics

Define the elements that make up the tectonics of the candidate area, and describe the pre-Quaternary and Quaternary structures and processes that may

affect the site screening and selection process. Structural features that may create pathways from the repository to the accessible environment should be described regardless of age. For structural features that provide evidence about the tectonic stability of the site, structures formed during the Quaternary will be of most interest. However, any pre-Quaternary structures that may be reactivated to create tectonic instability should also be described.

3.7.1 Tectonic Framework

Discuss the tectonic framework of the candidate area, and identify those tectonic processes that have been active since the start of the Quaternary. Maps and cross sections that show all major tectonic features, including crystalline shields, sedimentary basins, uplifts, orogenic and fold belts, volcanics, major faults, and major joint sets, should be provided.

3.7.2 Tectonic History

Describe the tectonic history of the candidate area from the earliest recognizable tectonic elements through the end of the Pliocene. All structures such as fractures, faults, and shear zones that may affect the hydrogeology and the ability of the site to isolate high-level waste should be described and appropriate sections of Chapter 5, "Hydrogeology," should be referenced. A table depicting the tectonic history of the area should be included. The table should include tectonic structures, the types and age of rocks that the structures deform, the type and style of deformation, cross-cutting relationships among structures, scale of structures, and any other information necessary to understand the tectonic history of the area. The tectonic history should include the age and sequence of development of all major crystalline shields, sedimentary basins, uplifts, orogenic and fold belts, volcanics, major faults, major joint sets, and any other structures that could affect the site screening and selection process.

3.7.2.1 Volcanic History. The volcanic history should be described. Extrusives such as lava flows, volcanoes, rifts, and dikes and intrusives should be identified.

A map of the candidate area showing the surface and subsurface distribution of all extrusive and intrusive rocks should be provided.

If there is more than one period of volcanic activity or there has been repeated volcanism during the Quaternary, a table listing the volcanic episodes should be included. The table should describe the type of extrusive or intrusive, composition of the volcanics, age, geometric relationship to other volcanics, and the stratigraphy of the surrounding rocks. A description of each major period of volcanism should be presented for each volcanic episode listed on the table.

The mineralogy and geochemistry of each flow should be described, or the appropriate sections on stratigraphy (see Section 3.5) and geochemistry (see Chapter 6, "Geochemistry") should be referenced. Alteration, contact metamorphism, and mineralization of country rocks surrounding the flows should also be documented. Fracturing and faulting associated with volcanism should be described. The description should include attitude and spacing of fractures, the size of the fractures, and cross-cutting relationships among fractures in country and volcanic rocks. Fracturing, weathering, and alteration of volcanics should be described.

The effects of the volcanism on the porosity and on interstitial and secondary permeabilities of the country rocks should be described. The effect of volcanism on the regional hydrogeology should be determined, or plans should be presented in Part C on how the determination will be made during site characterization.

Based on volcanic history during the Quaternary, a prediction of the potential for volcanic activity with emphasis on the next 10,000 years should be made.

3.7.2.2 Faulting History. The faulting history should be described. The description should include the distribution, attitude, and spacing of the faulting for the candidate area. A map showing the location, strike, and dip of all faults should be provided. The characteristics of all the faults should be described. The length of the fault, strike direction, dip of the fault plane, and width of the fault zone should be determined. The nature of the fault zone should be described. The extent to which faults may act as pathways to the accessible environment should be determined. A summary table listing all pertinent fault characteristics of each fault should be included.

The apparent offset, as well as the amount of true offset, of all the Quaternary faults should be determined. The amount of basement offset associated with each fault should also be determined. All assumptions for determining true offset should be explicitly stated. The age of displacement should be identified. Absolute and relative age-dating techniques should be applied where possible. If more than one period of Quaternary faulting is present within the candidate area, the fault system of different ages should be listed on a table, and the evidence for the age of each fault should be presented.

3.7.2.3 Folding History. The folding history of the candidate area should be described. A map showing the location and trend of folds in the candidate area should be included. The trends of Quaternary fold belts should be determined and shown on the map. The wavelength and amplitude of the folds should be determined.

Describe the geometry of the folds. The geometric style of the folds (concentric, similar, or disharmonic), the type of symmetry they display (symmetric or asymmetric), and their attitude relative to the earth's surface (upright, inclined, overturned, or recumbent) should also be determined. The trend and plunge of the fold axis and the strike and dip of the axial surface of each major fold, along with its sense of asymmetry, should be indicated on a map of the candidate area.

Describe the overall nature of the folding. "Thin-skinned" tectonics should be distinguished from "thick-skinned" or basement tectonics.

A table summarizing the properties of each major fold should be included. If more than one period of folding is present, the evidence that allows the relative and/or absolute dating of the individual episodes of folding should be included. Dating of the fold should be done using absolute techniques (where possible) and relative techniques.

Cleavage, fractures, and faults associated and coeval with the folding should be identified. Any effect of these features on the regional hydrogeology should be determined. Any change in porosity and permeability of the rocks due to folding should be discussed.

The mode of origin of the fold (i.e., flexural slip, passive slip, or quasi-flexural) should be determined from the fold geometry, where possible.

3.7.2.4 Jointing. The jointing history of the candidate area should be described. A map showing the location and trend of all joint sets should be included. For each joint set, the areal distribution within the candidate area and the intensity of jointing (i.e., joint spacing) should be determined, and the attitude of the joints should be measured and tabulated. Absolute and relative age dating of the joint sets should be done wherever possible.

The mineralogy and age of fillings along joints of any age should be determined. Discuss the effects of the joint on the regional hydrogeology. Analyze the possibility that joints may form a pathway from the repository to the accessible environment. The effect of various joint sets on the fracture permeability of the rock should be determined or the appropriate sections of Chapter 5, "Hydrogeology," should be referenced. The relationship of joints to the regional faulting and folding should be described.

The mode of origin of the joints, i.e., extension or shear mechanism, should be determined if possible. If microcracks are present describe their geometric and genetic relationships to systematic and nonsystematic joints.

A table listing the various joint sets, in order of age along with their principal characteristics, should be included.

If several joint sets are present, determine their relative ages with respect to each other and their absolute age where possible. Cross-cutting relationships may be useful for determining relative ages.

3.7.2.5 Uplift, Tilting, and Subsidence. Uplift, tilting, and subsidence in the candidate area, including effects caused by withdrawing or injecting fluids and mining, should be discussed. To the extent practicable, the suspected causes of uplift, tilting, and subsidence should be discussed. The rate, magnitude, and areal extent of the uplift, tilting, and subsidence should be described. Quaternary deformation not classified as folds, faults, or joints should also be described.

Present any stratigraphic evidence for uplift, subsidence, or tilting.

3.7.2.6 Active Stress Field. The active stress field in the candidate area should be discussed.

All fault plane solutions for hypocenters located within the candidate area should be tabulated on a table and located on a map. Analyze their

relationship to Quaternary tectonics. Include any stress drops that have been calculated within the candidate area.

All in situ stress measurements that have been done within the candidate area should be summarized. The data should be tabulated to show the type of stress measurement such as overcoring, the flat jack method, or hydraulic fracturing, the depth of the measurement, and the actual magnitude and orientation of the principal stresses.

3.7.2.7 Vertical Crustal Movement. Existing data on crustal movements should be summarized and tabulated. Time-dependent gravity surveys and geomorphic analyses of anomalous landforms should be summarized.

3.8 Long-Term Regional Stability with Respect to Tectonic and Geological Processes

Based on Quaternary and present-day active tectonic, geophysical, and geological processes, a prediction of the future stability of the candidate area should be presented with emphasis on the next 10,000 years. All models, assumptions, and parameters to be used for making these predictions should be explicitly stated.

3.9 Mineral Resources

Site screening will be determined, in part, by the relative attractiveness for mineral exploration. A site that is an attractive target for exploration because of the presence of mineral resources is more liable to human intrusion than one without resources. What is desired is a site that is unattractive to mineral explorers. At the time of this SCR, the assessment of resources and potential resources should be substantially complete, and the conclusions reached should be expressed in the SCR.

The following mineral resource information should be presented for the disturbed zone that extends at least a horizontal distance of 2 km from the limits of the conceptual repository excavation and a vertical distance from

the surface to a depth of 1 km below the limits of the conceptual repository excavation:

1. Present and past mining activity,
2. Present and past drilling, and
3. Estimated value of the mineral resources.

3.9.1 Subsurface Mining

Provide (1) a description of all active or inactive underground mines within the site and (2) plans and sections of any such mines. Include both conventional mines and in situ extraction types of operation. Describe the kinds of minerals extracted, methods of mineral extraction, the volume of rock removed, and the value of the minerals extracted. Include a statement of the present condition of the workings as to subsidence, stability, and flooding.

3.9.2 Mineral Resource Values

The value of resources in the site should be compared with the value of resources in comparable areas within a 100-km radius. Comparable areas include those of similar size and geology. Consider all mineral substances of value, including construction materials, hydrocarbons, metals, ground water, and geothermal resources. Both reserves and potential resources, as defined in DOE's National Uranium Resource Evaluation,[3] should be included. Estimate both the gross value and net value for resources of each substance that may be present in amounts of interest to an explorer. In these evaluations, current economic standards of industry should be used. Methods of assessment are expected to be modifications, as applicable, of the procedures used by the DOE for uranium and thorium, the USGS for oil and gas, and the Potential Gas Committee for gas.

Provide a tabulation of the resources, divided into reserves and potential resources, including (1) the quantity of resources, (2) the cutoff values used in estimating (1), (3) the present gross value of each substance, (4) the

[3]Hetland, Donald, and Meehan, Robert, in Uranium Industry Seminar, October 16-17, 1979, G50-108(79), pp. 133-172.

present net value of each substance, i.e., the gross value less the costs for exploring, developing, extracting, and marketing the substance, and (5) the unit values of the minerals evaluated in (3) and (4). For each substance, describe the method of assessment.

3.9.3 Assessment of Comparison Areas in Region

For comparison with the site, tabulate and discuss assessments of resources in nearby comparable areas of similar size to that of the disturbed zone. These comparable areas should be (1) within a 100-km distance of the proposed site, (2) similar in size to the area of the site, and (3) similar in geology to the site. For each comparison area, the information required in Section 3.9.2 should be provided. The number of comparative areas needed for this analysis cannot be specified. Include a sufficient number of areas to provide a statistically valid characterization of the resources of the geologic region within 100 km of the proposed site.

3.9.4 Analysis of Resources

The purpose of the resource assessments is to determine whether, with respect to similar nearby areas, the site is average, above average, or below average in value of mineral resources and potential resources. Analyze the information in Sections 3.9.2 and 3.9.3, and discuss the relative attractiveness of the site as a target for mineral exploration. The analysis, as well as the assessments, should be in terms of mineral economics.

For natural resources without current markets but that could be marketable as a result of credible projected changes in economic or technological factors, the resources should be described by physical factors such as tonnage or other amount, grade, and quality.

4. GEOENGINEERING

In this chapter the DOE should present the mechanical, thermal, and thermo-mechanical properties of the rock units and the expected mechanical boundary conditions that are the basis for the conceptual design. Each discussion should include (1) a brief summary of generic information from similar rock units and projects and (2) site-specific[1] information, if available. The information should be in sufficient detail to (1) support the geomechanical basis of the proposed conceptual design that is presented in Chapter 10, "Repository Design," (2) support the discussion of design issues in Chapter 15, "Repository Design Issues," and (3) support the plan for resolving the design issues in Chapter 16, "Site Characterization Plan To Resolve Repository Design Issues." The discussions should include values or ranges of values for the design parameters used in the conceptual design and should provide the rationale for selecting these preliminary values.

For each of the properties of the rock units, include a discussion of the equipment and procedures used, including their limitations and the errors produced by them. (Equipment and procedures should be referenced to the appropriate standards, e.g., ASTM, where available.) Geologic borehole logs, geologic cross sections, or photographs should be provided where possible to show where tests were made or samples were taken. The reasons for selecting the particular samples for place testing should be presented. Measures taken to preserve or restore the in situ chemical and physical environment should be described. The anisotropy of the properties should be addressed. If isotropic approximations are assumed, there should be a justification of that assumption.

4.1 Mechanical Properties of Rock Units - Continua

Present the mechanical properties of the rock units as determined by laboratory tests on small and medium-sized samples. Include host rock and other units important for repository design and performance. Provide site-specific data if available. Present generic data from similar rock units.

[1]Site-specific means information gained from tests done in, or samples taken from, limited borings, surface outcrops, near-surface test facilities, pre-existing tunnels or mines, etc., near the site proposed for characterization. It does not imply that a shaft has been dug.

Include elastic and inelastic behavior, compressive and tensile strength, and effects of heating and fluid pressure on these properties.

4.2 Mechanical Properties of Rock Units - Large Scale

Present the mechanical properties of the rock units as determined by large-scale laboratory and field tests such as plate-bearing tests, hydrostatic test chambers, flat jacks, Goodman jacks, and convergence tests. (Large-scale here means tests of sufficient size to take into account the discontinua (fractures, joints, inhomogeneities, etc.) of the media.) Discuss the relationship of the results of the laboratory tests to the results of the large-scale tests. Provide site-specific data if available. Present generic data for similar rock units and environments.

4.3 Mechanical Properties of Rock Units - Discontinua

Describe the mechanical properties of discontinua (fractures, joints, bedding planes, inclusions, voids) present in the rock units. Provide site-specific data if available. Discuss generic data from similar rock units and similar environments. The discussion should include coefficient of friction, compressibility of fractures and filling materials, and effect of heating and changes of pore pressure on the mechanical properties of the joints, fractures, bedding planes, and other discontinua. Discuss the effects of the discontinua on the mechanical properties of the rock mass (e.g., strength and deformation characteristics).

Describe results of discontinua characterization studies. Include, as applicable, seismic and other geophysical studies, borehole logging, borehole photography, and direct mapping. Appropriate parts of Chapter 3, "Geologic Description of Candidate Area and Site," may be included by reference.

4.4 Thermal and Thermomechanical Properties - Laboratory Results

Present results of laboratory studies of the thermal properties of the rock units. Provide site-specific data if available. Present generic data from similar rock units.

Include discussions on the thermal conductivity, heat capacity, thermal fracturing, and coefficient of thermal expansion of the rock units.

4.5 Thermal and Thermomechanical Properties - In Situ

Present the thermal properties of the rock units as determined by field heater tests. Present generic data from experiments done in similar rock units and environments. Present site-specific data if available.

The test procedures should be described, including location, duration, instrumentation, heat loading, and any thermal boundaries or barriers. Discuss the relationship between the laboratory and the field tests.

4.6 Stress Field

Present the stress field data. Present applicable stress measurements that have been made in the region and site-specific data, if available. Include a discussion of expected direction and magnitude of principal stresses as a function of depth.

Appropriate parts of Chapter 3, "Geologic Description of Candidate Area and Site," may be incorporated by reference.

4.7 Special Geoengineering Properties

Describe any special thermal, mechanical, thermomechanical, or other properties of the rock units that were considered in developing the conceptual design. These could be properties or processes such as brine migration, thermal decrepitation, or thermal dewatering. Provide site-specific data if available. Present generic data from similar rock units.

4.8 Excavation Characteristics of Rock Mass

Describe excavation investigations, if available, and excavation experience in similar rock under similar conditions using various techniques such as controlled blasting and mechanical nonblasting. The experience, including how

the investigations were monitored, analyzed, and applied to the anticipated construction of the underground test facility and the conceptual repository, should be described. The discussion should include the potential damages produced by the various techniques and the appropriate methods for avoiding or mitigating such damages.

5. HYDROGEOLOGY

Include in this chapter pertinent information gathered on hydrogeologic factors, including both regional and site-specific factors. The information should be presented in sufficient detail to (1) show that the site is adequate in regard to hydrogeology based on available literature and site screening studies, (2) provide information to identify issues to be resolved during site characterization, and (3) provide information to support the plan for resolving these issues.

Include in this chapter, as applicable, data sources and estimated uncertainties. Include a discussion of any significant consequences of the uncertainties on conclusions drawn from the data.

5.1 Regional Hydrogeologic Reconnaissance

Describe the regional hydrogeologic framework and regional ground-water flow systems and their boundaries.

5.1.1 Hydrogeologic Units

Present a hydrogeologic column of the region in a form as detailed as the information allows. Include the principal hydrogeologic units, their stratigraphic relationships, lithology, generalized potentiometric levels for a given time and location, and hydrologic characteristics. The terminology should be consistent with the terminology used in the regional stratigraphic column presented in Section 3.5.1. Further, a hydrogeologic map of the region should be presented indicating areal extent of the regional hydrogeologic units and unit interfaces.[1] Cross sections should be provided where appropriate.

[1] Use, where practicable, internationally recognized map symbols (UNESCO, International Legend for Hydrologic Maps, Paris, France, 1970, 101 p.).

5.1.2 Relationships Among Hydrogeologic Units

Describe the relationships among the regional hydrogeologic units. The principal relationships sought are potentiometric levels, recharge-discharge and leakage, hydrochemical facies, and the average interstitial ground-water velocities. References should be made to the hydrogeologic map and to the cross sections presented in Section 5.1.1.

5.1.3 Potentiometric Level

Provide in physical form (e.g., hydrographs and potentiometric contour maps) both a time history and areal distribution of measured potentiometric levels of each principal hydrogeologic unit. The method of assembling the data should include graphs to identify the characteristic fluctuations resulting from the various types of recharge-discharge (i.e., seasonal precipitation and evaporation fluctuations, seasonal pumping variations, seasonal response to surface-water bodies, etc.). Provide potentiometric surface maps, including such information as the location of the monitoring wells, hydrogeologic unit boundaries, surface-water bodies, and specific well information (i.e., screen elevations, history, casing, etc.).

5.1.4 Hydraulic Characteristics of Principal Hydrogeologic Units

Provide the ranges, mean values, and methods for determining the principal hydraulic characteristics for each of the principal hydrogeologic units such as hydraulic conductivity, storage coefficient, effective porosity, and saturated thickness. Also include a discussion of the appropriateness of assuming Darcian flow conditions in the various hydrogeologic units.

5.2 Regional Ground-Water Flow System

Provide detailed information on the regional ground-water flow system, including identification of recharge and discharge areas, principal ground-water flow paths, and ground-water ages based on isotopic hydrochemistry.

5.2.1 Identification of Recharge-Discharge Areas

Identify the areas and modes of recharge and discharge, residence times of the ground water, and the bulk rates of ground-water flow for the specific hydrogeologic units. Also include surface- and ground-water interrelationships. Present the information on hydrogeologic maps developed for the region. Using the information requested in Section 8.2, discuss the impact of future climatic variations on recharge rates.

5.2.2 Principal Ground-Water Flow Paths

Describe the principal ground-water flow paths with the associated fluxes and travel times to the accessible environment. Use cross sections and maps to indicate the principal ground-water flow paths. Using the information requested in Section 8.2, discuss the impact of future climatic variations on ground-water flow paths. Define the accessible environment for the site and the credible pathways to it from the anticipated host rock.

5.2.3 Isotopic Hydrochemistry

Describe the results of the isotopic composition of ground-water samples. Include stable isotopes, i.e., D/H, O^{16}/O^{18}, and unstable isotopes, i.e., C^{14}, H^{3}, Cl^{36}. Discuss the implication of the isotopic data concerning the age of the ground water, relative degree of circulation within the hydrogeologic unit, and areas and modes of recharge to the hydrogeologic units.

5.3 Ground-Water Uses

Identify the principal regional ground-water users, including locations, rates, typical well construction, and hydrogeologic unit source. Include irrigation, industrial, municipal, domestic livestock, and energy resource development uses. Identify areas of large ground-water pumping or injection on the regional hydrogeologic map. Include the extent of depression or impression cones on the potentiometric surfaces.

5.3.1 Regional Ground-Water Aquifers Used for Human Activities

Identify the specific aquifer units that provide the sources for the ground-water uses identified in Section 5.3. Also present the relationship between ground-water use and aquifer storage and recharge to identify areas of stress on the aquifer and mining of the ground-water resource.

5.3.2 Regional Hydrochemistry

Describe completed studies that characterize the regional hydrochemical zones. The principal ions of interest are Ca^{++}, Mg^{++}, Na^{+}, K^{+}, Cl^{-}, SO_4^{--}, HCO_4^{-}, and CO_3^{--}. The individual hydrochemical zones should be characterized in graphic form showing the relationship among the principal ions. Each zone should also be characterized by its pH, Eh, total dissolved solids (TDS), and aforementioned principal ions.[2] The major dissolved gases such as carbon dioxide, methane, and hydrogen sulfide should also be included.

5.3.3 Regional Ground-Water Management Plans (50- to 100-Year Projection)

Identify the regional ground-water management agencies and their programs. Also provide an assessment, using this information, of regional ground-water projections for the foreseeable future, preferably the next 50- to 100-year period. Include ground-water use, potentiometric level changes, and hydrochemical changes.

5.4 Site Hydrogeologic System

Describe the site hydrogeologic systems to the extent that available information will permit.

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[2]Field and laboratory analysis methods should conform to those in National Handbook of Recommended Methods for Water Data Acquisition, Chapter 5, Federal Interagency Committee on Water Data, Office of Water Data Coordination, U.S. Geological Survey, Reston, VA, 1977-78.

5.4.1 Baseline Monitoring

Provide information gathered from the baseline monitoring program that includes seasonal variations, long-term trends in potentiometric levels, and hydrochemistry (see Section 5.3.2) of the principal hydrogeologic units (as specified in Section 5.1.1).

5.4.1.1 Monitoring Network. Provide specifications and designs, including locations, elevations of screens and measuring points, elevations of seals, hydrogeologic units being monitored, method and frequency of measurement, and method of hydrochemical sampling for the monitoring network used in establishing the baseline monitoring program.

5.4.1.2 Potentiometric Levels. Provide representative hydrographs and potentiometric surface maps for each principal hydrogeologic unit. The hydrographs should include precipitation, surface-water levels, and rates of groundwater pumpage where appropriate. Based on this information, provide an assessment for the potential for long-term or significant short-term changes in the water levels, and indicate them on hydrographs and potentiometric maps.

5.4.1.3 Hydrochemistry. Provide the previously gathered information on the hydrochemistry of the principal hydrogeologic units. In characterizing each unit, identify the principal ions, dissolved gases, natural radioactive ions, Eh-pH values, organic components, temperatures, density of the fluid(s), and major ions. Using this information, provide an assessment of temporal and spatial variations of the hydrochemistry.

5.4.2 Hydraulic Characteristics of Matrix and Fluid

Provide information gathered on hydraulic characteristics of the matrix and fluid for each principal hydrogeologic unit. The method of determination and range and mean values should be provided. The information should be grouped into separate sections for each hydrogeologic unit and should include the following characteristics:

1. Intrinsic Permeability (m^2). Indicate whether the intrinsic permeability is developed by secondary processes such as fracturing, weathering, dissolutioning, or degassing of igneous rocks and the extent to which Darcian flow can be assumed.

2. Hydraulic Conductivity (m/sec) and Transmissivity (m^2/sec). Indicate the representative volume applicable and the saturated thicknesses assumed.

3. Total and Effective Porosity (dimensionless). Indicate the nature of the pore space, i.e., interstitial, fractured, or solutioning, and distinguish primary and secondary porosity.

4. Storage Coefficient. Indicate whether phreatic or confined conditions are constant throughout the region.

5.4.3 Ground-Water Flow System

Describe the ground-water flow system using the previously described hydraulic characteristics, and identify the accessible environment and credible pathways.

5.4.3.1 Accessible Environment and Credible Pathways. Identify the accessible environment associated with the geologic repository, making reference to Section 5.4.7. The credible pathways for ground-water transport from the geologic repository to the accessible environment should also be identified.

5.4.3.2 Potentiometric Levels and Head Relationships. Provide an analysis of potentiometric levels and head relationships as described in paragraph 5.4.1.2. Include hydraulic gradients, flow directions, and potential for variations.

5.4.3.3 Recharge-Discharge and Leakage. Provide information on completed investigations on the location and rates of recharge-discharge and leakage for the principal hydrogeologic units. Where appropriate, constant head, no-flow, and constant flux boundary conditions should be identified and indicated on the appropriate hydrogeologic map.

5.4.4 Ground-Water Velocity and Travel Time

Describe the method of determination and the ranges of values for the average interstitial velocities for Darcian flow conditions or the maximum velocities for fractured flow of the principal hydrogeologic units based on the respective elementary volume. Using the information gathered on credible pathways, indicate the expected range of advective travel times from the geologic repository to the accessible environment.

5.4.4.1 Radionuclide Transport Mechanisms. Provide information on the methods and the results of investigations used to determine the radionuclide transport mechanism for each hydrogeologic unit occurring in the credible pathway. The investigations and methods of analysis should take into consideration the temperature, viscosity, retardation, and oxidation-reduction potential within the hydrogeologic units and the projected thermal flux due to the emplaced waste.

5.4.4.2 Geothermal Gradient and Thermal Convective Component. Identify the existing geothermal gradient, and assess the effect of the thermal convective component introduced by the emplaced waste on the ground-water transport.

5.4.5 Hydrochemistry and Ground-Water Age

Describe the results of completed investigations of the hydrochemistry and ground-water age of each principal hydrogeologic unit. Include the tests and method of sampling to be performed for the hydrochemical investigation. For each principal hydrogeologic unit, provide the following information:

1. Saturation States of the Major Cations and Anions. Include an assessment of the effects of the major ions on the retardation factors for each hydrogeologic unit taking into consideration equilibrium conditions and reactive chemistry.

2. Eh-pH Relations. Include an assessment of potential for change.

3. Environmental Isotopes. Identify the isotope (i.e., C^{14}, H^3, O^{16}/O^{18}, D/H) used for ground-water age determinations, including the field and laboratory techniques used, the range of values, and an error analysis of the results.

4. Adsorption/Desorption Values. Include identification of retardation values for specific rock types, temperatures, solubility ranges of ions, and Eh-pH values.

5. Organic and Dissolved Gas Content. Include an assessment of the relationship of dissolved substances with pressure, temperature, and depth.

5.4.6 Monitoring and Verification

Provide information on the specific monitoring and verification programs, including their spatial and temporal bounds, implemented for the hydrologic system associated with the geologic repository.

5.4.6.1 Design Considerations. Specify the design basis conditions that are being monitored and the method and frequency of monitoring necessary to determine the design considerations.

5.4.6.2 Baseline Condition Changes. Specify the aspects of the monitoring program that will permit detection of baseline condition changes necessary to assess hydrologic stability and provide an historical background. Reference paragraph 5.4.6.1 of this chapter and Chapter 12, "Performance Analysis," in the development and documentation of the monitoring program.

5.4.6.3 Well Construction, Development, and Completion. Describe well construction and development techniques. Include such details as locations; elevations of screens and measuring data; hydrogeologic units encountered; method of development; types and locations of borehole seals, casing, and screen materials; mode of drilling; and method and schedule of development.

5.4.6.4 Monitoring Methods. Describe the method of sampling and/or surveillance used. Provide information on the indirect methods of sampling such as geophysical techniques and TV surveillance. Also provide information on

the direct methods of sampling such as water sampling, potentiometric level readings, and pressure testing. Indicate the hydrogeologic information collected using each monitoring method.

5.4.7 Local Ground-Water Users

Identify all the local ground-water users, including locations, rates, typical well construction, and hydrogeologic unit source. Include irrigation, industrial, municipal, domestic livestock, and energy resource development users. Determine what effect, if any, the local ground-water users have on the site's ground-water flow system.

6. GEOCHEMISTRY

In this chapter present pertinent descriptions of the geochemical pathways for and barriers to the migration of radionuclides to the accessible environment. Include anticipated geochemical reactions affecting radionuclide retardation or migration (1) in the "far field" in the proposed host rock and other rocks along pathways to the accessible environment and (2) in the "near field" of the repository where temperatures may be elevated and mineralogical changes may occur. Include also anticipated geochemical reactions that could cause failure of other repository systems (e.g., the effect of geothermal alteration of the host rock on the structural stability of the tunnel). Include generic data from similar media and site-specific information, if available. The information should be presented in sufficient detail to (1) show that the site is adequate in regard to geochemical factors based on available literature and site-screening studies, (2) support the discussion of geochemical issues related to the performance objectives in Chapter 13, "Siting Issues," and (3) support the program to resolve those issues in Chapter 14, "Site Characterization Plan To Resolve Siting Issues."

The discussion should include (1) expected waste/water/rock interactions, (2) the aspects of expected waste/water/rock/engineered barrier interactions that could impact radionuclide retardation in the far field (the full discussion of waste/water/rock/engineered barrier interactions should be presented in Chapter 11, "Waste Form and Packaging,") and (3) the aspects of ground-water geochemistry that impact radionuclide migration (the full discussion of ground water should be in Chapter 5, "Hydrogeology").

For each of the following sections, include the rationale for the values chosen. For natural variables (rock compositions, ground-water chemistry, etc.), indicate expected ranges of values and by what process these were assumed. For engineering variables (composition of backfill, waste form, canister, and temperature and pressure), indicate why these particular values were assumed and what is the reasonable range of expected values. For chemical and geochemical reactions (any of the reactions among the waste, water, rock, barrier, canister, etc.), indicate the rationale for the identification of

these reactions (theoretical, laboratory experimental, observed in nature) and to what extent the nature of the reactions would be expected to change because of uncertainties.

6.1 Host Rock Geochemistry

For rocks and fracture fill materials along credible pathways to the accessible environment, describe the petrology and mineralogy of the rocks and fractures. Describe the inferred or measured distribution and abundance of mineral phases that will retard radionuclide migration, and identify mineral assemblages that buffer pH and Eh of ground water.

6.2 Ground-Water Geochemistry

For the proposed host rock unit and other rock units along credible pathways to the accessible environment, describe the anticipated ground-water geochemistry. Include:

1. Major, minor, and trace-element composition of ground water, including organic and inorganic species, dissolved and suspended,
2. Ionic strength of ground water,
3. Complexes (organic and inorganic) that may pertain to radionuclide migration,
4. pH,
5. Eh (measured and calculated),
6. Temperature,
7. Pressure, and
8. Gas composition.

6.3 Chemistry of Waste, Barriers, and Near-Field Environment

Describe anticipated interactions among the waste form, engineered barriers, and near-field environment. Include analyses of generic interactions and, if available, include analyses of interactions of proposed specific waste forms and engineered barriers for the site.

Describe the anticipated (1) chemical composition and form of the waste, (2) solubility of the waste form in ground water under varying anticipated environmental conditions (e.g., temperature, oxidation states), and (3) species released by the leaching of the waste form under anticipated conditions.

Describe planned or anticipated (1) chemical and mineralogical composition of any barriers, (2) solubility of these barriers under varying anticipated physico-chemical conditions, (3) any changes in speciation imposed on radionuclides released from the waste, and (4) speciation of wastes crossing the engineered barrier/natural geological systems boundary.

Describe anticipated interactions of the waste water and rock. Include (1) hydrothermal alteration of the proposed host rock during the thermal pulse, (2) changes in the chemistry of the ground water in the proposed host rock during the thermal pulse, and (3) the effect of changes of mineralogy and hydrology on the radionuclide migration.

6.4 Geochemical Retardation

Describe the anticipated near-field and far-field retardation conditions. Include processes such as:

1. Adsorption-desorption,
2. Absorption,
3. Ion exchange,
4. Filtration,
5. Acid-base,
6. Solution-precipitation,
7. Oxidation-reduction, and
8. Complexing.

Describe anticipated geochemical retardation processes to include, but not be limited to:

1. Thermodynamic information,
2. Reaction mechanisms,
3. Impact of kinetic effects,
4. Retardation factors (Rf),

5. Mass distribution coefficient (Kd),
6. Surface distribution coefficient (KA), and
7. Solubilities.

6.5 Natural Analogues

Provide pertinent data, analyses, and current level of assessment of natural geochemical analogues to the repository. Provide a basis for comparing and contrasting the analogue environment with the site.

6.6 Field Tests

Describe any field tests from other sites that may be useful in interpreting expected results from this site.

6.7 Geochemical Stability

Describe the expected geochemical stability of the site. Include (1) potential human influences (i.e., solution mining, injection disposal, ground-water withdrawal, ground-water mining) and (2) natural changes due to climatic variation.

6.8 Geochemical Modeling

Describe any use of geochemical information in transport models and the results of any modeling. Discuss the comparison of modeling results with natural analogues or field tests for similar geochemical systems.

7. SURFACE HYDROLOGY

This section should present sufficient information to (1) show that the site is adequate in regard to surface hydrologic factors to the extent practicable based on available literature and site-screening studies, (2) show that the site characterization program will not be compromised by flooding, (3) provide preliminary design basis for flooding for the conceptual design of the surface facilities given in Chapter 10, "Repository Design," (4) identify any surface hydrology issues that will be resolved during site characterization, and (5) support the plan for resolving those issues.

In the following sections include as applicable the source of the information and discuss (1) any significant uncertainties in the information and (2) any significant effects of the uncertainties on conclusions drawn from the information.

7.1 Hydrologic Description

Describe the location and physical and hydrologic characteristics of surface-water bodies such as streams, lakes, and shore regions influencing facility siting. Include expected seasonal and other temporal variations of important parameters such as flow and currents. A flow-duration curve should also be provided for perennial streams that could be affected by the design and operation of the facility.

Where a stream is to be used by the facility in any way, present the estimated 7-consecutive once-in-10-years low flow, in addition to observed instantaneous and average daily minimums.

Include a description of existing and proposed water control structures, both upstream and downstream, that may influence conditions at the site. For those structures, (1) tabulate contributing drainage areas, (2) describe types of structures, all appurtenances, ownership, seismic design criteria, and spillway design criteria, and (3) provide elevation-area storage relationships and short-term and long-term storage allocations for pertinent reservoirs.

7.2 Floods

7.2.1 Flood History

Provide the date, level, peak discharge, and related information for major historical flood[1] events in the site region. Include stream floods, surges, seiches, tsunami, dam failures, ice jams, floods induced by landslides, and similar events.

Discuss the potential for future flooding of the facility over a 10,000-year period. Include long-term changes in the hydrometeorology of the region, the potential for floods induced by glaciation, and the failure of future hydraulic structures. Also describe planned or ongoing studies to thoroughly investigate the potential for future flooding. Reference may be made to Chapters 3, "Geologic Description of Candidate Area and Site," 8, "Climatology," and 9, "Environmental, Land-Use, and Socioeconomic Characteristics."

7.2.2 Flood-Dry Site

A flood-dry site is one where the disposal site is so high above potential sources of flooding that safety is obvious or can be documented with minimum analysis. A descriptive statement of circumstances and relative elevations may be sufficient. Analogy may be drawn with comparable watersheds for which probable maximum flood (PMF) levels have been determined. Approximate estimates of PMF levels may be used. If a margin of safety is not thus ensured, the site is not clearly floodfree and a detailed flood analysis should be made. Flood studies for dry sites should be carried only to the degree of detail required to provide that safety-related structures (both surface and subsurface) are safe from flooding. All methods and assumptions should be conservative and documented. Procedures that may be used are described below.

[1] A "flood" is defined as any abnormally high water stage or overflow from a stream, floodway, lake, or coastal area that results in significantly detrimental effects.

7.2.2.1 Approximation Procedures for Natural Flood. The following is an approximation particularly applicable to "hilltop" or "dry" sites for natural floods:[2]

1. Estimate PMF peak discharge on the basis of drainage area relationships to discharge derived from available PMF studies in the region.[3] State the basis of each study used.

2. Estimate river stage using Manning's equation, average river channel bottom slope, river cross sections, and conservative friction factors.

3. Test the stage estimated for sensitivity to potential errors in estimated values.

4. Make a detailed analysis for the PMF if this approximation does not result in a stage significantly below safety-related structures, systems, and components.

7.2.2.2 Approximation Procedures for Dam Failure. The following is an approximation to hill top or dry sites for dam failure:[4]

1. Select upstream dams within range of influence. Tandem structures should be assumed to fall like "dominoes." Parallel structures should be assumed to have common times of failure.

2. Assume vanishment of each dam under reservoir levels corresponding to the PMF.

3. Compute breach wave height, h = 4 (headwater-tailwater)/9. Transfer downstream without attenuation with the local PMF values. Channel restriction and obstruction downstream from the facility should be considered.

[2]See American National Standards Institute (ANSI) Standard N170-1976, "Standards for Determining Design Basis Flooding at Power Reactor Sites."
[3]Appendix B to Regulatory Guide 1.59 presents alternative methods of estimating PMFs.
[4]See ANSI N170-1976.

7.2.3 Non-Flood-Dry Site

If the site cannot be demonstrated to be safe from flooding using the simplified procedures outlined in Section 7.2.2, perform a detailed analysis. For a detailed PMF analysis, the procedures presented in ANSI N170-1976 may be used. If a detailed analysis is performed, it must include sufficient information to allow an independent analysis to be made as a check. If procedures other than those presented in ANSI N170-1976 are to be used, the reasons should be stated and the procedures should be described.

7.2.4 Flooding Protection Requirement

Describe the static and dynamic consequences of all types of flooding on each pertinent safety-related facility. Present the design bases required to ensure that safety-related facilities will be capable of surviving all design flood conditions, and reference appropriate discussions in other sections of this SCR where the design bases are discussed. Various types of flood protection used and the emergency procedures to be implemented (where applicable) should be described. If the flooding protection requirements are contingent upon refinement of the design basis flood analysis, state this and specify those items in the conceptual design that may be modified.

7.3 Surface-Water/Ground-Water Disposition of Releases

Discuss the potential for contamination of surface waters as a result of either surface or subterranean releases. Any surface discharge areas (springs and seeps) of aquifers that could be contaminated by releases from the facility should be identified and plotted on a regional map. (Parts of Chapter 5, "Hydrogeology," may be incorporated by reference.) Provide an estimate of the rate of ground-water discharge at these points. If the discharge is through the bottom or sides of a stream or lake bed, the discharge per square meter of lake bed or linear meter of stream channel should be estimated. Provide the bases for the discharge estimates such as base flow measurements, water balance calculations, and aquifer hydraulics.

7.4 Locations and Distances to Points of Surface-Water Use

7.4.1 Present Quantity and Quality of Surface Water Extracted

Provide a tabulation of existing surface-water intakes (including collector well systems) downstream of any ground-water discharge areas identified in Section 7.3. For each surface-water intake, the location, population served, type of intake, and the maximum daily and average quantities of water pumped should be provided. Also, the water quality at the intake locations and the type of treatment given to the water before distribution should be discussed.

7.4.2 Projected Surface-Water Uses

Estimate quantities and potential areas of water use for 50 and 100 years into the future for the region. Base projections on expected growth rate of the region; industries likely in the future because of location, climate, or natural resources; and probable changes in the technology or economic requirements. Do not base projections on extrapolations of historical data alone. Also locate possible points of withdrawal for any potential future water users that have been identified.

7.5 Chemical and Biological Composition of Adjacent Watercourses

Describe the chemical and biological composition of adjacent bodies of water that could conceivably be affected by releases from the facility. The chemical data should be sufficient to determine the salt seep or salt discharge rates into drainage basins for dissolution studies. This description should include measured baseline data from the preoperational monitoring program.

Identify, to the extent possible, the source and nature of the background pollutants (e.g., chemical species and physical characteristics such as color and temperature), the range of concentrations involved, and the time variation in release. Information relating to water quality characteristics should include measurements made on, or in close proximity to, the site.

The seasonal cycles of temperature and salinity structure should be provided. Additionally, information that describes the bottom and shoreline configuration,

sedimentation rates (suspended and bed load), sedimentation graduation analysis, and distribution (sorption) coefficients should be included.

7.6 Unresolved Hydrologic Issues and Plans

Summarize any issues or problems identified during the preliminary site investigation, and state the plans for resolving those issues or problems in Chapters 13, "Siting Issues," 14, "Site Characterization Plan To Resolve Siting Issues," and 21, "Site Characterization Program."

8. CLIMATOLOGY

Provide a description of the climatology and meteorology of the site and the surrounding area. An analysis of paleoclimatic conditions should provide an assessment of the climatic changes that might occur in the future, based on evaluations of the past and present climatic conditions. Meteorological and climatological conditions that influence the design and operation of the facility should be identified. The basis for all meteorological parameters used as a design basis for any portion of the facility should be described. Sources of the information and data provided should be presented. Information areas where sufficient data or information are presently not available should be identified.

8.1 Recent Climate and Meteorology

A climatological and meteorological description of the site and its surrounding areas should be provided.

8.1.1 Regional Climate

The general climate of the region should be described with respect to types of air masses, synoptic features and frontal systems, general airflow patterns and relationships between synoptic-scale atmospheric processes and local (site) meteorological conditions. Climatological characteristics attributable to the terrain should be identified. Data should be provided in sufficient detail to indicate impacts on facility design, operation, and long-term isolation of the waste.

The following information concerning the recent (i.e., 30 years) climatology of the region should be presented:

1. Total precipitation (rain and snow) by month, number of hours with precipitation, and rainfall rate distribution.

2. Cumulative frequency curves of monthly average precipitation, evaporation, and precipitation minus evaporation for each month of the year.

3. Estimate of the wind erosion index.

4. Monthly and annual dry bulb air temperature and dewpoint temperature summaries, including averages, measured extremes, and diurnal range.

5. Monthly and annual frequencies of wind speed and direction by atmospheric stability class at all heights at which wind characteristic data are applicable to the potential airborne effluent releases from the facility, including those associated with site investigation and facility construction.

6. Monthly mixing height data.

7. Seasonal and annual frequencies of severe weather phenomena, including hurricanes, tornadoes and waterspouts, thunderstorms, lightning, hail, freezing rain (ice storms), dust (sand) storms where applicable, and high air pollution potential.

8. One-hundred-year return period values for fastest-mile wind speeds, maximum and minimum air temperatures, and ground snowpack weights.

9. The 48-hour probable Maximum Winter Precipitation amount.

All information should be fully documented and should be based on data for the most recent 30-year record period. Sources of such information could include National Oceanic and Atmospheric Administration (NOAA) facilities such as the National Climatic Center (NCC) and the National Weather Service (NWS) stations; other government facilities (e.g., military stations); and private organizations such as universities that have maintained quality-controlled data collection programs. The validity of the information provided, with respect to representation of the conditions at and near the site, should be substantiated.

8.1.2 Local and Regional Meteorology

Plans for obtaining sufficient meteorological information to adequately characterize atmospheric dispersion processes (i.e., airflow trajectories,

atmospheric stability conditions, depletion and deposition characteristics) for population dose estimates within the candidate area should be provided. Meteorological conditions that influence the design and operation of the facility should be identified. Meteorological parameters expected to be used as a design basis for any facility structure should also be provided.

The following should be considered in developing any plan for characterizing dispersion processes or estimating population doses.

8.1.2.1 Dispersion Evaluations. In order to characterize local atmospheric dispersion, hourly averages of wind speed and direction and atmospheric stability (defined by vertical temperature gradient or other well-documented parameters that have been substantiated by diffusion data) from onsite meteorological measurements should be provided at all heights and intervals relevant to the atmospheric dispersion of airborne effluents released during the construction and operation of the facility. Monthly and annual joint frequency distributions of wind speed and wind direction by atmospheric stability class, compiled from these data, should also be provided. The relationship of the data collected on site to the meteorology of the region should be discussed. At least one annual cycle of data from the onsite meteorological program at the site characterization stage and the data for at least 2 additional years prior to facility construction should be provided. All data should be fully documented and substantiated as to validity with regard to representing expected conditions at and near the site during the operating life of the facility.

Atmospheric relative concentration (χ/Q) and relative deposition (D/χ) estimates for continuous and intermittent routine effluent releases from the facility during operation, to be used in population dose assessments, should be provided within the candidate area at appropriate distances and receptor locations. In addition, such estimates should be provided for use in assessing the consequences of accidental releases of airborne radioactive material or other hazardous, nonradioactive gaseous effluents. Estimates should be provided for instantaneous releases and for releases that might occur over several hours or days for appropriate operational modes of the facility. Unless it can be shown that the resuspension/deposition pathway of contaminated soil is not a critical pathway relative to the air pathway for offsite doses, estimates

of the resuspension and deposition of soil particles at critical offsite locations should also be provided.

Detailed descriptions of the models used to calculate χ/Q values and D/χ values and the models used for the resuspension and deposition of soil particles should be provided. A discussion of the accuracy and validity of the models, including the suitability of the input parameters, source configuration, and topography, should also be provided. Meteorological data used as input to the models should be identified.

8.1.2.2 Site Meteorological Measurement Program. The meteorological measurement program to be conducted to develop local data and programs that will be used during operation to estimate offsite concentrations of effluents released from the facility should be described. The information provided should include measurements made, locations and elevations of measurements, descriptions of the instruments used, instrument performance specifications, calibration and maintenance procedures, and data analyses procedures. The meteorological measurement program should be consistent with gaseous effluent release structures and systems design. (The effluent release structure and system design is assumed to be commensurate with the degree of risk to the health and safety of the public.)

8.1.2.3 Meteorological Conditions for Design Bases. All meteorological and air quality conditions to be used as design and operating bases against severe and extreme natural meteorological phenomena should be provided, including:

1. Design basis tornado parameters, including translational speed, rotational speed, and the maximum pressure differential with its associated time interval,

2. The 100-year return period "fastest mile of wind," including vertical distribution of velocity and appropriate gust factor,

3. The weight of snow and ice on the roof of each safety-related structure, and

4. The extreme maximum and minimum temperatures and expected persistences.

The period of data record examined should be identified, and the procedures used for selection of the critical meteorological data should be provided.

8.2 Long-Term Climatic Assessment

An analysis of paleoclimatic conditions at the site and surrounding area should be provided. Based on this analysis and on recent climatic characteristics of the region, an assessment of the magnitude and rate of climatic changes that might be expected to occur in the future should be provided. The information should be presented in sufficient detail to indicate impacts on long-term isolation of the waste.

8.2.1 Paleoclimatology

Provide an analysis of the Quaternary paleoclimatology of the site and surrounding area, which includes atmospheric, hydrospheric, and cryospheric aspects of the successive climatic regimes in the context of determining the magnitude of the climatic changes and the rates at which the changes occurred. Both geologic and biologic evidence to support the analysis should be provided. Changes in precipitation regimes, locations of potential aquifer recharge areas, glaciated areas, and windflow patterns should be identified. Information should be provided on the size (areal extent and thicknesses) of any glaciers and on accumulation and ablation rates. The impacts of any glaciers on precipitation regimes and windflow patterns should be discussed. Relationships between air temperatures and regional precipitation, in relationship to the water balance of the area, should also be discussed.

Sources of all information should be provided. The validity of the information provided, with respect to the representation of conditions at and near the site, should be substantiated.

8.2.2 Future Climatic Variation

An estimate of the potential impact of climatic change on precipitation patterns, windflow regimes, the cryosphere, and sea levels should be discussed

within the framework of time periods of (1) $<10^2$ years, (2) 10^2 to 10^3 years, and (3) 10^3 to 10^4 years.

Based on the reconstruction of the paleoclimate and the recent climate, long-term estimates (to 10^4 years) of the following should be provided:

1. Potential maximum and minimum changes and rates of change in precipitation and air temperature from the present that could be expected to occur,

2. Potential regional windflow and precipitation patterns that may evolve in the future as a result of climatic and geologic changes,

3. The potential for glaciation, including estimates of times of onset of glaciation and lengths and severity of glacial regimes in the site area, and

4. Future fluctuations in sea levels and cryosphere due to climatic changes.

All procedures, including models, used in the climatic extrapolations should be identified, as should all assumptions and areas where insufficient data make extrapolations questionable.

8.2.3 Site Paleoclimatic Investigation

Describe how information obtained during the site characterization stage will be used to increase the data base concerning the paleoclimatology of the area. This could include the examination of core samples for fossil pollen, ancient soil types, lake sediment varve sequences and thicknesses, etc. The application of the information thus developed to supplement places where data are sparse or lacking in the initial investigation should be emphasized. Any changes in the paleoclimatic assessment that results from this investigation should be reflected by revisions to the future climatic condition extrapolations.

9. ENVIRONMENTAL, LAND-USE, AND SOCIOECONOMIC CHARACTERISTICS

The description of the site should include a discussion of the environmental, land-use, and socioeconomic characteristics of the site, including the following:

9.1 Environmental

9.1.1 Ecology

Describe the terrestrial and aquatic flora, fauna, habitat areas, and ecological communities of the region in which the site is located and of the site itself. Particular attention should be given to endangered or threatened species, species of recreational and commercial importance, and the existence of important habitat areas.

9.1.2 Climate

Briefly summarize the climate of the region in which the site is located. Information may be cross-referenced from Chapter 8, "Climatology."

9.1.3 Geology

Briefly summarize the geology of the region in which the site is located. Information may be cross-referenced from Chapter 3, "Geologic Description of Candidate Area and Site."

9.1.4 Air Quality

Describe ambient air quality, including visibility.

9.1.5 Water Quality and Use

Describe ambient surface- and ground-water quality and current water use and availability.

Information may be cross-referenced from Chapters 5, "Hydrogeology," and 7, "Surface Hydrology."

9.1.6 Radiological Background

Describe the sources and amount of radiological background at the site.

9.2 Land Use

9.2.1 Land-Use Categories

Identify the distribution of land use among the following categories:

- Hydrologic features (rivers, lakes, streams, wetlands)
- Forest
- Wildlife preserve
- Parks and recreation
- Scenic views and vistas
- Archeological and historic areas
- Agricultural areas
- Grazing areas
- Timber production
- Mineral extraction
- Major transportation facilities (roads, railroads, air)
- Commercial, industrial, and residential sites
- Utility transportation lines (electric, gas, oil, coal slurry pipelines, water canals, and conduits)
- Communication facilities
- Community service facilities (refuse, dumps, sewage disposal plants, water supply reservoirs, and educational and scientific facilities)

9.2.2 Land-Use Change

Identify any planned or potential changes in the existing land-use distribution.

9.2.3 Ownership

Identify the distribution of land ownership among the following categories:

1. Federal Government,
2. State and local government,
3. Indian tribe, and
4. Private ownership.

9.2.4 Esthetics and Recreation

Identify any important scenic and natural features in the vicinity of the site, including unique surface formations, forest land, and terrestrial or aquatic habitats. Identify existing recreational activities in the vicinity of the site.

9.2.5 Historic, Archeological, and Cultural Resources

Identify any historic, archeological, or cultural features in the vicinity of the site. Particular attention should be given to any places listed in the National Register of Historic Places or the National Registry of National Landmarks.

9.3 Socioeconomic

9.3.1 Demography

Describe the population of the site and surrounding area in terms of size, distribution, average density, and composition.

9.3.2 Economy

Describe the economic characteristics of the area in terms of:

1. Contribution of the various economic sectors (agriculture, trade, industrial, service),

2. Size and composition of the labor force,
3. Employment levels,
4. Per capita income,
5. Size, value, composition of the housing market, and
6. Local government revenues and expenditures.

9.3.3 Service Facilities

Describe the service facilities in the area, including medical and educational facilities, municipal sewerage facilities, solid waste and water systems, and public safety facilities.

9.3.4 Government

Describe the relevant government units of the site area in terms of organization and function.

10. REPOSITORY DESIGN

In this chapter describe the conceptual design of the proposed repository and its relationship to known or inferred site conditions. The information should be in sufficient detail to (1) demonstrate to the extent practicable from the literature, the limited site screening activities, and the limited design activities that the site is adequate to host a repository of the proposed conceptual design, (2) provide a basis for identifying issues related to the suitability of the site to host a repository of the proposed conceptual design as described in Chapter 15, "Repository Design Issues," and (3) support the proposed program of exploration and testing to resolve these issues, as described in Chapter 16, "Site Characterization Plan to Resolve Repository Design Issues."

10.1 Description of Conceptual Design

Provide the conceptual design of the proposed repository facility. Provide plan, elevation, and cross-section drawings for the conceptual design showing the planned layout of surface and subsurface facilities, and describe how these are related to known or inferred site conditions. Provide the design bases, design assumptions, preliminary design criteria, and preliminary analyses that have been performed to develop the conceptual design, and relate these to known or inferred site conditions. Identify systems, components, and structures important to safety and the dependence of the conceptual design of these features on known or inferred site conditions. In addition, the following information on the conceptual design should be provided.

10.1.1 Design of Underground Openings

Provide the general layout and design of proposed subsurface openings in plan and cross section, and show their relationship to the proposed test facility and to known or inferred geologic and hydrologic conditions of the site. If known, identify proposed locations of shafts and their relationship to the proposed test facility and known or inferred subsurface conditions. Provide

shaft stability factors based on inferred subsurface rock stresses and ground-water conditions and their relationship to the proposed test shaft(s). Provide the basis used in determining the proposed sizing, shape, and orientation of the major subsurface openings. Include discussions of those considerations given to ground-water conditions, thermal output, the natural and thermally induced stress field, and the need for ventilation. Identify and discuss separately any design limitations due to factors not directly related to waste isolation but to the constructability or operability of the repository. These could be factors such as minimum space required for emplacement of the waste, layout requirements for separation and control of excavation and waste emplacement operations, ventilation requirements, and worker safety considerations.

10.1.2 Backfill

Describe the proposed functions of the backfill in the proposed conceptual design. Identify any proposed backfill materials being considered for use at the proposed site. Describe the mechanical properties of the proposed backfill that are critical for the site and design (use ASTM or other applicable standards, as appropriate). Describe the relationship between the mechanical properties of the proposed backfill and the expected conditions at the proposed site (e.g., temperature, moisture, stress). Describe the geochemical characteristics of the backfill materials. Describe the anticipated chemical interactions among the waste package, backfill, ground water, and host rock under assumed waste emplacement conditions. Identify the measured or inferred material and site parameters used to estimate those reactions. (Geochemical discussion here should be in sufficient detail to describe the geochemical role of the backfill at the site. The full descriptions of the geochemical investigations and the nature of backfill, waste form, package, rock, and ground-water interactions should be provided in Chapters 6, "Geochemistry," or 11, "Waste Form and Packaging.")

10.1.3 Strength of Rock Mass

Provide preliminary design values used for the mechanical properties of the rock, including elastic and inelastic behavior of the rock mass, the thermo-mechanical behavior of the rock mass, and the mechanical behavior of rock

discontinuities (e.g., joints, bedding planes, shear zones). Describe how they were determined. (The rock mechanics information should be presented here in sufficient detail to describe the relationship of the rock properties to the design. The full description of the rock mechanics background should be presented in Chapter 4, "Geoengineering.") Describe how these values for the mechanical and thermomechanical behavior of the rock were used in developing the conceptual design. Present the results of model studies used in developing the proposed design.

10.1.4 Sealing of Shafts, Boreholes, and Underground Openings

Describe proposed treatment of the disturbed section of rock around openings and excavated surfaces. Describe proposed design measures to control groundwater movement into the facility. Provide laboratory and field data and inferred site conditions on which the selection of the treatment measures were based. Describe the proposed conceptual design for the sealing of boreholes and shafts. Provide laboratory and field data and inferred site conditions on which the design was based. Provide the mechanical, chemical, and hydrologic properties of proposed sealing materials.

10.1.5 Construction

Describe construction techniques being considered for repository development. Describe in detail any known or inferred site conditions requiring specialized construction techniques. Describe actions that will be taken so that construction of exploratory workings and the planned repository will not compromise the ability of the site to isolate wastes.

Describe methods under consideration for breaking and removing rock and any special precautions needed to minimize fracture zones that could be potential pathways, taking into consideration the inferred rock conditions at the site proposed for characterization. Describe the geotechnical factors expected to bear on the suitability of proposed excavation techniques and their relationship to any information obtained during exploratory drilling. Mechanical excavation methods, controlled blasting, or other measures proposed to be used

in the construction of underground openings should be described and related to known or inferred rock conditions and the stability of the conceptual design. (The full description of excavation investigations should be given in Chapter 4, "Geoengineering.") Describe temporary or permanent support structures proposed and their relationship to the basis of the proposed conceptual design. Describe methods planned to be used to control, collect, and dispose of ground water during excavation and the relationship of the planned methods to ground-water information obtained from exploratory investigations.

10.1.6 Design of Surface Facilities

Provide a description of properties of overburden materials and foundation rock considered in the design of structural foundations for surface facilities. Describe expected or known soil and rock conditions, depth of overburden, and quality of foundation soil. Describe any known or inferred foundation problems. Also, describe sources of water for construction and operation of the proposed facility.

11. WASTE FORM AND PACKAGING

Discuss the strengths and weaknesses of principal candidate waste forms and packages with respect to meeting the performance objectives in 10 CFR Part 60, and describe how the range of waste package environments anticipated at the proposed site would affect these strengths and weaknesses. Describe alternative waste forms and packages and their development programs in sufficient detail to allow a determination of their compatibility with the site as it is understood at the time of this report and to allow a determination of any potential adverse effects to the host rock resulting from emplacement of the candidate waste forms and packages. Provide a basis for evaluating the adequacy of the information to be produced in the site characterization program described in Chapter 21, "Site Characterization Program," of this guide.

11.1 Waste Form

Describe the waste form (including physical form and properties, chemical form and properties, radionuclide inventory, thermal output, and radiation released) and waste packaging[1] (including types of packaging and their properties, container size and shape, and the weight, volume, and number of the containers to be emplaced.)

11.2 Design Concepts

Describe the waste form and packaging design concepts deemed compatible with the site and repository design. Include:

1. Identification and description of independent barriers within the waste package, and

2. Estimates of reliability of individual barriers.

[1]The waste package is defined as the physical waste form, containers, and any ancillary enclosures, including its shielding, packaging, and overpacks out to the outer surface of the last airtight and watertight sealed barrier.

11.3 Research and Development

Describe the status of research and development on appropriate waste form, packaging design, and the environment as it relates to characterization of the proposed site.

11.4 Emplacement Environment

Describe the type of environment into which the waste form and packaging will be placed. Include:

1. Chemical conditions and processes within and between the waste package and its environment that could compromise or enhance the ability of the waste package to support the performance objectives. Include appropriate thermodynamic equilibria, oxidation/reduction reactions, corrosion, leaching, dissolution, and gas generation.

2. Physical conditions and processes within and between the waste package and its environment that could compromise or enhance the ability of the waste package to support the performance objectives. Include thermal effects, mechanical strength, and mechanical stress.

3. Nuclear conditions and processes within and between the waste package and its environment that could compromise or enhance the ability of the waste package to support the performance objectives. Include radiolysis, potential radiation damage, and potential criticality.

11.5 Alternative Waste Packages

Sufficient information about alternative waste packages, including waste forms, packaging, and containers, should be provided to demonstrate full integration of the criteria and decision processes for site selection with those for waste package selection.

12. PERFORMANCE ANALYSIS

A significant part of the site characterization effort will be to produce data for use in models that predict the long-term release and transport of radionuclides to the biosphere. These models must be based on a sound understanding of the physical, chemical, and biological phenomena involved and must employ data that are as representative of actual site conditions as is possible.

Increasingly better data and better understanding of the physical phenomena will become available as research programs and site characterization work mature. At each successive step, the models must be upgraded to incorporate these research results, site data, and validating experiments. Site characterization must be focused on producing quality data to support performance assessments; the requirement for quality data is itself an issue to be addressed in Parts C and D of the SCR.

If the DOE has used the results of performance analysis as a critical issue in the decision process to (1) screen sites, (2) choose the site for characterization, or (3) design the site characterization program, the DOE should describe the performance analysis in this chapter. The description of the performance analysis should be presented in sufficient detail to allow an independent evaluation.

In the description, the DOE may incorporate by reference specific sections from other documents such as user manuals and code documentations, provided these documents are readily available to the NRC.

The DOE may also present descriptions of performance analysis or methods of performance analysis that the DOE wishes the NRC to review. Where practicable, the description of the results of the performance analysis should be presented in the appropriate chapters (i.e., Chapters 5, "Hydrogeology," 6, "Geochemistry," and 11, "Waste Form and Packaging").

12.1 Performance Analysis Issues and Information Needs Answered or Resolved by Previous Investigations

Discuss the performance analysis issues that have been resolved. Include the performance analysis issues critical in the decision process concerning:

1. Site screening,

2. Selection of the site for characterization, and

3. Design of the site characterization program (including interpretation of data gathered during site characterization).

As applicable, describe resolved issues related to overall system performance and performance of individual components. For each issue, describe the processes, properties, and scenarios of importance and the decision processes by which the issue was identified.

12.2 Methods of Analysis of Performance Analysis Issues

Describe the methods of analysis developed to address the performance analysis issues described in Section 12.1. For each method of analysis, include, as appropriate, the following information. (If a particular section is not applicable or the work is not completed, this should be noted. However, submittal of the document should not be contingent on development of information for these sections.)

12.2.1 Description of Geologic Repository Used in Analysis

Provide a description of the repository model that was used in the method of analysis. Include, as appropriate, a physical description of the repository, a description of the natural processes, human-induced processes, engineered features, and scenarios used in the performance analysis. To the extent practicable, abstract the description here and reference appropriate sections of this report for full descriptions of the information and the processes by which they were measured or estimated.

12.2.1.1 Physical Parameters. Describe the geometries and characteristics of the physical parameters relevant to the method of analysis. Where applicable, reference should be made to other sections for the complete information. For example, for an analysis of waste transport via ground-water flow, such information as the physical geometry of potential flow paths, the hydraulic characteristics (e.g., hydraulic conductivity, effective porosity) of those flow paths,

and relevant geochemical information would be included, but detailed descriptions would be in the chapters on hydrogeology and geochemistry.

12.2.1.2 Principal Natural Processes and Human-Induced Stresses. Describe the natural processes and human-induced stresses considered in the analysis. For example, if repository construction disrupts local ground-water flow conditions, both this disruption and the expected return to equilibrium conditions should be described. (Unexpected disruptive events or processes should be described in paragraph 12.2.1.3.)

12.2.1.3 Scenario Selection. Provide information on the scenarios studied in the performance analysis. Include the reason for the selection, the associated assumptions, and bounding conditions. The scenario should be described in sufficient detail to characterize its mode and frequency of occurrence.

12.2.1.4 Boundary and Initial Conditions. Provide information on the boundary and initial conditions that characterize the geologic repository. The information may be in the form of maps if it involves spatial relationships or in the form of graphs if it relates to temporal conditions. The actual boundary condition value may be in the form of an equation, and a rationale for the values chosen should be provided.

12.2.1.5 Engineering and Waste Package Design Features. Provide information and reference to the appropriate sections that describe the engineering and waste package design features relating to the analysis.

12.2.2 Mathematical Model of Repository Used in Performance Analysis

Present the mathematical equations and relationships used to simulate the physical and other processes analyzed.

12.2.2.1 Governing Equations or Relationships. Provide information on the governing equations or relationships that describe the conceptual model. In the discussion, fully identify the parameters, functions, and subrelationships in the equations.

12.2.2.2 Theoretical Assumptions. List the assumptions, including the natural processes and design features, necessary to represent the geologic repository as a conceptual model. The assumptions should be detailed, including such information as the choice of the equations, the coordinate system, and the spatial and temporal bounds.

12.2.2.3 Coupling of Equations and Relationships. Provide information on the means of coupling the equations and relationships, both internally within this analysis and as a link with other analyses. The common feature, whether it be a parameter such as density or a governing principle such as conservation of energy, should be specified.

12.2.3 Solution Technique

Provide information on the specific solution technique used in the analytical model. Include the rationale for the method chosen and the inherent stability criteria.

12.2.3.1 Detailed Equations or Relationships Being Solved. Document the detailed equations or relationships being solved. Define such details as the parameters, functions, and the exactness of the solution.

12.2.3.2 Data Requirements. Provide information on the specific data requirements of the solution technique. A discussion of the model parameters, including units, method of determination, and dimensionality, and their relationship to the detailed equations of paragraph 12.2.3.1 should also be provided.

12.2.3.3 Specific Numerical, Analytic, or Graphic Solution Used. Provide information on the internal solution methods, e.g., an iterative solution method, used to solve the detailed equations or relationships.

12.2.3.4 Spatial and Temporal Solution Stability Restrictions. Provide information on the spatial and temporal solution stability restrictions of the solution methods used. Such features as truncation errors due to spatial and

temporal representations, convergence problems of the solution, if iterative, and restrictions due to model parameter values should be discussed.

12.2.3.5 Predictive Capability. Provide information on the predictive capability of the solution technique. Such information as the limitations of the technique and a discussion of its relationship to the prescribed assumptions should be provided.

12.2.4 Program Logic and Subprogram Interrelationships

Depending on the complexity of the analytical method, provide at a minimum a documentation of the program logic and, if sufficiently complex, the subprogram interrelationships. The emphasis should be on providing a clear and concise logic framework. Provide computer code listings, an inspection and test run, and/or a users' manual.

12.3 Specific Input Parameters, Boundary, and Initial Conditions Used in Analytical Method

Provide detailed documentation of the input data used to represent the parameters, boundary, and initial conditions. Such information as detailed maps showing the mesh geometry, nodal values, and prescribed boundaries should be included. The internal model requirements such as error criterion, convergence interval, and time steps should be provided. A discussion of the internal balance checks such as water budget or radionuclide mass balance summaries should also be provided. Wherever appropriate, information contained in other chapters of this report should be incorporated by reference.

12.4 Documentation of Analysis Results

Provide detailed information on those performance analyses critical to the site characterization program (as described in the introductory paragraphs to this chapter). This information should contain the following:

12.4.1 Calibration Techniques

Provide both the results and methods for calibrating the analytical model. The calibration data should include the residual errors and the parameter adjustments.

12.4.2 Compatibility with Independent Tests for Validation

Provide information on the comparisons developed between the model results and the independent test data used for validation. The comparison data should be in graphic form and should indicate the presence of such features as divergence, overshoot, undershoot, and oscillations of the model-output plot versus the independent-test-output plot. The subsequent areas of agreement, disagreement, and instability should be documented and analyzed.

12.4.3 Verification of Model Predictability and Applicability

Provide information on the program for model verification. The independent data used for validation should be provided. Information on an assessment of applicability of the model to a family of differing scenarios and assumptions should be provided. Information on the predictability of the model for varying spatial and temporal conditions should also be included.

12.4.4 Sensitivity Analysis

Provide detailed information on sensitivity analyses performed. The sensitivity testing information should cover such topics as parameter interrelationships, boundary and initial conditions, and parameter data distributions. Emphasize the relationship among the sensitivity test results and the original initial and bounding conditions, site parameters, and scenarios.

12.4.5 Range of Values and Error Analysis of Quantitative Results

Provide information on all error analyses for both input data and subsequent results. The information should cover data distributions, truncation errors, approximation errors, and cumulative error accretion.

12.5 Analytical Methods Developed for Later Use

Present any analytic techniques that are developed to date for later use in interpreting information gained during site characterization. Present these techniques in the format of Sections 12.2 and 12.3, as applicable.

12.6 Performance Analysis Results

Present the results of any performance analyses critical to the site characterization program (as described in the introductory paragraphs to this chapter). Results that are presented in another section of the SCR or in other reports may be incorporated by reference.

PART C

STANDARD FORMAT AND CONTENT GUIDANCE FOR IDENTIFYING PERTINENT ISSUES

The issues identified in Chapters 13, "Siting Issues," 15, "Repository Design Issues," 17, "Waste Form, Waste Packaging, and Waste Environment Issues," and 19, "Performance Analysis Issues," should be related to those addressed in 10 CFR Part 60. Each of these chapters should include as an issue the limitations and uncertainties associated with the data and information (including methods of testing, analysis, and quality of data) presented in Part B. The site characterization plan chapters of Part C (Chapters 14, 16, 18, and 20) and of Part D should state which parts of the site characterization program will resolve issues related to the limitations and uncertainties of the data. There should be a thorough discussion of the options for resolving these questions and for the methods of testing and analysis that will reduce the limitations and uncertainties. The preferred options should be identified and defended in sufficient detail to permit independent evaluation and comment on the methods selected.

13. SITING ISSUES

This chapter should assimilate the results of previous investigations described in Part B into an identification of siting issues, a determination of what issues have been resolved by site screening investigations, and an identification of issues that remain to be resolved during site characterization.

13.1 Issues Related to Potentially Adverse Conditions and Favorable Characteristics

To the extent that available information will permit, the DOE should provide a summary of the extent to which each of the potentially adverse and favorable human activities and natural conditions are present at the site (as listed in the technical criteria in 10 CFR Part 60). This summary should include an assessment of the effects that these potentially adverse and favorable human activities and natural conditions have on the stability of the site, on the ability of the site to isolate high-level waste, and on pathways and travel times of radionuclides from the repository to the accessible environment. The summary should also include a discussion of the extent to which a particular characteristic has been adequately characterized, including the extent to which the characteristic may be present and still be undetected. Where adequate information exists, the summary should refer to the appropriate section of Part B in order to show that the particular characteristic has been adequately evaluated, using conservative analyses and assumptions in an evaluation sensitive to the particular characteristic. In the summary, the DOE should identify and evaluate interrelationships among particular characteristics, should refer to appropriate sections of Part B for documentation, and should summarize any remedial actions necessary to offset potentially adverse characteristics. Areas where information is incomplete should be identified in Section 13.4.

13.2 Issues Related to Performance Objectives

To the extent that available information will permit, identify and summarize all issues that may affect the performance of the repository in terms of the

degree of stability, ability to isolate wastes, and pathways and travel times to the accessible environment. Areas where information is incomplete should be identified in Section 13.4.

13.2.1 Stability

Summarize the present stability of the site and candidate area, and identify all issues that may affect the stability of the repository site. For each issue identified, refer to the appropriate section of Part B where the issue was discussed, and summarize to what extent it increases or decreases the future stability of the site.

13.2.2 Isolation

The ability to isolate waste may be affected by changes in the geologic framework, ground-water flow system, geochemistry, and geomechanical integrity. The DOE should summarize the current degree of isolation provided by the site and should identify the characteristics of the site that affect isolation. For each characteristic identified, refer to the appropriate section of Part B where the characteristic was discussed and summarize the degree to which the characteristic increases or decreases the capability of the site and geologic repository to inhibit the migration of radionuclides. The projected effects of the construction of the repository and the thermal load from the emplaced wastes should be included.

13.2.3 Credible Pathways and Travel Times

Identify known credible pathways from the site to the accessible environment, refer to the appropriate section of Part B where the pathways were discussed, and summarize the travel time and ground-water velocity for each pathway to the extent that available information will permit.

13.3 Summary of Issues Answered or Resolved by Preliminary Investigations Described in Part B

Summarize those issues discussed in Part B and summarized in Sections 13.1 and 13.2 that have been answered or resolved by preliminary investigations

already completed. Summarize the manner in which each identified issue has been answered or resolved.

13.4 Summary of Issues Unanswered or Unresolved by Preliminary Investigations Described in Part B

Summarize those issues discussed in Part B and summarized in Sections 13.1 and 13.2 that have not been answered or resolved by preliminary investigations already completed. For each issue identified, summarize the extent to which previous investigations address the issue and the remaining information needed to answer or resolve the issue. Site characterization plans to develop this information and resolve the issue should be described in Chapter 14, "Site Characterization Plan to Resolve Siting Issues."

14. SITE CHARACTERIZATION PLAN TO RESOLVE SITING ISSUES

For each issue identified in Section 13.4 as unanswered or unresolved, the DOE should indicate the appropriate tasks of the site characterization program that will address the issue and how these tasks will advance the knowledge of the suitability without adversely affecting the integrity of the site.

14.1 Methods of Investigation

For each issue, the methods of investigation, including techniques and analyses that will be used to resolve the issue, should be described. The description should include the specifications for performing the investigation and the applicability and limitations of the investigation in resolving the issue. Analytical techniques and plans for using analytical techniques described in Chapters 19, "Performance Analysis Issues," and 20, "Site Characterization Plan to Resolve Performance Analysis Issues," should be summarized here with appropriate cross references. For each method of investigation to be used, appropriate sections in Part D describing these analyses should be referenced.

14.2 Testing, Instrumentation, and Monitoring

For each technique described above, the testing and instrumentation that will be necessary for the investigation should be described. The description should include testing method and testing apparatus, data collection systems, methods of analysis and reduction of data, and the applicability and limitations of the testing and instrumentation in acquiring the necessary information.

For each issue and characteristic requiring short-term or long-term monitoring, the monitoring goal and technique(s) should be described. The description should include specifications for the monitoring system, the instrumentation and data collection systems, the methods of analysis and reduction of data, and the applicability and limitations of the monitoring system in acquiring the necessary information. Appropriate sections of Part D should be referenced.

14.3 Assurance of Site Integrity

Provide a description of the possible adverse effects resulting from the specific site characterization investigations, and specify appropriate measures to prevent, mitigate, or remedy these impacts.

15. REPOSITORY DESIGN ISSUES

Describe the design issues that are important for site characterization. These are the issues that form the basis for the design investigations that will be conducted during site characterization.

15.1 Verification or Measurement of Site Conditions

Describe those site conditions that are part of the design bases that must be verified or measured during site characterization to verify or advance the proposed conceptual design. Examples include such factors as the in situ stress field and ground-water flow and chemistry.

15.2 Verification or Measurement of Site Material Behavior

Describe the material behavior characteristics that are part of the design basis that must be verified or measured during site characterization to verify or advance the proposed conceptual design. Examples include such characteristics as geochemical, mechanical, hydraulic, and thermomechanical properties of the host media.

15.3 Design Optimization Issues

Describe the design optimization issues that require data acquisition during site characterization. These are issues in which a structure or material has conflicting performance requirements and an optimum will be determined from investigations during site characterizations. An example could be the backfill material. A low permeability could be desired for hydraulic sealing, and a high ion exchange capacity could be desired to sorb releases from canisters. This could lead to incompatible material requirements.

16. SITE CHARACTERIZATION PLAN TO RESOLVE REPOSITORY DESIGN ISSUES

Present the proposed plan for repository design investigations.

16.1 Resolution of Design Issues

Describe the plan for addressing each of the site conditions, site material behavior, and design optimization described in Chapter 15, "Repository Design Issues." Describe the method of the investigation and any limitations of the method.

16.2 Plan for Using Design Information

Describe how the information gained on each issue will be applied to the conceptual design.

17. WASTE FORM, WASTE PACKAGING, AND WASTE ENVIRONMENT ISSUES

The waste form, waste packaging, and the waste environment interact collectively in a waste repository. This chapter should describe the assimilation of existing data and the identification of the site-specific investigation program planned for site characterization as related to interaction issues.

17.1 Issues Answered or Resolved by Previous Investigations

Identify and discuss the waste form, waste packaging, and waste environment issues that have been answered or resolved by analyses and investigations already completed. An explanation of the manner in which the issues have been answered or resolved should be provided.

17.2 Issues Unanswered or Unresolved by Previous Investigations

Identify and discuss the waste form, waste packaging, and waste environment issues that have not been answered or resolved by analyses and investigations already completed. Present a site-specific investigation program to resolve these issues. This should also include a discussion of the extent to which previous investigations addressed the issues, along with the schedules for obtaining the additional information needed.

18. SITE-SPECIFIC WASTE-FORM INVESTIGATIONS

The performance of a waste-form barrier is closely coupled to the waste packaging and environment. This chapter should provide information on programs concerning ongoing and planned investigations on alternative waste forms and associated investigations on packaging and environment for sites to be characterized. Also include a description of activities to evaluate waste form and packaging design performance.

19. PERFORMANCE ANALYSIS ISSUES

In this chapter describe the unresolved issues concerning performance analysis that will be needed to evaluate data taken during site characterization. Include appropriate issues concerning analysis of the overall system performance such as ground-water flow and waste transport modeling, analysis of individual components, and analysis of disruptive events. For each issue, briefly describe the specific information needs and reference the appropriate chapter of this report for the description of the plans for developing the information.

19.1 Analytical Techniques Requiring Significant Additional Developmental Work

Describe those analytical techniques that are expected to be important for evaluating the performance of the site but that require significant additional developmental work at the time the report is prepared.

Describe both the analytical techniques expected to be important for site analysis and the associated data requirements. Available data should be summarized in this section, either directly or by reference to other chapters of this report. For each type of analysis, anticipated simplifying assumptions and boundary conditions should be described.

19.1.1 Applicable Generic Analyses

Identify and describe those types of analytical techniques not yet fully developed but expected to be applicable to a wide range of potential sites (e.g., thermally induced ground-water flows in and around a repository). The additional development work or data requirements should be identified here and should be described in Chapter 20, "Site Characterization Plan To Resolve Performance Analysis Issues."

19.1.2 Site-Specific Analyses

Identify and describe those types of analyses (e.g., fracture flow transport in basalts) that are not yet fully developed and that may be dependent on the characteristics of the specific site. Additional developmental work or data requirements should be identified here and should be described in Chapter 20.

19.1.3 Types of Scenarios

Identify and describe the types of scenarios and disruptive events considered to be potentially significant at the site and for which appropriate analytical techniques have not yet been completely developed. Additional developmental work on data requirements should be identified here and should be described in Chapter 20.

20. SITE CHARACTERIZATION PLAN TO RESOLVE PERFORMANCE ANALYSIS ISSUES

Describe the programs formulated for completing the developmental work identified in Chapter 19, "Performance Analysis Issues." This section should describe the types of analytical techniques to be developed or the data to be acquired, the programs for accomplishing this development or acquisition, and the schedules for completion. Data acquisition programs described in other chapters of this report may be incorporated by reference. The semiannual progress report described in paragraph 60.11(g) of 10 CFR Part 60 should describe (preferably by reference to other published reports) progress toward completing this developmental work and should contain updated plans, if appropriate.

PART D

STANDARD FORMAT AND CONTENT GUIDANCE FOR PRESENTING SITE CHARACTERIZATION PROGRAM

21. SITE CHARACTERIZATION PROGRAM

This chapter should describe in detail the program by which the investigations described earlier are to be carried out and the outstanding issues resolved. Specifically, schedules are to be set forth with key milestones identified. The milestones should be directly traceable to the planned investigations and resolution of issues. Also noted should be decision points at which the direction of the program might be changed if warranted by the results obtained.

This chapter will allow cross-referencing among the issues and technical tasks. More than one technical task will be required to resolve some issues; and conversely, some technical tasks may address more than one issue.

21.1 Narrative

Describe the site characterization programs at the named site identifying (1) the design of any underground test facilities to be constructed on site to carry out the site characterization program, (2) the sequence of construction activities needed prior to testing, (3) the tests and experiments themselves, (4) elements of the experimental design relevant to data acquisition, analyses, and scheduling, (5) schedule, sequence, and duration of testing and data analysis, (6) decision points and alternatives, (7) planned reports and summaries, (8) key milestones against which the progress of site characterization can be measured, (9) methods for maintaining the integrity of the site during and following site characterization such as proper sealing of exploratory shafts and borings when their use is no longer needed to continue site characterization, and (10) the quality assurance methods to be used in data acquisition and analysis. The discussion should be referenced to the matrix charts that show the relationship of each specific task to issues to be resolved.

21.2 Construction Activities

Describe briefly the construction needed to prepare the site for testing and experimenting, including anticipated start and completion dates. The

description should include the design of the necessary facilities and should be keyed to planned tests and experiments.

21.3 Underground Test Facility

Describe the underground test facility to be used if in situ testing at depth is to be part of the site characterization program. The description should include a detailed layout of the planned excavation, boring locations, and the planned location within the test facility of each anticipated test or experiment. In addition, details of construction, including the location of the underground test facility with respect to possible repository construction if the site is selected by DOE as its preferred site, should be provided. Particular attention should be paid to shafts excavated and borings made for the underground test facility and their location with respect to possible future shafts and excavations for a repository. An analysis of the potential impact of underground testing on the integrity of the site should also be included.

21.4 Tests and Experiments

Describe briefly the planned tests and experiments, which should be cross-referenced to technical areas identified in previous chapters and to the technical tasks described in Part B.

Tasks should be described in the following manner.

Task Number

Task Title

Issue(s) Task Addresses - Summarize why this task is proposed and which issue(s) in Part C this task will help resolve.

Objective(s) - Summarize the end use of each task, e.g., site suitability, design, waste emplacement.

Descriptive Summary - Summarize the methods, techniques, and analyses used in accomplishing this task.

Principal Investigator - Give the name and organization of the principal investigator, if known.

Contact - Give the name and address of the person to contact concerning this task.

21.5 Milestones, Analyses, Decision Points

Describe briefly (1) key milestones to be used to mark progress, (2) data analyses to be performed, (3) use of acquired data, including both direct use of the tests and experiments as well as integration of results of tests and experiments to resolve identified issues or to identify new issues, and (4) stages in the site characterization program when options would be assessed and decisions would be made as to how (or whether) to proceed. The descriptions should be keyed to the overall schedule as described in Section 21.6 below.

21.6 Schedule

Provide a graphic presentation (flow chart) of the site characterization program in which activities, analyses, milestones, decision points, reports, submittals for NRC and public review, and any other relevant information are identified. The presentation should be constructed so that tasks accomplished and tasks still to be accomplished can readily be identified. The presentation should also include, as appropriate, the logic leading to decision points and selection among alternatives.

22. IDENTIFICATION OF ALTERNATIVE SITES

Identify and describe all other sites and media for which DOE intends to conduct site characterization. Indicate the current status of site investigation, an outline of planned activity, and an estimated submittal date for future site characterization reports.