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MEMORANDUM FOR: Hubert J. Miller, Chief
High-Level Waste Technical Development Branch
Division of Waste Management

FROM: Robert J. Wright
BWIP Project Manager
High-Level Waste Technical Development Branch
Division of Waste Management

SUBJECT: DRAFT SITE CHARACTERIZATION ANALYSIS ON BWIP SCR OPS PLAN NO. 311221E

Attached is a preliminary draft of the Draft SCA for the Basalt Waste Isolation Project as required per OPS Plan Commitment No. 311221E for January 28, 1983.

The attached draft has been reviewed and revised by the BWIP Review Team except for revisions to the following sections: Conclusions and Comments, Chapter 9 (Performance Assessment), Chapter 11 (Summary of NRC Comments), and Appendix C (Tabulation of Site Characterization Issues). Current plans are to complete revisions to these sections and subsequently distribute a complete draft for inter-office review by February 2, 1983.

/S/

Robert J. Wright
BWIP Project Manager
High-Level Waste Technical
Development Branch
Division of Waste Management

same encl as w/ 1-28-83 memo
to BWIP coordinators

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Memo to BWIP Group
fr: Wright Re: Pr. Dr. 3
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SITE CHARACTERIZATI' ANALYSIS

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NOTE: THIS IS A DRAFT DOCUMENT FOR INTERNAL REVIEW ONLY

THE U.S. TMENT OF ENERGY

SITE ACTERIZATION REPORT

FOR THE

ALT WASTE ISOLATION PROJECT

MARCH 1983

OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS

U.S. NUCLEAR REGULATORY COMMISSION

CONTENTS

CONCLUSIONS AND COMMENTS

C.1 Introduction

In general, the contents of the SCR are well organized, and the arrangement of the material follows the suggestions of Regulatory Guide 4.17. The SCR is properly oriented toward the site issues: those technical questions about the BWIP that will need to be answered in making licensing assessments. The presentation of the site characterization program follows a logical progression. The present state of knowledge, from investigations to date, is stated in Chapters 1-12, inclusive; Chapters 13 through 16 provide information on issues, work elements and plans to resolve the outstanding issues; and, building upon the preceding chapters, Chapter 17 presents the integrated site characterization program. Chapter 18 discusses quality assurance and Chapter 19 covers alternative sites.

In this NUREG, attention of the NRC staff is centered upon the issues and the plans to resolve them. In Chapters 2-8 and 11, the issues are analyzed, and conclusions and comments on the issues and the plans are presented. In this chapter, the major conclusions and comments are summarized.

The analysis of the SCR by the NRC staff indicates that the overall scope of issues and work elements expressed in the SCR, taken collectively, is substantially the same as the scope of the issues developed by the NRC staff. Whereas the style of expression and the means of aggregation are different, the collective content of each issue set is similar. Appendix C discusses the logic and process used in the development of issues by the NRC staff. These issues are correlated with issues and work elements of the SCR through use of a matrix. Also, the site characterization program is rated, in tabular form, through use of the NRC issues.

The SCR provides preliminary conclusions on three important issues that are critical to the suitability of the Reference Repository Location to isolate waste. These three assertions are discussed in Section C.2 of this chapter. With respect to the site characterization plans, a number of specific comments are summarized in Section C.3. Section C.4 comments on the quality assurance program. Section C.5 provides recommendations on followup, during site characterization, of the concerns and comments of the NRC staff.

C.2 Important Assertions in the Site Characterization Report

Three assertions are presented in the SCR on factors that are critical to evaluation of the Reference Repository Location as a place for a geologic repository to isolate waste. If taken at face value, the assertions appear to provide assurance that the RRL is known, from present information, to satisfy draft regulatory standards of the NRC and the EPA. The NRC staff considers that the assertions are questionable, because the degree of uncertainty on these matters is inadequately portrayed by the SCR. A realistic assessment of the present level of uncertainty is needed, due to the impact on the site characterization plans and program.

The three assertions, which are discussed in the following subsections, have to do with:

- Groundwater travel time (C.2.1).
- Solubility of radionuclides (C.2.2).
- Tectonic processes (C.2.3).

C.2.1 Groundwater Travel Time

Page 12.4-53 of the SCR states, in connection with groundwater movement:

> "Studies conducted to date by Rockwell and other independent organizations unanimously agree that the minimum travel time from the repository to the accessible environment under natural, pre-waste-emplacement conditions is likely to be on the order of 10,000 years or longer."

The significance of this statement lies in the fact that the EPA standard for radionuclide releases is based on releases over a 10,000 year period; thus, travel time of 10,000 years or more would satisfy the EPA requirement without consideration of any other factors. The NRC staff is concerned that DOE appears to place too much confidence in the certainty of the present calculation. For reasons explained in Chapters 3 and 9, the estimation of groundwater flow time involves many uncertainties, due to the limited base of site data at the present time. Further, some of the assumptions used in the estimation are biased in favor of long travel time. Four key sources of uncertainty are summarized below and are discussed in Chapter 2.

(1) Sparseness of test data. Of the major hydraulic parameters that are needed to estimate travel time--horizontal conductivity, vertical conductivity, effective porosity and dispersivity--only the first has been measured at more than one location in more than one test interval. This limited data base can not be defended as representative of the RRL. Vertical conductivity, a critical factor in travel time estimation, has not been measured to date.

(2) Uncertainties in hydraulic head measurements. Due to the method of hydrologic testing used at the BWIP, reported measurements of hydraulic head are uncertain. These are critical values in calibrating the numerical groundwater model, from which travel time estimates are derived.

(3) Questionable use of porosity data. The single field test of rock porosity gave a value of 1×10^{-2} to 1×10^{-4}, but values at the high end of the range have been used for the travel time calculation. Since travel time is directly proportional to porosity, this practice overestimates actual travel time by a large (but yet unknown) factor.

(4) Lack of a defensible conceptual groundwater model. Due to the data limitations and uncertainties outlined above, together with others described in Chapter 3, the conceptual model in the SCR cannot be defended in opposition to others that satisfy the data base and provide the basis for other estimates of groundwater travel time.

Inasmuch as the characterization of the groundwater regime is still in a preliminary stage, it is considered premature to portray as realistic or reliable any estimate of travel time.

C.2.2 Solubility of Radionuclides

Page 6.4-3 of the SCR states:

> "Based on solubility, the maximum possible release rates for all the radionuclides considered will be below the NRC 10^{-5} proposed release rate criterion (NRC, 1981) and the draft cumulative release criterion (EPA, 1981)."

An understanding of several geochemical factors must be in hand before the above statement can be justified. An examination of these factors suggests that the present data base is much too limited to provide such understanding. Three key elements of uncertainty are summarized below. These and other critical factors are discussed in Chapter 5.

(1) Uncertainty About Groundwater Composition and the Geochemical Environment. The solubility of radionuclides is dependent on the presence and quantity of various chemical ions in the groundwater system; solubility is also influenced by other parameters such as Eh (oxidation/reduction ratio). The composition of the groundwater along the flow line away from the repository is not well known at this time. Also, the Eh of the groundwater is largely conjectural at present. The Eh measurements, made at surface, may not be reliable, and the calculations used in the SCR are both theoretical and based on unverified assumptions. With these uncertainties, estimates of solubility are uncertain.

(2) Uncertainties in Calculations. The solubilities presented in the SCR are based on simple oxides of the radionuclides in the waste. However, it is likely that the radionuclides, upon solution in groundwater, would form complexes with constituents of the groundwater, such as carbonate which is known to be present at the BWIP. Carbonate complexation has been shown to increase the solubilities of certain actinides (U, Pu, Np, and Am) by several orders of magnitude. Reactions of this nature, therefore, would invalidate the assertion stated above.

(3) Uncertainties Due to Lack of Experimental Confirmation. As stated in the SCR (page 6.4-5), the calculated solubility estimates presented in the SCR have not been confirmed by experiments performed under geochemical conditions expected to be present in the repository host rock at BWIP. In the absence of experimental validation, the staff has little confidence that the calculated results can be used with confidence to support statements about release rates.

For the above reasons, the assertion in the SCR is considered to be unsupportable by existing data.

C.2.3 Geologic Stability

Page 3.8-6 of the SCR states:

> "Detailed studies required to confirm a tectonic model remain to be performed. However, a preliminary quantitative assessment indicate that tectonic processes within the Pasco Basin do not pose a hazard to repository construction and operation or to long-term isolation of radioactive waste."

Although the Pasco Basin appears to be relatively stable, certain geologic features manifest a degree of instability. These features require assessment, in terms of possible earthquake damage to a repository. Such damage could take the form of: (1) impairment of the retrieval option, (2) damage to borehole and shaft seals, or (3) adverse changes in the groundwater system. Several features that may be earthquake hazards are described in SCR Chapter 5, but no account of earthquake risk is provided. Two features of this type are the following. These, and others, are discussed in Chapter 6.

(1) Rattlesnake fault. The Rattlesnake fault passes within 10 miles of the RRL and has a length of more than 100 miles. It has been judged by the NRC (NUREG 0892, 1982) as capable of sustaining an earthquake with a magnitude of 6.5 (Richter) at any time.

(2) Microearthquake swarms. Several clusters of recurring microearthquakes have been recorded to the north and east of the RRL. One such cluster is about 6 miles north of the RRL. While the earthquakes are of small magnitude (Richter = 1 to 3), they are believed to be caused by movement on faults less than 3 miles below surface, below the repository level.

C.2.4 Significance of SCR Assertions on Important Issues

At the time a construction authorization application is under consideration, the Commission will need to make a judgment as to whether it has reasonable assurance that the public health and safety suffers no unreasonable risk from construction and operation of the proposed repository. Such a decision must be made in the absence of prior experience and proof testing. Faced with this uncertainty, the Commission has adopted a regulatory approach that relies on a combination of natural and engineered barriers--the defense-in-depth approach. This means that the engineered system, consisting of the waste packages and the underground facility, shares with the natural system the task of isolating the waste. The engineered system is required to compensate for the uncertainties in the performance of the natural system so that there can be reasonable assurance that the overall system performance objective--the EPA standard--is met.

The analysis of the SCR data suggests that the SCR overstates the level of confidence to be placed at the present time on the natural system, given the key assertions described in the subsections above. Based on the SCR analysis, two undesirable consequences appear to flow from this misplaced confidence:

(1) Since the BWIP geology and hydrology is perceived to be favorable for waste isolation, based on investigations to date, the need for testing during site characterization is lessened. Concerns about the adequacy of the hydrology testing program are expressed in Chapter 3.

(2) Since the natural system, on its own, is perceived to provide isolation, the engineered system appears to receive inadequate attention in site characterization plans. Concerns about the adequacy of the waste package investigation program are expressed in Chapter 7.

Overemphasis on one portion of the total repository system, in this case the geologic barrier, is inappropriate. First, due to the variability of the geologic and hydrologic parameters of the site, predictions of performance by the natural system are subject to uncertainties. Even upon completion of site characterization, substantial questions about the natural system will, no doubt, remain. Second, the components of the engineered system are more amenable to quality control, performance testing, and performance verification than are the components of the natural system. To provide assurance on repository performance, and to meet the requirement for a multibarrier system, at the time of licensing steps should be taken to investigate and fully develop the performance capability of the barriers in the engineered system.

C.3 Plans and Program for Site Characterization

C.3.1 General Comments

The site characterization plans and program, as presented in the SCR, have been analyzed in terms of satisfying licensing information needs, if a license is advanced by DOE for the BWIP.

The plans and program are presented as narrative, tables and charts in SCR Chapters 13-17, inclusive. While a broad array of tests and investigations is portrayed, these are considered to be deficient in several respects. The deficiencies are discussed in the following subsections and are noted below.

(1) In one important area--hydrologic testing--the program does not appear adequate to address questions of the sort raised in subsection C.2.1. This matter is discussed in subsection C.3.2, below.

(2) Specific areas of investigation, which are believed by the NRC staff to be important in developing answers to licensing questions, appear to be absent from the SCR. This matter is discussed in subsection C.3.3, below.

(3) Several areas of investigation are discussed in general terms in the SCR, but critical details are lacking. As a result, these aspects of the site characterization program cannot be evaluated with respect to licensing information needs. This matter is discussed in subsection C.3.4, below.

C.3.2 Hydrologic Testing: Inadequacies of the Proposed Program

The proposed hydrologic testing program represents, for the most part, a continuation of present testing procedures at the BWIP. Except for one cluster of boreholes around DC 16, reliance is placed mostly on single hole, small-scale hydrologic tests. As these tests have been performed in the work to date, they suffer from several inadequacies. First, as shown by the NRC analysis, the values for hydrologic heads are questionable, and the measurements of hydraulic conductivity may be biased by the use of mud during drilling of the borehole. Second, the measurements that are obtained represent only a small volume of rock that extends only a few feet away from the test borehole and is not representative of the very much larger rock mass that controls groundwater flow. Further, vertical permeability, a key element in groundwater travel time estimation, will not be measured. Finally, the geologic/hydrologic discontinuities that are believed to be present, judging from investigations to date, will not be characterized.

It is doubtful that the test program proposed in the SCR will be successful in characterizing the hydrologic regime so that licensing decisions can be made. It is suggested that emphasis be given to large-scale, multiple-well pump tests that are combined with continuous head measurements in critical units to get the needed information.

C.3.3 Investigations That Appear to be Absent from the SCR

In spite of the wide range and great diversity of investigations described in the SCR, certain gaps appear upon analysis. Examples are given below:

Subject Area	Activity Needed During Site Characterization	Reason for Need
Exploratory shaft	Construction and sealing methods to control adverse effects	Control of adverse effects during site characterization
Waste package	Methods for analyzing reliability of performance and reliability design criteria	Assurance of contribution to repository performance
Waste package	Testing of components under the range of repository conditions	Validation of performance analyses
Waste form	Testing of borosilicate glass degradation	Validation of long-term release analyses
Geologic stability	Assessment of seismic hazard from Rattlesnake fault	Possible adverse effect on waste isolation

Subject Area	Activity Needed During Site Characterization	Reason for Need
Geologic stability	Assessment of seismic hazard from microearthquake swarms	Possible adverse effect on waste isolation
Groundwater	Accurate measurement of hydraulic heads	Development of conceptual flow model and calibration of numerical flow model
Groundwater	Characterization of effect of geologic structures on groundwater flow	Development of flow models
Geochemical parameters	Testing key minerals under repository temperatures	Assessment of geochemical retardation
Geochemical parameters	Characterization of organic compounds in groundwater	Assessment of complexing as transport process

C.3.4 Incomplete Site Characterization Plans

In several subject areas, incomplete site characterization plans are described, and significant aspects--particularly in testing methodology--are lacking to such an extent that analysis by the NRC staff is incomplete. These matters are discussed in chapters ________ and are summarized below:

Subject Area	Type of Investigation	Importance in Site Characterization
In situ test plan	Measurement of site parameters at repository depth	Definition of parameters for performance assessment
Retrievability of waste	Analysis of engineering and materials handling aspects	Provide assurance on availability of retrieval option

C.3.5 Quality Assurance Program

A well organized and implemented Quality Assurance (QA) program is essential to ensure that data collected during site characterization can be demonstrated to be reliable when reviewed at licensing time.

Analysis of the QA administrative program described in the SCR indicates that a good framework has been established. However, details on implementation of the

QA program are not presented. As an example, the QA program requires development of test plans for each major testing program; however, in most of the major technical areas test plans are neither presented nor referenced. Thus the QA program, in present form, appears inadequate to provide assurance of reliability of much of the data being collected at the BWIP.

C.5 Recommendations on Followup of Concerns and Comments on the Site Characterization Program

[to be added]

1 INTRODUCTION

1.1 Background Information on the Site Characterization Review Process

The U.S. Department of Energy (DOE) submitted to the U.S. Nuclear Regulatory Commission (NRC) a Site Characterization Report for the Basalt Waste Isolation Project, DOE/RL 82-3 (SCR). The SCR is for a high-level waste repository on the Hanford Reservation in the State of Washington and was received by the NRC on November 12, 1982.

The SCR is presented in three volumes and contains 19 chapters and approximately 2200 pages. A copy of the SCR is available for public inspection at the NRC Public Document Room, 1717 H Street NW, Washington, DC 20555. Copies of the SCR are available from the U.S. Department of Energy, Richland Operations Office, ATTN: Mr. Lee Olson, P.O. Box 550, Richland, WA 99352, Telephone (509)376-7334 or FTS 44-7334.

In accordance with the requirements for contents of the SCR as contained in §10 CFR Part 60.11(a) and as further specified in NRC Regulatory Guide 4.17, "Standard Format and Content of Site Characterization Reports for High-Level Waste Geologic Repositories," the SCR contains the following information:

1. A description of the site selection process,

2. A description of what is known about the site from site screening, selection and exploration activities completed to date,

3. A description of the issues that DOE has identified at the site in light of the results of investigations to date, and

4. A description of the plans of work for data acquisition and analysis to meet information needs for resolving unresolved issues during site characterization.

The SCR was submitted pursuant to 10 CFR Part 60 regarding the disposal of high-level radioactive wastes in geologic repositories. In accordance with § 60.11, "As early as possible after commencement of planning for a particular geologic repository operations area, and prior to site characterization, the DOE shall submit... a Site characterization Report."

New legislation, the Nuclear Waste Policy Act of 1982, Pub. L. 97-425 (Waste Act), has been enacted since submission of the SCR that deals in detail with procedures to be followed by NRC in connection with the licensing of high-level waste repositories. Section 113(b)(1) of the Waste Act provides for DOE to submit, and for NRC to review and comment upon, a site characterization plan that in large part is described in terms identical to, or parallel to, the earlier NRC regulations. Under this new statute, notwithstanding the "grandfather clause" contained in Section 112(f), a site characterization plan must be prepared for BWIP and submitted to NRC. Section 112(f)(3) requires conduct of public hearings (under Section 113(b)(2)) at discussion of NRC's role in site selection and environmental concerns).

which the site characterization plan described in Section 113(b)(1) of the Waste Act is to be available.

Under the Waste Act, the role of NRC in commenting upon DOE's site characterization plans is fully preserved insofar as it relates to any activity having potential radiological significance. In particular, NRC is expressly authorized to comment on activities that may affect the capability of the site to isolate radionuclides and plans to control adverse, safety-related impacts of site characterization activities (Sec. 113(b)(1)(A)(ii)). However, under the Act, the site selection process, insofar as it requires consideration of factors that are not radiologically important, is no longer to be a matter for NRC review (see Chapter 8 for further

Therefore, although the site characterization report was not submitted under the Waste Act, NRC believes that preparation of this Draft Site Characterization Analysis, primarily on the basis of the geotechnical issues ~~information~~ contained in the BWIP SCR, is in the public interest since it will afford an early opportunity to communicate relevant concerns to DOE.

1.2 Purpose of the Site Characterization Report

The basic purpose of the SCR is to identify potential licensing issues at a candidate repository site and the plans for gathering information to resolve them. The SCR is prepared at an early time to assure that the site characterization program adequately addresses the issues.

1.3 Purpose and Method of SCR Review

Following the intent of the Nuclear Waste Policy Act of 1983 and in accordance with §60.11(d), NRC staff prepared this Draft Site Characterization Analysis (Draft SCA) of the information provided in the SCR. This Draft SCA is issued for public comment for a period not less than ninety days. After this period the staff will then finalize the SCA, considering comments received. Staff will also comment on any updates to the SCR.

This Draft SCA is advisory in nature. It is a critical analysis of DOE's site characterization plans contained in the SCR, in terms of whether or not they will likely provide adequate information for licensing assessments.

The review of the SCR is not a licensing proceeding, but part of an ongoing preapplication process. This process is designed to enable DOE to gather the information it needs to decide whether to apply for an NRC authorization to construct a repository at a particular site. The SCR review process is intended to be a vehicle for identifying at an early stage what the specific potential licensing issues are at a site based on what is known from investigations to date. It permits an opportunity for consultation between DOE and NRC, with public involvement, on site selection and the site characterization program.

1.4 SCR Review Procedure

Because of the unique nature of repository development, many of the issues that will have to be settled in licensing will involve research and site-specific investigations with long leadtimes. In establishing its provisions for licensing a repository, the Commission has provided for extensive pre-licensing activities, including interactions with DOE, to identify potential licensing issues early and to consult on the programs for resolving them.

Prior to SCR receipt, the staff conducted several on-site, comprehensive reviews of the DOE program at BWIP. NRC staff also held detailed, technical meeting with DOE to acquire data and to consult on the identification of issues and site characterization plans. In addition, staff reviewed numerous technical reports and available site data. And contacts were established with State agencies and other individuals and organizations who expressed interest in the Draft SCA.

Some of these activities, such as site visits, began as early as July 1980. The staff plans to continue these activities, as necessary, throughout the DOE site characterization program. Documentation of these activities is available in the Public Document Room.

Staff in the Division of Waste Management developed detailed procedures for reviewing the SCR. They are described in the "Review Plan for Site Characterization Reports." Following those procedures and prior to SCR receipt, the staff prepared a systematic and comprehensive identificaiton of site issues, based on available information (see description of Appendix C below). This identification was performed to assure that the SCR review is complete and that all issues are relevant to assessments hat will have to be made in licensing.

1.5 SCR Review Products

Upon receipt of the SCR, the staff performed a thorough review of the SCR. The NRC analysis of the SCR includes the development of the following products:

Draft Site Characterization Analysis (Draft SCA; NUREG-0960)

This Draft SCA is a critical analysis of the SCR, focusing on the basic thrust and strategy of the DOE program, especially the site characterization plans on the critical path for licensing. This Draft SCA is used to check the completeness of the SCR and the adequacy of the issues presented by DOE in the SCR. It contains various summary tables and is supported by numerous appendices and site issue analyses as described below. This Draft SCA is not a complete summary or restatement of the SCR; the reader must refer to the SCR for details.

The main text of the Draft SCA is organized as follows:

Function	Chapter
Summary of SCR Analysis:	NRC Staff Conclusions and Comments
Background Information on SCR Review Process and Hanford Site:	Chapter 1. Introduction Chapter 2. Description of Site and Conceptual Design

Fuhction	Chapter
Critical Analysis of Issues and plans Presented in the SCR:	Chapter 3. Groundwater Chapter 4. Geologic Stability Chapter 5. Geochemical Retardation Chapter 6. Repository Conceptual Design Chapter 7. Waste Form and Waste Package Chapter 8. Site Selection and Environmental Factors Chapter 9. Performance Assessment Chapter 10. Quality Assurance Program
Summary of NRC Comments:	Chapter 11. Summary of NRC Comments

Staff analyses of the major geotechnical considerations of the site affecting health and safety of a repository at the RRL are contained in Chapters 3 through 7. To the extent practicable, each of these chapters is written in a standard format (see below) which includes an evaluation of issues and the DOE site characterization program as presented in the SCR.

Format for Chapters 3-7

Introduction

Type of Material Presented in the SCR
Relevant Sections of 10 CFR 60
Relationships Among Issues

Principal Issues in the SCR

(Presentation of DOE assertions, conclusions, and other major considerations relative to the subject of the chapter)

Analysis of Issues

Analysis of the Site Characterization Program

NRC Conclusions and Comments

Draft SCA Appendices

The appendices support selected aspects of the Draft SCA text and are a part of the Draft SCA. The appendices are:

Appendices A and B. Maps and other illustrations of the site, and table of contents of the SCR.

Appendix C. Identification of Site Characterization Issues - A comprehensive and systematic identification of issues at the site to assure that the SCR review is complete and relevant to potential licensing assessments. This includes a comparison and cross reference among issues and work elements presented in the SCR. Also, the site characterization program is rated, in tabular form, through use of the issues. The listing of issues in this appendix was developed in light of information available to staff and by rigorously considering the performance assessments that will be conducted in determining compliance with licensing requirements (see Appendix D below).

Appendix D. Sensitivity Analyses - Preliminary studies of elements in performance assessment of the site, incorporating selected hydrogeologic parameters and simplifying assumptions. The analyses incorporated into the Draft SCA are precursors to more detailed and complete performance assessments that NRC will conduct in licensing reviews.

Appendices E thru Y. Various Technical Analyses - Detailed data and analyses which provide supporting information for selected, major site issues addressed in Chapters 3 through 7. Technical analyses and background information is provided on hydrostratigraphy and geologic controls, environmental conditions for the waste form and metallic waste package component, stability of openings, retrievability systems, release rate for the engineered system and other subjects applicable to the BWIP.

Draft SCA References

Selected technical reports of NRC contractors are included as references to the Draft SCA. These include the general results of major technical assistance efforts over the past several years involving independent NRC evaluations of major issues of site characterization. These reports focus on selected important aspects of site characterization. They are available for public inspection at the NRC Public Document Room.

Site Issue Analyses (SIAs)

The SIAs are working papers for each major site issue and form the basis for organizing the SCR review. [An issue, as used in the context of the SCR review, is a question that must be answered or resolved to complete licensing assessments of site and design suitability in terms of 10 CFR 60 performance objectives and requirements and to make NEPA findings.] The SIAs are based on the major issues identified in Appendix C. Each SIA includes a summary of the issue, an evaluation of DOE plans for investigations and tests to acquire information to resolve the issue, and technical backup attachments as necessary. The SIAs are available for public inspection at the NRC Public Document Room.

2 DESCRIPTION OF SITE AND CONCEPTUAL DESIGN

2.1 Introduction

This chapter gives an overview on the geographic and geologic setting. Also, a description is given of the surface and subsurface facilities planned for the operational functions of the repository. A general understanding of the physical setting and planned facilities will help clarify discussions in later chapters of this Site Characterization Analyses.

2.2 Geographic and Geologic Setting

The reference repository location is in DOE's Hanford (nuclear) Reservation near Richland, Washington. This site is in a major Pacific Northwest physiographic province called the Columbia Intermontane (see Figure A-2). This province includes the Columbia River Plateau and lies between the Cascade Mountains and the Rocky Mountains.

The reference repository is in the Pasco Basin which is near the central part of the Columbia River Plateau. The Cold Creek Syncline (downwarping fold) geologic structure is a subdivision of the Pasco Basin (Figure A-3). It is in this structure that the repository would be built.

Major surface features in the area include the following (see Figure A-21):

- The Columbia River, Umtanum Ridge, Gable Butte, and Gable Mountain to the north
- Yakima Ridge to the west
- Rattle Snake Mountains to the south
- The Columbia River is also to the east and the Yakima River is to the south-east

The rocks in the region can be put into four general groups: basement, Columbia River Basalt, intercalated and suprabasalt sediments, and other late Cenozoic volcanic deposits.

- Basement Rock - Rock older than the Columbia River Basalt is exposed at the margins of the Columbia River Plateau and as isolated exposures in the basalt (Swanson, et al., 1979b; 1980). None of the exposures is in the central area of the Columbia River Plateau. The basement exposures consist of metamorphosed sedimentary and volcanic rocks such as crystalline gneisses and schists.
- Columbia River Basalt Group - The basalts of this group flowed from linear vents about 16.5 - 6 million years before the present (mybp). Individual

flows range from a few tens of centimeters to more than 100 meters thickness, averaging 30 to 40 meters.

- Intercalated and Suprabasalt Sediments - These include: sediments interbedded with Columbia River Basalt flows, sediments overlying the Columbia River Basalt, Pleistocene flood sediments, and Holocene sediments of alluvium (water) and eolian (wind) deposits.

- Late Cenozoic Volcanics - Post-Columbia River Basalt volcanics exist on the western edge of the Columbia River Plateau. Tephra (ashfall) deposits are interbedded with Pliocene to Holocene sediments in much of the western and central Columbia River Plateau.

The Columbia River Basalt group contains an upper (youngest) subgroup called the Yakima Basalt Subgroup. The Grande Ronde Basalt is the lower (oldest) formation in this subgroup which includes the Wanapum Basalt Formation and the Saddle Mountains Basalt Formation overlying the Wanapum (see Figure A-22).

The Grande Ronde Basalt would be the host formation for a repository. It consists of more than 50 flows extending to a depth of at least 3.2 kilometers (Reidal et al., 1981). The Umtanum and Middle Sentinel Bluffs are two separate thick flow members being investigated for the repository horizon.

The Umtanum flow is at a depth of about 1150m below the surface and is about 70m thick. The Middle Sentinel Bluffs flow is at a depth of about 950m below the surface and is about 80m thick. Note: these are very general approximations which may vary laterally due to flow thickness changes or vertically due to warping or overburden thickness.

The Wanapum Basalt overlies the Grande Ronde Basalt. It is about 350m thick and is at a depth of about 600m below the surface. This basalt flow forms much of the Columbia River Plateau surface.

The Saddle Mountains Basalt overlies the Wanapum Basalt. These two formations are generally separated by a local erosional surface (unconformity). The Saddle Mountains Basalt is about 275m thick at a depth of about 300m below the surface. Saddle Mountains time is marked by thick local sedimentary deposits (Ellensburg Formation) between flows.

Both the Wanapum and Saddle Mountains Basalts are interbedded with the Ellensburg Formation. The Ellensburg Formation and the basalt flows of the Saddle Mountains and Wanapum Formations occur either as distinct or mixed deposits (see Figure A-29). The Ellensburg Formation is a mixture of sediments including tuffaceous silts, petrified wood, arkosic sand, and volcanic gravels and cobbles.

The Ringold Formation overlies the Columbia River Basalt Group in most of the Pasco Basin, except where; (1) basalt crops out; and (2) the Hanford Formation sediments were deposited directly on basalt. The Ringold Formation is a fluvial sedimentary unit with some lacustrine and fanglomerate facies.

The Hanford is the top (most recent) formation consisting mainly of gravels with sand and varied bedding. The deposition was during Pleistocene glacial flooding.

Note: All of the formations above have been further subdivided into various members and units, for a more detailed stratigraphic column, see Figure A-6.

Basalt flows have unique characteristic joints (i.e., fractures) created by thermal contraction during cooling. These joints range from well-formed polygonal columns to hackly (irregular) blocks. Figure A-7 shows typical types of jointing which may be present in a Grande Ronde Basalt flow together with a comparison of nomenclature used in various studies. These joint patterns are termed intraflow structures. The types shown in Figure A-7 may vary in thickness, be absent from a flow, or occur repeatedly within a single flow. Basalt formations also have additional fractures formed by tectonic processes.

2.3 General Discussion Facility Conceptual Design

As required in 10 CFR 60, Chapter 10 of the SCR provides a description of the conceptual design for a repository within the RRL at the Hanford Site. The following sections briefly describe the surface and subsurface facilities planned for the RRL.

2.4 General Description of the Surface Facilities

The surface facilities are based on a conceptual design for the basic functions of waste receipt, overpacking, and transfer to the repository waste transport shaft; handling and disposal of excavated rock; and ancillary services. The surface facilities are near the repository shafts to minimize area requirements, travel and transportation distances. The following principal components are included:

- Facilities for administration, engineering and personnel, including a visitors center
- Equipment and storage area for excavated rock and supplies
- Transportation, maintenance, service, training center, and communication facilities
- Safety and security installations
- Waste handling facilities.

The restricted area (fenced) of the surface facilities forms an irregular polygon that covers approximately 220 acres (89 hectares) (Reference Figure __). A control zone extends 6,562 ft (2 km) beyond the outer limits of the subsurface repository. The area within the control zone, but outside the underground repository limits, encompasses 9,473 acres (3,834 hectares) (Reference Figure A-15).

2.4.1 Surface Facilities Important to Safety

Buildings important to safety are designed for construction to QA Level I standards as established in 10 CFR 50, Appendix B. These facilities consist of:

- Waste handling building
- Personnel and material access facility, headframe portion
- Standby generator building
- Security headquarters
- Mine exhaust air building
- Confinement exhaust ventilation building
- Basalt headframe
- Confinement air intake building

These buildings (Reference Figure A-16) are sealed, monolithic, concrete structures. The rest of the buildings are conventionally constructed and not designed to confinement construction standards.

2.4.2 Waste Handling Facility and Systems Important to Safety

The waste handling building receives and processes both remote-handled and contact-handled waste, and transfers it to the headframe area of the waste transport shaft for lowering to the subsurface facilities. This multi-story, monolithic, concrete structure provides confinement for the waste handling process, i.e., separates potential sources of contamination from the public and from the operating personnel.

The core of the building is the second-story hot cell flanked by the operating gallery and the service gallery. On the ground floor beneath this group, the shipping cask unloading area provides a space in which the cask is upended and connected to the shielding sleeve from the hot cell, thus providing a confined route for transfer of waste canisters from the cask to the hot cell.

A contact-waste handling area is located in the west side of the building. Waste containers are unloaded in a receiving area and are transferred to the drum unloading area. There, drums are removed from the containers, inspected, decontaminated, palletized, and moved through the low-level waste transfer room to the headframe area by forklift, for loading into the mine cage.

The building support areas include radwaste treatment, ventilation fan and filter rooms, mechanical and electrical rooms, service areas, and administrative areas. Two separate ventilating systems are furnished in the building: the confinement system for the waste-handling area and a standard ventilating system for support and administrative areas. The confinement system supplies fresh air to the waste-handling areas and exhausts it through High Efficiency Particulate Air (HEPA) filters to the stack.

2.5 Subsurface Facilities and Conceptual Design Details

The subsurface facilities include the main entries, storage panels (for 10 year old spent fuel and commercial waste), experimental panel, and contact waste-storage panel. These are engineered excavations in the repository horizon and are developed from the shaft station, providing storage capacity for waste receipts. The repository layout (Reference Figure A-13) is at the conceptual stage of design development. The proposed schedule for design development is outlined in a series of network diagrams. ~~(Reference Figures)~~

Shaft pillar facilities include areas for waste transfer, bulk material handling, maintenance, stores, service equipment and personnel, and administrative functions. Two independent ventilation systems are provided: a confinement air circuit to serve areas of the facility where nuclear waste is handled or stored, and a mining air circuit to serve development and support activities. A waste-shaft station unloading area and a transporter loading area are provided to handle the waste canisters. They are laid out for efficient waste-cage unloading and transporter loading.

The waste storage panels provide space for one year's receipts. The storage and design is based on emplacement of canisters in horizontal bore holes drilled into the rockwalls of the storage panels. (Reference Figure A-19). Main access ways leading to panel areas are separated from storage panels by a zone of pillar rock. The conceptual design has considered the analysis of data developed from preliminary tests of rock stress and strength (Reference Figure A-18).

The layout and spacing of the main access ways allow the total separation of the two air circuits. The main access ways will remain operational throughout the retrieval period.

Preliminary plans for backfill and seals in the repository are outlined in Sections 10.7 and 10.8 of the SCR. The conceptual design for backfill is a 25-75 mix of bentonite pellets and crushed basalt. The seals are treated as a component of a multiple barrier waste isolation system.

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3 GROUNDWATER

3.1 Introduction

Chapter 3 analyzes the information in the SCR which pertains to groundwater. The chapter summarizes the principal groundwater issues in the SCR, analyzes selected issues and the DOE plans and program for continuing site characterization, and presents a set of NRC conclusions. The issues which are analyzed in the chapter include: (1) the validity of the DOE's conceptual model of the hydrogeologic system; (2) the adequacy of the data on hydraulic parameters (vertical and horizontal hydraulic conductivity, hydraulic heads, effective porosity, dispersivity, and matrix diffusion); (3) the validity of using hydrochemistry to characterize flow systems; and (4) the high degree of confidence expressed by the DOE in the results of preliminary numerical models of groundwater flow.

3.1.1 Type of Material Presented in the SCR

DOE has provided a description of the hydrogeologic system within the Pasco Basin in Chapter 5 of the SCR. DOE presents values of hydraulic parameters and hydrochemical data gathered from DOE's hydrogeologic testing program to date. In light of these data and the results of preliminary mathematical modeling conducted over the past 4 years, DOE has developed a conceptual model of groundwater flow in the Pasco Basin. In addition, DOE has presented the results of recent numerical modeling based on the current conceptual model; this numerical modeling is used to determine flow paths and to calculate travel times under post-emplacement conditions (Chapter 12). DOE's issues and plans for hydrogeology are presented in Chapter 13; issues and plans for performance assessment, including numerical modeling of groundwater, are presented in Chapter 16.

The importance of understanding the groundwater system of the Hanford site is clearly stated by DOE:

> "It is generally recognized that the most probable mode by which radionuclides could be released from a repository facility is through the groundwater system" (SCR, page 12.1-1).

3.1.2 Relevant Sections of 10 CFR 60

Principal portions of proposed 10 CFR 60 which require evaluation of the hydrogeologic system at time of licensing include:

60.112 Overall System Performance Objective - This section requires that releases to the accessible environment meet standards set by the EPA.

60.113(a)(2) Geologic Setting - This section requires preemplacement groundwater travel times from the disturbed zone to the accessible environment exceed 1,000 years.

60.122 Siting Requirement - This section lists various favorable and potentially adverse conditions which require hydrogeologic evaluations.

3.1.3 Relationships Among Issues

Certain aspects of the hydrogeology of the Hanford site are closely related to topics covered in other chapters of this NUREG. The analysis of the conceptual groundwater model of the SCR, Section 3.3.1 of this chapter, is supported by material in Chapter 4, Geology and Geologic Stability. Hydrochemistry, discussed in Section 3.3.1.2, is related to concerns in Chapter 5, Geochemistry. Numerical groundwater modeling, analyzed in Section 3.3.3 and referred to frequently throughout Chapter 3, is related to issues raised in Chapter ~~10~~ 9, Performance Assessment. A table of open issues which will require further study and discussion between the DOE and the NRC is presented in Chapter 11.

The master list of NRC groundwater issues is presented in Appendix C of this NUREG. An analysis of each of the issues identified in Appendix C has been prepared by the staff. These Site Issue Analyses have been developed based on staff review of the SCR and supporting documents and the onsite reviews conducted within the last 2 years.

3.2 Principal Issues in the SCR

The ~~hydrogeologic system~~ description in the SCR of the hydrogeologic system includes:

- A conceptual model of the hydrogeologic system
- Hydraulic parameters (horizontal hydraulic conductivity, hydraulic heads, effective porosity, dispersivity, and matrix diffusion)
- Hydrochemistry
- A numerical groundwater model.

DOE presents a conceptual groundwater flow model in Chapter 5 of the SCR. The conceptual model is based on DOE's interpretation of the results of preliminary hydrogeologic investigations and preliminary numerical groundwater modeling activities. The basic hydrogeologic data at BWIP are developed by single-point testing in small-diameter boreholes. These holes are logged geophysically for delineation of flow tops and flow interiors. Single-hole hydraulic property tests are conducted, using packers to isolate flow tops and flow interiors. Hydraulic property tests include slug tests, injection tests and recovery tests. The results of these tests are incorporated into numerical models for purposes of travel-time calculations.

The conceptual groundwater model presented in the SCR is based essentially on a geologic system that consists of areally continuous, layered basalt flows and interbeds of the Columbia River Basalt Group (Figure 1). The main features of this model are that the flow systems are layered and confined, with interbeds and flow tops acting as homogeneous aquifers and low-permeability columnar basalt zones acting as homogeneous confining layers. Horizontal and vertical hydraulic gradients are interpreted to be minimal. While DOE recognizes that vertical leakage potentially occurs across flow interiors, strong assertions are made that little vertical flow occurs between shallow and deep flow systems in undeformed areas. Apparent breaks in key hydrochemical parameters are interpreted by DOE to indicate separation of shallow and deep flow system. While some vertical flow is hypothesized to occur along major geologic structures, particularly to the north of the RRL, this is not represented in the conceptual groundwater flow model presented in the SCR. Overall groundwater flow direction in the basalts is believed to be to the southeast, and the principal discharge area is south of the Hanford site. These assertions, in combination, constitute the conditions upon which calculation of travel time from the RRL to the accessible environment is based.

The conceptual model outlined by DOE has been incorporated into a numerical groundwater model which is used to identify flow paths and to calculate travel times. Consistent with the conceptual model, the hydrogeologic system of the numerical model is a simple, layered sequence of hydraulically homogeneous and areally continuous basalt flow interiors and interflows. Based on the performance assessment modeling noted in the SCR and earlier modeling efforts, DOE asserts that:

> "Even with the different assumptions used, and in light of different organizations performing these analyses, the pre-waste-emplacement travel times calculated to date significantly exceed the 1,000-year travel time from the repository to the accessible environment in the NRC proposed regulations (NRC, 1981)" (page 12.4-51).
>
> "With regard to waste isolation effectiveness, the results of the near-field performance analysis support the following conclusions:
>
> - The post-waste-emplacement groundwater travel times from the repository to the reference boundary (10 kilometers from the edge of the repository) are estimated to be greater than 10,000 years, ignoring the travel time through the engineered barriers.
> - The groundwater flow paths from both candidate repository horizons are predominantly horizontal and are restricted to the Grande Ronde Basalt" (page 12.4-51).
>
> "Studies conducted to date by Rockwell and other independent organizations unanimously agree that the minimum travel time from the repository to the accessible environment under natural, pre-waste-emplacement conditions is likely to be on the order of 10,000 years or longer. As a result, considerable confidence exists that compliance with the 1,000-year minimum travel time to the accessible environment specified in NRC proposed technical criteria will be demonstrated for the reference repository location" (page 12.4-53).

3.3 Analysis of Issues

The areally continuous, layered geometry of basalt flows and interflows, with minimal, homogeneous vertical hydraulic conductivity of each unit and minimal, homogeneous horizontal hydraulic conductivity of flow interiors establishes a very nonconservative base case for travel-time and transport calculations. The conceptual and numerical models presented in the SCR do not account adequately for the effects on groundwater of structural and stratigraphic discontinuities that are known to exist in the Columbia River Basalts (Appendix ~~2~~ L). Figure 2, which is a reproduction of SCR Figure 3-29 (page 3.5-30), illustrates complex, small-scale structural and statigraphic discontinuities that are spaced meters to tens of meters apart in the Umtanum Flow at the Emerson Nipple Section. Figure 3, a reproduction of SCR Figure 3-52 (page 3.7-29), shows the areal distribution of aeromagnetic anomalies which are interpreted by the BWIP staff as expressions of significant structural features in the subsurface. Many of these features correlate exactly with the trace of major structural features; other features are uncharacterized to date. Irregularities in the distribution of basalts illustrated in the "Top-of-Basalt Contour Map" (SCR Figure 3-51) may well be related to significant stratigraphic discontinuities. Structural discontinuities in the Pasco Basin exist at a variety of scales, from extensive zones of major structural influence (e.g., faulting and fracturing along the Gable Mountain-Umtanum Ridge anticline), through more discrete zones of offset (e.g., the "Nancy Linear"), to small-scale (mm to 1m) tectonic breccias, radiating fans, and cooling joints, which may be spaced meters to tens of meters apart. Stratigraphic discontinuities apparently range in scale from major pinch-outs of basalt flows and sedimentary interbeds to local thickening and thinning of flow-top breccias. The variety and ubiquity of structural and stratigraphic discontinuities apparent in Figure 2 contradict the simplicity of structure and stratigraphy shown in Figure 1, which represents the DOE's conceptual and numerical models.

In light of the oversimplification of the hydrogeologic system in the SCR, the validity of the DOE's conceptual and numerical models is so uncertain that little, if any, confidence can be placed in any present estimates of groundwater travel time or radionuclide transport based on these models. The staff concludes that the hydrogeology of the Hanford site is too poorly characterized at this time to develop or defend any single conceptual groundwater model. Travel time and transport calculations cannot be accredited any degree of confidence because a unique model cannot be defended.

3.3.1 Limitations in Site Characterization

The major weaknesses in site characterization which lead to uncertainty about the conceptual groundwater flow model are discussed in the three following subsections:

3.3.1.1 Hydraulic Parameters
3.3.1.2 Hydrochemistry
3.3.1.3 Hydrogeologic Boundaries

3.3.1.1 Hydraulic Parameters

Accurate knowledge of hydraulic parameters (hydraulic conductivity, effective porosity, hydraulic heads, dispersivity, and matrix diffusion) is essential for validation of a conceptual model and for calibration of numerical models for conclusive predictions of groundwater flow paths and travel times. The NRC staff concludes that there are the following major limitations in the DOE data on hydraulic parameters:

- o Certain key hydraulic parameters, such as vertical hydraulic conductiviy and matrix diffusion, have not been measured at all. The values of vertical hydraulic conductivity used by DOE in numerical modeling of groundwater flow (10^{-10} m/s to 10^{-12} m/s, e.g., page

5.1-44; page 12.4-14) are based on preliminary regional-scale numerical modeling and on a method of averaging hydraulic parameters for several flows into a single value for a numerical modeling unit. These techniques do not consider adequately the effects of observed structural and stratigraphic discontinuities described in Chapter 3 of the SCR and Appendix ~~J~~ L of this NUREG and illustrated in Figures 2 and 3; the values chosen by DOE cannot be described reasonably as conservative. The staff concludes that uncertainty in values of vertical hydraulic conductivity could affect travel-time calculations significantly and that the nonconservative values used in the SCR produce predicted travel times that are unrealistically long.

- Effective porosity and dispersivity have been measured only once and in only one test interval. The single tracer test reported at BWIP is interpreted in the SCR as indicating an effective porosity in the range of 1×10^{-4} to 1×10^{-2} (page 5.1-46). The lower end of this range (1×10^{-4}) corresponds well to an estimated fracture porosity of 2.5×10^{-4} to 6×10^{-4}, based on the volume of unfilled fractures observed in intact drill-core samples (page 3.5-33). However, in the SCR unrealistically high values of porosity - 1×10^{-3} to 2×10^{-1} - have been used in numerical modeling to determine flow paths and to calculate travel times (page 12.4-25). This practice is nonconservative and produces predicted travel times that are unrealistically long, perhaps by a factor of 100. Appendix F discusses the importance of matrix diffusion to travel-time calculations.

- The near absence of large-scale measurements of hydraulic parameters constitutes a major limitation in definition of areal hydraulic continuity, flow paths, and consequent travel-time and transport calculations. The single-hole tests of horizontal hydraulic conductivity used at BWIP are essentially point-tests that examine a limited volume of rock (within a radius of a few meters to a few tens of meters from the hole) and do not characterize adequately the bulk hydraulic conductivity of the rock unit or the areal hydraulic continuity of the unit tested. To test the bulk hydraulic properties of rock units integrated over a scale of several tens of meters to a kilometer or more and to characterize hydrogeologically significant structural discontinuities which are spaced several tens of meters to kilometers apart (and which may influence significantly both flow paths and travel times), it is necessary to use high-stress pump tests for which multiple observation wells are spaced at the scale of interest (Appendix E; Erlougher, 1977, Chapter 10).

  Furthermore, no indication is given in the SCR that hydraulic conductivity tests are evaluated for the effects of mud that is customarily used in drilling at BWIP. This "skin effect" often yields hydraulic conductivity values that are lower than the true value (Appendix I). If all other factors remain constant, low measurements of hydraulic conductivity would lead to unrealistically long travel times.

- The method by which measured hydraulic parameters are interpolated to describe the properties of mathematical modeling units is a major unresolved problem. Available BWIP data indicate large variations in measured parameters (e.g., of horizontal hydraulic conductivity). This does not allow reliable interpolation of values, even by geostatistical techniques (Appendix H). The measured hydraulic properties of the units used for modeling are not constant, nor do they vary systematically in space. This situation is commonly related to small-scale, point-source hydrogeological testing programs in complex groundwater systems; the problem is not likely to be mitigated by data from additional, single-hole hydraulic property tests. Further issues related to interpolation of hydraulic properties of mathematical modeling units are analyzed in Appendix K.

- Accurate knowledge of hydraulic head is essential to define boundary conditions, to calculate hydraulic gradients, and to calibrate numerical models. The distribution of hydraulic head at the site leads multiple interpretations of groundwater flow directions. North or south-southeast flow directions can be defended. It is not clear whether the complex distribution of hydraulic heads is a product of measurement error associated with the use of packer technology during the drill-and-test sequence (Appendix G) or a product of the existence of a very complex flow system (Domenico et al., 1981, p. VI-9). For example, the SCR (Table 5-9) states that the hydraulic gradient between boreholes RRL-2 and DC-15 is toward the southeast. The gradient between boreholes DC-12 and DC-15 is stated, correctly, to be toward the southeast. The three drill-holes are very nearly colinear in plan (see Fig. 5-2c, page 5.1-5). But comparison of heads between boreholes DC-12 and RRL-2 reveals that the gradient is to the northwest (toward the repository). In fact, gradients in all geologic units between boreholes DC-12 and RRL-2, boreholes DC-16A and RRL-2, and boreholes DB-15 and RRL-2 are north-northwest toward the repository. These data contradict the southeast flow proposed in the SCR.

  Because of its impact on determining flow paths, the absence of a unique interpretation of direction of hydraulic gradient produces considerable uncertainty with respect to-travel-time and transport calculations. Additional issues related to measurement and interpretation of hydraulic heads are analyzed in Appendix K.

The staff concludes that the uncertainties in the values of hydraulic parameters presented in the SCR are too large to assign credence to any single conceptual or numerical model that is derived from these data.

3.3.1.2 Hydrochemistry

DOE places major emphasis on the concept that the chemistry of groundwater defines separate shallow and deep flow systems. The NRC staff concludes from an evaluation of the hydrochemical data in the SCR and other available data that conclusive definition of separate flow systems is questionable with present data. One important shortcoming of the hydrochemical evaluation lies in the fact that the boreholes used for the data base are several miles outside the zone between the RRL and the accessible environment. Of the boreholes considered in the SCR, DC-12 is the only one close to the zone between the RRL and the accessible environment for which there is quantitative hydrochemical data on both the Wanapum and Grande Ronde Basalts. On the basis of the Stiff diagram (page 5.1-136) and the δ^2H-$\delta^{18}O$ relationships of DC-12 (Appendix F, Figure 5), there is no discernible hydrochemical separation between the Wanapum and the Grande Ronde in DC-12. Furthermore, in the absence of adequate geochemical modeling, including the effects of methanogensis, no credence can be placed in the carbon-14 model ages presented in the SCR (Appendix F).

When supported by state-of-the-art geochemical, paleohydrologic, and paleoclimatological models, hydrochemical data can constitute useful, supportive information for the characterization of flow systems. However, the primary evaluation of a flow system must be based on the hydraulics of the flow system. Additional issues related to hydrochemistry at the Hanford site are analyzed in Appendix K.

3.3.1.3 Hydrogeologic Boundaries

Knowledge of both external and internal hydrogeologic boundaries is essential to the development and interpretion of conceptual and numerical groundwater flow models. Accurate knowledge of external boundary conditions is prerequisite to using numerical models to determine flow paths and to calculate groundwater travel time and radionuclide transport. Uncertainty in the validity of external boundary conditions based on measurements of hydraulic heads is discussed in Section 4.3.1 and in Appendix G. The significant uncertainties in the validity of the hydraulic heads measured at BWIP lead the NRC staff to conclude that little confidence can be ascribed to travel-time calculations presented in the SCR.

Structural and stratigraphic discontinuities, such as those described in the introduction to Section 3.3 of this chapter, not only affect the bulk values of hydraulic parameters (Section 3.3.1.1), but also can act as internal hydrogeologic boundaries. Internal boundaries, which may be high permeability preferred pathways or low permeability barriers, can significantly affect groundwater flow paths and consequent groundwater travel time and radionuclide flux. Internal hydrogeologic boundaries have not been characterized by tests to date. Neither have such discontinuities been considered in formulating areally continuous, layered, geologic sections for the conceptual or numerical models. The SCR reports (Chapter 3) that observed discontinuities: (1) range in scale from the columnar fractures of inverted fans to major fault zones of the scale of Gable Mountain-Umtanum Ridge structure; (2) may be of high permeability or low permeability; and (3) may or may not be perpendicular to the rock layers. The SCR (page 3.5-32) states: "The occurrence of the dimples is particularly significant because the relatively porous nature of the flow top combined with the well-developed columnar fractures of the inverted fans may significantly reduce the amount of hydrologic isolation provided by the host flow itself." The term "dimples" refers to local thickening of flow-top breccias at the apices of radiating fans.

While DOE has noted the potential importance of structural discontinuities, they are not incorporated adequately into test plans nor into conceptual or numerical groundwater models. The impact of such boundaries on travel-time calculations is unclear, but possibly significant. Further issues related to both external and internal hydrogeologic boundaries are analyzed in Appendix K.

3.3.2 Conceptual Model Alternatives

The analysis presented in Appendix L shows that structural and stratigraphic discontinuities such as those illustrated in Figure 2 are common in the Columbia River Basalt Group and that they reasonably can be expected to exert significant controls on groundwater flow at the Hanford site. The NRC staff concludes that: (1) the present hydrogeologic data base can support a number of alternative conceptual groundwater models, (2) reasonable alternative models should include hydrologically important aspects of observed geologic features in order to credibly represent the hydrogeologic system at the Hanford site, and (3) the DOE's conceptual model, which is based on the assumed stratified nature of groundwater in basalts, does not consider many important observed features. Among the plausible alternative models which incorporate important aspects of observed geologic features are the four identified below:

(1) An areally continous, layered system with high vertical leakage. In this conceptual model, the intraflow structures, such as fanning columnar joints in the entablature, are considered to permit significant vertical leakage between layers and reduce but not eliminate totally the assumed confining nature of basalt flow interiors. In all other respects this is a porous-flow-equivalent, continuum model like that of the DOE.

(2) An areally discontinuous, layered system with high vertical leakage that performs hydraulically as a large-scale, homogeneous, anisotropic system. In this conceptual model, the layered basalt system is laterally discontinuous because of intraflow structures (e.g., page 3.5-25) and variable flow distribution (e.g., page 3.5-18, 3.5-22, 23 and discussion of those figures). These small-scale discontinuities would result in a homogeneous system on a large scale due to their high frequency of occurrence and random distribution. Furthermore, the high vertical leakage associated with intraflow structures would impart an anisotropy to this model system. This is also a porous-flow-equivalent, continuum model.

(3) An areally discontinuous, layered system bounded by high permeability structures. In this conceptual model, the layered basalt system is divided into a series of discrete blocks as suggested by SCR Figure 3-52 (page 3.7-29). The blocks are bounded by vertically disruptive features of high permeability (e.g., fault zones or tectonic breccias) which provide a direct means of recharge and discharge to and from deep aquifers. On the scale of the zone between the RRL and the accessible environment, this is a noncontinuum model for which the porous-flow-equivalent numerical modeling used in the SCR could yield erroneous and nonconservative flow paths, travel times, and radionuclide fluxes.

(4) An areally discontinuous, layered system bounded by low permeability structures. In this conceptual model, the layered basalt system is divided into a series of discrete blocks separated by low permeability zones which impede lateral groundwater movement. The low permeability barriers might consist of gouge zones along major faults or might

represent simple juxtaposition of low horizontal hydraulic conductivity units (e.g., a dense basalt flow interior) against high horizontal hydraulic conductivity units (e.g., a brecciated flow top). As with case 3 above, this is a noncontinuum model, although in this case containment of radionuclides might be exceptionally good, depending on the vertical leakage within a given block.

Specific aspects of these four model hydrogeologic systems could be combined variously, with groundwater discharging to the north (rather than toward the south), up the dipping limb of the Gable Butte anticline. Alternative models 1 to 4 or combinations of them not only satisfy the hydrogeologic data, but also take into account geologic features that are described in the SCR but are not incorporated into the conceptual and numerical models presented in the SCR. Each conceptual model would lead to a different numerical model which would yield a different estimate of groundwater travel-time from the RRL to the accessible environment and a different estimate of radionuclide flux at the accessible environment.

3.3.3 Numerical Groundwater Model

DOE has made conclusive predictions of groundwater flow paths and travel times based on numerical modeling. The NRC staff is handicapped by lack of documentation of the PORFLO computer code used by DOE to identify flow paths and to calculate travel time. There is no basis for doubt that it may be an acceptable two-dimensional code. However, reliable solutions to any boundary-value problem require accurate delineation of the boundaries and of the hydraulic properties of the porous media within the boundaries. The staff expresses reservation with DOE's conceptual model (3.3), with the nature and description of boundary conditions (3.3.1.3), and with the basic hydraulic data input (3.3.1.1). The model presented in Chapter 12 cannot be calibrated with available head data.

The SCR does not include the results of any quantitative sensitivity studies of groundwater flow for the conceptual model of the Hanford site. DOE planning documents cited in Chapter 13 of the SCR indicate that current level of predictive accuracy for critical hydraulic parameters is very low (BWIP, 1982). For example, the current predictive accuracy of vertical hydraulic conductivity for the candidate repository horizon is believed to be ±5 orders of magnitude (BWIP, 1982). The effects on calculated travel time of varying vertical hydraulic conductivity by several orders of magnitude is never discussed in the SCR, nor is such a sensitivity analysis described in the plans presented in Chapter 13. Preliminary sensitivity studies performed by the NRC staff show that for very simple model systems, variation of vertical hydraulic conductivity by only one order of magnitude can change calculated travel times by a factor of 2 to 5 (Appendix D). The NRC staff generally agrees with the staff of the Basalt Waste Isolation Project in saying that, "Given that [horizontal] hydraulic conductivity in some areas is known to within ±3 orders of magnitude, it follows that the travel times are known to no better than ±3 orders of magnitude in these same areas" (BWIP, 1982, p. 69). This very large uncertainty contradicts the high degree of confidence in long travel times expressed in the Executive Summary and Chapter 12 of the SCR.

Until reliable boundary conditions and hydraulic parameters are determined during site characterization and a defensible conceptual groundwater model is developed, little confidence can be attached to outputs from the PORFLO code. Further issues related to numerical modeling of groundwater flow are analyzed in Appendix D.

3.4 Analysis of the Site Characterization Program

This section of Chapter 4 deals with evaluations of DOE's plans and programs for issues of major significance identified in Section 3.3.

3.4.1 Hydraulic Parameters

DOE plans to collect new data on hydraulic conductivity, effective porosity, and dispersivity through tests in 30 single boreholes, four dual boreholes, and one three-borehole cluster. Some of these tests are contingent on DOE's ability to rehabilitate existing boreholes which have been constructed in such a way that their ability to be tested is limited. The only proposed cluster test (DC-16A, B, C) is located near RRL-2. The scale of the test is very small with respect to the dimensions of the RRL, the Cold Creek Syncline, and the controlled area; it will test only a small portion of the south side of the RRL. With the exception of the DC-16 cluster, the proposed test program is essentially a continuation of the present single-hole test program. As explained in subsection 4.3.1.1, the NRC staff questions the reliability of the current values of hydraulic parameters. Because small-scale testing cannot produce bulk hydraulic parameters which integrate the hydrologic effects of large volumes of rock, continued reliance on small-scale hydrogeologic testing is not likely to improve significantly the reliability of the data. DOE intends to measure vertical hydraulic conductivity in only two dual-boreholes (DC-4/5 and DC-7/8) and in an unspecified number of single boreholes using unspecified testing techniques (BWIP 1982). The staff concludes that this program will not provide an adequate data base of bulk values of vertical hydraulic conductivity which represent the effects of structural and stratigraphic discontinuities. Furthermore, the SCR offers no plans to test matrix diffusion, the importance of which is disscussed in Appendix F.

DOE proposes to continue collecting point-measurements of hydraulic head during the drill-and-test sequence. The SCR indicates that DOE is assessing the need for time-variant measurements. As discussed in subsections 4.3.1.1 and 4.3.1.3, accurate knowledge of hydraulic head distribution is a critical component in formulating defensible conceptual models and in calibrating numerical models. The NRC staff concludes that point-measurements of hydraulic heads must be verified by continuous hydrographs at several depths and locations near and within the RRL. The need for this information is exemplified by the conflicting information on groundwater flow direction as interpreted from boreholes RRL-2, DC-12, and DC-15 (see 4.3.1.1).

3.4.2 Hydrochemistry

DOE also plans to continue collecting samples for hydrochemical analyses during the drill-and-test sequence. The question of data integrity associated with mixing of waters from different aquifers in open boreholes is never addressed in the SCR (Appendix F; Witherspoon, 1979). Furthermore, the SCR does not indicate how DOE intends to integrate hydrochemical data with hydraulic data to help characterize the flow systems of the Hanford site. Finally, the SCR presents no indication that DOE intends to apply paleohydrologic and paleoclimatological models in interpreting the data on stable isotopes of oxygen and hydrogen nor to develop adequate geochemical models in interpreting carbon-14 relationships. In the absence of appropriate plans in these three areas, the NRC staff will be unable to assign any credence to delineation of separate flow systems based on hydrochemistry.

3.4.4 Hydrogeologic Boundaries

DOE plans to use a paired-hole test including the McGee well to test the nature of the apparent hydrogeologic boundary ("Nancy Linear") west of the RRL, and to use new borehole DC-18 to test the Gable Mountain-Untanum Ridge structural zone, using unspecified single-hole techniques. Because of potential structural and stratigraphic discontinuities at a wide range of scales and spacings, the state-of-the-art method of testing for acquisition of data for model input utilizes large-scale pump tests with multiple observation wells (Appendix E). In the absence of a systematic, state-of-the-art, hydrologic testing program for hydrogeologic boundaries, the staff concludes that it will be difficult to produce defensible conceptual or mathematical groundwater models that can yield reliable travel-time calculations.

3.5 NRC Conclusions and Comments

Based on analysis of the data and plans presented in the SCR, the staff concludes that the following problem areas must be addressed with a state-of-the-art testing program prior to licensing.

(1) DOE should determine bulk hydraulic parameter values, with emphasis placed on state-of-the-art, large-scale, multiple-well pump tests that are combined with continuous head measurements in various hydrostratigraphic units (see Appendix E). These bulk tests should include determination of vertical hydraulic conductivity of both flow tops and flow interiors. Such tests would facilitate objective verification of any conceptual model, provide bulk values of hydraulic parameters including vertical hydraulic conductivity, improve hydraulic head data, provide information on hydrogeologic boundaries, and permit calibration of the numerical model so that defensible travel-time and transport estimates can be obtained.

(2) DOE should delineate external boundary conditions supported by defensible hydraulic test data for use in numerical groundwater modeling. Modeling should not rest exclusively on boundary conditions that are hypothetical or inferred.

(3) DOE should measure effective porosity at several locations in several hydrostratigraphic units. State-of-the-art, multiple-well tracer tests are required for this purpose.

(4) DOE should fully integrate the hydrochemistry with defensible hydraulic parameters and hydraulic heads, if hydrochemical characterization is to be used for flow system interpretation. Additionally, DOE should base conclusions on a data base derived from boreholes near the RRL; conclusions based primarily on boreholes near the

Columbia River are inadequate. DOE should support conclusions based on stable isotope data or radiometric age determinations (including carbon-14), by appropriate, state-of-the-art geochemical, paleohydrologic, and paleoclimatological models (see Appendix F). DOE should obtain matrix diffusion data; these data may be important to transport modeling and travel time prediction.

(5) DOE should use the above data to characterize the hydrogeologic system by testing alternative conceptual models in appropriate sensitivity studies which assess the relative importance of various hydrogeologic factors to the performance assessment of a deep geologic repository system for disposal of high-level nuclear waste.

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3-14

BWIP DSCA/CH3/Logsdon

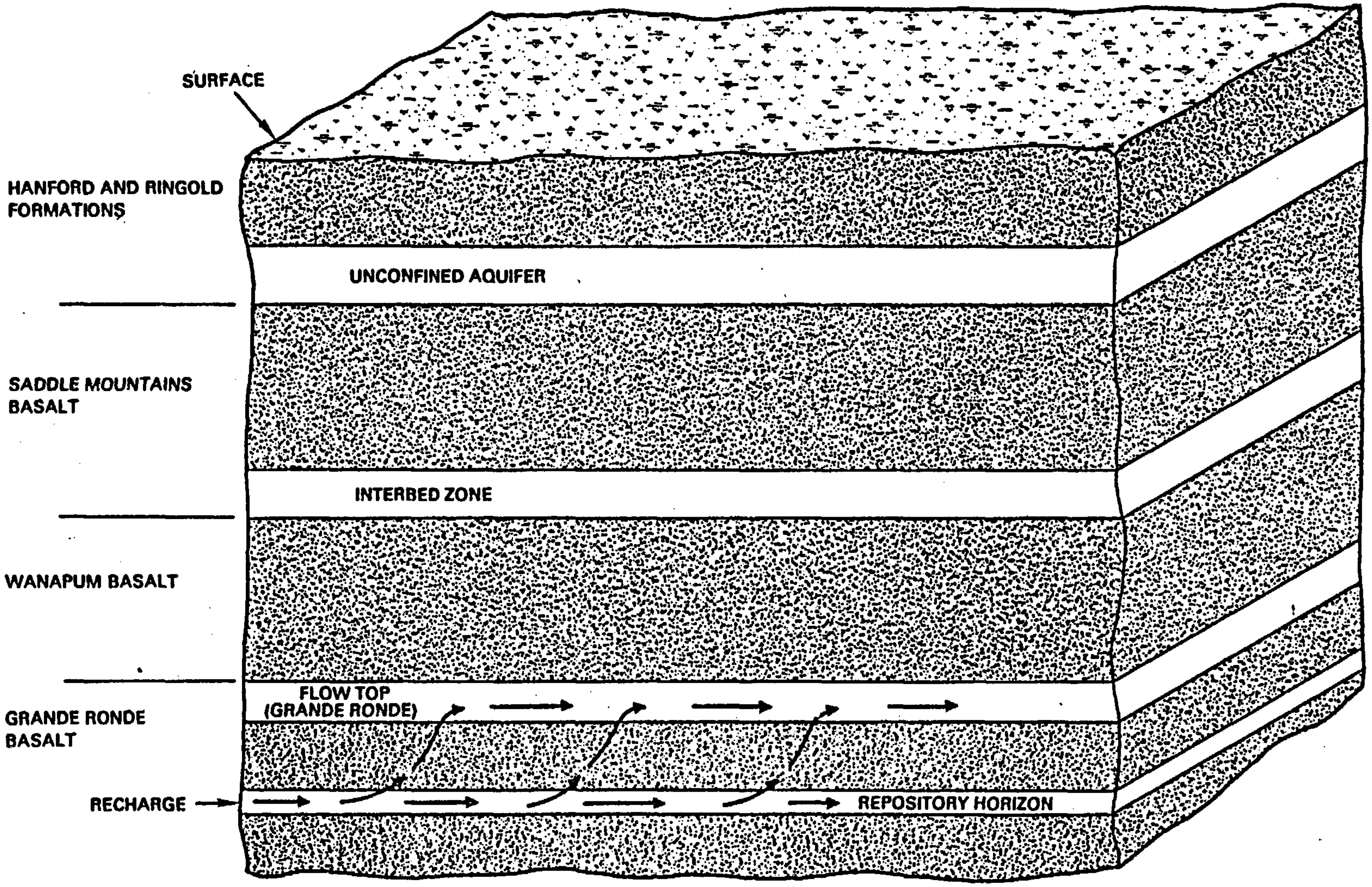

Figure 1. DOE's Conceptual Model of Groundwater Flow. RCP8109-264

(After SCR FIGURE 12-10. Schematic Representation of Groundwater Flow Path for Case I. page 12.4-46)

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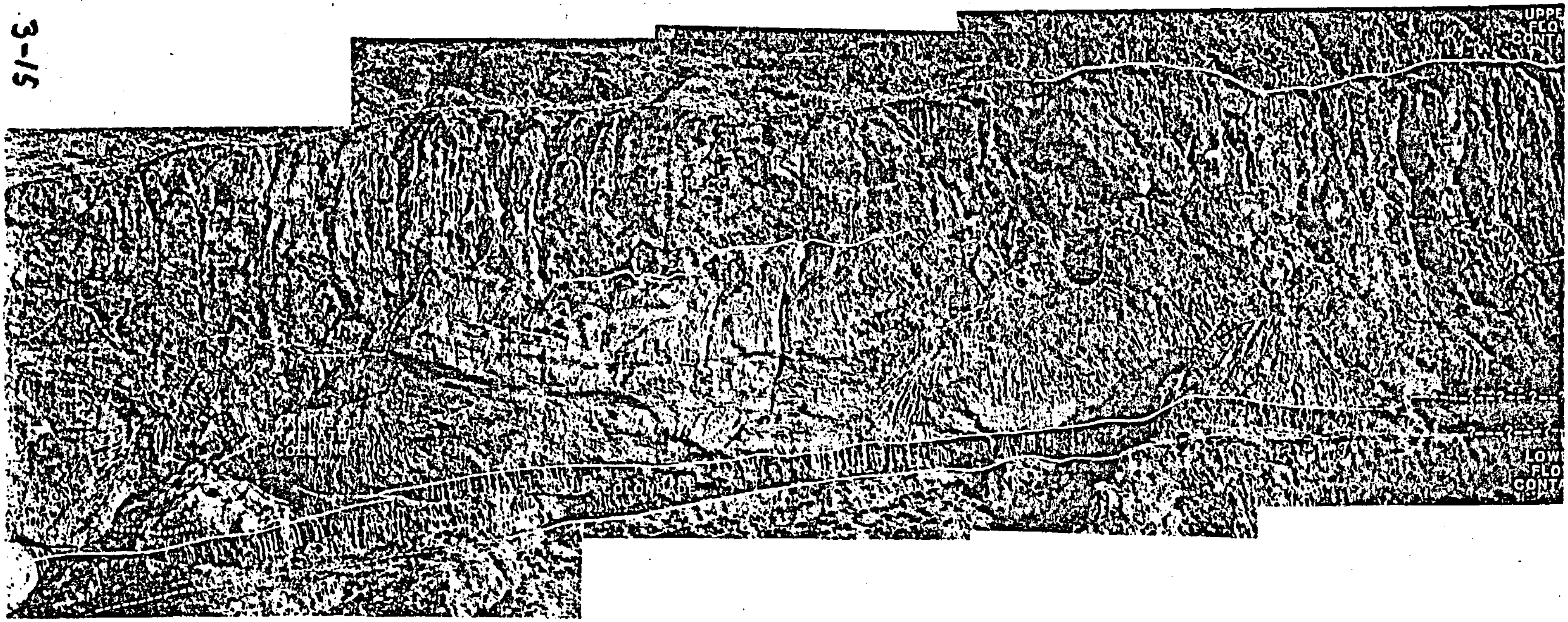
3-15



GURE 3-29. Cliff Exposure, Umtanum Flow at Emerson Nipple Section. Note the thick flow breccia and thin colonnade. Prominent fanning arrays occur in the entablatures and these atures are spatially associated with areas of thickening of the overlying flow top. The radiating columns of the fan in conjunction with the flow top and lower colonnade may be hydrologic significance.

Figure 2. Small-Scale Structural and Stratigraphic Discontinuities in the Umtanum Flow at Emerson Nipple Section. (After SCR FIGURE 3-29, p. 3.5-30)

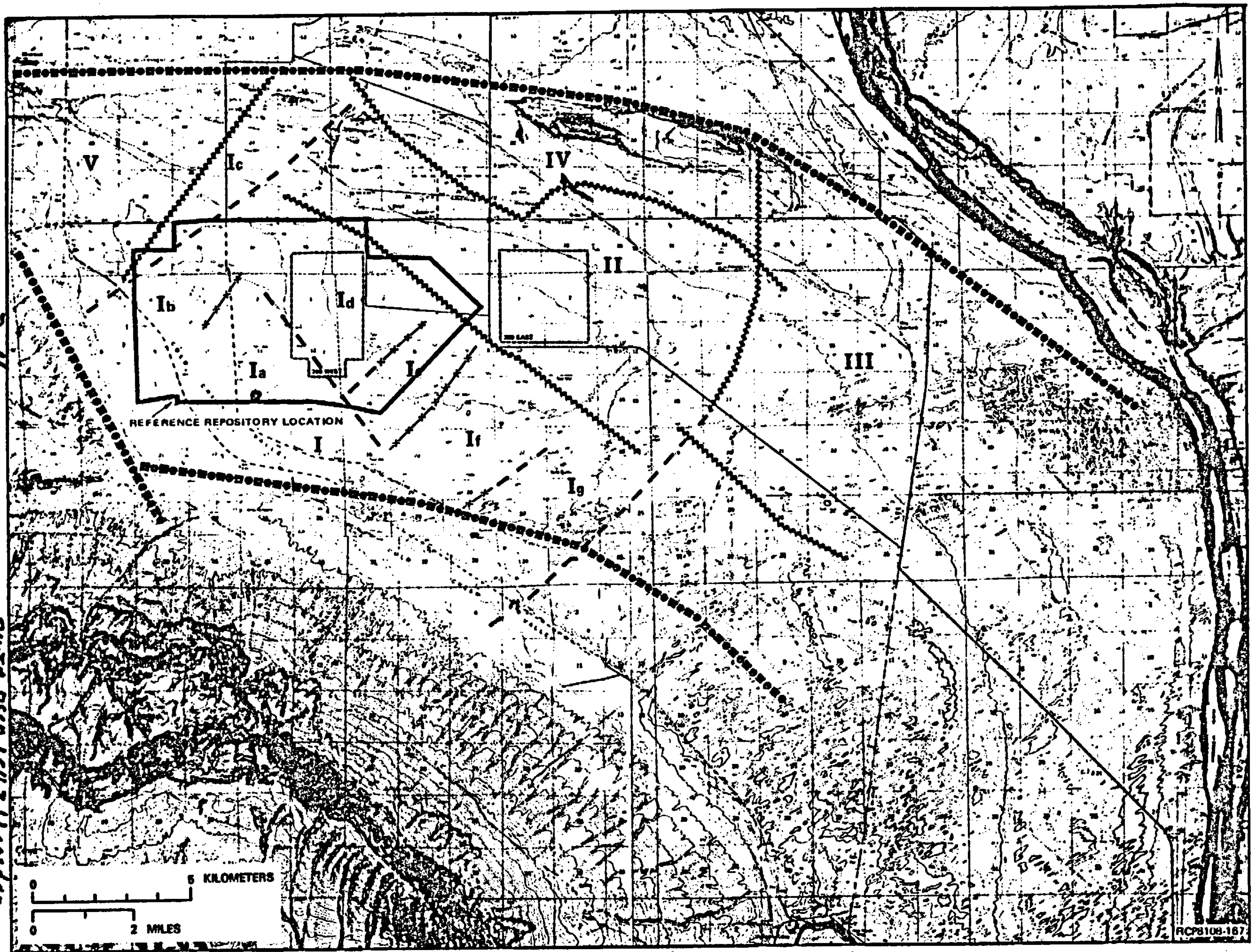


FIGURE 3-52. Interpretive
Structure Map. Areas I thı
are plan views of large, re
intact volumes of bedrock w
boundaries defined by known
inferred structures as show
Areas Ia through Ig are sub
divisions of Area I, also b
on known and inferred struc

Figure 3. Interpretive Bedrock Structure Map. (After SCR FIGURE 3-52, p. 3.7-29)

4 GEOLOGY

4.1 Introduction

This chapter provides an analysis of DOE's preliminary geologic investigations in stratigraphy, structure, geomorphology, tectonics, and seismology and their plans to characterize the geology of the reference repository location and surrounding areas as summarized in the SCR for BWIP. Following a summary of the DOE's main conclusions and assertions in geology, the chapter continues with a discussion of selected issues, followed by comments on DOE's plans and programs, and NRC's recommendations on issue resolution.

4.1.1 Types of Material Present in the SCR

Chapter 3 of the SCR summarizes the status of geologic investigations completed at the BWIP. These investigations, aimed at defining the geologic setting, the present geologic processes operating in the Pasco Basin and the long-term geologic stability of the BWIP site include: geologic mapping; evaluation of rotary and cored boreholes; and studies in geomorphology, stratigraphy, regional tectonics, seismology and mineral resources. Chapter 13 of the SCR summarizes work elements needed to resolve outstanding issues.

4.1.2 Relevant Sections of Proposed 10 CFR 60

Principal sections of the proposed 10 CFR 60 that require evaluation of geologic features and processes are:

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

60.113(a)(2) Geologic Setting - requires that pre-emplacement groundwater travel time from the disturbed zone to the accessible environment exceed 1,000 years.

60.122 Siting Requirement - lists various favorable and potentially adverse conditions which require geologic evaluations.

4.1.3 Relationship Among Issues

The identification and characterization of issues relating to geology presented in the SCR appear to be reasonably complete. They compare reasonably well with an independent breakdown of potential licensing issues developed by the NRC staff (Appendix C).

4.2 Principal Issues

The geology of the reference repository location (RRL) and surrounding areas is characterized by DOE in part in the Executive Summary and Chapter 3:

"The basalt stratigraphy, or sequence of basalt flows, beneath the Hanford site is well understood and the depth to the flows can be predicted with reasonable accuracy." (SCR, Executive Summary, p. 1.)

"The stratigraphy and structure of the basalt flows dominantly control the deep groundwater flow within the reference repository location and the Columbia Basin." (SCR, p. 13.3-1.)

"Basalt flows located more than 610 meters (2,000 feet) below the ground surface are not subject to significant erosion, and several flows may have thick enough flow interiors and sufficient lateral continuity to accommodate the construction of a nuclear waste repository." (SCR, Executive Summary, p. 1.)

"No faults have been identified on the Hanford site that would have an adverse impact on a repository constructed at the reference repository location." (SCR, Executive Summary, p. 2.)

"No known hydrologic influence from stratigraphic discontinuities has been detected to date." (SCR, p. 13.3-53.)

"...the Umtanum and the middle Sentinel Bluffs are the leading host-rock candidates within the reference repository location.... Both flows are interpreted to have sufficiently thick dense interiors to meet design and isolation requirements." (SCR, p. 3.1-1.)

"Anticlinal ridges of the Yakima folds were avoided, based on structural geology, by adopting an 8-kilometer offset from fold hinge lines...." (SCR, p. 3.4-1.)

"The present calculated rate of deformation poses no threat to the long-term integrity of a repository in a basalt at the Hanford site." (SCR, Executive Summary, p. 1.)

"The potential for renewed volcanism on the Hanford site is very low." (SCR, Executive Summary, p. 1.)

"There are no economic resources mined from the basalt in the vicinity of the Hanford site at the present time, other than groundwater pumped from shallow aquifers." (SCR Executive Summary, p. 2.)

"...a preliminary quantitative assessment indicates that the tectonic processes within the Pasco Basin do not pose a hazard to repository construction and operation or to long-term isolation of radioactive waste." (SCR, p. 3.8-6.)

"The general stratigraphic setting of the Pasco Basin and Cold Creek Syncline is well understood, and there are no currently known stratigraphic or lithologic factors that would preclude the siting of a repository in one of the two candidate horizons within the reference repository location." (SCR, p. 3.5-39.)

Based on a review of the present geologic data base, the DOE has identified two unresolved issues in geology at the BWIP:

> "What are the geologic, mineralogic, and petrographic characteristics of the candidate repository horizon and surrounding strata within the reference repository location?" (SCR, p. 13.1-3).

> "What are the nature and rates of past, present, and projected structural and tectonic processes within the geologic setting and the RRL?" (SCR, p. 13.1-3).

These two issues reflect the "basic data-gathering needs" (SCR, p. 13.1-1) necessary to complete a geologic stability assessment at the BWIP.

4.3 Analysis of Issues

The evaluation of geologic processes is necessary to demonstrate that the effects of geologic processes will not adversely affect the predicted radiological consequences of waste disposal. To complete this evaluation, it is necessary to assess the stability of the geologic setting over the long term (at least 10,000 years). This evaluation is completed by:

> "Determination of the past (i.e., approximately 3 million years before present), present, and projected (up to 10,000 years after present) nature and rates of geologic and hydrogeologic processes (i.e., site characterization)." (SCR, p. 13.1-1.)

> "Evaluation of the effect of the present and projected processes and rates on waste isolation (i.e., performance assessment)." (SCR, p. 13.1-1.)

While the NRC considers this approach to evaluating the stability of the geologic setting, as outlined by the DOE, to be valid, the staff has reservations about the present level of uncertainty in selected assertions as discussed below:

4.3.1 Uncertainties About Stratigraphic and Structural Discontinuities

If present in the RRL, stratigraphic and structural discontinuities may adversely impact facility design, constructability of the facility, and groundwater inflow into shafts and drifts. In addition, stratigraphic and structural discontinuities may adversely impact regional groundwater flow (SCA, Chapter 3). For instance, DOE considers the flowtop breccia of the candidate repository horizon to be a major horizontal flowpath for groundwater.

While much emphasis is placed on the predictive accuracy for total flow thickness, it is the predictability (or lack thereof) of intraflow structures, especially the dense interior, which is important in the candidate repository flows both in the RRL and in the Pasco Basin. "The intraflow structures may vary greatly in thickness, be absent entirely from any given flow, or occur repeatedly within a single flow." (SCR, p. 3.5-25.) Because of the variability in thickness and lateral extent of intraflow structure, the ability to predict the thickness and extent of intraflow structure is poor. For example, Table 4.1 compares two rock types (intraflow features) as a percentage of formation thickness in the Grande Ronde to actual thickness in the Umtanum flow in borehole RRL-2 (Appendix A, Figure A.8).

Table 4.1[b]

Rock Type as a Percentage of Formation Thickness

Basalt formation	Hypothetical Grande Ronde Flow	Umtanum Flow in RRL-2
Flow top (mainly breccia)	29%[a]	64%
Columnar zones (basal colonnade and entablature)	71%[a]	36%

[a]Percentage based on rock penetrated in borehole DC-4.

[b]Modified from Table 5.4, page 5.1-28, SCR.

The apparently anomalous thick flow top and correspondingly thin columnar zones (dense interior) of the Umtanum flow in borehole RRL-2, located 300 feet (91 m) from the proposed exploratory shaft ~~(Appendix A, figure)~~, exemplifies the uncertainty in predicting intraflow structure.

While lateral variation in pillowed zones may be predicted, the "locations of other features, such as thinning of colonnade, multiple tiers of entablature or colonnade, fanning of entablature columns, and thickening of flow-top breccia probably cannot be predicted with any certainty." (SCR, p. 3.5-32.) These stratigraphic features can act as barriers to groundwater flow (flow pinchouts) or may establish groundwater flowpaths (vesicular zones and fanning joints). The importance of these features in terms of regional groundwater flow is discussed in Chapter 3, Section 3.3.3.3.

The inverted fans (fanning of entablature columns) found in the Umtanum flow entablature in outcrop at Emerson Nipple, approximately 11 miles (18 km) to the northeast of borehole RRL-2, are of particular concern. The fans in this outcrop have flow top breccia at their apices (SCR Fig. 3-29, page 3.5-30). This breccia is connected to the flowtop breccia forming a dimple on the interface between the flowtop breccia and the underlying entablature. On page 3.5-32, paragraph one, the SCR states, "The occurrence of the dimples is particularly significant because the relatively porous nature of the flowtop combined with the well-developed columnar fractures of the inverted fans may significantly reduce the amount of hydrologic isolation provided by the host flow itself." "Recently obtained borehole data (RRL-2) indicate that localized increase or decrease in the flow-top thickness and related fanning joints occurs in the Umtanum flow in the reference repository location." (SCR, p. 3.5-35.) The extent to which these features influence hydrologic isolation in the host rock (see Chapter 3, page 3-7), inflow into drifts, and the stability of openings (see Chapter 6, page 6-2) must be determined.

In addition, the DOE should consider that the intact volumes of rock (Appendix A, Figure A.10) discussed by C.W. Meyers in RHO-BWI-ST-14 are far more complex in structure than is indicated in the SCR. These intact volumes of rock are described in the SCR on page 3.7-28, paragraph one. Five lines of reasoning support the NRC's concern:

- o Tectonic breccias occur in "all deep boreholes within Hanford Site and are principally in the Grand Ronde and Wanapum Basalts" (Meyers and Price, 1981, page 6-3). Such breccias suggest faulting and fracturing rather than intactness.

- o The presence of micro-earthquakes reported by the University of Washington (U of Wash., 1982) in the vicinity of the RRL. Earthquakes are evidence of the presence of fractures and faulting.

- o The surface of the top of basalt was used as "a datum for interpretation of the general structure of deep horizons" (SCR, page 3.7-26). However, "The use of this structure contour for extrapolating deep horizons is limited because of ongoing deformation throughout the Miocene, which resulted in thickness variations in deeper basalt flows" (SCR, page 3.7-26). The limited data points at depth in combination with interpretations of structure contours on a paleotopographic surface introduces uncertainties in the interpretation of geologic structure at depth.

- o "...major changes in fracture abundance or average column diameter are to be expected in at least some parts of the Umtanum flow interior; that is colonnade may occur in what would otherwise be homogeneous entablature." (SCR, page 3.5-32.)

- o Entablature zones will exhibit vertical fracturing, yet little evaluation of these vertical fractures appears to have been completed.

The NRC staff believes that the structural and stratigraphic discontinuities discussed above are likely to be present in the RRL (see Appendix J). Present conclusions by DOE on the occurrence of stratigraphic and structural discontinuities are based on limited outcrop data (SCR, Figure 3.29, p. 3.5-30) and widely spaced borings (SCR, Figure 3.18, p. 3.5-16).

4.3.2 Uncertainty About Tectonics and Seismicity

Tectonic processes, such as earthquakes and associated faulting/fracturing, may adversely impact repository performance by: (1) damage to the engineered system and waste package (Appendix M, N, and O) and (2) altering groundwater flow paths.

Preliminary data on strain rate, seismicity and faulting suggest that the Pasco Basin is relatively stable (NUREG-0892, 1982; Meyers and Price, 1982). Therefore catastrophic tectonic processes such as volcanism (flood basalts, dike injection, volcanoes) major faulting and earthquakes (>Ms=6.5) are unlikely during the next 10,000 years.

However, several lines of evidence show that there is ongoing tectonic activity. Quaternary deformation and historic seismicity (Appendix M and Appendix N) are indicative of potential tectonic instability. Earthquakes swarms (Mc = 2.5) occur in the vicinity of the RRL (Appendix N; U, of Washington, 1981, page 22 and U. of Washington, 1982, page 18). Additional evidence includes historic seismicity on faults associated with east-west trending folds at Toppenish Ridge (Campbell and Bentley, 1981) and Pleistocene displacements along faults at Gable Mountain (WNP-2 FSAR appendix 2.5; NUREG-0892, 1982).

"Adequate definition of tectonic processes and their rates of operation requires development of a conceptual tectonic model." (SCR, page 13.3-35.) "Detailed studies required to confirm a tectonic model remain to be performed." (SCR, page 3.8-6.) In addition, recent work developed in response to U.S. Geological Survey questions for WNP-2, support a model of primary low angle thrust faulting with 1-2 km of horizontal displacement that may project into the RRL. These data contradict Price's (1982) mechanical model which supports primary folding with secondary faulting and are not discussed in the SCR.

NW-SE trending structural (Fig. 1, Appendix N)

The dominant structure of seismic significance to the reference repository location, the Rattlesnake-Wallula Alignment (RAW), has been interpreted as a throughgoing right lateral strike-slip fault with some reverse oblique motion (NUREG-0892, 1982). This ~~fault~~ zone was additionally interpreted to be continuous for 120 km (74.6 mi) "from the bend in Rattlesnake Hill to the Hite Fault east of Milton-Freewater." (NUREG-0892, 1982.) On this basis, the DOE should consider that this structure may be capable of a Ms=6.5 earthquake, which may impact shaft stability during the required retrievability period.

4.3.3 Quality Assurance

The staff is concerned that Chapter 3 does not reflect a well-directed Quality Assurance program and the quality of the data presented can not, as such, be independently reviewed. For example, there are inconsistencies between the text and tables and figures. Figure 3-44 (SCR, page 3.6-28), is an example of the use of geophysical logs for stratigraphic correlation, is inconsistent with the text (SCR, page 3.6-27) describing correlations between four boreholes over a distance of 26 kilometers. Figure 3-51 (SCR, page 3.7-27) does not show all data points used to generate the Top-of-Basalt Contour map; thus, the contours cannot be reviewed for accuracy. Figure 3-52 (SCR, page 3.7-29) does not distinguish between known and inferred structure. Table 3-8 (SCR, pages 3.7-10 through 3.7-14) summarizes only faults within the Pasco Basin, although others are discussed in the text.

4.4 Analysis of the Site Characterization Program

The NRC staff has the following comments on DOE's plans and programs for the two unresolved issues discussed in Section 4.3.

4.4.1 General Comments

The SCR summarizes the details of plans and programs for the two unresolved issues discussed in Section 4.3 in the form of generalized work elements. "These specific work elements were further analyzed to identify in detail the data required and the analysis need to complete each work element" (SCR, page 13.6-1). The NRC staff ~~concludes~~ is concerned that the work elements do not provide the

Thus, it is premature to state that "the reference repository location meets the criteria for tectonic stability (SCE, p. 3.8-2) details of the data and analyses required to complete each work element. Therefore, it is difficult to make an independent assessment of the likelihood of success of the work plans. For example, additional boreholes in the RRL will be logged in detail to determine the primary internal structure of the candidate repository horizon (SCR, page 13.3-4). The additional boreholes are not specified and no angle holes are planned to map vertical fracturing.

(SCR, page 13.3-19)

Much of the work planned appears to be redundant to previously completed investigations, e.g., "review existing regional geologic work" ~~(SCR, page 13.3-18)~~, "evaluate geologic and remote sensing work" (SCR, page 13.3-18), "review and evaluate existing mapping," "evaluation of existing geophysical data set," and detailed logging of boreholes DC-4, -6, and -8 (SCR, page 13.3-4). While the NRC staff agrees that continued review of the existing data set is essential, the NRC staff is concerned that the DOE is placing too much emphasis on redundant studies and is thus relying on limited work from the contractor's staff geologists to refine the current interpretation of the geologic and tectonic framework of the Pasco Basin.

4.4.2 Structural and Stratigraphic Discontinuities

Planned geologic and geophysical investigations described in the SCR will not detect the stratigraphic and structural discontinuities of the Columbia River Basalts in the Cold Creek Syncline. Studies of lateral variations of basalt flows from outside the Pasco Basin, north of Vantage (SCR Chapter 13, Work Element S.1.1.A., page 13.3-9), are of limited use in predicting the occurrence of similar features at depth in the RRL. Intraflow structure will be determined in additional core holes in the RRL, but "Such data will provide only limited information regarding local variations in thickness of intraflow structures" (SCR page 13.3-11). The locations of "features, such as thinning of the colonnade, multiple tiers of the entablature or colonnade, fanning of entablature columns, and thickening of flow-top breccias probably cannot be predicted with any certainty" (SCR page 3.5-32). ¶ In situ testing in the exploratory shaft will provide only limited information on the lateral continuity of the potential host rocks, the strata above and below, and the structural discontinuities. The majority of existing boreholes were located away from known structures (Meyers and Price, 1979) to develop accurate stratigraphic framework. Therefore, the interpretation of geologic structures is apt to be oversimplified. In additio

4.4.3 Tectonics and Seismicity

No plans are discussed to resolve the recent interpretation of the Yakima anticlines as drag folds at the front of low angle imbricate thrust faults with the tectonic model proposed by Price (1982). This tectonic model was developed by geology advisors for WNP-2 and the Skagit/Hanford nuclear power plant investigation. If primary faulting of low angle and 1-2 km of near horizontal transport is necessary to accomodate the geologic data, then low angle thrusts may project to or under the repository site. Micro-earthquakes may be associated with these features.

The NRC staff is concerned with the reliance on geophysical investigations to define geologic structure in the Pasco Basin. Shallow geophysical studies completed at Gable Butte and the Eastern end of Yakima Ridge (Cochran, 1982) indicate that subsurface structure can not be unequivocally interpreted without subsurface exploration. Cochran (1982) states that "the complex relationship betweeen basalt surface elevation and Bouguer gravity emphasizes the need for borehole control before making absolute interpretations from the gravity data."

The NRC is concerned with the adequacy of plans to evaluate a possible bedrock structure identified through geophysical investigations (N-96 to N-84 linear) and remote sensing (Nancy Linear) in close proximity to the reference repository location in terms of its hydrologic significance only. The geologic significance of this inferred structure should be addressed and factored into the conceptual tectonic model.

No plans were noted to evaluate anamolous zones identified in borehole DC-1 from 3,970 to 4,010 and 4,175 to 4,270 feet (1,210 to 1,222 and 1,273 to 1,301 m). Low density and high porosity zones within the 3,970 to 4,010 foot zone may indicate "open fractures or shear zones" (Meyers, C.W., p 6-8). "Further examination of their possible relationship to the regional stress field and to subsurface features detected by geophysical surveys is planned" (Meyers, C.W., 1981, p 6-8). These anamolies may be indicative of larger structures than the "small fault zones a few centimeters to 1 meter in apparent width" (SCR, page 3.7-17) identified in many core holes in the Pasco Basin.

Micro-earthquake swarms have occurred within 10 kilometers of the RRL indicating that fractures exist and that some fractures are close to (or have exceeded) their failure strength (Appendix N). Stress pertubations from the mining operation may initiate movement along fractures thus affecting shaft stability (retrievability) and or cannister/backfill integrity. Plans should be developed to evaluate the affect of near-field ground motion from micro-earthquakes to determine what influence the micro-earthquakes may have on seismic design.

The general structural data summarized in Chapter 3 of the SCR is, in some respects, not current, i.e., does not take into account recent investigations such as findings of WNP-2 and Skagit power plant investigations (NUREG-0892, 1982).

4.5 NRC Conclusions and Comments

Based on review of the data and plans outlined in the SCR, the NRC staff has the following concerns:

- General work plans are presented in Chapter 13. Details of the work plans for issue resolution are not provided. Updates to the SCR should include the details of work plans as they are developed so that the NRC can evaluate the applicant's conclusions.

- Presentation of data is insufficient for a technical reviewer to complete an independent review of conclusions drawn from the data. This format would be unacceptable for licensing documents. The DOE should implement a standard quality assurance program.

- Adequate definition of tectonic processes requires the development of one or more tectonic models that are consistent with the geologic data. The DOE should consider alternative tectonic models developed in recent investigations completed for WNP-2 (NUREG-0892, 1982).

- The subsurface geology of the relatively intact volumes of basalt that are bounded by known and inferred structure is too complex to be adequately characterized through planned geologic and geophysical programs.

- The DOE appears to be placing too much reliance on geophysical surveys to interpret known and inferred structure in the Cold Creek Syncline. Subsurface structure, such as the Nancy Linear, cannot be unequivocally interpreted through the planned geophysical programs.

- There are no explicit plans to investigate microearthquake triggering mechanisms in the controlled zone. If causative structures are present in the near field of the repository, then the seismic hazard to shafts and horizontal emplacement holes backfilled with a clay-crushed basalt mixture should be considered.

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5 GEOCHEMISTRY

5.1 Introduction

This chapter provides an analysis of both preliminary DOE assessments of the geochemical conditions that will effect the long-term containment of HLW in the candidate repository horizon of the Grande Ronde, and the DOE plans for characterizing the geochemical conditions and for assessing radionuclide release rates. DOE has asserted that the results of their preliminary work "have established the prevailing geochemical conditions..." (SCR, page 7 and 6.7-1). The NRC analysis presented in this chapter indicates the basis for the staff's opinion that this general contention is premature because it is only superficially and inadequately supported by the data presented in the SCR.

The most likely means of migration of radionuclides from a HLW repository to the accessible environment is transport in solution by groundwater. After decommissioning and upon breach of a waste package, radionuclide-containing 's groundwater moves through the rock environment. As ~~it~~ moves, interactions among the radionuclides, rock and water result in changes in chemical form (speciation) and concentration of the radionuclides and thus ~~will~~ affect ~~their~~ radionuclide migration behavior. Some interactions will accelerate or retard the movement of radionuclides whereas others will deplete or increase radionuclide concentrations. Reactions near the waste will be influenced by radiation and elevated temperatures. The total effect of geochemical processes and conditions on radionuclide migration is important in modeling radionuclide release to the accessible environment.

5.1.1 Type of Material Presented in SCR

The SCR presents selected results of preliminary investigations and general plans for characterizing (1) geochemical/petrographic observations for the basalt and the fracture/vesicle filling (2) site-specific groundwater-rock (basalt) alteration reactions, (3) chemical reactions among the materials used in the engineered waste package, (4) dissolution reactions of waste forms, (5) concentration limits imposed on selected dissolved radionuclides by solubility constraints, and (6) selected radionuclide precipitation and sorption reactions in both the near-field and far-field environments. However, no specifics for conducting further investigations (such as experimental assumptions, experimental design, experimental methods or approaches to data analysis) are provided.

5.1.2 Relevant Sections of Proposed 10 CFR 60 (Subpart E)

Relevant sections of draft NRC Technical Criteria (10 CFR 60 Subpart E) are:

1.	60.21(c)(1)	4.	60.122(b)(4)	7.	60.122(c)(10)
2.	60.113(b)(3)	5.	60.122(b)(5)	8.	60.122(c)(11)
3.	60.122(b)(1)	6.	60.122(c)(9)	9.	60.122(c)(21)
				10.	60.140(d)(3)

5.1.3 Relationships Among Issues

The identification and characterization of issues relating to geochemical retardation presented in the SCR appear to be reasonably complete. They compare reasonably well with an independent breakdown of potential licensing issues by the staff presented in Appendix C. These issues address Eh-pH (hydrochemical) conditions, radionuclide speciation, solubility and sorption.

In general terms, these issues are aimed at defining:

(1) The geochemical conditions of the waste package initially, and over time.

(2) The conditions and processes affecting radionuclide retardation, in the engineered system and in the natural system, over time.

5.2 Principal Issues in the SCR

A key assertion about the performance of a repository at the BWIP is provided in SCR Chapter 6, Geochemistry, on page 6.4-3:

> "Based on solubility, the maximum possible release rates for all the radionuclides considered will be below the NRC 10^{-5} proposed release rate criterion (NRC, 1981) and the draft cumulative release criterion (EPA, 1981)."

This assertion could mean that adequate performance is assured by one favorable geochemical condition at the site. It is based, in part, on three conclusions about the geochemical interactions within the basalt environment:

- Radionuclide release is, in most cases, solubility controlled (SCR page 6.4-1, 6.4-3, 6.4-11)

- The prevailing Eh environment at Hanford is estimated to have low oxidation potential (reducing conditions). After waste emplacement and closure, it is estimated that the repository will quickly return to some low oxidation potential (SCR pages 5.1-131, 5.2-26, B.2-5, 6.4-3, 6.5-10, 6.7-1)

- The pH of the rock-water system is restricted by silica dissolution to a range between 8.8 to 10.1 (SCR pages 5.1-130, 5.2-26)

In addition to limitation of radionuclide migration by solubility, a further restriction to migration is asserted to be provided by sorption (SCR pages 6.1-20, 6.4-1). Also, it is concluded that the sorptive properties of host rock and backfill will not degrade, to any significant extent, due to heat ~~of~~ generated by the waste (SCR pages 6.3-9, 6.3-10, 6.3-11, 6.3-12, 6.3-13, 6.5-12).

Finally, natural analog studies of waste form, canister, overpack and repository suggest that long-term hazards from high-level waste in a repository in basalt should be minimal (SCR pages 6.5-8, 6.5-10, 6.5-12).

As discussed in Section 5.3, it is the opinion of the NRC staff that the above assertions and conclusions are only superficially supported by data presented in the SCR and do not accurately reflect the extent of present uncertainties. An extended list of other unsupported assertions and conclusions of concern to the NRC staff are presented in Chapter 12, Table __.

5.3 Analysis of Principal Issues in the SCR

Although the SCR contains a large amount of geochemical data, it is deficient when viewed as more than preliminary support for the conclusions presented in Section 5.2. There are several reasons for this: (1) a detailed description of experimental strategy and analytical techniques, such as would be needed for peer review, is not provided; (2) conclusionary statements concerning the status of RHO geochemical concerns are seldom documented; (3) many conclusions, where referenced, are broad generalizations or extrapolations based on very narrowly conceived and executed research results; and (4) there is little discussion concerning the methods of assessment of uncertainties on existing data or data to be obtained.

The primary geochemical mechanisms for controlling the transport rate of radionuclides to the accessible environment are the insolubility of the radionuclides and the sorption of the radionuclides during migration through the repository. The solubility and retardation of the radionuclides are established by the geochemical conditions (e.g., groundwater chemistry, temperature, pH, Eh) along the migration path.

The following subsections deal with specific uncertainties pertaining to solubility, sorption, and long-term (predicted) geochemical interactions.

5.3.1 Uncertainties of Solubility Determinations

Once radionuclides are released from the waste package, those that remain dissolved in the groundwater can be transported to the accessible environment at the rate of groundwater flow. It is of fundamental importance to determine the quantity of radionuclides that is transported to the accessible environment by this mechanism. Therefore, it must be determined whether each radionuclide will remain in solution (in a form called a species) and how much of it (its concentration) will be present. Whether or not a radionuclide remains in solution and how much of it does remain is known to depend upon specific groundwater characteristics (such as chemical composition, Eh, pH) and repository conditions (such as temperature and pressure) along the flow path.

Therefore, the values or ranges of values of at least those groundwater characteristics and repository conditions must be defined and used to determine the limits of radionuclide concentrations. Quantitative assessments of concentrations of dissolved radionuclides (such as release rates or cumulative concentration values) should reflect the uncertainties of the values defined for the characteristics and conditions which control radionuclide solubility (see Appendix U).

~~It is the opinion of the NRC staff that quantitative assessments based on solubility (such as the one quoted in SCR p. 6.4-3) do not reflect the extent of the present uncertainties in the supporting data. Such assessments are~~

clearly premature in view of the preliminary or nonexistent status of basic water-chemistry data at BWIP (RHO, 1982, pp. 8-12; pp. 13-17). These and other parameters on which radionuclide concentrations depend are discussed further in Apps (1982) and Appendices S and U.

5.3.1.1 Discussion and Evaluation of Data Needs for Solubility Determinations

There are two general approaches to the determination of radionuclide concentrations. Solubilities can either be calculated from theoretical (thermodynamic) data or measured directly from laboratory experiments. However, there are examples of directly measured concentrations of a radionuclide dissolved in a groundwater exceeding, by three orders of magnitude, the calculated solubilities (Moody, 1982, p. 27; Appendix U). Thus, the NRC staff considers it essential that the relevant thermodynamic data which underlie the theoretical calculations be verified by selected laboratory measurements using site-specific groundwater compositions and conditions.

Radionuclides that form very insoluble compounds with common groundwater ions could form colloids. Chemically, colloids behave differently from dissolved species, and would not be expected to be retarded in the same way, during migration (Apps, 1982). Therefore, it is important to determine what fraction of the radionuclides is released from the waste in a colloidal form compared to a dissolved species.

Speciation is a function of groundwater characteristics, temperature, pressure, and interactive effects between the aqueous phases and solids along the transport path. The groundwater characteristics also determine whether a radionuclide will occur in solution as a simple or complex ion. Most studies have demonstrated that uranium and actinide ions, regardless of valence state, tend to form complexes of varying stability with all major ions (ligands) found in groundwater (e.g., carbonate (CO_3), fluoride (F), phosphate (PO_4), chloride (Cl), hydroxide (OH), silicate (SiO_4), and sulfate (SO_4). The level of uncertainty and therefore the value of solubility data is directly related to our understanding of use of site-specific conditions. However, according to RHO (1982, pages 8-12), the groundwater chemistry data at the BWIP is either preliminary or nonexistent.

A complete analysis of the groundwater is required so that possible radionuclide species can be predicted. Once the possible species are predicted, experiments should be pursued to identify those that are dominant. A number of components present in basalt groundwaters (OH, CO_3, PO_4, F, Cl, S:O_4, and SO_4) can form species with radionuclides (Allard, 1982; Moody, 1982; Cleveland, 1982). Some of these complex ions could play a dominant role in determining the speciation and solubilities of important radionuclides. However, the SCR presents data only on the solubility of simple oxide species (based on the calculations of Wood (1980) and Rai, et al. (1981)). In general, the data base used by Wood (1980) and Rai, et al. (1981) is limited to room temperature (25°C) and oxidizing conditions (high Eh). These conditions are significantly different from the high-temperature, reducing conditions presented in the SCR. Thus, the solubility estimates discussed in the SCR could be unrealistically low when applied to high-temperature conditions near the waste. In the vicinity of the waste package, the solubilities may far exceed those measured at room temperatures (see Appendix U).

The measured Eh values in Grande Ronde basalt groundwater range from low to high (-0.22 volts to +0.21 volts; SCR, page 5.1-131). The predicted values are extremely low and have a range around -0.45 volts. The measured values are probably, but not necessarily, imprecise, because of well known uncertainties associated with analytical techniques. The predicted values are based on assumptions that iron-bearing minerals in the host rock control the redox potential. However, the calculated Eh values, based on mineral assemblages (notably magnetite and pyrite), have not been verified. While magnetite and pyrite are present throughout the basalt, it has not been shown that they are in close proximity to each other and in contact with the groundwater sufficient to control Eh. Further, according to Benson (1978, page 16) and the SCR (page 5.1-129, Table 5-29; page 5.1-125, Table 5-28), the concentration of dissolved species is not large enough to control (poise) Eh. Finally, there is no information in the SCR on the buffering capacity of the system. For example, if water is flowing through this system, the Eh could become reducing for a short time, and then become oxidizing after the buffering minerals have been depleted.

Also, SCR solubility estimates may not be relevant because pH may be significantly lowered by hydrolysis reactions and by gamma-ray-induced production of H_2 and H_2O_2. Further, the groundwater composition in the near field may be altered by radiolysis reactions and by the degradation of the waste package with the addition of waste package chemicals such as borate from proposed borosilicate glass and iron from proposed canisters (see Chapter 7).

Until the uncertainties associated with the above parameters are significantly reduced, little confidence can be placed in the preliminary RHO quantitative assessment that solubilities of certain radionuclide species might be sufficient to demonstrate satisfaction of the EPA standard for those nuclides. Such assessments are clearly premature in view of the preliminary or nonexistent status of basic water chemistry data at BWIP (RHO, 1982, pp. 8-11). These and other parameters on which radionuclide concentration depend are discussed further in Apps (1982) and Appendices S and U.

5.3.2 Uncertainties of Sorption Determinations

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data needed for

Another mechanism for removing or retarding the movement of radionuclides in groundwater is the sorption of radionuclides onto basalts, secondary minerals, sedimentary rocks or engineered barrier materials contacted by radionuclides transported by groundwater away from the repository (see Appendix T). To date, hydrochemistry ~~inputs~~ to sorption studies are preliminary or nonexistent (RHO, 1982, pages 3-7) and therefore the associated sorption data must be considered preliminary.

The sorption work at the BWIP deals primarily with the interpretation of results from batch sorption experiments carried out under oxidizing conditions (SCR pages 6.4-6 through 6.4-13). Since repository conditions are presumed (in the SCR) to be reducing, the results of experiments under oxidizing conditions (reported in the SCR-pages 6.4-6 through 6.4-13) provide data of uncertain relevance. This problem was addressed briefly through the use of hydrazine to control and lower the Eh during some of the experimental runs. However, hydrazine is not an expected repository constituent and no discussion of the dissociation of hydrazine hydrate and experimental complications due to the possible sorption of the hydrate or possible complex ion formation was presented.

Barney (1981, 1982) showed that sorption (Kd) values for most radionuclides are not constant at varying radionuclide concentrations, indicating that the sorption isotherms are not linear over the concentration ranges studied. Although some isotherm data are presented in the SCR (Table 6-21), they are inadequate because there is no discussion concerning their inherent uncertainties. These uncertainties are due to the large number of variables identified by Barney (1981) and discussed in Appendix T that must be adjusted in the laboratory to bound the conditions present in the groundwater pathway from the waste form to the biosphere.

Some of the data reported in SCR Table 6-20, demonstrate the variability in results under the anticipated range of Eh that characterizes the repository environment. For example, the reported Kd for ^{237}Np/basalt ranges from 7 to 2,000; the reported Kd for ^{233}U/basalt ranges from 1 to 650; and the reported valve for ^{79}Se/basalt ranges from 2 to 18 (SCR, page 6.4-12).

Further, in the basalt environment, sorption of radionuclides can occur on the basalt itself, on the secondary minerals associated with the basalt flows, glaciofluial sediments above the basalts, and on backfill material used to close repository openings. Therefore, considerable uncertainty in sorption data can be introduced if experimental design does not bound expected repository mineralogy/temperature conditions. However, while the general mineralogy, petrography, and chemistry of the Grande Ronde basalt are known, only a qualitative description of the composition of the glassy portion of the basalt, and of the flowtops and interbeds are provided.

It is the secondary mineral content and the basalt glass of the basalt flows that are expected to provide sorptive mineral and alteration products to retard radionuclide migration along potential pathways. Primarily, smectite clay, zeolite, and silica make up the fracture filling. Backfill will likely be composed of a mixture of crushed country rock (~40%) and smectite clay (~60%). If potassium is available, the clay component could change its mineral structure under the elevated temperatures anticipated in the repository. The SCR position is that the smectite clay (whether in the backfill or in the fractures) will be stable under repository temperature conditions since there is currently not much potassium in the groundwater. This conclusion is premature, since the potassium concentration in the groundwater increases markedly with elevated temperature due to the dissolution of the potassium-enriched basalt glass (SCR, page 6.4-8). Further, hydrothermal experiments of Koster van Gros cited to support stability of the fracture filling clay (SCR, page 6.1-20) and backfill clay (SCR, page 11.3-38) were not designed in a manner which proves stability. Also, the scenario proposed in the SCR (page 6.1-20) is unrealistic and appears to make inappropriate use of the cited Koster van gros (1981) data in that it requires immediate saturation to provide the necessary water pressure to ensure the stability of the clays. Thus, it might be expected that dissolution of the potassium-rich basalt glass (at elevated temperatures) could increase the stability of Illite over smectite clay on altered basalts and lead to the alteration of the smectite clay in the backfill to illite, thereby reducing the sorptive and swelling capacity of these materials.

One other concern is the lack of discussion, in the SCR, of the uncertainties associated with the effect of speciation on sorption measurements. Batch experiments provide valid Kd's only if a single species dominate in the test solution. Actinides, as well as technetium and selenium are noted for providing more than one species in solution.

These and other uncertainties associated with sorption measurements are summarized by Apps (1978) and in Appendix T. Until these uncertainties are significantly reduced, little confidence can be placed in the RHO assertions concerning sorption.

5.3.3 Uncertainties of Geochemical Stability

There are uncertainties involved in the transferability of information derived from short-term laboratory-scale experiments to the prediction of long-term repository behavior. The study of natural analogs of waste repository environments and the use of geochemical models can provide important information about long-term chemical reactions and transport. Such work can be used to extrapolate experimental data from laboratory time (days/months) to geologic time (hundreds to hundreds of thousands of years) that may be required for modeling isolation of waste in a repository.

The discussion of natural analogs in the SCR (pages 6.5-1 to 6.6-1) involves waste form analogs, uranium ore bodies as natural analogs, canister and overpack analogs, and backfill analogs. The discussion, however, draws no direct relationship to the conditions at the RHO.

The only field test discussed in the SCR involved granite, not basalt. There was no discussion concerning how these results relate to basalt.

5.4 Analyses of the Site Characterization Program

Plans are presented in limited detail. However, if these plans are broadly interpreted and carried out accordingly, then it should be possible to adequately characterize the geochemistry at BWIP.

5.4.1 Solubility - Plans

RHO proposes to experimentally measure the solubilities of compounds of uranium, plutonium, americium, and other key radionuclides under site-specific conditions anticipated to occur in the basalt repository (i.e., low Eh, high temperature, high radiation field, and complexing ligands). (SCR RHO Work Elements: W.1.4.A, W.1.10.A, W.1.12.A, W.2.4.A, W.2.5.A, W.2.6.A, W.2.8.A., W.2.11.A, W.2.9.B, W.1.11.D, W.2.12.D, W.2.13.D, R.1.18.D, S.1.26.C, S.1.38.D.)

Specifically, RHO intends to:

(1) continue experiments already initiated on the interactions between the waste form, basalt and groundwater over the temperature, pressure, and Eh-pH conditions expected for the repository,

(2) use data supplied by other laboratories from long-term static and low flow rate dynamic leach tests on simulated spent fuel and borosilicate glass,

(3) experimentally identify the dominant radionuclide species in basalt groundwater, and to evaluate conditions that could lead to possible radionuclide colloid formation and subsequent particulate transport,

(4) investigate the possible effects of the radiation field on radionuclide geochemical behavior.

(5) The solubility, speciation and colloid data will be coupled with an uncertainty analysis to ensure the successful prediction of radionuclide concentrations in the basalt groundwater.

The plans for determining solubilities, speciation and colloid transport are not detailed enough to assess whether they are adequate and thus timely. This statement is based on the following:

(1) A detailed description of experimental and analytical techniques was not provided. A more complete characterization of solubilities is derived from experiments that approach equilibrium from both under- and oversaturation starting conditions.

(2) A rationale concerning the choice of radionuclide spiking compounds to be used in the solubility experiments was not provided. In addition, it is not clear whether they will examine the compounds one at a time, or as aggregates.

(3) A strategy for determination of the speciation of critical radionuclides was not provided. Calculations to date have considered only simple oxide species.

(4) A discussion concerning the types of colloids expected to form was not provided (e.g., oxides, hydroxides, oxyhydroxides, organics). Colloids can form from solution as the result of oversaturation or from physical degradation of the basalt (i.e., particulate exfoliation).

(5) The expected influence of the radiation field (radiolysis) on radionuclide behavior at high temperature was not discussed.

(6) The methods of insuring compatability between BWIP data and data generated by other labs trying to simulate the in situ conditions of the basalt repository were not described.

(7) The methods of assessment of uncertainties on existing data or data to be obtained were not provided.

(8) The use and limits of stability diagrams, computational schemes, or numerical codes required to address solubility, speciation, and colloidal transport in a complex fluid flow regime was not considered.

RHO plans to experimentally determine more precisely the redox conditions (ambient) present in the basalt groundwater system including collection of in situ data from drill holes. Critical Eh values will be estimated in several ways (RHO Work Element W.2.10.C) including (1) down-hole potentiometric methods using reversible electrodes, (2) redox indicator dyes and (3) measurement of selected redox couples (e.g., As^{3+}/As^{5+}) in groundwater. Post-closure conditions will be extrapolated from experimental data from autoclave tests (elevated temperature and pressure) using basalt and/or mineral assemblages and site groundwater (RHO Work Element W.1.5.A). Emphasis will be placed on defining Eh-pH controlling mechanisms and the kinetics of changes from oxidizing to reducing conditions.

These plans for better definition of redox conditions, both pre-emplacement and post-closure, are presented in a vague manner and the practicality of some of the proposed approaches to estimating Eh is questionable. For example, it seems unlikely that attempts to make down-hole potentiometric measurements will be successful, or if such measurements are obtained, that their credibility and meaning will be established unequivocably. Indirect approaches to Eh estimation, and direct measurements at the well-head, are more likely to be successful. Plans to define Eh controlling mechanisms and the kinetics of changes from oxidizing (repository operation period) to reducing (post-closure period) conditions, although not given in much detail, represent a reasonable approach to assess post-closure conditions. The experimental plans presume that the rate of return to equilibrium conditions (reducing) will be rapid enough to be detectable in laboratory hydrothermal experiments and preliminary RHO experiments seem to confirm this.

RHO plans to approach the defining of Eh-controlling reactions using a combination of geochemical modeling and hydrothermal experiments (RHO Work Element W.1.5.A). The modeling will be accomplished using mineralogy, water chemistry, dissolved gas and thermodynamic data to develop a model that realistically describes Eh and pH as a function of temperature. Data from hydrothermal experiments for the basalt groundwater system will be compared and contrasted with data from drill holes. The hydrothermal experiments are also expected to yield sufficient reaction rate information to allow estimation of changes in repository Eh values following repository closure. The effect of radiolysis on solution chemistry (presumably including redox conditions) will be determined using hydrothermal testing on radionuclide waste forms, packaging and host rock (RHO Work Element W.1.3.A).

No plans were given which would approach the questions of presumed equilibrium between radionuclide redox couples and the predominant mineral redox couple controlling Eh within various zones of the repository. Predictions of repository performance for redox sensitive radionuclides based on the use of mineral couple data will not be reliable if equilibrium cannot be demonstrated (Morris and Stumm, 1966).

Finally, colloid/particulate formation by groundwater interaction with the waste form or dissolution/precipitation phenomena, as well as the transport of radionuclides as colloids or particulates, is only superficially treated in the Site Characterization Report. It is mentioned under RHO Work Element W.1.10.A, (Determine the formation and stability of complexes and/or colloids over expected repository near-field and far-field conditions). However, the colloid/particulate radionuclide transport discussion in the Site Characterization Report is intermixed with a general discussion of complex ions and sorption phenomena. The treatment is inadequate and the issue cannot be resolved by the given approach or plans. It is not possible to estimate when an understanding of colloid/particulate migration/retardation may be completed since it appears that a practical approach has yet to be developed.

5.4.2 Sorption - Plans

The geochemical process of sorption is not specifically addressed as an issue in the Site Characterization Report. However, the need to develop additional sorption data is identified in work elements under RHO Issue W.2.A, "Are the geochemical and hydrologic properties of the geologic setting (in conjunction with the waste forms) sufficient to meet or exceed U.S. NRC proposed waste isolation requirements?", and the utilization of sorption data in modeling and analysis is treated under RHO Issue W.3.A, "Testing and Performance Confirmation." Planned work for additional sorption experiments includes investigation of irreversible phenomena and the effect of multiple speciation. Confirmation of the distribution coefficients and sorption isotherms obtained in the laboratory by field migration tests may also be conducted. The plans associated with RHO issues and work elements are not detailed enough to assess whether they are adequate.

The expected temperature and radiation regime to be experienced by backfill and the water-exclusion and radionuclide-sorption properties needed are included in RHO Issue W.1.B, (Is a unique borehole backfill required?). The general approach appears to be technically sound and seems likely to succeed in developing a satisfactory backfill. The greatest uncertainty which will impact on the likelihood of success lies in the area of the availability of an adequate characterization of the waste form and load. Spent fuel elements and glass or ceramic waste forms could require different backfill materials due to different behavior in the presence of groundwater. Also, the waste load has not been finalized, and this also will influence the backfill requirements and materials. The work elements in the Site Characterization Report appear to cover a great enough range of possible parameters to develop either a superior backfill which can satisfy all possible situations, or a number of backfills for different situations.

Near-field and far-field mineralogy and its influence on radionuclide migration is not specifically addressed as an issue in the Site Characterization Report. However, the use of mineralogical information and the impact of mineralogy on the parameters that control geochemical processes and radionuclide migration are recognized and identified in a number of work elements which are components of RHO Issue W.1 ("Design"), RHO Issue W.2 ("Site Geochemistry"), and RHO Issue W.3 ("Testing and Performance Confirmation"). The need for additional petrography and minerology activities is identified under Issue RHO W.2.A ("Are the geochemical and hydrologic properties of the geologic setting...sufficient to meet or exceed U.S. NRC proposed waste isolation requirements?") and RHO Issue W.2.C, (Can valid Eh measurements for the candidate repository horizons in the reference repository location be made either by potentiometric measurement or indirectly by measurement of dissolved redox couples?").

The general near-field and far-field mineralogy in the Columbia River basalts is known. However, the heterogeneity of their distribution has not been established. Therefore, the limited additional testing indicated is not adequate to meet the information needs. More detailed mineralogical data in the near-field vicinity of the planned repository is desirable. Further, the stratigraphy and minerology below the Grande Ronde is not sufficiently characterized. This may be important if migration downwards of released radionuclides occurs (a possibility that Guzowski et al., (1981) concluded does exist based on the available hydrologic data. In addition, more information is required to fully characterize the mineralogy of the flow tops and interbeds since these are potential paths to the biosphere.

The issue of near-field mineralogical information and its use in determining radionuclide migration data or predictions seems adequately identified in the Site Characterization Report but specific experiments remain to be identified. The proposed extensive use of hydrothermal studies using the host basalt and groundwater is a reasonable approach but experimental materials and conditions need to be carefully chosen to be relevant. For example, whereas crushed basalt may be relevant for defining backfill chemical reactions, an assemblage of secondary minerals known to be major components of fracture fillings in the near-field and far-field is relevant to define reactions in these zones. The effect of accelerated potassium leaching from basalt at elevated temperature on the stability of Na-bentonite will apparently be examined under RHO Work Element W.1.12.A but is not mentioned specifically. Additional emphasis should be given to maintaining a reducing environment during the tests, if these conditions are expected to prevail in the repository. Determination of solubility/concentration information needed for sorption work may require substantial additional work and possibly a shift in the approach (see 6.4.1).

5.4.3 Geochemical Stability - Plans

DOE gives no specific plans for analog research beyond stating: "Determine what natural analogs of waste package components can be used to verify the compatibility of the waste package with the repository environment" (RHO Work Element W.3.4.A), and "Determine suitability of using nonradioactive chemical analogs for actual waste forms in the hydrothermal testing program" (RHO Work Element W.3.7). The expectation of using metal artifacts, nickel-iron meteorites, and basalt-iron deposits is expressed. However, no discussion is provided to demonstrate how the environments of these analogs is related to BWIP conditions.

It is not clear what kind of field tests are planned beyond the general statement of RHO Work Element W.3.6, "Determine and conduct field, engineering, and in situ testing as may be appropriate to meet design needs...and proposed performance requirements."

5.5 NRC's Conclusions and Comments Concerning Site Characterization Plans and Program

5.5.1 General Conclusions and Comments

In general, planned tests and experiments to be conducted during site characterization should be described in detail and submitted to the NRC for review as part of the first SCR 6-month update. The relationship of the planned tests and experiments to information presented in the SCR and to the unresolved issues should be clearly stated. The quality assurance program to be applied to data collection during site characterization should also be described. A detailed schedule for completion of the tasks showing how work will be completed in time to support construction authorization, should also be presented with the first 6-month update.

For each test or experiment, 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 test or experiment 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. Also, RHO should identify and evaluate alternative methods of testing and analysis that might achieve the same goals as the methods proposed.

Finally, the use of geochemical data for characterizing radionuclide transport relies on demonstrated accuracy, precision, and reproducibility of the data. Given the requirement for data of high quality, there is a need for interlaboratory comparisons of research results in order to demonstrate reproducibility. In this regard, results and procedures should be accurately reported and widely circulated in order to increase peer review. A suggested format for description of planned tests and experiments is provided in the Standard Format and Contents of Site Characterization Reports for High-Level-Waste Geologic Repositories (USNRC Regulatory Guide 4.17).

5.5.2 Conclusions and Comments on Solubility Determinations

- There is a need to greatly increase the collection effort of radionuclide solubility date (especially within the actinide series) on site-specific species. The NRC staff believes that solubility determinations (steady-state condition) should be approached from both over and undersaturation directions.

- The reliability of the equilibrium constants (or free energies) used in solid-solution modeling needs to be established for conditions dominating the basalt repository environment. It is quite common for experimental solubility product constants and complex formation constants to vary by 1 to 3 orders of magnitude. Quite clearly this amount of uncertainty can cause large differences in the computed results and probably contributes the largest single source of error.

- Since solubilities are in general a function of temperature, efforts should be directed toward measurements of solubilities as a function of temperature for critically important solid phases and aqueous species.

- The formation of colloids and their influence on solubility in waste/basalt/groundwater interactions are, at present, poorly understood and should receive more attention. Measurements are needed on the nature, radionuclide content and migration properties of colloidal forms produced through degradation of proposed high level waste forms.

In addition, the nature, concentrations, particle size distribution and migration properties of naturally occurring colloidal material suspended in the subsurface waters should be evaluated.

- Identification of mineral couples and mineral-water reactions that control Eh in various zones of the repository represents the most important needed information.

- The effect of groundwater radiolysis on Eh values needs to be examined experimentally.

- The kinetics by which repository conditions (especially Eh) will return to original equilibria, or evolve to new equilibria imposed by repository construction and waste emplacement is virtually unknown but is vital information to close out this issue.

- It must also be confirmed that key radionuclide redox couples, e.g., Tc(VIII)/Tc(IV), will be reactive (i.e., exhibit equilibrium) with the mineral redox couple controlling repository Eh. Nonequilibrium between these couple will invalidate predictions of repository performance overtime which are based on Eh values derived from the mineral couple.

5.5.3 Conclusions and Comments on Sorption Determinations

- The chemistry of the leachate released from the waste package must be characterized. This requires that many engineered system parameters and components must be defined. These include waste form chemistry and load, chemistry of any overpack materials, and chemistry of backfill components. These data are required so that the radionuclide source term which might be released from the waste package, for the anticipated thermal and radiation conditions can be established. Additional experiments that bound expected repository conditions will be necessary to define radionuclide retardation in the near-field and far-field.

- Isotherms should be the minimum acceptable approach for quantitative analyses,

- The use of constant Kd's are only acceptable if isotherm determination show that the ratio between the radionuclide in solution and the radionuclide sorbed is constant.

- Materials for sorption determination should include backfill materials, altered basalt, fracture filling minerals, interbed materials, and fresh basalt,

- Whether accelerated dissolution of potassium from basalt/backfill (due to elevated temperatures) will lead to degradation/alteration of backfill and fracture filling clays should be examined.

- The effects of speciation on sorption needs clarification, and

- The importance of colloidal transport needs to be addressed.

5.5.4 Conclusions and Comments on Geochemical Stability

Bullet and indent

Greater emphasis should be placed on understanding the causes and effects of naturally occurring processes that are relevant to assessing long-term repository performance. Emphasis should be given to forming a connection between the natural occurrences of radionuclide migration being studied, site-specific repository conditions, field experiments, and laboratory experiments. This connection is necessary in order to establish a basis for extrapolating with confidence the results of laboratory analyses and short-term field experiments to the assessment of the performance of a repository over long time periods. Further, such a connection would ensure that mathematical modeling of long-term repository performance is more than a paper exercise.

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6 REPOSITORY DESIGN

6.1 INTRODUCTION

This chapter focuses on assessment of potential licensing concerns related to short-term construction and operation issues and long-term waste containment and isolation issues. The conceptual design and data presented in the SCR were reviewed to assess whether the design issues are adequately identified and site characterization plans to resolve these issues are adequate.

The proposed EPA standard specifies limits on releases to the accessible environment through the multiple barriers (i.e., both natural and engineered barriers). The proposed NRC rule 10 CFR 60 provides performance objectives for a nuclear waste repository. Performance objectives include: (1) containment of waste for many years; (2) limiting of releases from the engineered system to 10^{-5} of the inventory per year; (3) maintenance of the retrieval option for a specified period of time; and (4) protection against radiation exposures and releases during repository construction and operation.

The discussions in this chapter focus on how the performance objectives are accounted for and how they influence the repository design. For example, retrieval options are directly dependent on repository design configurations, and waste canister performance is affected by stresses around the waste package. The discussions made in this chapter are related to material presented in other chapters of this DSCA, specifically chapters 7 and 9. The overall system performance is discussed in Chapter 9, and specific waste package concerns are discussed in Chapter 7.

6.2 Principal Issues in the SCR

The conceptual design presented in the SCR is based on functional design criteria found in Reference (-). Site characterization data obtained to date are presented in Chapter 4 of the SCR, and the conceptual design details are found in Chapter 10. Two candidate repository horizons (Umtanum flow at a depth of 1,100 meters and the Middle Sentinnel Bluffs flow at a depth of 910 meters) have been identifed in the SCR. The conceptual design is considered by DOE to be applicable to either of the candidate horizons. Five vertical access shafts of diameters 11 to 16 feet are located on a line parallel to the long axis of the repository. After analyzing 11 alternate arrangements of the underground facilities, a "bow-tie" arrangement (see Figure ___) for the shaft pillar layout is considered the optimum from the point of view of haulage and ventilation.

The conceptual design shows that the waste will be emplaced in multiple horizontal holes perpendicular to horizontal emplacement rooms (see Figure ___). Waste emplacement holes extend 61 meters horizontally at mid-height between adjacent panel rooms. The construction technique and equipment needed for drilling 61 meters long, 686 millimeter diameter horizontal holes in hard rock remain to be developed.

Shape, size and orientation of various underground openings and pitch of emplacement holes in the conceptual design are based on simplified assumptions and elastic analyses. The rock mechanics design parameters related to mechanical and thermal characteristics of basalt have been adapted from the literature for use in the conceptual design. Strength, modulus and thermal properties used in the conceptual design are essentially those of the intact rock, without consideration of the pervasive fractures in the BWIP basalts. Stresses induced by excavation and heat load due to waste emplacement have been calculated using the theory of linear elasticity, i.e., strain is assumed to be proportional to stress. An in situ stress ratio of two (horizontal to vertical stress) has been assumed in the conceptual design.

The feasibility of boring large-diameter shafts in basalt, as noted in the SCR, is as yet unproven, and this will require the development of larger drill rigs and new shaft liner designs. Because of this reason, the SCR states that the final decision on the sinking method for the repository shafts will depend on site-specific geotechnical and hydrologic conditions and the results of the exploratory shaft sinking demonstration. The underground openings will be excavated by conventional drilling and blasting techniques or by tunnel boring machines.

The SCR recognizes that the assumptions concerning geology and other underground parameters contain a measure of uncertainty. In some areas the repository host rock may dip, thin, yield water, or otherwise exhibit discontinuities that preclude development of the repository as laid out in the design. The SCR notes that the design and construction planning will contain contingency plans to cover such occurrences. Exploratory drifts and pilot holes in advance of excavations are planned to provide early warnings.

The SCR contains brief discussions about the type of backfill that may be used to fill up the underground openings and the procedures that may be used in emplacement of the backfill. A backfill mixture of crushed basalt and bentonite is proposed.

The SCR identifies plans to evaluate a number of schematic seal designs which have already been developed and then select specific seal designs for boreholes, tunnels and shafts. Materials will be developed and screened for use as seals. Selected materials will be tested in the laboratory while emplacement techniques will be field tested. The BWIP approach is to assess the overall performance by apportioning the performance between the geologic barrier and the engineered barriers such as the backfill and the seals. Computer models are being used to estimate the groundwater travel times, release rates and the effectiveness of seals.

6.3 Analysis of Issues and the Site Characterization Program

Four key geoengineering design elements have been identified by the NRC staff. The resolution of the issues related to these design elements before license application is considered necessary by the staff. The four design elements are: (a) stability of repository openings; (b) engineered barriers (backfill component); (c) sealing of shafts, boreholes and tunnels; and (d) retrievability of waste. Discussion and concerns related to these four design elements are presented in the following subsections: 6.3.1, 6.3.2, 6.3.3, and 6.3.4. Subsection 6.3.5 deals with the general evaluation of the BWIP in situ test plan.

6.3.1 Stability of Repository Openings

The stability of repository openings affects the integrity of the canisters in waste emplacement holes, the ability to retrieve waste, operational safety, and the long-term performance of the repository. Therefore, the design of stable openings is an important aspect of the total repository design. The discussions presented in the geoengineering sections of the SCR suggest that the in situ rock mechanics parameters could vary significantly within the candidate repository horizons. However, the conceptual design of repository openings has not considered such variability in rock strength. Besides, the rock strength used in the design corresponds to the intact basalt specimen tested in the laboratory and not the rock mass strength which is controlled by the discontinuities. The basic concerns of the NRC staff at this time are: (a) test details for critical parameters, such as the rock mass strength, are nonexistent in the SCR; (b) no rationale is presented in the SCR for developing a test plan or for identifying critical design parameters; and (c) constructibility of various repository openings has not been discussed in sufficient detail to provide assurance to the NRC staff regarding its feasibility. For example, the conceptual design of the exploratory shaft phase-II has not been initiated according to the SCR. In view of the fact that the at-depth testing is crucial to characterizing the repository horizon, detailed exploratory shaft phase-I and phase-II testing should have been presented in the SCR.

For the design of repository openings in rock, a clear understanding of the following information is necessary: (a) rock properties; (b) stresses in rocks; (c) rock behavior under external loading; and (d) rock strength and rock deformability. A brief discussion of each of the above and the methods of stability analysis follows.

<u>Rock Properties</u>

Thermal and mechanical properties of rocks required to perform a stability analysis of repository openings include: (a) density; (b) modulus; (c) Poisson's ratio; (d) diffusivity; (e) thermal conductivity; (f) specific heat; and (g) thermal expansion coefficient. Measurements of these properties can be made by performing laboratory and field tests on rock samples of different sizes. Effects of discontinuities can be studied by performing large-scale laboratory tests and in situ tests. Variation of properties can be studied by performing a number of tests on samples from different locations. Some of the properties vary considerably with time, temperature, applied stress level, moisture content, and the size of the sample tested. The number of tests to be performed and their locations depend on the relative importance of the parameters being measured, their effect on the design, and the required reliability of the test data.

<u>Stresses Around the Repository Openings</u>

Repository openings, such as tunnels and waste emplacement holes, are subjected to two types of stresses: existing and imposed stresses. Existing stresses include: (a) lithostatic stresses due to the weight of the rock, or the "overburden," and (b) built-in stresses of tectonic origin. Imposed stresses include excavation induced stresses and thermal stresses resulting from the heat load due to waste emplacement. Earthquakes and groundwater also induce stresses. In situ stresses are measured and the imposed stresses are computed and verified by testing.

Rock Behavior Under External Loading

The host rocks at the proposed repository horizons at the BWIP are heterogeneous masses with discontinuities of different orientations and frequencies. Therefore, the host rock stress-strain characteristics are complex. The behavior of the small-size, intact rock specimens tested in the laboratory under simple boundary conditions differ significantly from the rock mass behavior under complex repository conditions. Thus, the laboratory study of stress-strain characteristics of rocks should be supplemented by large-scale in situ tests (see Appendix Y). Simplified assumptions of linear elasticity that have been used in the BWIP analyses to date are generally not applicable to jointed basalts.

Strength and Deformability of Rocks

When the combination of imposed and in situ stresses reaches a certain limit, excessive deformation can result. Such an excessive level of deformation can be termed as "failure." The level of acceptable deformation is different for different design objectives. In order to understand the deformability of repository openings, various possible modes of failure, such as in tension, compression, and shear, should be identified and the associated failure criteria need to be established and evaluated. Laboratory and in situ tests are required to establish and evaluate the failure criteria.

Methods of Analysis

Available empirical and analytical methods for stability analysis of repository openings range from simple to complex (see Appendix V). Numerical models are available which can account for nonlinear stress-strain behavior, inelastic response, time-dependent deformation, spacial variability and directional dependence of mechanical properties, and complex boundary conditions. Effects of construction sequence, size, and shapes of openings and in situ stress conditions on the stability of openings can be studied in a rational way using such models. Coupling effects of thermal, mechanical, and hydrological phenomena can also be handled in a limited way by numerical analyses. The validity of the results of such analyses depends entirely on the input parameters and design assumptions.

The analyses presented in the SCR rely on simple analytical techniques based on simplified assumptions. Such techniques can be good starting points at the conceptual design stage. However, to come up with a defensible test~~ing~~ plan, it is important and necessary to perform a sensitivity study to establish the relative importance of various input parameters and priorities for testing.

BWIP Plan to Resolve Key Issues

The SCR identifies many work elements to address the geoengineering concerns related to the stability of repository openings. Some of the more important work elements are: R.1.1.A, R.1.2.A, R.1.3.A, R.1.4.A, R.1.5.A, R.1.8.A, R.1.10.A, R.1.11.B, R.1.12.B, R.1.13.B, R.1.14.C, R.1.15.C, R.1.47, and R.1.70.

Evaluation of the BWIP Plan

The staff concludes that a judicious execution of the work elements related to the design of ~~stable~~ repository openings is necessary to resolve the issues before license application. The staff emphasizes the following:

- The design of ~~subsurface~~ repository openings should be based on rock mass strength.

- Parametric studies to demonstrate the sensitivity of various input design parameters such as stress, strength, modulus, size, shape, and orientation of openings, temperature, thermal properties, and the presence of discontinuities, are necessary to design an effective test plan.

The staff's concerns stem from the lack of such a recognition at the current conceptual design stage as represented in the SCR. Two examples can be given to demonstrate the inadequacy of the conceptual design of repository openings:

(1) a single value of compressive strength of 200 MPA, based on data from the literature, has been used in the stability analysis of repository openings. This value may represent the strength of an intact laboratory specimen, but does not represent the rock mass strength, nor does it represent the range of possible variation of compressive strength under repository conditions;

(2) an elastic analysis has been performed to compute the excavation-induced and thermally-induced stresses. Such an analysis does not take into account the presence of discontinuities, nonhomogeneities, anisotropies, nonlinear and time-dependent behavior of jointed basalt.

The lack of a parametric study to establish the relative importance of design parameters poses serious limitations while developing a rational in situ test plan. No priorities for testing can be established without first establishing the importance of the parameters to be measured in situ. The NRC staff view is that the conceptual design stage is the right stage to perform sensitivity analyses and the results of such analyses should have been reflected in the test plan. The staff finds that such details are missing in the SCR and therefore finds it difficult to provide any detailed evaluation of the BWIP plan.

6.3.2 Engineered Barriers (Backfill)

Engineered barriers discussed here refer to the backfills used to fill up the annulus surrounding the canister in the waste emplacement hole and the backfill that may be used to fill up other openings. These backfills can contribute to the long-term stability of openings and can increase the isolation capability of the repository by retarding groundwater movement and radionuclide migration. The staff is concerned about the almost exclusive commitment to placement of waste in long horizontal boreholes. Placement density of backfill in this configuration is extremely difficult to control. Also, if the flow occurs vertically up in the rock, as suggested by the present knowledge of hydraulic and thermal gradients, any potential retardation benefits from emplacement room backfill may be lost.

Discussion

The degree of contribution of backfill to the isolation capability depends on: (a) the type of backfill and its geochemical properties, and (b) the waste emplacement configuration. Waste may be emplaced in horizontal or vertical holes or simply in the middle of the rooms with or without backfill. Each emplacement configuration has its own advantages and disadvantages. The advantages and disadvantages of each from the point of view of isolation capability should be documented. Analytical sensitivity studies considering a range of waste emplacement configurations and backfill properties will be appropriate before final design recommendations can be made.

BWIP Plans to Resolve the Issue

The SCR identifies many work elements relating to the issue of engineered backfill. The important ones are: R.1.26.D, R.1.57, R.1.66, R.1.67, R.1.71, R.2.1, R.1.7, W.1.12.A, W.1.15.B, and W.1.16.B.

Evaluation of BWIP Plan

It is difficult to follow in the SCR how the performance objectives for any backfill material will be determined or how uncertainty in parameters (e.g., density) will be accounted for in the design. The staff offers the following comments on the current BWIP emplacement method.

- The current conceptual design at BWIP is based on a horizontal waste emplacement hole. This arrangement does not take advantage of the emplacement room backfill contribution to improving the isolation capability (see discussions in Appendix W). It is not clear from the SCR how other configurations of waste emplacement, such as vertical or room emplacement, will be considered. The staff considers the selection of horizontal emplacement option premature and recommends several alternatives be considered for the geometry of emplacement configuration.

- As a practical matter, achieving high and uniform density and providing quality control of backfill in horizontal holes may be extremely difficult (see NUREG/CR-____).

6.3.3 Sealing of Shafts, Boreholes and Tunnels

The sealing of repository openings is an important aspect of the repository design to help prevent them from becoming preferential pathways to groundwater flow and radionuclide migration. Improper sealing could compromise the isolation and containment characteristics of a deep geologic repository. The staffs' primary concern is that the SCR does not provide or reference detailed information concerning construction and sealing programs for the exploratory shaft and associated quality assurance (QA) and testing procedures as they relate to this concern. A design and construction quality assurance plan is mentioned but not presented (see page 14.3-73 of SCR). This concern was identified to DOE in January 1983 (Ref. _____). A second concern is with delaying laboratory and field testing until preliminary performance assessments are completed. Considering the uncertainties involved in performance assessment and the need

to understand the potential problems with site specific placement techniques, delaying laboratory and field testing could impact schedules.

Discussion

For the design of seals, several topics must be investigated. They include: (a) long-term stability of the seal materials, (b) construction considerations (c) installation procedures for the seals, (d) impact of thermal loading on the seals, (e) compatibility of the seals to the host rock environment, and (f) verification of seal performance. A discussion of each of the above follows.

Long-term Stability

The performance of the seal system must be adequate over a time span which exceeds any attainable test period. Therefore, predictive methods must be utilized, based on long-term and accelerated laboratory and field testing.

Construction Considerations

The damage incurred during excavation could be a factor in the effectiveness of the seal system. If the rock becomes extensively fractured by either excavation damage or stress redistribution, the flow of groundwater and transport of radionuclides could occur through the fractured area and around the emplaced seal. Further, the design and use of reinforcements such as the shaft liners require assessment from the stand point of long-term sealing.

Installation Procedures

The placement techniques used in sealing underground openings will be a controlling factor in seal performance (Ref. _____). Reliable methods and equipment should be used for the installation of the seal materials. The reproducibility of results using these methods and equipment must be demonstrated.

Impact of Thermal Loading

The thermal loading caused by the emplaced waste may damage the seal system. There must be confidence that the seal system will perform adequately under the adverse conditions that result from the high temperatures (up to 300°C) that will occur in the repository. This includes stability of the seal materials, the interface between the seal material and the host rock, and the adjacent host rock.

Compatibility

The compatibility of the physical and chemical characteristics of the seal material and the host rock is an important consideration in seal design. Incompatibility could result in inadequate bonding between the host rock and seal material or seal deterioration by chemical attack or physical failure, which could result in degradation of the seal system. The specific data for basalt and interbeds needs to be considered in the development of the seal design. Chapters 5 and 7 of DSCA provide additional discussion.

Performance Vertification

In situ tests of the repository seals are required as part of the performance confirmation program. These in situ tests will verify that the minimum design criteria established for the repository seals can be met in actual field applications. The in situ testing will be a key factor in resolving the repository sealing issue.

BWIP Plan to Resolve Key Issues

The SCR identifies many work elements to address the sealing of repository openings. Some of the important work elements are: R.1.16.D, R.1.17.D, R.1.18.D, R.1.19.D, R.1.20.D, R.1.21.D, R.1.22.D, R.1.23.D, R.1.24.D, R.1.25.D, R.1.26.D, R.1.72, R.2.6, and R.2.8.

Evaluation of the BWIP Plan

It is difficult to follow the logic behind the development of the sealing program. A detailed description of the methods and what specific data will be acquired during site characterization is needed (see Chapter 10 for discussion of the level of details needed). Specific statements of the methodology to be employed in determining the need for and adequacy of such tests as they relate to the performance objectives is not discussed. Specific comments are as follows:

- Detailed plans for construction and sealing the exploratory shaft and details of the quality assurance procedures are not presented. (For example, the design and construction quality assurance plan, noted on page 14.3-73 of the SCR, is not provided). A detailed test plan as identified in Sections 18.3, 18.9, 18.10, 18.11, and 18.17 of the SCR is needed. As noted in Chapter 10 of this DSCA, test plans for current activities are needed now. Other test plans can be submitted prior to field implementation.

- The BWIP sealing program seems to rely heavily on the results of performance assessment failure scenarios. These scenarios consider performance of the site and waste package in determining what performance from the seal system is necessary. While the staff agrees that such an approach is necessary and useful in developing design criteria, it should not be the only approach used in determining the design criteria. Minimum design objectives should be developed based on industry sealing experience and experimental studies.

- According to Figure 17-9, selection of candidate sealing materials will be delayed until 1984. This is late in the program and forces delays in other work elements such as selecting, testing and placement techniques for seal materials, longevity tests, and field tests. If there is any slippage in the proposed schedule, the test program may not be adequately completed by license application time.

- o BWIP work elements do not identify how the long-term stability of seals (i.e., longevity) will be evaluated so that reasonable assurance of performance can be presented at licensing time.

- o The effects of reinforcements, such as shaft liners, on long-term sealing are not addressed adequately (e.g., will production shaft liners be removed?).

6.3.4 Retrievability

A geologic repository design should include the retrievability option, as required in the proposed rule 10 CFR 60.111(b). The option is required to be available up to 50 years after waste emplacement. The in situ tests to be conducted at the site characterization stage should therefore include any tests that may be required to provide support for the retrieval concept. The NRC staff concern at this stage is that the SCR does not contain sufficient details of how retrieval affects the repository design. Inadequate discussions are made about the constructibility of horizontal waste emplacement holes. No plans are provided in the SCR to evaluate problems associated with the concept of horizontal waste emplacement.

Retrieval may be full (or total) retrieval, in which case the entire emplaced waste may be retrieved, or local, in which case only a part of the emplaced waste will be retrieved (see Appendix __). Any reason may lead to retrieval, such as defective canisters, or unanticipated geologic or hydrologic conditions. The retrievability option affects the design in a significant manner. For example, the waste emplacement configuration, equipment design, development of procedures, canister design, stability requirements for emplacement rooms and holes and backfill design will be significantly affected by the retrievability option. Therefore, a thorough analysis of retrievability and its effects on design, operation, and schedule should be performed early on in the design stage.

BWIP Plans to Resolve the Issue

The SCR does not list retrievability under key issues identified by the BWIP. However, the work elements identified to address the concerns related to retrievability are: R.1.3.A, R.1.59, R.1.61, R.1.62, and R.1.68.

Evaluation of BWIP Plan

There are many uncertainties associated with the current horizontal emplacement concept presented in the SCR. These uncertainties directly affect the retrievability option. Some of the concerns are:

- o The constructibility of the waste emplacement hole is unproven (there are no known case histories of drilling 27-inch-diameter, 200-foot-long holes in jointed rocks, such as the Hanford basalt).

- o Equipment and technique to be used for drilling such holes is yet to be developed.

- The complexities of maintaining the stability of such holes in a jointed rock under thermal stresses due to waste emplacement, swelling pressures due to saturated backfill, and excess hydrostatic pressure that may eventually build up, are unknown.

- Equipment and procedures for retrieving waste are yet to be developed.

There must be reasonable assurance at the time of the license application that retrievability of waste is indeed possible if required. The NRC staff confidence in the BWIP design will be greatly enhanced if the following can be demonstrated: (a) drilling of a 200-foot-long horizontal waste emplacement hole of 27-inch-diameter in jointed basalt; (b) drilling of the waste emplacement hole from a room with dimensions of 20 feet by 10 feet; (c) emplacement of test canisters into the hole; and (d) retrieval of a random test canister from the hole. Such a test will not only demonstrate the constructibility of the waste emplacement holes, but will also provide valuable input to the retrieval design. Further demonstration tests can then be designed to study the feasibility of canister retrieval. It is the view of the NRC staff that such demonstrations will enhance confidence in the licensability of the design.

6.3.5 Evaluation of BWIP In Situ Test Plan

Chapter 17 of the SCR summarizes the BWIP site characterization program. Some comments on the contents of SCR Chapter 17 and some general observations will be presented in this section.

While presenting the logic for accomplishing the various work elements, the following is stated:

> "Each sequence shown is one of several that could be selected and is somewhat flexible in response to schedule and budgetary requirements. The logic diagrams may also be changed as increased knowledge is acquired.... These schedules will be updated semiannually in response to the increased knowledge of the site, changes in priorities, changes in regulatory guidance, and changes in budget" (p. 17.1-1).

While the staff agrees that flexibility in the schedules must be kept, it is difficult to evaluate a test plan which does not exhibit a commitment to perform necessary and sufficient testing to resolve key issues before license application. While the staff recognizes the need to work within budgetary constraints, it should be kept in mind that necessary and sufficient in situ tests will have to be performed if all key issues have to be resolved satisfactorily.

Under the discussion of "in situ test facilities," it is stated:

> "Specific tests have been identified to obtain the needed data. Test plans are being prepared that provide the basis for detailed designs of both the test facilities and the tests themselves...." (p. 17.2-1).

Details of the specific tests and the test plans should have been included in the SCR. Figure 17-1 shows that the test plans will not be available until January 1985. But, the construction of the exploratory shaft will begin by

January 1983. The staff finds it difficult to evaluate the BWIP site characterization program in the absence of test plan details. (See Chapter 10 of DSCA for discussion on the level of details required.)

Again, while presenting the objectives of E.S. Phase II at-depth testing, it is stated:

> "Tests may be conducted, if required, to establish the rock mass strength. No specific test has been identified for this purpose but ongoing testing of equipment, procedures, and techniques at the Near Surface Test Facility could be used to develop the testing techniques...." (p. 17.2-26).

The staff's view is that such critical tests as rock mass strength characterization should be assumed as required tests and planned for, unless other information invalidates such an assumption. Another important observation that causes concern to the staff is that "the conceptual design of the exploratory shaft - Phase II has not been initiated" (p. 17.2-33, Section 17.2.9).

Statements such as, "It is not possible to determine the exact tests and the detailed test designs until access to the candidate repository horizons is available through the exploratory shaft" (p. 17.2-24, Section 17.2.6) cause concern to the staff because such a lack of advance planning may lead to unpreparedness to adequately handle all reasonable scenarios.

In summary, the staff finds that the vagueness in the test plans and the lack of details for in situ tests, tight schedules, and the apparent conditional commitments to execute the tests make the evaluation of the proposed site characterization plan difficult. Lack of plans for a full scale room excavation to demonstrate the stability of repository openings during the phase-II testing is a limitation of the proposed site characteration program at the BWIP.

6.4 NRC Conclusions and Comments

Summary

This chapter of the DSCA is concerned with geoengineering issues of the repository design. Presentations made in the SCR are reviewed for adequacy in terms of 10 CFR 60 requirements. Four key design elements are identified: (a) stability of repository openings; (b) engineered barriers; (c) sealing of boreholes, shafts and tunnels; and (d) retrievability.

Conclusions and Comments

Based upon the review of relevant portions of the SCR, the following conclusions and comments are made:

- o Details on the adverse effects of site characterization and provisions to control them are missing in the SCR. For example, construction and quality assurance plans for the exploratory shaft construction are neither provided nor referenced.

- Conceptual design of geoengineering aspects provided in the SCR is vague in many respects because of simplified analyses and assumptions. Sensitivity studies are needed to identify the relative importance of geoengineering design parameters.

- Inadequate details are provided regarding the in situ tests and test plans making it difficult for the NRC staff to evaluate the BWIP site characterization plan.

- Selection of horizontal waste emplacement configuration seems to be premature and is not backed up by sensitivity analyses of alternative concepts.

- Sealing program has placed disproportionately high reliance on performance assessment modeling studies and made little provision for selection and testing of materials and techniques during the early stages of site characterization.

- Retrievability has not been given due consideration and the conceptual design appears to assume that retrieval is a simple reversal of placement. A plan to demonstrate the constructibility of waste emplacement holes and feasibility of emplacement and subsequent retrieval of waste, is needed.

7 WASTE FORM/WASTE PACKAGE

7.1 Introduction

One BWIP waste package design (see Appendix A for an illustration) includes three major potential barriers which can contribute to isolation of radioisotopes from the accessible environment. They are the crushed basalt/bentonite clay packing surrounding each carbon steel container, the carbon steel container, and the waste form (either borosilicate glass or spent fuel). These waste package components act to, first, exclude water from the waste form, and second, to control release from the waste package to the underground facility. The packing and the container retard water migration to the waste form and all three components act to control release once containment has been lost. Release rates subsequent to container failure depend in part on the waste form - borosilicate glass or spent fuel.

7.1.1 Type of Material Presented in the SCR

The SCR presents (1) selected features of potential designs for the waste package, including a partial identification of design criteria; (2) limitations in the capabilities of the waste form; (3) an extensive discussion of the anticipated chemical conditions around the waste package components; and (4) identification of major areas for research and development related to waste package analyses and validation of these analyses.

7.1.2 Relevant Section of 10 CFR 60

Sections of draft 10 CFR 60 which are pertinent to the waste package design are 60.11(6), 60.11(7) and 60.11(8) concerning the content of the Site Characterization Report; 60.111, 60.112 and 60.113 concerning performance objectives; 60.135 concerning design requirements for the waste package; 60.137 and 60.140 concerning performance confirmation; 60.143 concerning monitoring and testing of waste packages and 60.150 and 60.151 concerning quality assurance.

The purpose of this chapter is to identify the most significant technical issues which must be resolved during site characterization to determine whether or not the performance of the waste packages, including their contribution to engineered system performance, is of sufficient reliability to justify a finding that there is reasonable assurance that the overall repository system will meet EPA standards. Draft 10 CFR 60.113 provides the pertinent performance objectives. Description of a sample method for integrating waste package and engineered system performance into an overall repository system assessment is contained in Appendix D. However, other methods may be found acceptable.

In addition, this chapter identifies issues which must be resolved during site characterization to demonstrate whether or not the waste package design meets design requirements of 10 CFR 60.135 concerning the evaluation of various chemical, physical, and nuclear processes as well as demonstration that waste packages and the underground facility performance is not compromised by interactions of these processes and waste package components.

Finally, this chapter assesses the adequacy of the BWIP site characterization plan to resolve the major technical issues. Other waste package-related issues of lesser importance, along with respective Staff assessments, are identified in individual Site Issue Analyses (2.1 through 2.27) given in Appendix C.

7.1.3 Relation of SCR and NRC Issues

NRC waste package issues, identified in Appendix C and addressed in individual Site Issue Analyses reflect technical questions regarding the functional performance and interactions of the various parts of the waste package and the underground facility. Proposed 10CFR60.135 requires that such issues be considered in the design. Many of the BWIP issues presented in the SCR are similar to the NRC issues, in that the data and/or analyses required to resolve the issues are the same. The similarities are identified in Appendix C. However, some NRC issues have no corresponding issue or work element in the SCR. These include NRC Issues 2.12, 2.13, 2.16, 2.23, 2.25 and 2.27.

7.2 Summary of SCR Conclusions and Assertions

The SCR states that details of work needed to satisfy applicable regulatory and programatic technical criteria are presented in the form of Work Elements for waste package issues. The SCR states that information presented is sufficient to understand the present status of ongoing work and future plans for each work element. The SCR states that design criteria for the waste package are contained in referenced documents.

7.3 Analysis of Issues and Site Characterization Program

7.3.1 Reliability of Waste Package

A major feature of activities associated with complex new engineering projects is the systematic identification and quantification of uncertainties in predicted component or system performance. Such efforts can be accomplished by a reliability analysis. (Reliability of a system or component of a system is defined the probability that it will perform a specified function successfully for a given operating time under a range of environmental conditions. The environmental conditions can be specified as a probability of occurrence within the range identified at times throughout the operating perid.) These reliability analyses serve to demonstrate and document the quality of engineering designs and are considered by the NRC staff to be a necessary part of the BWIP design control measures within the project's quality assurance program. (See evaluation of the BWIP quality assurance program in Chapter 10.)

In addition to providing a measure of the quality of a design, reliability analyses can also be used to determine the importance of specific uncertainties in the overall system performance. When used for this purpose, they are called sensitivity analyses and serve to focus research and development testing and/or design analyses to improve understanding of processes, material properties, and conditions and, hence, guide redesign or provide greater assurance of meeting system design or performance goals.

An acceptable methodology for performing sensitivity or reliability analyses is described in Reference 8, NUREG/CR-2350. The methodology described in

NUREG/CR-2350 was used to produce the sensitivity analyses described in Appendix D. The staff considers this methodology equally applicable to sensitivity/reliability analyses for waste packages as well as the entire engineered system.

Evaluation of BWIP Plan

The SCR does not identify plans for reliability analyses of the waste packages. This represents a major shortcoming in the site characterization plan presented in the SCR. The staff considers that early identification of reliability design objectives for each of the components of the waste package, as well as for other barrier components, is necessary in order to achieve a coherent and complete system design effort. These design objectives should be properly documented in accordance with accepted nuclear power industry quality assurance program requirements.

7.3.2 Processes Controlling Waste Package Performance

To accurately quantify the radionuclide source term the behavior of the waste package over long periods must be predicted. In order to accomplish this, it is necessary to consider the most likely failure/degradation processes for the package components since this will allow radionuclide containment times and radionuclide release rates to be determined. Below are described the most important processes affecting waste package performance.

7.3.2.1 Pitting Corrosion

Low carbon steel undergoes both uniform and localized corrosion in aqueous environments. It is particularly vulnerable to stress corrosion cracking in many aqueous environments under stressed conditions. Such stresses could result from heat generation by the waste form, from residual stresses, particularly in weldments and from external loads. However, if local stresses are maintained below a threshold of about 150 MN/m^2 at 100°C (about 22,000 psi) by design, stress corrosion cracking should not be a problem (Parkins R.N.).

Pitting on the other hand is judged by the staff to be a very likely failure mode for low carbon steel containers in a basalt repository environment as explained in Appendix P. The staff recognizes that predictive analyses of pitting must necessarily include large uncertainties reflecting an inability to predict local electrochemistry accurately. However, long-term testing under repository conditions (with measurement of those conditions) combined with theoretical analyses and research on electrochemical effects can reduce uncertainties in predictions such that a reliable container design can be achieved.

Tests under more aggressive (accelerating) conditions should also be carried out to obtain pitting characteristics more quickly and the data acquired extrapolated to prototypic BWIP conditions. It is important to measure the pit initiation time, the pit density and size, and the pit initiation rate as a function of time, Eh, pH, dissolved oxygen, and chemistry of the groundwater between the low carbon steel container and packing material as a function of time. It is also important to monitor heat fluxes, temperatures/gamma fluxes and electrical conductivities of the media around the containers or corroding surface. It is especially important to consider low alloy steel weldments in the pitting tests since the structure of the weld is very different from that for base metal. The use of bentonite/basalt mixture as packing material may encourage pitting corrosion. Its contribution as packing material must be weighted against any detrimental effects it may have on the container's corrosion resistance.

Evaluation of BWIP Plan

A number of Work Elements in the SCR broadly address the characterization of pitting corrosion for the container system, including W.1.3.A, W.1.11.A, W.2.2.A and W.2.3.A.

If these programs are carried out comprehensively with the container material exposed for long periods (several years), and the results integrated with fundamental studies described above, it should be possible to develop a suitable long-term prediction for pitting. However, details of the information provided (on test plans) are insufficient to determine whether testing will be adequate.

7.3.2.2 Waste Form Matrix Degradation

In modeling rates of release of the various chemical species of solid nuclear waste forms undergoing chemical degradation in aqueous media, a distinction exists between the processes which control releases under conditions of short repository water residence times (high flow) on one hand and of long residence times (low flow) on the other. At high flow rates (or high dilutions) the degradation rates are largely affected by the leaching kinetics of the solid. At low flow rates the loss rates depend in part upon the thermodynamic solubility and upon the rate at which the water in contact with the solid is replaced with fresh, unreacted water. The composition of the water reflects reaction in the local chemical system of the waste package. The solid with which the water comes in contact may be considerably modified as a result of selective dissolution of species from the waste form. Under repository conditions, water exchange rates are likely to be low. Therefore, solubilities of the waste form are proposed by DOE to constitute a key factor in determining the long-term durability of the material.

Water subjected to prolonged interaction with the solid becomes substantially altered. The altered water affects the reactivity of the solid with respect to the dissolution of a particular species from the waste form in the following ways: (i) pH changes may cause large effects on solubility limits as well as on leach rates; (ii) increasing concentration levels of species of interest may result in approaching saturation for nearly insoluble species; (iii) increasing concentrations of other degradation products can affect subsequent dissolution of the species of interest due to secondary interactions; (iv) increasing solute concentrations in the aqueous phase can give rise to phenomona such as re-adsorption, ion-exchange and other modifications of the solid-liquid interface which affect further material transport processes across the surface; (v) pH changes as discussed in (i) above may influence formation of complex ions, such as borate and ferro-silicate complexes, and colloidal particles which in turn pickup radionuclides and effect their mobilization (Macedo, Avogadro).

Detailed discussions of degradation mechanisms of borosilicate glass, radionuclide speciation and solubilities and sorption of radionuclides are presented in Appendices Q, U and T respectively.

For an engineered system design which does not include barriers which impede radionuclide transport or provide sorptive properties the release rate from the waste form would determine the engineered system performance. For engineered systems with multiple barriers controlling release the waste form release rates will greatly affect the reliability of the overall system performance.

Evaluation of BWIP Plan

Specific plans for collecting data to understand the processes described above are not presented in the SCR. Instead, the report provides a statement that such understanding will be obtained within the DOE waste package program.

Multicomponent testing of materials utilized in the waste package with conditions controlled, i.e., gamma radiation, temperature and heat flux, must be accomplished to verify anticipated ranges of the key chemical parameters, such as Eh and pH as a function of water resident time. Testing to identify complexes and colloidal particles which may occur in the multicomponent system must also be carried out.

7.3.2.3 Transport

Assuming a typical value for the diffusion coefficient of approximately 3×10^{-6} cm^2/sec, then for a flow rate greater than about 10^{-8} to 10^{-7} cm/sec, the movement of water through the packing material in the presence of a hydraulic gradient may be described by Darcy's law (NUREG/CR-2333 Vol. 4 Chap. 6 1982). The rate of movement of radionuclides depends on the mean velocity of the water and also on the sorption processes for particular radionuclide species in that medium. The sorption processes such as ion exchange and surface adsorption will further retard migration. Precipitation of radionuclides within the packing material because of solubility limitations will provide an initial constraint on retardation. Particulates carried by the flow of water through the packing material may also transport radionuclides. A thermal gradient across the packing material may superimpose differential pressures influencing the Darcian flow with corresponding effects on velocity of the water. In saturated packing materials with very low hydraulic conductivities ($<10^{-11}$ cm/sec) or in the absence of a hydraulic gradient, radionuclide transport through the material is dominated by diffusion. In addition to diffusion of radionuclides along a concentration gradient, thermally induced diffusion across a temperature gradient is possible. Further details are provided in NUREG/CR-2333, vol. 4 (1982); NUREG/CR-2755 (1982); and PNL-4382 (1982). The mechanism for transport of radionuclides from the backfill is discussed in more detail in Appendix R.

Evaluation of BWIP Plan

According to the SCR, investigations of transport processes are in progress or are planned although the specific details of these investigations are not given. The investigation of Darcy's law processes is considered in SCR Work Element W.1.15.B, but hydrothermal conditions are not specifically mentioned. The transport of radionuclides through the packing material under hydrothermal conditions (300°C and 300 bars pressure) and in the presence of a radiation field is addressed in the SCR in Work Elements W.1.3.A, W.1.12.A, and W.1.16.B. Particulate transport is addressed in a very general sense in Work Element

W.1.10.A. Overall the plan is insufficient since it lacks the detail necessary for assessment.

7.3.3 Material Properties and Their Changes

Physical, chemical and mechanical properties of the waste package components are expected to change significantly after waste emplacement. Short term laboratory tests will be inadequate to characterize the performance of the waste package since many of the changes will only become significant after very extended time frames. Quantification of the changes and their impact on waste package behavior need to be determined to reduce uncertainties in estimating radionuclide containment times and release rates. The NRC staff considers that materials property changes discussed below are of great importance with respect to waste package reliability.

7.3.3.1 Packing

The hydraulic conductivity, diffusion coefficients, and radionuclide retardation factors are the transport properties of the packing material which most directly affect the transport processes discussed in 7.3.2.3, above. These transport properties may change because of chemical degradation of the packing material by mechanisms such as loss of hydrothermal stability, aging, decrease in sorptive capacity by chemical reaction or poisoning, selective dissolution or leaching of the packing material matrix, and radiation effects including radiolysis, all resulting from near-field conditions. The mechanical integrity of the packing and the hydrothermal stability of the material are the principal source of uncertainty. Hydrothermal stability depends not only on the temperature, but also on the groundwater composition (including Eh and pH), the exchangeable cations within the material, the extent of water saturation, and pressure. The transport properties of the packing material may also change as a result of the self-sealing properties (swelling pressure and plasticity) of the bentonite component upon the sorption of water; the accompanying increase in the compaction density may cause a decrease in the hydraulic conductivity. (BNL-NUREG-31770, 1982)

<u>Evaluation of BWIP Plan</u>

Measurements of the hydraulic conductivity of candidate packing materials are planned (Work Element W.1.15.B of the SCR), but it is not clear from the discussion in the SCR whether these measurements will be done under hydrothermal conditions (300°C and 300 bars pressure). The effects of such conditions on the radionuclide transport properties of packing material are considered in Work Element W.1.16.B. The effects of interaction with other waste package components and with the host rock are discussed in W.1.12.A. In W.1.3.A the effects of a radiation field are considered. The details of these investigations are not given.

7.3.3.2 Waste Forms

Properties of the waste form will impact on the underground facility, particularly the groundwater. Vitrified radioactive waste and spent fuel will cause thermal and radiation induced changes in the groundwater. Since the backfill performance, the corrosion behavior of the container(s) and the leaching of the waste form itself are all dependent on the water pH, Eh, and chemical composition, the changes in these properties induced by the presence of the waste should be addressed. (It should be noted that by simply increasing temperature of the medium, leaching can be increased by many orders of magnitude and corrosion rates will also be enhanced.) The effects of the water environment will alter the time of containment and the rate of radionuclide release. If not considered properly in design so as to assure the waste package performance is not compromised, such effects could constitute a compromise of design requirements in proposed 10 CFR 60.35(a).

In addition, the waste form may undergo changes with time that affect the rate at which radionuclides are released. Devitrification (Hench, 1982), phase separation, as well as glass changes induced by fission product decay may alter the leach properties of the glass. Phase separation resulting from isothermal devitrification of the glass may result in as much as a factor of 140 increase in the leach rates of glass (Hench, 1982). Decay of the fission products will produce compositional changes in the glass, the magnitude of which will depend on waste composition.

Data reported in section 11.3.2 of the SCR (pages 11.3-2 to 11.3-15) identify effects of hydrothermal conditions on the deterioration of both spent fuel and borosilicate glass. Data reported in the SCR appears to cover relatively high temperatures (300°C), and a statement is made that extrapolation of data would indicate that complete hydration of 30.5 centimeter diameter waste forms would occur in 10 years.

There is also evidence that surface film formation on Savannah River Plant glass results in a more durable waste form (Wicks, 1982). The film, which is rich in Fe and Mn, appears to be protective. In contrast, the presence of iron in the leaching medium has been shown to increase the leach rate of glass (McVay, 1982). While these results are not directly comparable, the question of surface film formation and the effect of the environment and other package components on the durability of film is an issue that should be addressed if film formation is claimed to enhance the performance of the glass. Appendix Q discusses degradation of borosilicate glass in more detail.

For spent fuel the effects of aging on its performance have not been determined, nor have the effects of cladding failure and corrosion buildup.

Evaluation of BWIP Plan

The BWIP plans pertinent to this issue are contained in work elements W.1.12.A and W.1.3.A in Chapter 15. These briefly discuss plans to evaluate changes in properties of the waste forms and do not provide an adequate basis to determine that this issue will be resolved.

In addition, the design plans and design limits for waste packages within the BWIP repository environment do not consider the requirement that waste package performance not be compromised by the design itself. For example, it appears that combination of maximum allowable temperature (i.e., those specified in RHO-BW-ST-25) and long design life are inconsistent with the use of borosilicate glass if hydrothermal conditions could occur at the waste form. The reliability of the containers would not be sufficient to eliminate this concern.

Appendix P discusses failure of metallic containers by corrosion including stress corrosion cracking, hydrogen embrittlement and pitting.

7.3.3.3 Containers

The reliability of the container is central to the predictions of the radionuclide containment time and subsequent radionuclide release, since as suggested above the exposure to hydrothermal conditions will compromise waste form integrity. Physical changes in the container, for example, the size and distribution of pits and the presence of voluminous oxide scale will be expected to retard the water flow rate over the surface of the waste form and, therefore, affect the leach rate. To determine uncertainties regarding the rate of water flow passing the waste form surface, estimates need to be made of the water penetration rates through the oxide layers on the container surface and through pits which are filled with corrosion products. If accurate water flow rates can be determined, it will significantly improve the estimation of waste form leach rates and radionuclide release rates from the engineered system and to the accessible environment.

Evaluation of BWIP Plan

With respect to the above issue, only one SCR Work Element addresses groundwater flow through the individual barriers to and from the waste form. This is Work Element W.2.8.A. Until more details are obtained on the development program it is not possible to determine whether water flow through a perforated container to the waste form will be specifically addressed.

7.3.4 Conditions Affecting Waste Package Processes

The conditions which affect processes involving waste package performance can be divided into four major categories: (1) chemical, (2) thermal, (3) hydraulic and (4) mechanical. Chemical conditions are generally the most difficult to determine owing to the complicated set of reactions involving hundreds of different chemical species in the repository environment. In general, only bounds on key chemical parameters can be predicted with confidence. Hydraulic and mechanical conditions are more accurately predictable, because good modeling is available. Also, pertinent material properties can be readily measured to facilitate the prediction of mechanical and hydraulic conditions with time. The best understood are thermal conditions although uncertainty in hydraulic conditions can reduce this understanding.

It is the staff's conclusion that uncertainty in conditions over the life of the repository is most limiting in demonstrating high reliability in system performance. Uncertainties in the quantitative modeling of processes and determination of pertinent material processes--area discussed in the sections above--are of lesser importance in the reliability analyses.

Discussion of major issues related to chemical and mechanical conditions follow.

7.3.4.1 Chemical Conditions

During the first several hundred years after waste emplacement, the immediate surroundings of the waste package may change from a high temperature, high radiation, acidic, oxidizing environment to a cooler, alkaline, reducing one. These changes in physiochemical conditions will affect the corrosion resistance of the container, the degradation of the waste form the composition of groundwater and the release and transport of species.

With respect to the environment immediately adjacent to the container, the amounts of moisture will be limited by physical constraints so that any changes brought about by thermal, chemical (corrosion), and radiation environments may be large and significantly different from those present in simple corrosion experiments. The radiation environment, in particular, will be a major consideration (Glass, 1981) since the following radiolysis species will be present in large concentrations: H·, H_2, H_2O_2, H_3O^+, ·OH, HO_2. In the presence of dissolved oxygen in the groundwater, the yield of H_2O_2 will increase and together with other oxidizing species may significantly increase the uniform and localized corrosion rates. Also, trapped air in the region of the container will form various oxides of nitrogen during irradiation which are likely to dissolve in water to form nitric acid, again leading to enhanced corrosion. These localized environmental conditions must, therefore, be fully addressed and correlated with container behavior.

When the container has been breached, the local environment will also affect the rate of release of radionuclides from the waste form.

As discussed in Chapter 3, it is not possible to predict the solubilities of radionuclides at elevated temperatures (150-300°C) with confidence. Most of the available radionuclide complexation stability constants have been obtained at temperatures below 50°C. Theoretical calculations and a limited amount of experimental data at elevated temperatures suggest that some of the actinides and rare earths in candidate waste forms exhibit negative temperature coefficients of solubility.

Waste elements that can have several oxidation states may exhibit lower solubilities under reducing conditions. The solubilities of monovalent elements generally will be independent of redox potential, unless the element forms complexes with ligands whose concentrations are Eh-dependent. The solubilities of elements which form aqueous hydroxyl or carbonate complexes and solid oxides, hydroxides and carbonates may exhibit a complicated dependence upon the pH of the solution. Appendix S discusses these phenomena in more detail in the context of a basalt repository environment.
The leaching behavior of waste glass and spent fuel is also dependent upon the environmental conditions described above (see discussion on waste form leaching in § 7.3.2.2 and Appendix Q). The relationship between temperature and leach rate of an individual radionuclide is element-specific and depends upon the solution chemistry, the formation of secondary phases and the thermal and radiation history of the waste form. Studies of the leach behavior of borosilicate glass in the presence of packing material, basalt and canister material suggest that synergistic effects in the waste package system could be as important as effects observed in simpler waste form-water systems. A nontrivial fraction of the radionuclides could be released from the waste package as radio-colloids or pseudocolloids. Radionuclides can be sorbed by or complexed with ferrosilicate and aluminosilicate colloids and complexes produced by degradation of the container and glass matrix. The radionuclide species produced by degradation of the waste form and the rates of radionuclide release from the waste package are dependent upon intensive physicochemical parameters of the system and as well as interactions between the system components.

Evaluation of BWIP Plan

Work elements discussed in Section 7.3.2.1 (pitting corrosion) address chemical conditions also. Comments on these work elements also apply to adequacy of BWIP Plan on chemical conditions.

7.3.4.2 Mechanical Conditions

Stresses arising from seismic and lithostatic/hydrostatic effects, and bentonite swelling pressures should be addressed in detail if uncertainties in the deformation of the container are to be assessed. The repository design assumptions indicate that the horizontal rock stress may be double the estimated lithostatic stress in the Umtanum layer. It is, therefore, necessary for similar in situ stresses to be measured at depth to determine the maximum anticipated stresses which could act on the BWIP container/packing material system. Thermally induced stresses and residual stresses must also be considered in design.

Swelling pressures in bentonite need to be evaluated under prototypic test conditions since values as high as 20-30 MPa have been measured in the laboratory (PNL-3873, 1981). An additional concern requiring investigation is the possibility that the swelling pressure is additive to the hydrostatic pressure (AESD-TME-3113, 1981). If this is the case, the design stress for the container may be exceeded.

Finally, there is considerable uncertainty regarding the magnitude of stresses from rock movements, and their impact on container failure. For granite, Pusch (1977) stated that downstream stresses could be exerted on container/bentonite/quartz sand systems due to rock movement along fault planes in granite. Containers lying across the fault plane could fail if they were not designed for the maximum shear loads. The packing material according to Pusch, could help alleviate the problem by acting as a deformable medium adjacent to the container. A detailed stress analysis is, therefore, necessary to determine whether the container will remain intact during rock movement along a plane intersecting the container. Such analyses will depend on identifying and validating the range of rock deflections possible in the emplacement holes throughout the repository.

Evaluation of BWIP Plan

There does not appear to be a detailed evaluation in the SCR of the anticipated stresses that will act on the BWIP container/packing material system.

Work Element W.1.2.A will determine conditions that affect design of waste packages, including thermal loading, mechanical loading, shipment, emplacement, retrieval, and after repository decommissioning. Without a full description of tests to determine the range of the mechanical loading on the waste package it is not possible to ascertain whether sufficient data will be obtained to bring this issue to closure.

7.4 NRC Conclusions and Comments

- The SCR should identify plans for reliability analyses of the waste packages, including reliability design objectives for each of the waste package components and other barrier components.

- Effects of pitting corrosion on the integrity of the carbon steel container should be determined. Work elements W.1.3.A, W.1.11.A, W.2.2.A and W.2.3.A should be carried out comprehensively and the container material including weldment should be exposed for long periods of time.

- Detailed plans should be identified for collecting data needed to understand the effect of groundwater residence time on waste form degradation rates and on transport rates.

- Although the SCR describes generally investigations of transport processes that may be adequate, we cannot comment on whether the investigations will yield the desired information because details are not given.

- Details of planned investigations of transport properties of the candidate packing materials (i.e., hydraulic conductivity, diffusion coefficients and radionuclide retardation factors) should be identified, including the measurement of hydraulic conductivity under isothermal conditions.

- Detailed plans to investigate changes in properties of the waste form with time should be identified; in addition because hydrothermal conditions may prevail after failure of containment, the rationale for expecting low rates of degradation for the borolilicate glass should be presented.

- The plan to collect data needed to estimate the rate of flow of groundwater through a failed container should be presented in detail.

- Detailed plans to develop the information needed to predict the changes in the chemical environment surrounding the waste package should be identified. The discussion of chemical changes in work elements W.1.3.A, W.1.11.A, W.2.2.A and W.2.3.A is too general for use to determine whether this subject will be addressed adequately.

- A comprehensive description of the program to collect information that will determine the mechanical loading of the waste package should be presented. This is needed to demonstrate that mechanical loading of the package is being properly addressed.

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8 SITE SELECTION AND ENVIRONMENTAL FACTORS

As noted in Chapter 1, new legislation has been enacted since DOE submitted the SCR on November 12, 1982. The legislation, entitled "Nuclear Waste Policy Act of 1982," has defined the scope of the site-selection process and the procedures DOE must follow in complying with the National Environmental Policy Act (NEPA). Under the Waste Act, the role of NRC in commenting upon DOE's site characterization plans is fully preserved insofar as it relates to any activity having potential radiological significance. However, the Act now specifies that site-selection and environmental factors (i.e., NEPA issues) are no longer a part of site characterization. Consequently, the staff feels that it would be inappropriate to comment on site-selection and environmental factors in its Site Characterization Analysis. Instead, the staff will voice its concerns through the mechanisms provided in the Act and briefly described in this chapter.

The Waste Act requires that DOE issue general guidelines for the selection of sites for repositories 180 days after the date of enactment of the Waste Act (January 7, 1983). These guidelines must be concurred in by the NRC. Using these guidelines, DOE must prepare an environmental assessment for each site that DOE determines to be suitable for site characterization. The environmental assessment shall include, among other things, (1) an evaluation by DOE as to whether the site is suitable for site characterization under the guidelines and (2) an evaluation by DOE as to whether the site is suitable for development as a repository under the guidelines that do not require site characterization as a prerequisite to their application.

The NRC intends to critically review the siting guidelines prior to concurring in them. ~~offering its concurrence~~. With regard to the environmental assessments prepared by DOE for each site, the NRC will provide DOE with written comments on the assessments ~~if that is~~ as necessary.

The Waste Act also requires that any environmental impact statement (EIS) prepared in connection with a repository proposed to be constructed by DOE shall, to the extent practicable, be adopted by NRC in connection with the issuance by NRC of a construction authorization and license for such repository (see Section 114(f)). Thus, when DOE prepares an EIS to support its recommendation to the President to approve a site for a repository, the NRC is required under Section 114(f) of the Act to adopt the EIS "to the extent practicable."

The NRC will adopt DOE's EIS only if it complies with NEPA and reaches the same conclusions that NRC would reach had NRC prepared the EIS. The NRC expects that the EIS will be built upon the environmental assessments prepared for each site selected for characterization. The staff's comments on these environmental assessments should forewarn DOE of any NRC concerns well before DOE prepares the EIS, but NRC will also be prepared to follow up, as needed, in comments on the draft EIS itself. Thus, NRC's continuous participation in the NEPA process should ensure that DOE will prepare an EIS that is consistent with the views of the NRC.

9 PERFORMANCE ASSESSMENT

9.1 General

The Executive Summary of the SCR states that current data from the BWIP site indicate groundwater travel times from a repository to the environment will exceed 10,000 years and that radionuclide releases to the environment will be within regulatory limits.

The SCR presents (Chapter 12) a discussion of the long-term repository performance issues identified by the DOE including groundwater flow paths and travel times, repository radionuclide release rates, and releases of radionuclides to the accessible environment. Chapter 12 describes the DOE's overall approach to long-term repository performance analysis: identification of release modes followed by analyses of release consequences using numerical models. The characteristics of these predictive models are described, including (1) the general mathematical models used to describe natural processes, (2) the specific numerical computer codes used to implement the mathematical models, and (3) the general verification, validation and benchmarking procedures appropriate for such codes.

Chapter 12 also presents the results of a number of preliminary performance assessments conducted for the BWIP site. These performance assessments suggest that the groundwater travel time from a repository to the environment is likely to exceed 10,000 years (SCR page 12.4-23), and indicate that releases of radionuclides to the environment are likely to be within anticipated regulatory constraints. This chapter states (pages 12.4-1) that "substantial interpolation and subjective judgment were required to prepare the model inputs," and therefore refers to these analyses as "in the category of performance assessment precursors." Section 12.4.5 discusses the uncertainties in the results of these preliminary analyses, and identifies some of the major contributors to uncertainties in flow path and travel time estimates.

Chapter 13 describes the plans for future site investigations, including studies (e.g., investigations of structures) which will help to refine the conceptual model of groundwater flow needed for specific groundwater and radionuclide transport analyses.

Chapter 16 discusses plans for additional performance assessment work including development and documentation of models and codes, verification and validation of codes, and additional performance analyses.

9.2 Conclusions and Assertions in the SCR

The major assertion of Chapter 12 (and one of the key conclusions of the Executive Summary) is that the groundwater travel time will substantially exceed the NRC's proposed minimum value, and that releases of radionuclides to the environment will be below likely regulatory constraints. As noted previously, Chapter 12 of the SCR recognizes that performance assessments to date are very preliminary and are based, in part, on subjective judgment in the absence of field data.

Chapters 13 and 16 assert that the plans identified are appropriate to resolve all outstanding performance assessment issues regarding the suitability of the BWIP site for disposal of high-level wastes.

9.3 Discussion of Critical Issues

The staff considers the assertions of Chapter 12 regarding groundwater travel time and radionuclide release rates to be unsupportable and presented without recognition of the many inherent uncertainties at the present level of knowledge. The main reasons for this concern are discussed in the following subsections: 11.3.1, 11.3.2, 11.3.3, 11.3.4 and 11.3.5.

9.3.1 Lack of Data

As noted in Section 12.4.5 of the SCR, there is not enough reliable data to permit assessment of repository performance at a reasonable level of confidence. In the absence of adequate data, subjective judgment is used. For at least one parameter--effective porosity of the basalt--the judgment is unsubstantiated and yields a nonconservative result in the estimation of groundwater travel time. On page 5.1-46 the SCR states that the single field test conducted to date indicated an effective porosity of basalt in the range of 1×10^{-2} to 1×10^{-4}. In the analysis of Chapter 12, an effective porosity value of about 10^{-2} was generally used. Since the groundwater travel time is proportional to the effective porosity, the use of the more conservative value of 1×10^{-4} would reduce the calculated groundwater travel times by about two orders of magnitude.

Other deficiencies in experimental data, including the critical vertical conductivity parameter, are discussed in Chapter 4 of this Draft SCR. Until more complete data are obtained by field testing, the results of groundwater flow and radionuclide transport calculations will be considered by the staff to be inconclusive and speculative.

Appendix D of this Draft SCA presents the results of a sensitivity analysis conducted by the staff for the BWIP site. In this analysis the staff used groundwater flow and radionuclide transport codes similar to the one-dimensional codes described in Chapter 12 of the SCR. Appendix D demonstrates the significance of data uncertainty on the analysis results, and provides some insights into appropriate areas for uncertainty reduction through field measurements.

9.3.2 Incomplete Conceptual Model

The SCR states (page 13.3-28) that "the Gable Mountain-Gable Butte structure is currently interpreted to have an effect on groundwater circulation within the

Pasco Basin, especially in providing a possible avenue of interconnection between the unconfined and the upper confined aquifer." However, the effects of this structure have apparently not been incorporated into the numerical groundwater codes used for the analyses of Chapter 12. Similarly, the SCR states on page 12.4-12 that "the two-dimensional analysis was basically an instructional exercise and the results are considered non-conservative." While the three-dimensional Rockwell analysis described in Section 12.4.1.2.1 is a step in the right direction, it is apparent that additional development of the conceptual model is needed. Additional deficiencies in the current conceptual model of the BWIP region are discussed in Chapter 4 of this SCA, in the Site Issue Analyses, and on page 12.4-52 of the SCR. Until the conceptual model has been adequately developed, and the numerical codes adapted to the conceptual model, groundwater flow analyses will remain inconclusive.

9.3.3 Lack of Code Validation

The SCR gives no indication that the computer codes used for the analyses of Chapter 12 have been validated for use at the BWIP. The staff considers code validation specifically for the BWIP site to be a critical step in demonstrating compliance with regulatory requirements for groundwater travel time and radionuclide releases. While the codes described in Chapter 12 appear to generally represent the state-of-the-art, it remains to be determined whether these codes provide an adequate representation of the physical processes occurring at the BWIP site and, particularly, whether the assumptions inherent in these codes are valid.

9.3.4 Incomplete Code Documentation

Despite the discussion of the site selection process presented in Chapter 2 of the SCR, it appears that the results of the groundwater travel time and radionuclide release analyses (described in Section 12.4 of the SCR) played a major role in selection of the BWIP site for characterization. Some of the computer codes used for these analyses (e.g., PORFLO) are not sufficiently well documented to allow an "independent evaluation" of the analyses as recommended by Section 2.5 of the NRC's Regulatory Guide 4.17. Until the documentation of a code is complete and available to the staff, the staff cannot evaluate the merits of that code and must consider the results of analyses using the code to be speculative and inconclusive.

9.3.5 Incomplete Scenario Set

The set of disruptive event scenarios listed on page 12.2-4 of the SCR does not include reasonable scenarios such as future groundwater pumping in the Pasco Basin or neighboring basins which could substantially alter the hydraulic gradient at the BWIP site. In view of increasing population trends and increasing pressure on water supplies of all kinds, groundwater pumping is probably the most likely of foreseeable disruptive events.

9.4 Evaluation of Site Characterization Plans

The plans presented in the SCR related to performance assessment are, in some cases, merely statements of goals rather than plans for achieving those goals. The "plans" for code validation are particularly deficient in this respect, and are essentially summarized in a single sentence from page 16.3-3: "Validation of the performance assessment codes will be performed on two-levels: (1) validation using data from laboratory experiments, and (2) validation with field data from the candidte siting area." There is no information in the SCR to indicate the types of experiments which are planned, the relevance of these experiments for code validation, or the areal extent over which field measurements will be taken. There is only a slight clue as to the time duration of the validation work (apparently no more than a few years for laboratory experiments and the period of site characterization for the field work). It is also unclear whether specific field experiments are planned for the purpose of code validation or whether field validation is essentially incidential to other data-gathering work during site characterization.

The SCR does not appear to present a definite plan for field testing of the appropriateness and completeness of the conceptual model of groundwater flow in the vicinity of the BWIP site.

Page 13.3-38 of the SCR states that "an iterative process exists between data collection and numerical modeling to assure that sufficient data are available for confidence in the modeling results." This process is not described further, and the site characterization plans do not explicitly include provisions for taking advantage of this process. There is also no indication of a plan or process for using collected data to validate or modify models and codes (except for the brief validation statement discussed above). It appears that this iterative process may not be serving its purpose since Chapter 12 of the SCR describes codes with a dual-porosity analysis capability, but the SCR does not appear to contain plans for obtaining the dual-porosity data required by such codes. If Work Element 5.1.5.A is intended to produce this data, the description of the Work Element should be modified appropriately.

9.5 Recommendations

(1) Because of the limitations described above, the conceptual groundwater flow model must be considered to be tentative, with alternative models as distinct possibilities.

(2) Any present estimates of groundwater travel times must be regarded as speculative and unreliable for use in developing site characterization test plans.

(3) Systematic plans should be developed for code validation. The staff considers validation to be a critical step in performance analyses which will have a major impact on the validity and acceptability of those analyses.

(4) An explicit plan should be developed to verify the conceptual model of groundwater flow.

(5) The iterative process between data collection and numerical modeling should be described in more detail, and plans for its use should be developed.

(6) Additional information on plans for estimating data uncertainties and for incorporating these uncertainties into performance assessments is needed.

10 QUALITY ASSURANCE PROGRAM

10.1 Introduction

10 CFR 60.11(a) identifies quality assurance (QA) as a key element of site characterization activities for a nuclear waste repository. An adequate QA program is necessary to assure confidence in the geologic and geotechnical data obtained during site characterization and to support potential licensing of the BWIP site.

10.2 Description and Evaluation of the Quality Assurance Program

Chapter 18 of the SCR addresses the 18 criteria of 10 CFR 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," as required by 10 CFR 60, Subpart G. The administrative procedures presented in the SCR are based on the 18 criteria of 10 CFR 50, Appendix B. Beyond this, however, it is necessary that detailed technical (i.e., implementing) procedures be developed for each technical area following the requirements spelled out in the administrative quality assurance procedures. These implementing procedures should contain instructions for actual performance of testing and investigations. In addition to providing a framework for an adequate QA program, DOE should also provide evidence of proper implementation of the program. In the description of site screening and site characterization activities in the SCR, a detailed description of the QA procedures in each program area is lacking (e.g., detailed QA program for the exploratory shaft is not provided). This is a major concern that will need attention. It is discussed in more detail in the following narrative.

10.2.1 Quality of Data

An important first question in conducting licensing assessments will relate to quality of data used in support of the license application for the proposed site and repository design. In addition to questioning relevance and completeness of data supplied in the license application, the licensing process must explicitly address the question of whether or not data is of adequate quality to make licensing determinations with reasonable confidence.

The quality of data is virtually determined by the specific data gathering methods and procedures that are used. It is important, therefore, that specific methods to be used in data gathering and site characterization program be the subject of the prelicensing consultation between DOE and NRC. The need to deal with the question of data gathering methods was identified very clearly in the Standard Format and Content Guide for site characterization (Section 1.3, Regulatory Guide 4.17). The need for these details to be addressed in the SCR is noted below.

10.2.2 Level of Detail of Plans and Procedures Needed

The SCR does not present adequate details regarding implementation of site characterization plans. A complex technical program needs to be based on a systematic approach to planning and controlling the program. The plans need to go from the general to the specific. Quality assurance needs to be applied at all levels. Figure 1 illustrates such an approach.

As shown in Figure 1, site characterization must start by considering EPA and NRC criteria. After a specific site is selected, specific issues are identified, based on these criteria and evaluation of repository performance.

The program can then be divided into program areas related to technical disciplines of investigations. These program areas then develop work plans which identify information needed to resolve issues in the site characterization program. From these work plans, "test plans" are developed to gather the needed information identified. These test plans identify the framework of how the testing will be accomplished. As part of the test plans, detailed test procedures and instructions are developed which describe in detail what the test involves.

The development of these test plans and test methods is an important element in providing quality assurance for site characterization data. Figure 2 illustrates the development and chronology of events in planning a testing program. This also shows the involvement of QA throughout the entire procedure.

In reviewing the SCR, the staff generally found that "test plans" and "test procedures" were not provided or referenced. The SCR stops at the "work plan" level. The information presented is very general and does not give the staff enough information to provide comments on detailed test plans. The staff expected this information to be at least referenced in the SCR. The staff recognizes that not all test plans and procedures may be needed at this point in time. However, some test plans (e.g., exploratory shaft phase I and phase II) are under way now and should be available for both technical and QA review. Each chapter of this DSCA includes comments on the level of detail~~ed~~ of the plans provided and gives examples of any deficiencies.

10.3 NRC Conclusions and Comments

The following is a summary of the major NRC conclusions and comments. Other comments on QA needs in each technical program area are provided in each individual chapter of the SCA.

(1) Documentation of Data Gathering Procedures. Many documents are referred to in the discussion of the QA program. These include: implementing functional-procedures manuals, BWIP procedures manual, Rockwell data package manual, and Rockwell functional manual. However, these are not listed as references at the end of the chapter. In fact, no BWIP document is referenced at the end of the QA chapter. In order to evaluate whether the QA program described in Chapter 18 is being implemented properly, all of these documents should have been identified as references in the QA chapter. Those that contain

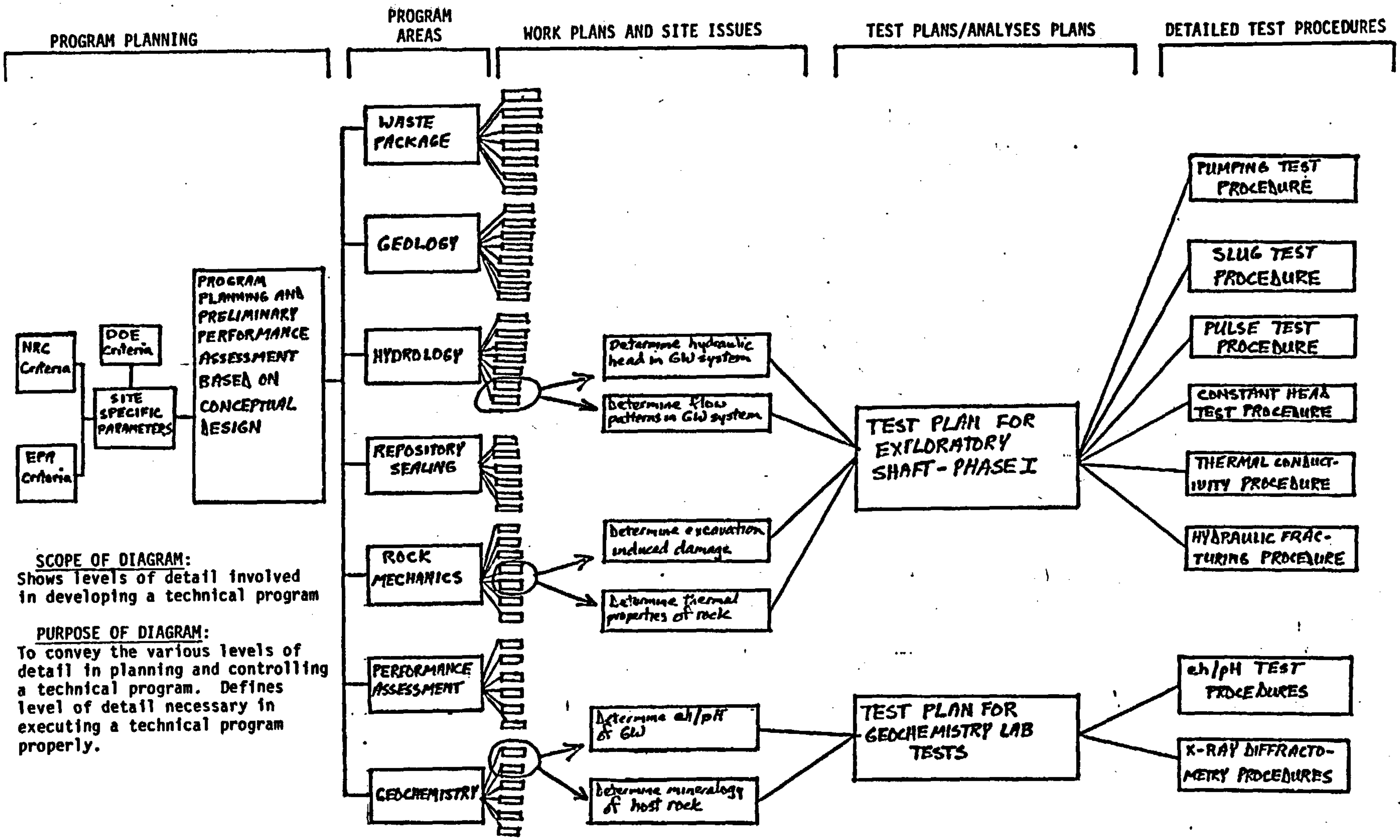
the technical procedures to be used during site characterization activities should also be made available for review.

(2) Test Plans for Major Test Programs. Section 18.11 of the SCR states that test plans are prepared for each major test program. However, few detailed test plans are referenced in the SCR for any of the major test programs mentioned. For example, the discussion of the exploratory shaft in Chapter 17 does not reference any detailed test plan. Since this activity is scheduled for January 1983, a detailed quality assurance program and test plan for the exploratory shaft (as mentioned on Page 14.3-73 of the SCR) should be available now. Further, few of the planned individual tests listed in the SCR provide any reference to test plans. Also, Regulatory Guide 4.17 requested a description of the quality assurance program to be applied to each planned test and a discussion of the limitations and uncertainty in the data. No such details are included in any of the plans listed in Chapters 13 through 16 of the SCR.

(3) Reliability Analyses in Design Control. Section 18.3 of the SCR should have addressed the methods to be used to quantitatively define the degree to which analytic methodologies should be validated for application to any particular time in repository history. Methods for reliability analyses, as well as requirements for establishing reliability design goals for components and systems, should have been identified, but are absent. Reference is made to DOE-RL Order 5700.2 and DOE Order 6430 which identify the process for design and planning. These documents contain requirements for the information to be presented in the conceptual design. The SCR does not contain reference to such information required by these documents.

In summary, the SCR is deficient in not providing or referencing enough detail on the QA methods to be used in each technical area for the staff to make an independent evaluation of the quality of data being gathered and to be gathered.

FIGURE 1: TECHNICAL PROGRAM CONTROL: TEST PLANS AND PROCEDURES (ILLUSTRATIVE)



SCOPE OF DIAGRAM:
Shows levels of detail involved in developing a technical program

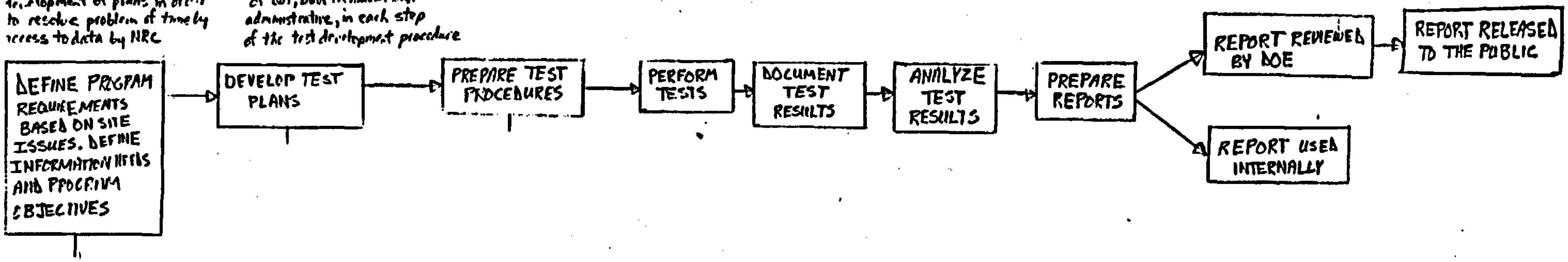
PURPOSE OF DIAGRAM:
To convey the various levels of detail in planning and controlling a technical program. Defines level of detail necessary in executing a technical program properly.

Comments	References to NRC Documents
The conceptual model proposed in the SCR does not adequately represent the nature of flow in the present groundwater system.	Chapter 3 Appendix K SIA 1.1, 1.1.7
The three-dimensional distribution of hydraulic parameters (vertical and horizontal conductivity, hydraulic heads, effective porosity, dispersivity, and matrix diffusion) is not known with sufficient accuracy or in sufficient detail to defend any single conceptual model.	Chapter 3 Appendix E, G, H, I, K SIA 1.1.1
Several critical hydraulic parameters (e.g., vertical hydraulic, conductivity, and matrix diffusion) have been measured in too few boreholes to form a reliable data base.	Chapter 3 Appendix K SIA 1.1.1.1
Several critical hydraulic parameters (e.g., horizontal hydraulic conductivity and hydraulic heads) are subject to large uncertainties due to experimental errors.	Chapter 3 Appendix G, I, K SIA 1.1.1.1
Continued, primary reliance on single-hole hydrologic testing will not develop an adequate data base of hydraulic parameter measures which reflect the effects of structural and stratigraphic heterogeneities on the bulk hydraulic characteristics of the present groundwater system.	Chapter 3, 4 Appendix E, K SIA 1.1, 1.1.1, 1.1.1.1
Interpolation of hydrogeologic parameters between points at which measured values exist is not feasible based on existing data, and the SCR does not include plans for such data integration and interpretation.	Chapter 3 Appendix H, K SIA 1.1.1.2
Groundwater recharge and discharge locations, mechanisms, and amounts are highly uncertain.	Appendix C SIA 1.1.2
The importance of vertical leakage has not been sufficiently evaluated as a major recharge-discharge mechanism.	Chapter 3 Appendix C SIA 1.1.2

FIGURE 2: TEST METHOD DEVELOPMENT (ILLUSTRATIVE)

SCOPE OF DIAGRAM:
Shows chronology of events in development of a testing program.

PURPOSE OF DIAGRAM:
1) Breakdown sequence of development of plans in order to resolve problem of timely access to data by NRC
2) To show the involvement of QA, both technical and administrative, in each step of the test development procedure



11 SUMMARY OF NRC COMMENTS

The following tabulates the critical comments of the NRC staff on the proposed site characterization program at Hanford as presented in the SCR. These are comments on (1) the adequacy of the identification and characterization of the issues (including the status of programs to resolve them) in the SCR and (2) the adequacy of future plans for resolving issues. This table summarizes comments presented in the preceding chapters, in appendices and in supporting SIAs prepared by the staff. The pertinent chapter or appendices is cited in each case as a guide to readers interested in complete development of the briefly stated comment. The comments, in specific technical areas, are presented in this chapter in the same order as in the body of the DSCA.

This tabulation essentially represents an agenda for future consultation between the NRC and DOE staffs intended to resolve the NRC staff comments on the proposed DOE program. In part, these concerns can be resolved through the periodic site characterization program updates that are called for by NRC regulation. However, it is expected that because of the complex nature of many of the technical matters, and the fact that the DOE program is ongoing, a sense of urgency exists for resolving many of the comments at an early time. Technical meetings between the NRC and DOE staffs, with opportunity for public and state involvement, similar to those held prior to issuance of the SCR (described in Chapter 1) will be required.

Comments	References to NRC Documents
Continued, primary reliance on single-hole hydrologic testing will not develop an adequate data base on vertical hydraulic conductivity.	Chapter 3 Appendix E, C SIA 1.1, 1.1.1, 1.1.1.1, 1.1.2
Recharge and discharge locations asserted for the Wanapum and Grande Ronde Basalts are not based on field measurements.	Appendix C SIA 1.1.2
Structural and stratigraphic discontinuities which may affect groundwater flow have not been characterized by state-of-the-art hydrogeologic tests.	Chapter 3, 4 Appendix E, H, K, L SIA 1.1.4, 1.1.5
The hydrochemistry of the groundwater systems of the Pasco Basin has not been integrated with hydraulic data to characterize flow systems.	Chapter 3 Appendix F, K SIA 1.1.6
The SCR does not address the issue of contamination due to mixing in open boreholes.	Chapter 3 Appendix F, K SIA 1.1.6
Carbon-14 model ages have not been corrected for the effects of methanogenesis.	Chapter 3 Appendix F, K SIA 1.1.6
Stable isotopic data for hydrogen and oxygen have not been integrated with paleohydrologic and paleoclimatological models in formulating interpretations.	Chapter 3 Appendix F, K SIA 1.1.6
Mathematical models of groundwater flow reported in the SCR are based only on a single conceptual model which does not adequately represent the nature of flow in the present groundwater system.	Chapter 3, ~~10~~ 9 Appendix K SIA 1.1.8
The code PORFLO has not been documented adequately.	Chapter 3, 9, 10
The level of confidence in preliminary travel-time calculations is too high.	Chapter 3, ~~10~~ 9
No quantitative sensitivity studies which show the effects of uncertainty in key parameters (e.g., vertical hydraulic conductivity) have been reported in the SCR.	Chapter 3, ~~10~~ 9 Appendix D

Comments	References to NRC Documents
The SCR does not include a full description of plans to determine the probabilities and consequences of natural changes which could affect groundwater flow.	Chapter ~~8~~ 10 Appendix C SIA 1.2, 1.2.1, 1.2.2, 1.2.3, 1.6
The SCR does not include a full description of plans to determine the probabilities and consequences of human-induced changes (excluding repository-induced changes) that could affect groundwater flow.	Chapter ~~8~~ 10 Appendix C SIA 1.3, 1.3.1, 1.3.2, 1.3.3, 1.3.4, 1.5
The SCR does not include a full description of plans to determine the probabilities and consequences of repository-induced changes that could affect groundwater flow.	Chapter ~~8~~ 10 Appendix C SIA 1.4

Chapter 4 Geology

Comments	References to NRC Documents
Can the geological and geophysical exploration program at the BWIP characterize the structural and stratigraphic discontinuities in the host rock?	Chapter 4 SIA 5.1, 5.2
What is the impact on the facility design?	Chapter 4 SIA 5.1, 5.2
What is the impact on facility constructibility?	Chapter 4 SIA 5.1, 5.2
What is the predictability of the thickness of the flowtop breccia in the Umtanum flow and the Sentinal Bluffs flow?	Chapter 4 SIA 5.2
Are the discontinuities pathways for the inflow of water into the underground facility? At present? In the future?	Chapter 4 SIA 5.1, 5.2
What is the effect of the presence of breccias within the dense interior of the Sentinal Bluffs flow (tiering) and in some places within the Umtanum flow?	Chapter 4
What is the consequence of the possible presence of inverted fanning joints through the dense interior (entablature) of the host flow?	Chapter 4 SIA 5.1
Investigations have apparently not reviewed data supporting primary thrusting and secondary folding in the region.	Chapter 4 SIA 5.1, 5.3.4
Investigations apparently have not given consideration to recent work by other investigators (WPPSS, FSAR, WNP-2; USNRC NUREG-0892).	Chapter 4 SIA 5.3.4
What is the consequence of the Pasco Basin being a seismically active area?	Chapter 4 SIA 5.3.4
There are no plans to determine the triggering mechanisms of the earthquake swarms that have occurred in the vicinity of the RRL.	Chapter 4 Appendix M, N, O SIA 5.3.1

Comments	References to NRC Documents
There are no plans to determine the nature of the structures (faults) on which earthquake swarms occur.	Chapter 4 Appendix N SIA 5.3.1
What is the probability of a major earthquake ($M_s \cong 6.5$) on the Rattlesnake-Wallula fault zone?	Chapter 4 SIA 5.3.1
What is the effect of seismic activity (RAW, Swarms) on the underground facility (seismic design) and on groundwater movement?	Chapter 4 Appendix M, N, O SIA 5.3.1
DOE's plans to resolve issues and concerns place excessive emphasis on redundant studies to those already completed.	Chapter 4
DOE may be placing too much reliance on geophysical investigations to define geologic structure in the Pasco Basin.	Chapter 4
No plans were presented to evaluate low density and high porosity zones in borehole DC-1 that may be open fractures or shear zones.	Chapter 4
DOE has concluded that volcanic activity in the Pasco Basin in the next 10,000 years is very unlikely. This conclusion is based on frequency studies. No consideration has been given to the causes of past volcanism. Studies should consider both causes and frequency of volcanic activity when considering the probability and nature of future volcanism in the Pasco Basin.	Appendix C SIA 5.3.2
DOE recognizes that renewed glaciation is a possibility if present cooling trends continue, however unlikely. DOE should use worst-case scenarios to estimate stress changes and their impact on the host flow in the RRL.	Appendix C SIA 5.3.3

Comments	References to NRC Documents
The redox conditions of the site through time have not been bounded even though they are important for understanding and predicting solubility speciation and sorption of radionuclides.	Appendix S
Eh (redox potential) may determine the oxidation state of radionuclides in groundwater and as a result their dominant species, their solubility, and their sorptive behavior.	Appendix S
Measured values of Eh (-0.22 to +0.21V for Grande Ronde water) may not be indicative of the actual redox potential of the aquifer.	Appendix S
There are thermodynamic limitations to measurements of Eh with the platinum ("inert" metal) electrode due to reactions of the electrode with dissolved substances in the water.	Appendix S
Measured Eh may be more dependent on the rate of reaction for a redox controlling reaction than on actual redox potential.	Appendix S
Concentrations of possible redox buffering substances in Grande Ronde water may be too low (generally less than 10^{-5} M total iron for example) to effedtively control Eh.	Appendix S
The calculation procedures used to obtain a theoretical estimate of groundwater Eh are based on invalid assumptions.	Appendix S
The assumption of (rapidly) reversible equilibrium between groundwater and the various mineral assemblages proposed as Eh buffers is not demonstrated.	Appendix S
The assumption of effective physical connection between minerals of the buffer assemblages and the groundwater is not demonstrated.	Appendix S
There is no information presented in the SCR to estimate the buffering capacity of the system (amounts of minerals of the buffering assemblage).	Appendix S

Comments	References to NRC Documents
It has not been demonstrated that the buffers chosen for calculation, developed for work at high temperature and shown to be operative for basalt magmas and in high-grade metamorphic terrains, are applicable to ambient (~ 60°C) or perturbed (< 300°C) condition for the repository.	Appendix S
Calculated oxygen fugacities of 10^{-68} to 10^{-37} are unrealistic.	Appendix S
Radionuclide sorption on solid phases of the backfill and along the groundwater flow path is an important retardation mechanism which must be quantified in order to characterize the site.	Appendix T
The majority of the radionuclide sorption experiments, both K_d measurements and isotherm determinations, have employed the batch method. This method, where a batch of substrata is reacted with a solution containing the radionuclide of interest, has several problems that have not been adequately addressed by DOE.	Appendix T
The grain surfaces produced by fire grinding are much different than those expected in either the backfill or the far field.	Appendix T
The rock:water ratio affects measured K_d but the effect has not been considered in the SCR. Most of the experimental results presented in the SCR are for oxidizing conditions. It is not clear how these can be applied to the reducing conditions predicted for the repository.	Appendix T
The experimental results presented in the SCR are for single radionuclides. It is not clear how competition for sorption rates due to preferential sorption and other synergistic effects is being considered.	Appendix T
It is not clear that sorption data obtained on groundup materials can be used to describe the interaction of radionuclides and fracture fillings such as those illustrated in SCR Figure 6.9.	Appendix T
The large variability of the K_d values presented in the SCR leaves some question as to their validity.	Appendix T

Comments	References to NRC Documents
Are some of the extreme values "tiers" that can be explained by reference to the experimental technique or other variables, such as exceeding the solubility limit?	Appendix T
Can the variability of the results be used as an indication of the value of the results?	Appendix T
What is the statistical distribution of the measured results?	Appendix T
The groundwater chemistry does not seem to be well enough defined for the entire groundwater pathway to the accessible environment to use as input to sorption experiments.	Appendix T
Sorption is dependent on the groundwater species present and available to complex with released radionuclides.	Appendix T
Mineralogical changes due to heat generated by the repository may enhance (formation of smectite from basalt glass) or impair (formation of illite from smectite) sorption.	Appendix T
The availability of potassium as the result of dissolution of basaltic glass has been inadequately evaluated since potassium release would promote formation of illite and reduce sorptive capacity along the flow path.	Appendix T
The changes predicted in the SCR, dehydration under reduced water pressure, and hydration under later saturated conditions, are unlikely and not supported by the experiments cited.	Appendix T
There is no indication of how the SCR analysis determined whether an isotherm was nonlinear since the data used for the analysis were not presented and the errors associated with the various isotherm parameters were not given.	Appendix T
There is no indication in the SCR that the reversibility of the sorption reactions has been demonstrated.	Appendix T

Comments	References to NRC Documents
The effect of hydrazine on the sorption of various radionuclides is assumed to be nil but no experiments have been performed to verify this assumption.	Appendix T
The effects due to variation of ionic strength as the result of dissolution of the waste form, backfill, or host rock/fracture filling minerals have not been considered but could have a significant effect on sorption.	Appendix T
The effects on sorption of any tendencies of the waste radionuclide to polymerize and/or form colloids has not been considered.	Appendix T
Solubility is an important property of radionuclides because it can be quantified (or at least bounded) and values can be compared with safety standards to indicate favorable (i.e., limiting the amount of nuclides into solution) or adverse (i.e., virtually all waste released enters groundwater as dissolved species) repository conditions.	Appendix U
The relationship between actinide solubilities at BWIP and the maximum permissible concentrations (MPCs) proposed by the NRC is misrepresented in the SCR: "Based on solubility, the maximum possible release rates for all the radionuclides considered will be below the NRC 10^{-5} proposed release criterion (NRC, 1982) and the draft cumulative release criterion (EPA, 1981)" (SCR, 1982).	Appendix U
Based on currently available thermodynamic data of Allard (1982) and MINEQL data (Table 5), we find that the concentrations of uranium, neptunium, americium, and plutonium will exceed the maximum permissible concentration limits (MPC) by several orders of magnitude under anticipated ranges of basalt repository Eh-pH and groundwater compositions. It appears that carbonate complexation and to a lesser extent fluoride and sulfate complexation in BWIP groundwater greatly increase the solubilities of these four actinides. Therefore, the SCR is not justified in ignoring the effects of common groundwater ligands on actinide solubility.	Appendix U
In reaching the above conclusion, BWIP has made several assumptions that are extremely tentative. These include the following:	Appendix U
Oxide phases are phases that will precipitate under repository conditions.	Appendix U

Comments	References to NRC Documents
Significant concentration increases due to complex or colloid formation are not considered.	Appendix U
Crystalline solids control solubility.	Appendix U
Effect of presence of common inorganic ligands found in BWIP groundwaters under expected range of repository Eh-pH and temperature are not considered.	Appendix U
Potential for actinide complexation with organic ligands is not considered.	Appendix U
Whereas a nonconservative assumption, if it can be justified, may enter into an approximation, a significant conclusion should not be based entirely on unsupported assumptions.	Appendix U
Until the uncertainties associated with the above assumptions are significantly reduced, little confidence can be placed in the preliminary RHO quantitative assessment that solubilities of certain radionuclide species might be sufficient to demonstrate satisfaction of the EPA standard for those nuclides.	Appendix U
Several assertions are made for which no support or inadequate support is provided by the SCR.	Appendix U
It is not likely that silica is the only control of pH since calcium carbonate is saturated.	Appendix U
The evidence presented in the SCR does not preclude vertical mixing of groundwater.	Appendix U
No coherent effort is being made to use the baseline information which must be gathered during characterization of the prevailing in situ geochemical conditions as a "natural experiment" on the long-term effects of low temperature hydrothermal alteration of basalt by groundwater.	Appendix U

Comments	References to NRC Documents
The following statements from p. 6.1-15 of the SCR are contradictory and do not support DOE's contention that they have "established the prevailing geochemical conditions for the candidate repository horizons" through time. "It has been experimentally demonstrated that this glass is the most reactive basaltic phase with groundwater at low-temperature (less than 300°C) hydrothermal conditions. Preliminary analysis of in situ hydrochemistry, as well as laboratory tests, confirm that hydrolysis and dissolution of silicate glass minerals act to buffer pH (Barnes and Scheetz, 1979) and Eh (Jacobs and Apted, 1981).... The mechanism for the control of solution compositional parameters through hydrothermal reaction of the glass phase has not been confirmed by direct experimentation."	Appendix U
The origin of the fluoride in the groundwater of the Grande Ronde has not been determined even though it is a potential radionuclide complexant. If its source is dissolution of basalt glass, a process that is accelerated at temperatures higher than ambient, increased fluoride contents and hence increased radionuclide transport could result due to waste generated heat.	Appendix U
The stability of montmorillonite (smectite) and smectites in general has not been adequately defined.	Appendix U
The possible effect of release of potassium from basalt glass has not been evaluated.	Appendix U
The thermal properties cited by DOE in the SCR conflict and should be investigated to resolve the conflict.	Appendix U
The DOE natural analog program is skeletal and does not address real situations that will help understand the behavior of a repository in basalt over long periods of time.	Appendix U
It is not clear how much emphasis DOE puts on particulate transport at the BWIP site.	Appendix U
The SCR does not evaluate the possible role of polymers or colloids in transporting radionuclides.	Appendix U

Comments	References to NRC Documents
Inadequate treatment is given to radiolysis and the possible effects that radiolysis products could have on radionuclide transport.	Appendix U
The statement that the basalt groundwater and geochemical environment is benign is not adequately supported by the data presented in the SCR.	Appendix U
There are contradictory statements made about the necessity for a waste package.	Appendix U

Comments	References to NRC Documents
Evaluate stable opening requirements.	Chapter 4, 6 SIA 4.2.2, 4.2.3, 4.2.4 Appendix V
Evaluate which parameters are important.	Chapter 4, 6 SIA 4.2.2, 4.2.3, 4.2.4 Appendix V
Define acceptable methods of evaluation.	Chapter 4, 6 SIA 4.2.2, 4.2.3, 4.2.4 Appendix V
Define failure criteria.	Chapter 4, 6 SIA 4.2.2, 4.2.3, 4.2.4 Appendix V
Determine the role of engineered backfill performance.	Chapter 6 SIA Appendix W
Evaluate construction constraints.	Chapter 6 SIA Appendix W
Evaluate alternative materials.	Chapter 6 SIA Appendix W
Evaluate characteristics of backfill placed by pneumatic methods in log horizontal boreholes.	Chapter 6 SIA Appendix W

Comments	References to NRC Documents
Review results of sealing performance assessment.	Chapter 6 SIA 4.5.1, 4.5.2
Review preliminary sealing criteria based on performance assessment.	Chapter 6 SIA 4.5.1, 4.5.2
Compare with industry standards.	Chapter 6 SIA 4.5.1, 4.5.2
Review proposed lab and field testing.	Chapter 6 SIA 4.5.1, 4.5.2
Evaluate retrieval options and construction problems.	SIA 4.1.2 Appendix X
Evaluate constructibility problems with horizontal emplacement holes.	SIA 4.1.2 Appendix X
Evaluate support problems in small diameter horizontal holes.	SIA 4.1.2 Appendix X
Evaluate backfill placement problems and quality control.	SIA 4.1.2 Appendix X
Evaluate ongoing thermal and geomechanical test plans.	Chapter 6 Appendix Y
Evaluate exploratory shaft construction and QA procedures.	Chapter 6 Appendix Y

Chapter 7 Waste Package

Comments	References to NRC Documents
A reliability program to demonstrate satisfaction of NRC performance criteria.	
Features of a good reliability program are as follows:	
Systematic and continuous effect in all program activities to:	
Search for system failures and their corrections.	Chapter 9 All SIA 2's, especially SIA 2.1, 2.4, 2.7, 2.20
Remove or minimize detrimental environmental conditions.	Chapter 7 All SIA 2's, especially 2.3, 2.9, 2.18, 2.21
Generate realistic specification ~~of~~ to guide designers.	Chapter 7
Generate realistic simulation of environmental conditions during reliability tests.	Chapter 7
Carry out established plans to complete predetermined number of tests to establish the reliability of the system.	Chapter 7
Guarantee quality of information obtained throughout the reliability program through a quality assurance program.	Chapter 10

Chapter 10 Quality Assurance Program

Comments	References to NRC Documents
A test plan for each testing program should be documented and reviewed for completeness by an independent peer review team. These test plans should include state-of-the-art geotechnical tests which are clearly documented and approved by a peer review panel of independent experts. The limitations and uncertainty associated with each test plan should be clearly stated.	Chapter 10
A complete QA reference list should be assembled and the documents which take precedence should be clearly identified.	Chapter 10
Methods for reliability analyses should be identified. Implementation of the requirements of DOE-RL Order 5700.2 and DOE Order 6430 involving design control should be identified and documented.	Chapter 10
The effectiveness of the QA program should be addressed in detail. Revisions to the program which were implemented to increase effectiveness should be discussed.	Chapter 10

APPENDIX A

Maps and Sections of Hanford Reservation

All figures from Hanford Site Characterization Report

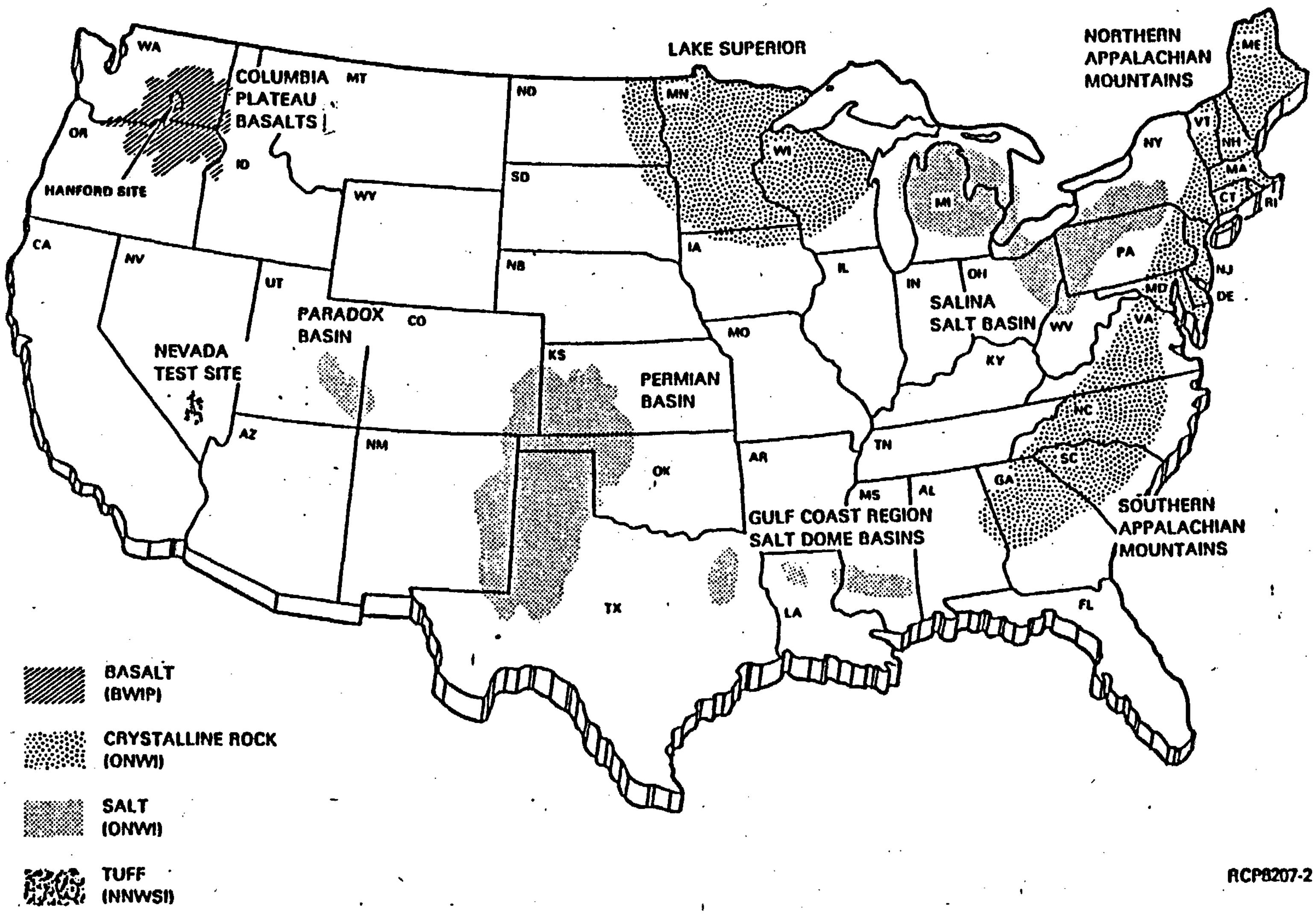
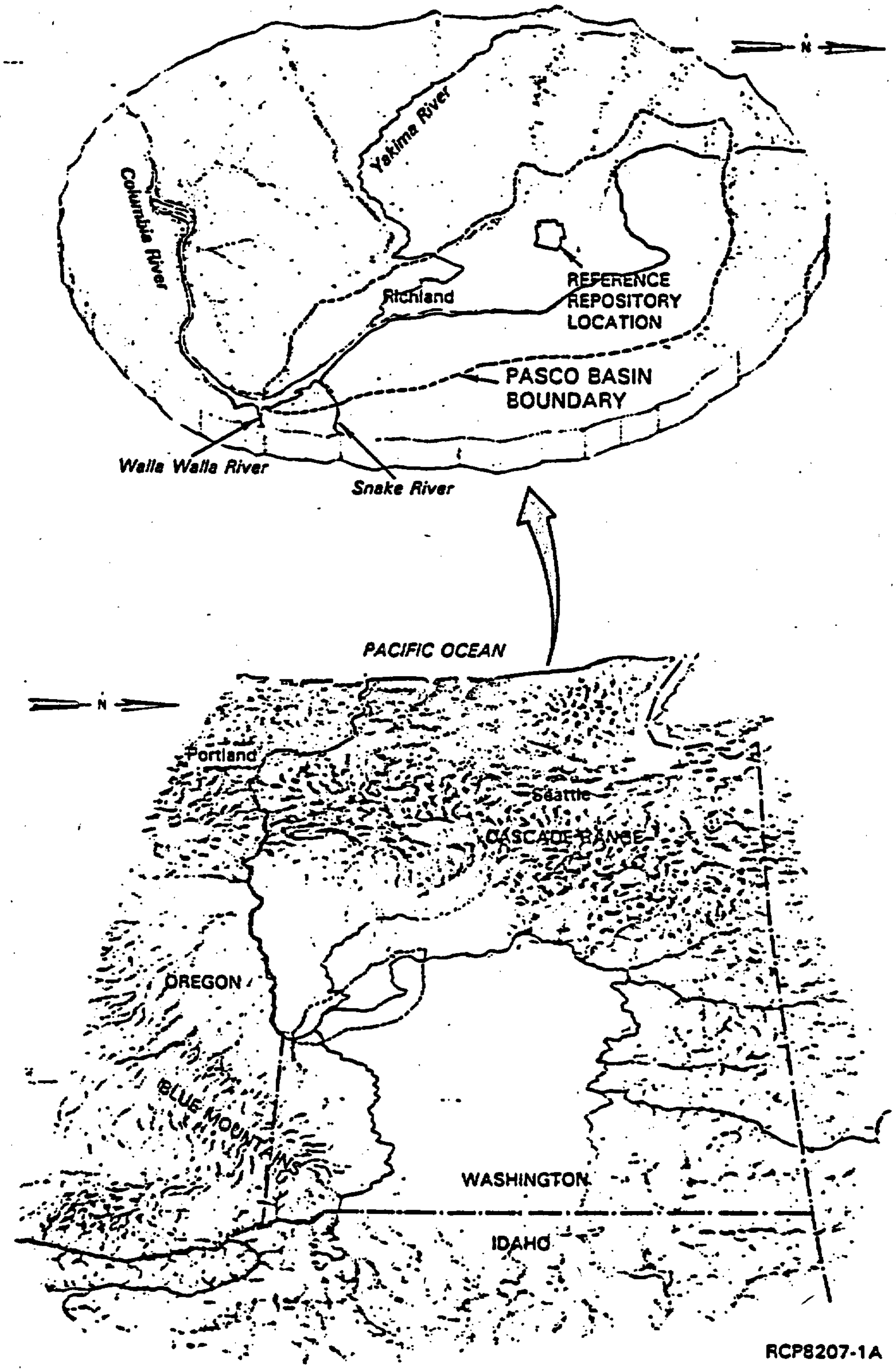


Figure A-1

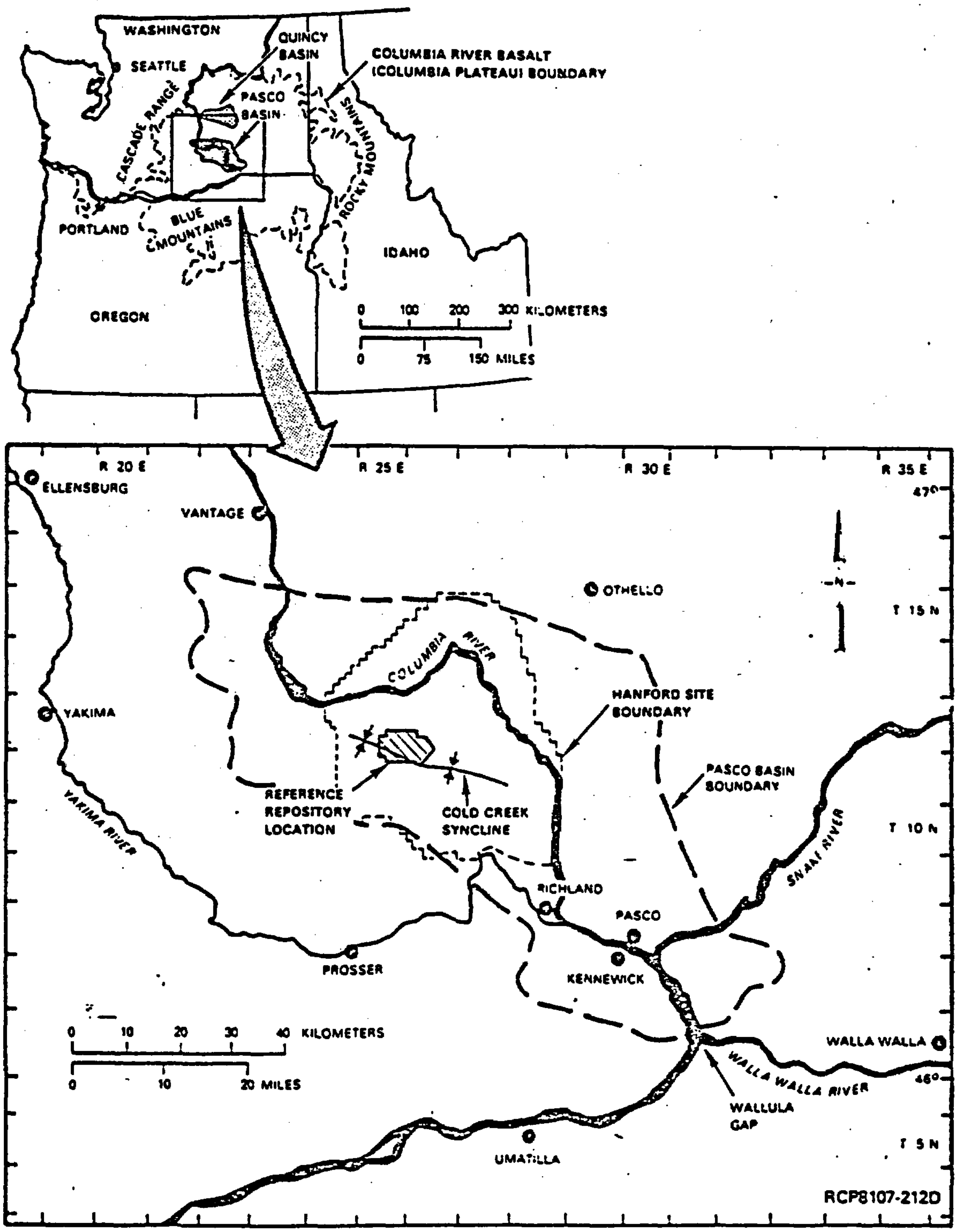
Regions That are Being Considered for Geologic Disposal of Radioactive Waste.

Figure A-2

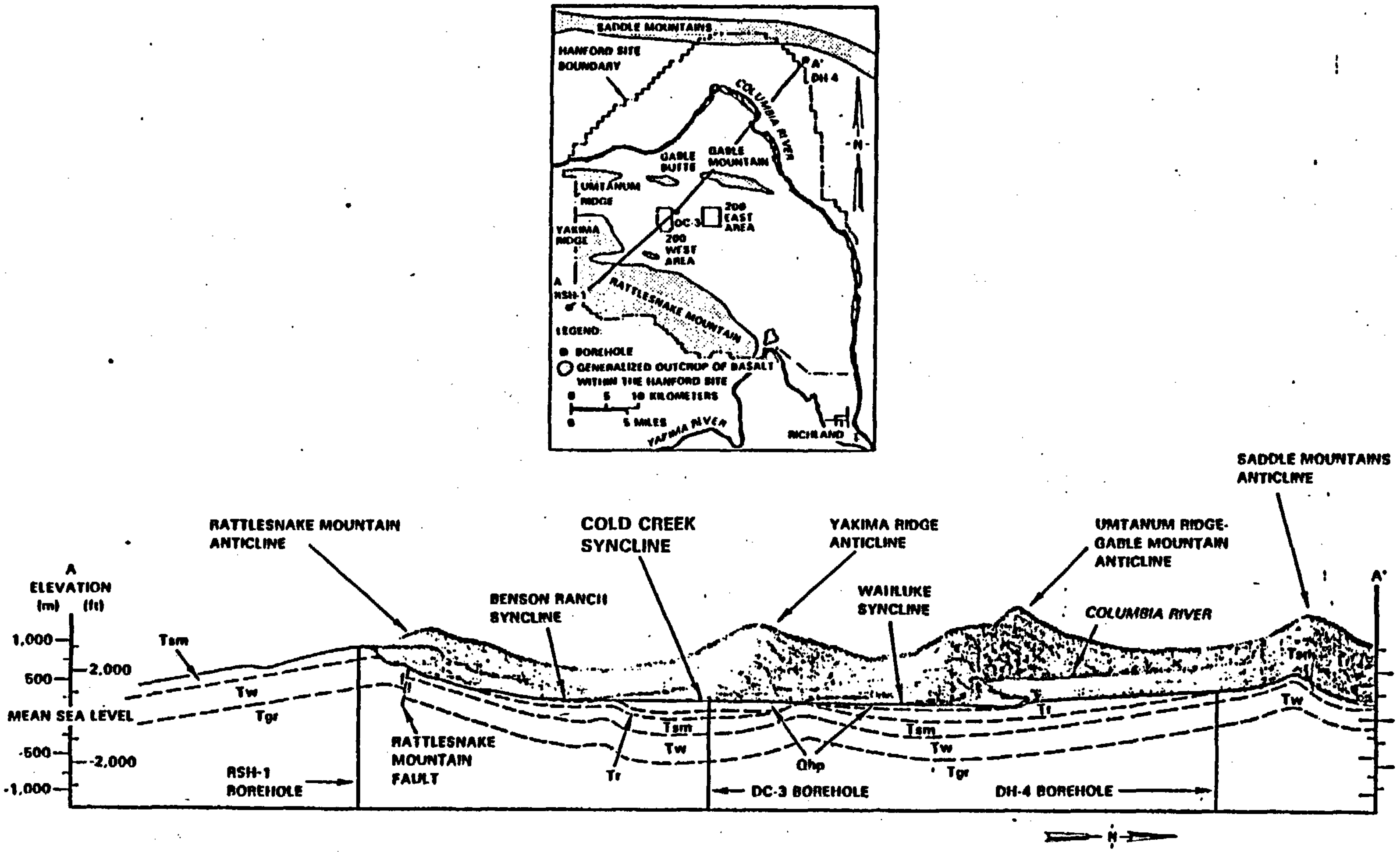


Location (in perspective) of the Pasco Basin and Hanford Site, Washington State.

Figure A-3



Location of the Columbia Plateau, Hanford Site, Cold Creek Syncline, and Reference Repository Location.



Qhp = HANFORD FORMATION - PASCO GRAVELS
Tr = RINGOLD FORMATION
Tsm = SADDLE MOUNTAINS BASALT
Tw = WANAPUM BASALT
Tgr = GRANDE RONDE BASALT

NOTE: ONLY THE BORINGS ALONG THE SECTION ARE SHOWN. GEOLOGY IS PROJECTED FROM OTHER BORINGS.

VERTICAL EXAGGERATION - 4.2X

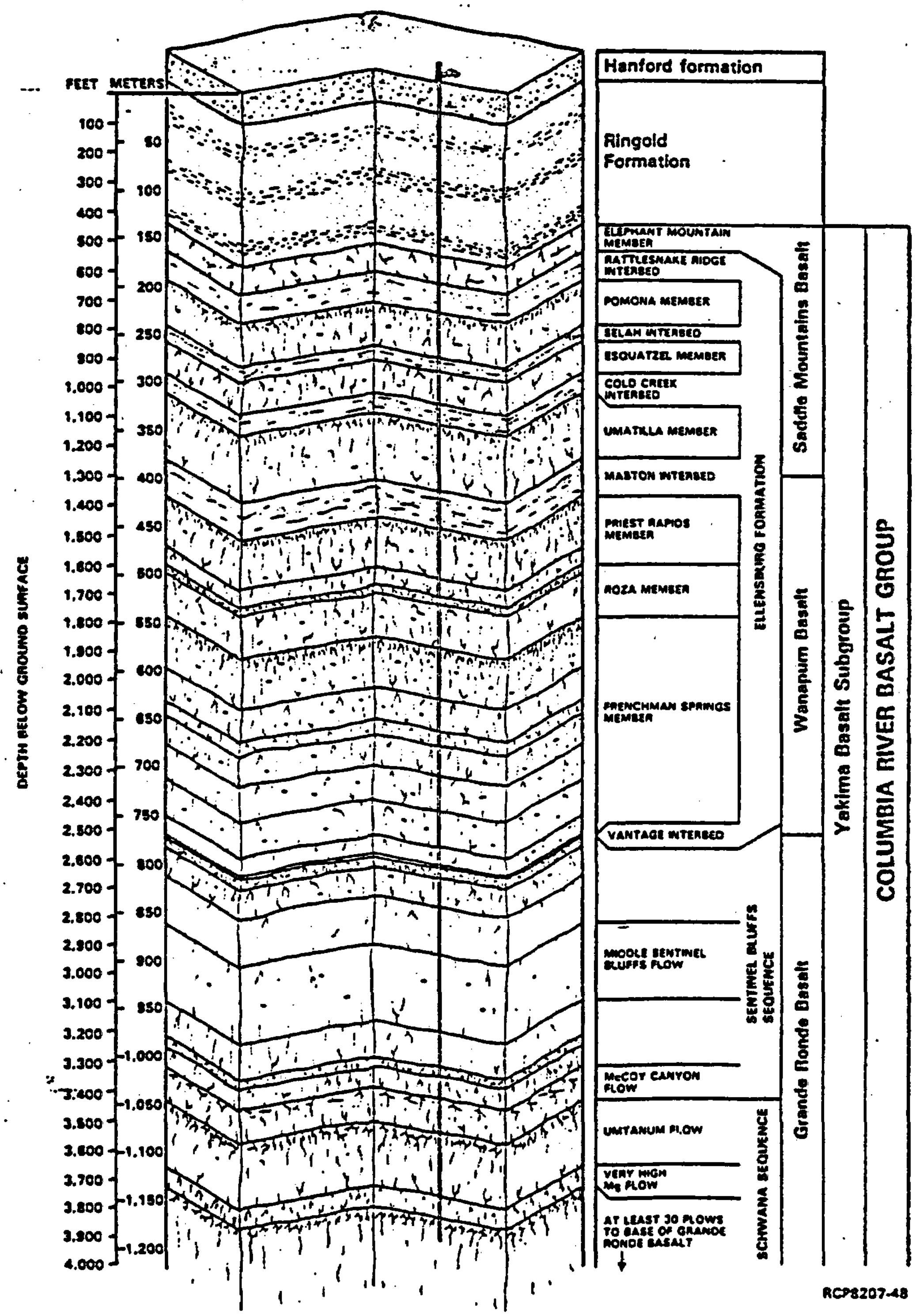
0 5 10 KILOMETERS
0 5 MILES

RCP8207-6A

Figure A-4

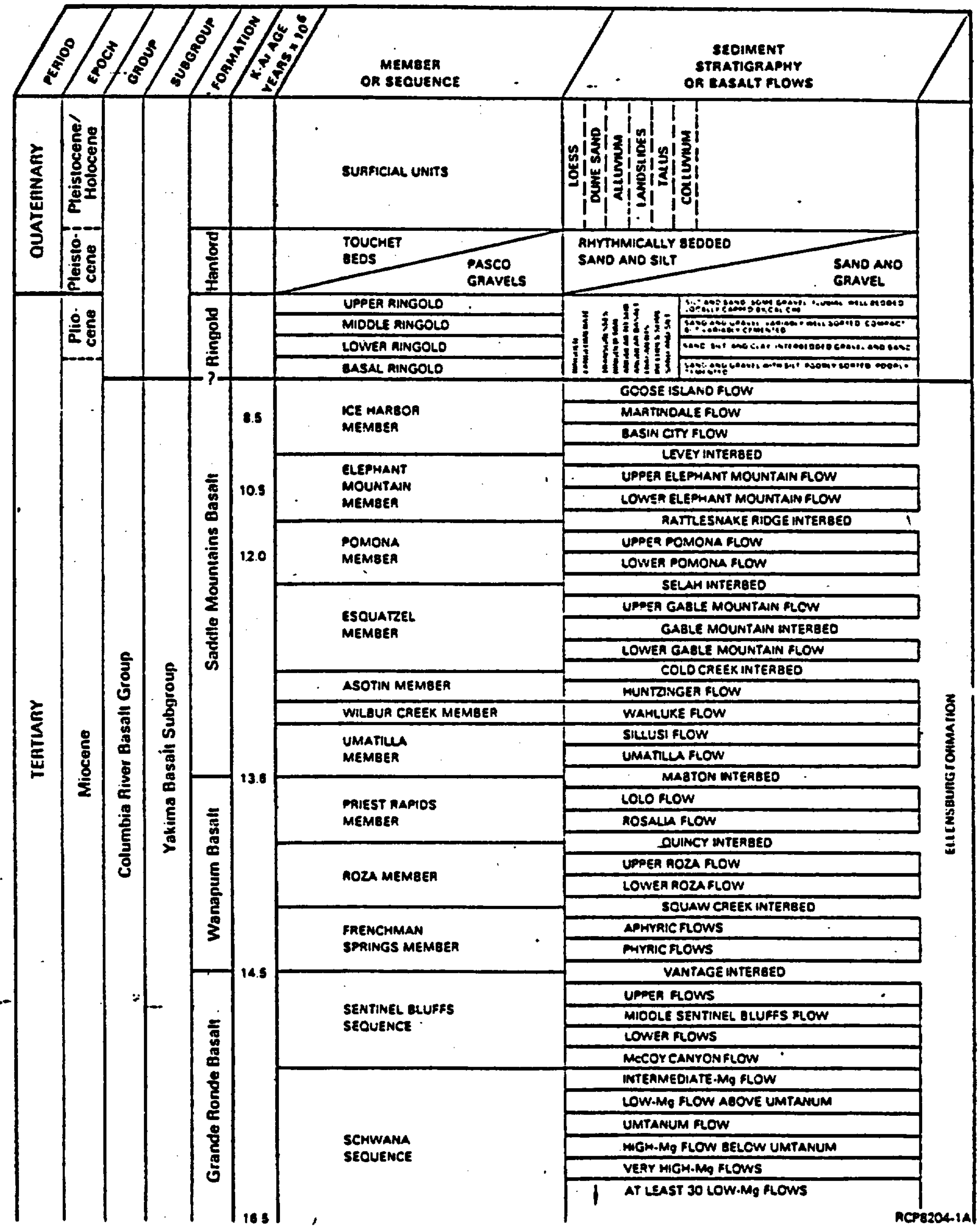
Generalized Cross Section Through the Pasco Basin.

Figure A-5



Stratigraphy of the Columbia River Basalt Group, Yakima Basalt Subgroup, and Intercalated and Suprabasalt Sediments Within the Pasco Basin.

Figure A-6



Stratigraphic Nomenclature, Pasco Basin, Cold Creek Syncline.

A-7

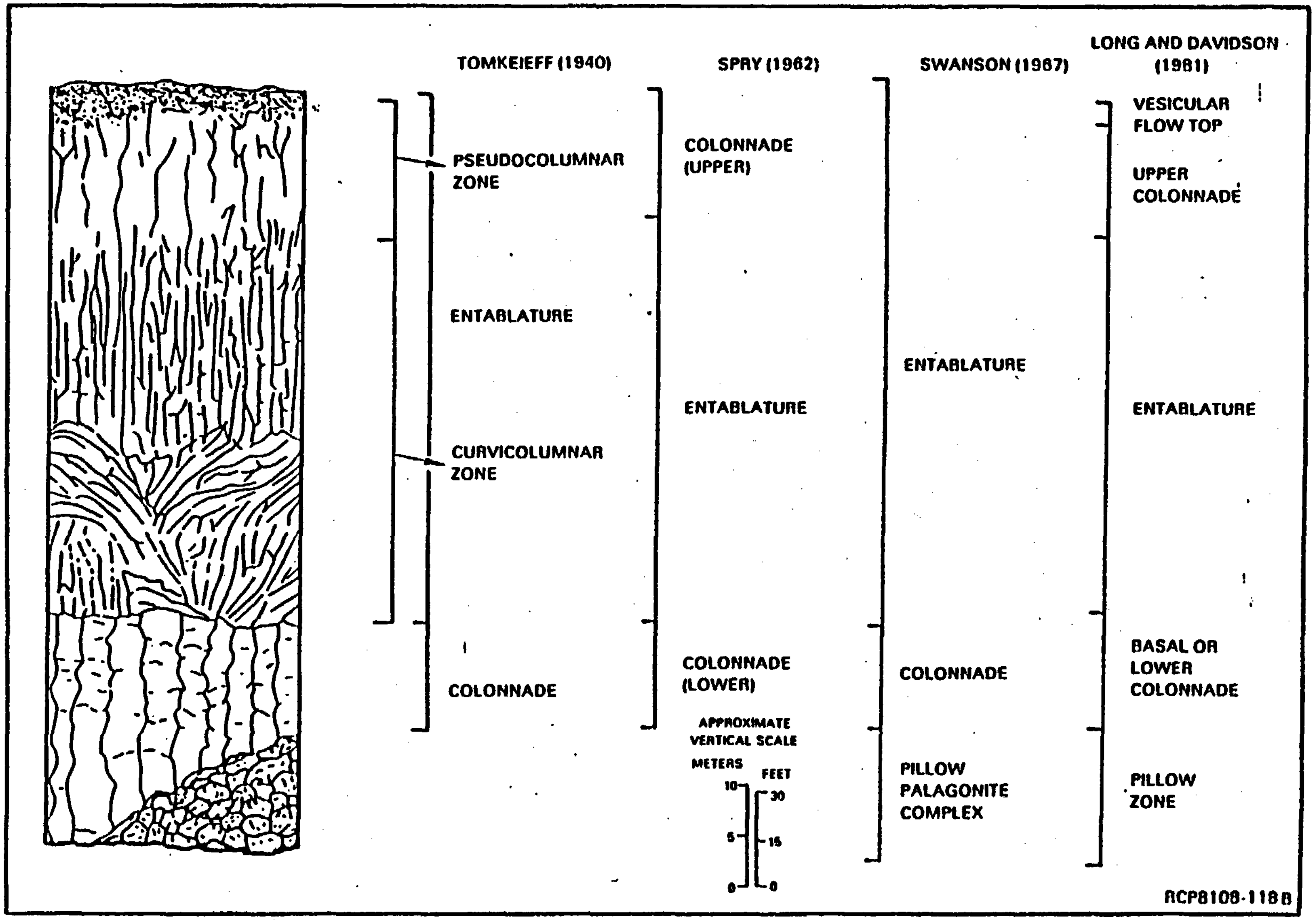
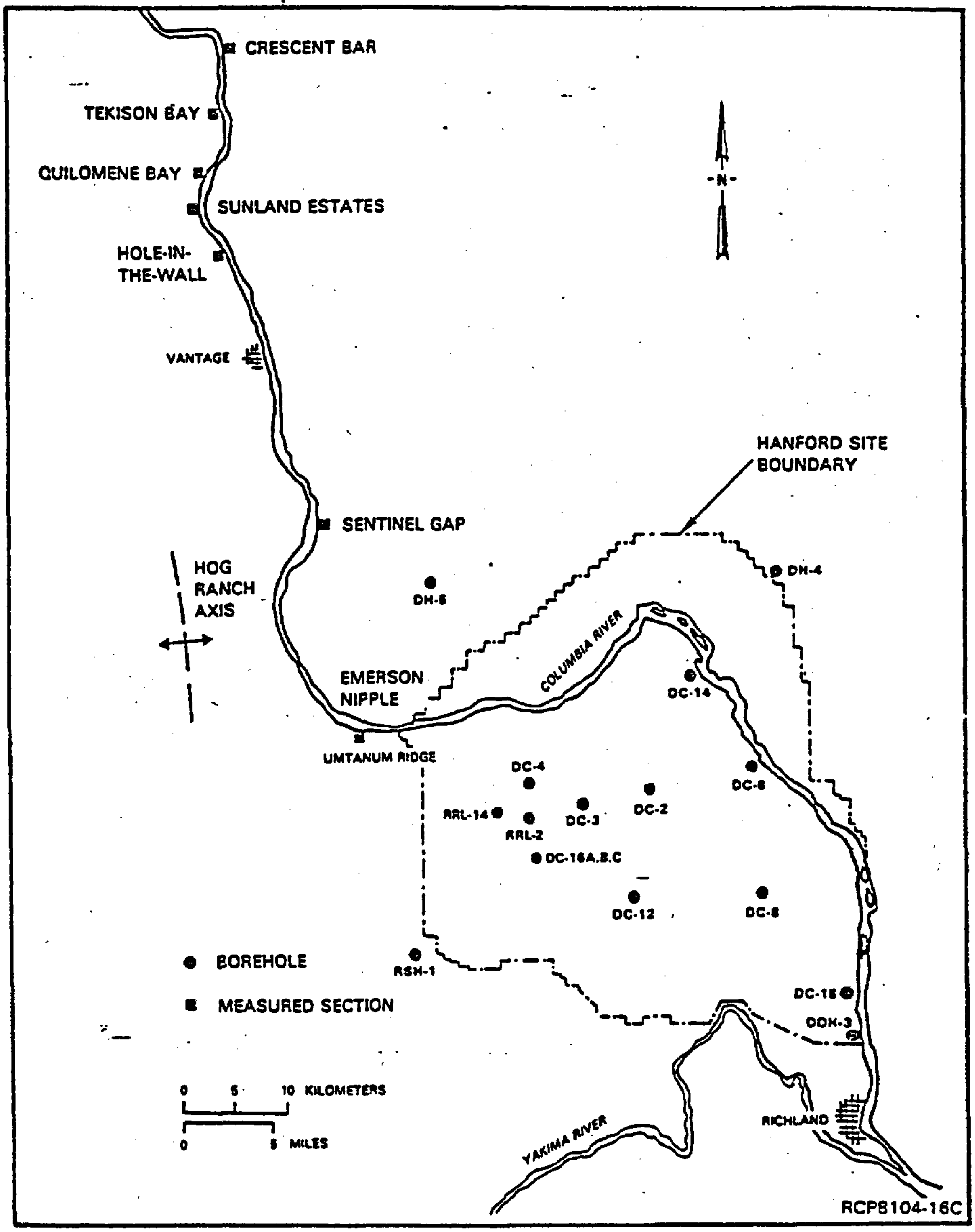


Figure A-7

Typical Intraflow Structures Present in a Grande Ronde Basalt Flow. Nomenclature used in various studies is compared.

Figure A-8



Location Map, Pasco Basin and Surrounding Areas (showing location of boreholes penetrating the candidate repository horizons and geologic sections).

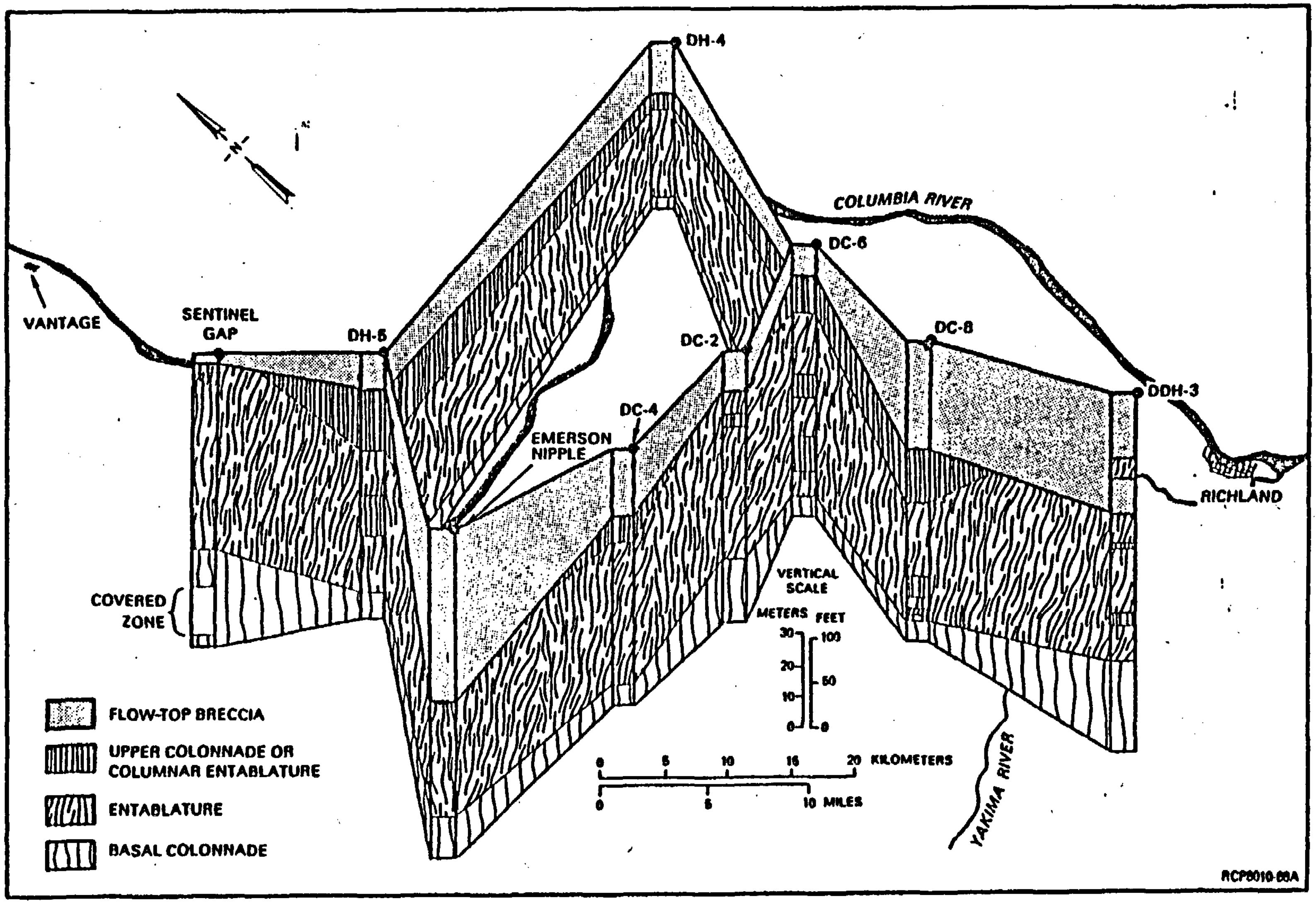


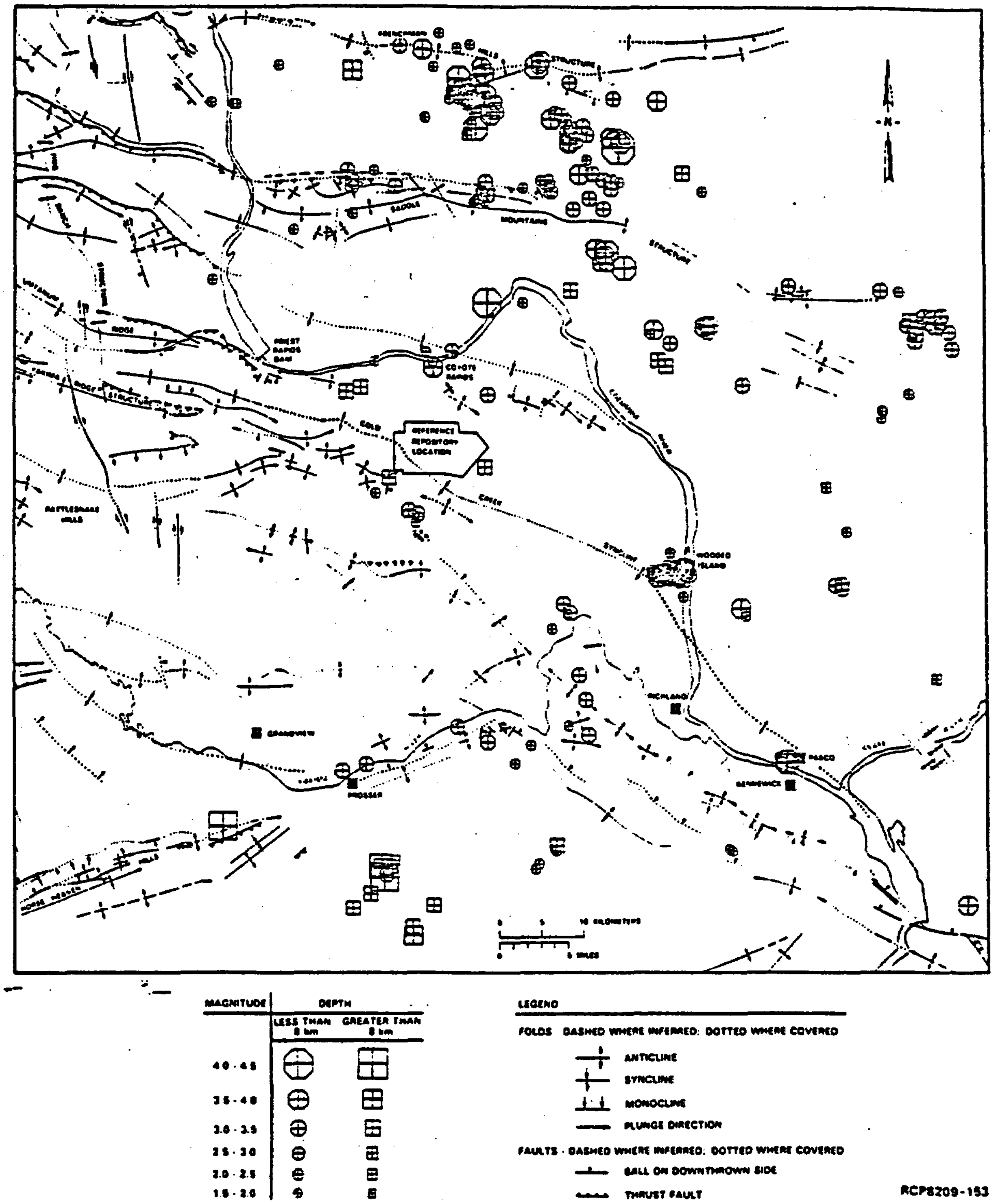
Figure A-9

Fence Diagram, Umtanum Flow. This figure is an illustration of the lateral variation of internal structures of the flow in subsurface borings and surface exposures. (See Fig. 3-18 for location.)

A-10

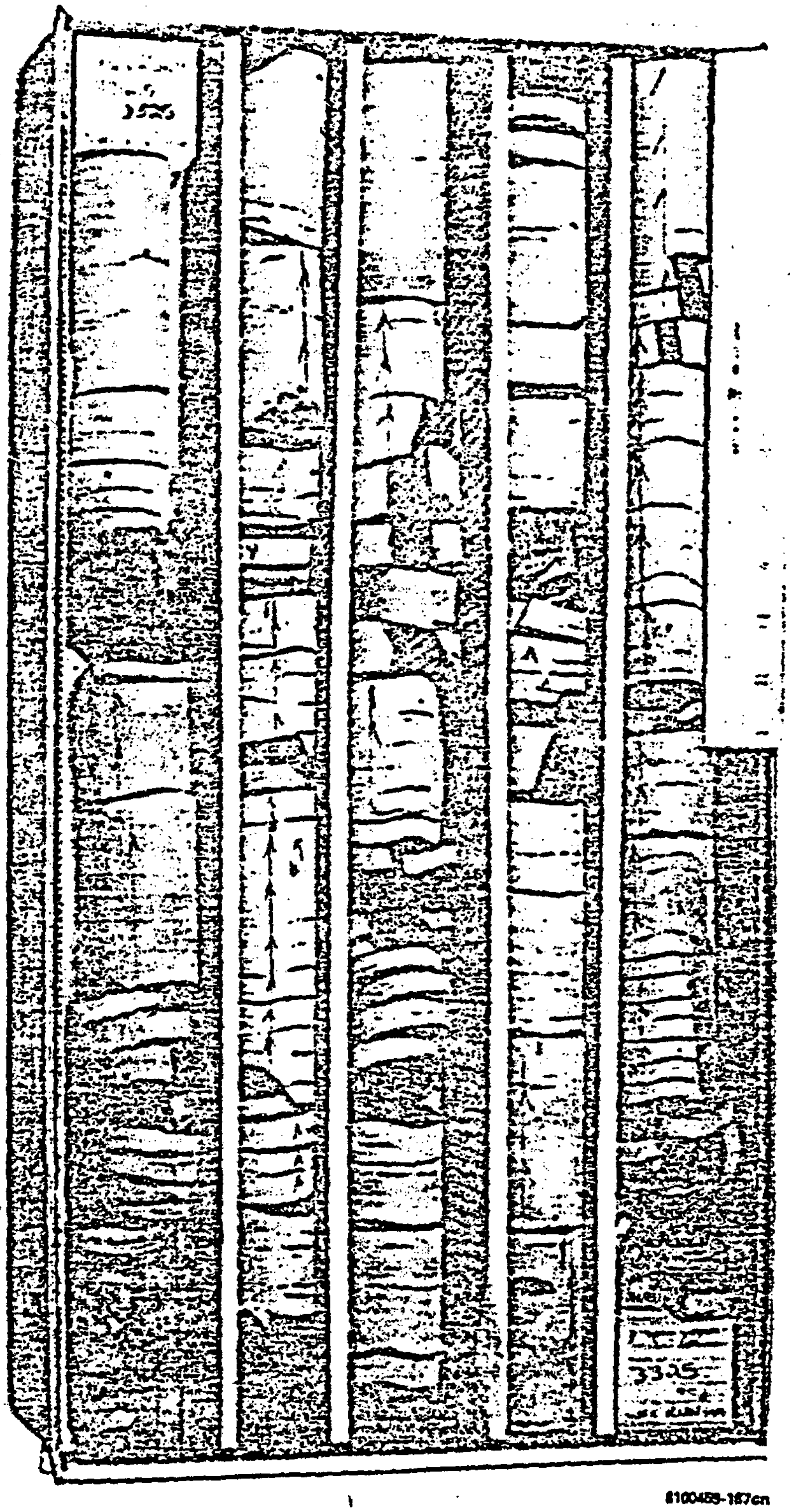
Figure A-10 Interpretive Bedrock-Structure Map. Areas I through V are plan views of large, relatively intact volumes of bedrock with boundaries defined by known and inferred structures as shown. Areas Ia through Ig are subdivisions of Area I, also based on known and inferred structures.

Figure A-11



Instrumental Seismicity of the Pasco Basin. The largest events are concentrated near the Saddle Mountains and Frenchman Hills.

Figure A-12



Basalt Core Recovered from Borehole DC-12 at Test Depth Between 1,011 and 1,014 Meters (3,317 and 3,325 feet).

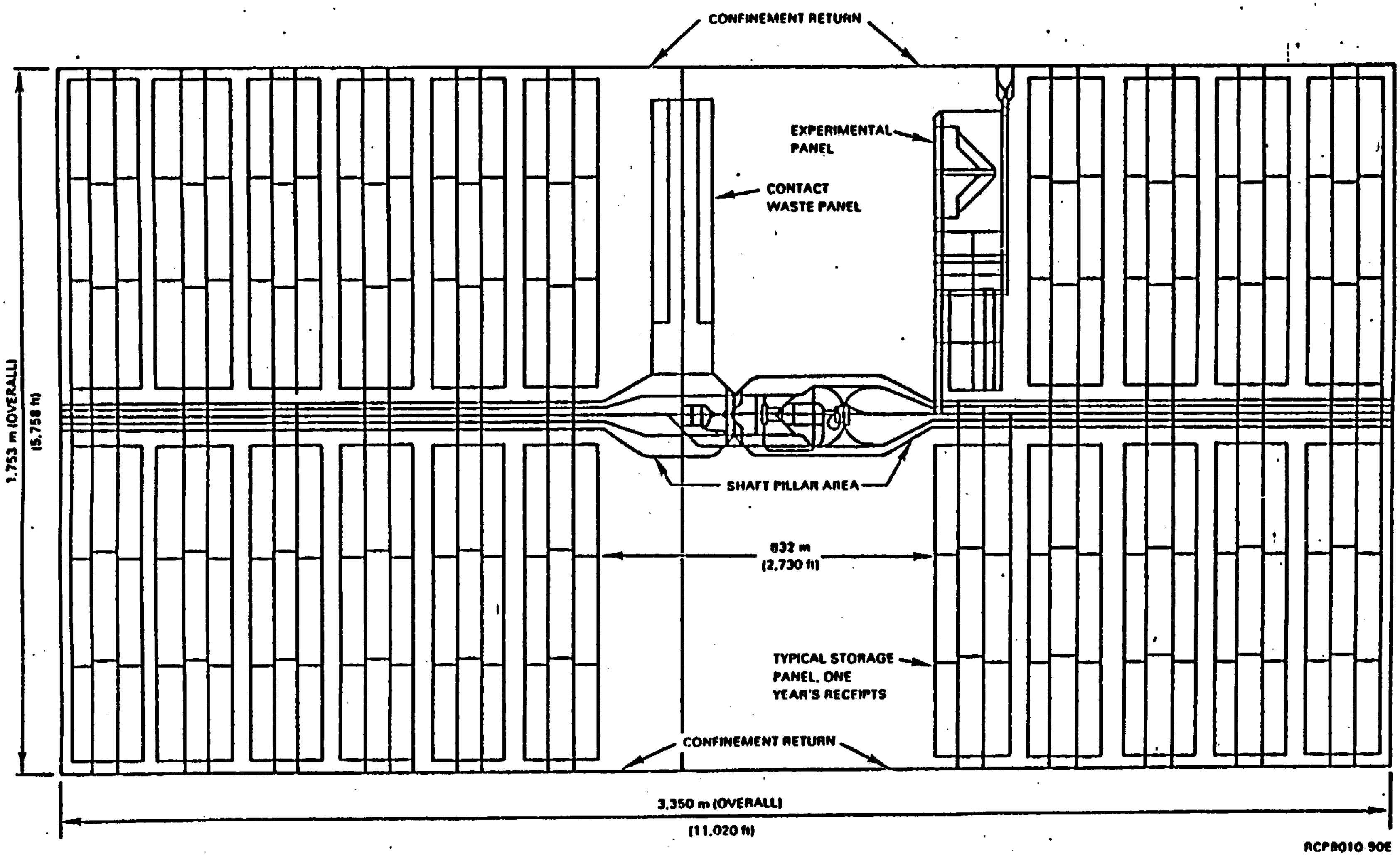


Figure A-13

Subsurface Facilities Layout (bow-tie arrangement).

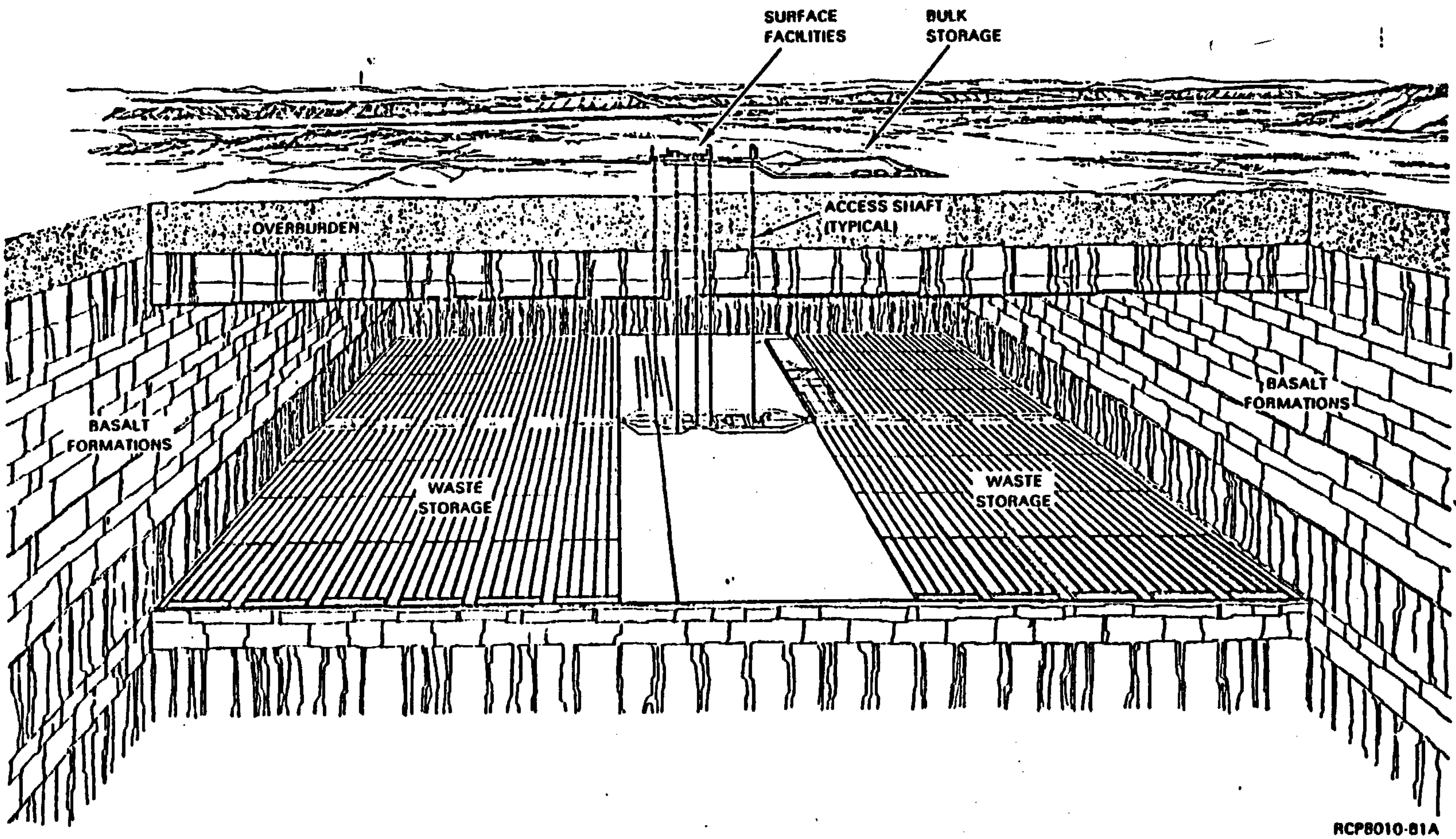


Figure A-14

Repository Cutaway.

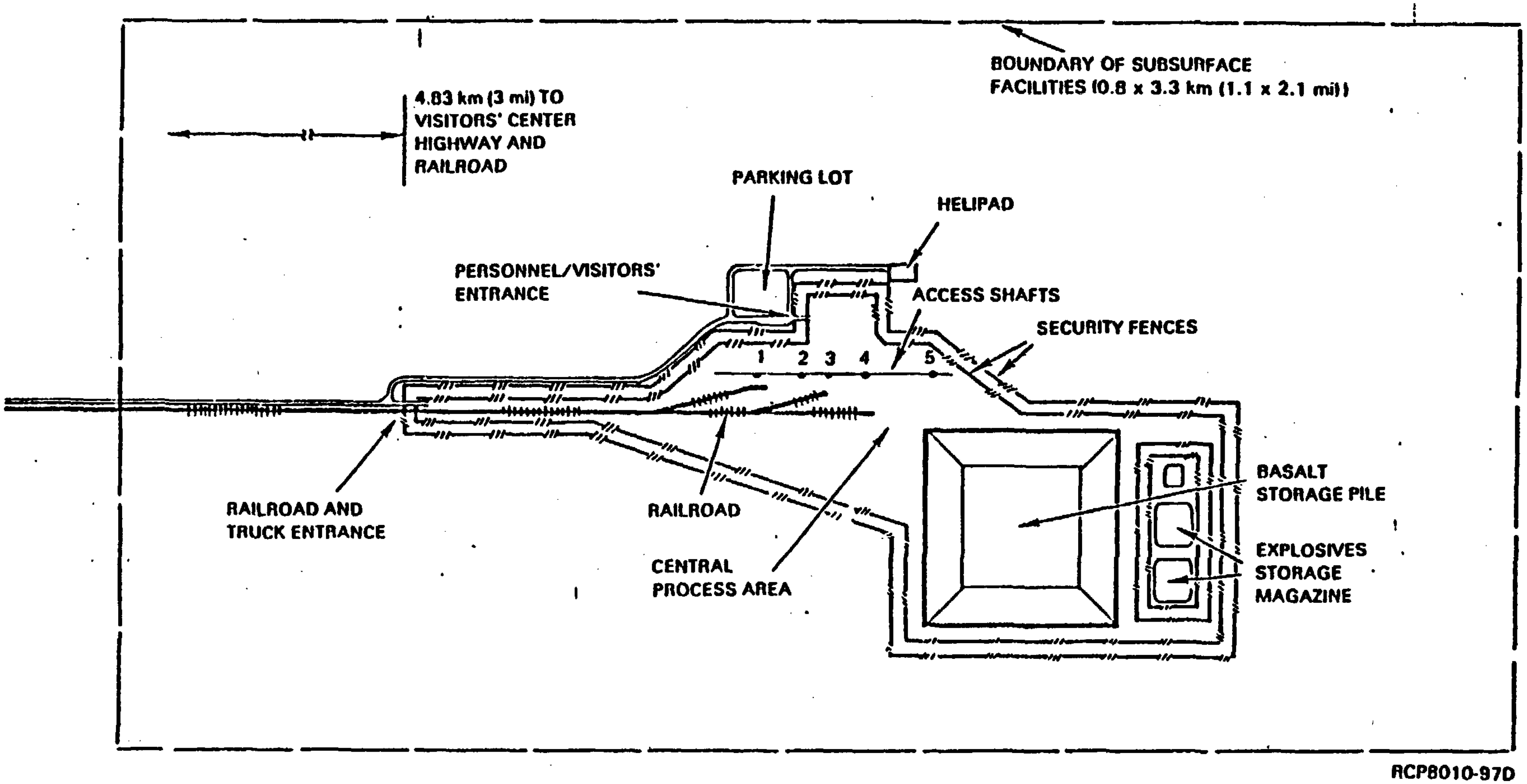


Figure A-15

Site Arrangement.

A-16

1. PERSONNEL/VISITORS' ROAD
2. TRUCK ROAD
3. SECURITY FENCES
4. PARKING LOT
5. GATEHOUSE NO. 1
6. HELIPAD
7. ADMINISTRATION BUILDING
8. LUNCHROOM
9. SUBSTATION
10. INDUSTRIAL SAFETY CENTER
11. TRAINING CENTER
12. GATEHOUSE AND SECURITY BUILDING
13. FIRE STATION
14. CONFINEMENT EXHAUST BUILDING
15. STACK
16. SHAFT NO. 1--CONFINEMENT EXHAUST
17. COOLING TOWERS
18. STACK
19. SHAFT NO. 2--WASTE TRANSPORT
20. WASTE HANDLING BUILDING
21. CASK CAR STORAGE YARD
22. REFRIGERATION BUILDING
23. SHAFT NO. 3--CONFINEMENT INTAKE
24. CONFINEMENT AIR INTAKE BUILDING
25. PERSONNEL AND MATERIAL ACCESS FACILITY
26. SHAFT NO. 4--SERVICE AND REPOSITORY DEVELOPMENT VENTILATION INTAKE
27. REPOSITORY AIR INTAKE
28. MAINTENANCE
29. SHAFT NO. 5--BASALT HOISTING AND REPOSITORY DEVELOPMENT VENTILATION EXHAUST
30. REPOSITORY EXHAUST STACK
31. REPOSITORY EXHAUST BUILDING
32. BASALT AND MATERIALS HANDLING BUILDING
33. PATROL ROAD
34. BASALT CRUSHER BUILDING
35. REPOSITORY CORE STORAGE AND LABORATORY BUILDING
36. SLEEVE AND PLUG STORAGE YARD
37. SUSPECT RAIL CAR AND TRUCK STORAGE AREA
38. STANDBY GENERATOR BUILDING
39. REPOSITORY WATER RETENTION PONDS
40. RECEIVING SUBSTATION
41. WAREHOUSE
42. SANITARY SEWAGE TREATMENT PLANT
43. PROCESS WASTE EVAPORATION PONDS
44. OVERHEAD POWERLINES
45. REPOSITORY WATER PERCOLATION POND
46. BASALT HAUL POND
47. BASALT STORAGE PILE

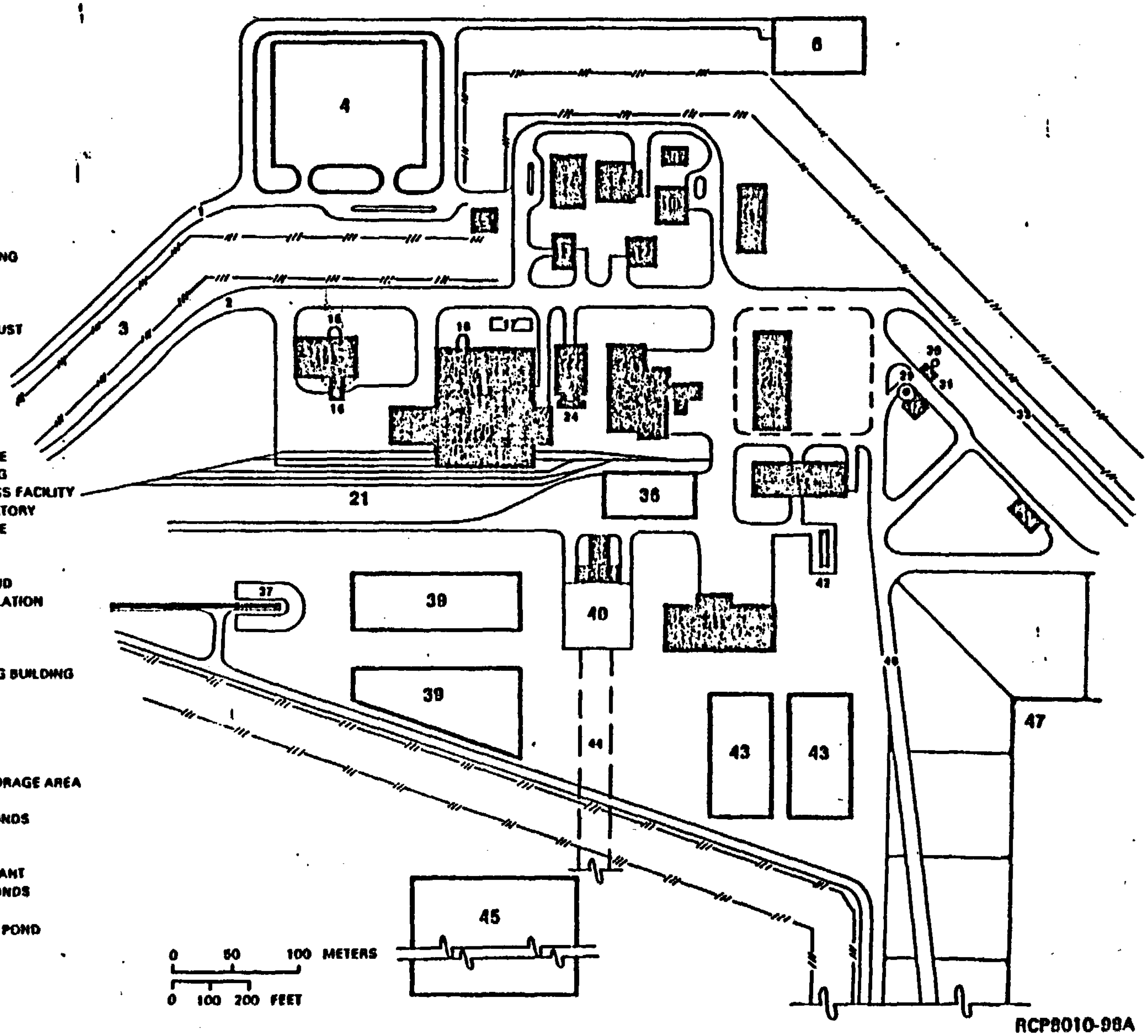


Figure A-16

Surface Facilities Plan--Central Process Area.

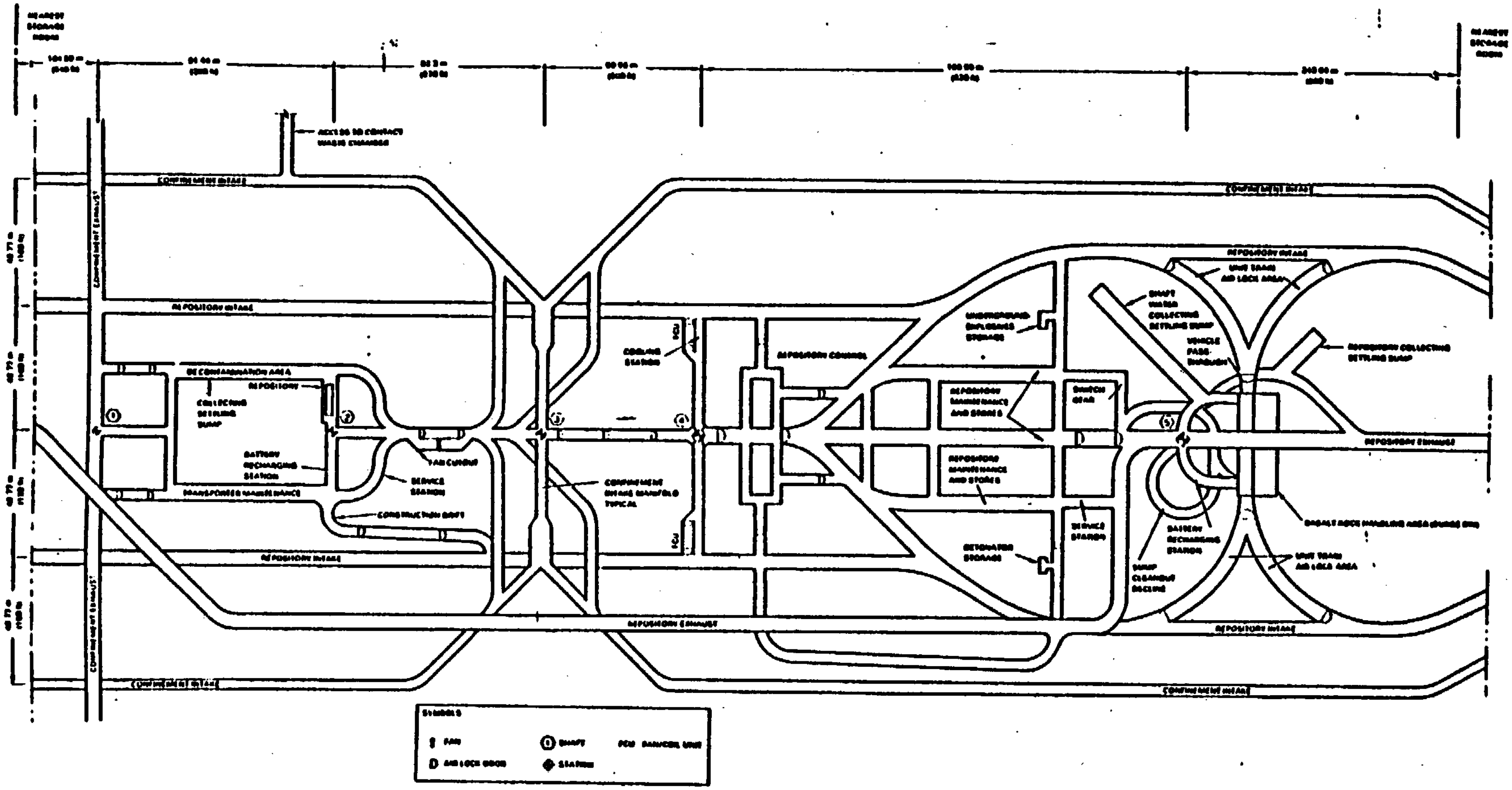
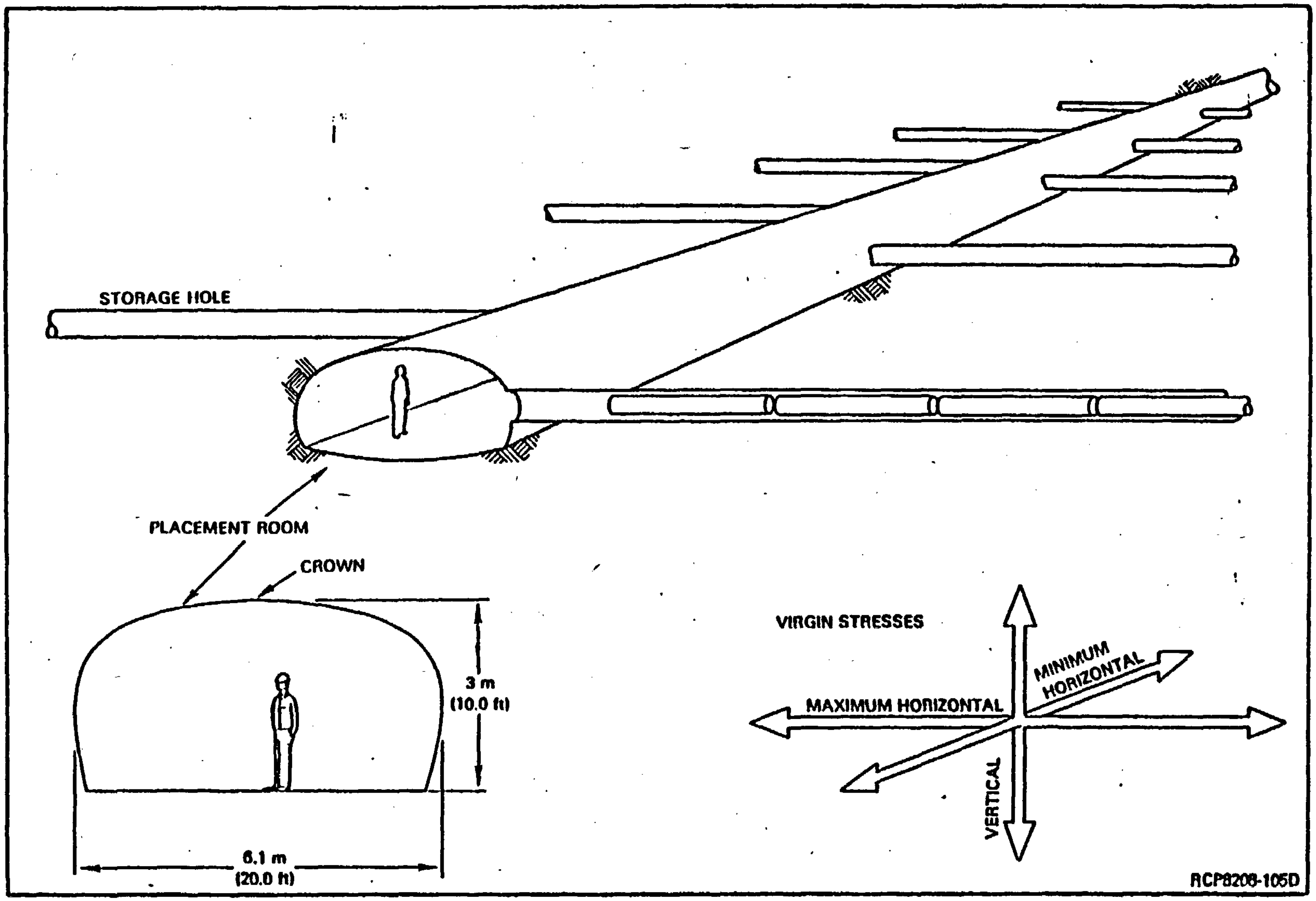


Figure A-17 Shaft-Pillar Layout.



Orientation of Rock Stresses and Excavations.

Figure A-18

A-18

A-19

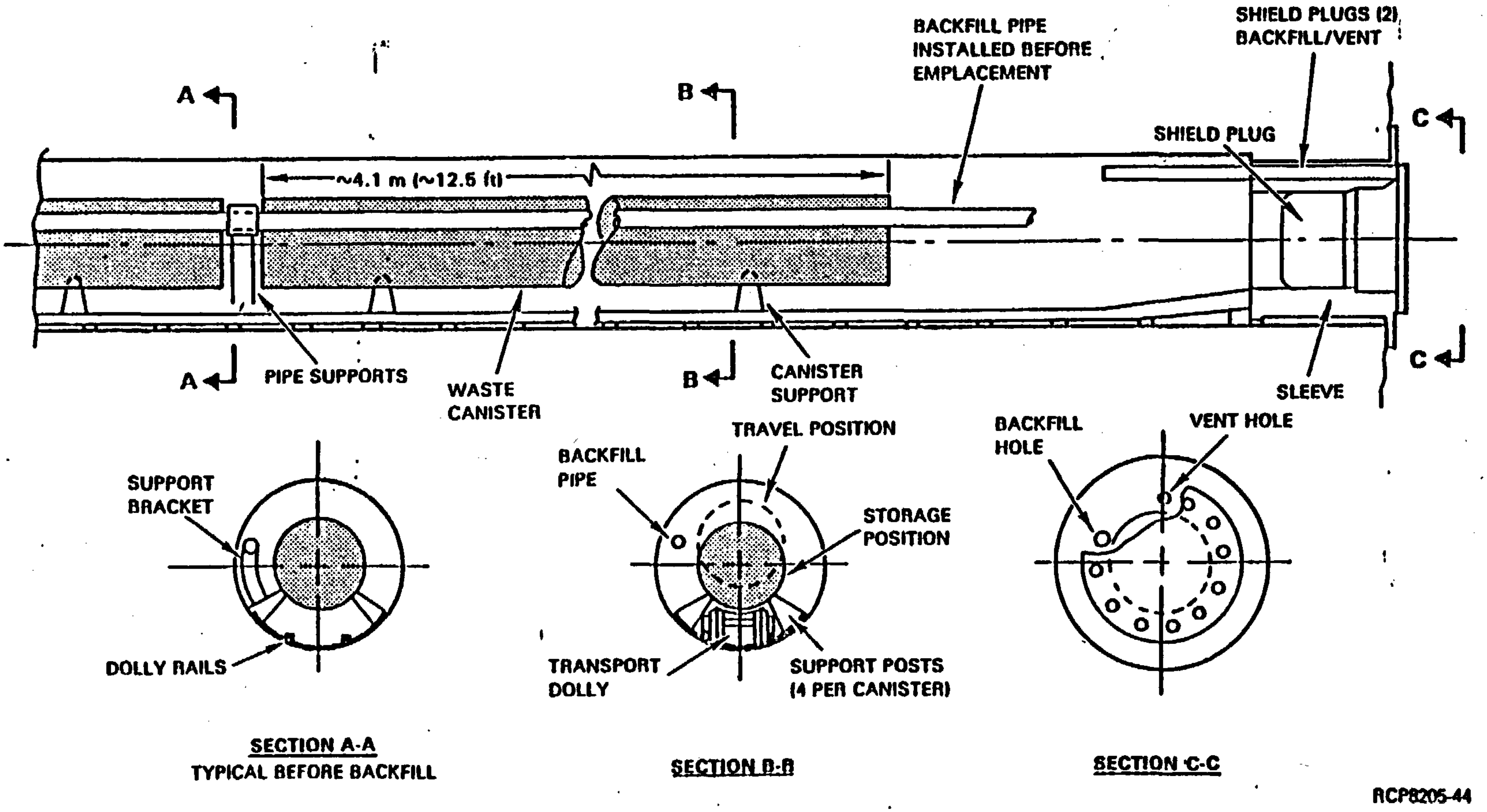
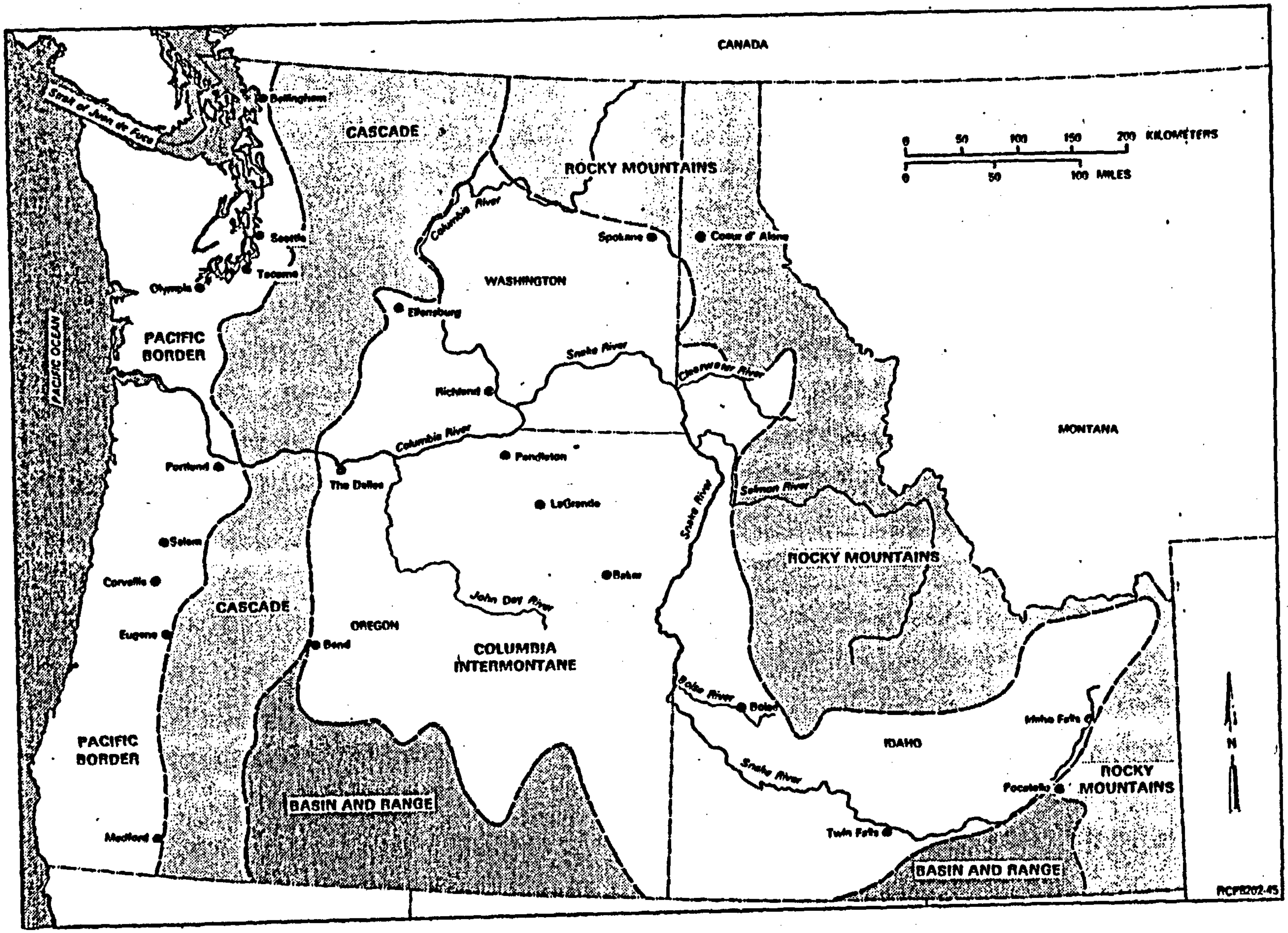


Figure A-19

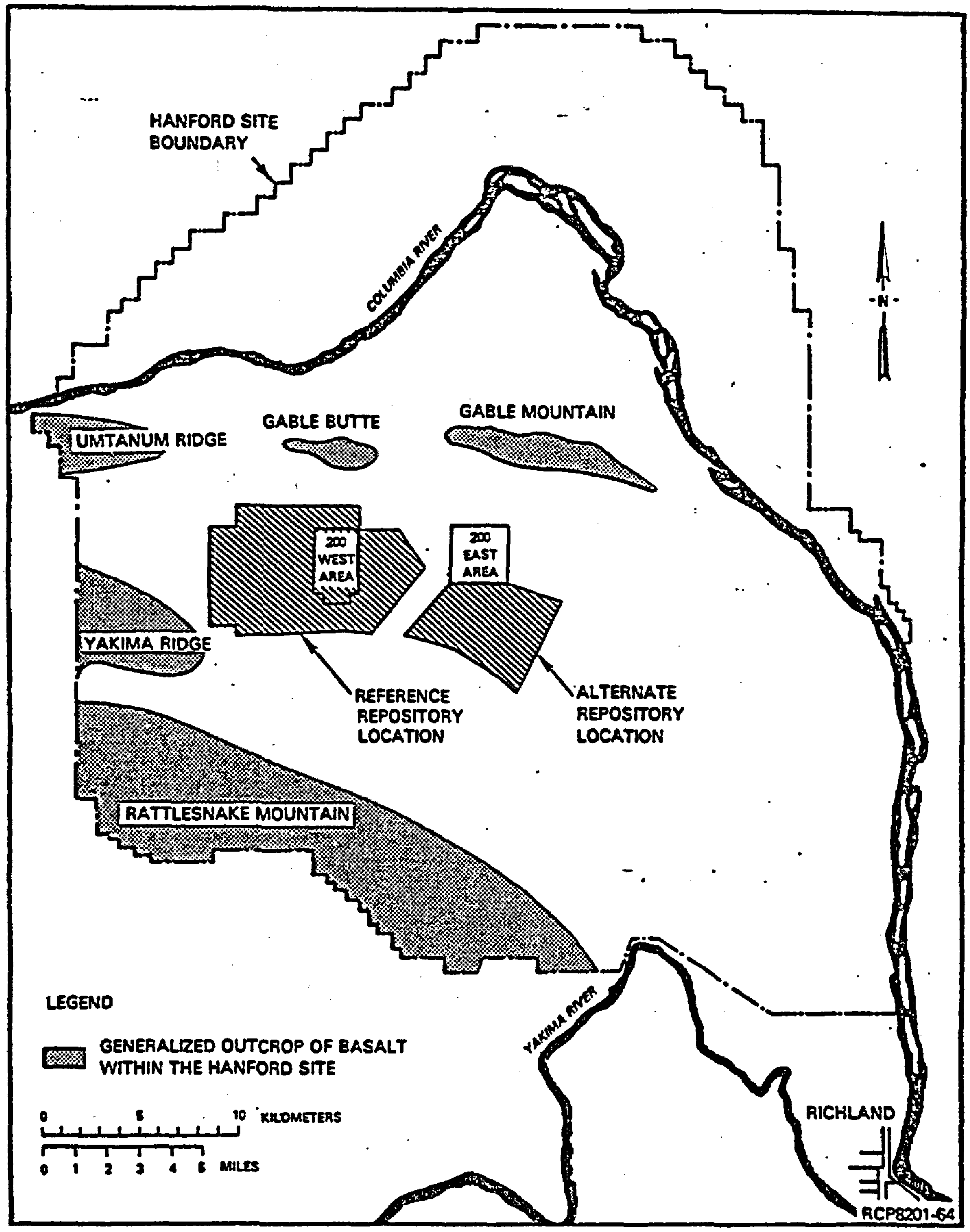
Waste Canister in Horizontal Storage Borehole.

Figure A-20



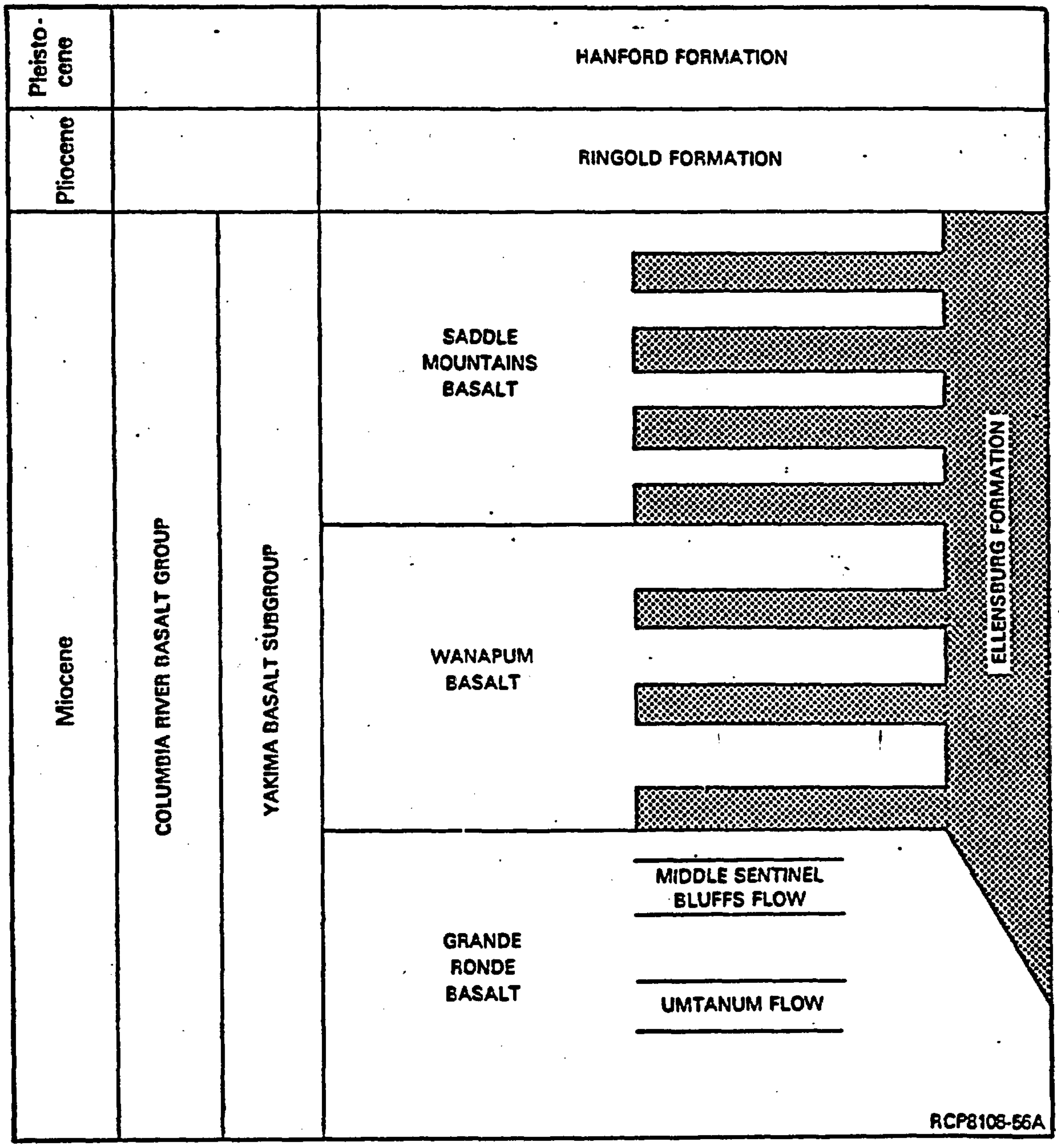
Physiographic Provinces of the Pacific Northwest.

Figure A-21



Location of the Reference Repository Location and Alternate Repository Location.

Figure A-22



Stratigraphy of the Columbia River Basalt Group, Yakima Basalt Subgroup, and Intercalated and Suprabasalt Sediments Within the Pasco Basin.

APPENDIX B

TABLE OF CONTENTS
OF THE
SITE CHARACTERIZATION REPORT
FOR THE
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