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WM-10

MEMORANDUM TO: Michael J. Bell, Chief, WMHL
Joseph O. Bunting, Chief, WMPI
Hubert J. Miller, Chief, WMHT
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FROM: Robert J. Wright
BWIP Project Manager, WMHT

SUBJECT: DRAFT 2 OF SITE CHARACTERIZATION ANALYSIS

Attached is Draft 2 of the DSCA, consisting of:

Executive Summary (mock-up)
Chapters 1-11

Ron Uleck and I are starting a thorough editing job on all the attached material. Meanwhile, it is yours for general review. If you have comments or suggestions for improvement please pass them along to me before December 28.

I am working on Conclusions and Recommendations and should have material in your hands for review by COB, December 27.

/S/

Robert J.Wright
BWIP Project Manager
High-Level Waste Techncial
Development Branch

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NAME	RJWright	HJMiller					
DATE	82/12/21	12/21/82					

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Encl to 12-21-82
Memo to Bell, etc.
fr. Wright re: Dr. 2 of
SCA

CONCLUSIONS AND RECOMMENDATIONS

The final site characterization analysis will contain an opinion by the Director of Nuclear Materials Safety and Safeguards that "he has no objection to the DOE's site characterization program, if such an opinion is appropriate, or specific objections...to DOE's proceeding with characterization of the named site" (10 CFR 60.11(e)). In addition, the Director may make specific recommendations to DOE in connection with site characterization.

The Director's opinion will take into account comments received and any additional information acquired during the public comment period. In addition, the Director's opinion, and any recommendations related thereto, is expected to take into consideration the conclusions and recommendations of the NRC staff, based on its analysis of the Site Characterization Report.

As part of the present analysis of the Site Characterization Report, the NRC staff has reached a number of conclusions about the contents of the report. The conclusions and recommendations are presented in the following sections of this chapter.

EXECUTIVE SUMMARY

(The Executive Summary will be no longer than 3 pages single spaced; it will include the topics shown below.)

- SCR Review Process (summary of Chapter 1 of SCA)

- Summary of SCR (maximum one short paragraph of each SCR chapter)

- NRC Staff Conclusions on SCR (summary of information in DO)

    - Deficiencies in SCR Contents as Required by 10 CFR 60
    - Discussion of DOE Assertions on Groundwater Travel Time
    - Analysis of SC Program

- NRC Staff Recommendations on SC Program

- Summary of SCA Chapter 12 (NRC concerns and open issues)

CONCLUSIONS AND RECOMMENDATIONS

1 Introduction

This chapter treats two subjects: (1) of conclusions reached by the NRC staff resulting from its analysis of the site characterization report; and (2) the staff's recommendations to DOE concerning the proposed site characterization program.

The conclusions are divided into three groups. First, attention is given to the contents of the site characterization report in the light of 10 CFR 60.11, which preserves certain subjects for inclusion. Second, attention is given to key assertions by DOE concerning groundwater travel time and radionuclide release rate. The third group of conclusions deals with the proposed site characterization program. This is viewed from the standpoint of satisfying information needs for a construction authorization application, if one is presented to NRC for the BWIP.

1.1 Contents of the site characterization report that are required by 10 CFR 60.11

In this section the specific SCR contents required by 10 CFR 60.11 are cited, together with the conclusion reached on each by the NRC staff upon analysis of the SCR.

1.1.1 60.00(a)(1): "a description of the site to be characterized;"
Analysis: This is included in the SCR.
References: SCR pages _____.

1.1.2 60.11(a)(2): "the criteria used to arrive at the candidate area;"

Analysis: This is included in the SCR.

References:

1.1.3 60.11(1)(3): "the method by which the site was slected for site characterization;"

Analysis: This is not included in the SCR.

Discussion: DOE's selection of a reference repositiory location within the Hanford Reservation is well described in the SCR. The selection was based on extensive geological and geophysical investigation of both the Hanford Reservation and the Pasco Basin, the somewhat larger geological entity within which the reservation is located. It appears clear that the reference repositiory location is among the best that can reasonably be found within the Hanford Reservation.

However, the documentation in the SCR, including the references cited therein, is considered insufficient to demonstrate that the Pasco Basin is a reasonable study area within which to select a site. If the SCR is to provide the basis for future National Environmental Policy Act (NEPA) decisions for repositiory licensing, DOE should show, in the SCR, how the Pasco Basin compares to other study areas, particularly those which ar also dedicated to nuclear activities (e.g., DOE-reserved lands in South Carolina, Idaho, New Mexico, and Nevada). As an alternative, DOE could compare the Pasco Basin study area to study areas selected by the host-rock approach. That is to say that the Pasco Basin, underlain by basalt, should be compared with other basaltie areas of the United States.

By comparing the Pasco Basin to other study areas, DOE coul confirm that Hanford is a reasonable repository site alternative for NEPA purposes. The NRC will be required to prepare an environmental impact statement (EIS) to support its deciion to authorize the construction of a geiologic repositiory. Under the provisions of the National Environmental Policy Act (NEPA) and the NRC procedural rule (46 FR 13973), the alternative repository sites, presented in the EIS, must be among the best that can reasonably be found. DOE should demonstrate that the Hanford Reservation is a reasonable alternative for a repositiory site before extensive site characterization is undertaken.

References: SCR pages _____.

1.1.4 60.11(a)(4): "identification and location of alternative media and sites at which DOE intends to conduct site characterization and for which DOE anticipates submitting subsequent Site Characterization Reports;"
Analysis: This is included in the SCR.
References: SCR pages _____.

1.1.4 60.11(a)(5): "a description of the decision process by which the site was selected for characterization, including the means used to obtain public, Indian tribal and State views during selection;"
Analysis: This is included in the SCR, except that no mention is made of the means to obtain Indian tribal views.
References: SCR pages _____.

1.1.6 60.11(a)(6): "a description of the site characterization program including (i) the extent of planned excavation and plans for in situ testing, (ii) a conceptual design of a repositiory appropriate to the site in sufficient detail to allow assessment of the site characterization program with respect to investigation of activities which address the ability of the site to host a repository and isolate radioactive waste, or which may affect such ability, and (iii) provisions to control any adverse, safet-related effects from site characterization, including appropriate quality assurance programs;"

Conclusions: A site characterization program is presented in the SCR. It does not now, howver, comply with the requirements of 60.11(a)(6) in three respects. First, the SCR is not clear with respect to 60.11(a)(6)(i). Whereas Figure __ portrays a scheme of excavation, there is no narrative that explains the scheme or indicates whether it represents the testing plans during site characterization.

Second, with respect to 60.11(a)96)(ii) the conceptual design does not include sufficient detail on the design of waste package components to permit an assessemnt of the site characterization program.

effects from site characterization as required in 60.11(a)(6)(iii); and (4) description of research and development activities on waste from and packaging.

The DOE response....

1.2 DOE Assertions Concerning Groundwater Flow and Radionuclide Release Rate

It is generally agreed that the key factor in radionuclide release from a repository is the movement of groundwater from the repository to the accessible environment. For this reason, particular importance atttaches to certain assertions of the SCR concerning groundwater flow, expecially the travel time needed for groundwater to move from a repository to the accessible environment. The Executive Summary states (page 7):

> Results of modeling also indicate that the minimum groundwater travel times from the repository site to the accessible environment, a distance defined by the U.S. Environmental Protection Agency in its draft regulations as 0 kilometers (6.2 miles), would be on the order of 10,000 years or greater."

If the DOE assertion were shown to be in the quotation alludes . The modeling referred to the sevelopment of a cnceptual model of the groundwater flow; the inputting of critical parameters into a mathematical, computerized code; and the exercise of the code to provide travel times. True, it would automatically mean that the BWIP satisfies the EPA standard for radionuclide releases. That standard is based on cumulative release over a 10,000 year period.

The NRC staff is concerned that DOE appears to place too much confidence in the reliability of the modeling results. For reasons explained in Chapters 4 and 11, and summarized below, it is believed that the stimation of groundwater flow time involve many uncertainties and, therefore, should be regarded as preliminary with little credibility attached to the results.

. Sparseness of test data. Of the major hydraulic parameters-horizontal conductivity, conductivity, effective porosity and dispersitivity, only the first has been measured at more than one location in more than one test interval. Vertical conductivity has not been none of the geologic discontinuities, which are predicted in the SCR to influence groundwater movement, have been measured.

. Uncertainties in head measurements, Due to the method of testing, considerable uncertainty attaches to reported head measurements. These are ___ values in calibrating the groundwater model.

. Questionable use of porcosity data. The one field test of rocks porosity gave a results of 1×10^{-4}; however, a value of 1×10^{-2} is used in modeling reported in the SCR. Since, travel time is directly proportional to porosity, lthe use of 10^{-4}, the measured value, would yield numbers about 100 times less, i.e., "on the order of about 100 years."

. Lack of a defensible conceptual groundwater model. Due to the data limitations and uncertainties descrived above, no single conceptual model can be defined in opposition to others that satisfy the data base but provide a range of estimated travel times for groundwater.

. Lack of computer code validation. The SCR provides no indication that the computer codes have been validated or use at the BWIP. This is considered to be critical in demonstrating groundwater travel times.

It should be noted that the technical chapters of the SCR appear to take a more open viewpoint toward modeling uncertainties than does the Executive Summary. Foe example, section 12.4.5 discussed uncertainties in these "preliminary analyses" and states that "substantial interpolation and subjective judgement were required to prepare the model inputs" (page___). Page 17.2-24 states: "To allow final assessments of the situ suitability from a hydrologic standpoint, the vertical grondwater paths must be identified by testing"..."because vertical transport is likely to be the controlling factor for radionuclide migration." A realistic assessment of uncertainities in boreholes, drilling and testing for hydrologic testing needs is provided by a Rockwell document, RHO-BW-EV-3 p, June 1982.

If DOE erroniously places too much confidence in present estimates of groundwater travel time, as is suggested by the Executive Summary, judgements on the planning and execution of the site characterization program may be biased, to the detroment of a judicious and balanced group of investigations.

1 DESCRIPTION OF SITE CHARACTERIZATION REVIEW PROCESS

1. Submission of BWIP Site Characterization Report

The U.S. Department of Energy has filed with the Nuclear Regulatory Commission the "Site Characterization Report for the Basalt Waste Isolation Project," DOE/RL 82-3 (hereinafter "SCR"). The SCR is for a high-level waste repository at a Reference Repository Location on the Hanford Reservation in the State of Washington. The SCR was received by the Nuclear Regulatory Commission on November 12, 1982, and has been designated as Project WM-10.

The submission of the SCR is pursuant to the Commission's procedural rule regarding disposal of high-level radioactive wastes in geologic repositories. The rule is codified as 10 CFR Part 60 and was published February 25, 1981 (46 FR 13971). 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."

The SCR is presented in three volumes and contains 19 chapters and approximately 2200 pages. The complete table of contents of the SCR is included as Appendix B of this Draft SCA.

It should also be noted that under 10 CFR Part 51, §51.40(d), DOE is required to characterize at least three sites representing two geologic media, one of which is not salt, as "the minimum necessary to satisfy the requirements of NEPA [the National Environmental Policy Act]." DOE has informed NRC that it has ongoing studies at Yucca Mountain in the Nevada Test Site (NTS) and at salt sites in the Gibson Dome area of Utah's Paradox Basin, the Texas Panhandle area of the Permian Basin, and four salt domes in the Gulf Interior Region in Louisiana, Mississippi, and Texas. A description of DOE activities in these areas is presented in Chapter 19 of the SCR. DOE currently plans to submit a site characterization report for NTS in June 1983, but has not notiified NRC of any final decision as to which of the salt sites it plans to characterize.

A copy of the SCR is available for public inspection at the Nuclear Regulatory Commission, 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 444-7334.

1.2 Purpose of the Site Characterization Report

The basic purposes of the SCR are: (1) to describe the site selection process and (2) to identify issues at a candidate repository site and the plans for resolving them. The SCR is prepared at an early time in site characterization in order to avoid delays if and when the site is selected for licensing consideration.

The specific requirements for contents of the SCR are contained in §60.11(a). Further guidance on the types of information to be provided in the SCR is contained in NRC Regulatory Guide 4.17, "Standard Format and Content of Site Characterization Reports for High-Level Waste Geologic Repositories." Copies of Reg. Guide 4.17 are available from NRC/GPO Sales Program, Division of Technical Information and Document Control, Nuclear Regulatory Commission, Washington, DC 20555.

The SCR, in accordance with Regulatory Guide 4.17, should accomplish the following:

1. Describe the site selection process, including selection criteria and involvement of States, Indian tribes and the public,

2. Establish what is known about a site from site screening, selection and exploration activities completed to date,

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

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

1.3 Purpose and Method of Site Characterization Analysis

In accordance with §60.11(d), the Director of NRC's Office of Nuclear Material Safety and Safeguards (Director) prepared this Draft Site Characterization Analysis (Draft SCA) of the information provided in the SCR. This Draft SCA is advisory in nature; it conveys NRC comments on the thrust of DOE's plans for site characterization.

A period not less than 90 days will be allowed for public comments on the Draft SCA. The Director will then prepare a final site characterization analysis issuing an opinion that the Director has either no objection to DOE's site characterization program, if such an opinion is appropriate, or specific objections to DOE's proceeding with characterization of the named site. In addition, the Director may make specific recommendations to DOE on matters relating to its site characterization activities.

This Draft SCA is a critique of DOE's site characterization plans contained in the SCR, emphasizing open items for continued, follow-up interaction. Readers of the SCA interested in detailed aspects of the DOE site characterization program are refered to the SCR.

The NRC staff review of this SCR is not a licensing proceeding, but part of an ongoing pre-application 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. To ensure continuous review of DOE activities at the site, DOE is required by NRC regulations §60.11(g) to submit semiannual reports on the progress of site characterization. The first semiannual report for the Basalt Waste Isolation Project will be due six months after the final SCA is issued.

1.4 SCR Review Procedure

In preparation for the BWIP SCR review, a BWIP review team was named and a project manager was selected prior to SCR receipt. All of the individuals on the review team are NRC staff; most are members of NRC's High-Level Waste Technical Development Branch (WMHT), the High-Level Waste Licensing Management Branch (WMHL) and the Licensing Process and Integration Branch (WMPI) in the Division of Waste Management, Office of Nuclear Material Safety and Safeguards. These individuals had primary responsibility for developing this Draft SCA and supporting documents. In addition, assistance was provided by NRC's technical assistance consultants, national laboratories and NRC personnel from other offices, namely: the Office of Research, the Office of the Executive Legal Director, the Office of State Programs and the Office of Administration.

Prior to SCR receipt, the BWIP review team undertook a variety of activities to prepare for the review. These activities included conducting several on-site technical reviews of DOE activities at BWIP; participating with BWIP personnel in technical workshops to identify issues and exchange technical information; developing technical background material; reviewing available site data; and establishing and maintaining contact with DOE technical staff. Contacts were also established with State agencies and other individuals and organizations who expressed interests in the Draft SCA. Some of these activities, such as site visits, began as early as July 1980. NRC staff plans to continue these activities, as necessary, throughout the DOE site characterization program.

Based on available information and prior to SCR receipt, the BWIP Review Team prepared an inventory of documents and other data pertaining to BWIP. The review team also developed a systematic and comprehensive review of BWIP site issues. Next the review team prepared a partial, preliminary Site Issue Analysis (SIA) for selected site issues (see 1.5 below for a description of SIAs) and annotated outlines of portions of the Draft SCA text and appendices.

Upon receipt of the SCR, NRC's BWIP review team, undertook a thorough review of the SCR, finalized the Site Issue Analyses and prepared the Draft SCA text and appendices.

1.5 Site Characterization Analysis Products

The NRC analysis of the SCR includes the development of the following products:

Draft Site Characterization Analysis (Draft SCA)

The Draft SCA (NUREG-0960) is a critique of the SCR, focusing on major concerns and comments on the basic thrust and strategy of the DOE program, especially the site characterization plans on the critical path for licensing. The Draft SCA is used to check the completeness and 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. The Draft SCA is not a complete summary or restatement of the SCR; the reader must refer to the SCR for details.

Chapters 3 through 11 of the Draft SCA contain critiques of key issues in site selection, groundwater flow, geologic stability, geochemical retardation, design of facilities, waste package, institutional and environmental factors, quality assurance and performance assessment. In addition to these key issues, other NRC concerns that will require further interactions with DOE are summarized in Chapter 12. A complet tabulation of all these issues is presented in Appendix C.

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 of a several year period addressing selected, major issues and identifying the basic elements of an acceptable site characterization program to allow addressing these issues in licensing. These reports focus on technical issues that are new, unconventional and unique to the development of a high-level waste repository, especially in geochemistry and hydrogeology. The references accompany the Draft SCA, but are not included in NUREG-0960; they are available for public inspection at the NRC Public Document Room.

Site Issue Analyses (SIAs)

An analysis of each major site issue. 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. 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 accompany the Draft SCA, but are not included in NUREG-0960; they are available for public inspection at the NRC Public Document Room.

2 DESCRIPTION OF FACILITY AND CONCEPTUAL DESIGN

2.1 General Discussion

As required in (10 CFR 60), Chapter 10 of the SCR provides a description of the conceptual design for the Reference Repository Location at the Hanford Site.

2.2 General Description of the Surface Facilities

The surface facilities are based on a conceptual design which provides 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 arranged around the repository shafts in an attempt to minimize area requirements, travel and transportation distances, and include the following principal components:

- 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____) .

2.2.1 Surface Facilities Important to Safety

Buildings important to safety are design for construction to QA Level I standards as established in 10CFR50, Appendix B. These facilities consist of:

- o Waste Handling Building;
- o Personnel and Material Access Facility, Headframe Portion;
- o Standby Generator Building;
- o Security Headquarters;
- o Mine Exhaust Air Building;
- o Confinement Exhaust Ventilation Building;
- o Basalt Headframe
- o Confinement Air Intake Building

These buildings (Ref. Figure___) all sealed, monolithic, concrete structures. The remainder of the buildings will be of conventional construction, not designed to confinement construction standards.

2.2.2 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 multistory, 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. Above the hot cells is the transfer cask into which canisters are loaded for transfer to the waste cage at the shaft.

A contact-waste handling area is located in west side of the building. Waste containers are unloaded in a receiving area and are transferred by air pallet 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 are a 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 adminstrative 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.

2.3 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 at a depth of approximately 1100 meters (3700 ft) and are developed from the shaft station, providing storage capacity for waste receipts. The repository layout (Reference Figure___) is at the conceptual stage of design development. The proposed schedule for design development is outlined in a series of network diagrams (Reference Figure___).

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 cansiters. They are laid out for efficient waste-cage unloading and transporter loading.

The waste storage panels provide space for one years 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__). 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___).

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 50-50 mix of bentonite pellets and crushed basalt. The seals are are treated as a component of a multiple barrier waste isolation system.

NOTE: THE ENACTMENT OF THE NUCLEAR WASTE POLICY ACT OF 1982 WILL REQUIRE MODIFICATIONS TO THIS DRAFT SCA CHAPTER

3 SITE CHARACTERIZATION ANALYSIS: THE SITE SELECTION PROCESS

3.1 Introduction

In this chapter of the Site Characterization Analysis, the staff will analyze the process by which DOE selected a site, or what it calls a "reference repository location," at the Hanford Reservation for further characterization of the site's ability to isolate waste.

3.1.1. Type of Material Presented in DOE's Site Characterization Report (SCR)

Essentially, Chapter 2 of the SCR is a description and explanation of the process by which DOE selected a site on the Hanford Reservation. The decision process started at the Pasco Basin, the 1600-square mile area underlying Hanford and its environs, and the SCR describes the technical, environmental, and legal and institutional factors used to screen successively smaller areas within the Basin. The SCR also explains how different sets of guidelines and criteria were applied at each step in the screening process to rank each area in order to arrive at the reference repository location to be characterized. DOE did not select the Hanford site for characterization on the basis of screening studies of any areas outside the Pasco Basin.

3.1.2. Relevant Sections of 10 CFR 60

Under Section 60.11(a) of the rule, the SCR is required to describe, among other things:

1. "(2) the criteria used to arrive at the candidate area;"

2. "(3) the method by which the site was selected for site characterization;"

3. "(4) identification and location of alternative media and sites at which DOE intends to conduct site characterization and for which DOE anticipates submitting subsequent Site Characterization Reports;" and

4. "(5) a description of the decision process by which the site was selected for characterization, including the means used to obtain public, Indian tribal and State views during selection"

(A word about terminology, since DOE's differs from NRC's. "Candidate area" is defined under Section 60.2(a) of our rule as "a geologic and hydrologic system within which a geologic repository may be located." NRC considers the Pasco Basin a candidate area, while DOE calls it a "study area," and uses "candidate area" to describe an area within the Pasco Basin. This enables DOE to say that it has described "the criteria used to arrive at the candidate area" under Section 60.11(a)(2) above. Unless otherwise noted, however, NRC will use the term as it is defined in the rule throughout this chapter.)

(As discussed under 3.3 below, DOE also makes a distinction between site screening and site selection. "Screening" is used to denote the process of finding a site for characterization, while site "selection" is the process of choosing a site for a license application to NRC. The provisions of the rule cited above refer to the selection of a site for characterization, but NRC believes that DOE's distinction is useful, and will use the word "screening" to refer to the process leading to selection of a site for characterization.)

3.1.3. Relation of SCR and NRC Issues

Early resolution of siting issues has been a consistent NRC priority. When the proposed procedural rule setting forth these requirements was published in the Federal Register in late 1979, the accompanying Statement of Considerations noted: "The Commission believes that many issues, including the NEPA [National Environmental Policy Act] questions related to alternatives and alternative sites, will be more easily resolved if ... concerns are identified and addressed at the earliest possible time." The Statement also pointed out that "it is important to the Commission's ability to discharge its licensing responsibilities that the course which the Department follows to select sites is systematic, well-reasoned, publicly accessible, and ultimately will result in a slate of candidate sites whose members are among the best that can reasonably be found." (FR Vol. 44, No. 236 (December 6, 1979), p. 70412)

This concern remained an NRC priority in the final version of the 10 CFR 60 procedural rule. In discussing its reasons for requiring DOE to characterize at least three sites before selecting one for a license application, the Commission said it continued to believe that multiple site characterization "will prevent a premature commitment by DOE to a particular site, and will assure that DOE's preferred site will be chosen from a slate of candidate sites that are among the best that can reasonably be found. ... What is important is that there be sufficient information for NRC to be able to evaluate real alternatives, in a timely manner, in accordance with NEPA."

The purpose of the NRC staff analysis of DOE's site screening and selection process is to assess whether the site named in the SCR is a reasonable alternative. Before significant further commitments of government resources are made to characterize the site, the question for NRC staff at this point is whether, on the basis of what is known about the site and DOE's process of selecting it, there is anything that would prevent the site from taking its place on a slate of candidate sites "among the best that can reasonably be found." The Commission would probably consider a site as an adequate candidate if the Commission found that, in accordance with the provisions of Section 60.11(a) above, the criteria, methodology, and decision process used by DOE in selecting the site were reasonable.

It must be recognized, however, that as a practical matter, a candidate site which appears satisfactory after a reasonable screening process and preliminary site investigation may subsequently be found to have technical flaws as it is subjected to more extensive investigation during the site characterization process. The phrase "among the best that can reasonably be found" does not necessarily mean that each of the three or more candidate sites nominated by DOE must in fact be licensable after the completion of site characterization.

3.2 Summary of SCR Conclusions and Assertions

In identifying the reference repository site proposed for characterization, DOE has concluded that the Hanford Reservation has "a high likelihood of containing a potential repository site." Among other things noted in the Executive Summary of the SCR, DOE has also concluded that on the basis of geotechnical data now available:

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. The Hanford Site is relatively unattractive to future subsurface mineral exploration and development within the Columbia River Basalt Group compared with other areas of the Columbia Plateau.

2. The reference repository location is situated in a favorable position with respect to available transportation modes, support and service facilities, remoteness from population centers, and smoothness of the terrain.

3. There is no land conflict with currently planned or existing facilities on the Hanford Site.

3.3 Description and Evaluation of Site Characterization Plans and Programs; Analysis and Discussion of BWIP SCR Issues

3.3.1. Background: Relationship of Basalt Waste Isolation Project (BWIP) to the National Repository Siting Program

BWIP is one project within the National Waste Terminal Storage (NWTS) Program, which was created to find and characterize sites for a geologic repository.

The NWTS geologic field offices are also investigating volcanic tuff (Nevada Nuclear Waste Storage Investigations (NNWSI)) and salt and crystalline rocks (Office of Nuclear Waste Isolation (ONWI)) as potential geologic media for a high level waste (HLW) repository. Figure ____ in Appendix A shows where these investigations are taking place.

Basalt, volcanic tuff, and salt are the primary media under consideration. A schedule for the activities planned for each of these media appears in Figure___, Appendix A. The BWIP SCR is the first of several SCR's DOE will submit to NRC. The SCR for tuff is scheduled for June 1983, and for salt, July 1983.

The NWTS Program is following a three-phase siting process consisting of (1) site screening (2) detailed site studies, and (3) site selection (see Figure___ in Appendix A). This siting process is described in the DOE Public Draft, National Plan for Siting High-Level Radiactive Waste Repositories and Environmental Assessment, DOE/NWTS-4 (Ref. 7). (The staff will refer to this document as the National Siting Plan). To permit a comparison between the NWTS and the BWIP processes, a brief description of each phase of the NWTS siting process follows.

3.3.1.1. Site Screening

The first phase of the NWTS siting process, which DOE terms site screening, consists of "a set of decisions made sequentially to identify sites from vast land areas favorable for waste disposal" -- in other words, to find sites suitable for detailed characterization. DOE has used several approaches to site screening that begin on different geographic scales. The host-rock approach begins by identifying large, multi-state regions of the country overlying geologic formations of potential interest. Early in the NWTS program, DOE used the host rock approach to delineate regions containing salt domes and bedded salt formations that may be suitable for a geologic repository. More recently, DOE has screened the U.S. for regions containing crystalline rocks such as granite.

DOE has also applied another approach, termed the land-use approach, to investigate land already owned by the federal government and committed to nuclear activities. Using this approach, DOE has initiated siting studies both at Hanford and the Nevada Test Site. This approach enables DOE to by-pass the national and regional surveys conducted under other approaches and begin with what it calls an "area survey" (see Figure ____, Appendix A). In the case of BWIP, the area survey was conducted on the Pasco Basin. Chapter 2 of the SCR discusses the results of DOE's site screening process for BWIP, and is the focus of NRC's analysis here.

DOE is also pursuing two additional approaches to site screening: province screening, which begins by looking at hydrologic formations rather than geologic ones; and simultaneous screening, which looks at both together. DOE expects that the nation's first repository will be selected either by the land-use or host-rock approach, however.

3.3.1.2. Detailed Site Studies

After completing site screening for each site to be characterized, DOE will begin what it calls detailed site studies, which include the sinking of an exploratory shaft and the in situ testing activities required under NRC rules for site characterization. At this stage, DOE will assess the safety, environmental, regulatory, and societal concerns associated with constructing and operating a geologic repository at a particular site. In addition to describing its decision process for selecting the site, the BWIP SCR is also required to detail how DOE plans to make the above assessments at Hanford.

3.3.1.3. Site Selection

DOE defines site selection as "the decision to choose a site for a repository." For the site selected, DOE would prepare an application to NRC to authorize construction of the repository. As part of this licensing process, DOE will also prepare a Safety Analysis Report and an Environmental Report for the site it has chosen. Based on the information in the Environmental Report, NRC will

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3.3.1 DOE Rationale For Its Selection of the Hanford Reservation

The DOE is considering the thick basalt sequence of the Columbia Plateau for siting the repository. The Columbia Plateau covers 78,000 mi^2, extending across southeast Washington and parts of Idaho and Oregon. In 1976, DOE began site feasibility studies in the Columbia Plateau to assess the hydrologic and geologic properties of basalt. The purpose of these investigations was: "...to provide geologic and hydrologic information necessary to identify areas beneath the Hanford Site that have a high probability of containing basaltic rock suitable for a nuclear waste repository" (Refs. 1,2). Later, in 1978, the National Academy of Science (NAS) recommended that DOE consider the Rattlesnake Hills at Hanford as a possible storage site for nuclear wastes (Ref. 15). The NAS concluded that a nuclear waste repository could be excavated between the perched water table, high in the hills, and the main water table.

DOE selected Hanford as a favorable area for a potential repository site primarily because of its existing land-use. Hanford is owned by the Federal government and has been committed to nuclear activities since 1943. In the BWIP SCR, DOE argues that after many years of commitment to nuclear activities, extensive portions of the Hanford Reservation would never be returned to unrestricted land-use, and Hanford is therefore highly appropriate for continued equivalent use. DOE also has technical reasons for selecting Hanford. Considerable geologic and hydrologic data has been gathered on the Pasco Basin, which underlies the area of the Hanford site, and much of this data is closely aligned with the objectives of finding a site for a nuclear waste repository (Refs. 2,3). In addition, DOE maintains that the Pasco Basin's nearly uniform physical characteristics and thick basalt flows make it an attractive site for a repository (Ref. 5).

3.3.2 Staff's Analysis of DOE's Rationale For Selecting the Hanford Reservation

Using the land-use approach to site screening, DOE has made its decision to characterize the site at Hanford on the basis of an investigation of one candidate area -- the Pasco Basin -- and no national or regional surveys. This contrasts with the host rock screening approach, where national and regional surveys have led to several candidate areas. Investigations of salt geologies at the Paradox Basin alone have delineated four such areas: Salt Valley, Gibson Dome, Elk Ridge and Lisbon Valley.

If the BWIP SCR is to provide some basis for future NEPA decisions, DOE should have shown in this document how the Pasco Basin compares to other candidate areas, both those dedicated to nuclear activities (e.g., in South Carolina, Idaho, New Mexico and Nevada), and those selected by other screening approaches (e.g., Louisiana, Mississipi, Texas, and Utah.)

The NRC will be required to prepare an environmental impact statement (EIS) to support its decision on whether to authorize construction of a geologic repository. Under NEPA and the NRC procedural rule (46 FR 13973), the alternative repository sites presented in the EIS must be among the best that can reasonably be found. The staff recommends that DOE confirm as soon as possible that Hanford is a reasonable alternative under NEPA before too much is invested in a site that may turn out to compare unfavorably with sites selected under other screening approaches, or even sites selected under the land use approach.

3.3.3. The BWIP Site Screening Process

The BWIP site screening process begins at the Pasco Basin (1600 mi^2) and ends at the reference repository location (18 mi^2). In the SCR, DOE says that three objectives guided its progression from large to smaller land areas:

- maximize public health as safety

- minimize adverse environmental and socioeconomic impacts
- minimize system costs

Before these objectives could be realized, DOE had to make some assumptions on how a repository would be constructed, how it would operate, and what impacts it may have. These assumptions are listed in reference 5.

Having established its objectives and made its assumptions, DOE prepared screening guidelines. (see p.p. 2.2-9 through 2.2-13 of the SCR) The guidelines were depicted on map overlays and applied in five steps to areas under study. Starting at the Pasco Basin, each step successively reduced the land area that would be considered in the following step. At the end of each step the following areas were defined:

Step 1 - Pasco Basin or "study area" (1,600 mi^2 -- candidate area in NRC terms)
Step 2 - "candidate area" (several hundred mi^2)
Step 3 - subarea (approximately 100 mi^2)
Step 4 - site locality (up to 50 mi^2)
Step 5 - candidate site (approximately 10 mi^2)

The overlay process ended with nine candidate sites, all on the Hanford Reservation.* At this point in the screening program DOE discontinued using overlays and began a comparative evaluation of the candidate sites. Five attributes were used to provide a means of comparing and eventually differentiating among the sites. The attributes include:

- Distance to discharge areas
- Structural geologic considerations
- Site biologic impact
- Distance to potentially hazardous facilities
- Potential for repository expansion

These attributes were used quantitatively to measure a condition or characteristic of the candidate site by means of an actual unit scale, such as distance, or a constructed scale that quantified the conditions. For example, under the site attribute, "potential for repository expansion," a site condition which would allow expansion for, say, 6 miles would be given a higher value than one which would allow expansion for 2 miles. In a similar fashion, all the conditions or charac teristics for a particular candidate site were assigned a value, the values were totalled, and the sites with the highest score were considered the most attractive. The results of the comparative evaluation of the candidate sites showed that the central portion of the Cold Creek syncline area (Figure ___, Appendix A) should be evaluated in the final screening phase.

The final phase of site-selection delineated a reference repository location (18 mi^2) within the Cold Creek syncline area. Ranking criteria, analogous to the attributes used in the previous screening phase, were applied to each candidate site in the Cold Creek syncline area. The ranking criteria include:

- Structural geology
- Seismicity
- Geohydrology
- Man's activities
- Host rock characteristics
- Environment

*At one point in the site screening process, DOE evaluated 4 subareas (each approximately 100 mi^2) located outside the boundary of the Hanford Reservation but within the Pasco Basin. Three subareas were eliminated from consideration because of "land use" and hydrological conflicts. The remaining subarea was dropped because of conflicts in "land use," hydrology, bedrock dip and tectonic stability. DOE concluded from this evaluation: "Because no area of the Pasco Basin outside of the Hanford Site was found to be obviously superior to areas within the Hanford Site, further study to identify (repository) site localities was concentrated on the subareas of the Hanford site." (Ref. 4)

Then the sites were ranked using a statistical analysis (see ref. 5 for details). The outer boundaries of the sites ranked highest describe the reference repository location (Figure__, Appendix A).

3.3.4. Staff Analysis of the BWIP Site-Selection Process

The screening guidelines applied to the Pasco Basin enabled DOE to find nine candidate sites for a geologic repository. The SCR says that these guidelines are comparable to those resulting from the NWTS screening process. The SCR then references a document comparing the BWIP screening guidelines to those recommended by the National Waste Terminal Storage Program (NWTS) (Ref. 13). This document, entitled Comparison of NWTS-33(2) Criteria and Basalt Waste Isolation Project Screening Considerations, RHO-BW-EV-IP, compares BWIP criteria with a draft version of the NWTS criteria (Ref. 12). The final NWTS document (Ref. 12) recommends several screening criteria which were not applied at BWIP. Specifically, the staff finds that the following NWTS criteria were omitted from the BWIP site-selection process:

A site's geohydrology should:

1. be compatible with retrieval.
2. minimize contact time between groundwater and waste.
3. permit modeling.

A site's geochemistry should have characteristics compatible with retrieval. The site should also be located so that chemical interactions between radionuclides, rocks, groundwater, or engineered components will not unacceptably affect system performance.

A site's resources, such as water, should be evaluated to assess the likelihood of human intrusion (BWIP guidelines cover mineral resources but not water).

A site should be located such that risk to the population from transportation of radioactive waste can be reduced below acceptable levels to the extent reasonably achievable.

There should be no significant unexplained differences between the siting criteria for the national waste disposal program and the siting guidelines for a repository project within that program. Unless each repository project builds its site screening guidelines from the NWTS criteria, there can be no common basis for comparing alternative repository sites in different geologic media. Without a comparative analysis of alternative sites, NRC may be unable to find that the site selected for characterization is "among the best that can reasonably be found" -- that is, that the criteria, methodology, and decision process used in screening it are reasonable.

One example of the possible risks of using different guidelines for different repository projects is that under the NWTS criteria, DOE would have evaluated water resources as well as mineral resources, but under the BWIP guidelines, no such evaluation was required. Given the arid environ ment of the Pasco Basin and the expected agricultural growth, water resources may be a limiting factor when repository construction begins. In its discussion of legal and institutional factors affecting site selection, DOE should also have included a discussion of pertinent State and federal water rights.

Another deficiency in the BWIP guidelines that would have been corrected by conforming them to NWTS criteria, in the view of NRC staff, concerns transportation factors. DOE did not consider transportation guidelines until the locality phase of site screening. Transportation impacts will not be limited to the locality of the proposed site alone. High level waste must be transported across the nation to reach a repository at Hanford, Washington. To enable NRC to make timely, well-documented judgments on the reasonableness of BWIP as a siting alternative, the staff recommends that DOE evaluate both transportation and water-use impacts at the earliest practicable stage in its detailed investigations at Hanford.

In sum, although the reference repository location may well be at least as good as any location within the Pasco Basin, the selective application of NWTS criteria in choosing the candidate area makes it difficult for NRC staff to judge whether the site would compare reasonably with other sites. BWIP should not omit any of the NWTS screening criteria, nor any of the siting surveys, without some explanation. Selective implementation of the NWTS criteria can create inconsistencies among repository investigations in different geologic media. For example, the Office of Nuclear Waste Isolation (ONWI), which is investigating domal salt for a potential repository site, is using terminology different from BWIP. In reference 14, an ONWI document, each of seven salt domes is called a "candidate site" while the same term does not appear in the BWIP program until DOE was fairly certain where the repository would be located. Likewise, reference 14 refers to a "repository location" but does not define its size. At BWIP a repository location can cover an area of up to 50 mi^2 (except for the reference repository location which covers 18 mi^2).

3.4 Recommendations for DOE Site Characterization Plans and Program

Based on our review of the BWIP SCR and its supporting documents, the staff offers the following comments and conclusions regarding the DOE site selection process.

> DOE did not adequately compare the Pasco Basin candidate area to other candidate areas selected by the land-use and other approaches, as described in the NWTS National Siting Plan. The staff believes that DOE should make this comparison and make it public as soon as practicable. The candidate areas should be defined in a manner consistent with 10 CFR 60, and should be compared at the same level of detail as the area survey phase of characterization in the National Siting Plan. An early comparison of candidate areas will ensure that only reasonable alternatives will be considered during the licensing process.
>
> From the information presented in the SCR, none of the other sites that were evaluated by DOE within the Pasco Basin appear to be preferable to the reference repository location.
>
> Most of the differences between the BWIP and NWTS siting criteria can be attributed to the different geographic starting point for the host-rock and land-use screening concepts. These differences will complicate a comparison between BWIP and repository projects have followed the NWTS guidelines more closely.

Because of the information gaps in the SCR described above, NRC staff believes that the DOE conclusions about the site listed in Section 3.2 above are insufficient to enable the Commission to find that the reference repository location at Hanford is "among the best that can reasonably be found."

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4 GROUNDWATER

4.1 General Discussion

DOE has provided a description of the hydrogeologic system within the Pasco Basin in Chapter 5 of the SCR. A conceptual model of groundwater flow is incorporated into a numerical groundwater model, and the numerical model is exercised using selected values from the BWIP data base to determine flow paths and to calculate hypothetical travel times in Chapter 12 of the SCR. 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 of the SCR.

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

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

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

> 10.112 Overall System performance Objective - This section requires that release 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.

4.2 Summary of Conclusions and Assertions in the SCR

The hydrogeologic system description in the SCR includes:

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

The groundwater flow systems in the basalts are characterized by DOE as follows in SCR Chapter 5 and Executive Summary:

> "The flow systems in the basalts are confined" (5.1-198).
>
> "Little vertical groundwater mixing is occurring between shallow and deep flow systems in non-structurally deformed areas" (5.1-202).
>
> "Some vertical groundwater mixing is believed to take place along major geologic structures such as the Umtanum Ridge-Gable Mountain anticline" (5.1-202).
>
> "The principal discharge area for the deep basalts is still suspected to be south of the Hanford Site" (5.1-202).
>
> "The presence of interbeds has no discernible influence on vertical-head distributions" (5.1-202).
>
> "The principal confining units in the basalts are the low-permeability columnar zones of individual basalt flows" (5.1-202).
>
> "The structural discontinuity trending north between the Cold Creek Valley and the reference repository location has a significant influence on local hydraulic heads and, therefore, groundwater-flow directions" (5.1-203).
>
> "The overall groundwater flow direction for both shallow and deep basalts in the Cold Creek syncline is toward the southeast" (5.1-203).
>
> "Lateral groundwater movement occurs within sedimentary interbeds and flow tops" (5.1-203).
>
> "Vertical groundwater leakage between different permeable zones takes place across the interiors of basalt flows" (5.1-203).
>
> "Groundwater beneath the Hanford Site from both confined and unconfined aquifers discharges to the Columbia River" (Executive Summary, 6).
>
> "The recharge areas are the highlands adjacent to and beyond the Hanford Site to the west" (Executive Summary, 6).

"There are some zones between flows that transmit large quantities of water; such zones are found primarily in the upper basalt section within the Wanapum and Saddle Mountains Basalts" (Executive Summary, 6).

"Data in hydrologic properties, hydraulic heads, and groundwater chemistry indicate that lateral groundwater flow takes place primarily through permeable flow tops and sedimentary interbeds. Vertical groundwater flow or mixing between these different permeable layers may occur along geologic structures such as the Umtanium Ridge - Gable Mountain anticline" (Executive Summary, 6-7).

"Results of modeling also indicate that is minimum groundwater travel times from the repository site to the accessible environment, a distance defined by the U.S. Environmental Protection Agency in its draft regulation as 10 kilometers, would be on the order of 10,000 years or greater" (Executive Summary, 7).

These conclusions by DOE are derived primarily from data from small-diameter drill-holes that have been adapted to the purpose of single-point hydraulic testing. These holes have been logged geophysically for delineation of flow tops and flow interior so that single-hole hydraulic property tests could be 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 were incorporated into one or more numerical models for purposes of travel-time calculations.

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. 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)" (SCR, p. 12.4-51).

"With regard to waste isolation effectiveness, the results of the near-field performance analysis support the following conclusions:

o 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.

- o The groundwater flow paths from both candidate repository horizons are predominantly horizontal and are restricted to the Grande Ronde Basalt" (SCR, p. 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" (SCR, p. 12.4-53).

4.3 Discussion of Selected Issues

4.3.1. Site Issue Analyses and Appendices

The master list of NRC and DOE site issues is presented in Appendix C of the SCA; Appendix C compares the DOE and NRC issues. Groundwater issues identified by the NRC are similar to the work elements described by the DOE in Chapter 13 of the SCR. Some of these issues and related topics are treated in the appendices of the SCA. The appendices pertinent to prediction of groundwater travel time are:

Appendix E - Potential for Large-Scale Pump Tests in the Grande Ronde.

Appendix F - Use of Hydrochemistry for Flow System Interpretation in Hanford Basalts.

Appendix G - Limitations of Packer Testing for Head Evaluation in Hanford Basalts.

Appendix H - Hydrogeologic Data Integration for Conceptual Groundwater Flow Models.

Appendix I - Drilling Mud Effects on Hydrogeologic Testing.

Appendix J - Structural and Stratigraphic Characteristics Related to Groundwater Flow at the Hanford Site, Washington.

An analysis of each of the issues identified in Appendix C has been prepared by the NRC staff. These Site Issue Analyses (SIA's) have been developed based on staff review of the SCR and supporting documents and the on-site reviews conducted within the last two years. The SIA documents are located in the NRC Public Document Rooms. Selected issues of major significance are discussed below.

4.3.2 Conceptual Groundwater Models and Impact on Travel Time Assertions

Issues related to conceptual groundwater models at the Hanford site are analyzed in SIA 1.1.7. DOE's conceptual groundwater model, as presented in the SCR, is based on a geologic system which consists of areally continuous layered basalt flows and interbeds of the Columbia River Basalt Group. The main features of this model are that the flow systems are layered and confined, with interbeds and flow tops acting as aquifers and low-permeability columnar basalt zones acting as 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 in the SCR that little vertical flow occurs between shallow and deep flow systems in undeformed areas. Some vertical flow is hypothesized to occur along major geologic structures, particularly to the north of the RRL. The SCR further asserts that the overall groundwater flow direction in the basalts is to the southeast and that 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 are based. The layered geometry with minimal vertical conductivity of interflows and minimal horizontal hydraulic conductivity of flow tops establishes a very conservative base case for travel-time calculations.

DOE has placed major emphasis on the concept that the hydrochemistry of groundwater defines separate shallow and deep flow systems. 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 and clearly premature (Appendix F). The primary boreholes for the hydrochemical data base are several miles outside the accessible environment. While hydrochemical data can constitute useful, supportive information, primary evaluation of a flow system and its hydrostratigraphic units must be based on the hydraulics of the flow system. The hydraulic data can be refined by additional geologic information on structural control (Appendix J), the results of state-of-the-art, large-scale hydraulic testing (Appendix E), and accurate, continuous measurements of hydraulic head (Appendix G).

NRC staff concludes also that the conceptual model presented in the SCR depends heavily on information from holes DC-6, DC-14, and DC-15, which are located near the river, well outside the proposed 10-kilometer radius from RRL to the accessible environment. Data from holes RRL-2, DC-12, and other holes near the RRL are to a large extent not considered in the development of DOE's conceptual model. More fundamentally, the basic inputs needed for the model - hydraulic properties, hydraulic heads, and hydrogeologic boundaries, including both external boundary conditions and internal hydrogeologic discontinuities - are so uncertain that several alternative conceptual models can be defended based on existing data and the present state of knowledge. NRC staff concludes that the data base presented in the SCR supports any of the following conceptual models (Appendix J), all of which would lead to different travel time estimates:

1. The DOE's conceptual model of an areally continuous layered system with low vertical leakage.

2. An areally continous layered system with high vertical leakage.

3. An areally discontinuous layered system with high vertical leakage that performs hydraulically as a large-scale, homogeneous, anisotropic system.

4. An areally discontinous layered system bounded by high permeability structures.

5. An areally discontinuous layered system bounded by low permeability structures.

6. Any combination of the above, with groundwater discharging toward the north (rather than toward the south), up the dipping limb of the Gable Butte anticline.

NRC staff concludes that the hydrogeologic setting of the Hanford site is such that large-scale, state-of-the-art hydraulic testing can effectively evaluate the groundwater system (Appendix E). Such tests would reduce uncertainty about large-scale hydraulic continuity and would provide true values of basic hydrogeologic parameters. Such tests also could be used to test directly many of the possible conceptual groundater models. Confidence limits on travel-time calculation would be increased concomitently. Also, without such tests, travel-time calculations cannot be supported, due to insufficient information to establish definitively the uniqueness of any of the 5 aforementioned conceptual models.

4.3.3 Hydraulic Parameters

Issues relating to the measurement and interpolation of hydraulic parameters are included in SIA's 1.1.1.1 and 1.1.1.2. The near absence of state-of-the-art, multiple-hole pump test measurements of hydraulic parameters and the absence of any measurements of vertical hydraulic conductivity constitute a major limitation with respect to definition of areal hydraulic continuity, flow paths, defense of any of the 5 aforementioned conceptual models, and consequent travel-time calculations. Single-hole tests of horizontal hydraulic conductivity are essentially point-tests that do not describe adequately the bulk hydraulic conductivity of the hydrostratigraphic unit tested or its areal hydraulic continuity. Furthermore, the SCR indicates no correction applied to hydraulic conductivity tests for the effects of drilling mud ("skin effect"), which often yields hydraulic conductivity values that are lower than the true value (Appendix I). Effective porosity and dispersivity have been measured in only one test interval at the site. In the NRC staff's opinion, unrealistically high values of porosity have been used for travel time calculations. This practice over-maximizes predicted travel times.

Of the hydraulic parameters (vertical hydraulic conductivity, horizontal hydraulic conductivity, effective porosity, dispersivity, and matrix diffusion), only horizontal hydraulic conductivity has been measured at more than one location and in more than one test interval; two of the five parameters, vertical hydraulic conductivity and matrix diffusion, have not been measured at all. Appendix F discusses the importance of matrix diffusion to travel-time calculations. In light of the uncertainty inherent in the present limited data base, the NRC staff cannot support a high level of confidence in any unique conceptual groundwater flow model. Under these conditions numerous values of travel time over a range of several orders of magnitude can be defended.

The method by which measured hydraulic properties are interpolated to describe the properties of numerical modeling units is a major unresolved issue. Available data indicate large variations in measured parameters (i.e., of horizontal hydraulic conductivity) which do not facilitate reliable interpolation of values, even by geostatistical techniques (Appendix H). The range in values is such that a random distribution with a large coefficient of variation can be defended. Randomness could be shown by the use of unstratified statistical analysis to indicate that the geologic section or portions of it are homogeneous and that additional drill holes will yield only random values. This observation is a common consequence of point-source hydrogeologic testing programs. Unfortunately, in this case such ranges occur within the same modeling unit. This problem is not likely to be rectified by data from additional, single-hole hydraulic property tests.

The NRC staff concludes that the uncertainties in the values of hydraulic parameters presented in the SCR are too large to assign credence to any unique conceptual or numerical model which depends on these data. In particular, travel time calculations cannot be accredited any degree of confidence because a unique model cannot be defended.

The staff concludes that large-scale, long term, multiple-well pump tests can be designed, run and analyzed to provide much of the information required to characterize and ultimately model the BWIP site (Appendix E). The design can include determination of vertical saturated hydraulic conductivity at several locations.

4.3.4 Hydraulic Head

Issues related to hydraulic head are discussed in SIA's 1.1.1, 1.1.2, 1.1.3, 1.1.7, and 1.1.8. The distribution of hydraulic head at the site leads to multiple interpretations of groundwater flow directions (north or south-southeast) can be defended. It is not clear whether the complex distribution of hydraulic head is a product of measurement error associated with packer technology (Appendix G) or a product of the existence of a very complex flow system at the Hanford site (Domenico, Ford and others, 1981, p. VI-9). For example, the SCR (Table 5-9) states that the hydraulic gradient between RRL-2 and DC-15 is toward the southeast. The gradient between DC-12 and DC-15 is stated correctly to be toward the southeast also. The 3 drill-holes are very nearly colinear in plan. But comparison of heads between holes DC-12 and RRL-2 reveals that the gradient is to the northwest (toward the repository). In fact, gradients in all geologic units between holes DC-12 and RRL-2, holes DC-16A and RRL-2, and holes DB-15 and RRL-2 are north-northwest toward the repository. Accurate knowledge of hydraulic head is essential to define boundary conditions, to calculate hydraulic gradients, and to calibrate numerical models. The absence of a unique interpretation of direction of hydraulic gradient produces considerable uncertainty with respect to travel time calculations. These problems can be minimized by the installation long-term head-monitoring devices.

4.3.5 Hydrogeologic Boundaries

Hydrogeologic boundaries are considered in SIA's 1.1.2 to 1.1.8. Knowledge of hydrogeologic boundaries is essential to the development and interpretion of conceptual and mathematical groundwater flow models. Hydrogeologic boundaries, such as structural and stratigraphic discontinuities, have not been defined by state-of-the-art tests. Neither have such continuities been considered in formulating areally continuous layered hydrostratigraphic sections for purposes of numerical modeling (Appendix J). The DOE has reported (SCR, Chapter 3) that discontinuities may range in scale from the columnar fracture of inverted fans to major fault zones of the scale of Gable Mountain-Untanum Ridge structure; that the structures may be high permeability or low permeability discontinuities; and that the discontinuities are not necessarily perpendicular to the stratigraphy. The SCR (p.3.5-32) states: "The occurrence of such 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." While DOE has recognized the potential importance of such structural discontinuities, they are not incorporated into tests plans nor into conceptual or numerical groundwater models. The impact of such boundaries on travel-time calculations can be significant.

4.3.6 Mathematical Groundwater Model

Issues related to mathematical groundwater modeling are analyzed in SIA 1.1.8. DOE has made conclusive predictions of groundwater flow paths and travel times based on numerical modeling. The NRC staff believes that the computer code (PORFLO) used by DOE to identify flow paths and to calculate travel time is 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 by state-of-the-art testing methods. In this regard the NRC staff expresses reservation with DOE's conceptual model (4.3.1), with the nature and description of boundary conditions (4.3.4), and with the basic hydraulic data input to the iterative process (4.3.2). The model presented in Chapter 12 cannot be calibrated with available head data. Large-scale pumping tests using multiple observation wells along with continuous head measurements could provide much of the data needed to test alternative conceptual models and to supply reliable boundary conditions and hydraulic parameters for a numerical model.

The NRC staff believes that PORFLO can be used satisfactorily for identifying areas of uncertainty and for evaluating proposed strategies for mitigating uncertainties, provided input data and boundary conditions are identified by state-of-the-art technologies.

4.4 Evaluation of DOE's Plans and Program

Evaluations of DOE's plans and program for each of the NRC groundwater issues are presented in SIA's 1.1 to 1.6. This section of Chapter 4 deals only with evaluations of DOE's plans and programs for issues of major significance identified in Section 4.3 preceding.

4.4.1 Conceptual Model

DOE proposes to refine the conceptual model presented in the SCR primarily with data from a continuation of their present program of relatively small-scale, primarily single-hole hydrogeologic testing.

The NRC staff concludes that DOE's plans must be revised to include details of state-of-the-art, long term, large-scale testing in order to address alternative conceptual models. The testing program is inherently limited by its reliance on DOE's current conceptual model. Travel-time calculations are predetermined to a large extent by the acceptance of this model.

4.4.2 Hydraulic Parameters

DOE plans to collect new data on hydraulic conductivity, effective porosity, and dispersivity through tests in 30 single boreholes, 4 dual boreholes, and one 3-hole 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, and it will test only the south side of the RRL. With the exception of the DC-16 cluster and considering the problems of disturbance, alteration and small bore-hole diameter, the proposed test program is essentially a continuation of the present single hole test program. The SCR offers no plans to test matrix diffusion (Appendix F). Because of the large variability of parameters in the existing data base (Appendix H) and problems associated with the drilling and testing methods used by DOE (Appendix I), the NRC staff questions the reliability of the current values of hydraulic parameters. The NRC staff concludes that the continued reliance on small-scale hydrogeologic testing is not likely to improve significantly the reliability of the data on essential hydraulic parameters. Under the present plan only one set of state-of-the-art data points (DC-16 cluster test) can be obtained for vertical saturated hydraulic conductivity.

4.4.3 Hydraulic Head

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.

Accurate knowledge of hydraulic head distribution is a critical component in formulating defensible conceptual models and in calibrating numerical models (4.3.3). 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 rational for this position is exemplified by the conflicting information on groundwater flow direction as interpreted from bore-holes RRL-2 - DC-12 - DC-15, (See 4.3.3).

4.4.4 Hydrogeologic Boundaries

DOE plans to use a paired-hole test on the the McGee well to test the nature of the apparent hydrogeologic boundary 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. No specific plans are persented in the SCR for testing these or other possible hydrogeologic boundaries.

Hydrogeologic boundaries cannot be investigated adequately by geologic means. 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 NRC staff concludes that it will be difficult to produce defensible conceptual or mathematical groundwater models that can yield reliable travel-time calculations.

4.4.5 Mathematical Modeling of Groundwater Flow

DOE plans to verify and benchmark the computer codes used in modeling. DOE plans to use data and mathematical modeling intensively in parametric and sensitivity studies as a guide to model input. DOE recognizes the need to develop stochastic models to identify the predictive uncertainty indicated by the current deterministic models.

The NRC staff believes that computer code development is proceding appropriately. However, DOE presents no plans to simulate alternative conceptual interpretations. Furthermore, the NRC staff reiterates its position that the numerical models constitute boundary value problems, and that reliable results must be based on state-of-the-art data input.

4.5 Recommendations on NRC Key Issue Resolution by Licensing Time

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

1. Bulk hydraulic parameter values should be determined, 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. Bulk tests should include determination of vertical saturated 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, improve hydraulic head data, provide information on hydrogeologic boundaries, and permit calibration of the numerical model so that more accurate travel time calculation can be obtained.

2. Boundary conditions supported by hydraulic data must be delineated. Modeling should not rest exclusively on boundary conditions that are hypothetical or inferred.

3. Effective porosity must be measured as several locations in several hydrostratigraphic units. State-of-the-art, multiple-well tracer tests are required for this purpose.

4. Matrix diffusion data should be obtained; these data may be important to transport modeling and travel time prediction.

5. The above data should be used to characterize the hydrogeologic system by testing alternative conceptual models as well as systems performance.

6. A definition of hydrostratigraphic units must be developed for the BWIP site. If hydrostratigraphic units are to be identified as flow tops and flow interiors, then it is necessary to demonstrate that they are hydraulically continuous, discontinuous, or some combination thereof. The SCR contains no information of this type, nor does it contain plans for addressing this problem. The SCR merely assumes that hydraulically continuous layers exist for the purposes of modeling.

REFERENCES

1. Domenico, P., Remson, I., and others, "Hydrology and Geology Overview Committee Reports and Responses from the Basalt Waste Isolution Project," Rockwell Hanford Operations, RHO-BWI-LD-50, 1981.

5 GEOLOGIC STABILITY

5.1 General Description

5.1.1 Geologic Stability Information in the Site Characterization Report (SCR)

As required in 10 CFR 60 (proposed), Chapter 3 of the SCR summarizes the status of geologic investigations at the BWIP site. 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 in geomorpholoy, stratigraphy, regional tectonics, seismology rotary and cored boreholes, and mineral resources. Chapter 13 of the SCR summarizes elements of work needed to resolve outstanding issues.

5.1.2 Relevant Sections of 10 CFR 60 (proposed)

60.113(a)(2); 60.122(b)(1),(c)(4, 6, 13, 14, 15, 16, 17, 21)

5.1.3 Relation of SCR and NRC issues

The critical issues, with work elements, concerning geology and long-term geologic stability as defined by DOE are found in Chapter 13 of the SCR. A comparison of the DOE issues and work elements and the NRC issues is presented in Appendix C. The DOE issues and work elements are, in general, consistent with the issues identified by the NRC staff.

5.2 Summary of Main Conclusions and Assertions in the SCR

The two critical issues (with work elements) identified in the SCR are:

- What are the geologic, mineralogic, and petrographic characteristics of the repository horizon and surrounding strata within the RRL (SCR 13.3-1, Issue S.1.A.).
- What are the nature and rates of past, present, and projected structural and tectonic processes within the geologic setting and the RRL (SCR 13.3-17, Issue S.1.B.)

Investigations that DOE states have satisfied regulatory criteria are:

- Determine the nature of igneous activity within the Pasco Basin area [SCR 13.3-37, Work Element (W.E.) S.1.23.B.].
- Determine the potential for, and effect of, failure of existing or planned man-made surface water impoundments (SCR 13.3-75, W.E. S.1.44.D.).
- Evaluate the effect of possible climatic changes (SCR 13.3-78, W.E. S.1.49.D.).
- Determine whether the range of geomorphic conditions since the start of the Quaternary Period indicates instability from a waste isolation standpoint (SCR 13.3-83, W.E. S.1.60.D.).
- Determine the likelihood of repository exhumation due to extreme erosion over the next 10,000 years (SCR 13.3-84, W.E. S.1.61.D.).

5.3 Discussion of Critical Issues in 5.2

5.3.1 Critical Issue S.I.A.

Stratigraphic and structural discontinuities [Site Issue Analysis (SIA) 5.1 and 5.2] may impact facility design, constructability of the facility, groundwater inflow into shafts and drifts, and regional groundwater flow (refer to S.I.A. 1.1.4 and 1.1.5). Preliminary conclusions by DOE on the occurrence of stratigraphic and structural discontinuties in the Columbia River Basalts in the Cold Creek Syncline are based on limited outcrop data (SCR Fig. 3-29, page 3.5-30) and widely spaced borings (SCR Fig. 3-18, page 3.5-16). Contrary to assertions that considerable continuity of intraflow structures exists in some flows such as the Umtanum (SCR 3.5-28), the occurrence of thick flowtop breccia and a correspondingly thin dense interior in the Umtanum Flow in boring RRL-2 points to the lack of predictability of intraflow features in the Grande Ronde and specifically in the Umtanum flow. Other stratigraphic discontinuities such as flow-pinchouts, vesicular zones and fanning joints are equally difficult to characterize.

Subtle structural discontinuities (fault/fracture zones) have not been adequately investigated to date. The NRC staff considers that minor faulting is pervasive throughout the controlled zone. Tectonic breccias occur in "all deep boreholes within the Hanford Site and are principally in the Grande Ronde and Wanapum Basalts" (Meyers and Price, 1981 page 6-3). The number of micro-earthquakes reported in the controlled zone (U. of Wash. 1982) is further evidence of faulting in the vicinity of the Reference Repository Location (RRL). To date, geologic investigations have been aimed at identifying known or inferred structures (SCR Fig. 3-52, page 3.7-29) bounding relatively intact blocks of rock (C.W. Meyers, 1981). The NRC staff considers that the structure and stratigraphy of the "intact" blocks of rock are far more complex than is indicated in the SCR. It is further considered by the staff that the groundwater flow model presented in Chapter 12 of the SCR does not take into account the structural and stratigraphic discontinuities that are, in all probability, present in the controlled zone (SCA Appendix J).

above and below, or the structural discontinuities. The impact of these discontinuities on groundwater flow must be assessed through appropriate hydrologic testing (see Chapter 4). The majority of existing borings were located away from known structures (Meyers and Price, 1979)in order to develop accurate stratigraphic control. The limited number of additional borings planned will not characterize stratigraphic and structural discontinuities.

Planned investigations to evaluate the regional structural and tectonic setting of the Pasco Basin lack the level of detail necessary to evaluate the adequacy of the plans. Review of existing regional geologic data (W.E. S.1.11.B) should have been largely completed during site screening. General 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 fndings of WNP-2 and Skagit power plant investigations (NRC 1982).

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 "the complex relationship between basalt surface elevation and Bouguer gravity emphasizes the need for borehole control before making absolute interpretations from the gravity data." No plans to obtain borehole control to ground truth the geophysical interpretations were presented in Chapter 13 of the SCR.

As stated in 5.2 above, DOE considers that five investigations have satisfied regulatory criteria. The NRC staff agrees, with the exception of W.E. S.1.23.B, "determine the nature of igneous activity within the Pasco Basin area." DOE's conclusion that volcanic activity in the Pasco Basin is extremely unlikely is based primarily on frequency studies (Johnpeer et al., 1981). The frequency of volcanic activity in the Pasco Basin has been studied in detail but the causes remain unresolved.

5.5 Recommendations

- Other structural studies should be factored into DOE's structural analyses of the Yakima folds. Semi-quantitative balanced cross-sections, producted in response to USGS 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) tectonic model which does not require "faulting along the Umtanum fault below the level of the fold core "(SCR, ch. 3, p 3.7-20). Modeling of a series of profiles from aeromagnetic data (Weston Geophysical), across and between, the brachyanticlines (short anticlines) SE of Rattlesnake Mountain (RAW), show identical signatures and are aligned so that "the interpretation of a linear, throughgoing fault is difficult to avoid" (USNRC NUREG-0892 1982, 2-16). These data impact the evaluation of fault continuity along RAW. NUREG-0892 concludes (p. 2-17) that RAW is a throughgoing right lateral strike-slip fault with some reverse oblique motion, and is about 120 km (74.6 mi) long. On this basis, it is concluded that this structure is capable of a Ms=6.5 earthquake.

- There are no explicit plans to investigate micro earthquake triggering mechanisms in the controlled zone, or for determining the size and frequency of structures (faults, fractures) on which earthquake swarms occur.

- With the exception of the investigation of the Nancy linear, there are no planned geologic borings to investigate known or inferred geologic anomalies.

- The NRC staff considers that the subsurface geology of the RRL and the Cold Creek Syncline, including stratigraphic and structural discontinuities, is to complex to adequately characterize through geologic and geophysical investigations. The influence of geologic structures on groundwater flow must be investigated by hydrologic testing (Ch. 4, appendix G). The lateral continuity, thickness and elevation of dense basalt of the host rock is critical to repository design (see Chapter 7).

6 GEOCHEMISTRY

6.1 Introduction

The most likely means of migration of radionuclides from a HLW repository to the accessible environment is transport in solution by groundwater. After a waste package is breached, radionuclide-containing groundwater moves through the rock environment. As it moves, interactions among the leached radionuclides, rock and water will result in changes in type (speciation) and solution concentration of the radionuclides and thus affect their migration behavior. Some interactions will accelerate or retard the movement of radionuclides whereas others will deplete or increase radionuclide concentrations. Hydrothermal interactions controlled by geochemical reactions and kinetics will dominate the near-field host environment. Radionuclide reactions with fracture surfaces and the kinetics of these reactions at ordinary (ambient) temperatures will control the far-field host rock environment. The total effect of geochemical processes and conditions on radionuclide migration is important in performance assessment modeling of radionuclide release to the accessible environment.

6.1.1 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/vesicule 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 given.

6.1.2 Relevant Sections of 10 CFR 60 (Subpart E)

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

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

6.1.3 Relation of SCR and NRC Issues

NRC major issues and BWIP SCR issues are similar. These issues (questions) address Eh-pH (hydrochemical) conditions, and radionuclide speciation, solubility and sorption (See Appendix C).

In general, these issues are aimed at defining:

1. What are the (geochemical) environmental conditions of the waste package and released waste initially, and as they change with time?

2. What are the conditions and processes affecting radionuclide retardation, in the near field and the far field, through time?

6.2 Summary of SCR Geochemical Conclusions and Assertions

Based on preliminary scoping studies consisting of limited experimental work and the review and reference to selected published work, the following preliminary conclusions and working assertions are made:

1. The prevailing Eh environment at Hanford is estimated to have low oxidation potential (reducing conditions) at this time; after waste emplacement and closure, it is estimated that the repository will quickly return to some low oxidation potential (SCR Page 5.1-131, 5.2-26, b.2-5, 6.4-3, 6.7-1);

2. Radionuclide release is, in most cases, solubility controlled, not leach-rate limited (SCR Page 6.4-1, 6.4-3, 6.4-11);

3. In the in situ groundwater environment, the backfill, host rock and fracture filling minerals have a high sorptive capacity for released radionuclide species (SCR Page 6.1-20, 6.4-1);

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

5. Groundwater and the mineralogy of the likely backfill and the host rock and fracture-filling are subject to little or no permanent alteration due to waste emplacement (SCR Page 6.3-9, 6.3-10, 6.3-11, 6.3-12, 6.3-13);

6. Based on chemistry of the groundwater, there is no vertical mixing of groundwater between aquafers (SCR Page 5.1-132, 5.2-139);

7. In modeling radionuclide transport, the geochemical retardation of radionuclides can be accounted for by simple use of a Kd or sorption isotherm data in solute transport codes (SCR Page 6.4-6);

8. Analogs of waste form, canister, overpack, backfill and repository suggest that hazards from HLW in repositories should be minimal (SCR Page 6.5-8); and

9. Basalt stratigraphy within the Grande Ronde is chemically distinguishable (SCR Page 6.1-3, 6.1-11).

As discussed in Section 6.3, it is the opinion of the NRC staff that all of the above conclusions are premature and only superficially supported by data presented in the SCR.

6.3 Analysis and Discussion of Issues, Conclusions and Assertions in the SCR

In order to validate the foregoing preliminary assumptions the following questions were established by DOE to generate specific experimental strategies:

1. What are the geologic, mineralogic, and petrographic characteristics of the candidate repository horizons and surrounding strata within the reference repository location?

2. Do the very near-field interactions between the waste package and its components, the underground facility, and the geologic setting compromise waste package or engineered system performance?

3. Are the geochemical and hydrologic properties of the geologic setting sufficient to meet NRC proposed requirements?

4. What is the relative importance of the waste form leach rate versus solubility of key radionuclides in the near-field environment for controlling release?

5. 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?

6. To what degree does the geologic setting retard migration of key radionuclides from the engineered system in meeting U. S. Environmental Protection Agency draft release criteria?

7. How can very near-field waste/barrier/rock materials interaction data, as measured experimentally, be extraploated over time to reasonably assure that overall waste package and repository performance meets regulatory criteria?

Based on the foregoing questions, a list of work elements was developed as a strategy for site characterization. This approach implies that RHO will develop the geochemical data needed for the resolution of issues.

However a detailed description of experimental strategy and analytical techniques was not provided. In addition, conclusionary statements concerning the status of geochemical inquiries are seldom referenced. Further, conclusions, when referenced, are often broad generalizations or extrapolations based on very narrowly conceived and executed research results. Also, field measurements that do not fit repository conditions preconceived to be necessary are de-emphasized in favor of calculational procedures that give "acceptable" answers. Finally, there is little discussion concerning the methods of assessment of uncertainties on existing data or data to be obtained. Thus, in general the geochemistry discussions in the SCR, as presented, are not technically sound.

6.3.1 Solubility

A major mechanism for controlling release of radionuclides from a repository in basalt is precipitation or incorporation of radionuclides into new mineral phases. These solubility contraints are discussed in Appendix U. Solubility is dependent on environmental conditions such as Eh, pH and groundwater composition. Site specific solubility data are crucial to establishing reproducible sorption data (See 6.3.2). Further, it is possible that the low solubility of some radionuclide species may significantly limit radionuclide mobility and potential dose to man. However, much of the available solubility data are not valid for high temperature conditions.

The SCR presents data on only the solubility of simple oxides. In addition, most of the discussion in the SCR is based on solubility data which come from measurements or calculations made at laboratory room temperature and under oxidizing conditions. These conditions are significantly different from the anticipated repository conditions presented in the SCR.

A number of components will be present in most groundwaters which can form solution complexes with the actinides. For example, hydroxide, carbonate, phosphate, fluoride, chloride, silicate, and sulfate are important anions (Allard, 1982). Borate, leached from the waste glass, could also be important. Since hydroxide and carbonate anions are common to all groundwaters, these anions are expected to play a dominant role in determining the speciation and solubilities of the important actinides (Allard, 1982; Moody, 1982). According RHO (1982), groundwater chemistry data is either preliminary or non existant and SCR statements based on oxide solubilities are premature.

Further, SCR solubility estimates could be unrealistically low if disequilibria conditions allow supersaturation conditions. For high-temperature near-field conditions the solubility limit may far exceed the limit for a low temperature environment. Also, SCR solubility estimates may not be relevant in the very near-field of the repository where pH may be significantly lowered by:

i. hydrolysis reactions
ii. gamma ray induced production of H_2O_2.

Finally, the arguments in this section, which relate solubility to MPC are not relevant to high-level waste repository performance after closure. Post closure release limits must comply with applicable EPA standards. The draft EPA standard (40 CFR 191) is in terms of cumulative releases over a 10,000 year period and is not in terms of MPC.

6.3.2 Sorption

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 the waste leachate as it is transported by groundwater through the Hanford controlled zone (See Appendix T). To date, "hydrochemistry inputs to sorption studies are preliminary or non-existent (RHO 1982)

Preliminary sorption work at RHO deals primarily with batch sorption experiments carried out under oxidizing conditions (SCR Page 6.4-6 through 13). Therefore, many of the distribution coefficients and the sorption isotherms given contain values relevant only to oxidizing conditions. This problem was addressed briefly through the use of hydrazine to 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.

No discussion is presented to describe how speciation will affect either the distribution coefficients or sorption isotherms. Batch sorption experiments give valid distribution coefficients only if a single radionuclide species dominate in the test solution (See Appendix T). Actinides, as well as fission products such as technetium and selenium, are notorious for simultaneously displaying more than one species in solution (Ref.___). Different species may exhibit very different sorption behavior and under such conditions the measured distribution coefficient is only an average of the values for the different species, weighted by the quantities of the species present. Therefore, the presence of a dominant, highly sorbted species would mask species undergoing little or no sorption (Coles and Ramspott, 1982).

Also, the RHO isotherm data presented in SCR Table 6-21 are only results; no supporting bases are presented. The sorption data used to define the isotherms were presumably generated using batch techniques. These data are subject to variations due to changes in:

i. Solution Eh, pH, T, groundwater composition, and
ii. Substrate surface chemistry.

Further, the distribution coefficient (Kd) data presented in SCR Tables 6-18, 6-19, 6-20, and 6-21 are subject to considerable error due to variability in temperature, Eh, pH, and groundwater composition (Apps. 1978). In addition, serious complications can arise from experimental techniques, particularly batch tests. The RHO data presented were determined using an "equilibrium batch technique." Because of the large discrepancies and errors resulting from batch technique many authors have recommended that they not be used (for example Miller and Benson, 1983; Reardon, 1981; Apps, 1978). The data reported in Table 6-20 of the SCR, for example, demonstrate the wide variability in results. For examples, under the anticipated range of Eh:

1. The reported Kd for ^{237}Np/basalt ranges from 7 to 2,000;
2. The reported value for ^{233}U/basalt ranges from 1 to 650; and
3. The reported value for ^{79}Se ranges from 2 to 18.

Apps (1979) has summarized the sources of uncertainty associated with Kd measurements (Appendix T). This variation in data will introduce serious uncertainties in radionuclide transport modeling if bounding values are not established.

Historically, much emphasis has been placed on distribution coefficients in evaluating the likelihood of significant retardation of radionuclide in geologic media. The degree of confidence that we place in Kd values should be dependent on the strength of the data from which they are derived. Assumptions made in reaching conclusions must be substantiated. Assessment of very reducing conditions in the Umtanum groundwater has not been substantiated. Until it is, a conservative bounding approach should be taken as opposed to the opposite position that "extremely reducing conditions (are) expected for a repository in basalt" (SCR Page 6.4-6).

Similarly, BWIP should adopt a consistently conservative position on pH, and not as on SCR page 6.4-6 assess U sorption at pH of "7 to 8" where it is greater while assessing sorption of other elements at pH 9 to 10.

6.3.3 Redox Potential (Eh)

The redox potential (Eh) determines the stable state of the radionuclides entering the groundwater system effects radionuclide solubility and sorption. Under reducing (low Eh) conditions the solubility of most relevant radionuclides is low and the formation of positively charged species is favored rather than the negatively charged species formed under oxidizing conditions (See Appendix S). Oxidizing Eh conditions (values greater than 0.0 volts) enhance radionuclide transport by promoting the formation of more mobile (high-valence) species. According to RHO (1982) redox data at RHO is either preliminary or conjectural in nature.

For example, measured Eh values in Grande Ronde basalt groundwater range from -0.22 to +0.21. DOE staff considers the measured determinations imprecise, particularly the positive values, and present calculated values to suggest that the Eh is in the range of -0.45 volts. However, oxygen has been detected in some groundwater samples and the oxidation of the sulfide in pyrite has been cited as a likely source of sulfate ($SO_4{}^{2-}$) found in the groundwater system. Further, the measured Eh values (-0.22 to +0.21) are consistent with water which has equilibrated with the phase assemblage (common to Hanford basalt fractures and vesicles): smectite + clinoptilolite + silica.

The high ferric to ferrous ratio of the smectite (nontronite) is also consistent with the measured (oxidizing to slightly reducing) Eh values.

While it would be geochemically advantageous to have highly reducing conditions associated with the proposed repository, the less reducing measured values cannot be dismissed out-of-hand.

As presented, BWIP redox calculations are based on assumptions that iron bearing minerals in the host rock control the redox potential and yield predicted Eh values near -0.45 volts. However, the calculated Eh values, based on mineral assemblages, have not been verified. For example, the magnetite-pyrite couple is assumed to buffer the basalt groundwater system Eh. Both magnetite and pyrite must be common minerals throughout the basalt deposit in close proximity to each other and in contact with the groundwater in order to control Eh. It is well established that magnetite is a primary phase (at 3%-7%, SCR Page 6.1-15) in Grande Ronde Basalt, but is generally isolated from flowing water. Pyrite is reported to occur as a rare secondary mineral along cooling joints and in fractures. Until evidence for the wide spread coexistence of pyrite and magnetite can be established along groundwater flow paths, repository

Eh conditions based on this couple, while possibly reducing, are not established.

Finally, besides being physically unrealistic, the procedure for Eh calculation makes unrealistic assumptions as to the applicability of the work of Eugster and Wones (1966). According to Eugster and Wones (1966) H_2 gas must be shown to be confined to the basalt water system for the proposed buffering mechanism to be valid. Further, the mechanism under consideration must be shown to operate at the temperatures under consideration. For example, Eugster and Wones (1962) suggest a minimum practical limit of about 600°C for the Hemetite magnetite buffer (an important limiting buffer assemblage in the SCR-Page 11.4-13). Last, it is not clear that the calculated oxigen fugacities of 10^{-68} to 10^{-37} (SCR Table 11-26) are realistic.

6.3.4 Composition and Stability of Solid Phases (Rocks, Minerals, Volcanic Glass)

The general mineralogy, petrography and chemistry of the Grande Ronde basalt are known, with the exception of flowtops and interbeds. Only a qualitative description of the composition of the interbeds is given. There is little or no information on the composition of the glassy mesostatis (SCR Page 6.1-20), yet it is claimed to control groundwater pH (SCR Page 6.1-15).

On a chemical basis it appears that the Umtanum flow is distinct from the McCoy flow. However, it also appears that the Umtanum and underlying low Mg flows of the Schwana sequence are chemically equivalent. When one compares the standard errors and arithmetic means of the analyses of the Umtanum and low Mg flows in SCR Table 6-1, the two flows are chemically similar and cannot be discriminated solely on a chemical basis. Also the data presented in SCR Figure 6-3 differ from the summary of data reported in SCR Table 6-1. For example, the maximum TiO_2 value reported in SCR Table 6.1 for the low Mg flows is 1.96%. However, more than 15 measurements for the same flow in SCR Figure 6-3 are greater than this value. Further, zirconium and chromium data for the Umtanum flow and the low-Mg flows are nearly identical and cannot be used to discriminate among these flows.

Finally, the RHO position is that montmorillonite will be stable under repository temperature conditions since (K) in groundwater is low. This is contradicted since:

1. Illite is found to occur in Grande Ronde Basalts at temperatures of about 55°C (see SCR page 6.1-22, Paragraph 1) and therefore stable over long time periods in far-field repository conditions;

2. Illite is formed in hydrothermal experiments using Grande Ronde Basalt as a starting material Koster van Gros, A81); and

3. The potassium concentration in the groundwater increases markedly with elevated temperature due to dissolution of the potassium-enriched basalt glass promoting illite stability (SCR Page 6.4-8).

4. Hydrothermal experiments (Koster van Gros, 1981) cited to support stability of the fracture filling mineral montronite (SCR Page 6.1-20) and of bentonite, a proposed backfill ingredient (SCR, Page 11.3-38) were not designed in a manner which would prove bentonite stability. The scenario proposed on SCR 6.1-20 is unrealistic and makes inappropriate use of the Kostar van Gros (1981) data. In addition, the proposed stability (SCR Page 6.1-20) would require immediate saturation to provide the necessary water pressure to ensure stability of the smectites.

The relative stabilities of montmorillonite and illite under the expected repository conditions needs confirmation. Illite occurs in the Grande Ronde basalts indicating a long term stability. It might be expected that dissolution of potassium-rich mesostasis (at elevated temperatures) could increase the stability of illite over montmorrillonite in altered basalts and lead to the alteration of the bentonite backfill to illite, thereby reducing its sorptive and swelling capacity.

6.3.5 Uncertainity Assessment

6.3.5.1 Transferability-Lab To Field

There are uncertainties involved in the transferability of information derived from short-term laboratory-scale (simplified) experiments to natural systems. The only field test discussed involved granite not basalt. It is not clear how these results relate to basalt.

RHO proposes use of Kds and isotherms determined on crushed basalt interbed materials and ground up fracture fillings in performance assessment modeling. It is not clear how surface effects due to grinding and differences in rock/water ratios between field and laboratory are accounted for in the models used.

6.3.5.2 Natural Analogs

The discussion of natural analogs draws no direct relationship to the conditions at the RHO. It is unfortunate that RHO does not follow up on their suggestion (SCR Page 6.1) to use the Hanford basalt water system as a natural analog. There is little evidence that knowledge gained from studies of natural analogues of repository systems or components has been utilized by RHO in the laboratory, in the field or in modeling. There are uncertainties involved in the transferability of information derived from the study of ancient or existing natural processes to the assessment of future geochemical changes in a repository. However, an understanding of natural analogues is needed to extrapolate in time and in space, the data and concepts derived from short-term lab-scale simplified experiments and modeling exercises. In addition, because of ICRP revisions of the relative toxicity of radionuclide, DOE calculations (SCR Figure 6.21) that high level waste is less toxic than a uranium ore body, is no longer valid. Because of these revisions the relative toxicity of an ore body is now calculated to be lower and high level waste is calculated to be substantially more hazardous.

Finally, the discussion of uranium solubility greatly over-simplifies the issue. The solubility of uranium is strongly controlled by complexation as well as Eh conditions. The stable oxidation states of radionuclides are a function of pH as well as Eh. High pH conditions such as are reported for the Grande Ronde groundwater makes oxyanions more stable than they would be under neutral or low pH. Therefore, mobile solution species which might not occur under the more acidic conditions at Oklo or other ore bodies must be considered.

6.3.6 Diffusion

The mechanism suggested by RHO for Eh control involves the coupling of groundwater and basalt, silicate and oxide phases. This presupposes diffusional processes. The same can be said for the RHO pH buffering mechanisms. However, there is no discussion of the nature and rates of the diffusion process in fracture filling, fresh basalt, interbeds, flow top and backfill material.

6.4 Evaluation of SCR Plans and Program

The RHO plan for issue resolution involves bounding both near-field and far-field geochemical conditions and processes. Single-phase experiments involving waste/water/rock interactions under the anticipated environmental conditions are under way. Basic radionuclide solubility data are being integrated into the sorption experiment program. The sorption experiments are conducted using basalt, bentonite (possible backfill material) and typical basalt fracture-filling material.

6.4.1 Solubility/Sorption

Specific DOE plans to identify and evaluate solubility constraints include:

1. Continue experiments on the interactions between the waste form, basalt and groundwater over the temperature, pressure, and Eh-pH conditions expected for the repository,

2. Use of 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 evaluate conditions that could lead to radionuclide colloid formation and subsequent particulate transport, and

4. Investigate the possible effects of the radiation field on radionuclide geochemical behavior.

DOE plans to determine the sorptive capacity of backfill and host rocks involve the uses of static and dynamic (flow through) experiments to determine the sorption behavior of key radionuclides (equations developed from these data will be used to evaluate radionuclide retardation factors for use in transport modeling).

There is however, inadequate discussion of the following:

1. The experimental and analytical techniques to be used in order to determine solubilites and sorption.

2. What Eh (redox) conditions are being considered in experiments.

3. The validity of the expected conditions in the repository environment condition chosen.

4. Which radionuclide compounds are to be studied in the solubility experiments. In addition, it is not clear whether single species will be examined one at a time, multispecies will be examined (important for determination of possible synergistic effects) or both.

5. What strategy will be used to determine of the speciation of critical radionuclides (calculations to date have considered only simple oxide species).

6. The types of colloids expected to form (e.g., oxides, hydroxides, oxy-hydroxides and organics).

7. The expected influence of the radiation field on radionuclide behavior at high T.

8. The methods of determining transferability of BWIP data and data generated by other labs trying to simulate the in situ conditions of the basalt repository to actual repository conditions.

9. The methods of assessment of uncertainties of existing data or data to be obtained.

10. What computational schemes are required to address solubility, speciation, and colloidal transport in a complex fluid flow regime.

11. What is the BWIP QA/QC program for solubility geochemistry.

6.4.2 Redox Potential (Eh)

DOE work elements address:

1. The determination of methods and techniques that can be used to provide in situ Eh measurements for the reference repository location, and

2. Determining the extent of Eh-pH and groundwater compositional control by the basalt.

However, the SCR presents no discussion of what experiments will be conducted. The NRC needs to review the experiments with regard to applicability and transferability of the experimental data to in situ conditions. This requires a detailed discussion of the methodology, precision, accuracy, and assumptions.

Also, the only mechanism advanced by RHO/DOE (Jacobs and Apted, 1981) to explain Eh control in the basalt groundwater system, estimated Eh values in the very reducing range of -0.45 to -0.55 volts. This is not consistent with measured values for Grande Ronde waters presented in Chapter 5 of the SCR which range from oxidizing (0 to + 0.21 volts) to slightly reducing (0.0 to -0.22 volts).

Finally, the hydrothermal experiments used to estimate repository Eh are not representative of repository conditions and therefore possibly yield anomalously low Eh values. The experiments referenced are not representative since:

1. The solid materials (crushed basalt) will be subject to: (i) weathering in the storage piles prior to emplacement in drifts; (ii) alteration in an oxidizing hot-dry environment prior to resaturation of water; and (iii) alteration during an oxidizing hot steam environment. Therefore, the faces of the basalt chips will be at least partially coated with a weathered rind.

2. The hydrothermal experiments used a fixed water to rock ratio. However, water will continuously flow through the repository. The water flowing through the repository will have an Eh in the range of +.21 to -0.22 volts.

Therefore, the buffering capacity of the crushed basalt may not maintain an Eh of -0.45 to -0.55 volts since it will be offset by the continuous flushing of these relatively more oxidizing groundwaters through the backfilled zones. The interaction of the more oxidizing groundwaters with the basalt will produce coatings on the basalt chip surfaces which will isolate the buffering capacity of the fresh basalt surfaces from the groundwater system.

6.4.3 Compoition and Stability of Solid Phases (Rock, Minerals, Volcanic Glass)

DOE geochemical characterization activities include the definition of host rock properties, such as the composition and petrology of primary and secondary minerals. Also, specific work elements are aimed at determining the effect on radionuclide mobility of changes in the primary and secondary mineralogic conditions in the near-field and the far-field.

The "plans" section of the SCR does not discuss specific plans for making the determinations described. The proposed extensive use of hydrothermal studies with 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 filling in the near-field and far-field is relevant to define reactions in these zones. Two sub-issues alluded to briefly in the BWIP/SCR, effect of radiolysis on Eh values and effect of groundwater K concentrations on Na-bentonite stability, are not dealt with explicitly in BWIP plans but seem important enough that their investigation should be pursued.

6.3.4 Uncertainty Assessment

6.3.4.1 Field Tests

It is not clear what kind of field tests are planned or are actually being carried out. The only field tests discussed involved tests in granite. It is not clear how these results relate to basalt.

6.3.4.2 Analogues

RHO gives no specific plans for analog research. The expectation of using metal artifacts, nickel-iron meteorites and basalt ion deposits is exposed, however, no discussion is provided to demonstrate how the environments of these analogs is related to BWIP conditions. The cooper analog study, RHO-BW-ST-26P, is not of any use since there is no metion of cooper in the SCR as a container material.

6.5 Recommendations for Site Characterization Plans and Program

The open items involved with coming to closure on this geochemical characterization work will require studies and experiments to bound radionuclide solubility, sorption, Eh, and pH, under present and anticipated repository temperature conditions.

6.5.1 Solubility

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 believes that solubility determinations (steady-state condition) should be approached from both over- and undersaturation directions.

6.5.2 Sorption

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 under expected repository conditions will be necessary to define radionuclide retardation in the near-field and far-field.

The NRC considers that in determining sorption behavior:

(a) Isotherms should be the minimum acceptable approach for quantitative analyses,

(b) Constant Kd's are only acceptable if isotherm determination shows that the isotherm is linear,

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

(d) The effects of speciation on sorption needs clarification, and

(e) The importance of colloidal transport should be addressed.

6.5.3 Redox

Current Eh field measurement techniques may be inadequate for repository investigations because the sensing electrode may respond preferably to certain aqueous species and not provide a representative measurement.

Therefore, in addition to electrode measurement of Eh, RHO effort to define ion couples is well targeted. However, to close out this item, Eh calculations have to be corroborated by petrographic observations and further experiments on the rate of oxygen comsuption by basalt must be run. Also, work has to be done to characterize the site-specific Eh envirnonment and to run experiments under site-specific Eh conditions as well as the changed conditions resulting from waste implacement.

6.5.4 Temperature

In general, increased emphasis should be given to performing experiments over a range of temperature, that bound those which will occur over the long-term in a repository. To date, insufficient attention has been given to the effects of temperature on geochemical processes. Most testing has been done under ambient conditions. The geochemical behavior of a waste-package, backfill, groundwater and surrounding host rock may alter significantly as temperature rises in the repository. Thus, site characterization should include not only identification of existing conditions, but also assessment of the kinds and magnitudes of changes caused by repository induced hydrothermal processes.

6.5.5 Analogues

Greater emphasis should be placed on understanding the causes and effects of naturally occuring processes that are relevant to assessing long-term repository and waste package performance.

Emphasis should be given to forming a connection between the natural occurrences of radionuclide migration being studied (natural analogues), site specific repository conditions 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 is more than a paper exercise.

6.5.6 Geochemistry and Performance Assessment Modeling

Communication among researchers and performance assessment modelers concerning the establishment of what is necessary for numerical performance assessment models, needs to be increased. For example, geochemists no longer give much credit to Kd values although modelers continue to use these data. It is clear from the geochemical research performed thus far, that indiscriminant use of an empirical "Kd" (without taking into account a solubility and/or speciation function along with the several important and site specific parameters which control the extent to which these functions vary (viz: pH, Eh and temperature, etc.) will lead to unrealistic and unsupportable assessments. In addition, it is important for geochemists and modelers to determine through preliminary performance assessment the levels of precision and accuracy that can be tolerated in individual geochemical parameters. Finally, performance assessment models should better reflect the significance of the uncertainties inherent in the determination of geochemical retardation.

6.5.7 Planned Testing, Instrumentations, and Monitoring

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 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. 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 attenuation relies on demonstrated accuracy 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 addition, results and procedures should be accurately reported and widely circulated in order to increase peer review.

6.5.7.1 Suggested Format for Description of Planned Tests and Experiments

1. Title of Test or Experiment.

2. Purpose of Test or Experiment -Summarize why the test or experiment is proposed and what types of information will be obtained.

3. Objective(s) - Discuss how the results of the test or experiment will relate to the overall site characterization program. Describe how the results will be used to help resolve specific information needs or unresolved issues.

4. Descriptive Summary - Summarize the methods, techniques, and analyses used in the test or experiment. Describe in detail the procedures expected to be used.

5. Quality Assurance - Describe the quality assurance program to be applied to data collection, and discuss the limitations and uncertainty in the data.

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

7. Contact - Provide the name, address, and telephone number of the person(s) to contact concerning the status of the test or experiment.

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7 REPOSITORY CONCEPTUAL DESIGN

7.1 General Discussion

This chapter of the DSCA deals with certain aspects of the repository conceptual design affecting the site characterization activities at the BWIP site. Many aspects of the conceptual design related to surface facilities are not discussed here. Discussions are confined to issues related to design of subsurface facilities controlling the test plans for the site characterization activities.

As required in the standard format and content guide (Ref. 7-1), SCR contains information related to geoengineering (Chapter 4), and a description of the conceptual design (Chapter 10). The procedural rule (Ref. 7-2) requires that a conceptual design be presented in sufficient detail to allow an independent NRC staff assessment of the adequacy of the DOE's site characterization program. This requirement is partially met by the contents of Chapter 10 of the SCR.

The proposed technical rule (Ref. 7-3) provides details on the performance objectives for a nuclear waste repository site and associated designs. Performance objectives include: (1) containment of wastes for 1,000 years; (2) limiting of release rates to 10^{-5} of the inventory per year; (3) maintaining of retrieval option for a specified period of time; and, (4) protection against radiation exposures and releases during repository construction and operation. Further, the proposed rule requires assurance that the natural and engineering barriers together shall meet the proposed EPA standards specifying releases to the "accessible environment." The SCR discusses all of the above performance objectives with varying degrees of detail.

The repository design issues are identified in Chapter 14 of the SCR. Most of the design issues identified in the SCR compare favorably with the NRC issues identified by the staff independently, with the exception of the issue of retrievability. The SCR does not identify retrieval as an issue to be considered during the conceptual design stage, even though discussions related to retrieval are provided in Chapter 10. NRC staff, however, considers retrievability as a key design issue.

Design issues covered in the SCR and also considered important by the NRC staff include: (1) stability and isolation capability of the repository (BWIP issue R.I.A.); (2) rock mass strength (R.I.B.); (3) in situ stress (R.I.C.); and (4) shaft, tunnel and borehole construction and sealing (R.I.D.).

The SCR should have addressed "provisions to control any adverse, safety-related effects from site characterization, including appropriate quality assurance programs" as required (proposed rules, 10 CFR 60.11(a)(6)(iii)). However, no discussions related to adverse effects of construction of boreholes and exploratory shafts were found in the SCR.

7.2 Summary of Key Design Assumptions Assertions and Conclusions in the SCR

Conceptual design presented in the SCR is based on functional design criteria found in Reference 7-4. 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 applicable to either of the candidate horizons. There are five vertical access shafts located on a line parallel to the long axis of the repository. After analyzing eleven alternate arrangements of the underground facilities, a bow-tie arrangement for the shaft pillar layout was considered the optimum from the point of view of haulage and ventilation.

Waste will be emplaced in multiple horizontal holes perpendicular to horizontal emplacement rooms. Waste emplacement holes extend 61 meters horizontally at midheight between adjacent panel rooms. The construction technique and equipment needed for drilling 61 meters long, 686 millimeters diameter horizontal holes in hard rock are yet to be developed.

Shape, size and orientation of various underground openings and pitch of emplacement holes are optimized in the conceptual design based on simplified assumptions and simplistic analyses. Rock mechanics design parameters related to mechanical and thermal characteristics of basalt have been taken from the literature for use in the conceptual design. Strength, modulus and thermal properties used in the conceptual design essentially correspond to those of the intact rock. Stresses induced by excavation and heat load due to waste emplacement have been calculated using the theory of linear elasticity. In situ stress ratio of two (horizontal to vertical stress) has been used in the conceptual design.

The feasibility of boring large-diameter shafts in basalt is as yet unproven, and 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 however, will be excavated by either conventional drilling and blasting techniques or by tunnel boring machines.

The SCR recognizes, and rightly so, that the assumptions concerning geology and other underground parameters contain a measure of uncertainty. In some areas the selected repository horizon may dip, thin, infiltrate water, or otherwise vary in an anomalous manner that precludes development of the repository as conceived in the SCR. The design and construction planning will contain contingency plans to cover such occurrences. Exploratory drifts and pilot holes in advance of repository excavation are planned to provide early warning of anomalies. The SCR anticipates that changes to the current design will be required because of the unanticipated underground conditions.

SCR contains brief discussions related to the type of backfill that will be used to fill up the underground openings and the procedures that may be used in the backfilling operation. The SCR stresses the importance of considering the isolation capability of the overall repository system rather than that of the individual barriers, such as the backfill, or the seal materials used for sealing the boreholes and shafts.

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 as needed. The current approach at BWIP 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.

Retrievability of the wastes has been discussed in the SCR. The current concepts of retrieval have not been fully developed and are assumed to be more or less simple reversal of the emplacement procedures.

7.3 Discussion of Key Issues

Based on the staff's review of the SCR, the following are identified as topics requiring discussion in the SCA: (1) Stability of Openings; (2) Engineered Barriers; (3) Sealing; and (4) Retrievability.

These topics are discussed in some detail below.

7.3.1 Stability of Openings

The design of stable openings is an integral part of the repository design because it affects the integrity of canisters in waste emplacement holes, the ability to retrieve waste, operational safety, and the long-term performance of the engineered barrier system.

The conceptual design of the repository must be based on technically sound criteria and tested predictive models. The subsequent design updates should reflect the new information gathered during site characterization activities. The quantity and quality of data that will be collected during site characterization and their effective use will determine the adequacy of the repository design. From this point of view, the test plans for collecting at-depth data are critical to the design. Conceptual design details presented in the SCR provide the basis for evaluating the adequacy of the proposed test plan. In light of the above, the NRC staff finds that the level of detail of conceptual design presented in the SCR provides insufficient information to evaluate the adequacy of the proposed test plan. Further, the staff notes that conclusions drawn on optimization of the conceptual design including statements of extraction ratios, pitch of horizontal emplacement holes and method of waste emplacement should be considered tentative, until substantiated by in situ test data and detailed analyses.

The staff observes that the design of underground openings presented in the SCR makes inappropriate assumptions and uses nonrepresentative design parameters. For example, the use of 200 MPa intact rock strength, and assumed elastic behavior for analyses of the thermal and mechanical response of jointed rock mass are unrealistic. Also, assumptions of in situ stress ratios and magnitudes are at best only approximate estimates until verified by at-depth testing. Even at this conceptual design phase, the extent of the disturbed zone and accompanying stress distribution around underground openings must be recognized. The sensitivity of the opening stability to the stresses induced and their effects on basic design concepts should be assessed.

The staff is concerned that the design process and associated test plans (See Appendix Y) related to stable openings as presented in the SCR have not taken into account geologic and hydrologic variability. For example, the rationale for choosing one repository horizon in preference to the other is not provided in the SCR. Determining the thickness and elevation of the dense basalt and its lateral extent is crucial to the repository design. The proposed test plan does not identify how and when the repository horizon will be chosen and its geometry defined. These concerns should be addressed in future SCR updates. Specifically, the updates should provide the following:

- o An overall design logic explaining the relationship between the stability of openings to the overall performance of the repository should be provided. The relationship between in situ stress and excavation and thermally induced stresses to the rock mass strength should be defined. In addition, the deformation of the openings particularly the waste emplacement holes, during the retrievability period should be estimated using appropriate test data and models.

- The in situ stress data should be carefully analyzed to provide the design criteria and assumptions for design optimzation. Evidence provided by core discing should be taken into account in estimating the in situ stress conditions. Problems associated with the hydro-fracturing technique and the limitations of the procedure and the resulting data should be identified. (For example, the difficulty in interpreting test data when the vertical stress is the minimum principal stress.)

- Design analyses should reflect the discontinuties in the rock mass. State-of-the-art analytical approaches should be used in analyzing the coupled thermomechanical and hydrological behavior of rock mass (See Appendix O). All existing site specific data at BWIP and the scatter in the data should be accounted for, not just "average" data from the literature.

- Appropriate failure criteria should be developed taking into account acceptable/tolerable levels of deformation of the underground openings. Required degree of conservation should be established based on performance objectives.

The SCR identifies that the design approach and the associated test plans are flexible and may be changed with the availability of new information. In view of the above, the staff opinion is that the logic of the design process including the proposed decision analysis techniques should be clearly stated in future updates in conjunction with any changes and the reasons for changes. Critical input parameters and predictive models and techniques used in the design should be verified on a continuous basis. Such an approach will provide an essential framework for supporting the design of the repository at the time of License Application.

7.3.2 Engineered Barriers

Engineered barriers are a part of the engineered system aiding the isolation capability and thus are important contributors to the performance of the repository. The degree of contribution of the engineered barriers can be measured by comparing the predicted release rates from the engineered system with the (proposed 10 CFR 60) 10^{-5} release rate criterion. Such a comparison will indicate the importance that should be placed on engineered barriers during the Site Characterization Process. Further, this comparison will provide guidance concerning the required specification of the components of the engineered barriers.

The current assumptions and analytical models used in the SCR for predicting groundwater travel times and release rates suggest that apart from the waste package itself, engineered barriers will contribute little to the performance of the repository system. However, sensitivity analyses using a range of possible hydrologic parameters and emplacement configurations may demonstrate that engineered barriers other than the waste package could be significantly more important in controlling release rates than currently stated in the SCR.

The conceptual design considers waste emplacement in horizontally bored holes. The current assumption and estimates of the hydrogeological and geochemical framework and the waste heat load indicate an essentially vertical groundwater flow path through the repository horizon. Under these conditions the potential release rates of almost all radionuclides from the edge of the emplacement hole are essentially the same as those calculated at the boundary of the waste canister. Except, there may be minor delays in commencement time due to the presence of a few inches of backfill in the annulus. (See Appendix W for more details on the contribution of engineered barriers to the overall repository performance.)

In the current BWIP conceptual design, it appears that the contribution of engineered backfill in controlling release rates is small. However, it should be noted that the release rates decrease in an approximately exponential sense as the path length of an engineered barrier with favorable retardation characteristics increases. Therefore, the engineered barriers could become vital contributors to controlling release rates if designed properly. It is possible that future testing and analyses may dictate a change in the current hydrogeological, geochemical, and associated modeling assumptions. In such an event the requirements of engineered barrier design may lead to a change in the emplacement hole configuration. Further, such a change in design may dictate alterations of in situ and other test plans during site characterization to adequately determine the properties of engineered barriers and verify their predicted performance. The SCR has not included such possibilities in its presentation of test plans.

The design of the alternative engineered barriers and their predicted performance should be assessed because they contribute to controlling release rates and therefore to the overall performance of the entire repository system. The staff recommends that the future updates to the SCR contain the logic of how the site issues relate to engineered barriers and how they would be resolved.

7.3.3 Sealing of Boreholes, Shafts, and Underground Openings

The man-made openings required for characterization and access to the high-level waste repository in basalt must be sealed at permanent closure of the facility (proposed 10 CFR Part 60; § 60.2). The regulatory requirements of the proposed rule, provide criteria on the performance of these seals (proposed 10 CFR Part 60; § 60.134) and the information that is needed to assess this performance (proposed 10 CFR Part 60; § 60.142).

The SCR correctly notes the need for identification of performance requirements for sealing (work element R.1.18) as a priority item. Initial efforts at BWIP have been concentrated on computer modeling (RAFSCATT program) to define an acceptable flow rate and travel time for the seal system and other isolation components. In order to adequately determine the importance of the Seal System, reasonable scenarios should be analyzed using representative hydrologic and mechanical input parameters.

The staff is concerned with the schedule for development of seal materials. Figure 17-9 in the SCR shows that selection of candidate materials does not start until 1984. The selection process is a controlling factor in accomplishing the other work elements. Until the selection process has been initiated, other work such as placement methods, testing and verification plans, quality assurance procedures, equipment to be used, etc. cannot be determined. Therefore, in view of the above, the schedule for development of seal materials should start earlier than indicated in the SCR.

The staff is also concerned with the coordination of work elements in the sealing program. Table 14-2 lists 10 work elements designed to resolve the key issues of sealing. Although many of the major concerns of sealing are listed, there is no logical approach presented on how this information will be collected or how it will be used to design a sealing system. The only specific reference to testing to be done is in the exploratory test shaft in Chapter 17 under test program objective 3. This test will measure only depth of disturbed rock, water inflow, pressure differential, and grout strength. These measurements alone will not resolve other major concerns; such as, long-term stability of seals, placement and testing techniques to be used, etc., (See SIA 4.5.1 and 4.5.2). There appears to be a lack of coordination between the exploratory shaft program and the sealing program. For example, plans for sealing the liner inplace in the exploratory shaft include the use of chemical grouts. However, the sealing programs referred to (e.g., the Pennsylvania State University and Waterways Experiment Station, Refs. 7-5 and 7-6) have not yet developed any chemical grouts.

Sealing studies by D' Appolonia (1978, 1980a, 1980b, Refs. 7-7, 7-8 and 7-9) and Taylor (1980, Ref. 7-10) have identified a number of areas that require further investigation for seal design. One of the most important of these is long-term stability of seal materials. Because the performance of the seal system must be adequate over a time span exceeding any reasonable test period, short-term test results must be extrapolated to predict the long-term behavior using analytical methods. This extrapolation must cover the chemical and mechanical stability of the seal materials under a range of conditions: temperatures; variable bond strengths between rock and seal; the effect of drilling mud on bond strength; joint filling; and, many other parameters. Long-term or accelerated laboratory and field testing must serve as the basis for this extrapolation. The SCR does not describe what testing will be done or how the extrapolation will be made.

Another concern is the extent of damage of the rock surrounding opening induced by the excavation process or as a result of the redistribution of stresses. Although the SCR outlines testing to evaluate the disturbed zone in the exploratory test shaft, there are no plans provided to study the scale effects of the disturbed zone for different sized openings (boreholes to 19-foot diameter shafts) or the effects of different excavation schemes (i.e., conventional sinking vs. blind boring).

Other areas not addressed in the SCR are reliability of sealing techniques and quality acceptance criteria to be used in determining seal effectiveness. All of the above concerns should be addressed early in the program to insure reliable seal design prior to license application.

7.3.4 Retrievability

Retrievability must be a planned contingency incorporated into the repository system but need not be specifically designed in as an end item. A repository systems must not preclude retrieval as required and defined by 10 CFR 60, 132(4)(d). Hence, retrievability will affect design, operational, and safety considerations. Events or situations leading to retrieval should have been described in the SCR in sufficient detail to allow the NRC staff to assess the adequacy of retrieval as a planned contingency. It should be noted that retrieval may be full (or total) retrieval of the entire inventory, or local retrieval of one or more canisters for some reason. Such retrieval alternatives need definition (see Appendix X). The SCR does not discuss the local and total retrieval scenarios and the conditions leading to such scenarios.

One of the major concerns at the conceptual design stage is the lack of experience in the constructability of 61 meter long 686 millimeter diameter horizontal hole in jointed rock. Therefore, the constructability of the waste emplacement holes should not be taken for granted until a demonstration can be made. In view of the above, confidence in the retrievability concept cannot be enhanced unless reasonable assurance can be provided by demonstrating the constructability, emplacement and retrieval procedures prior to license application. This can be done at the surface if at-depth demonstrations pose difficulties.

The SCR is vague concerning the impact of retrievability on repository design. Specific provisions of design to accommodate retrieval are not clearly indicated. For example, the six-inch annulus around canisters in the emplacement hole is indicated as aiding cooling of canisters. But, backfilling and retrieval are also aided by the provision of the annulus. If cooling were no longer required, would the benefits to backfilling and retrieval be compromised by minimizing the annulus size?

The rate at which canistered wastes are planned to be emplaced is one of the major factors determining the total effective shaft diameters (Appendix X). This decision must be made early in the conceptual design phase because the shaft diameter will affect many of the repository operations and once fixed, will control the rate of emplacment and retrieval.

The effect of local retrieval on fixed ventilation capabilities should be integrated into the design process. The retrieval scenarios should include but not be limited to cooling the emplacement rooms and treating contaminated air during different stages of repository development. These assessments are required to establish the allowable rate of retrieval, and the safety requirements for the operating personnel, and therefore should be presented in the future updates to the SCR.

The rate of groundwater flow into the repository is as yet undetermined. No scenario is offered in the SCR that considers the effect of groundwater contamination due to a breached canister, nor to the procedures that will be used to detect and control this contaminated water within the repository before it is treated on the surface. Although monitoring for radionuclide releases in the canister waste rooms is mentioned, the threshold values which indicate a breach and the measurement techniques for both air and water borne contaminents are not presented.

The methods used for retrieving breached canisters from horizontal waste emplacement holes assumes that the procedure is a simple reversal of the emplacment procedure. Such retrieval procedures will need to be presented at License Application, incorporating anticipated environmental conditions at the time of potential retrieval. The effect of locally retrieving breached canisters on air quality, operating personnel, groundwater if present, and removal of contaminated materials or equipment must be considered.

Consideration is given to a plan for backfilling the waste emplacement rooms after about five years while still maintaining the retrieval option. Such action, if undertaken, implicitly assumes that no scenarios during the subsequent operational and decommissioning phases of the repository will be encountered which will exceed the design and performance limitations imposed during the initial five year verification period. Cooling and removal (remining) of backfill is mentioned as a pre-requisite to retrieval under these conditions, but this time-consuming and difficult task needs careful development and consideration of their impacts (environmental as well as radiological conditions).

The staff's recommendation is that DOE should adequately consider and develop the impact of these anticipated conditions on equipment performance, personnel safety, and potential radionuclide release into the ventilation and water circuits while cooling, remining, and retrieving. Then, remining of backfill may be maintained as a viable scenario to be incorporated into repository design and operation.

7.4 Summary of NRC Staff Review Comments on Geoengineering and Conceptual Design

This section summarizes the major concerns that require to be addressed in the future updates to the SCR. The following ~~are among high priority~~ items the description in the SCR for which was either missing or inadequate.

1. Discussion of adverse effects of site characterization and how they can be overcome;

2. Discussion of the effects of the variability of the key design parameters on the repository design;

3. Presentation of the logic and rationale for the selection of the repository horizon;

4. Presentation of the rationale for the waste emplacement configuration selection;

5. Discussion on the contribution of the engineered barriers to the isolation capability of the repository system;

6. Test plans for the demonstrating the constructibility of horizontal waste emplacement holes;

7. Test plans for the demonstration of waste emplacement in and retrieval from horizontal holes;

8. Testng program to study the effectiveness and longevity of the seal materials; and

9. Sufficiently detailed Quality Assurance program and details of implementation procedures to provide confidence in the quality of data being collected and to be collected during the site characterization program.

CONTENTS

8 WASTE FORM/WASTE PACKAGE

8.1 Introduction

The BWIP waste package conceptual design (see Appendix A for an illustration of this design) includes three major potential barriers which can contribute to isolation of radioisotopes from the biosphere. 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 are functional in the first case and all three components act to control release once containment has been lost. Depending on the waste form (either borosilicate glass or spent fuel) release rates subsequent to container failure may vary significantly.

8.1.1 Type of Material Presented in the SCR

The SCR presents selected feature of conceptual designs for the waste package including a partial identification of design criteria, limitations in the capabilities of the waste form, an extensive discussion of the anticipated chemical conditions which the BWIP project experts for waste package components, and identification of major areas for research and development related to waste package analyses and validation of these analyses.

8.1.2 Relevant Section of 10 CFR 60

Sections of 10 CFR 60 which are pertinent to the Waste Package Design and 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 section is to identify the most significant technical issues needing resolution 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. (See 10 CFR 60.113 for 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 section identifies issues needing resolution 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 and 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) referenced in Appendix C.

8.1.3 Relation of SCR and NRC Issues

NRC waste package issues, identified in Appendix C and addressed in individual Site Characterization Analyses reflect technical questions regarding the functional performance and interactions of the various parts of the waste package and the underground facility, since 10 CFR § 60.135 required 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 ame. The similarities are identified in Appendix C. However, some NRC issues have no corresponding issue or work element in the SCR.

8.2 Summary of SCR Cnclusions and Assertions

The SCr states that details of work needed to satisfy applicable regulatory and programatic technical criteria and presente in the form of work elements for waste packae 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.

8.3 Discussion of Issues and Evaluation of Site Characterization Plans and Programs

8.3.1 Reliability of Waste Package

A major feature of activities associated with complex new engineering projects is the systematic evaluation and quantification of uncertainties in predicted component or system performance. Such evaluation and quantification can be accomplished by a reliability analysis. Such reliability analyses serve to demonstrate and document the quality of engineering designs and are considered by the Staff to be a necessary part of the BWIP project 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 are also used to identify 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 condition and, hence guide redesign or provide greater assurance of meeting system design or performance goals.

An acceptable methodology for performing such 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 BWIP Site Characterization Report does not identify plans for reliability analyses of the waste packages. This represents a major shortcoming of the project. The staff considers that early identification of reliability design objectives for each of the components of the waste package, as well as other barrier components, is necessary in order to achieve a coherent system design effort, properly documented in accordance with common quality assurance program requirements.

8.3.2 Processes Controlling Waste Package Performance

To accurately quantify the source term the behavior of the waste package over long periods of times must be estimated. 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.

8.3.2.1 Pitting Corrosion

Low carbon steel undergoes both uniform and localized corrosion in aqueous environments. From a review of corrosion mechanisms (Appendix P) the staff considers that the formation of pits is the most likely way in which steel containers will be breached by groundwater in a basalt repository. In the pitting process, many workers have shown that pits form in localized regions where the oxide scale on the metal is broken. Hydrolysis reactions occur and there is acidification inside the waste package. If the pH is sufficiently low the break in the oxide film is not repaired and a deep pit begins to form.

To quantify the pitting of low carbon steel for the BWIP effort, it is necessary to carry out very long-term testing under simulated repository corrosion to ensure that the time to initiate pits is less than the testing time. Tests under more aggressive (accelerating) conditions may also be carried out to obtain pitting characteristics more quickly and the data acquired extrapolated to prototypic BWIP conditions. The more important parameters to measure include (a) the pit initiation time, (b) the pit density and size as a function of time, (c) the pit propagation rate, (d) the Eh/pH, dissolved oxigen, and chemistry of the groundwater between the low carbon steel container and packing material as a function of time, and (e) the effect of temperature and gamma irradiation on the properties in (a) through (d). It is especially important to determine pitting behavior in welded steel since the structure of the weld is very different from that for base metal.

<u>Evaluation of BWIP Plan</u>

A number of Work Elements in the SCR broadly address the characterization of pitting corrosion for the container system, including:

W.1.3.A - Determine the effect of the waste package radiation environment on new field geochemistry, waste package, and barrier material performance.

W.1.11.A - Determine the chemical properties and inflow rate of groundwater and their effect on canister corrosion during the 1000-year containment period.

W.2.2.A - Determine the extent of Eh-pH and groundwater composition control by the host basalt after repository closure.

W.2.3.A - Determine the effects of waste/barrier/rock/water interactions on the performance of the underground facilities of geologic setting.

If these programs are carried out comprehensively, and the container material is exposed for long periods (several years), then the pitting of the carbon steel should be sufficiently understood to determine its effects on radionuclide containment by this barrier.

8.3.2.2 Waste Form Matrix Degradation

In modeling rates of release of the various chemical species of solid nuclear waste forms exposed to chemical degration in aqueous media, a distinction exists between the process which controls the overall degradation rates and transport of material away from the waste form 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 rates (or high dilutions) the degradation rates are largerly 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 the condition prevailing in the environment of the waste package. The solid which the water comes in contact with may have been considerably modified as a result of dissolution of species from the waste form. Under repository conditions, water exchange rates are likely to be low in a large number of cases, and therefore solubilities of the waste form are proposed by DOE to constitute a key factor in determining the long-term durability of the material.

As mentioned above, water subjected to prolonged interaction with the solid becomes substantially altered. This alteration of the groundwater composition 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 in the case of 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 for example, carbonate oxilate, sulfonate, borate and ferro-silicate complexes, and colloidal particales which in turn pickup radionuclides and effect their mobilization (Macedo, Avgado). All of these processes affect transport of radionuclides in the engineered barrier system and hence rates at which they will be released from the system.

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 fully understand the processes described above are not presented in the BWIP 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, Eh and pH, and properly identified as a function of water resident time. Testing to identify complexes and colloidal particles which may occur in the multicomponent system must also be accomplished.

8.3.2.3 Transport

For values of the hydraulic conductivity greater than about 10^{-7} to 10^{-8} cm/sec, the movement of water through the packing material in the presence of a hydraulic gradient may be described by Darcy's law for laminar flow through a porous medium. In any case the rate of transport 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 as well as 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 convective motion of the water upon the Darcian flow with corresponding effects on the mean velocity of the water and thus on the transport of the radionuclides. 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 processes. In addition to diffusion of radionuclides along a concentration gradient, thermally assisted diffusion across a temperature gradient is possible. See NUREG/CR-2755 (1982) and PNL-4382 (1982) for further details.

Evaluation of BWIP Plan

According to the SCR, investigations of these transport processes are in progress or are planned and, in general, appear to be adequate, 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.

8.3.3 Material Properties and Their Changes

Physical chemical and mechanical properties of the waste package components are expected to change significantly. 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 radionuclide release rates, once containment has been lost. The

Staff considers that materials property changes discussed below are of great importance with respect to waste package reliability.

8.3.3.1 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 8.3.3, 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 environmental conditions. The hydrothermal stability of the material is the principal source of uncertainty, depending 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)

Evaluation of BWIP Plan

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, but, with the exception of the lack of mention of hydrothermal conditions in W.1.15.B, the planned approaches to these measurements appear to be adequate.

8.3.3 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 would constitute a compromise of design requirements in 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. Recently it has been suggested that the 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. 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 BWIP SCR identifies effects of hydrothermal condition on the deterioration of both spent fuel and boroselicate glass. Data reported appears to cover relatively high temperature (300°C), however, the 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 SRP 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 [2] claimed to enhance the performance of the glass.

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

<u>Evaluation of BWIP Plan</u>

The BWIP plans pertient to this issue are contained in work elements W.1.12.A and W.1.3.A in Chapter 15. They are only briefly discussed 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 in anticipation of hydrothermal conditions at the waste form.

8.3.3 Containers

The integrity of the container is central to the predictions of the radionuclide containment time and subsequent radionuclide release. 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 (Determine acceptable release rates of key radionuclides from the engineered system as a function of containment time, groundwater travel time to the accessible environment, and water flow through the repository. Until more details are obtained on the research program it is not possible to determine whether water flow through a perforated container to the waste form will be specifically addressed.

8.3.4 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 this staff's conclusion that knowledge of 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.

8.3.4.1 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 physicochemical conditions will affect the corrosion resistance of the container, the degradation of the waste form and the generation of species for transport.

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: $H\cdot$, H_2, H_2O_2, H_3O^+, $\cdot OH$, 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 enhance 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.

At present, 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 which 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 and alkalinity of the solution.

The leaching behavior of waste glass and spent fuel is also dependent upon the environmental conditions described above. Degradation rates of the waste form generally increase with temperature and can be related to the Arrhenius equations. 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 non-trivial fraction of the radionuclides could be released from the waste pakcage as radiocolloids or pseudocolloids. Radionuclides can be sorbed by or complexed with ferrosilicate and aluminosilicate colloids and complexes produced by degradation of the canister and glass matrix. The radionuclide species produced by degradation of the waste form and the rates of radionuclide release from the waste package are very 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 8.3.1 (pitting corrosion) address chemical conditions also. Comments on these work elements also apply to adequacy of BWIP Plan on chemical conditions.

8.3.4.2 Mechanical Conditions

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. Stresses arising from seismic and lithostatic/hydrostatic effects, and bentonite swelling pressures must be addressed in detail if uncertainties in the deformation of the container are to be assessed. In the SCR (Vol. II, p. 6.2-5) it states that the estimated lithostatic stress in the Umtanum layer, based on rock overburden stresses, is about 11.1 MPa. However, work reported by ONWI (1980) shows that in Stripa granite the horizontal component of the stress could be close to double the value calculated from rock overburden considerations. 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.

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 then 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 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 to read 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 if the BWIP container will remain intact during rock movement along a plane intersecting the container.

Evaluation of BWIP Plan

Work Element W.1.2.A will determine conditions which affect design of waste packages, including thermal loading, mechanical loading, shipment, emplacement, retrieval, and after repository decommissioning. Until a comprehensive breakdown is available on the determination 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.

8.4 Summary of Comments on BWIP Plans and Programs

(TBD)

REFERENCES

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2. NUREG/CR-2755, "Discrete Backfill Testing Required to Demonstrate Compliance with 1000-Year Radionuclide Containment," G. Bida and D. Eastwood, Brookhaven National Laboratory, May 1982.

3. PNL-4382, "Workshop on the Leaching Mechanism of Nuclear Waste Forms, May 19-21, 1982 - Summary Report," J. E. Mendel, Pacific Northwest Laboratory, Section 6.8. "Waste Glass - Seabed Sediment Interactions: Observations of the Soret Effect," L. N. Brush, Sandia National Laboratory, August 1982.

4. AESD-3113, "Engineered Waste Package Conceptual Design - Defense High Level Waste (Form 1), Commercial High Level Waste (Form 2), Disposal in Basalt," Westinghouse Electric Corporation, Appendix A, 1981.

5. ONWI-9(4), "Stripa In-Situ Measurements," Office of Nuclear Waste Isolation, 1981.

6. PNL-3873, "Development of Backfill Material as an Engineered Barrier in the Waste Package System," Wheelwright, E. J., and others, Pacific Northwest Laboratory, 1981.

7. Pusch, R., "The Influence of Rock Movement on the Stress-Strain Situation in Tunnels or Boreholes With Radioactive Canisters Embedded in a Bentonite/Quartz Buffer Mass," KBS-TR-22, 1977.

8. NUREG/CR-2350, "Sensitivity Analysis Techniques: Self-Teaching Curriculum," R. L. Iman and W. J. Conover, Sandia National Laboratory, June 1982.

9. Macedo, P. B., et al.; "Aluminosilicate Saturates As A Solubility Control in Leaching of Nuclear Waste-Form Materials" PNL-4382, Workshop on the Leaching Mechanisms of Nuclear Waste Forms, May 1982.

10. Avagadro, C. N., et al.; "Underground Migration of Long-Lived Radionuclides Leached From A Boreosilicate Glass Matrix"; IAEA-SM-257/73, International Symposium on Migration in the Tesstrial Environment of Long-Lived Radionuclides From the Nuclear Field Cycle; July 1981.

11. BNL-NUREG-51494, Review of DOE Waste Package Program, Subtask 1.1, February 1981.

12. Hench, L., NRC Research Contractor Meeting, Silver Spring, Maryland, October 7-8, 1982.

13. Wicks, G. G., B. M. Robnett, W. D. Ranklin, "Chemical Durability of Glass Containing SRP Waste - Leachability Characteristics, Protective Layer Formation and Repository System Interactions" presented at the Fifth International Symposium on the Scientific Basis for Radioactive Waste Management, Berlin, Germany, June 7-10, 1982.

14. McVay, G. L., "Review of Recent PNL Research Activities Related to Glass Leaching Mechanisms of Nuclear Waste Forms, May 19-21," PNL-4382, August 1982.

15. SAND 81-1677, "Effects of Radiation on the Chemical Environment Surrounding Waste Canisters in Proposed Repository Sites and Possible Effects on the Corrosion Process," Glass, R.S., Sandia National Laboratory, 1981.

9 SITE CHARACTERIZATION ANALYSIS: INSTITUTIONAL AND ENVIRONMENTAL FACTORS

9.1 Introduction

In this chapter of the Site Characterization Analysis, the staff will point out the environmental factors at Hanford that could be particularly sensitive to the operation and construction of a geologic repository. Environmental factors will be used as a collective term for institutional, ecological, and radiological factors and air and water quality.

NRC regulation 10 CFR 51 requires DOE to prepare an environmental report as part of a license application for constructing a geologic repository. The NRC, in turn, will prepare an environmental impact statement (EIS) for its decision to authorize the construction of a repository. In preparing the EIS, the staff will depend to a large degree, upon the DOE environmental report for pertinent and reliable data.

The BWIP Site Characterization Report (SCR) describes, in general, the type of environmental data that will be presented in the environmental report. The staff feels that the DOE has overlooked a few environmental issues that, if left unresolved, could protract the NEPA process and delay licensing. In this review, the staff will identify these environmental issues and recommend how they should be resolved.

9.2 Institutional Factors

For the purposes of this review, the staff defines an institutional factor as an objective of an organized segment of society (e.g., state and local laws, Indian tribal views). Institutional factors are not discussed, in detail, in the SCR. DOE has held some public workshops and hearings. The staff expects that these public meetings will become more frequent as licensing approaches.

DOE has not adequately shown, however, the means used to obtain public, Indian tribal and State views during the selection of the reference repository location (see 10 CFR 60.11).

The staff recognizes that Hanford's prior long-standing use and commitment to nuclear activities and existing government ownership may preclude some institutional concerns during the site-selection process. Thus, institutional factors may not occur to the same degree at Hanford as they might at non-DOE land.

9.3 Ecology

The SCR identified three wildlife preserves within the Hanford Reservation: the Saddle Mountain National Wildlife Refuge, the McNary Wildlife Refuge, and the Arid Lands Ecology Reserve (managed by DOE). It appears, from Figure 9-1 in the SCR, that the reference repository location would not extend into any of the wildlife preserves. The SCR does not mention, however, that both the reference repository location and its alternate lie completely within the Rattlesnake Hills Critical Wildlife Habitat (CWH) and 25% of each lies within the Cold Creek Critical Wildlife Habitat (Ref. 1).

Although DOE may be able to construct a repository at the reference repository location without diminishing its ecological value, the DOE should recognize the location's ecological significance. Provisions of the Endangered Species Act regarding critical habitats and endangered species should be considered before DOE commits itself to the reference repository location (RRL). The SCR states: "Two threatened and endangered bird species, the bald eagle, Haliaeetus leucocephalus, and the peregrine falcon, Falco peregrinis are known to occur as winter migrants on the Hanford Site." The SCR does not recognize the status of some other important bird species which nest at the Hanford Site. The prairie falcon (Falco mexicanus) nests in several regions on the Hanford Site, with the number of nesting pairs being approximately six. This species is listed as threatened by the U. S. Department of Interior (Ref. 2). The western burrowing owl and the long-billed curlew (both possibly in danger) nest on or near the reference repository location in significant numbers, particularly around the 200 area (Ref. 2). DOE should keep abreast of the status of all rare, endangered, threatened or special species that could be affected by the construction and operation of a geologic repository.

9.4 Water Use

Given the arid environment of the Pasco Basin, a repository could compete with irrigated agriculture for water. During a repository's construction, large quantities of water will be needed for drilling and dust control. Coupled with continued agriculatural growth, a repository could have an impact on the area's water resources.

The SCR does not estimate the quantity of water needed to construct, operate and decommission a repository. Nor does the SCR identify the source of water or have any programs in place (i.e., work elements) that would obtain water-use information. This apparant oversight of possible water-use conflicts is inconsistent with a previous DOE position which states:

> "The source and quantity of water required for use in repository processes will be established during conceptual design. Water consumption should then be evaluated with respect to the results of an economic geology study (water resources assessment) by the Basalt Waste Isolation Project, which will provide an analysis of historical trends in regional water use. Together, these studies should indicate whether or not a potential conflict on water use exists in the Hanford Site" (Ref. 3).

The staff recommends that DOE complete the water-use studies described above.

9.5 Radiological Background

A shallow depression within the RRL, called "U Pond," has received radioactive effluents since the beginning of the Manhattan Project in World War II (Ref. 2). Additionally, five ditches or ponds, all within the RRL, are used for the disposal of low-level radioactive wastes, certain industrial wastes, laboratory and sanitary wastes and discharge of water used for plant cooling (SCR p.

7.1-11). As a result of these discharges, soil and vegetation within the RRL have a higher concentration of radionuclides than the median concentration for the Hanford area. Of 21 soil samples taken within the RRL, 10 show radionuclide concentrations higher than the Hanford median. ^{90}Sr concentration in the RRL soil (Control Plot No. 2) is more than 1000 times that of the Hanford median. Bioaccumulation of ^{137}Cs and ^{90}Sr into RRL vegetation (Control Plot No.2) is up to 100 times the median concentration for the Hanford area (see Tables 9-6, 9-7, 9-8, 9-9 in SCR), and groundwater beneath the RRL shows H^3 levels from 30 to more than 3000 pCi/ml (Ref. 1).

Knowing that a repository may be constructed in a contaminated area raises some questions on how DOE plans to monitor the repository's performance. Background radiation levels will fluctuate with the continued use of the RRL as a low-level waste disposal site. Likewise, radioactivity in the surface water (including the Columbia River) can change from day to day; depending upon what is being discharged and sampling conditions.

Reference 1 (p. iv-27) has indicated that repository development will be supported by additional monitoring. Yet the SCR contains little information on the repository monitoring program. Although it may be premature to discuss in depth how DOE plans to monitor radiation releases from a repository, the staff feels that DOE should affirm, as soon as possible, that Hanford's background radiation will not interfere with repository monitoring. Thus, the staff believes that DOE should consider how it intends to monitor the radiological performance of a geologic repository at Hanford.

9.6 Staff Conclusion

After reviewing the environmental and institutional sections of the BWIP SCR, the staff comes to the following conclusions:

- Institutional factors played a minor role in the BWIP site-selection process. DOE should explain if Hanford's prior commitment to nuclear activities and federal ownership precluded the need for considering institutional factors.

- DOE should examine, in detail, the ecological significance of the reference repository location. A mitigation plan may be needed for possible adverse impacts on two critical wildlife habitats and several bird species.

- DOE should ensure that a repository's water requirement will not limit agricultural growth.

- DOE should begin to consider how it intends to monitor the radiological performance of a repository at Hanford.

REFERENCES

1. W. C. C., 1981, Study to Identify a Reference Repository Location for a Nuclear Waste Repository on the Hanford Site, RHO-BWI-C-107 Volume I, Woodward-Clyde Consultants for Rockwell Hanford Operations, Richland, Washington.

2. DOE, 1982, Environmental Assessment For The Basalt Waste Isolation Project Exploratory Shaft Construction; Hanford Site, Richland, Benton County, Washington, DOE/EA-0188, U. S. Department of Energy, Washington, D. C.

3. Carrel and Jones, 1980, Environmental Issue Identification For The Basalt Waste Isolation Project, RHO-BWI-LD-25, Rockwell Hanford Operations, Richland, Washington.

10 QUALITY ASSURANCE PROGRAM

10.1 Introduction

As noted in the procedural rule (60.11(a) the NRC identifies Quality Assurance (QA) as a key element of site characterization activities for nuclear waste repositories. An adequate QA program is necessary to assure confidence in the geologic and geotechnical data obtained during site characterization and to assure licensability of the BWIP site. The NRC has established QA regulatory requirements for nuclear waste repositories in proposed 10 CFR Part 60, Subpart G.

The Quality Assurance chapter in the SCR addresses the eighteen criteria of 10 CFR 50 Appendix B, and the material presented appears to be relatively well developed. DOE makes a distinction between technical and administrative documents. The staff considers the destinction very important in developing a QA program for geotechnical investigations. The administrative procedures are based on the 18 criteria of 10 CFR 50 Appendix B. Beyond this, however, it is necessary that detailed technical (or implementing) procedures are developed by 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. Although the framework for an adequate QA program is present at BWIP. 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 description of the role of QA in each program is not included. This is a major concern that will need attention in the SCR update and will be discussed in more detail in the following narrative. Additional comments on the administrative aspects of the QA program will be discussed in Chapter 12.

10.2 Concerns About the Quality Assurance Program

The Standard Format and Content Guide (Regulatory Guide 4.17) states that "QA methods should be presented in sufficient detail to allow NRC to make an independent evaluation of the precision, accuracy, reproducibility, analytic sensitivity, and limitations of data acquisition and analysis methods that was used during site exploration and will be used during site characterization." In many of the technical areas, such a detailed presentation was not given in the SCR. For example, calculated solubility limits were discussed in the geochemistry chapter. However, a discussion of the limitations of the solubility estimations was not given in enough detail for the staff to adequately evaluate it. Without significant details of the QA method (test plans, test procedures, acceptance criteria, etc.) used for each technical area, the quality of the data processed cannot be assessed. Based on this statement and after review of the SCR, the staff is concerned about the effectiveness of the QA implementation procedures. Other concerns involving the implementation of the QA program include the following:

1. Reference of Key BWIP QA Documents. Many documents are referred to in the discussion of the QA program (e.g. implementing functional-procedures manuals, BWIP procedures manual, Rockwell data package manual, Rockwell functional manual, etc.) that are not listed as a reference at the end of the chapter. In fact, no BWIP document is referenced at the end of the QA chapter. If the QA program described in Chapter 18 is being implemented properly, then all of these documents should have been identified as references in the QA chapter. Those containing the technical test procedures to be used during site characterization activities should also be made available for review.

2. QA Organization. Section 18 of the QA Chapter states "Implementation of the quality assurance program for the BWIP is the responsibility of the BWIP Director". This is not considered an acceptable situation for implementation of the QA program. Implementation of the QA program should be a function of a QA Director, not the BWIP Director.

3. Reliability Analyses in Design Control. Section 18.3 should address the methods to be used to quantitatively define the degree to which analytic methodologies are verified for application to any particular time in the repository history. In this regard, it is expected that methods for reliability analyses and requirements for establishing reliability design goals for components and systems should be identified.

4. Identification and Control of Samples. Several comments made in other chapters of the SCR indicate Section 18.8 of the QA program has not or is not being implemented properly. Statements such as "Sample identification, preparation, and testing techniques contributed significantly to this scatter" (Page 4.1-7, Section 4.1.3, Paragraph 1, Sentence 6) may indicate a lack of adequate QA control of samples, as required by criteria VIII of 10 CFR 50 Appendix B. These type of statements should be clarified.

5. Hydrofacturing Calculations

   There are apparent discrepancies in the computation of in situ stress data presented in Tables 4-11. For example, if values of shut-in pressures obtained from Figures 4-17 and 4-18 are used in equations presented on page 4.6-2 to compute minimum horizontal pressures, one can illustrate the discrepancies. Presentation of information such as this in the SCR raises questions about the QA procedures for this test.

6. Test Plans for Major Test Program. Section 18.11 states that test plans are prepared for each major test program. However, few 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 mention or reference any test plan. Since this activity is being conducted in the very near future, a detailed quality assurance program (including a test plan) should be available for the exploratory shaft. Further, few of the planned individual tests listed in the SCR reference

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. None of the plans listed in Chapter 13 through 16 have a designated level of quality assurance to be applied or a discussion of the limitations and uncertainty involved.

The items mentioned above give an indication that the SCR did not include 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 gathered.

11 PERFORMANCE ASSESSMENT

11.1 General

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 (page 12.4-23), and indicate that releases of radionuclide 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.

The Executive Summary also states that current data from the BWIP site indicate groundwater travel times form a repositiory to the environment will exceed 10,000 years and that radionuclide releses to the environment will be within regulatory limits. The Executive Summary does, however, identify radionuclide releases as a key issue to be resolved during site characterization.

11.2 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 rather than actual data.

Chapter 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.

11.3 Discussion of Critical Issues

The NRC staff considers the assertions of Chapter 12 regarding groundwater travel time and radionuclide release rates to be premature and unsupportable. The main reasons for this concern are discussed in the following paragraphs.

11.3.1 Lack of Data

As noted in Section 12.4.5 of the SCR, there is a lack of reliable data for performance analyses. In the absence of adequate data subjective judgment is used. In at least one case--effective porosity of the basalt--the judgment is unsubstantiviated and yields a nonconservative result in the estimation of groundwater travel time. On page 5.1-46 the SCR states that the only experimental data available indicate an effective porosity in the range of 10^{-2} to 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, substituting the more conservative value of 10^{-4} could reduce the calculated groundwater travel times by about two orders of magnitude.

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

Appendix D of the SCA presents the results of a sensitivity analysis conducted by the NRC 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.

11.3.2 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." The NRC staff agrees that groundwater flow in the Pasco Basin may be inherently three-dimensional. 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.

11.3.3 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 site. The NRC 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.

11.3.4 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 relese 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 NRC staff, the staff cannot evaluate the merits of that code and must consider the results of analyses using that code to be speculative and inconclusive.

11.3.5 Incomplete Scenario Set

The set of disruptive event scenarios listed on page 12.2-4 does not include reasonable scenarios such as future groundwater pumping in the Passo 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.

11.4 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 candidate 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 incidental 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.)

11.5 Recommendations

(1) Because of the incentives described above, the conceptual groundwater flow mode must be considered to be tentative, with alterntiave models as distinct prossibilities.

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

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

REQUEST FOR CLARIFICATION OF ITEMS IN SCR
CHAPTER 6 GEOCHEMISTRY

p.6.1- and Table 6-3

- Are the discriprcies in primary numerial phases in para. 1, p.6.1-1 and Table 6-3, p.6.4-12 attributable to typographical errors? If so, which is correct?

p.6.1-6 (Table 6-1) and p.6.1-7 (Figure 6-2)

p.6.1-13 (Table 6-4)

Clay Minerals

- Is an asterisk omitted by nontronite? On page 6.1-3 nontronite is listed as the principal smectite. Which is correct.

- Is the omission of illite (p.6.1-22), vernicalite (p.6.1-11) and chlonite (p.6.1-22) a typegraphic error? If so, which is correct?

Feolites

- Is an asterisk omitted by mordenite? On page 6.1-11 mordenite was stated to be as important as clinoptilolite. Which is correct?

Silica Polymorphis

- Is the omission of chalcedony (p.6.1-11) a typographcal error? If so, which is correct?

- Which silica polymorph is dominant?

Miscellaneous Species

- Pyrite is the only sulfide listed; yet on p. 6.1-11 the presence of more flow one sulfide is suggested. Which is correct? If other sulfides are present, what are they?

- Is the omission of chlorophirite and iddiopite (p.6.1-24) a typographical error? If so, which is correct?

p.6.1-15

- What is reference for last statement in para.6.1.4.7, "Other reactive phases, such as glassy, ______ have also been suggested as a source for fluorine ions..."

- What is reference for third statement in para. 6.1.4.8, "It has been experimentally demonstrated that this glass is the _____ basalt phase..."?

p.6.1-21 (Figure 6-8)

- What is the reference which supports this data?

p.6.1-24 and 25

- What is the reference which supports statements in para. 6.1.6?

p.6.1-25

p.6.2-1

- What is the reference which supports statements three and four in para. at bottom of page concerning the concentration of fluoride in basaltic glass horizons and selective leading of fluoride along interflow contacts.

p.6.2-3 (Table 6-7)

- What is the reference which supports these data?

p.6.2-4 (Table 6-8)

p.6.2-5

p.6.2-6 and 6.2-7 (Figures 6-11 and 6-12)

- What are the error limits (basis) for these data at the candidate repository horizons? If this question is discussed in a reference which supports these data, simply state the reference.

p.6.2-8

- In the bottom para., reference is made in data from the Untanium flow top and bottom which appear in Table 6-9 at bottom of page. The table lists data only for the whole Grande Ronde. If this point is discussed in a reference which supports these data, simply state the reference.

p.6.3-2

- The conclusion at top of the page, "...repository conditions are under control of the basalt and the highly reducing..." is supported by reference to Jacobs and Apted (1981). Jacobs and Apted (1981) is an abstract of an oral presentation. Is a complete reference available?

- What is the reference for the UO_2 solubility thin line in Figure 6-13?

- Para. at bottom of page refers to experiments conducted at Penn State University. What is the written reference which supports these data?

p.6.3-11

p.6.4-2

- What is the reference for the last statement on the page that, "Under reducing conditions, the solubility of plutonium is not extrivated to change significantly..."

p.6.4-3

- What is the reference to the last statement in top para. concerning the valve of americium solubility?

- What is the reference which supports the conclusion in middle of para. two, "...the maximum concentration of uranium, neptunium, americium, and plutonium in the repository itself will be below maximum permissible middle concentration..."

- What is the reference which supports the conclusion which begins on the 14th line from the bottom of the page, "...these concentrations will be considerably lower at the point of discharge to the biophere..."?

- What is the reference which support the last two statements on the page regarding calculation of radionuclide release rate based on solubility?

p.6.4-5

- What is the reference which supports the assertion made in the last statement in the top para, "...solubilities and maximum permissible nuclide concentrations, unlike nuclide velocities, are independent of both the release scenario and the hydrology..."?

p.6.4-8 and 6.4-9 (Table 6-18)

- What is the reference that supports the data specifically mentioned in the top two para. on p.6.4-8 and Table 6-18 regarding temperature effects on sorption and on distribution coefficient?

- The explanation of high valves, in note "c", Table 6-18, is not clear to us. Please explain this interpretation or state a reference which discusses the point.

Page 6.1-2, Figure 6-1

What is the meaning of the notation 19^{+2}_{-13} used in the stratigraphic column? (Maybe in Chapter 3?)

Page 6.1-3, Second Paragraph

Why does cooling of basalt lead to only partial crystallization? The word partial is misleading.

Page 6.1-4, Figure 6-2

Which nomenclature given in this figure has BWIP adopted for their use? It is not clear from the text.

Page 6.1-5, Trace-Element Analyses

In the second to last sentence, the word are should be replaced with is.

Page 6.1-6, Table 6.1

In Table 6.1, it is not clear what is meant by minimum and maximum values. The maximum value for TiO_2 in the low-Mg flows is given at 1.96 wt. %, whereas close to a third of the values shown in Figure 6.3 exceed 1.96 (they go as high as 2.25 wt. % TiO_2). In addition, on Figure 6.3, at least 45 values are plotted for low-Mg flows, whicle only 13 are used for averaging in Table 6.1. What gives?

Page 6.1-10, Figure 6.5

Should the phrase "flow number" read "flow member"?

Page 6.1-15, Apatite

A reference should be added for the suggestion that F^- may be derived from the glassy mesostasis as well as the apatite.

Page 6.2-4, Table 6-8

This table consists of trace element data from groundwaters sampled from the flow top and flow bottom of the Grande Ronde Basalt. The Grande Ronde Basalt is comprised of approximately 18 separate flows, each presumably with a flow top and bottom. This begins so, what is the source of the data given in this table? Which flow top? Which flow bottom? Does the table consider al flow tops and bottoms?

The symbol "Ca" should probably be changed to "Cu."

It is not clear what is meant by "a nonrepresentative" sample? What criteria are used to make this distinction?

Page 6.2-5, Eh

In para. 6.2.3.4 the range (0 to -0.21 volts) of measured Eh values given on page 6.2-5 seems to conflict with the range (+0.21 to-0.22 volts) given in Table 5-28 (page 5.1-125) of Chapter 5. Is this simply a typographical error?

Page 6.3-9, Backfill (continued)

The relative stabilities of montmorillonite and illite under the expected repository conditions still needs to be confirmed experimentally. Illite does occur in the Grande Ronde basalts indicating a long-term stability. It might be expected that dissolution of potassium-rich mesostasis could increase the stability of illite over momtmorillonite in altered basalts, particularly at elevated temperatures.

Should check the appropriate date for the reference Deer et al. (1967?).

Page 6.3-11, Waste-Basalt-Water Interactions

It is not obvious from this discussion (para. 6.3.3.1) or the original reference (Komarneni et al., 1980) whether distilled water was used or simulated basalt groundwater. The former is suspected.

Page 6.5-1, Volcanic Glass as a Natural Analog

A reference is needed for the greatest age of a natural volcanic glass (4 x 10^7 years), as well as the other ages referred to in the second paragraph on this page.

Page 6.9-1, References

Check Ross et al. (1978) and Smith et al. (1980); they could not be located in the text.

Page 5.1-105, last paragraph

Why use the $As3^+/As5^+$ redox couple when As values are not even reported in the trace element data tables?

Insert "F"

p.6.1-25

- Last statement in para. 1 mentions presence of saprolite in Grande Ronde basalt where Vantage interbed is absent. This is not discussed in Section 3.4.2, p.3.5-35. What is the reference which supports the statements about saprolite and its extent?