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Nuclear Waste Policy Act
(Section 112)

Environmental Assessment

Reference Repository Location, Hanford Site, Washington

Volume III

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Appendix C

COMMENT-RESPONSE DOCUMENT

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Appendix C

C.1 INTRODUCTION

This appendix responds to the issues raised by Federal, State, and local governments, affected Indian Tribes, private citizens, and other organizations on the draft environmental assessment (EA) that was prepared pursuant to Section 112 of the Nuclear Waste Policy Act of 1982 (the Act). In addition to presenting the issues raised in the comments and the responses, it describes where changes were made in the final EA.

C.1.1 THE COMMENT PROCESS FOR THE ENVIRONMENTAL ASSESSMENTS

A notice of availability of the draft EA appeared in the Federal Register of December 20, 1984. This notice requested interested parties to review and comment on the draft EA, allowing 90 days for the comment period. The notice also announced an extensive series of public briefings to be held in each of the six States containing potentially acceptable sites for the first repository. These briefings were conducted solely to provide information on the draft EAs, not to solicit comments. Several weeks after the briefings, the DOE held hearings in which the public was invited to submit testimony for the public record.

Comments on the draft EA were in the form of letters addressed to the U.S. Department of Energy and of oral statements presented at 19 public hearings conducted in February and March 1985. Each comment letter or the recorded statement of each hearing participant was given a document-identification number and examined to identify comments. The comments in each letter were numbered sequentially. Copies of the comments and letters can be seen in the public reading rooms at DOE Headquarters and the Project Offices.

Each comment was classified according to subject area and assigned a classification number that corresponds to a section of the Comment Response Document. By referring to the index at the end of this section, each commenter can find the section of the appendix where the issues raised by the comments are addressed.

The subject matter of the comments fell into seven different areas: policy issues; siting process and decisions; data base, proposed activities, and repository design; postclosure performance; preclosure radiological safety; environment, socioeconomics, and transportation; and ease and cost of siting, construction, operation, and closure. The last four groups correspond to the division of technical areas in the general siting guidelines (10 CFR Part 960). Each group is further broken down into more specific topic areas shown in Section C.1.2. Where appropriate, Section C.1.2 shows the section of the EA to which the comment referred.

Within each topic area the the individual comments were screened to determine the specific issues they addressed. Responses were then prepared for each issue. Editorial comments (e.g., spelling and grammatical errors, incorrect cross-referencing, and errors in tables and figures) were considered during the preparation of the final EA, and the appropriate changes were made. Such comments are not specifically discussed in this appendix. Responses to technical issues identify how and to what degree the issue has been incorporated into the final EA. Where possible, the response identifies the places in the final EA where the change was made. For technical comments addressing concerns outside the scope of the document, a statement is made to that effect.

C.1.2 CLASSIFICATION OF COMMENTS

C.1.2.1 Policy and programmatic issues

Section C.2 summarizes and responds to comments that are concerned mainly with policy and programmatic issues. Most of these comments do not address siting decisions or the evaluations reported in the EAs. The exceptions are general comments on transportation, many of which are directed at Appendix A of the draft EAs.

Classification number	Subject
C.2.1	Public involvement and institutional issues
C.2.2	Legal and regulatory issues
C.2.3	Program management, costs, and schedules
C.2.4	Transportation, retrievability, and second repository
C.2.5	Other waste-management activities
C.2.6	Types of waste to be received at a repository
C.2.7	The draft environmental assessments
C.2.8	Miscellaneous

C.1.2.2 Siting process and decisions

Section C.3 addresses questions on the siting process and decisions. Many comments on siting decisions are closely related to technical evaluations of baseline conditions at the sites and of site suitability on the basis of the technical guidelines. Comments that primarily address site-suitability evaluations or supporting information are not included in this section; comments that address the application of suitability evaluations in the rankings of sites are included in this section.

Classification number	Subject	EA section
C.3.1	Site screening and guidelines issues	1.2, 2.2
C.3.2	Evaluation of disqualifying conditions	2.3
C.3.3	Evaluation of the geohydrologic setting	1.3, 2.4
C.3.4	Nomination and recommendation of sites for characterization	7.1, 7.2, 7.3

C.1.2.3 Data base, proposed activities, repository design

Section C.4 addresses comments on the accuracy or adequacy of the baseline information about the repository system, site characterization activities, and the site itself that is used to evaluate site suitability and the impacts of developing the site.

Classification number	Subject	EA section
C.4.1	Baseline conditions at the site	3.2, 3.3
C.4.2	Activities proposed for site characterization	
C.4.3	The repository (including the waste package	5.1

C.1.2.4 Postclosure performance

Section C.5 includes comments on the condition and performance of the repository after it is closed and sealed.

Classification number	Subject	EA section
C.5.1	Geohydrology	6.3.1.1, 5.2.2
C.5.2	Geochemistry	6.3.1.2, 5.2.1, 3.2
C.5.3	Rock characteristics	6.3.1.3, 5.2.1, 3.2
C.5.4	Climate changes	6.3.1.4, 3.4.3
C.5.5	Erosion	6.3.1.5, 5.2.1, 3.2

Classification number	Subject	EA section
C.5.6	Dissolution	6.3.1.6, 5.2.1, 3.2
C.5.7	Tectonics	6.3.1.7, 5.2.1, 3.2
C.5.8	Human interference (natural resources)	6.3.1.8, 5.2.1, 3.2
C.5.9	Postclosure site ownership and control	6.2.1.1, 3.4.1
C.5.10	Postclosure system guideline	6.3.2
C.5.11	Assessment of postclosure performance	6.4.2

C.1.2.5 Preclosure radiological safety

Section C.6 addresses comments on the behavior and effects of radionuclide releases during repository operations.

Classification number	Subject	EA section
C.6.1	Population density and distribution	6.2.1.2, 5.4.1, 3.6.1
C.6.2	Site ownership and control	6.2.1.3, 3.4.1
C.6.3	Meteorology	6.2.1.4, 3.4.3
C.6.4	Offsite installations and operations	6.2.1.5
C.6.5	System guideline	6.2.2.1
C.6.6	Assessment of preclosure performance	6.4.1

C.1.2.6 Environment, socioeconomics, and transportation

Section C.7 addresses comments on (1) the environmental, socioeconomic, and transportation-related effects of repository development and site characterization; (2) the technical guidelines for socioeconomics, transportation, and the environment; and (3) the use of these guidelines in evaluating the relevant system guideline. Most comments in this category are concerned with the characteristics of the repository before it is closed and decommissioned.

Classification number	Subject	EA section
C.7.1	Expected effects of site characterization	6.3.5
C.7.2	Environmental quality	6.2.1.6
C.7.3	Expected effects of transportation	5.3, 6.2.1.8, 3.5
C.7.4	Expected effects on socioeconomic conditions	6.2.1.7
C.7.5	System guideline	6.2.2.2

C.1.2.7 Ease and cost of siting, construction, operation, and closure

Section C.8 addresses comments about the problems and costs of siting, constructing, operating, and closing the repository.

Classification number	Subject	EA section
C.8.1	Surface characteristics	6.3.3, 3.4.1, 5.1
C.8.2	Rock characteristics	6.3.3, 3.2, 5.1
C.8.3	Preclosure hydrology	6.3.3, 3.3, 5.1
C.8.4	Preclosure tectonics	6.3.3, 3.3, 5.1
C.8.5	System guideline	6.3.4

C.1.2.8 Project-specific miscellaneous

Section C.9 addresses site-specific issues that are not addressed in the technical sections of the document.

C.2 POLICY ISSUES

Many of the comments on the draft EAs were concerned with various policy issues, which are addressed in this section: public involvement and institutional issues (Section C.2.1); compliance with Federal and State laws and regulations, including interpretations of the Nuclear Waste Policy Act (Section C.2.2); program management, costs, and schedules (Section C.2.3); policy issues related to waste management, such as transportation, retrievability, monitored retrievable storage, and spent-fuel reprocessing (Sections C.2.4 and C.2.5); and the types of waste to be received at the repository (Section C.2.6). Also included in this section are direct comments on the draft EAs (Section C.2.7) and miscellaneous issues (Section C.2.8).

C.2.1 PUBLIC INVOLVEMENT AND INSTITUTIONAL ISSUES

This section addresses comments on public involvement and institutional issues. These issues are divided into five categories: conduct of the public-participation process; interactions with States, affected Indian Tribes, and local communities; working with Federal agencies; working with other countries; and socioeconomic impacts.

C.2.1.1 The DOE's public participation process

Comments on the DOE's public-participation process were concerned mainly with reviews of, and hearings on, the draft EAs. Other issues in this category were related to the DOE's relations with the public and access to information.

C.2.1.1.1 Public review of the draft environmental assessments

Many commenters said that the 90-day comment period for the draft EAs was not long enough for a thorough review. Others complained about delays or difficulties in receiving copies of the draft EAs and suggested that the documents should have been available in public libraries.

Issue

Many commenters said that the 90-day public comment period did not permit a thorough review of the lengthy and technical draft EAs, especially since the beginning of the comment period coincided with the year-end holidays.

Response

The DOE issued the draft EAs for public comment in the interest of expanding public participation in the site-selection process. The issuance of draft EAs was not required by the Act, and it entailed significant penalties in schedule. The DOE decided to accept these penalties because it deemed this opportunity for public involvement to be important. Futhermore, in response to public comments on the draft Mission Plan (DOE, 1984a) the DOE extended the planned EA comment period from 60 to 90 days. One of the purposes of this extension was to compensate for potential delays in the mailing and distribution of the documents during the holiday season.

To help the public understand the draft EAs, the DOE conducted a series of interactive briefings in January 1985 and 19 public hearings in February and March 1985 in the six States containing the sites and in an adjacent State.

In revising the EAs, a special effort was made to consider comments received after the March 20, 1985, deadline. The final EAs reflect comments received as late as August 30, 1985.

Issue

DOE representatives allegedly had promised that the comment period would be extended, but it was not.

Response

The DOE did not officially extend the public-comment period. However, as explained above, the DOE made every effort to consider comments received after the deadline, and, as mentioned above, the final EAs reflect comments received up to 5 months after the deadline.

Issue

Because the 90-day comment period began before his term, the new Governor of Utah had less opportunity for involvement.

Response

The State of Utah submitted supplementary comments. These comments were received on May 1, 1985, and were considered in revising the EAs.

Issue

Some persons said they had experienced difficulty in obtaining copies of the draft EAs or felt that the DOE's response to requests for copies was very slow.

Response

To facilitate requests for the draft EAs, the DOE set up toll-free telephone numbers for use by the general public during the 90-day comment period. Despite some initial difficulties, the toll-free system worked well as a means for requesting the EAs. However, the DOE recognizes with regret that some persons may have experienced delays in receiving the EAs. The demand for the EAs was great, and over 5,000 copies were distributed.

Issue

Some commenters said that documents like the EAs should be available in libraries to facilitate timely review. One party complained that access to the reference documents for the EAs was very poor in the local libraries.

Response

Copies of the draft EAs were placed in the public libraries of local communities closest to the potentially acceptable sites. In addition, copies were available in DOE public reading rooms, which are open during normal business hours and have copies of all available program-related materials, including most of the reference documents cited in the EAs. Moreover, the draft EAs and the reference documents were available in the DOE public information offices in communities near all the potentially acceptable sites.

Issue

One commenter recommended that in soliciting comments the DOE should give a name to whom to write, rather than "comments."

Response

In the Federal Register notice that announced the availability of the draft EAs, interested parties were requested to send comments to "Comments--EA," which was a special mail stop set up to receive comments letters. The names of several DOE officials were also given for further information on specific draft EAs. The intent was to facilitate the comment-response process by not overloading any single individual or mail stop.

C.2.1.1.2 Hearings

Several commenters complained about the public hearings on the draft EAs; they said that the DOE had not adequately notified the public about the hearings and that the hearings were scheduled at inconvenient times and locations. Others said that there were problems with the conduct of the hearings themselves: that unreasonable limits were placed on the scope of the subject matter and on the time allotted each speaker; that the hearings became an exchange of misinformation; and that panel members did not adequately represent the views of the community.

Issue

Some comments alleged that the public was not adequately notified about the hearings.

Response

Notices about the public hearings were published in the Federal Register. In order to reach the general public that does not have ready access to the Federal Register, the DOE also issued press releases from the DOE offices in Washington, D.C., as well as the DOE Project Offices responsible for investigating the three types of host rock (basalt, salt, and tuff). In addition, the Project Offices mailed copies of the Federal Register notice of the availability of the draft EAs and the announcements of the public briefings and hearings to more than 4,000 persons and organizations that had in the past commented on, or inquired about, various aspects of the DOE's geologic-repository program. The DOE Office of Consumer Affairs made a similar mailing to approximately 200 consumer and public-interest groups, and the DOE Office for Congressional, Intergovernmental and Public Affairs notified the offices of U.S. Senators and Representatives. In addition, news releases were issued, paid advertisements were run in many local newspapers, and notices were posted in the public buildings of the local communities. In January 1985, the DOE held interactive briefings for State officials and for the public to provide information on the EAs and the public-comment process; the dates and locations of the hearings were publicized during these briefings.

Issue

Some persons objected that the schedules and the locations of the public hearings were inconvenient.

Response

The hearings were scheduled to begin more than 6 weeks after the draft EAs were issued on December 20, 1984, and several weeks after the briefings held to provide information about the EAs. This schedule allowed several weeks for preparing comments before the hearings and also time for preparing written comments after the hearings. The written comments were accorded the same importance as the oral testimony.

During February and March 1985, 19 public hearings were held in the six States containing the sites under consideration and in 1 adjacent State. The hearings were scheduled for both day and evening hours to accommodate as many people as possible. They were held in major cities that are readily served by all modes of transportation as well as in the local communities closest to, and most likely to be affected by, a repository at a particular site.

Issue

Commenters said that unreasonable limitations were placed on the scope and the procedures of the hearings, undue time limitations were placed on speakers, and the ground rules of the hearings were changed at the last minute.

Response

Although the DOE had hoped that the public would address the draft EAs in its comments, no attempt was made to limit the scope of the hearings.

In the notices of the public hearings, the DOE requested all people who wished to testify to register in advance. The agendas of the hearings were based on this preregistration. However, the DOE made it clear at each hearing that every person wishing to speak would have an opportunity. This was accomplished by adjusting the time allotted each speaker, by extending the length of a session where necessary, and by holding an additional hearing in the State of Washington.

Hearing procedures were discussed at the public briefings that preceded the hearings, explained during registration, and again explained at the beginning of each session. They included time limits, which were necessary to give all interested parties a chance to speak. However, it was made clear at each hearing that, to accommodate all speakers, the session would be extended or additional hearings would be held. In addition, the public was reminded that written comments were welcome and could be submitted after the hearings, through March 20, 1985.

Issue

According to some commenters, public hearings should be forums for the DOE to educate the public rather than public exchanges of misinformation.

Response

The purpose of the hearings was to give the public an opportunity to be heard. The DOE uses other forums to supply information; an example is the series of briefings held during January 1985 to explain the draft EAs and the siting process and to answer questions. The hearing is the citizens' forum for educating the DOE about their needs, concerns, perceptions, and ideas. The DOE did not present information, nor did it discuss, except to clarify, the comments received at the hearings.

Issue

Some parties felt that "community representatives" on the hearing panels did not always accurately reflect the views of the community; in some cases, the presence of a particular individual could have been considered a conflict of interest.

Response

The role of the panelists was to clarify the testimony for the record, not to represent the community. Although the non-DOE panelists were selected by the DOE, they were not selected to represent any specific viewpoint.

Issue

Some commenters suggested that the DOE should open each public hearing to testimony on all of the sites rather than one specific site. This would help the public to compare the sites.

Response

None of the public hearings was restricted to the discussion of a particular site. Chapter 7, which presents a comparative evaluation of the sites against the siting guidelines, is common to all of the EAs, and to provide the reader with a basis for the comparison, the draft EAs for all nine sites were available as a package.

C.2.1.1.3 DOE relations with the public

Comments on the DOE's relations with the public covered a variety of topics, ranging from recommendations for a public referendum on waste disposal to complaints about the DOE's attitude toward the public. They also included requests for an early announcement of the sites to be recommended for characterization.

Issue

Some commenters suggested that there should be a public referendum on the issue of radioactive-waste disposal.

Response

The American political process provides citizens with several opportunities to make their views known at the local, State, and Federal levels. In 1982, the U.S. Congress, the elected representatives of the American people, found that "high-level radioactive waste and spent nuclear fuel have become major subjects of public concern, and appropriate precautions must be taken to ensure that such waste and spent fuel do not adversely affect the public health and safety and the environment for this or further generations" (Section 111(a)(7) of the Act) and therefore enacted the Nuclear Waste Policy Act of 1982. The Act stipulates the technical and public process that the DOE has been following since January 1983.

Issue

A commenter requested that the EA emphasize the "development of appropriate mechanisms to achieve public consensus" mentioned in a report.

Response

The progress report referred to a series of socioeconomic studies that will be undertaken throughout the repository-siting program. The development of public consensus is one of the objectives for the socioeconomics portion of the siting program.

Issue

Some commenters felt that the DOE has a negative attitude toward the public. Several people said that the public-involvement process was carried out solely for the sake of appearance, public comments were not taken seriously, and local sentiments will not really be considered in making the final decision.

Response

The comments of the public have been, and will continue to be, seriously considered in the decisionmaking process. The comments of the public were considered in revising the siting guidelines, and issues raised in the EA scoping hearings were considered in preparing the draft EAs. Substantive comments on the draft EAs have been considered in producing this appendix and the final EAs. Furthermore, the DOE believes that local citizens have legitimate and vital interests in the repository program and has sought to learn their attitudes and concerns through meetings and workshops. Any appearance that the DOE has a negative attitude toward local citizens is unintended and clearly not in the interests of the DOE.

Issue

The DOE was accused of not being honest with the public, both in the context of the general program and on specific issues. For example, some persons felt that the presence of a drill rig at the Hanford site suggests that the DOE is already committed to that site.

Response

The perception of dishonesty may stem from two sources: ongoing changes in policy direction and inadequate information. Changes in policy direction are the by-product of a process that involves many people on all levels of government and the private sector. They result from changing circumstances, long time spans, improving data, and program growth and development. Although the unfortunate result may be the appearance of a coverup of facts as policy direction changes, the only alternative is an unacceptable rigidity.

To improve the problem of inadequate information, the DOE is committed to provide a full and timely flow of information about program activities to all affected parties and to provide frequent opportunities, both formal and informal, for the fullest possible participation in program activities. Accomplishing this depends on developing and maintaining information and interaction programs that meet the needs and address the concerns of States and Indian Tribes, local governments, affected citizens, the general public, and other interested parties. Detailed plans for achieving these goals are discussed in Part I of Volume I of the Mission Plan (DOE, 1985a).

Contractual arrangements for a drill rig at the Hanford site were made before the passage of the Act, but the rig has not been used at the site since the Act was passed and will be used only if Hanford is one of the sites recommended and approved for site characterization. The DOE is not committed to the Hanford site or any other site.

Issue

Commenters said that the public has not been fully informed about the site-selection process, particularly for the Deaf Smith and the Swisher sites in Texas.

Response

The potentially acceptable sites in Swisher and Deaf Smith Counties, Texas, were identified in the report Identification of Preferred Sites Within the Palo Duro Basin (DOE, 1984b) which was issued in draft form for comment in March 1984. The final report was released in November 1984. The boundaries of the sites in the final report were revised on the basis of comments on the draft report by the State of Texas and other parties. Both the draft and the final reports were broadly distributed and made available in local libraries and information offices. Further, after the draft reports, the DOE held briefings to explain the site-selection process.

Issue

Some persons felt that a general mitigation policy of indemnifying local citizens against the burden of uncertainties should be developed.

Response

The DOE cannot eliminate uncertainty. However, it is taking steps to inform local citizens about its activities and to involve both State and local representatives in the siting process.

Issue

A number of commenters requested early announcement of the sites to be recommended for characterization. They said that the DOE should remove as soon as possible the worry of repository siting from the areas not being recommended.

Response

The DOE is acutely aware of the apprehension that citizens of the States with potentially acceptable sites are experiencing. However, the announcements of the sites nominated and recommended for characterization had to await the completion of the final comparative evaluation of the sites and the publication of the final EAs, the multiattribute utility analysis of the nominated sites, and the recommendation by the Secretary of Energy of candidate sites.

C.2.1.1.4 Access to information

Many parties felt that opposition to the waste-management program results from misinformation about, and exaggeration of, the possible adverse effects associated with a geologic repository. They suggested that an improved program of public information and education would increase understanding and thereby the acceptance of the program. Several commenters recommended improved information programs because informed consent by the public depends on the availability of accurate, intelligible information. Others offered specific recommendations or complaints.

Issue

The DOE should establish a major information program, including (1) a constant flow of information that is timely, accurate, and easily understood and (2) more-frequent hearings and information sessions.

Response

Recognizing that public information is crucial to the success of the repository program, the DOE is committed to a thorough program of public participation. Its plans for public information and outreach are described in Chapter 4 of Part I of Volume I of the Mission Plan (DOE, 1985a). Valuable contributions to the development of these plans have come from States, affected Indian Tribes, and the public. The DOE will continue to seek information from interested parties on developing ways to identify public concerns, to provide information that addresses these concerns, and to involve the public in the decision process.

Issue

Some commenters alleged that the DOE will disclose information only under a formal request under the Freedom of Information Act.

Response

The DOE routinely shares program information with all of the affected parties and public and has specifically established information offices for that purpose. Information is disseminated through responses to letters, news releases, public announcements, and technical reports. Other vehicles for sharing information are exhibits, briefings, workshops, and meetings. In some cases, States and citizens have used the Freedom of Information Act as a means to obtain specific data or copies of letters.

Issue

Some persons felt that the DOE's ability to supply information to the public will be limited by the acceptance of defense waste in the repository.

Response

The acceptance of defense waste for disposal (see Section C.2.6.1) will not affect access to information or opportunities for public comment. Information on the quantities, characteristics, and environmental impacts of the defense waste is not classified.

Issues

Persons gathering information about the sites allegedly did not identify themselves as DOE employees or contractors.

Response

The DOE's policy is for its employees and contractors to clearly identify themselves when requesting information. The DOE or its contractors have not deliberately misrepresented the objectives of gathering information and would appreciate being informed directly of the specific dates and events when such misrepresentations were made.

C.2.1.2 Interactions with States, affected Indian Tribes, and local communities

C.2.1.2.1 Interactions with States

A number of commenters said that the DOE needs to set up better mechanisms for working with States and notifying them about the program. Others asked how the DOE intends to comply with existing State regulations. In addition, the DOE was asked to give Oregon affected-State status.

Issue

Commenters said that the DOE needs to develop better mechanisms for working with States, rather than simply assuming that States will agree to the DOE's suggestions.

Response

As explained in Chapter 4 of Part I in Volume I of the Mission Plan (DOE, 1985a), the establishment of mechanisms for working with States is an important objective of the DOE's institutional program. The DOE has worked closely with the representatives of every State that has a potentially acceptable site for the first repository. Futhermore, informal meetings with first-repository States and discussions with the second-repository States have been initiated. These meetings are intended to give the States additional opportunities to express their concerns and to participate in the development of the repository program. The DOE will continue to attempt to secure smooth working relationships.

Issue

Some States contended that they have not been notified in sufficient time, are not consulted, and their requests for information are not acknowledged or satisfied.

Response

Since the identification of the States with potentially acceptable sites for the first repository, the DOE has tried to consult with them on various siting issues. An example is the extensive consultation process on the siting guidelines, which involved both meetings with individual states and plenary sessions with the first- and second-repository States as well as the submittal of several drafts of the guidelines for State review. This process is described in the "Supplementary Information" for the DOE's siting guidelines (DOE, 1984c).

Although the DOE has made a concerted effort to provide full information to the States, it recognizes that information has not always been provided promptly. The DOE is trying to improve its capability to provide timely responses and is developing program data bases specifically for that purpose. If the States so desire, procedures for providing information may be specified in consultation-and-cooperation agreements.

Consultation and cooperation between the DOE and States is a dynamic process; it will not be limited to activities specified in the consultation-and-cooperation agreements. Further information about the consultation-and-cooperation process can be found in Chapter 4 of Part I of Volume I and in Chapter 3 of Part II in Volume I of the Mission Plan (DOE, 1985a).

Issue

One party recommended that the DOE conclude consultation-and-cooperation agreements with States to provide a formal structure for information and comment.

Response

To ensure that States are actively involved in the program, a formal consultation-and-cooperation process will be established through the written agreements provided for in Section 117(c) of the Act. High priority has been placed on concluding these agreements promptly. No formal consultation-and-cooperation agreements have yet been signed with any State, although negotiations have been initiated with the State of Washington.

In the absence of a consultation-and-cooperation agreement, the DOE will continue to provide both information and opportunities for comment.

Issue

Some commenters felt that the States should have been part of the EA process from the beginning and that the EAs could have benefitted from their involvement.

Response

The States with potentially acceptable sites were asked to participate very early in the EA process, starting with the scoping hearings held early in 1983. Subsequently, the DOE shared various drefts of the EAs with these States. The EAs did indeed benefit from the careful reviews performed by the States, and the DOE is grateful for their thoughtful comments.

Issue

Some States expressed concerns about the DOE's plans for compliance with State regulations in the siting process.

Response

The DOE intends to comply with the substance of any applicable State and local regulations that are consistent with its responsibilities under the Act.

The applicable regulations will be identified in consultation with the affected States and local governments. One of the objectives of the consultation process (see Section C.2.1.2) will be to identify which State or local regulations are applicable to a particular siting, construction, or operation activity and are consistent with the DOE's responsibilities under the Act (i.e., do not include onerous reporting requirements or entail unacceptable delays). Another objective will be to agree on the mode or the extent of compliance. For the repository program, this consultation process is to begin immediately after the Presidential approval of the three sites recommended for characterization.

Issue

Several States oppose the siting of a repository within their borders.

Response

The Act outlines the process to be followed in the event that the Governor or the legislature of the State opposes the selection of a site in its borders for development as a geologic repository. The Act encourages the DOE to work closely with States in advance of recommendation and to develop a technical program that is credible to the State. However, the Act also provides the opportunity for the State to issue a notice of disapproval, with explanation, at the time that a site in that State is recommended for a repository (Section 116(b)(2)). Such disapproval can be overridden only by a joint resolution of Congress.

Issue

Some States felt that they should have the right to comment or concur on the DOE's plans without losing their rights to issue a notice of disapproval.

Response

The Act empowers a State with a site selected for a repository to submit a notice of disapproval to Congress. This right is not affected by previous comments on the site-selection process. Indeed, States are encouraged to submit comments throughout the process and to provide suggestions to improve the technical quality of the program.

Issue

Some comments urged that States be given the authority to monitor and review activities at every step of the process.

Response

The DOE has been encouraging States to participate in the siting process for more than 5 years through regular interactions with designated representatives. Consultation-and-cooperation agreements will allow each State and affected Indian Tribe to identify and describe in more detail the rights and responsibilities of the parties to each agreement. The agreements can include provisions for States to monitor and review program activities.

Issue

The State of Louisiana expects the DOE to honor the memorandum of understanding that grants the State veto power over any DOE plans for a repository. The agreement was signed February 27, 1978.

Response

The DOE has always maintained the position that the memorandum of understanding between the DOE and the State of Louisiana is valid consistent with the provisions of applicable law. However, if Vacherie Dome in Louisiana were clearly the best site, the DOE, being committed to implementing the Act, would recommend the site to Congress for development as a repository. At that time, Louisiana, like any other State, would have the opportunity to issue a notice of disapproval. The memorandum of understanding was signed before the enactment of the Act, which gave States the opportunity to veto the selection of a site within their borders; the Act supersedes prior agreements.

Issue

One commenter pointed out that a request by the Washington State legislature that granite be considered for the first repository was ignored by the DOE.

Response

The Act required the DOE to identify the potentially acceptable sites for the first repository within 180 days after the Act was passed. Studies of granite had not progressed to the point where the DOE could identify potentially acceptable sites in granite for the first repository. Granite is, however, being considered for the second repository.

Issue

The DOE was asked how it would respond to such State initiatives as Mississippi's statement that it is the policy of the State that radioactive waste may not be stored in Mississippi or the Oregon measure, passed by a ballot, requiring that there be no postclosure releases of radioactive material. Similarly, several comments from communities in Nevada said that their governing bodies had passed resolutions voicing opposition to waste transportation through these communities and to the siting of a repository in Nevada.

Response

The DOE intends to comply with all State regulations consistent with its responsibilities under the Act. However, in some instances State or local legislation that attempts to directly regulate the repository program may not be permissible under the U.S. Constitution.

Issue

According to some comments, Oregon should be recognized as an affected State and be accorded the rights and privileges of an affected State because of its proximity to the Hanford site and to the potentially affected Columbia River.

Response

Because none of the potentially acceptable sites is located within its borders, Oregon is not eligible under the Act for the rights and privileges of an affected State. Nonetheless, Oregon has participated actively in the site-selection process. It has appointed both a Hanford repository review committee composed of State officials and a citizens advisory committee to provide review from a public perspective. Recognizing the high level of interest among local citizens, the DOE held a public hearing on the EAs in Portland on March 11, 1985, and will continue to seek comment from the State of Oregon.

C.2.1.2.2 Interactions with affected Indian Tribes

Issue

Some commenters said that the DOE had not considered the religious attitudes of the Indians toward their land and the effects of site characterization on Indian lands. The Western Shoshone Indian Nation requested that it be declared an affected Tribe and that its tribal council be consulted before the start of any site-characterization activities at the Yucca Mountain site in Nevada.

Response

The DOE recognizes the importance of Indian religious and cultural resources and has specifically included proximity to significant Indian resources, such as major religious sites, as a potentially adverse condition in the siting guidelines.

The Western Shoshone Indian Nation requested affected-Tribe status because it claimed ownership of the land on which the Yucca Mountain site is located. The Federal Government's position that the Shoshone Tribe does not own the land was upheld by the Supreme Court (United States vs. Mary Dann and Carrie Dann, 105 U.S. Supreme Court 1058, February 20, 1985). The Tribe will be able to interact with the DOE through the public comment and interaction process.

C.2.1.2.3 Working with local communities

Issue

Several comments suggested that local communities should have more input and involvement in the siting process and in the development of the waste-management program.

Response

The DOE plans to continue working with both State and local governments during the siting process. The DOE intends to continue holding public meetings and outreach programs for local leaders and the general public in the vicinity of potential sites and to keep State officials informed of such activities. Although not required by the Act, procedures for local-government representation could be included in consultation-and-cooperation agreements.

The DOE plans to encourage the participation of local community representatives in assessing the potential socioeconomic impacts of a repository, in developing plans to avoid or mitigate significant adverse impacts, and in preparing the impact-identification report that the State is to submit with its request for mitigation assistance. States will be encouraged to provide for and support such local participation.

The DOE is developing policies for providing financial assistance to support local participation in the program either through the State or, if necessary, by direct means. If the State government has established mechanisms for direct local participation and financial support for local efforts, the DOE will provide adequate funding to the State agency responsible for implementing local participation. Where the State government does not provide for direct local participation and support, the DOE will work directly with local representatives to assess potential impacts and may provide direct funding to units of local government.

The DOE meets frequently with local officials and other interested parties for exchanges of views and information.

DOE information offices in communities near the sites under consideration are walk-in sources of information. They provide answers to questions and educational materials. These offices also serve as libraries for public documents and short films, as well as places for the public to submit comments and questions about the program. (See Appendix B for the locations of these offices.)

Issue

Most people in Beatty, Nevada, want Yucca Mountain to be the selected site because of the economic benefits to the area, but the Governor responded negatively, overriding the desires of the citizens closest to the potential site.

Response

The DOE is aware that the interests of local citizens and the State may conflict, but will not intervene in intrastate political or economic disputes. Nonetheless, the DOE welcomes the input of local citizens in the waste-management program and will seek their participation through provisions in consultation-and-cooperation agreements with the States and through the socioeconomic impact assessments that will be conducted concurrently with site characterization.

C.2.1.2.4 Financial assistance

Several States and localities requested information about the distribution and availability of financial assistance. Some States complained that the grants they received for EA review were late; others requested funds to conduct independent technical studies. Several comments were concerned with grants to local communities or private organizations.

Issue

The DOE should provide information about the purpose, timing, and distribution of grants.

Response

The Act authorizes the DOE to provide financial assistance to States and affected Indian Tribes for (1) participation in the repository program and for facilitating effective public participation (2) participation in the consultation-and-cooperation process (see also Section C.2.1.2.1); and (3) the mitigation of socioeconomic impacts. To date, all six States considered for the first repository and three affected Indian Tribes have been awarded grants for participation in the program. In fiscal years 1983 and 1984 a total of $2,157,301 and $4,590,356, respectively, was awarded. Grants also have been extended to the 17 States being considered for the second repository to enable them to participate in site screening. In fiscal years 1983 and 1984, these awards totaled $930,376 and $2,942,186, respectively. Grants allow States and affected Indian Tribes to review and comment on documents, like the technical reports, the siting guidelines, the draft EA, and the Mission Plan and to participate in program meetings and workshops.

The nature and level of grants for the mitigation of socioeconomic impacts will be largely based on the socioeconomic-impact reports that States or affected Indian Tribes will submit and on discussions and negotiations between the DOE and States, affected Indian Tribes, and communities. Both financial and technical support will be provided for the development of such reports. This support can assist States and affected Indian Tribes in examining the public health and safety, environmental, social, and economic impacts of a repository. Also provided for the mitigation of fiscal impacts will be grants equal to the taxes that would be collected if the repository were a commercial project. (See Section C.2.1.5.1 for comments and responses on the mitigation of socioeconomic impacts.)

The DOE will work with States, affected Indian Tribes, and localities to develop impact-mitigation plans in response to the siting of a repository. These plans will address ways to augment community services as well as ways to minimize socioeconomic disruptions and maximize the benefits of new economic activity related to program activities.

Issue

Some State grants for the review of the draft EA were allegedly late, and they were smaller than requested.

Response

All requests for financial assistance from States or affected Indian Tribes are reviewed for conformance to the DOE guidelines on financial assistance. These guidelines ensure compliance with the requirements of the Act as well as consistency and equity among States and Indian Tribes. Once the DOE has reviewed the request, negotiations with the State can begin. Sometimes these negotiations can be lengthy. Delays have occurred when a request lacked key information or when States requested funds for activities outside the scope of the Act or the DOE financial assistance guidelines.

The amount of a grant is decided case by case, but each request is evaluated against similar requests from other States and Indian Tribes. Once the DOE obtains all the information necessary and discusses it with the State, adequate funding levels are determined and awarded. Interim funding is often extended if a grant is delayed.

Issue

Several States asked for funds to conduct independent technical assessments, both for developing new information and for checking the DOE's analyses. Some States alleged that requests of this type were turned down by the DOE.

Response

The Act requires the DOE to provide financial assistance to States or affected Indian Tribes "to engage in monitoring, testing, or evaluation activities with respect to site characterization programs with respect to such site." The DOE's guidelines on financial assistance also extend this funding to phase II (i.e., States and Tribes that have potentially acceptable sites, but have not yet been notified of their status as candidate sites). The DOE had interpreted the Act to mean that activities thus funded should focus on independent monitoring, testing, and evaluation of DOE data.

On December 2, 1985, the Court of Appeals for the Ninth Circuit ruled that the DOE is required under the Act to fund States and Indian Tribes to conduct pre-site characterization studies involving primary data collection if such studies "would be essential to an informed statement of reasons explaining why [the State/Indian Tribe, if on tribal land] disapproved the recommended repository sites" and if the ability of the studies to contribute to the statement of reason "depends on their being initiated prior to site characterization" (State of Nevada vs. Herrington, (No. 84-7846). The DOE is revising its financial assistance guideline in accordance with this ruling.

Issue

Local communities want to share in the grants available under the Act.

Response

Financial assistance to local governments is addressed in Section 4.12 of Part I, Volume I, of the Mission Plan (DOE, 1985a):

> The DOE will continue to provide grants and other financial assistance, as appropriate, to States, affected Indian Tribes, and others to facilitate effective public participation in the program. In addition, the DOE will seek ways to encourage the involvement of other interested parties through grants and other technical or financial assistance.... The DOE will also seek ways to facilitate effective participation by units of general local government that may be affected by program activities.

As already mentioned, the DOE is developing policies for providing financial assistance to support local participation in the program. If the State government has established mechanisms for direct local participation and financial support for local efforts, the DOE will provide adequate funding to the State agency responsible for implementing local participation. Where the State government does not provide for direct local participation and support, the DOE will work directly with local representatives.

Issue

One party said that requests by a private organization for funds to develop balanced information have been denied by the DOE.

Response

The DOE provides financial assistance to national and regional organizations that represent an extension of State and Tribal interests to facilitate their participation in the waste-management program. The organizations that have received such grants are the National Congress of American Indians, the National Conference of State Legislatures, the Western Interstate Energy Board, and the Southern States Energy Board. Where such organizations are likely to improve coordination or the involvement of affected parties, future funding will be provided.

C.2.1.3 Working with other Federal agencies

A number of commenters addressed the participation of other Federal agencies in the repository program. Most of them were interested in the roles of the Nuclear Regulatory Commission and the Department of Defense. (See also Section C.2.2 for comments and responses about the regulations of Federal agencies.)

Issue

A commenter alleged that too many Federal agencies are involved in the siting process. Another suggested that it is vital that agencies whose primary concern is public safety be involved in developing the repository.

Response

The management of spent fuel and high-level waste requires the participation of many agencies of the Federal Government because of their regulatory responsibilities. The Act assigns lead responsibility to the DOE, but significant roles are expected for the following other agencies:

- The Nuclear Regulatory Commission.
- The Environmental Protection Agency.
- The Department of Transportation.
- The Bureau of Indian Affairs.
- The Bureau of Land Management.

- The U.S. Geological Survey.
- The U.S. Army Corps of Engineers.
- The Advisory Council on Historic Preservation.

More-detailed information about the roles of these agencies can be found in the DOE's Project Decision Schedule (DOE, 1985b).

Issue

Information about the involvement and responsibilities of the Nuclear Regulatory Commission and the Department of Defense was requested by several commenters.

Response

The DOE must obtain from the Nuclear Regulatory Commission (NRC) concurrence on the siting guidelines, a license to construct the repository, a license to receive and possess the waste at the site (i.e. to operate the repository), and subsequent license amendments for the closure and decommissioning of the repository. The NRC also will issue site-characterization analyses based on the DOE's site-characterization plan for each site approved for characterization. The NRC licensing process is based on the procedures and the technical criteria issued as 10 CFR Part 60 (NRC, 1983). The objective is to implement the standards set by the Environmental Protection Agency for waste isolation in geologic repositories and thus provide reasonable assurance that geologic repositories will isolate the waste for at least 10,000 years without posing undue risk to public health and safety. Since 10 CFR Part 60 was issued before the Act was passed, the NRC is revising it for compliance with the Act; 10 CFR Part 60 may also change in response to the Environmental Protection Agency's final environmental standard (40 CFR Part 191), which was published on September 19, 1985 (EPA, 1985).

The Department of Defense is involved in the program through the U.S. Army Corps of Engineers, which is advising the DOE on the acquisition of private lands.

Issue

One party stated that the DOE should complete consultation with the U.S. Fish and Wildlife Service on threatened and endangered species before proceeding with site recommendation for characterization.

Response

The DOE has been communicating with the U.S. Fish and Wildlife Service on designated critical habitats and the possibility of threatened or endangered species occurring at any of the sites. In response to specific concerns about the presence of protected species at the Davis Canyon site, the DOE participated with interested agencies and individual experts in a field survey conducted in July 1985. When a site has been selected for repository development, the DOE will enter into a formal consultation with the Service. Until then, the DOE will remain in contact with the Service and with State agencies regarding protected species.

C.2.1.4 Working with other countries

Issue

Because the disposal of radioactive waste is an international problem, the DOE should seek technical assistance and independent scientific analyses from other nations that do not have a vested interest.

Response

It has long been U.S. policy to cooperate with other nations in developing waste-management technology. As described in the Mission Plan (DOE, 1985a, Volume I, Part I, Chapter 5), the DOE actively participates in international cooperation and information exchange through bilateral agreements, multinational activities, and international forums and programs. These activities are part of the DOE's overall program under current agreements with Belgium, Canada, France, the Federal Republic of Germany, Japan, Sweden, Switzerland, the United Kingdom, the Commission of European Communities, the International Atomic Energy Agency, and the Nuclear Energy Agency (NEA) of the Organization for Economic Cooperation and Development. The DOE is currently most active in joint projects with Canada, Germany, Sweden, and the NEA. These projects include (1) an underground crystalline-rock research laboratory in Canada; (2) ongoing tests in the Asse salt mine in Germany; and (3) tests in the Stripa mine in Sweden, which are being performed in crystalline rock.

C.2.1.5 Socioeconomic impacts

This section covers two topics that drew many comments: (1) socioeconomic impacts and their mitigation and (2) the acquisition of laws and effects on property values.

C.2.1.5.1 Socioeconomic impacts and their mitigation

Many comments, from the States, local communities, and the public, addressed various issues related to the socioeconomic impacts of a repository and their mitigation. Some of them alleged that the DOE had not adequately involved local communities in assessing the effects and did not understand local values. Others were concerned about the timing and adequacy of mitigation grants.

Issue

Some comments said that the DOE has not adequately involved the citizens of local communities in evaluating the effects of a repository on local people, businesses, and services.

Response

The DOE will conduct socioeconomic studies that will involve local communities and will collect information from local sources (schools, local officials, etc.). These studies will be conducted concurrently with site characterization and will be much more detailed than the preliminary assessments included in the EAs.

Some socioeconomic impacts, such as increased demands for public services, will affect local governments directly. For this reason, the DOE will encourage the participation of local governments in the preparation of the socioeconomic-impact reports as early and as fully as possible. The DOE will encourage the States to allocate of a portion of their grant to affected localities.

Issue

The DOE allegedly does not understand and appreciate the values of the local communities at the sites that are being considered.

Response

After the President approves the sites recommended for characterization, the DOE will begin detailed studies of the demographic and social and economic conditions in local communities, collecting information from local sources. These studies will examine the effects of the repository on the local economy, community services, housing, and the like. Transportation-related effects on local communities will also be analyzed. Local communities will continue to have opportunities to be directly involved in the assessment of socioeconomic effects, and their officials will be asked to provide information not only about local economic and social conditions but also about the attitudes of the community.

Issue

The EAs should include more information in Chapter 5 about the financial impacts of site characterization and repository development on local communities and the grant programs applicable to individual sites.

Response

Chapter 5 of the EAs has been revised to provide more-detailed information about socioeconomic effects. Information about grants is available in the Mission Plan (DOE, 1985a, Volume I, Part I, Chapter 4).

Issue

Some persons said that there is no guarantee that the local economy and local employment picture will improve because of the presence of a repository. On the other hand, one commenter noted the economic benefits that could accrue from a repository nearby and wanted assurances that the residents of the local community would have job opportunities. He said that the local business community saw the repository as being beneficial as long as the "boom-and-bust" cycle can be broken.

Response

Although there may be no guarantee of an improvements in the employment situation, such improvements are likely because of improvements in the local economy. Federal procurement law requires the DOE to advertise for, accept bids from, and hire contractors on the basis of competitive bids. However, the DOE will make available to local businesses complete descriptions of the required contract work and will meet with local leaders to describe the project. Where possible, the DOE and the general site contractor may divide contracts into smaller subcontracts to facilitate bidding by local contractors. This approach is being successfully used for the Waste Isolation Pilot Project in New Mexico. Furthermore, local residents may find employment with any outside contractors that may be hired. The DOE will also widely publicize locally business and job opportunities and work with community leaders to provide contract-procurement workshops and vocational training programs.

The DOE plans to take mitigative measures to reduce the impacts of the "boom-and-bust" cycle--the buildings and eventual reduction in local populations that will result from siting a repository in a rural area.

Issue

- Some States and communities indicated that mitigation efforts and funds must precede or be concurrent with program activities to avoid adverse impacts. In particular, some potentially affected communities expressed concern that the need to improve community services may occur before impact-mitigation funds are distributed.

Response

The Act does not provide for impact-mitigation funds before repository construction begins, but the Act does allow grants equal to taxes to be provided to units of general local government beginning with site characterization. The DOE will therefore work with States, affected Indian Tribes, and local governments to minimize or avoid adverse impacts and to identify mechanisms for the timely provision of assistance within the authorization provided by the Act. Financial assistance will be provided to States and affected Indian Tribes throughout the construction and operation phases to enable them to mitigate repository-related impacts.

Issue

Some parties were concerned that the grants will be cut and thus will not provide adequate assistance (i.e., the grants will not be equal to the amount lost in the reduced assessments of the value of surrounding land and will not make up for taxes lost as a result of business relocations).

Response

The levels of impact-mitigation funding will be based on assessments of potential impacts, in which local communities will be encouraged to participate. The funding levels agreed on will be based largely on the socioeconomic-impact reports that will accompany the requests of States and affected Indian Tribes for financial assistance. Included in the impact-mitigation assistance will be grants equal to taxes.

In general, applications for grants will be submitted by the State or the affected Indian Tribe to the appropriate DOE Project Office. The DOE will process these applications as quickly as possible under Federal procurement regulations. When agreement on terms has been reached by the DOE and the State or affected Indian Tribe, the grant will be awarded.

Issue

Commenters requested that the DOE furnish temporary housing for transient workers during site characterization.

Response

With the exception of the Davis Canyon site, adequate housing is expected to be available in the vicinity of the nominated sites during site characterization. The DOE may consider providing temporary housing at the Davis Canyon site if the site is recommended and approved for characterization.

C.2.1.5.2 Land acquisition and property values

The subject of land acquisition and property values was raised by many commenters, who expressed concern about decreases in property values, fair compensation for land acquired from private owners, the uncertainty resulting from a long site-selection process, and similar issues.

Issue

A number of persons expressed concern about the effects of site characterization and repository development on property values. Some made suggestions about the approach to compensation; others wanted to know what the DOE considers reasonable compensation. Some said that the value of property near a site being considered for a repository has already decreased and will continue to plummet as the process continues, but that compensation should be based on the nondepreciated land values that could be expected without the repository project.

Response

The DOE recognizes that some people believe that the value of some lands at or near a potential repository site may have decreased, but there is no concrete evidence of such decreases. However, for the sites that are not recommended for characterization, it can reasonably be expected that property values, if decreased, will return to normal once the site is removed from consideration. At the sites recommended for characterization, private land may be leased or purchased for the characterization phase. If there is private land at a site selected for a repository, the DOE will acquire the land through purchase, at fair market value.

All land-acquisition activities will be performed in accordance with the Uniform Relocation Assistance Act. The DOE will ask for assistance from the U.S. Army Corps of Engineers in the acquisition process because of its extensive experience. The Corps will assess the value of the land, basing the assessments on the value of land that is similar but outside the immediate area. This approach will ensure that the assessment is not reduced by any land-value decreases that may result from the repository project.

Issue

One commenter suggested that a one-mile buffer zone should be established around the site, within which owners could choose to keep their property with compensation from the DOE for its devaluation or sell to the DOE under the same terms as those offered for land at the site.

Response

Land values will be assessed during the studies that will be conducted concurrently with site characterization. At this time the DOE has made no decision about establishing a buffer zone or how compensation in a buffer zone will be handled. If the siting of a repository causes a clearly demonstrated adverse effect on the values of the surrounding land, impact-mitigation funds may be made available as compensation.

Issue

Some felt that landowners who have already sold property at prices depressed by repository siting should be compensated for their losses.

Response

The DOE will examine case by case any claims from landowners who feel that they have received a depressed price for their property because the land is or was being considered for a repository.

Issue

The DOE was asked to issue a specific statement explaining what it considers reasonable mitigation and compensation for relocation.

Response

In providing relocation assistance, the DOE will follow the procedures specified in the Uniform Relocation Assistance Act. Information about relocation procedures has been distributed at meetings of landowners in the Deaf Smith site and is available from the DOE.

Issue

Some commenters urged the DOE to decide on a site as soon as possible because otherwise people cannot make decide about making necessary improvements to their property and do not know whether their lives will be disrupted. One party said that the DOE should "stop casting a cloud" on land titles near potential sites. Another commenter said that the DOE should develop a mitigation policy of indemnifying local citizens against uncertainty.

Response

The siting of a repository requires extensive and detailed study to collect sufficient information and must follow the process outlined in the Act. Therefore, it is not possible for the DOE to decide now which site will be selected. This choice will be made several years from now. However, the DOE believes that landowners should not base decisions about improvements to their property on the anticipation of a repository. If the land is acquired, landowners will be compensated at fair market value, including any improvements that have been made.

Issue

The DOE should arrange an exchange of land with the Bureau of Land Management rather than condemning private farmland for the repository.

Response

The DOE recognizes that the acquisition of private land may have significant impacts on its owners and will follow the provisions of the Uniform Relocation Assistance Act. However, in selecting a site for a repository, the ability of the site to contain and isolate the waste is more important than current land use.

C.2.2 LEGAL AND REGULATORY ISSUES

Most of the issues raised in comments on legal and regulatory matters were concerned with the EPA standards for geologic disposal. Other issues included emergency response responsibilities, liability for accidents, and the applicability of Federal mining regulations.

Issue

Several commenters asked which Federal agencies set standards for radioactive-material releases from the repository.

Response

The Act (Section 121(a)) directs the Environmental Protection Agency (EPA) to develop standards for protecting the general environment from radioactive-material releases from repositories. Responsibility for implementing the EPA standard is assigned to the Nuclear Regulatory Commission (NRC).

The EPA standards were issued in final form as Title 40 of the Code of Federal Regulations, Part 191 (40 CFR Part 191), on August 15, 1985; they were published in the Federal Register on September 19, 1985 (EPA, 1985), and became effective on November 18, 1985. The NRC criteria for implementing these standards were issued as Title 10 of the Code of Federal Regulations, Part 60 (10 CFR Part 60). They were published on June 21, 1983 (NRC, 1983). Since 10 CFR Part 60 was issued before the Act was passed, the NRC is revising it for compliance with the Act; 10 CFR Part 60 may also change in response to the above-mentioned final EA standard (40 CFR Part 191).

Issue

A number of comments pertained to the postclosure safety of the repository. Some of them asked what levels of radiation are harmful and who determines what levels are not harmful and what is considered to be an acceptable death rate. One commenter objected that, in the absence of individual dose standards, the EPA's population standard is unacceptable.

Response

According to the National Council on Radiation Protection and Measurements (1974), the lowest radiation doses that produce evidence that a person has been affected by radiation are in the range of 75 to 125 rem, which is the "minimal dose likely to produce vomiting in about 10 percent of people so exposed." The individual dose limits set by the EPA for the repository are more than 1,000 times lower. During repository operations, no member of the general public may receive more than 25 millirem (0.025 rem) to the whole body, 75 millirem (0.075 rem) to the thyroid, and 25 millirem to any other critical organ; during the first 1,000 years after closure, the limits are 25 millirem the whole body or 75 millirem to any critical organ. The EPA estimates that, for the first 10,000 years, releases from a repository containing 100,000 MTU of waste would cause no more than 1,000 premature deaths from cancer, or an average of no more than one death every 10 years. The projections for actual repositories are expected to be about 10 times lower. For comparison, it is estimated that about 6,000 premature cancer deaths per year are caused by natural background radiation (radiation from cosmic rays, the rocks in the earth, etc.).

In its final standards, 40 CFR Part 191, the EPA has included individual protection requirements (40 CFR 191.15), which are expressed as the maximum permissible individual dose for 1,000 years after repository closure.

Issue

A few commenters questioned the 10,000-year standard for waste isolation.

Response

The 10,000-year standard was chosen by the EPA because at 10,000 years after repository closure the risk posed by the repository to public health and safety is comparable to the risk from unmined uranium ore.

Issue

Some parties expressed concern that the final EPA standards had not been promulgated at the time the draft EAs were issued.

Response

As already mentioned, the final EPA standards were published on September 19, 1985. These final standards were used in revising the EAs.

Issue

One commenter asked who would be responsible for responding to emergencies during repository operation and waste transportation.

Response

The DOE is responsible for emergency preparedness and response at the repository, as specified in DOE Order 5500.3 ("Reactor and Non-Reactor Facility Emergency Planning Preparedness, and Response Programs for Department of Energy Operations").

Responsibility for emergency preparedness and response in the event of a transportation accident involving radioactive materials is spread among the DOE, the carrier of the waste, and the Federal, State, and local governments. The carrier of the waste has the initial responsibility for "onsite" activities to minimize the hazards to life and property from a possible spill of radioactive materials. State and local governments have the primary responsibility for emergency measures that must be undertaken to protect persons, property, and the environment on lands within the State's boundaries from the threat of harm from an accident involving the transportation of nondefense radioactive waste. Upon request by State or local authorities, the DOE and the Federal Emergency Management Agency will provide assistance in responding to emergency situations. (The DOE's personnel will also respond to emergency-assistance requests from private persons and companies, including transportation carriers.)

In regard to emergency response at the Hanford and the Yucca Mountain sites which are Federal nuclear reservations, any onsite accidents would be the DOE's responsibility, not that of the State or the local jurisdiction.

Issue

Commenters questioned the extent of the Federal Government's liability in case of a transportation accident or an accident at the repository in light of the Price-Anderson Act, which limits coverage to $570 million. They claim that the sum is inadequate and that the Federal Government must assume 100 percent liability in the case of an accident. The failure to address this indicates the government's unwillingness to realistically address the risks associated with the repository.

Response

The Price-Anderson Act provides liability for damages suffered by the public in the event of nuclear accidents at certain facilities, including DOE contractor-operated facilities. The Price-Anderson Act is now under Congressional review, and the Secretary of Energy has made recommendations for extending liability coverage for activities carried out under the Act. (See Appendix A of the EAs for a more detailed discussion.)

Issue

One commenter wanted to know whether DOE contractors are subject to the Mine Safety and Health Act.

Response

The DOE is not subject to the requirements of the Mine Safety and Health Act but intends to comply with its provisions in the repository program. The decision to construct two exploratory shafts (rather than one) at each site recommended for characterization was based partly on compliance with this regulation.

Issue

One commenter asked whether a repository would be excluded from "public health scrutiny" under the Atomic Energy Act of 1954.

Response

Under the Atomic Energy Act of 1954, all facilities in the commercial nuclear fuel cycle, including repositories, are subject to licensing by the NRC, and for this purpose the NRC has promulgated regulations whose objective is to protect the health and safety of the public. For a repository, NRC licensing is also required by the Act, which also stipulates that geologic disposal must be safe and environmentally acceptable.

C.2.3 PROGRAM MANAGEMENT, COSTS, AND SCHEDULES

Included in the comments on the draft EAs were a number of comments on program management, costs, and schedules. The DOE's schedule for repository siting and development was of concern to many parties, most of whom urged the DOE not to sacrifice excellence for schedule.

C.2.3.1 Program management

The comments on program management were concerned mainly with the potential for conflicts of interest in DOE contractors, peer review of the technical program, the need for a program plan, and assurance that DOE contractors will take the necessary measures to protect the environment.

C.2.3.1.1 Conflicts of interest

Issue

Some commenters stated that contractors with a high financial stake in repository development should not perform analyses for site evaluation. Many commenters suggested that, out of the wide range of available data, the contractors choose to analyze only the data that favorably depict the site. The DOE should either employ different contractors for the analysis of site data or allow the current contractors to continue with site-data analysis of with the stipulation that they will not be considered for prime-contractor positions for repository construction or operation.

Response

Conflict of interest is a potential problem in any large program where individuals and organizations may have a long-term vested interest in the continuation of the program. However, the repository program is divided into several major phases, and the contracts now in effect are limited to the current phase only (development and evaluation). Furthermore, the contracts of the major support contractors are opened for bids every 5 years. Because of the different skills and experience that will be required for repository construction and operation, many of the contractors for these phases are likely to be different from those involved in site evaluation.

There is little likelihood of biased analyses because the analyses conducted for site evaluation are reviewed by the DOE Project Offices, peer review groups, independent experts hired by other DOE organizations (e.g., the Office of Environmental Compliance, which is under the Assistant Secretary for Environment, Safety and Health), other Federal agencies, and technical experts hired by the States. Documents important to the siting process, such as the draft EAs and the environmental impact statement, are submitted for review by the public. The draft EAs were also reviewed by the Nuclear Regulatory Commission, the U.S. Geological Survey, and the National Academy of Sciences. Finally, the ultimate decision on the suitability of a candidate site will be made by the Nuclear Regulatory Commission, which is continuously reviewing the DOE's work through its staff and consultants.

C.2.3.1.2 Technical peer review

Issue

Several comments referenced a report by the General Accounting Office (GAO) report, issued January 10, 1985, that concluded that the program lacks consistent peer review and that this lack may ultimately subject the DOE's technical analyses to challenges and revisions.

Response

Peer review is an important part of the process by which a repository is sited, constructed, and operated. Peer-review groups have already participated in the early stages of the process. For example, the DOE has assembled a group of independent experts, the Performance Assessment National Review Group, to examine the performance-assessment work of the first repository projects. As the repository program continues, the OCRWM expects to assemble similar groups to examine other parts of the work. Other DOE organizations--for example, the Office of Environmental Compliance--also use independent experts in their review of work sponsored by the OCRWM; their peer reviews are significant contributions to the program. The DOE Project Offices also employ peer review groups in many of the technical aspects of the program.

The States in which a repository may be located also provide independent peer reviews; some of the funds distributed by the DOE as financial assistance to the States are used for that purpose.

Another source of independent peer review is the National Academy of Sciences. This organization has contributed a review of the draft EAs and is expected to contribute further reviews in the future.

The ultimate peer review of the program will be provided by the Nuclear Regulatory Commission. Through its staff and consultants, the Commission will continuously review the DOE work, as it already has the siting guidelines and the draft EAs.

C.2.3.1.3 Need for program plan

Issue

A commenter said that the DOE needs a program plan for waste disposal.

Response

The DOE issued the draft Mission Plan for the Civilian Radioactive Waste Management Program in April 1984 (DOE, 1984a) and the revised plan in June 1985 (DOE, 1985). The Mission Plan describes the objectives and strategies of the program, summarizes current program plans, and summarizes the technical status of the program.

C.2.3.1.4 Protection of the environment

Issue

Some commenters said that government contractors will not spend the money to ensure that the environment is protected during the construction of the repository.

Response

The DOE will oversee all construction activities to ensure compliance with Federal environmental regulations. An environmental plan that specifies procedures to be followed will be prepared for the construction project. Potential impacts are discussed in the EAs. A more comprehensive analysis will be presented in the Environmental Impact Statement, which will also discuss measures for mitigating any significant adverse impacts.

C.2.3.2 Program costs

Several commenters inquired about the total cost of repository development, who was responsible for these costs, and whether the cost of defense-waste disposal would be borne by the Federal Government.

Issue

Commenters asked about the total costs of repository development and waste-management activities.

Response

The costs of the Civilian Radioactive Waste Management Program are divided into four major categories: (1) development and evaluation; (2) geologic repository construction, operation, closure, and decommissioning; (3) transportation; and (4) storage. Estimates of costs for each category depend on the assumptions about such variables as the quantity of waste to be emplaced, the minimum "age" of the waste, the host rock of each repository, the repository design receipt rate, the beginning operation date for each repository, the technology used for waste-transportation casks, and the basis for expressing costs. The figures discussed below were taken from Chapter 10 of Part II of Volume I of the Mission Plan (DOE, 1985a), which discusses in more detail the total costs of managing commercial radioactive wastes.

The costs of development and evaluation (D&E) include all the siting, repository design, testing, regulatory-compliance activities, and institutional activities associated with the repository, waste transportation, and monitored retrievable storage (MRS). The current reference case for total D&E costs is $7.8 billion (in constant 1984 dollars).

Repository costs include the costs of construction, operation, closure, and decommissioning. Depending on the host rock, the costs of the first repository may vary from $6.8 billion to $10.7 billion (in constant 1984 dollars) for the reference cases. The repository costs of the second repository may vary from $5.8 billion to $6.1 billion (in constant 1984 dollars).

Waste-transportation costs will be derived from a unit charge for transportation cask use, shipping, and security for each potential transportation pathway. The pathways include transportation from the commercial reactors to each repository, from reactors to an MRS facility (if such a facility is approved by Congress and developed), and from an MRS facility to each repository. The total transportation cost is the sum of these three transportation unit costs. Estimates for transportation costs for the reference cases vary from $3.3 billion to $5.1 billion.

Current planning assumptions for an MRS facility estimate the costs at between $1.6 and $2.6 billion, or about 5 to 11 percent of the estimated costs of a waste-management system without an MRS facility.

Issue

Commenters asked who is responsible for the costs incurred in constructing the repository. How will these costs be covered and who will pay for the program if the nuclear power plant industry dies out before the closure of the repository?

Response

The Act requires the owners and generators of commercially generated radioactive waste to pay the full costs of its disposal and established a Nuclear Waste Fund to ensure the full-cost-recovery funding of the waste-management program. This Fund receives revenues from an adjustable fee charged quarterly for all electricity generated by commercial nuclear facilities beginning April 7, 1983, as well as a one-time fee, estimated to produce a total of $2.3 billion, for radioactive waste produced before April 7, 1983. The revenues generated from these two sources, in addition to interest earned from the investment of any surplus in U.S. Treasury securities, are deposited in the Fund, and disbursements are made to cover costs as the program progresses.

Forecasts of future nuclear power generation are incorporated into the management of the Fund. Representative scenarios are presented in DOE documents describing the adequacy of the fund (DOE, 1985c) and analyzing the total-system life-cycle cost for the program (DOE, 1985d).

Issue

Some commenters wanted to know who is responsible for paying for the disposal of defense high-level waste?

Response

As stipulated in the Act, the Federal Government will cover all costs of defense-waste disposal through contributions to the Nuclear Waste Fund (see also Section C.2.6.1).

Issue

Some commenters noted the need for an independent waste-fund audit.

Response

As required by the Act, the Comptroller General of the United States makes annual audits of the Nuclear Waste Fund and submits reports to Congress. An independent audit is also performed for the DOE by a certified public accounting firm. The latest audit covered the period from January 7, 1983 to September 30, 1984, and the results are summarized in the DOE's Annual Report to Congress (DOE, 1985e).

C.2.3.3 Schedule

Many commenters expressed concern that the DOE's schedule for repository siting and development would adversely affect the selection of sites, the consultation process, and the adequacy of the technical data.

C.2.3.3.1 Dependence of site-selection process on schedule

Many comments contended that the mandated repository schedule is driving the site-selection process. Commenters felt that the DOE's schedule is inadequate in that it is an unrealistic list of dates dictated by political decisions rather than by sound geologic site-screening criteria. They requested that the date for the final site selection be postponed and the number of potential repository sites be increased. (See also Section C.3.4.4 for comments on related issues.)

Issue

A number of commenters requested that the date for the final site selection be postponed and the number of potential repository sites be increased.

Response

Being committed to a schedule that will lead to the receipt of waste in 1998 for emplacement in the first repository, the DOE will make every effort to meet intermediate milestones, such as the selection of the site for the first repository, without sacrificing technical excellence.

As explained in Section C.3, the DOE believes that the number of potential repository sites is adequate and in compliance with the requirements of the Act.

Issue

A commenter requested that the DOE recommend that Congress amend the Act to reduce the time constraints in order to allow sufficient time for the entire process.

Response

The DOE recognizes that its schedule is success oriented, but it is also achievable. Hence, a recommendation for an amendment of the Act is not needed.

C.2.3.3.2 Effects on the consultation process

Issue

One commenter said that the DOE could not stay on schedule and conduct a satisfactory program of consultation and cooperation with States and affected Indian Tribes.

Response

As discussed in detail in Chapter 4 of Part I of Volume I of the Mission Plan (DOE, 1985a), the DOE maintains an ongoing program of consultation and information exchange with the States and affected Indian Tribes. The scope of this program is not determined by the overall project schedule. The DOE will seek to enter into negotiations with States for written consultation-and-cooperation agreements(s) within 60 days after the approval of sites for characterization.

Issue

Some commenters stated that the DOE's tight schedule means closed decisions and no public input.

Response

Recognizing that the schedule is very tight, the DOE is nonetheless fully committed to a process of open and active consultation with all interested parties (see DOE, 1985a, Chapter 4 of Part I of Volume I). Closed decisions are not in the DOE's interest because the schedule can be met only if the States, Indian Tribes, and the public are confident that the siting decisions are sound.

C.2.3.3.3 Effects on the adequacy of technical data

Many comments about the schedule stated that it did not allow time for adequate scientific study and hence might compromise the site-selection process. One commenter doubted that 5 years was enough time for data gathering during site characterization. Conversely, another party noted that the characterization process should follow the mandated schedule so as not to increase costs.

Issue

Many comments objected that the schedule does not allow sufficient time for adequate scientific study.

Response

The DOE cannot meet the schedule without adequate scientific study because it will not be able to obtain an NRC license unless it can demonstrate that the site can meet the standards of the EPA and the technical criteria of the NRC. Furthermore, the DOE believes that it can meet the schedule without sacrificing technical excellence.

Issue

The reference schedule does not allow adequate scientific analyses during site characterization.

Response

The DOE is confident that the schedule for site characterization is adequate.

Detailed plans for the studies to be conducted will be included in the site-characterization plans, which will be submitted to the Nuclear Regulatory Commission, the U.S. Geological Survey, the States, and the public for review.

The Mission Plan (DOE, 1985a) outlines four alternative cases for site characterization in addition to the reference case. Each case identifies and discusses potential delays. The measures that could be used to compensate for these delays are discussed in the draft Project Decision Schedule (DOE, 1985b).

C.2.4 TRANSPORTATION, RETRIEVABILITY, AND SECOND REPOSITORY

C.2.4.1 Transportation

This section presents general, rather than site-specific, comments on transportation and the analyses presented in Appendix A; these comments are national in scope.

Most of the site-specific comments on transportation pertain to the local and regional transportation impacts of repository operation and are discussed in Section C.7.3. Typical examples of the repository-related transportation comments covered in Section C.7.3 include (1) the impacts of constructing repository access routes, (2) the transportation impacts of repository operation on the local and regional population and environment, (3) the suitability of candidate local and regional transportation routes, and (4) the compliance of the site with the conditions of the transportation guideline.

Many commenters said that the Appendix A should contain more-detailed analyses (e.g., route-specific analysis) and more background information (e.g., legislative and regulatory history). The more-detailed analyses will be performed after the necessary data are collected during site characterization; they will be reported in the environmental impact statement that will accompany the recommendation of one site for development as a repository.

The information provided in the EAs is believed to be sufficient to support preliminary findings on the conditions of the transportation guideline and to discriminate among the sites and is in accordance with the requirements of the siting guidelines (DOE, 1984c). For transportation, the types of information that should be used in nominating sites as suitable for characterization are listed in Appendix IV as follows:

- Estimates of the overall cost and risk of transporting waste to the site.
- Description of the road and rail network between the site and the nearest interstate highways and major rail lines; also description of the waterway system, if any.
- Analyses of the adequacy of the existing regional transportation network to handle waste shipments; the movement of supplies for repository construction, operation, and closure; the removal of nonradioactive waste from the site; and the transportation of the labor force.

- Improvements expected to be required in the transportation network and their feasibility, cost, and environmental impacts.

- Compatibility of the required transportation-network improvements with the local and regional transportation and land-use plans.

- Analysis of weather impacts on transportation.

- Analysis of emergency-response requirements and capabilities related to transportation.

C.2.4.1.1 Cost and risk estimates for transportation

Issue

The transportation cost and risk analyses in the draft EAs were generally considered inadequate by many commenters. Specifically, four main inadequacies were identified: (1) the methods and inputs used were not valid; (2) food-chain and water pathways were overlooked; (3) centroids (i.e., points representing the geographical setting of groups of reactors) were used in lieu of actual reactor locations; and (4) route-specific data were not used.

Response

The DOE believes that the methods and input to the cost and risk analyses are valid and that the results provide an adequate basis for comparing the transportation impacts that would result from shiping waste to each of the sites. However, as discussed below and in Sections C.2.4.1.3, C.2.4.1.4, and C.2.4.1.7, some changes in the methods and input were made. The results of these changes are found in Appendix A.

The RADTRAN II radiological risk code was modified to include the food chain, though the overall impact of this exposure pathway is minor. This change is reflected in the results presented in Appendix A. The relative importance of water pathways can be inferred from similar analyses developed for studies of the risk from nuclear reactors. These studies have examined hypothetical accidents with large radionuclide releases to the environment and have shown that water pathways on the average are small contri- butors to the total health risk from accidents. However, the consequence analysis included in Appendix A does evaluate the radiation doses received from the water pathway. (See also Section C.2.4.1.3.)

In the draft EAs, which considered shipments from reactors to repository only, the sensitivity of the result to the use of centroids rather than individual reactor locations should be small. However, by introducing the MRS facility, the sensitivity may increase. In the final EAs, actual reactor locations were used in lieu of centroids to evaluate the fractions of travel in the various population-density zones because the MRS facility is now included in the analyses. The results in Appendix A reflect this change.

The issue of route-specific analyses is addressed below.

C.2.4.1.2 Route-specific analysis

Issue

The transportation-risk analyses, which were based on national average data, were challenged in many comments as being inadequate and improper for comparing the repository sites. Furthermore, some commenters said that such analyses do not highlight the special impacts on some States through which a large fraction of all shipments to the repository will pass.

Response

The DOE believes that the general methods and national average data used are adequate for this stage of the repository-siting process. Route-specific analyses and an evaluation of the impacts on host States and States along transportation corridors will be included in the environmental impact statement.

The route-specific analyses to be performed in the future will proceed in the following sequence: (1) define important parameters; (2) gather data; (3) develop models as required; (4) perform analysis; (5) consider mitigating measures; (6) report results. Much coordination and cooperation will be required from State governments and Indian Tribes, particularly in the early stages where parameter identification and data gathering will take place.

C.2.4.1.3 Assessment of the consequences of accidents

Numerous comments said that Appendix A should discuss the consequences of accidents that could occur during transportation and recommended that the analysis consider such factors as route-specific anomalies, the cost of emergency response and cleanup, ingestion pathways, and occupational and non-occupational exposures.

Response

The analyses described in the draft EAs were presented in terms of risk, which is the product of the probability of occurrence and the consequences of that occurrence. Consequence analyses had been performed, but their results were used in producing the risk values published and were not presented separately.

For the final EAs, the consequences of accidents were reevaluated, considering the suggestions of the commenters. The results, consisting of both costs and radiation doses, are in Appendix A. The potential impacts of releases to the atmosphere with deposition on land and on a reservoir are evaluated. Also included are the estimated probabilities of the accidents.

Emergency-response and cleanup costs are described in detail in a study prepared for the NRC (NRC, 1980) and thus are not included in the final EAs.

C.2.4.1.4 Maximum exposure of individuals

Several commenters stated that there were plausible scenarios in which an individual would receive more radiation exposure than the maximum dose estimated in Appendix A. Others said that Appendix A should include the maximum exposure received by an individual during an accident.

<u>Response</u>

Elements of the suggestions received have been combined to define a new set of circumstances for estimating the maximum exposure that individuals might receive during shipments to a repository under normal conditions. Similarly, accident descriptions have been developed for estimating the maximum radiation exposure received by a rescue worker and a member of the public. These analyses are presented in Appendix A.

C.2.4.1.5 Modal split for shipments

Several commenters were confused about the percentage of shipments that will occur by truck and by rail. Some analyses assumed that 70 percent of the shipments would be by rail and 30 percent by truck, while most of the analyses assumed for 100 percent by rail or 100 percent by truck. Furthermore, earlier studies were based on 50 percent of shipments going by rail and 50 percent by truck.

<u>Response</u>

Analyses have not been inconsistent. In order to calculate the maximum national impacts of transportation to a repository, two cases were evaluated. One case evaluated the impacts resulting from making all shipments by rail (100 percent rail) and the other from all shipments by truck (100 percent truck). It is expected, however, that during the early years of repository operations rail shipment will be used for no more than about 50 to 70 percent of the total spent-fuel shipments because of the lack of rail spurs at some reactor sites and other limitations. In later years it is expected that reactor capability to ship by rail will be improved, and the fraction of spent fuel shipped by rail will increase to a least 70 percent. In addition, the rail-to-truck ratio will vary from year to year, depending on which reactors are making shipments.

Assumptions of 100 percent by truck and 100 percent by rail will continue to be used, except that for shipments from the MRS facility to the repository only the rail made will be considered. For national risk and cost impacts resulting from radioactive-material shipments and directly attributed to transportation operations, these cases result in the maximum predicted impact.

C.2.4.1.6 Defense waste

Several commenters stated that the volume of defense waste to be shipped to a repository was understated in the draft EAs. In particular, the EAs only considered the transportation of defense high-level waste from the Savannah River Plant and did not consider transportation from either the Hanford Site or the Idaho National Engineering Laboratory (INEL). One commenter asked about shipping liquid high-level waste.

Response

The final EAs consider shipments of defense high-level waste from the Savannah River Plant, the Hanford Site, and the INEL. Defense high-level waste will not be transported as a liquid nor will separate shipments of krypton-85 or iodine-129 be made.

The transportation of defense high-level waste is discussed in Chapter 5 and Appendix A of the final EAs. This discussion also recognizes that the President has decided that defense high-level waste should be shipped to a civilian repository for disposal; this decision had not been made when the draft EAs were issued.

C.2.4.1.7 Monitored Retrievable Storage

Issue

Some commenters objected that the transportation analysis was inadequate because a facility for monitored retrievable storage (MRS) was not included in the waste-management system considered in the draft EAs.

Response

The MRS facility had not been proposed when the analyses were prepared for the draft EAs. Preliminary transportation analyses indicate that the total number of miles traveled by the cask fleet can be decreased by introducing an MRS facility into the waste-management system. A description of a representative transportation system designed to support the MRS facility was used to estimate transportation costs and risks for a waste-management system with an integrated MRS facility; the results are included in Appendix A. This new analysis supplements, rather than replaces, the analysis for the reference case.

C.2.4.1.8 Barge transportation

Issue

Several commenters objected that the use of barges had not been given any consideration in the transportation risk assessment, calling this a serious deficiency because barge transportation is a discriminator among the potential candidate sites; some of them felt that this omission was most serious for the Hanford site, which is close to a navigable waterway (approximately 16 miles away).

Response

A discussion of the barge mode is included in Appendix A to the final EAs. The discussion is in two parts: a description of the mode as a feasible alternative that can play a secondary or supplementary role in the transportation of radioactive wastes and a synopsis of a risk and cost study performed by the Argonne National Laboratory (Tobin and Meshkov, 1985) to examine the normal risk of transporting by barge and to examine costs of shipment, including transfers to truck or rail. The set of circumstances considered does not include the shipment of spent fuel from reactors in the East through the Panama Canal to the Hanford site. The discussions explain the premise that barge transport is not a sensitive discriminator among sites, and it is unnecessary therefore to include an exhaustive analysis in the final EAs.

The particular logistics for using barge to transport spent fuel from some reactors near the West Coast to the Hanford site are discussed in the final EA for Hanford.

C.2.4.1.9 Consideration of a second repository

Issue

Some groups were critical of the fact that the EAs did not consider the implications of a second repository on transportation. They postulate that a two-repository system would minimize the overall cost and risk of transportation.

Response

Favorable condition 5 of the transportation guideline is the "total projected life-cycle cost and risk for transportation of all wastes designated for the repository site which are significantly lower than those for comparable siting options, considering locations of present and potential sources of waste, interim storage facilities, and other repositories." The second-repository program has not yet reached the point where potential sites can be identified--in contrast to the MRS facility, where an analysis is now possible because, since the publication of the draft EAs, potential MRS sites have been identified. As a result, the DOE cannot perform rigorous cost and risk analyses analogous to those done for the MRS case. However, certain assumptions about the potential impacts of a second repository can be based on previous studies. A discussion of the potential impacts of a second repository is found in Appendix A.

C.2.4.1.10 The use of existing casks in the EA analysis

Issue

A number of comments challenged the validity of using the characteristics of currently existing and NRC-certified casks for the transportation risk analysis in the draft EAs. The commenters recognized that the design of the new casks to be used for most shipments will reduce the number of shipments because of higher capacities. However, they questioned that the greater quantities of fuel in a single cask would provide a greater source for the release of radionuclides in a serious accident.

Response

The risk and cost assessments for transportation have been reevaluated, using the predicted characteristics of the new family of casks, even though their designs are not yet available. Risks were assessed for both normal and accident conditions, and assumptions that would result in the maximum expected impacts were used. Because of the conservatism in all assumptions, the impacts are similar to those calculated for existing casks, even though the new casks will require fewer miles of travel and fewer shipments. The results are found in Chapter 5 and in Appendix A.

C.2.4.1.11 Adequacy of current cask designs

Issue

Some commenters questioned the adequacy of the design of currently existing casks.

Response

The adequacy of cask design is a regulatory issue, and, since the existing spent-fuel casks have been certified by the Nuclear Regulatory Commission, the DOE has no reason to question the adequacy of their design. The existing casks have carried thousands of shipments without an accident that resulted in the release of radioactive material. The DOE will develop a new family of casks because it seeks to increase efficiency, not because it is concerned about the safety of existing casks. The new-generation casks will also have to meet regulatory requirements for cask design and be certified by the Nuclear Regulatory Commission. A more detailed discussion of the new family of casks is found in Appendix A.

C.2.4.1.12 Additional testing of casks

Issue

Several commenters expressed concern that casks are not sufficiently tested to ensure that the public is safe during transportation. Some suggested destructive testing of full-scale prototype casks.

Response

The Nuclear Regulatory Commission has specified a series of hypothetical accident conditions that a cask must be shown to survive. Survival can be demonstrated through analysis should the designer so choose or through testing, but destructive testing is not mandatory. However, many tests, including full-scale crash tests, have been conducted to verify analytical models. The results of analyses and experiments have been quite close, and hence considerable confidence has been developed in the analytical models used in design analysis.

Casks developed for the shipments to a repository will be certified by the Nuclear Regulatory Commission. The private contractors chosen to design and obtain certificates for the casks will be allowed to choose the manner of demonstrating how their designs comply with NRC regulations. At a minimum, the DOE will use an independent testing laboratory to perform destructive tests of scale models for cask designs as a benchmark or check of structural performance under accident conditions. In addition, nondestructive tests will be performed on each cask during and at the completion of manufacture, and the casks will be inspected before each shipment.

C.2.4.1.13 Cask weeping

Issue

Some commenters said that the phenomenon called "cask weeping" had not been considered in the risk assessments.

Response

The phenomenon of cask weeping can be described as follows: A cask that has been loaded or unloaded in a reactor storage pool becomes contaminated with radioactivity on its surface. Before shipment, the external surface of the cask is decontaminated to levels specified by regulations, but when the cask is inspected on arrival at its destination, contamination above the levels allowed by regulation is found. Though the actual mechanism is not understood, a possible explanation is that, when a cask is repeatedly placed into water-filled spent-fuel storage pools, it becomes contaminated over time, with the contamination penetrating deeper into the pores of the cask body. The cleaning removes the surface contamination, but the contamination that is deep in the pores remains. During the transportation of a loaded cask, the surface can become contaminated again as the deep contamination is driven out of the pores by the heat of the spent fuel inside the cask.

However, the levels of contamination associated with the weeping phenomenon are not high enough to be factored into the risk assessment for transportation, and procedures will be used to effectively preclude this problem during shipments to a repository. For example, wrapping the cask in plastic before entry into reactor fuel storage pools is an effective practice that is currently used. Therefore, weeping is not expected to be a significant contributor to risk during spent-fuel transportation to a repository and is not included in the transportation-risk assessment presented in Appendix A.

C.2.4.1.14 Adequacy of NRC testing requirements

Issue

Several commenters said that the tests that casks must pass to receive NRC certification are not severe enough.

Response

The conditions being challenged are established by the Nuclear Regulatory Commission, and the DOE will continue to rely on the Commission to verify the adequacy of the test conditions.

C.2.4.1.15 Legal impediments

Issue

Two commenters took exception to the DOE's interpretation of State or local restrictions against radioactive-waste transportation as "legal impediments" in favorable condition 7 of the technical guideline on transportation (10 CFR 960.5-2-7). In particular, the U.S. Department of Transportation (DOT) commented that, since its regulation of highway routing of radioactive materials (HM-164) has been established as valid by the U.S. Supreme Court, the only "legal impediment" would be a State or local routing rule that renders compliance with HM-164 impossible but is found not to be preempted under provision 112(b) of the Hazardous Materials Transportation Act (HMTA). If such a finding cannot be made, any State or local routing rule that prevents or seriously impedes compliance with HM-164 is preempted by the HMTA (Section 112(a)).

Response

Favorable condition 7 of the transportation guideline is the "absence of legal impediments with regard to compliance with Federal regulations for the transportation of waste in or through the affected State and adjoining States."

Insofar as the Department of Transportation is the responsible regulatory agency, the DOE defers to its interpretation of "legal impediment." Because State, local, or tribal laws or regulations restricting the transportation of radioactive waste that are inconsistent with either the HMTA or the DOT regulations issued thereunder are preempted by the HMTA, such laws or regulations are not considered legal impediments in the final EAs; a formal nonpreemption determination by the DOT, in response to a sepcific request, is required for such laws or regulations to become legal impediments. The findings in Chapter 6 reflect this change in interpretation and appropriate rationales for the finding are included in all EAs. A more extensive discussion of HM-164 is presented in Appendix A.

C.2.4.1.16 State designation of alternative routes

Issue

The commenters noted that in Appendix A the EAs contain an incorrect statement--namely, that State designation of alternative preferred routes must be approved by the Department of Transportation. They said that HM-164 does not require States to seek DOT approval of alternative designated routes.

Response

The Department of Transportation requires, under HM-164, that a "preferred route" be used for the transportation of controlled-quantity shipments of radioactive materials. Preferred routes are interstate highways and State-designated alternative routes. Although the States and Indian Tribes must comply with DOT guidelines (or an equivalent routing analysis that adequately considers the overall risk to the public) and consult with affected local jurisdictions, Indian Tribes, and potentially affected adjacent States before establishing a preferred route, there is no requirement to seek DOT approval of alternative designated routes. The EAs have been revised to reflect this in Appendix A.

C.2.4.1.17 Indian Rights

Issue

Several Indian Tribes commented that the EAs failed to recognize the authority granted to tribal governments on federally recognized Indian reservations under the HMTA and the rules set forth by the Department of Transportation in HM-164. One Indian Tribe noted that a ban on radioactive-waste transportation through its reservation constituted a "legal impediment."

Response

The final EAs use the DOT definition of "State routing agency." The DOT rules (HM-164) include appropriate Indian tribal authorities in the definition of "State routing agency" and, as such, allow the governments of Indian Tribes to exercise routing authority in a similar manner as provided for the State governments.

If a ban enacted by an Indian Tribe meets the criteria of the HMTA for nonpreemption, then (as in the case of any State ban) a legal impediment will be present. A more detailed discussion is given in Appendix A, (see also Section C.2.4.1.15).

C.2.4.1.18 Availability of railroads for transporting radioactive waste

Issue

One commenter noted that, though the DOE states that rail carriers are available for shipping radioactive waste, the willingness of the railroads to transport the waste is questionable.

Response

There have been a series of decisions by the Interstate Commerce Commission (ICC), affirmed on judicial review, on this and related issues over the past several years. The Commission has ruled that, as common carriers, the railroads cannot refuse to carry cask loads of spent fuel and to return empty rail casks. Furthermore, this transport must be accomplished in regular train service (as opposed to "special trains," which the Commission has found to be a "wasteful transportation practice"), unless the DOE chooses otherwise.

At this time uncertainty in rail transportation remains in the tariff rates. For eastern railroads, the Commission has upheld a DOE and industry challenge to the published tariff rates and has reduced and set the rate levels. However, for western and southern railroads, the question of rate appropriateness is pending before the Commission. Therefore, the issue does not appear to be whether the railroads will transport radioactive waste, but rather at what rates.

In order to more closely work with the railroads and to understand the concerns that do remain, the DOE has and will continue to invite them to participate in all stages of the transportation program, including the development and testing of shipping casks. Also, the DOE and the Association of American Railroads are planning joint activities to resolve issues.

C.2.4.1.19 Railroad regulations

Issue

A commenter asked for a description of the existing regulations for the transportation of radioactive waste by rail.

Response

Federal regulations regarding the transportation of hazardous material, including radioactive material, can be found in Title 49 of the Code of Federal Regulations, Parts 174.83-174.93. These regulations are concerned with the handling of placarded cars. In particular, for cars containing radioactive material, the regulations deal with the switching of cars, the ban on the use of passenger trains, and the position of cars in a train. A more-detailed discussion of rail regulations is included in Appendix A of the final EAs.

C.2.4.1.20 Dedicated trains

Issue

Several comments concerned the treatment of rail transportation in the EAs. In particular, the commenters objected that discussions and analyses of rail shipments were based on shipping in general commerce rather than by dedicated trains.

Response

Appendix A has been revised to include a general discussion of the use of dedicated trains and an analysis of the risks associated with using dedicated trains for the movement of waste from an MRS facility to a repository.

C.2.4.1.21 Regional transportation analysis

Issue

Federal agencies as well as several States and Indian Tribes criticized the regional transportation analysis, stating that it did not extend far enough from the site to include all of the pertinent impacts, such as weather hazards, the cost of building access routes, the radiological risk, traffic hazards and increased traffic volumes on highways connecting interstate highways with access roads, and possible routes across Indian lands.

Response

The "regional" transportation analysis includes, as a minimum, the routes from the potential site to the nearest interstate highway or mainline railroad; the analysis may be extended beyond that area if the circumstances at the particular location warrant it. However, the intent of the siting guidelines (10 CFR Part 960) is to focus on effects near the site. The estimates of the costs of building access routes will be improved during site characterization. Currently available data on road conditions (e.g., traffic volumes and potential hazards) are presented in the EAs. More-detailed data and a discussion of mitigation measures will appear in the environemental impact statement.

C.2.4.1.22 Weather impacts

Issue

Many commenters criticized the way in which weather impacts were considered in the transportation analysis. Some gave examples of weather-related road closings; others asked about the effect of weather on frequency and severity of accidents.

Response

Weather conditions are considered in favorable condition 9 of the transportation guideline: "A regional meteorological history indicating that significant transportation disruptions would not be routine seasonal occurrences" (emphasis added). This favorable condition is concerned with the absence of routine seasonal conditions that could disrupt repository activities to the extent that the annual waste-acceptance rate could not be met. Weather-related route closures are considered in the final EA, and the analysis of such closures is considered adequate for this stage of the site-selection process. When the number of sites has been narrowed and route-specific analyses are conducted, concerns about occasional weather-related bottlenecks between specific reactors and repository sites can be addressed.

C.2.4.1.23 Potential for human error

Issue

Some commenters stated that the potential for human error in the transportation of radioactive waste is not treated adequately in Appendix A.

Response

The DOE has considered the potential for human error in the assessment of transportation risks. A study prepared for the Nuclear Reguluatory Commission (NRC, 1980) analyzed detailed incidents of human error and deviations from accepted quality-assurance (QA) practices in the transport of radioactive materials. The results indicate that the risks from human errors or deviations from accepted QA practices are extremely small (i.e., 0.000012 latent-cancer fatality per shipment-year for packages tested to accident conditions), and thus it is not meaningful to include these risks in the radiological risk analysis for transportation.

C.2.4.1.24 Retrieval of waste

Issue

Commenters asked about the impacts that would result from the transportation of waste retrieved from a repository should retrieval prove to be necessary.

Response

At this stage in the repository-design process, the full impacts of retrieval on transportation requirements are not known. If retrieval proves to be necessary, the spent fuel will be older and less radioactive than at the time of emplacement; it is therefore expected that the transportation of such waste should have less of an impact. A discussion of the retrievability issue in general can be found in Chapter 5.

C.2.4.1.25 Financing infrastructure improvement

Issue

Several commenters suggested that the costs of infrastructure improvements, such as the upgrading or reconstructing of roads or rail lines, should be considered in the cost analysis and that more information is needed on how such improvements would be integrated with local economic development plans.

Response

A preliminary analysis of the need for upgrading or reconstructing local roads and railroads was performed for the comparative evaluation of sites. Related discussions can be found in Chapter 6 of the individual EAs. The condition of local roads or railroads will be established during site characterization; it will be analyzed more rigorously for the environmental impact statement and again before the repository begins operation, and plans for integration into local development plans will be developed.

C.2.4.1.26 Adequacy of the transportation guideline

Issue

Many commenters expressed the opinion that the transportation guideline is not adequate for discriminating among sites. In particular, they stated that the use of legal impediments as a discriminator is inappropriate, as they may change over time; that transportation costs should not be considered in the ranking because they are of minor importance in comparison with transportation risks to the public and the environment; and that the guideline condition discussing weather impacts on transportation in the vicinity of the site should be expanded to include potential disruptions between the reactors and the site. Other commenters criticized the weight given to the transportation guideline, considering the potential impact of transportation.

Response

The siting guidelines (DOE, 1984c) were developed through consultation with affected and interested States, the Council on Environmental Quality, the Environmental Protection Agency, and the U.S. Geological Survey and received the concurrence of the Nuclear Regulatory Commission. The transportation guideline is one of three guidelines in the preclosure group on environmental, socioeconomics, and transportation. This group of guidelines is second in importance to the preclosure group on radiological safety but all the guidelines in any preclosure group are assigned equal importance.

C.2.4.1.27 Inadequate treatment of transportation issues

Issue

Many comments stated that a variety of general transportation issues received inadequate or no attention in either the body of the EA or in Appendix A. Among the issues listed were emergency-response responsibilities, the impacts of using overweight trucks, rail routing requirements, inspection and enforcement, liability, safe havens, advance notification, training, sabotage, NRC safeguards regulations, and the responsibilities of the DOE as the shipper of record.

Response

Many of the topics listed by the commenters are discussed in the EAs, particularly in Appendix A. Since the draft EAs were published, additional policy decisions about several of the issues have been made, and, where additional information is available, the discussion of the issue has been expanded. It should be pointed out, however, that most of these issues, while of concern in the overall context of the transportation program, have little bearing on the site-selection process. They were included in the EAs primarily to give the reader a better understanding of the transportation program. For further information on how the DOE plans to interact with the States, Indian Tribes, and industry to resolve these other issues, the reader is referred to the Transportation Institutional Plan (DOE, 1985f).

C.2.4.2 Retrievability

Several commenters addressed the need and the desire to retrieve spent fuel and high-level waste after emplacement in the repository. The issues they raised include the view that wastes should not be placed where they cannot be retrieved, the DOE's plans for the length of the retrievability period, and the methods to be used in retrieval.

Issue

Some commenters said that at some point the United States may want to retrieve the spent fuel or high-level waste to reuse some of its components or to take advantage of new technical developments. The wastes should therefore not be emplaced where retrieval is not possible.

Response

In compliance with the Act and the NRC criteria for geologic repositories (10 CFR Part 60), the waste will be retrievable for up to 50 years after the emplacement of the first waste. The reason for retrieval would be to protect public health and safety. The DOE does not intend to recover the wastes for their economic value. The commitment to geologic disposal implicitly forfeits the future use of the waste in return for assurance that the waste has been permanently isolated from the human environment.

Issue

A commenter asked whether there is a scientific and political consensus about whether the wastes should be retrievable or permanently disposed.

Response

By mandating geologic disposal, the Act implies a political consensus that disposal must be permanent. The concept of permanent disposal is widely supported by the technical community and is explicit in the NRC and EPA regulations (10 CFR Part 60 and 40 CFR 191, respectively). The NRC requirement for retrievability is directed at demonstrating that the performance of the repository is adequate for permanent disposal.

Issue

Commenters asked that the DOE specify the period during which it plans to be able to retrieve waste.

Response

As required by the Nuclear Regulatory Commission in 10 CFR Part 60.111, the retrieval of waste from a repository will be possible at any time up to 50 years after the start of waste emplacement.

Issue

One commenter wanted to know how retrieval will be accomplished.

Response

If retrieval is necessary, it will be accomplished by reversing the steps taken for waste emplacement. The exact sequence and the equipment to be used for retrieval will depend on the design of the repository, the host rock of the repository, as well as the reason for retrieval (e.g., degree of container failure). Equipment for retrieval will be designed and tested before the license application, and the DOE's retrieval capability will have to be approved by the Nuclear Regulatory Commission.

C.2.4.3 Second repository

A number of comments concerned the location of the second repository and succeeding repositories and asked whether an indefinite expansion of the first repository is an alternative to constructing a second repository. Some parties wanted to know whether sites characterized for the first repository or sites not nominated for characterization for the first repository could be potential sites for the second repository. Others wanted to know why crystalline and argillaceous rocks were not considered for the first repository.

Issue

Commenters asked where the second repository will be located and whether both repositories could be located in the same State.

Response

With the exception of sites that were nominated but not recommended for characterization, the DOE may consider for the second repository any site previously considered for the first repository that was (1) not disqualified and (2) not selected for the first repository. The DOE is considering sites in crystalline-rock bodies in the eastern United States and announced 12 potentially acceptable crystalline sites as suitable for further consideration for the second repository (DOE, 1986).

The Act and the siting guidelines specify that the DOE must consider regionality in selecting the site for the second repository. It is therefore unlikely that the first and the second repository will be located in the same State.

Issue

A commenter wanted to know what will prevent an indefinite expansion of the first repository as an alternative to constructing a second repository.

Response

The Act allows the first repository to accept no more than 70,000 metric tons of uranium or the equivalent waste from reprocessing until a second repository is in operation.

Issue

Commenters asked for clarification on whether sites characterized for the first repository but not selected for the first repository can be considered for the second repository.

Response

The Act specifically states that sites that have been characterized for the first repository and are suitable but were not chosen for the first repository may be considered for the second repository. It is expected that all three sites characterized as part of the selection process for the first repository will be found suitable. The fact that only one of the three sites characterized is chosen for the first repository does not mean that the other sites are significantly less suitable.

Issue

The DOE should clarify whether potentially acceptable sites not nominated for characterization for the first repository can be nominated for characterization for the second repository.

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Response

The Act permits the four sites designated as potentially acceptable sites but not nominated as suitable for site characterization to be considered as potential sites for the second repository. Whether they survive the selection process for the second repository will depend on the merits of those sites vis-a-vis other potential sites.

Sites that were nominated, but not recommended for site characterization, are not eligible to be considered for the second repository.

C.2.5 OTHER WASTE-MANAGEMENT ACTIVITIES

This section presents comments and responses on monitored retrievable storage, which the DOE plans to propose to Congress as an integral part of the waste-management system, the storage of spent fuel at the site of the reactors, and the reprocessing of spent fuel for the recovery of uranium and plutonium.

C.2.5.1 Monitored retrievable storage

A number of comments were concerned with retrievable storage, the DOE's plans for a facility for monitored retrievable storage (MRS), and the lack of information in the draft EAs about the role of an MRS facility in the overall waste-management system. Several commenters recommended that the DOE consider monitored retrievable storage as an alternative to permanent disposal. Some commenters requested information on the possible locations of the MRS facility.

Issue

The DOE should consider the retrievable storage of spent fuel in a facility where it can be monitored.

Response

The DOE has indeed considered of the need for, and the feasibility of, monitored retrievable storage, and was required to do so by the Act. The DOE considered alternative roles and schedules for MRS facilities and has assessed their value to the waste-management system. Specifically, the DOE evaluated a backup MRS facility to be constructed only if there is a significant delay in the repository program and an integral MRS facility that would receive and prepare spent fuel for disposal. Both options have been compared with the currently authorized system, which does not include an MRS facility. Early in 1986, the DOE expects to propose to Congress the construction of an MRS facility as an integral part of the total waste-management system.

Issue

Some parties said that the draft EAs lacked information about the role of an MRS facility in the waste-management system and suggested that the DOE discuss the possible locations for the MRS facility.

Response

The principal functions of an MRS facility would be to receive and prepare the waste for disposal, thus eliminating the waste-preparation functions from a repository, to serve as a hub for transportation operations, and to provide temporary storage.

After issuing the draft EAs, the DOE concluded that monitored retrievable storage should play an integral role in the waste-management system. Section 3.2 of Part I of Volume I of the Mission Plan (DOE, 1985a) describes this integral MRS concept and plans for its development.

On April 26, 1985, the DOE selected three candidate sites in Tennessee for an MRS facility (DOE, 1985g). The preferred site is the site of the canceled Clinch River breeder reactor; alternative sites are a site on the DOE's Oak Ridge Reservation and the site of the canceled Hartsville nuclear power plant.

The introduction to Chapter 5 of each EA has been augmented to discuss the role of the MRS facility, and the transportation analyses have been expanded to treat the effects of using an MRS facility.

C.2.5.2 Onsite storage

Some commenters asked about the potential for long-term or permanent storage at the power plants that generate the wastes as an alternative to transporting wastes over long distances. Other commenters suggested that the DOE should continue storage in existing spent-fuel pools.

Issue

Commenters said that the DOE should consider developing repositories near the reactors generating the waste instead of in one or more central repositories.

Response

Nearness to the reactors generating the waste is not an acceptable criterion for siting repositories. The principal criteria are those embodied in the siting guidelines: waste containment and isolation from the accessible environment after closure; preclosure radiological safety; suitable environmental, socioeconomic, and transportation conditions; and ease and cost of construction, operation, and closure. Even if sites meeting the siting guidelines could be found near the reactors, it would be imprudent and impractical to develop many repositories. In addition to requiring very large expenditures, a multiple-repository program would require acceptance of many States and individual licenses for multiple facilities, long-term safety of each repository--a task that is formidable even for one repository. Two centralized repositories, as currently planned, would be able to accommodate all the waste and would solve the national problem of radioactive-waste disposal at reasonable cost.

Issue

The DOE should consider continuing storage in existing spent-fuel storage pools at reactor sites.

Response

In accordance with the Act, the DOE encourages the efficient use and expansion of at-reactor storage. At-reactor storage and the expansion of the on site capacity for that storage are the prime responsibility of the plant operators and owners, and not of the Federal Government. The Federal role is to encourage and expedite, where necessary, the expansion of that storage capacity until the spent fuel is shipped for emplacement in a repository for permanent disposal. However, the Act specifies geologic repositories as the means for permanent disposal and requires the DOE to site two repositories. Onsite storage is to be provided for a limited amount of fuel (1,900 metric tons of uranium) if any utility requests it and the Nuclear Regulatory commission determines that the utility is eligible. The DOE's program for such Federal interim storage is discussed in the Mission Plan (DOE 1985a, Vol. I, Part I, Chapter 3).

The storage of spent fuel in storage pools at reactor sites is safe for the purpose for which the pools were designed. Spent-fuel pools are meant to provide temporary storage, not an alternative to permanent disposal.

C.2.5.3 Reprocessing

Some commenters asked about the feasibility of reprocessing spent fuel, the use of stabilizing matrices for high-level waste, and the possibility of retrieving wastes from a repository for reprocessing. Other commenters wanted to know whether the wastes from the repository could be applied to any useful purpose.

Issue

Commenters questioned whether there are ways to recycle the components of the spent fuel or waste to be placed in the repository or in some way reverse the process of creating radioactive materials.

Response

There is no practical way known today of reversing the process that creates radioactive materials. The spent fuel could be reprocessed to remove the plutonium and uranium for use in other reactors. However, that does not substantially reduce the volume, heat generation, or radioactivity of the material requiring disposal. Currently there are no plans for reprocessing spent fuel. The DOE is planning to accept spent fuel for disposal with no intent to retrieve it for reprocessing unless required to do so for the purposes of recovering economically valuable as required by the Act.

Both President Ford and President Carter imposed a ban on reprocessing commercial spent fuel in the United States in response to concerns that the recovered fissile could be diverted to foreign nations or terrorists and used in making nuclear bombs. President Reagan lifted the ban on commercial reprocessing on October 8, 1981, but it is current U.S. policy that the reprocessing of spent fuel from nuclear power plants must be a private-sector enterprise. Because of the lack of economic incentives, industry concern about licensing uncertainties, and the potential for changes in government policy, there is little industry interest in reprocessing.

Issue

Commenters feared that the spent fuel and high-level waste in the repository will be dug up for reprocessing and be reused.

Response

As already mentioned, the DOE plans to accept spent fuel for disposal with no intent to retrieve it for reprocessing unless required to do so for the purposes of recovering the economically valuable resources, as required by the Act. However, the Act requires the repository to be designed and constructed to permit the retrieval of any spent fuel emplaced in the repository during an appropriate period of operation of the facility. The reasons for such retrieval, may pertain to public health and safety, the environment, or the recovery of the economically valuable contents of the spent fuel. In addition, the Nuclear Regulatory Commission requires that the waste emplaced in the repository be retrievable for 50 years after the start of waste emplacement, and the satisfactory completion of a performance-confirmation program. The DOE will comply with these requirements.

Issue

Some comments recommended that glass or ceramic matrices be used to immobilize high-level waste.

Response

All of the high-level waste to be accepted by the repository--the defense high-level waste and the commercial high-level waste from the West Valley Demonstration Project--will be in the form of borosilicate glass.

Issue

Some commenters expressed concern that the materials in the repository will be used to make bombs.

Response

The nuclear materials for weapons are obtained from defense reactors specifically designed to produce such materials. The spent fuel from power reactors is much less useful in the manufacture of modern nuclear weapons, and the DOE has not intention of using it for this purpose.

C.2.6 TYPES OF WASTE TO BE RECEIVED AT A REPOSITORY

A number of commenters asked about the nature of the wastes to be received at the repository. Other comments concerned the effects of slower or faster rates of waste generation and the minimum age of the spent fuel to be emplaced in the repository.

Issue

Commenters wanted to know what kinds of waste are to be emplaced in the repository.

Response

The Nuclear Waste Policy Act, which authorizes the construction of the repository and prescribes procedures for its siting and financing, specifies that the repository is to accept high-level waste and spent fuel. Thus, the wastes that will be accepted by the repository will consist of spent fuel from commercial nuclear power plants, solidified high-level waste from the reprocessing of nuclear fuel from defense reactors, and a small amount of commercial high-level waste from a demonstration facility at West Valley, New York. Also emplaced in the repository will be the low-level waste that is generated at the repository during operations. If spent fuel is consolidated before emplacement in a repository, the repository may also accept some or all of the fuel-assembly hardware that will be left by the consolidation process. No other low-level waste, such as the waste from research centers, hospitals, and general industry, will be accepted. Although the Act does not forbid it, the DOE does not at present plan to accept foreign wastes for disposal in the repository. The acceptance of foreign wastes requires a report to Congress.

The volume of the waste will be such that two repositories are expected to meet the requirements for disposal well into the twenty-first century.

Issue

Commenters wanted to know how changes in the rates of waste generation would affect the operation of the repository.

Response

The duration of operations at the repository will be determined to a large extent by the rate of waste. The currently projected operational period of 28 years for the first repository will not be affected by changes in the rate of waste generation because much of the waste that will go into the first repository will exist by the time the repository starts accepting waste. The length of operations at the second repository will be determined to a larger extent by its planned capacity and the rate of waste generation in the twenty-first century. The rate of receipt of wastes at the repository will have an impact on employment during the operations phase of the repository, but the impact will be relatively minor.

Issue

The EA analyses are based on 10-year-old spent fuel, but the DOE is committed to accept spent fuel as early as 5 years after it leaves the reactor.

Response

The DOE's contracts with the utilities obligate it to accept spent fuel that is 5 years old or older. The current DOE specification of generic requirements for repositories shows 5-year-old fuel as the baseline for design. The analyses reported in the EAs are based on an earlier assumption that only fuel that is 10 years old or older would be emplaced in the repository. The DOE has not yet performed an analysis for 5-year-old fuel. The final EAs have been revised to add a discussion that explains the DOE's plans to perform analyses for 5-year-old fuel in the repository and the possible impact of an MRS facility on the age of the spent fuel emplaced in the repository.

C.2.6.1 Defense waste

A number of commenters addressed the status and potential impacts of plans to accept defense high-level waste in the repositories.

Issue

Some persons wanted to know how the decision made to include defense high-level waste in the repository was made.

Response

In compliance with the Act, the Secretary of Energy reported to the President, in January 1985, the results of a study showing that there are no clear health and safety, transportation, public acceptance, regulatory, or national-security advantages or disadvantages associated with a separate repository for defense high-level waste and that there are clear cost advantages to emplacing defense and commercial wastes in the same repository. The President agreed with the Secretary's findings that a separate repository is not necessary for defense high-level waste. Therefore, in accordance with the Act, the Secretary of Energy is proceeding to arrange for the use of repositories developed under the Act for the disposal of defense waste. The evaluation report was released for general distribution in June 1985 (DOE, 1985h).

Issue

Many commenters felt that the subject of defense waste was not adequately covered in the draft EAs.

Response

The draft EAs did not contain much information about defense-waste disposal in the repositories, because the report on the subject (DOE, 1985h) was sent to the President in January 1985 (after the publication of the draft EAs), and the Presidential decision to include defense waste in the repository was made after that date.

It is important to note that defense high-level waste presents a lower radiological hazard per unit volume than does commercial high-level waste or spent fuel and a much lower heat-generation rate. The radiological risk analyses in the draft EAs, which are based on the assumption that only civilian waste will be accepted, therefore overestimate the risk of a repository containing both commercial and defense high-level wastes.

Some changes have been made to the EAs to reflect the decision to emplace defense waste. These include the addition of an entry in the tables on the incremental impacts of alternative repository designs. This new entry deals with the addition of defense waste. For consistency, these tables all appear at the beginning of Chapter 5 in the final EAs.

Issue

Several parties wanted to know who would pay for the costs of defense-waste disposal.

Response

The Act requires that, if defense waste is emplaced in any of the repositories developed under the Act, then a proper share of the costs of developing, constructing, and operating the repository is to be paid by the Federal Government into the Nuclear Waste Fund, which is used to finance the activities required by the Act.

Issue

Some persons asked whether the same safety standards will be applied to both defense and commercial high-level wastes.

Response

The January 1985 report to the President on the use of commercial repositories for the disposal of defense high-level waste (DOE, 1985h) stated that all defense waste to be disposed of will be in a form that satisfies the regulations governing the repository--namely, 10 CFR Part 60 (NRC, 1983), 10 CFR Part 960 (DOE, 1984c), and 40 CFR Part 191 (EPA, 1985).

Issue

Many commenters asked about the nature of defense high-level waste and the effect of its emplacement in the repository.

Response

Defense high-level waste results from the reprocessing of spent fuel. It differs significantly from commercial high-level waste and spent fuel because it has much lower concentrations of radioactive fission products and hence a much lower rate of heat generation. The 20,000 packages of defense high-level waste expected to be produced by the year 2020 are considered equivalent to 10,000 metric tons of uranium (MTU) of spent fuel. At the end of 1982, approximately 15 percent of the total radioactivity in spent fuel and high-level waste in the United States was from defense activities; most of the remaining 85 percent was from commercial spent fuel. By the year 2000, the amount of radioactivity in the defense waste is expected to drop to 3 percent of that of all wastes to be accepted by the repository.

In his report to the President (DOE, 1985h) on the potential uses of the repositories for defense high-level waste, the Secretary of Energy explained the DOE's interpretation of the capacity limit (70,000 MTU) imposed by the first repository until a second repository is in operation; the DOE's interpretation is that the limit applies to total quantity of waste--that is, both commercial and defense waste. The analysis in the report assumed that the firs repository would accept the 10,000 MTU equivalent of defense waste and 60,000 MTU of commercial waste and that the second repository would be in operation before the 70,000-MTU limit was reached. The report also said that, if all the defense-waste canisters expected to be produced by 2020 were emplaced in one repository with a capacity of 70,000 MTU, it would occupy only about 10 percent of the volume of repository. This fact is attributed to the low heat-generation rate of defense waste, which allows closer spacing between canisters than that for spent fuel. Thus, the inclusion of defense-waste canisters produced by 2020 will not necessitate any significant expansion of the repository. The Mission Plan (DOE, 1985a) includes a schedule for the acceptance of commercial and defense wastes in the first two repositories.

Issue

Commenters wanted to know about the origin of defense and commercial waste.

Response

Defense high-level waste results from reprocessing of spent fuel at DOE facilities. Commercial high-level waste and spent fuel come from nuclear power plants operated by electric utilities.

Issue

Commenters alleged that the DOE withheld the defense-waste report (DOE, 1985h) to make it appear that defense waste would be disposed of separately from commercial wastes.

Response

The DOE was required by the Act to submit a report to the President on the feasibility of combining defense and commercial waste in the repository. This report was released before the deadline (January 7, 1985), mandated by the Act. The DOE was not required to circulate the report for public comment before it was issued, but the report has been available to the public on request since its release was announced in the Federal Register (DOE, 1985i).

Issue

Some commenters were concerned that the repository might become a military operation because of the disposal of defense waste.

Response

The repository will not become a military operation. The defense wastes are produced at facilities operated by the Department of Energy, not the Department of Defense. Furthermore, there are no plans at present to use additional security measures because of the disposal of defense waste. Normal security measures taken to protect spent fuel during receipt and emplacement will be sufficient for protecting defense high-level waste. These security measures will not interfere with the liberties of citizens in the surrounding areas and will probably not involve military personnel in any capacity.

Issue

Some persons asked whether defense high-level wastes from Hanford will be disposed of in the repository.

Response

Defense wastes from Hanford, the Idaho National Engineering Laboratory, and the Savannah River Plant will be disposed of in the repository. Appendix A in the EAs has been changed to reflect that fact.

C.2.6.2 Foreign waste

Issue

Commenters asked whether foreign wastes will be emplaced in the repository.

Response

Although the Act does not specifically forbid the acceptance of foreign wastes at the repository, the DOE has no plans to do so.

C.2.6.3 Other wastes

Issue

Several persons wanted to know whether the repository will accept low-level radioactive waste from various sources or wastes, other than spent fuel, generated from the decommissioning of nuclear power plants.

Response

The Act authorizes the DOE to site and construct a repository for high-level radioactive waste and spent fuel. Wastes from the decommissioning of military or commercial nuclear reactors are not considered high-level waste at present, and therefore these wastes will not be accepted in the repository. Instead, these wastes are considered low-level wastes.

C.2.7 THE DRAFT ENVIRONMENTAL ASSESSMENTS

Many comments were concerned directly with the EAs. The issues they raised included the format, content, organization, consistency, and documentation of the draft EAs. In addition, many of the comments offered editorial suggestions; all of these were carefully considered in revising the EAs.

C.2.7.1 General comments on the environmental assessments and their function

Some commenters asked why the EAs were issued or why they preceded the DOE's Mission Plan and the EPA final standards. Others objected to their size and complexity, alleged inaccuracies, or incompleteness.

Issue

Some commenters questioned the place of the environmental impact statement (EIS) in the siting process, asking why environmental assessments were prepared rather than an EIS.

Response

The Act specifically requires an EA to accompany the nomination of a site as suitable for characterization (Section 112(b)(i)(E)). An environmental impact statement is one of the documents that will accompany the Secretary's recommendation to the President of one site for development as a repository.

Issue

Commenters pointed out that the Act requires the DOE to prepare a mission plan that would provide a base of information for the site evaluation and selection process. They questioned whether the draft EAs, and the preliminary site nomination and recommendations they contain, should have been prepared before the issuance of the mission plan.

Response

Section 301 of the Act requires the DOE to develop a mission plan that provides sufficient information for informed decisions in carrying out the repository program. A draft mission plan was issued in April 1984 (DOE, 1984a), 8 months before the draft EAs. The revised mission plan was issued in June 1985 (DOE, 1985a) and was used in revising the final EAs. The process and schedule established by the Act, however, did not allow the draft EAs to be delayed until the mission plan was published.

Issue

Several commenters stated that the EAs do not satisfy the requirement of the Act to identify unresolved technical issues and the problems that impede the implementation of the Act. In addition, they felt that the DOE's response to data gaps had been to say that issues would be settled in the final EAs.

Response

Although not required by the Act to do so, the EAs do identify the unresolved issues with regard to the siting guidelines; these issues are discussed in Chapter 6 of the EAs. The DOE believes that the findings made for the guidelines are based on sufficient data and information; the findings made at this stage of the site-selection process are to be based on available information. Definitive data will be collected during site characterization.

Some of the statutory requirements identified by the commenters pertain to the DOE's Mission Plan, not the EAs. Among them are requirements to identify unresolved issues and problems that may impede the implementation of the Act (see Sections 301(a)(2) and (3) of the Act). These requirements are addressed in Chapters 2 and 3, respectively, of Part II in Volume I of the Mission Plan (DOE, 1985a).

Issue

A commenter suggested that the DOE issue another set of draft EAs. The commenter expressed concern that the EAs would be so extensively rewritten in response to public comments that the public should be allowed to review the revised EAs in draft before they are issued in final form.

Response

The DOE will not reissue the EAs in draft for comment for the following reasons. First, most of the changes in the final EAs were made in response to public comments and are explained in this comment-response appendix. Second, the final EA is a final agency action and is therefore subject to judicial review. Third, the DOE believes that it has been responsive to comments on the draft EAs and that an additional comment period would not result in further significant improvements. Finally, interested parties will have additional opportunities to comment on the site-selection process through hearings and comments on the site-characterization plans, the environmental impact statement, and other program documents.

Issue

A number of comments implied that the DOE treated the EA process in a perfunctory manner. Some commenters felt that the DOE did not produce EAs that met the intent of the Act; some even stated that the documents were worthless.

Response

The Act requires the following six major assessments to be included in the EAs:

1. An evaluation by the Secretary as to whether the site is suitable for site characterization under the guidelines.

2. An evaluation by the Secretary as to whether the site is suitable for development as a repository under each such guideline that does not require site characterization as a prerequisite for the application of such guideline.

3. An evaluation by the Secretary of the effects of site-characterization activities at the site on public health and safety and the environment.

4. A reasonable comparative evaluation by the Secretary of the site with the other potentially acceptable sites.

5. A description of the decision process by which the site was recommended.

6. An assessment of the regional and local impacts of locating the repository at the site.

The EAs contain all of these evaluations or descriptions.

The DOE went beyond the requirements of the Act in issuing draft EAs and revising the documents in response to the comments, which required substantive changes. The EAs provide a workable data base for site nomination and recommendation for characterization.

Issue

Commenters said that the draft EAs, and the preliminary site nominations and recommendations they contain, should not have been prepared before the issuance of the final NRC and EPA standards for geologic disposal.

Response

The Act requires the Environmental Protection Agency to establish standards for protecting the public from the radioactive material in geologic repositories. These standards are to be implemented and enforced by the Nuclear Regulatory Commission. The EPA standards are contained in 40 CFR Part 191. The NRC technical criteria for implementing the EPA standards are contained in 10 CFR Part 60. Both sets of regulations were issued in draft form in 1982 and were used in developing the siting guidelines. The final NRC criteria were released in June 1983, before the draft EAs; the final EPA standards were released in September 1985, after the draft EAs. The schedule requirements of the Act did not allow the draft EAs to be delayed until September 1985, but the final EPA standards were used in revising the EAs.

Issue

Many commenters felt that the size and technical complexity of the EAs discourage review by the public.

Response

The EAs are indeed long documents that contain many technical discussions. Their length is the result of an attempt to present as much information as was deemed necessary for compliance with Appendix IV of the siting guidelines (DOE, 1984c), which specifies what kinds of information should be used to support findings about compliance with the guidelines, and as much information as was needed for the evaluations required by the Act. For the same reasons, much of the material presented in the EAs, especially in Chapter 6, is of necessity technical because it presents evaluations of sites against the various conditions specified in the guidelines--conditions that are usually specified in technical terms. Every effort was nonetheless made to make the technical presentations clear and comprehensible.

Issue

Some parties criticized the organization of the EAs, saying that it was confusing to find certain topics discussed in more than one chapter.

Response

The organization of the EAs was based on (1) the requirements of the Act, which specifies, in Section 112(b)(E), the evaluations, descriptions, and analyses that are to be included; (2) the requirements of the siting guidelines, which specify the order of certain evaluations (e.g., the identification of the preferred site in a geohydrologic setting); and (3) the general format and content usually followed in preparing environmental assessments.

Thus, Chapter 2 includes an evaluation of the site against the disqualifying conditions of the guidelines as required by the guidelines; for completeness, this evaluation is repeated in Chapter 6, which presents the Act-mandated evaluation against the guidelines. Chapter 7, which is also required by the Act, of necessity repeats some material contained in Chapter 6, though in a greatly abbreviated form. The repetition is unavoidable because Chapter 7 is essentially a summary compilation and comparison of the data presented in Chapter 6 for every site. A few commenters felt that the EAs should include more information in Chapter 5 about the financial effects of site characterization and repository development on local communities and the grant programs applicable to individual sites.

Issue

One commenter asserted that the analyses performed by a former DOE contractor that was fired for unsatisfactory performance were nonetheless used to substantiate the draft EAs.

Response

The commenter is incorrect in asserting that the work of a "fired" DOE contractor was used to substantiate the draft EAs. The DOE contractor in question was a general program-management contractor that prepared area-characterization studies. This contract expired and was opened for bids according to Federal procurement regulations. The contractor was not selected for further work, but was not dismissed for unsatisfactory performance as the commenter alleges. The DOE considers the analysis performed by this contractor to be valid and useful.

Issue

Some commenters suggested that technical review groups should be assembled to verify the data, procedures, assumptions, and conclusions in the draft EAs.

Response

Technical review groups were used to review the EAs at several levels. Such groups were used by the DOE Project Offices that prepared the EAs, by the Office of Civilian Radioactive Waste Management and its contractors, and by the Office of Environmental Compliance of the DOE's Assistant Secretary for Environment, Safety and Health.

Issue

Some commenters objected that, although a significant percentage of the residents in the area of Swisher and Deaf Smith Counties, Texas, are Spanish-speaking, the reports were released only in English.

Response

To translate documents as long and complex as the EAs would require an expenditure of time and resources that could not be justified. However, the DOE is preparing a variety of public-information materials in Spanish in response to requests to provide information to the Spanish-speaking residents of Texas. The DOE expects that, by being prepared especially for the general Spanish-speaking public, these materials will prove to be a more practical means of access to information about the program than the EAs.

Issue

Some parties suggested that the DOE publish an abbreviated version of the EAs.

Response

Like the final EAs, the draft EAs contained an executive summary that briefly described the site, the process by which it was selected, and its evaluation against the guidelines. These executive summaries were also distributed separately as overviews. Overviews are also available for the final EAs.

Issue

Commenters complained that the DOE issues inaccurate reports, expecting the States and the general public to find the inaccuracies without paying for these services. Others said that the EAs are propaganda for the program and do not present scientific findings.

Response

The DOE tried hard to ensure that the draft EAs were correct, including several reviews by the DOE, its contractors, and peer review groups. However, in documents of the size and the scope of the EAs, some errors are bound to occur.

The objective of issuing the draft EAs, which was not required by the Act, was to increase the participation of the public in the siting process and to apprise the public of the bases for decisions in the siting process. Though the DOE is pleased to acknowledge the many helpful contributions made by the commenters, in no sense did the DOE view the publication of draft EAs as a means of obtaining free services from the general public.

Issue

Some commenters expressed the view that the technical inaccuracies in the EAs caused the public to lose confidence in the entire process.

Response

The draft EAs represent the best available information. In accordance with the Act, they were prepared before site characterization and hence before many site-specific data were available. During site characterization and the concurrent environmental and socioeconomic studies, the DOE will collect the detailed information required to demonstrate compliance with the guidelines and with NRC and EPA regulations. Even with thorough and repeated critical reviews by different parties, some technical inaccuracies are unavoidable in documents as large and complex as the draft EAs, especially since some of the analyses were based on information from the literature rather than studies performed at the site. As already mentioned, every effort was made to correct the inaccuracies in the final EAs.

Issue

Some commenters objected to the use of averages instead of worst-case scenarios in the EAs.

Response

The use of averages is appropriate, especially for this stage in the site-selection process. For nomination and recommendation of sites for characterization, the siting guidelines (10 CFR Part 960) require only that the evidence available does not support findings that the sites are unsuitable. At any stage, worst-case analyses that are not accompanied by information on the probabilities of those cases are inappropriate. The EPA has recognized the latter fact in its environmental standards for the disposal of spent fuel and other wastes. In those standards, specific probabilities of compliance--representative of less than worst-case scenarios--are required.

C.2.7.2 Supporting references

A number of comments were directed at the references that support the analyses and results presented in the EAs. Among these were comments objecting that these references were not available to the public or that the quality of the references was poor.

Issue

Some persons stated that the public was not able to participate fully in the evaluation of the EAs because it was not provided with the data base that supports the decisions.

Response

The reference documents for the draft EAs are available in the public reading rooms of DOE Headquarters and Project Offices (see Appendix B) and were mailed to each affected State and Indian Tribe for review.

Issue

Commenters said that some of the references that supported the draft EAs were either completely unavailable or were not released until half-way through the 90-day comment period. This delayed release did not allow the States and interested parties adequate time for review.

Response

The DOE made every effort to make references available for public review by collecting them in DOE public reading rooms. Some of the references were in draft form at the time the draft EAs were published and were not available for public review until later in the comment period. These were added to the collection as they became available. All references cited in the final EAs are available for review at the locations listed in Appendix B.

Issue

Some commenters contended that the quality of the references was poor; some analyses relied on personal communications for support, rather than published documents.

Response

In the absence of published data, it was occasionally necessary to rely on documents in preparation or on personal communications from the investigators performing the analyses for the EA. Personal communications, DOE memoranda, and DOE correpondence were also used to document the site-selection process, and communications obtained in interviews with representatives of local governments were used as sources of information about local conditions (e.g., availability of community services) for which no published data are available. These informal references could have been cited parenthetically in the text or presented in footnotes. The DOE decided, however, to treat them as formal references and to make them available to the public together with the formal references to published documents. The locations where these references are available for review are given in Appendix B.

Issue

Commenters requested that a list of references for Chapter 7 be included in the EAs.

Response

Since Chapter 7 is based on the information given in Chapter 6 and does not rely on additional sources of data, no references are included. Otherwise it would have been necessary to combine five long lists of references (those presented in Chapter 6 of the EAs for the nominated sites). The reader interested in the supporting data for the findings on which Chapter 7 is based should refer to the section of Chapter 6 that covers the particular guideline of interest.

Issue

A commenter requested that the final EAs list the locations where copies of the references cited in the EAs can be examined.

Response

At the public briefings held in each affected state, the DOE distributed booklets listing the locations where copies of draft-EA references were available. In response to the above request, a list of all locations where copies of references can be examined is given in Appendix B of the final EAs.

Issue

Some commenters pointed out that additional reference material was submitted for DOE review and requested that specific reports and lists be used in the final EAs.

Response

The DOE recognizes and appreciates the efforts expended in sending materials for review. The documents were directed to the appropriate EA authors to be considered in revising the EAs.

During the Utah hearings, several persons read pages from the log book for visitors to the Canyonlands National Park. The comments of the tourists were entered into the official EA comments and were considered in reanalyzing for the final EA the potential effects of a repository on tourism.

References that were not within the scope of the Civilian Radioactive Waste Management Program were forwarded to the appropriate persons in other DOE programs.

C.2.7.3 Content of the environmental assessments

Issue

Among the comments was the objection that the draft EAs did not list the rankings of all nine sites studied.

Response

As discussed in Chapter 1 of the environmental assessments, the siting guidelines specify the following steps for ranking the potentially acceptable sites:

1. Evaluate the potentially acceptable sites in terms of the disqualifying conditions specified in the guidelines.

2. Group all potentially acceptable sites according to their geohydrologic settings.

3. For those geohydrologic settings that contain more than one potentially acceptable site, select the preferred site on the basis of a comparative evaluation of all potentially acceptable sites in that setting.

4. Evaluate each preferred site within a geohydrologic setting and decide whether such site is suitable for the development of a repository under the qualifying condition of each applicable guideline.

5. Evaluate each preferred site within a geohydrologic setting and decide whether such site is suitable for site characterization under the qualifying condition of each applicable guideline.

6. Perform a reasonable comparative evaluation under each guideline of the sites proposed for nomination.

Because one site is selected in each geohydrologic setting that contains more than one site, it is not consistent with the siting guidelines to rank all nine potentially acceptable sites.

Issue

Some persons felt that the EAs did not adequately consider the religious attitudes of Indians about land.

Response

The DOE recognizes the need to identify and respect Indian values and is in the process of developing a programmatic memorandum of agreement with the Advisory Council on Historic Preservation. The agreement will ensure the consideration of Indian religious freedom under the American Indian Religious Freedom Act. In revising the EAs, Indian cultural values have been considered. The EA for the Hanford site notes that the Yakima Indian Nation has extensive historical and spiritual ties to the land on which the site is located.

Issue

Several commenters said that the draft EAs did not consider the impacts of site characterization on Indian Tribes, ceded lands, and treaty rights to off-reservation fishing.

Response

As explained in Chapter 4 of the EA for the Hanford site, the DOE believes that Indian Tribes will not be significantly affected by site characterization.

Issue

Commenters stated that discussion of the siting process for the first repository was deficient in the draft EA. Because siting decisions were made before the Act was passed and before the publication of the guidelines, the DOE should discuss the basis for these decisions in the draft EA.

Response

The siting decisions made before the publication of the guidelines were based on criteria similar to the guidelines. The bases for these decisions are discussed in detail in the documents cited in Chapter 1 of the EAs. A more detailed discussion of the process in Chapter 1 is therefore unnecessary.

Issue

Specific suggestions for improving the EAs included the addition of a glossary and a key-word index.

Response

A glossary was included in the draft EAs, as it is in the final EAs. However, because of the limited time available to prepare and revise these documents, it was not possible to add a key-word index.

Issue

A number of commenters suggested specific revisions to Chapter 1 of the draft EAs. Some of those suggestions were editorial; some were specific suggestions applicable to only one site. The suggested general changes can be summarized as follows:

1. Chapter 1 should describe how the DOE would substitute sites for those eliminated by characterization.

2. Chapter 1 should point out that the Act requires the DOE to issue the site-characterization plans for review by the States and the public as well as the NRC.

3. Chapter 1 should be revised to indicate that site characterization begins only after the completion and review of site-characterization plans and public hearings.

4. Chapter 1 should mention the right of an affected Indian Tribe to issue a notice of disapproval.

Response

In response to the first three comments, Chapter 1 was revised as appropriate.

In regard to comment 4, the Act allows an affected Indian Tribe to issue a notice of disapproval if a proposed site is located on its reservation (Section 118(a)). However, none of the potentially acceptable sites is located on any Indian reservation, and although the DOE welcomes their participation in the repository program as affected Indian Tribes, the Indian Tribes do not have the statutory authority to issue a notice of disapproval.

Issue

One commenter said that the EAs should include a detailed explanation of how the entire process is funded.

Response

The DOE's program for the management of civilian radioactive waste is funded from the Nuclear Waste Fund, which was established by Congress and consists of monies paid into the fund by the utilities that generate the radioactive waste. A more detailed explanation of the funding is given in the Mission Plan (DOE, 1985a).

Issue

One commenter felt that the EAs should include more information in Chapter 5 about the financial effects of site characterization and repository development on local communities and the grant programs applicable to individual sites.

Response

The socioeconomic impacts expected during site characterization are discussed in Section 4.2 of the EAs, which also explains what financial assistance would be available to the affected community.

The impacts expected during repository development are examined in Section 5.4.5 of the EAs; this section includes a discussion of the financial assistance that will be available. Information on financial assistance can also be found in the DOE's Mission Plan (DOE, 1985a, Vol. I, Part I, Chapter 4). (See also Sections C.2.1.2 and C.2.1.5.1 for comments and responses on the mitigation of fiscal and socioeconomic impacts.)

Issue

Some commenters said that more-detailed schedules are needed in the final EA.

Response

The EAs do not contain detailed schedules because the latter are given in the Mission Plan (DOE, 1985a) and the draft Project Decision Schedule (DOE, 1985b). The schedules of activities for site characterization will be presented in greater detail in the site-characterization plans. Plans and schedules for the environmental, socioeconomic, and transportation studies to be conducted concurrently with site characterization are also being prepared.

Issue

A commenter felt that the discussion of qualifying conditions in the EAs is given more prominence than the discussion of the disqualifying conditions.

Response

Disqualifying conditions describe conditions that are considered so adverse as to constitute sufficient evidence to conclude without further consideration that a site is disqualified; they were formulated to provide early evidence of the suitability of a site and hence require fewer data and less-complex analyses than do the qualifying conditions. They are discussed in both Chapter 2 and Chapter 6 of the EAs.

Issue

Some commenters asked that more information be included in the EAs about the program for public education and participation.

Response

The program for public information and participation is explained in detail in the DOE's Mission Plan (DOE, 1985a, Vol. I, Part I, Chapter 4). (See also Section C.2.1 for comments and responses on this topic.)

Issue

Commenters requested that the discussion of the guidelines in the EAs be clarified.

Response

The format, structure, purpose, and application of the guidelines in the EAs are discussed in Section 6.1. Additional information can be obtained from the "Supplementary Information" on the guidelines themselves (DOE, 1984c) or from the DOE's responses to comments on the proposed guidelines (DOE, 1983).

Issue

Commenters suggested that an appendix listing all EA authors and their qualifications should be added to the EAs.

Response

A list of contributors is not included in the EAs because a fair and comprehensive list would consist of hundreds of names. To prepare such a list of persons who contributed to the EAs would be a task requiring a great deal of time. The commenter can be assured, however, that the contributors to the EAs are qualified and experienced professionals, and many of them have earned distinction in their scientific discipline.

C.2.7.4 Inconsistencies in the environmental assessments

Inconsistencies in the EAs were the subject of many comments, which noted inconsistencies in the assumptions about the age of the spent fuel, the waste package, the exploratory shafts and the shafts for the repository, the descriptions of surface facilities, assumptions used in radiological assessments, the models and assumptions used in analyses of socioeconomic impacts, analyses of worker health and safety, and several other topics.

Issue

A number of commenters pointed out inconsistencies between the executive summaries and the corresponding chapters in the draft EAs.

Response

There were indeed some inconsistencies, resulting mainly from a failure to update the executive summaries after the last revision (one of several) of the draft EAs. In revising the final EAs, the executive summaries were corrected to reflect the corresponding chapters.

Issue

Some commenters pointed out that the draft EAs were inconsistent in their presentation of air-quality impacts. For example, the EA for the Deaf Smith site considers vehicle emissions and fugitive dust in evaluating the impacts of repository operation, whereas the EA for Davis Canyon does not do so. The draft EAs were also said to be inconsistent in their treatment of regulations for the Prevention of Significant Deterioration (PSD).

Response

The air-quality evaluations for each site have been revised as a result of comments from the States, the public, and other Federal agencies; the results are presented in a format that is as consistent as possible. Some differences remain, however, because the evaluations must use available data, which can vary among the different sites, and because the air-quality regulations are implemented by different agencies for each site. The revised impact analyses have reconsidered air-quality models, inputs (e.g., vehicle emissions, fugitive dust), operating assumptions, and PSD applicability according to guidance from the appropriate regulatory agencies.

Issue

Many commenters said that the EAs need to provide a fuller and more realistic discussion of socioeconomic impacts and to expand the discussion of mitigation measures. They also need to address the positive socioeconomic impacts of a repository.

Response

Chapter 5 of the EAs addresses general provisions for financial and technical assistance to mitigate adverse socioeconomic impacts. Site-specific mitigation measures will be developed after the DOE has performed a detailed impact analysis and the affected State or Indian Tribe has submitted an impact report for the site recommended for repository development. (See also Sections C.2.1.2.4 and C.2.1.5 for comments and responses on this topic.)

The EAs also address some of the positive socioeconomic impacts of a repository, such as the potential for new local jobs, total project and local purchases, and likely sources of additional tax revenues. The final EA for the Hanford site also discusses the potential for greater use of the area's available human and physical resources.

Issue

Some commenters criticized the EAs for using different approaches and bases for the socioeconomics analyses--in particular, different labor-force estimates, different multipliers for the indirect employment expected to result from the repository, and different assumptions about the in-migration of repository workers. One comment objected that no adequate explanation was given in the EAs for the differences in the employment and in-migration estimates and stated that the population increase estimated in the EA for the Yucca Mountain site appears to be due to an "overly conservative analysis."

Response

It is true that the EA analyses for the different host rocks used different labor-force estimates, employment multipliers, and assumptions about in-migration. However, some of the differences to which the commenters object are unavoidable because of differences in the design of the repository, the availability of data, and local conditions, which vary significantly among sites. Furthermore, the socioeconomic analyses were performed by several different groups of analysts, who used assumptions and multipliers they deemed most suitable for the socioeconomic conditions of the site and the available data.

The population increase estimated for the Yucca Mountain site did indeed differ greatly from that for the other sites, but a significant part of this difference was attributable to the larger work force required for a repository at Yucca Mountain. The work force estimated in the draft EA for Yucca Mountain was as much as three times the work force estimated for the other sites. In the final EA for Yucca Mountain, the work-force estimate is lower, and so is the population increase projected for southern Nevada. The employment multiplier, while higher than that for the other sites, is the most reasonable multiplier for southern Nevada and is based on published analyses of historical data on employment in southern Nevada. The assumption that all of the repository workers would in-migrate was recognized and identified as being conservative in Chapter 5 of the draft EA for Yucca Mountain. It was chosen because detailed information about labor skills was not available and because it allowed the DOE to estimate the worst-case impacts on community services.

For the Hanford site, the socioeconomic analysis presented two scenarios. A maximum population estimate was based on an assumption of 100 percent in-migration, and a more likely estimate assumed that 75 percent of the miners and 25 percent of all other workers would in-migrate. The employment multiplier used was only slightly lower than that for Yucca Mountain. Again, the 100 percent maximum estimate was used to present a conservative analysis that would demonstrate that even worst-case impacts would be insignificant in this area, which has an excess of housing and public services.

For the salt sites, the lack of local socioeconomic data for a project as large as a repository led to an approach based on data for the study area and the use of multipliers from the literature (energy developments in the western States and projects of the Tennessee Valley Authority). This approach produced a high and a low range of estimates for in-migration and the associated impacts. The case of high in-migration was selected as a realistic, though conservative, case and was used for the impact analysis. Unlike the Hanford and Yucca Mountain sites, an assumption of 100 percent in-migration for the salt sites would have been inappropriate considering the socioeconomic conditions of the study area. It would have produced unrealistic overestimates of population increases in the smaller communities near the sites.

Issue

One commenter noted that the draft EAs are inconsistent in their treatment of worker health and safety. In particular, the following inconsistencies were pointed out:

1. The EAs for Yucca Mountain and Hanford present estimates of expected worker injuries and fatalities during site characterization, while the EAs for Davis Canyon, Deaf Smith, and Richton present estimates of only injury and fatality rates.

2. The Yucca Mountain analysis uses 1982 statistics provided by the National Safety Council. The Hanford analysis is based on a 1980 DOE report, while the Davis Canyon, Deaf Smith, and Richton analyses used 1976-1979 statistics from the Mine Safety and Health Administration (MSHA).

3. The EA for the Hanford site discusses occupational safety and health in Chapter 5, including specific numbers of expected injuries and fatalities during mining and construction. The EAs for Davis Canyon, Deaf Smith, and Richton give only rates. The EA for Yucca Mountain has no such analyses in Chapter 5.

4. The EAs for Hanford and Yucca Mountain discuss occupational safety in Section 6.3.3.2. The other three EAs do not.

5. The EAs for Hanford, Davis Canyon, Deaf Smith, and Richton discuss the applicability of various Federal and State occupational safety and health regulations. The EA for Yucca Mountain does not.

Response

The draft EAs for Hanford, Yucca Mountain, and the salt sites used different sources for their safety analyses. Hanford cites DOE Order 5480.1A, Yucca Mountain cites the National Safety Council (NSC), while the salt-site analyses are based on injury experience reports from the MSHA. Nonetheless, the estimates of fatalities, accident rates, etc., are not inconsistent. There is a direct correlation between the various sources.

From 1930 through 1977, MSHA statistical measures for injuries in mining used a basis that was somewhat different from that for the other industries. However, beginning with calendar year 1978, the MSHA adopted measures for injury experience that compare closely with the measures used in the Office of Occupational Safety and Health Statistics, the Bureau of Labor Statistics, and the U.S. Department of Labor. Therefore, beginning with 1978 data, the mining industry can be compared on a standard basis with other U.S. industries.

The MSHA requires all mine owners to report all accidents to the district office on a prescribed form. Because of the modification in reporting and processing procedures that became effective January 1, 1978, injury rates as currently computed are not precisely comparable to those of the previous years. Fatality rates, however, in which the "incidence rate" (the term used after 1977) is one-fifth of the "frequency rate" (the term used before 1978) for otherwise similar grouping, remain comparable.

The statistical data in the MSHA reports cover the work experience of all personnel engaged in exploration, development, production, maintenance, repair, and construction work, including supervisory and technical personnel, and onsite office workers. These activities cover the entire spectrum of the exploratory-shaft activities and, as such, are a better tool for statistical

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projections of probable exploratory-shaft injuries. As compared with the reported accidents in the MSHA report, the National Safety Council uses sampling techniques for projections of probable injury experience.

The NSC statistics show that in 1982 there were 600 fatalities for 1.1 million workers in the mineral-extraction industry (including quarries). This figure reduces to 0.05 per 200,000 man-hours and compares with 0.06, 0.04, and 0.3 in MSHA's reports for the years 1976, 1977, and 1978, respectively. Similarly, the NSC statistics show 3.1 nonfatal injuries with days lost, which compares with 3.87, 3.78, and 5.48 such injuries reported by the MSHA for the 3 years. The NSC projected 4.7 total injuries per 200,000 man-hours for 1982, which compares with 5.96, 5.73, and 8.81 total injuries for the 1976-1978 period.

The final EA for Yucca Mountain includes a discussion in Chapter 5 of occupational health and safety.

Issue

Some commenters stated that the analyses for all sites should be based on the assumption of 10-year-old spent fuel because this assumption is likely to be conservative and will provide a common basis for comparison.

Response

All analyses in Sections 6.4.1 and 6.4.2 of the final EAs are based on the emplacement of spent fuel that is 10 years old.

Issue

One commenter recommended that the assessments of preclosure radiological safety under normal conditions should be based on similar assumptions about failed fuel rods.

Response

The analyses presented in the final EAs are based on the conservative assumption that 0.5 percent of the fuel rods arriving at the site have failed.

Issue

Several parties commented that, in estimating waste-package failure, all EAs should assume that failure occurs when some portion of the container wall corrodes, not necessarily the entire thickness.

Response

The approach suggested by the commenters is used in the Hanford EA and in the EAs for all of the salt sites. The approach of the Yucca Mountain EA was to use a simple estimate that is based on expected conditions, taking into account that few data have yet been obtained for repository conditions at Yucca Mountain. Thus, although the estimates indicate a lifetime of 30,000 years, the value actually used is 3,000 years to provide a very conservative lower bound for container lifetime.

Issue

Some commenters complained that comparisons among the sites are difficult because the EA analyses are based on different container designs.

Response

The design of the container depends on the characteristics of the site. For example, one of the criteria for design is usually the peak rock temperature, which depends on both the thermal properties of the rock and the amount of heat generated by the waste in the container. Therefore, container sizes and designs are different for different rock types, and the assumption of a common canister size or design in the EAs would not facilitate valid comparisons among the sites. For this reason, the EAs were not changed to reflect a common canister size or design.

Issue

One commenter stated that variations in container-design criteria need to be explained or justified in the EAs.

Response

Each of the repository projects is developing waste-package designs to meet the NRC's requirement for a container lifetime of 300 to 1,000 years and a radionuclide-release rate of less than 10^{-5} per year.

Issue

Several commenters asserted that the analysis and findings in the draft EAs did not reflect sufficient conservatism, considering the lack of site-specific data on which to base site nomination and recommendation decisions.

Response

Where no site-specific data were available, the EAs used extrapolations of regional data or conservative assumptions, in accordance with the DOE siting guidelines. A conservative approach was taken in evaluating the site characteristics that are important to the performance of the repository.

Issue

One commenter noted that the draft EAs differ in the number and the size of shafts drilled for site characterization and repository operations and said that the DOE should explain the technical basis for these variations.

Response

The draft EAs for the Yucca Mountain and the salt sites presented analyses based on the sinking of only one exploratory shaft. At the time the draft EAs were published, the DOE had already decided to sink two shafts at each site, but there was no time to revise the analyses in the draft EAs. The construction of a second shaft would not significantly increase the impacts of site characterization. The final EAs have been revised to account for two shafts at all sites.

The number of shafts required for the repository depends on the host rock; thus the numbers of shafts is different for a repository in basalt, salt, or tuff.

Issue

One commenter stated that the surface-facility descriptions for all of the EAs should be the same, or the variations should be explained.

Response

The surface facilities of a repository depend partly on site-specific conditions, such as the terrain, and partly on the host rock; the host rock determines the number and size of shafts, the layout of the underground repository, the ventilation requirements, and similar factors that affect the design and layout of some surface facilities. Thus the surface facilities vary for repositories in basalt, salt, and tuff.

C.2.8 MISCELLANEOUS

Many of the comments in the draft EAs covered various topics, many of which were not concerned with the nomination of sites or even repository siting in general. These comments have been divided into three categories: production of radioactive waste, alternatives to geologic disposal, and general technical issues.

C.2.8.1 Production of radioactive waste

Several commenters maintained that the production of nuclear energy should never have been begun without establishing a method for radioactive-waste disposal. Many commenters recommended that the production of nuclear energy and thereby the production of radioactive waste be stopped until a solution is found for the permanent disposal of radioactive waste.

Issue

Commenters expressed the opinion that the production of nuclear energy should not have been begun before the development of a method for the permanent disposal of the radioactive waste.

Response

The search for suitable methods of permanent disposal began early in the development of nuclear energy. By 1957, for example, the National Academy of Sciences had already recommended geologic disposal in salt formations. Furthermore, in the early days of nuclear-energy development, it was generally assumed that spent fuel would be reprocessed after being discharged from the reactor. The spent-fuel rods were stored in water pools at the sites of the reactors pending the start of reprocessing, and until the U.S. moratorium on reprocessing was declared in 1976 (see Section C.2.5.3), there was little incentive to develop disposal methods for spent fuel.

Issue

Commenters requested a moratorium on the production of commercial radioactive wastes.

Response

The production of electricity by nuclear energy is important to the national economy. In 1984, nuclear energy provided about 14 percent of the U.S. domestic electricity (DOE, 1985i). Nuclear energy is able to provide economical electric power, independent of foreign energy sources, while allowing the conservation of fossil-fuel reserves for other critical applications; it can help meet the future energy needs of this country. A moratorium on nuclear-energy production would severely damage U.S. energy and economic security.

Furthermore, a moratorium on radioactive-waste production would not remove the need for a repository. A large inventory of spent fuel has been accumulating at reactor sites. According to recent estimates, over 12,000 metric tons of spent fuel currently require disposal and over 130,000 metric tons will require disposal by the year 2020 (DOE, 1984d).

C.2.8.2 Alternatives to geologic disposal

Many comments suggested methods of disposal other than geologic repositories. Other commenters expressed concern that the DOE has not adequately considered all feasible options for disposal, such as disposal in space or beneath the seabed.

Issue

Some commenters wanted to know whether the DOE has considered space as a safe and feasible method for radioactive-waste disposal.

Response

Before deciding on geologic repositories, the DOE evaluated many alternative waste-disposal concepts, including space disposal (DOE, 1980). The DOE, in conjunction with the National Aeronautics and Space Administration (NASA) and others, studied the space-disposal concept, but did not favorably consider launching radioactive wastes into the sun because of excessive fuel requirements. Disposal on the moon was also rejected as an alternative because it might interfere with future lunar exploration. NASA's favored concept was to place high-level waste into a solar orbit about halfway between the Earth and Venus. This concept would use space shuttles to place the packaged waste into the appropriate solar orbit.

While the volume and weight of high-level radioactive waste are relatively small when handled on Earth, the cost would be enormous to launch all of the wastes into space. A fundamental requirement for space disposal is to separate the waste into short-lived and long-lived portions. The short-lived waste that would decay to innocuous levels in hundreds of years would be managed on Earth. Only the long-lived waste, which must be isolated for thousands of years, would be disposed of extraterrestrially. Therefore, disposal in space would only reduce, not eliminate, the need for terrestrial waste management.

The results of these studies led the NASA and the DOE to conclude that further study of space disposal is not warranted at this time. The reason for this conclusion was the expected additional cost of space disposal without achieving a significant reduction in long-term risk in comparison with the risk of disposal in a geologic repository. The concept of space disposal will be reconsidered if, at some future time, the DOE's program for waste-disposal technology or space-technology developments by NASA warrant the need for further study.

Issue

The DOE should consider disposal in relatively thick, stable beds of sediments located in deep, quiet, and remote regions of oceans or disposal in volcanic trenches throughout the world.

Response

The DOE is sponsoring a subseabed-disposal project as part of a multinational effort through Fiscal Year 1986. The disposal of high-level waste in the oceans has never been practiced by the U.S. Government and was prohibited by the Marine Protection, Research, and Sanctuaries Act of 1972 and under the London Convention on the Prevention of Marine Pollution by Dumping Wastes and Other Matter. The uncertainties and issues to be resolved regarding subseabed disposal are significant, and efforts to resolve them are under way.

Issue

A number of comments requested the DOE to start over with a safe answer to the problem of radioactive-waste disposal. It was noted that the concept of geologic repositories was developed in the 1950s. Many comments suggested that the DOE should accept new technology as it becomes available, and some commenters said that research and development on alternative methods of disposal should continue.

Response

A number of methods for the disposal of high-level radioactive waste have been examined by the Federal Government during the past 10 years, including subseabed, deep-hole, ice-sheet, and outerspace disposal. Of these alternative technologies, only subseabed disposal is currently funded by the DOE. The remaining alternative concepts were found to have no obvious advantages over geologic disposal. The primary consideration in evaluating these alternative technologies was public health and safety. The state of technology, the potential environmental impacts, and suitability for spent-fuel disposal have been studied for each of these methods and are discussed in the final environmental impact statement for the management of commercially generated radioactive waste (DOE, 1980).

C.2.8.3 General technical issues

A number of comments addressed technical issues that are not site specific. There were a large number of such issues, and they covered a broad range of subjects, including the accuracy and conservatism of the analyses used in the EAs, conditions at the repository site after closure, etc.

Issue

Some persons asked whether a large number of small disposal facilities would be safer.

Response

No clear reduction in risk would result from using a large number of smaller repositories. No net advantages would be realized in terms of monitoring the performance of the repositories. While there may be some reductions in costs of transportation, these would be greatly outweighed by the extra cost of finding and qualifying a larger number of repository sites and developing many repositories.

Issue

Several commenters felt that a burden is placed on future generations for the disposal of the wastes.

Response

Geologic disposal was chosen for high-level waste and spent fuel because it minimizes the potential burden on future generations. Once the repository is closed, there is no need for maintenance. The use of geologic formations as barriers to radionuclide migration helps to ensure that there will be no significant health burdens to future generations even if the waste containers are eventually breached.

Issue

Some commenters said that the DOE needs to consider how it will prevent human intrusion over the long term.

Response

The DOE feels that human intrusion can be prevented through prudent siting in locations that have few, if any, natural resources and through institutional management. Several years ago, the DOE convened a human-interference task force to determine whether reasonable means exist (or could be developed) to reduce the likelihood of unintentional human intrusion into a repository. The task force concluded that a significant reduction in the likelihood of human intrusion could be achieved, for perhaps thousands of years into the future, if appropriate steps are taken to communicate the existence of the repository to future generations.

Issue

One person asked whether the conclusions in the EAs on compliance with the guidelines are supportable.

Response

At the steps of site nomination and recommendation, the requirement for disqualifying conditions is evidence that does not support a finding that the site is disqualified. Likewise, the qualifying conditions are deemed to be present if the evidence does not support a finding that the site is not likely to meet the qualifying condition. The DOE believes that the available data and analyses for each site indicated that no site has a disqualifying condition and that all sites are likely to meet all the qualifying conditions.

Issue

One commenter asked whether the DOE can guarantee that no new mutations will occur from the waste-emplacement practices.

Response

Absolute guarantees are hardly ever possible, but the DOE believes that new mutations are extremely unlikely because there is very little likelihood that radioactive materials from the repository will reach the human environment.

Issue

One person asked whether the hydrogeologic conditions will be known well enough to make predictions over 10,000 years or more.

Response

At the time of application for a license for the repository, which comes after thorough site characterization, the hydrogeologic environment at the site will be well known. Not only will nominal values be determined for the parameters needed to predict the migration of radionuclides from the repository but also the uncertainties in those values due to measurement uncertainties and nonhomogeneous rock properties will have been determined.

Issue

One party asked whether the DOE plans to close the site without subsequent monitoring or retrieval.

Response

The DOE currently plans to be able to begin retrieval for up to 50 years after the start of waste emplacement and to monitor the site for some period, not determined at present.

Issue

One commenter noted that canisters need to stay intact for 300 years but monitoring will be for 50 years.

Response

The monitoring referred to by the commenter apparently is the 50-year period of waste retrievability and plans to monitor selected individual waste containers until the repository is closed; the objective of monitoring individual containers is to confirm their performance. Monitoring the containers after repository closure would be very difficult and could compromise the performance of the repository as a whole.

Issue

Some persons asked about the measures that will be used to protect the integrity of the controlled area for long periods after closure.

Response

At present, placing some form of physical markers around the site is the most likely method for notifying future societies of the presence of a repository. In addition, records will be kept.

Issue

Hanford will be accepting 60 percent of the Nation's defense waste.

Response

Whatever site is chosen for the first repository, it will receive up to 10,000 metric tons uranium equivalent of defense high-level waste.

Issue

One commenter said that phased repository construction will circumvent the NRC's requirement to review and approve complete site construction before accepting any waste for disposal.

Response

The Act (Section 114(d)) states that "the Commission shall consider an application for construction authorization for all or part of a repository...." Therefore the Act does not prohibit authorization for phased construction. The DOE has discussed this concept with the Nuclear Regulatory Commission and has received no objections to the concept. The sequence of license applications is described in the Mission Plan (DOE, 1985a).

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C.3 SITING PROCESS AND DECISIONS

This section addresses comments on the siting process and decisions. It covers issues related to site screening and the siting guidelines (Section C.3.1), the evaluation of sites against the disqualifying conditions of the guidelines (Section C.3.2), the grouping of sites into geohydrologic settings and the selection of the preferred site for each setting (Section C.3.3), and the nomination and recommendation of sites for characterization (Section C.3.4). The section on nomination and recommendation is concerned with general issues related to the DOE's approach in selecting the sites proposed for nomination and recommendation in the draft EAs and with issues related to the comparative evaluation and ranking of sites. It does not include issues related to the evaluations of individual sites; these issues are addressed in Sections C.5 though C.8. With a few exceptions, Section C.3 addresses comments on Chapters 1, 2, and 7 of the draft EAs.

C.3.1 SITING GUIDELINES AND SITE SCREENING

Addressed in this section are comments on the DOE's siting guidelines, published as 10 CFR Part 960 on December 6, 1984 (DOE, 1984), and comments on site-screening issues. The latter are divided into two parts: general site-screening issues (Section C.3.1.2) and issues specific to a particular host rock or site (Section C.3.1.3).

C.3.1.1 The siting guidelines

Most of the comments on the DOE's siting guidelines (10 CFR Part 960) addressed general issues like the development of the guidelines, the timing of their publication, and their adequacy. These are summarized and answered in Sections C.3.1.1.1, C.3.1.1.2, and C.3.1.1.3, respectively. Comments on specific guidelines are covered in Section C.3.1.1.4.

C.3.1.1.1 Development of the guidelines

The development of the guidelines drew comments and questions from several parties who were concerned about the derivation of the guidelines, the level of State involvement, and the content of the guidelines.

Issue

Several parties questioned the origin and the derivation of the guidelines.

Response

After the Act was passed, the DOE assembled a task force of program experts to prepare proposed guidelines. The task force began by considering the criteria used earlier in the National Waste Terminal Storage (NWTS)

Program, including program objectives, system-performance criteria, and site-performance criteria (DOE, 1981, 1982); other sets of criteria defined for geologic repositories by the National Academy of Sciences (NAS, 1978), the International Atomic Energy Agency (IAEA, 1977), and earlier programs in the United States (Brunton and McClain, 1977; DOE, 1980); advance information made available by the NRC (1980); and the requirements of the Act.

In the development the proposed guidelines, great care was taken to make them compatible with the existing applicable regulations of the Environmental Protection Agency (EPA), published as 40 CFR Part 190 (EPA, 1977) and the Nuclear Regulatory commission (NRC), published as 10 CFR Part 20 (NRC, 1960) and with the regulations that had been recently proposed by the NRC and the EPA concerning the disposal of high-level radioactive waste and spent nuclear fuel in geologic repositories. The NRC had by then nearly completed the pertinent technical criteria for geologic repositories, 40 CFR Part 60 (NRC, 1982), and the EPA had issued, for public comment, proposed environmental standards, 40 CFR Part 191 (EPA, 1982).

Several draft versions of the siting guidelines were released: the proposed guidelines of February 1983 and the alternative guidelines of May 1983, both of which were issued for review and comment by the States, affected Indian Tribes, and the public; the revised guidelines of August 1983, which served as a basis for additional consultation with States, Indian Tribes, and Federal agencies; and the revised guidelines of November 1983, which were sent to the NRC for concurrence. The NRC held several meetings on the guidelines at which the DOE, States, affected Indian Tribes, and Federal agencies presented comments.

The revisions that resulted from this comment and consultation process are discussed in the "Supplementary Information" for the guidelines (DOE, 1984, pp. 47714-47751) and in the comment-response document for the guidelines (DOE, 1983). After NRC concurrence, the guidelines were published in final form (December 1984), and many copies were distributed to States, Indian Tribes, and the public.

Issue

Some commenters asked about the level of State involvement in developing the guidelines.

Response

As explained in the "Supplementary Information" for the guidelines (DOE, 1984, pp. 47717-47720), the siting guidelines were developed after two formal public-comment periods and two rounds of consultation with the interested States, including both separate meetings with individual States and plenary sessions. The comments submitted by the States on the proposed guidelines of February 7, 1983, led to a division of the guidelines into postclosure and preclosure guidelines and to the addition of the implementation guidelines. Many other changes were made to the guidelines in response to comments from the States. In addition, the States and Indian Tribes had opportunities to provide comments to the NRC during the concurrence process.

Issue

One commenter asserted that the DOE intentionally slanted the content of the siting guidelines to favor the selection of a particular site.

Response

The guidelines were not prepared with the intent of selecting any particular site for the first repository. The purpose of the guidelines is to provide an objective framework for ensuring that potential repository sites meet the standards established for radioactive-waste disposal.

C.3.1.1.2 Time of publication

A number of comments addressed the timing of the publication of the siting guidelines, both in relationship to the site-screening process and the publication of the pertinent EPA and NRC regulations.

Issue

Several commenters inquired why the publication of the final siting guidelines was delayed.

Response

The DOE realized that it was important to get public and State input on the content of the guideline. This was a time-consuming process, but the DOE thought that the additional time required for this review was warranted in light of the benefits received.

Issue

Several commenters questioned how the nine potentially acceptable sites for the first repository could be identified before the final siting guidelines were issued and argued that the guidelines should have been issued before the identification of potentially acceptable sites.

Response

When the Act mandated the preparation of the guidelines, the DOE had already identified nine sites as potentially acceptable for the first repository; the screening that led to them had been based on criteria defined by the National Academy of Sciences (NAS-NRC, 1978), the International Atomic Energy Agency (IAEA, 1977) and earlier programs in the United States (Brunton and McClain, 1977; DOE, 1980). The DOE believes that Congress did not intend this screening to be repeated on the basis of the new guidelines required in the Act. Section 116(a) of the Act requires that, within 90 days of its enactment, the DOE identify the States with potentially acceptable sites and, within 90 days after such identification, notify the States and affected Indian Tribes of the potentially acceptable sites within their jurisdictions. Such a notification would be impossible if Congress had intended a repetition of the screening against the guidelines, which were to be issued within the first 180 days. The screening that led to the nine potentially acceptable sites did not use the guidelines per se, but it was based on the same principles. The guidelines have been and will be used in the remainder of the site-selection process for the first repository and for screening potential sites for the second repository.

Issue

Several commenters contended that the guidelines should not have been developed before the promulgation of the EPA standards and the NRC criteria for geologic disposal because the guidelines are based on compliance with the EPA standards and the NRC criteria.

Response

The Act did not allow the DOE to delay the guidelines until the publication of the NRC and the EPA regulations. It required the DOE to issue guidelines within 180 days of the enactment of the Act (i.e., in August 1983), whereas the NRC and the EPA were to issue their regulations by January 1, 1984, and January 7, 1984, respectively.

However, the guidelines were based on proposed EPA and NRC regulations. Their compatibility with the NRC's 10 CFR Part 60, which was published in final form on June 21, 1983 (NRC, 1983), has been verified by the NRC, which used absence of conflict with 10 CFR Part 60 as one of the criteria for its concurrence on the guidelines. Throughout the guideline-development process, the DOE was able to review the working drafts of the EPA's 40 CFR Part 191 to ensure absence of conflict. The final EPA rule, published on September 1, 1985 (EPA, 1985a), is not in conflict with the guidelines. As explained in the "Supplementary Information" for the guidelines (DOE, 1984, p. 47721), in the event of any future conflict between the guidelines and either 10 CFR Part 60 or 40 CFR Part 191, these NRC and EPA regulations will supersede the guidelines and constitute the operative requirement in any application of the guidelines. The guidelines also contain provisions for their amendment to maintain compatibility with the NRC and the EPA regulations.

C.3.1.1.3 Adequacy of the siting guidelines

Many of the comments received on the guidelines addressed the adequacy of the guidelines. The issues raised ranged from doubts about the ability of the guidelines to protect public health and safety to suggestions for revising the guidelines.

Issue

A number of comments expressed doubt that the guidelines would protect public health and safety and the quality of the environment.

Response

The siting guidelines are based on compliance with the EPA standards for the geologic disposal of radioactive waste (40 CFR Part 191) and the NRC criteria for implementing the EPA standards (10 CFR Part 60). Protection of the health and safety of the public and the quality of the environment is the basic objective of both the EPA and the NRC regulations.

Issue

Several commenters requested that "proximity" be included as a factor in selecting and evaluating potential repository sites, and one commenter questioned why proximity to dedicated lands is not a disqualifying condition.

Response

Proximity is included as a factor in the preclosure guidelines on population density and distribution, offsite installations and operations, the environment and transportation. Proximity is also implicit in the third disqualifying condition on the environment, which is concerned with the previously designated resource-preservation use of National or State parks, forest lands, etc.

Issue

Some parties said that, because no sites have been disqualified, the validity of the guidelines is questionable.

Response

The nine potentially acceptable sites for the first repository were identified in a site-screening process that evaluated regions, areas, locations, and potential sites against various criteria that were based on the same principles as the siting guidelines. One of the objectives of this process was to eliminate sites that do not merit the investment necessary for detailed studies and site characterization. It is therefore not surprising that none of the sites identified as potentially acceptable have not been disqualified in evaluations against the guidelines.

Issue

The guidelines were criticized by some parties for failing to specify procedures for verifying findings.

Response

The guidelines are intended to provide the framework for a site-screening and site-selection process that can lead to the selection of suitable sites. They do not contain any procedures for the conduct of site screening, methods of date collection and analysis, etc. Such procedures will be included in other documents, such as the site-characterization plans. The plans for site characterization will be reviewed by the NRC and the affected State, and the information collected during site characterization will be reported to the NRC every 6 months. The final determination of the suitability of any site will be made by the NRC.

Issue

Some comments alleged that, because the guidelines may be challenged by litigation, the EA findings are tenuous.

Response

As explained in Section C.3.1.1.1, the siting guidelines were developed through a process of extensive consultation with the States and affected Indian Tribes and review by the public. As required by the Act, they received the concurrence of the NRC. The DOE is therefore confident that litigation challenges will not bring about any significant changes in the guidelines or require changes in the EA findings.

Issue

The DOE was advised that the controlled area and the accessible environment should be defined before site characterization begins.

Response

The DOE siting guidelines define the accessible environment as the atmosphere, the land surface, surface water, oceans, and the portion of the lithosphere that is outside the controlled area.

The definition of the controlled area is derived from the NRC's 10 CFR Part 60 (NRC, 1983); it establishes an area of no more than 10 kilometers (6 miles) around a repository that is to be identified by markers, records, and other possible institutional controls intended to exclude incompatible activities from the area. The EPA's final standard in 40 CFR Part 191 (EPA, 1985) establishes a more restrictive definition of controlled area: it limits the controlled area to 5 kilometers in any direction from the outer boundary of the original location of the waste in a repository. Furthermore, the controlled area is also limited to 100 square kilometers, which is approximately the area that would be extend for a distance of 3 kilometers from all sides of an undergound repository in a typical configuration. The EPA definition thus substantially reduces the area of the lithosphere that would be contained if the controlled area and thus decreases the distance to accessible environment. The 5-kilometer distance was chosen to retain reasonable compatibility with the NRC's requirement that the pre-waste-emplacement time of ground-water travel to the accessible environment be at least 1,000 years.

Issue

The adequacy of the guidelines for the ranking of sites was questioned.

Response

As explained in the multiattribute utility analysis of the nominated sites, the DOE developed a revised method for using the guidelines to rate the technical adequacy of sites. This method has been reviewed by the National Academy of Sciences and other peer reviewers.

Issue

Some parties suggested that the guidelines should establish procedures for determining the end point of site characterization.

Response

The end point of site characterization will be established by the site-characterization plans, which will describe in detail the tests to be performed, the data that are needed, and what the data will be used for. Each plan will be specific to a particular site and will be based on the data and analyses needed to resolve outstanding issues about the suitability of the site. Because the end of site characterization depends on site-specific conditions, it cannot be defined by general siting guidelines. As already mentioned, these plans will be reviewed by the NRC, the affected States and Indian Tribes, and the public through a formal hearing process. The data collected during site characterization will be reported to the NRC every 6 months in progress reports that will also discuss any needed changes in the plans for testing. After site characterization is completed, the NRC may request the DOE to collect more data for the confirmation of the results of site characterization.

Issue

One commenter suggested that the potential impact on system performance by discrete hydraulic features (joints, faults, fractures, and dissolution conduits) be incorporated into the DOE guidelines and the EAs.

Response

The impact on system performance of discrete hydraulic features is not included in the guidelines because the guidelines must be general enough to cover all types of host rock. The impacts of such features, if they are present, will be assessed during site characterization.

C.3.1.1.4 Comments on particular guidelines

Issue

The guideline concerning the 10,000-year travel time from the repository to the accessible environment is not appropriate for radioactive waste that will be subject to dispersive and diffusive mixing processes.

Response

A 10,000-year travel time to the accessible environment is a favorable condition in the postclosure guidelines on geohydrology; it was derived from the NRC's criteria in 10 CFR Part 60. The qualifying condition for geohydrology says that the present and expected setting of a site shall be compatible with waste isolation, taking into account the characteristics of, and the processes operating within, the geologic setting.

Issue

Ground-water modeling should be specified in the postclosure guideline on geohydrology (and the EAs) as a screening tool rather than as a predictive tool. Modeling results should not be substituted for "hard data" where inadequate data would make verification impossible.

Response

As already mentioned, the guidelines are not intended to specify procedures for data collection, data analysis, or performance assessment. Detailed information on the technical approach will be presented in the site-characterization plans.

Issue

Some commenters asked why the technical guideline on preclosure site ownership and control is assigned to the system guideline for preclosure radiological safety instead of ease and cost of construction, operation, and closure.

Response

The primary purpose of the preclosure guideline on site ownership and control is to ensure compliance with the NRC's requirement that the DOE obtain ownership as well as surface and subsurface rights to land and minerals within the controlled area of the repository (10 CFR 60.121). The objective of this requirement is to protect the general public from any radioactivity that might be released in the repository, and hence this guideline is concerned mainly with preclosure radiological safety. The system guideline on the ease and cost of repository siting, construction, operation, and closure, on the other hand, is concerned with the use of reasonably available technology and assurance that the cost of siting, constructing, operating, and closing a repository at a particular site is reasonable in comparison with the costs of other available and comparable siting options.

C.3.1.2 General site-screening issues

Summarized and addressed in this section are comments on several generic site-screening issues: the site-screening process, the importance of host-rock diversity, the selection of sites on the basis of land use, and the screening for sites in salt. In addition, this section includes comments on particular siting issues, such as proximity to a national park.

C.3.1.2.1 Use of ambiguous criteria and lack of uniformity

The site-screening process was criticized because it allegedly varied from site to site and because host rocks other than basalt, salt, and tuff were not considered.

Issue

One party alleged that Chapter 1 of the draft EAs reveals the site-screening process to be full of ambiguously defined criteria, arbitrary cutoffs, and site deferrals and said that the criteria used to eliminate sites were aimed at reaching an arbitrary number of sites, rather than eliminating inferior ones. Size was cited as one such arbitrary factor, particularly the 2,000-acre minimum that led to the elimination of three salt-dome sites.

Response

The criteria used in screening for potentially acceptable sites were based on waste-isolation requirements, natural processes and conditions that could affect isolation, engineering design requirements, and factors particular to the rock type under consideration (i.e., dome size is pertinent only to salt domes). The size criterion, for example, was derived from repository designs and NRC requirements. The three domes were eliminated because the 2,000-acre criterion was established during the time the salt domes were being screened.

Chapter 1 of the EAs only highlights the site-screening processes. For a complete description of the processes, the supporting references cited in Chapter 1 should be consulted.

Issue

The DOE was advised to begin the national screening process for the first repository again, implementing a uniform process for all sites.

Response

To begin another national screening process for the first repository would violate the requirements of the Act, which specifies that the potentially acceptable sites for the first repository be identified at the time the guidelines are issued--within 180 days of the enactment of the Act. The requirement for the identification of potentially acceptable sites was derived from the recognition by Congress that the DOE had been conducting screening studies for several years. As explained in the "Supplementary Information" for the guidelines (DOE, 1984), the screening processes were based on principles similar to the guidelines.

Issue

Several commenters questioned why granite, considered by countries like Sweden as the best rock for a radioactive-waste repository, or argillaceous rocks (shale) are not being considered for the first repository.

Response

Because basalt, salt, and tuff are suitable host rocks for waste isolation, screening in these rocks had identified promising sites, the cost of characterizing more than three sites for the first repository seemed unwarranted, and the Act required potentially acceptable sites to be identified within 180 days, the DOE decided to reserve granite for the second repository. Thus, studies of granite, a crystalline rock, have not progressed as far as studies of other host rocks. Several years will be required to identify potentially acceptable sites in crystalline-rock formations and to collect for such sites as much information as is available for the basalt, salt, and tuff sites in order for all sites to be considered on a comparable basis.

Argillaceous rocks at the Nevada Test Site were considered for the first repository in the late 1970s. As explained in Chapter 2 of the EA for the Yucca Mountain site, general studies were made of low-permeability shale, and detailed studies were made of the argillite-rich Eleana Formation. However, because the argillite rock was judged to be too complex for characterization, further consideration was suspended.

C.3.1.2.2 Importance of host-rock diversity

The DOE was criticized by some commenters for using the diversity of host rocks as a requirement in the site-screening process. Conversely, other commenters wanted to know why screening for the first repository was limited to basalt, salt, and tuff.

Issue

There were objections to the importance assigned to host-rock diversity. The requirement for diversity automatically places the Hanford and the Nevada sites in the top five and makes it possible for technically superior sites to be overlooked in favor of sites in different settings. (See also Section C.3.3 for comments and responses on geohydrologic settings.)

Response

The need to recommend and characterize sites in different host rocks is well established in the NRC requirements (10 CFR Part 60) to characterize three sites in two host rocks, at least one of which is not salt; in the requirement of the Act that, to the extent practicable, the DOE recommend sites in different host rocks; and in Section 960.3-1-1 of the siting guidelines. The consideration of alternative host rocks is also implicit in the requirements of the National Environmental Policy Act (NEPA). The DOE is nominating a set of sites that meet both the NRC's technical criteria in 10 CFR Part 60 and requirements for a diversity of host rocks. Without diversity, the discovery of a generic flaw in some particular host rock during site characterization would lead to unacceptable delays in the siting process.

C.3.1.2.3 Selection of sites on the basis of land use

Many comments addressed the screening of sites on Federal lands and the identification of the Hanford site in Washington and the Yucca Mountain site in Nevada as potentially acceptable on this basis.

Issue

Commenters said that the Hanford and the Nevada sites were selected on the basis of Federal ownership rather than geologic superiority, whereas the Act requires that geologic conditions be the primary criteria.

Response

Geologic conditions are the primary criteria. However, the DOE used two approaches to screening for geologically suitable sites for the first repository. One approach began with the identification of salt as a potentially suitable host rock and proceeded with a screening process that narrowed the size of the land unit under consideration from regions to sites.

The other approach began with the evaluation of certain Federal lands that are dedicated to nuclear-energy operations to see which contain potentially suitable host rocks; it led to screening at Hanford and at the Nevada Test Site. This approach was endorsed by the Comptroller General of the United States (General Accounting Office, 1979) and by a resolution by the House of Representatives (1979). Although land use formed the initial basis for the screening of Federal lands, the subsequent progression to smaller land units was based on evaluations of geologic and hydrologic suitability, using criteria that are similar to the siting guidelines. Since the publication of the guidelines, the evaluations of these sites have been based on the guidelines. If the results of site characterization cause a site on Federal land to be disqualified because of geologic conditions, the site would be dropped from consideration regardless of land ownership.

Issue

Some commenters asked why the DOE did not investigate government-owned sites other than Nevada and Hanford and other sites already set aside for nuclear-energy activities.

Response

Other DOE-owned sites dedicated to nuclear-energy activities were considered. However, the geologic and hydrologic conditions at the other sites did not seem as favorable as those of the Hanford Site and the Nevada Test Site. In addition, preliminary investigations of the Hanford Site and the Nevada Test Site had been conducted for defense programs, and experienced staff were available to assist in repository-site investigations. Another reason for choosing the Hanford and the Nevada sites for site screening is their large geographic area, which increases opportunities for finding sites with favorable combinations of geologic and hydrologic characteristics. For example, the large size of the Nevada Test Site allowed preliminary investigations in nine different host rocks in saturated and unsaturated environments before it was shown that the unsaturated environment in tuff was preferred to other geologic environments at Nevada.

C.3.1.2.4 Screening for sites in salt

There were a number of comments on the screening of sites in salt. Some of them questioned the suitability of salt, in general, whereas others asked about particular regions or sites.

Issue

Some commenters said that the EAs should explain why salt is the best host rock or the relative advantage of salt domes and bedded salt. They said that salt seems to be a candidate because it is the most-studied host rock rather than the best host rock, and its suitability has been questioned.

Response

Salt was recommended as a potentially suitable host rock for waste disposal in 1955 by the National Academy of Sciences-National Research Council (NAS-NRC 1957), which made this recommendation after evaluating many options. This recommendation was reaffirmed in a subsequent report (NAS-NRC, 1970) and endorsed by the American Physical Society (1978).

The characteristics of salt that are favorable for waste isolation are discussed in Section 1.2.2 of the EAs. The features of salt beds and salt domes were described in Section 1.3.2.2 of the EAs and in the DOE's Mission Plan (DOE, 1985, Vol. I, Part I, Chapter 5). The DOE has never claimed that salt is the "best" host rock for waste isolation. All of the host rocks considered for repositories have both advantages and questions to be resolved.

Issue

One commenter wanted to know why the Salina Basin was deferred for further study even though it is closer to a larger number of reactors than other salt sites and its selection would alleviate the problem of transporting waste over long distances.

Response

The Salina region includes portions of Michigan, New York, Ohio, Pennsylvania, West Virginia, and Canada. Regional analyses had indicated that bedded salt potentially suitable for a geologic repository occurs in Michigan, northeastern Ohio, and a portion of northwestern New York. Plans for field investigations in Michigan were halted in 1977 because of the enactment of a State law (Public Act 113) barring the disposal of high-level radioactive wastes in the State. Regional studies of the Salina Basin based on the geologic literature and geologic data from public and private sources were completed in 1978. These studies identified study areas for field investigations in New York and Ohio, but no field work was carried out for the reasons explained below.

The studies of the Salina region were not specific or detailed enough to judge that any part of the region was suitable or unsuitable for a repository. They did reveal, however, unfavorable characteristics in several parts of the basin. Among the most important was the high population density and the concentration of urban areas (more than 50,000 inhabitants) in Ohio and southern Michigan. Another was the abundance of natural resources, especially the oil and gas deposits in Ohio and throughout the Michigan Basin. When the State of Ohio objected to further studies, the DOE was in the process of examining its goals and objectives in the management of radioactive waste and had begun investigations of alternative host rocks (basalt and tuff). Evaluations of salt were restricted to the Permian Basin of Texas, the Paradox Basin in Utah, and the salt domes in the Gulf interior region of Louisiana and Mississippi.

Issue

The DOE needs to discuss why the first two sites selected in the salt-screening process--Lyons, Kansas, and the WIPP site--were rejected and are not even mentioned in the description of the siting process.

Response

The site at Lyons, Kansas (an already existing salt mine), was used by the Atomic Energy Commission (AEC) from 1965 to 1967 for a large-scale experiment with simulated waste and electrical heaters. The purpose of this experiment, called Project Salt Vault, was to observe the response of salt beds to heat. In June 1970, the Lyons site was selected as a potential location for a geologic repository; the selection, however, was conditional on the satisfactory resolution of site-specific issues under study. The concept and the location were conditionally endorsed in November 1970 by the waste committee of the National Academy of Sciences. A conceptual design for a repository was completed in 1971. In 1972, however, the Lyons site was judged to be unacceptable for technical reasons: there were previously undiscovered drill holes nearby, and some water used in nearby solution mines could not be accounted for. Accordingly, the AEC decided to abandon Lyons as a demonstration site and to search for sites elsewhere.

In 1974, field investigations for a site for the Waste Isolation Pilot Plant (WIPP) were begun in the northern part of the Delaware basin in New Mexico. Selected by the Oak Ridge National Laboratory, the site was on the Eddy-Lea County line, about 30 miles east of Carlsbad. However, drilling and geophysical investigations produced unexpected results showing that the geologic structure appeared to be unpredictable because of proximity to a major aquifer. The structure could have been delineated by more drilling, but extensive drilling would have been contrary to the principle of minimizing the number of holes drilled into the repository. That site was therefore given up, and a new survey for sites in the New Mexico portion of the Delaware basin was begun by the U.S. Geological Survey and the DOE's predecessor, the Energy Research and Development Administration. In 1975, these efforts led to the identification of a site in the Los Medanos area, about 25 miles east of Carlsbad. The Waste Isolation Pilot Plant now being constructed there has been designated (by Public Law 96-164) a research-and-development facility for the national defense effort (to demonstrate the disposal of high-level waste) and for the disposal of defense transuranic waste. This plant is not part of the DOE's program for the management of commercial radioactive waste.

C.3.1.2.5 Particular siting issues

A number of comments addressed particular siting issues, such as proximity to a national park or the potential for contaminating water supplies.

Issue

The DOE was urged not to consider a repository site near a national park.

Response

The DOE recognizes its responsibility to protect the national parks from irreconcilable conflicts. According to the siting guideline on environmental quality, if the "presence of the restricted area or the repository support facilities would conflict irreconcilably with the previously designated resource-preservation use of a component of the National Park System," the site would be disqualified.

Issue

Some persons were concerned that a repository would contaminate water supplies and nearby rivers, thus adversely affecting the water supply of downriver populations.

Response

Water supplies and nearby rivers are protected by EPA and NRC regulations, which require complete containment of all radioactive material for 1,000 years and limit any releases thereafter to extremely low rates that would pose no hazard to public health or safety. Requirements for ground-water protection are explicitly included in the EPA's final standards (EPA, 1985).

Issue

Several comments said that a repository should not be located near prime farmland.

Response

The siting guidelines provide a number of opportunities to evaluate the potential impacts of a repository site on prime agricultural lands. For example, the preclosure guideline on socioeconomics says that the "potential for major disruptions of primary sectors of the economy of the affected area" is a potentially adverse condition. The DOE is concerned about impacts on prime agricultural lands and will not select any site that would irreconcilably damage farm capability.

Issue

Many commenters wanted to know why the DOE is continuing to consider the Hanford site. They claim that the highly fractured basalt rock has been shown to be a poor host rock for a repository.

Response

The Hanford site and the basalt host rock have many favorable characteristics for waste isolation and some questionable characteristics, just as the other rock types have. The DOE recognizes that the hydrologic conditions of the Hanford site are an important issue, but the results of studies conducted since 1976 have not revealed any technical reasons for finding the site unacceptable. If Hanford is selected for site characterization, the studies performed will provide the information needed for determining compliance with the siting guidelines and hence NRC criteria and EPA standards.

C.3.1.2.6 Alternative repository locations

Issue

Many commenters suggested alternative repository locations with particular characteristics (e.g., location away from populated areas, in an arid desert, or on barren government-owned land) or recommended specific sites.

Response

The characteristics suggested by the commenters are considered favorable conditions in the siting guidelines. However, the geologic conditions that are important to waste containment and isolation after repository closure are the primary considerations. No single site characteristic is sufficient because each site must meet the qualifying conditions of every guideline. While other possible repository locations may possess particular characteristics that are favorable, the DOE is confident that the sites being considered for the first and the second repository possess the combination of characteristics needed for compliance with the DOE siting guidelines and with the regulations promulgated by the EPA and the NRC for the protection of public health and safety.

C.3.1.3 Site-specific screening issues

The comments that pertained to site-specific site-screening studies were divided into four categories: (1) site-identification studies, (2) identification of the candidate horizon, (3) repository layout and exploratory-shaft site, and (4) continuation of siting investigations at the Hanford Site.

C.3.1.3.1 Site-identification studies

Several commenters questioned the methods by which the Hanford (basalt) site was selected.

Issue

The commenters asked the DOE to explain why portions of the basalt site were eliminated from further consideration.

Response

Several areas within site locality H-3 (see Figure 2-22, of the draft EA) were eliminated during site screening, but were included as part of candidate-site identification and ranking. The areas previously excluded were (1) the locations of surface facilities for chemical separations and defense-waste management at Hanford (i.e., 200 East and 200 West Areas) and (2) the slope of the Umatanum Ridge bar (see Figure 3-5 of the Draft EA). The facilities or the terrain slope would not affect a repository at 3,000 feet below the surface as long as the repository surface facilities were located away from the existing facilities of chemical separations and defense-waste management and the shoulder of the bar.

Issue

Some commenters complained that the objectives of the siting studies were not clearly stated.

Response

The site-screening area under consideration for a repository in basalt was the Pasco Basin, with emphasis on the Hanford Site, as discussed in Section 1.2.3.1 of the draft EA. It is important to note that the objective of the siting studies was not to find the best location for a repository but to progressively focus on smaller areas within the Hanford Site with the highest potential for containing suitable sites. Also, Rattlesnake Mountain was included in the area for site screening, but was found to have negative attributes (e.g., faulting that may have been active during the Quaternary Period) and was eliminated from further consideration earlier in the site-screening study.

Issue

The commenters pointed out that the potentially acceptable site is near active faults and criteria for the distance from active faults are not discussed in the draft EA.

Response

The cited 5-mile distance from known capable faults was applies as an inclusionary screening guideline for site selection based on information available at the time and on a conservative application of available siting criteria, which did not set minimum distance standards (see p. 2-46 of the draft EA). The inclusionary or exclusionary guidelines used for site selection are not statutory standards and do not necessarily become disqualifiers. One guideline used in the identification of the site required that a site be at least 5 miles from known faults interpreted to be capable. This guideline was discussed as an example on page 2-41 of the draft EA. Since the identification of the site, capable faults have been found within 5 miles of the site boundaries. These faults, which were investigated for a different nuclear project by Golder Associates (PSPL, 1982, Sec. 20) and the Nuclear Regulatory Commission (NRC, 1982, App. G and H), are discussed in Section 3.2.3.2 of the draft EA. While the northeastern margin of the site is within 5 miles of the central Gable Mountain area, the entire site and the area of the surface facilities are farther than 5 miles from the central Gable Mountain area.

The potential for fault rupture is considered in the NRC review of nuclear reactors (NRC, 1985). In this review, capable faults, or faults interpreted to be capable, that are more than 1,000 feet long and are within 5 miles of the facility, must be subjected to detailed studies to determine the potential for fault rupture. These studies are conducted for faults located within an area called the "zone requiring detailed faulting investigations." Nuclear facilities may not be located within such a zone unless the effects of potential surface faulting have been properly determined. A radioactive-waste repository, which has less-stringent safety requirements than reactors, could be subject to similar site-suitability criteria for fault rupture. Therefore, a 5-mile setback from capable and potentially capable faults was considered to reasonably satisfy the present and any future NRC regulatory position on fault rupture.

Issue

Some parties felt that the draft EA did not present sufficient information on the screening process.

Response

Section 2.2 of the draft EA presented a summary of the screening process used to select the Hanford site. More detailed information is available in the referenced documents.

Issue

Some commenters wanted to know why areas outside the Hanford Site were not considered.

Response

In 1977, the national waste-disposal program was expanded to consider previous land to use as an alternative basis for site screening. The approach considered the advantages of locating a repository on land already withdrawn and committed to long-term institutional control. Because the hanford Site (and the Nevada Test Site) is dedicated to nuclear operations, will remain under Federal control, and is underlain by potentially suitable rocks, screening was initiated within the Hanford Site. The Pasco Basin was selected for screening sites to provide a broader scope from which to study conditions and processes that might affect the Hanford Site and to determine whether there were obviously superior sites in the natural region outside, but contiguous with, the Hanford Site.

Issue

The commenters objected that the draft EA did not discuss how geohydrologic data were used in site screening.

Response

The use of geohydrologic data in site screening at Hanford was summarized in Section 2.2 of the draft EA. Detailed discussions are available in the reference documents (WCC, 1980, 1981).

Issue

The commenter said that the draft EA did not explain how geophysical anomalies were used in screening.

Response

A geophysical anomaly is generally a departure in the geophysical character of a specific area from that of the surrounding area or region, and it may represent geologic structures (i.e., faults or folds). Geophysical anomalies are not readily identified from geophysical maps and cross sections and do not necessarily geologic structures; they can be identified from the results of geophysical surveys. The geophysical surveys conducted in the Cold creek syncline resulted in the identification of geophysical anomalies (generally linear trends), many of which were interpreted to represent known or inferred geologic structures (Myers and PRice, 1981). Candidate sites H, J, and K were defined by areas of bedrock that are generally free of major geophysical anomalies. The boundaries of these three sites correspond to what were considered by Myers (1981) to be known or inferred structures. Specific geophysical anomalies in the Cold Creek syncline are discussed in detail in the referenced document (Myers and Price, 1981). Additional information on geophysical anomalies has been added to Section 3.2.3.3.4 of the final EA.

C.3.1.3.2 Identification of the candidate horizon

Several comments questioned the processes and conclusions of the horizon-identification study reported in Section 2.2 of the EA.

Issue

One commenter felt that the draft EA did not clearly explain the comparison of candidate horizons on the basis of hydrologic properties.

Response

The DOE agrees that the discussion in the draft EA about the hydrologic properties used to compare candidate horizons is unclear. The discussion was necessarily a very brief summary of a document on the identification of a preferred candidate horizon (Long and WCC, 1984). The final EA revised to remove any ambiguities in the comparison of the hydrologic properties of candidate horizons, and the reader is directed to the above-mentioned reference document.

Issue

One party noted "apparent discrepancies in travel-time calculations and cummulative-activity values for iodine-129.

Response

There is no discrepancy between travel time and cumulative activity of iodine-129 crossing a vertical boundary 1.6 miles from the repository over a period of 10,000 years. The travel-time values and cummulative-activity values are not proportional for a given candidate horizon because effective-thickness values are not the same for each of the horizons. Both conductivity and flow-top thicknesses were assigned values specific to a given horizon. This fact was presented in the reference document (Long and WCC, 1984, p. 2-59). Because a detailed discussion of the modeling conducted for horizon identification was included in the reference document, it was judged inappropriate for the EA.

Issue

One commenter objected to the conclusions of the study because of the lack of reliable estimates of vertical conductivity in the relatively dense interiors of basalt flows.

Response

The lack of reliable estimates of vertical conductivity in the relatively dense interiors of basalt flows means that it was not possible to directly compare the vertical isolation potential of the candidate horizons on the basis of hydrologic tests. As explained in the draft EA (pp. 2-59 and 2-60) and in the reference document (Long and WCC, 1984) the comparison of the vertical isolation potential of candidate horizons was based on the results of modeling in which an assumed ratio for vertical to horizontal conductivity in the dense interiors was used; they are therefore primarily dependent on the depths of the candidate horizons. The draft EA also noted that the modeling results were preliminary and should not be construed as a performance estimate of the site. Subsequent analyses, based on new data, are not expected to change the relative rankings of horizons.

Issue

The commenters questioned the decision analysis used in the study and said that its role in screening the basalts of the Pasco Basin was not clear.

Response

Section 2.2.3.2 of the draft EA discussed a mainly deductive evaluation of the candidate horizons. This process took available data into account but was designed to determine whether the results of the formal decision analysis were consistent with the informal reasoning of experts. As noted in the draft EA, expert judgement corroborated the decision-analysis approach.

Decision analysis was considered a vital part of the process for screening basalts in the Pasco Basin and beneath the Hanford Site. Technical input from geoscientists, engineers, and consultants was used for the ranking and selection process. This process was more fully described in some of the references cited in the draft EA.

Issue

Some commenters questioned the reliability of the hydrologic and radionuclide-transport models used in the study.

Response

The methods and models used to calculate ground-water travel times and radionuclide transport for a comparison of candidate horizons are believed reliable and were described in the reference document (Long and WCC, 1984), which is extensively cited in Section 2.2.3 of the draft EA. Uncertainties about the median ground-water travel times were included in the probabilistic ranking of candidate horizons (see Figure 2-30 of the draft EA) and were therefore taken into account in the decision analysis. Uncertainties were not derived for radionuclide transport, but it was judged that the data were sufficiently reliable for a comparison of candidate horizons. Estimates for ground-water travel times and radionuclide transport are suitable for comparison only because they are based on limited hydrologic data and a simplified conceptual model (see p. 2-59 of the draft EA). Although new data collected during site characterization might change the estimates given, the comparative relationship among the estimates is not likely to change.

Issue

Several commenters questioned the suitability of the McCoy Canyon and Rocky Coulee flows as candidate horizons, and one party said that the thicknesses given in the draft EA for the McCoy Canyon flow are in error.

Response

The McCoy Canyon flow is suitable as a candidate horizon for a repository at Hanford. The screening of flows for the selection of candidate horizons was based only on data from cored boreholes within approximately 1.4 miles of borehole RRL-2. A minimum dense-interior thickness of 80 feet was required for screening. The McCoy Canyon flow had an adequate thickness of dense interior to pass this phase of the screening process. The pillow zones north of the Pasco Basin are approximately 40 miles north of the site; no pillow zones have been observed in borehole within the Pasco Basin for the McCoy Canyon flow. Sporadic vesicular zones found within the McCoy Canyon flow were not judged to be disqualifying; however, the McCoy Canyon flow did rank lower than the Cohasset flow in a detailed ranking of candidates, partly because of the presence of vesiculation (see Section 2.2.3 of the draft EA).

Since the minimum thickness required for the dense interior by the screening criteria (i.e., boreholes RRL-2, RRL-6, and RRL-14) was 80 feet the Rocky Coulee flow would have passed this screening criterion even if paired boreholes DC-4 and DC-5 had been included in the screening data base. The intraflow structures that cannot be readily correlated from borehole to borehole are tiers of entablature and colonnade that, for the horizon-identification process, were not considered particularly significant to Section C.4.1.1 of this appendix, issue on geologic conditions, for further discussion of entablature-colonnade tiers).

There was an inconsistency in the draft EA regarding the thickness of the dense interior of the McCoy Canyon flow. It also stated that the minimum thickness of the McCoy Canyon flow is less than 80 feet in borehole DC-22C. The minimum thickness actually occurs at the northwestern corner of the site. The thickness of the flow has been corrected in Section 3.2.2.1.2 of the final EA.

Issue

Some commenters said that the draft EA did not adequately explain the minimum-thickness criterion on 80 feet for the dense flow interiors.

Response

Conceptual repository designs must allow for enough thickness of relatively intact rock to accommodate the maximum expected height of the mined area of the repository, plus sufficient competent rock above and below to ensure a stable mined opening. A minimum thickness of mined openings in basalt. This minimum thickness was based on the conceptual design of a repository in the Umatanum flow. Such an analysis has not been conducted for the other flows. For the purposes of screening, 80 feet was also assumed the appropriate cutoff level for the other candidate horizons.

Issue

One party felt that a statement about the continuity of flows in the Pasco Basin could be misinterpreted.

Response

The statement that candidate horizons are continuous throughout the Pasco basin (see p. 3-i of the draft EA) could be misinterpreted to mean continuity of intraflow structures. Therefore, the phrase "the candidate horizons" has been changed to "these four flows" in the final EA.

C.3.1.3.3 Repository layout and exploratory shafts

Issue

One comment suggested that the site of the first shaft was "chosen to fit the given physical confines of the Hanford Site" rather than to meet scientific criteria.

Response

The selection of a location for the first exploratory shaft was discussed in Section 2.2.2 of the draft EA. The selection for the principal borehole and the exploratory shaft was based on land ;use, surface contamination, ground-water contamination, and the orientation of the exploratory shaft. The exploratory-shaft site was not "chosen to fit the given physical confines" of the Hanford Site.

Issue

One commenter reported an apparent contradiction between the layout area for surface facilities and areas previously eliminated during site screening.

Response

There is an apparent contradiction in the layout of repository facilities in Figures 2-28 and 3-31 of the draft EA. Figure 2-28 shows the area available for surface facilities at the time of site screening. Since the siting of the exploratory shaft and the principal borehole (see Figure 2-28), much of Section 2 has become available for repository surface facilities. Figure 3-31 shows proposed repository surface facilities that are now outdated. These will be deleted from the figure. The layout for surface and subsurface repository facilities is not in final form; most of these facilities are currently planned for locations west of the 200 West Area.

C.3.1.3.4 Continuation of siting investigations at the Hanford Site

Issue

Several comments questioned why the DOE is continuing siting investigations at the Hanford Site when the U.S. Geological Survey states that the site is not suitable for a repository.

Response

The U.S. Geological Survey (USGS) has been critical of some data and reports released by the DOE for the basalt repository project. THe DOE asked the USGS to become involved in the project in order to gain a mutual understanding of technical concerns and develop comprehensive plans to address these concerns.

In 1983, the USGS issued an analysis of the DOE's Site Characterization Report (DOE, 1982). Comments focused on such issues as the availability, interpretation, and uncertainty of earth-sciences data, but did not address the suitability or the nonsuitability of basalt for waste isolation.

Questions about the suitability of a site for waste isolation can be answered only with extensive data collected in the field. This is reflected in recent statement by the USGS: U.S. Geological Survey, "...the issue of the geologic suitability of the Hanford Site is complex, just as it is for all of the sites being considered....The process laid out in the Nuclear Waste Policy Act requires sites to be nominated for characterization, and DOE is not at that stage in the process. The answer to the questions concerning geologic and hydrologic suitability can only be answered by the characterization process itself" (Meyer, 1985).

C.3.2 EVALUATION AGAINST DISQUALIFYING CONDITIONS

No comments were received on the evaluations, reported in Section 2.3 of the draft EA, of the Hanford site against the disqualifying conditions of the guidelines. Comments on evaluations of the site against specific guidelines are presented in Sections C.5 through C.8.

C.3.3 DIVERSITY OF GEOHYDROLOGIC SETTINGS AND THE SELECTION OF PREFERRED SITES

The DOE's emphasis on a diversity of geohydrologic settings and the selection of the preferred site in each setting were the topics of many comments. The issues raised included objections to the grouping of sites into geohydrologic settings, requests for detailed explanations of the selection of preferred sites, and doubts about the availability of sufficient information to discriminate between sites in a geohydrologic setting.

Issue

There were objections that the requirement for grouping sites into geohydrologic settings and selecting one preferred site from each setting artificially elevates the importance of host-rock diversity over geologic conditions. It automatically places the Hanford and the Nevada sites in the top five and makes it possible for technically superior sites to be overlooked in favor of sites in different settings.

Response

It is indeed true that the second-best site in one geohydrologic setting may be in some respects superior to the best site in another geohydrologic setting. However, it is not necessary to find the absolutely best site for the repository; a research for the absolutely best site could be almost endless. It is necessary to find and qualify good sites--ones that meet or exceed all of the technical requirements that bear on protecting public health and safety during repository operations and over the long term. In order to find satisfactory sites in a reasonably expeditious manner, and to satisfy the requirement of the Act that sites from different host rocks be recommended, the DOE has chosen to emphasize diversity of geohydrologic settings in the process of selecting sites for nomination and recommendation. Maintaining a diversity of rock types has the added advantage of minimizing the possibility of a program delay that could be caused by an as-yet-unrecognized basic flaw in a particular host rock.

The fact that the emphasis on geohydrologic diversity automatically places the Hanford and the Nevada (Yucca Mountain) sites in the top five is an artifact of the processes that led to the nine potentially acceptable sites. The searches that yielded the nine potentially acceptable sites were not necessarily identical. Those that took place on DOE-controlled land, ending with the selection of the Hanford and the Yucca Mountain sites, were directed at choosing a single site on Federal land dedicated to nuclear activities. For example, 9 rock types in 15 alternative locations were considered in the site-screening process for the Yucca Mountain site. The site-screening process for the salt sites had not yet narrowed the candidates down to a single site per geohydrologic setting at the time the nine potentially acceptable sites were identified.

Issue

Several commenters recommended that the final EA should state more clearly the importance to site selection of establishing candidates in a variety of geohydrologic settings and that the selection of the preferred site in each geohydrologic setting should be explained in detail, with reference to the siting guidelines.

Response

The importance of maintaining diversity in geohydrologic settings in the siting process is explained in the preceding response.

Section 2.4 of the EAs for the salt sites describes how the preferred site in each geohydrologic setting was chosen, with reference to the siting guidelines.

Issue

Some parties wanted to know why only one tuff and one basalt site were considered as compared to seven salt sites. The Nevada and the Hanford sites were compared with no others in the same geohydrologic setting or in the same host rock.

Response

Because the studies of the Nevada (tuff) and the Hanford (basalt) sites were started on the basis of favorable land use (Federal ownership and dedication to nuclear activities), they were focused on locating a geologically suitable site on a particular Federal reservation. The DOE did not need to progress through regional, area, and location studies--the process that identifies alternative sites at each major screening step.

Issue

Some commenters did not believe that the DOE had sufficient information to discriminate between sites in a geohydrologic setting (between Davis Canyon and Lavender Canyon; among Richton, Cypress Creek, and Vacherie Domes; and between Deaf Smith County and Swisher County).

Response

The basis for selecting the preferred site in a geohydrologic setting is discussed in Section 2.4 of each EA. It is the DOE's position that the information currently available on the different sites is adequate for choosing a preferred site in each setting.

C.3.4 NOMINATION AND RECOMMENDATION OF SITES FOR CHARACTERIZATION

In Chapter 7 of the draft EAs, each of the five sites proposed for nomination (Davis Canyon, Deaf Smith, Hanford, Richton Dome, and Yucca Mountain) was assigned a ranking for each technical guideline. Three quantitative methods were then used to aggregate these rankings. Two of the methods were criticized by the commenters for lacking firm theoretical foundations. The third method--described variously as the utility-estimation, rating, or weighting-summation method--was criticized because its application did not follow the procedures suggested by the professional literature. The methods were briefly described in Section 7.4 of the draft EAs, which also presented the results of their application--the identification of three sites as preferred for nomination. A more detailed discussion of the three methods was given in Appendix B.

In response to these comments, the DOE undertook a more formal application of the utility-estimation method (referred to as the decision-aiding methodology) to provide a more defensible overall comparative evaluation as a basis for determining which three sites appear most favorable for recommendation for characterization. The decision-aiding methodology is intended to provide a framework for systematically accounting for the technical and value judgments required in selecting sites for recommendation. It has been reviewed by the Committee on Waste Management of the National Academy of Sciences.

The various steps of the analysis were conducted by a DOE team consisting of experts in decision analysis, the technical disciplines corresponding to the technical siting guidelines, and repository performance. The technical information for the analysis was obtained from the final EAs. The value judgments were provided by DOE management and staff. A detailed explanation of the decision-aiding methodology, the analyses that were performed, and the results are presented in the multiattribute utility analysis of the nominated sites and the recommendation of candidate sites, which are being issued separately.

The rankings reported in Chapter 7 of the draft EAs elicited numerous comments, some of which objected to the rankings assigned for a particular guideline and some of which suggested different rankings. A number of comments were also directed at the methodology used in aggregating the rankings, at the weighting used for the postclosure and the preclosure guidelines, and at the choice of preferred sites.

In the final EAs, Chapter 7 presents only a comparative evaluation of the nominated sites that does not rank the sites on individual guidelines and does not aggregate rankings to identify preferred sites for recommendation. The ranking is performed in the multiattribute utility analysis of the nominated sites. For this reason and because the process of identifying the most favorable sites for recommendation is significantly different from that described in the draft EAs, comments on Chapter 7 and Appendix B of the draft EAs that were specifically concerned with the ranking of sites or the methodology are not addressed here. These include comments on the specific ranking (i.e., criticisms or endorsements) of sites on particular guidelines, aggregate rankings, and the methodology itself. For such comments the issues are summarized, however, to show the concerns of the commenters. The reader interested in the ratings assigned to the sites is referred to the multiattribute utility analysis of the nominated sites and the recommendation of candidate sites. The comments that are addressed here are those that sought clarification about, or commented on, the comparative evaluation of the sites in the draft EAs rather than simply disagreeing or agreeing with a ranking; they include, for example, comments suggesting factors that should have been considered in the evaluation or questioning the use of a particular assumption. These comments were divided into two categories: (1) comparative evaluations against postclosure guidelines and (2) comparative evaluations against preclosure guidelines.

C.3.4.1 Comparison of sites on the basis of postclosure guidelines

Comments on the comparative evaluation of sites against the postclosure guidelines covered each guideline. They included questions about the findings made for particular conditions of the guidelines, comments about the data base, and recommendations for expanding or improving the analysis. As already explained, comments that were specifically concerned with ranking or methodology are not addressed here. Comments about the evaluations of individual sites against the postclosure guidelines are addressed in Section C.5 of the final EA for the particular site.

C.3.4.1.1 System guideline

Issue

A commenter stated that the DOE's failure to compare the sites on the basis of the postclosure system guideline masks the Hanford site's alleged inferior performance in comparison with the other sites.

Response

A comparison of sites against the system guidelines was not performed for the draft EA, because the available data were deemed insufficient for assessing the performance of the total repository.

Both the draft and the final EAs report the results of preliminary performance assessments, but these results were not appropriate for use as the basis for selecting sites for recommendation.

C.3.4.1.2 Geohydrology

The comparative evaluation of the sites against the postclosure guideline on geohydrology elicited many comments. The issues raised included the definition of the accessible environment, the estimates of ground-water travel times and the analyses on which they were based, risk to regional water sources, the comparison of sites in saturated and unsaturated zones, the adequacy of the data base, and criticisms of the findings for specific sites.

Issue

One commenter noted that Chapter 7 of the EAs should be revised to take into account the 2-kilometer distance to the accessible environment rather than 10 kilometers. This would be consistent with draft 5 of the EPA standard.

Response

Analyses in Chapters 6 and 7 have been revised to use a distance of 5 kilometers to the accessible environment. The 5-kilometer distance is consistent with the final EPA standards, which were published in September 1985 (EPA, 1985). (See also Section C.3.1.1 for comments on the definition of the accessible environment in the guidelines.)

Issue

Two commenters felt that the discussion of favorable condition 3, ease of characterizing and modeling, was much too brief. This condition is considered to be not present at all five sites.

Response

The DOE agrees with the comment; the text has been revised to indicate that favorable condition 3 is a major consideration. The discussion has been expanded to more completely discuss uncertainty in characterizing and modeling each of the sites.

Issue

Two commenters asked whether the four subconditions under favorable condition 4 are of equal weight and recommended that ground-water flux be a factor in assessing the sites.

Response

In terms of making a finding on this favorable condition, the four subconditions are of equal weight in that the presence of any one subcondition results in a finding of present. The DOE agrees that ground-water flux should be a factor in assessing the sites and has revised the evaluation of the sites against the geohydrology guideline to explicitly consider it.

Issue

Several commenters were concerned with the uncertainty in ground-water travel times in the comparative evaluations of sites against the geohydrology guideline. One commenter said that the lack of data on the complexity of ground-water flow paths was not adequately assessed. Another party provided alternative travel-time calculations, including faster travel times than those presented in Chapter 7. A third commenter contended that the approach to ground-water modeling in the draft EA is not conservative and therefore does not compensate for uncertainty in data. One commenter felt that the range of travel times, such as 87,000 to 361,000 years, is large enough to indicate that not enough data are available for an accurate prediction. Another commenter challenged the statement that the dry conditions at Yucca Mountain almost compensate for the shorter travel times in comparison with salt, saying that this conclusion is unsupported, and questioned DOE's ability to ultimately characterize and model this site.

Response

The travel-time analysis has been reviewed and extensively revised in response to various comments. A stochastic analysis has been completed for all five sites, using ranges of key hydrologic parameters to better represent the varying uncertainties in the data base. The DOE agrees that there are not enough data to make accurate predictions of ground-water travel times. However, the DOE considers that the preliminary modeling is sufficient for comparative evaluations of the five sites for the purposes of the EAs. With respect to Yucca Mountain, the DOE has reconsidered the relative ranking of the site to reflect the uncertainties in characterizing and modeling and in the range of travel times when compared with the salt sites. However, the DOE considers that all five sites can ultimately be characterized and modeled with reasonable certainty.

Issue

One commenter questioned whether the four subconditions under favorable condition 4 of the geohydrology guideline are of equal weight. If they are not, then the sites are not being evaluated against this guideline in an equitable manner.

Response

The four subconditions of favorable condition 4 address the components of ground-water travel time and therefore bear on a single parameter. In that respect, the guideline can be viewed as treating each site equitably.

Issue

One comment said that neither Chapter 7 nor Appendix A of the draft EAs discusses the relative risk posed by a repository to various regional water resources, such as the Ogallala aquifer and the Colorado River.

Response

Risk to various regional water resources is considered under the qualifying condition for each postclosure technical guideline: a site will be qualified under each of the postclosure technical guidelines only if the repository will not be likely to lead to radionuclide releases greater than those referenced in the postclosure system guideline. The postclosure system guideline requires compliance with the EPA and NRC regulations for waste disposal and requires that the geologic setting of a site allow for the physical separation of radioactive waste from the accessible environment in accordance with the specified regulations. The accessible environment by definition includes regional water resources outside the controlled area of the repository. In addition, the guideline on geohydrology includes a potentially adverse condition of the presence of ground-water sources, suitable for crop irrigation or human consumption without treatment, along ground-water flow paths from the host rock to the accessible environment. If this potentially adverse condition is present at a site and is judged to be sufficiently adverse to preclude meeting the qualifying condition, then a site will be disqualified.

Issue

Some parties said that the flow of ground water through salt may not be in accordance with Darcy's law. The process of diffusion and the flow of ground water through fractures in salt may predominate and should be considered.

Response

The question of Darcian flow in salt and the potential for diffusion and flow through fractures are evaluated in the final EAs. The question of ground-water flow through a body of salt has not been resolved at this time and will be addressed during site characterization.

Issue

Many comments said that the calculations of ground-water travel time for the Hanford site are inappropriate. In addition, one party noted that the Basalt Waste Isolation Project had failed to comply with NRC's request in the "Draft Issue-Oriented Site Technical Position (ISTP) for BWIP," Section 1.0, page 6.

Response

Concerns about the analysis of ground-water-travel time for the Hanford site have been reviewed and are addressed in Section C.5.11 of the final EA for the Hanford site. Modifications to the conceptual model, the data base, and the revised calculation of the ground-water-travel time from the repository to the accessible environment 5 miles away have been made in Section 6.4.2.6.1 of the final EA for Hanford. Such an analysis is required to determine whether the first favorable condition and the disqualifying condition for the geohydrology guideline are present.

Compliance with the "Draft Issue-Oriented Site Technical Position for the Basalt Waste Isolation Project" is not in question. The purpose of the document was to identify technical issues that would have to be resolved during site characterization. The Nuclear Regulatory Commission did not request that the issues be resolved before the publication of the final EA.

Issue

One commenter noted that the travel-time discussion for the Hanford site gives the misleading impression that the travel times are based on 50 transmissivity values.

Response

The discussion of travel time has been extensively revised to be consistent with additional analyses completed for the final EA. The point raised by the commenter has been clarified.

Issue

One commenter stated that favorable condition 1 of the geohydrology guideline should not be considered present at the Hanford site. Hanford may be the only site where this condition is not met.

Response

Ground-water-travel times have been extensively reanalyzed for all five sites in response to comments on the draft EAs. For the Hanford site, key hydraulic parameters were conservatively evaluated over appreciable ranges in the stochastic model to account for uncertainty. The results indicate a probability of 0.22 for a travel time of less than 10,000 years. However, the median travel time is less than 34,000 years. Because the median travel time best represents the expected value, it appears that, on the basis of currently available data, this favorable condition can be met. The commenter is referred to Sections C.5.8 and C.5.11 of the final EA for the Hanford site for detailed responses to comments on the analysis of ground-water-travel time and uncertainties in the key hydraulic parameters used in this analysis.

Issue

One commenter argued that, since the ground-water-travel times for the bedded-salt sites in Utah and Texas were attributed to secondary permeability features and this was untrue, favorable condition 1 of the geohydrology guideline is not present at the Utah and the Texas sites.

Response

The appropriateness of including secondary permeability features is evaluated in the final EAs.

Issue

One commenter suggested that the DOE reconsider the rating of the Davis Canyon site under the geohydrology guideline in Chapter 7. Specific findings for Davis Canyon were questioned, with comments including the following:

- Favorable condition 1 should be considered to be not present, because a conservative analysis should include a catastrophic early release to the upper and the lower hydrostratigraphic units. If fracture flow is assumed, the ground-water-travel times within these units could be less than 10,000 years.
- Favorable condition 2 should be considered not present, because the effects of potential dissolution features, such as fault R, were not considered.
- Favorable condition 4 should be considered not present. Credit should not be taken for conditions 4(i) and 4(ii) if the effect of secondary permeability is considered.
- Potentially adverse condition 1 should be reevaluated to take into account the effects of thermal buoyancy or the hydraulic gradient.
- Potentially adverse condition 2 should be reevaluated to consider flow paths upward to overlying units with a total-dissolved-solids content of less than 10,000 ppm.

Response

The DOE has reconsidered the rating of the Davis Canyon site with respect to the geohydrology guideline. The relative ranking of this site with respect to the Richton Dome has been lowered. The specific comments on guideline conditions can be answered as follows:

- Favorable condition 1 is still considered to be present. No mechanism has been identified for a catastrophic early release to the upper and the lower hydrostratigraphic units. Revised travel-time calculations consider unlikely flow paths that might result from fracture zones, although there is no evidence that such zones exist. The revised travel times exceed 10,000 years.

- Favorable condition 2 is also still considered to be present. The revised discussion takes into account the potential for dissolution, including fault R. The stratigraphic offset along fault R is interpreted to be insufficient to be conducive to dissolution. Breccia pipes and other dissolution features are discussed in Chapter 6 of the Davis Canyon EA under the postclosure guideline on dissolution.

- The DOE has reevaluated favorable condition 4 and agrees that condition 4(ii) is not present. However, condition 4(i) is considered present because available data indicate that the host rock and the immediately surrounding units have low hydraulic conductivities. To claim that favorable condition 4 is present, only one of the subconditions needs to be present.

- Potentially adverse condition 1 covers only natural changes in geohydrologic conditions; changes related to repository construction and waste emplacement, such as thermal buoyancy, are evaluated under the postclosure guideline on rock characteristics.

- The revised travel-time analysis does evaluate flow paths upward from the proposed repository host rock because of the potential for localized upward gradients at the Davis Canyon site. The results of this analysis suggest that upward flow paths would reach the accessible environment laterally rather than through overlying units containing ground-water sources with a low total-dissolved-solids content.

Issue

One commenter noted that Davis Canyon has superior geohydrologic conditions when compared with Deaf Smith in terms of the ground-water-travel time and should rank high.

Response

The DOE agrees; the relative ranking on the geohydrology guideline has been revised to show that, with respect to the geohydrology quideline, the Davis Canyon site is preferable to the Deaf Smith site.

Issue

Two commenters suggested that the hydraulic conductivities in the host rock and the surrounding units are low at the Richton Dome; therefore favorable condition 4(i) and hence favorable condition 4 should be considered present at this site.

Response

The DOE agrees that the hydraulic conductivity within the host rock is very low at the Richton Dome. However, the horizontal hydraulic conductivity in the surrounding units ranges from 2.2 to 4.6 x 10^{-6} meter per day (7.2 to 1.5 x 10^{-5} foot per day). This range of horizontal hydraulic conductivities for the surrounding units does not support a finding that condition 4(i) is present.

Issue

One commenter suggested that the ranking of the Richton Dome should be lowered because of the likelihood of radionuclide transport in water and pointed out that, according to Chapter 3 of the draft EA, ground water moves up from the lower to the upper aquifer, providing a mechanism for radionuclide contamination of usable aquifers. Water in the upper aquifer flows toward Richton. There are no data on fluid movement in anomalous zones or within the salt. In addition, consideration should be given to the possible contamination of drinking water during site characterization.

Response

In the final EA for the Richton Dome, the boundary of the accessible environment is considered the edge of the salt dome. Therefore, if the Richton Dome is selected for site characterization, any radionuclide releases to the lower aquifer will have to be demonstrated to be within the limits specified by the EPA standards. In addition, the presence or the absence of anomalous zones and the mechanism of fluid movement within the dome will have to be resolved. Preliminary estimates of fluid movement within the Richton Dome suggest that ground-water travel within the Dome is very slow if it happens at all. Therefore, the DOE considers the Richton Dome to be more favorable than the other four sites with respect to the geohydrology guideline. No contamination of ground water is expected from site characterization; the commenter is referred to Chapter 4 of the final EA for the Richton Dome for a discussion of the possible effects of site characterization.

Issue

One commenter noted that the ground-water-travel times for the Yucca Mountain site in Chapter 7 are inconsistent with the travel time in Chapter 6 of the draft EA for Yucca Mountain. The final EA should contain a consistent value or range of values for travel times.

Response

For the Yucca Mountain site, Chapter 7 of the draft EA cites a minimum ground-water-travel time from the edge of the engineered-barrier system to the accessible environment of 23,000 years, and not 47,000 years as noted in the comment. Estimates of ground-water-travel time for the Yucca Mountain site have, however, been extensively revised for the final EA, and a consistent range of travel times is contained in the final document.

Issue

For Yucca Mountain, one commenter questioned the finding of "present" for favorable condition 2 of the geohydrology guideline, saying that the data on cyclic fluctuations in precipitation and changes in water-table elevation are insufficient to make a positive finding for this condition.

Response

The effects of Quaternary hydrologic processes on the ability of the Yucca Mountain site to isolate waste have been evaluated. These evaluations were based on geologic data, preliminary modeling of a rise in the water table under pluvial conditions, and a preliminary performance assessment. Preliminary modeling of increases in the water table during a full pluvial cycle with a 100-percent increase in precipitation suggests that the water table would experience a 130-meter rise. If pluvial conditions were to recur, significant increases in ground-water flux and decreases in ground-water-travel time could occur. However, a preliminary performance assessment for a repository at Yucca Mountain does not suggest a significant effect on waste isolation.

Issue

One commenter noted that, because of the lack of understanding of the unsaturated zone and the fact that the DOE concludes that the knowledge of the waste-isolation capability of Yucca Mountain is uncertain, it is unrealistic to compare a site in the unsaturated zone (Yucca Mountain) with four sites in saturated zones.

Response

The DOE acknowledges the lack of understanding of the unsaturated zone at Yucca Mountain. However, there are also uncertainties in the characterization and modeling of the four sites in saturated zones. For example, the mechanism of ground-water flow in salt is uncertain, the role of fracture flow at the bedded-salt sites is uncertain, and the magnitude of vertical conductivity at the basalt site has not been quantified. The DOE has not concluded that the waste-isolation capability of Yucca Mountain is uncertain; on the contrary, it expects that the uncertainties in the data base and in the preliminary modeling of the unsaturated zone can be resolved with reasonable assurance during site characterization. The DOE does not consider that a comparison of a site in the unsaturated zone at Yucca Mountain with four sites in the saturated zone is unrealistic.

Issue

One commenter noted that the data base used for the comparative evaluation of Yucca Mountain against the geohydrology guideline consists of two wells in the unsaturated zone and 30 wells in the saturated zone. Additional data from the unsaturated zone are required to base conclusions about geohydrology; data should not be extrapolated from the saturated zone to the unsaturated zone.

Response

The DOE agrees that additional data from the unsaturated zone will be required if the Yucca Mountain site is selected for characterization. However, the preliminary data from the unsaturated zone at Yucca Mountain are considered sufficient for comparative evaluations of sites against the guidelines. The site-specific data base for Yucca Mountain is, in fact, more extensive than the data base for the three salt sites.

Issue

One commenter asked why, in the discussion of favorable condition 2, which is related to hydrologic processes during the Quaternary Period, cyclic fluctuations in precipitation were considered only for the Yucca Mountain site.

Response

The discussion of cyclic fluctuations in precipitation during the Quaternary is emphasized for Yucca Mountain because increased precipitation affects flow through the unsaturated zone and the elevation of the water table, and therefore favorable condition 2 is not present at Yucca Mountain. As stated in the text, similar processes have been evaluated for the other sites, but the effects of these processes are not likely to adversely affect waste isolation; therefore, the favorable condition is present at the other four sites. The text of the final EAs has been revised to discuss Quaternary hydrologic processes at each of the sites in greater detail.

Issue

One commenter recommended that the discussion of ground-water-travel time at Yucca Mountain, specifically travel through the Calico Hills nonwelded tuff unit, be clarified.

Response

The suggestion was accepted, and the discussion has been clarified.

C.3.4.1.3 Geochemistry

The comments about the comparative evaluation of sites against the geochemistry guideline covered inconsistencies in the discussion of geochemical conditions in Chapters 6 and 7 of the EAs, disparities in the data available for the various host rocks, and specific suggestions for the findings made for particular sites.

Issue

One commenter was concerned with disparities in the comparison of the sites with respect to the availability of data and the types of data for the geochemistry guideline. Favorable conditions 1 through 4 compare sites on the basis of various conditions that lead to a common result (i.e., isolation). It is not understood how distinct properties like oxidation-reduction conditions and sorptive properties can be equated, especially in light of differing uncertainties.

Response

Uncertainties in the geochemistry of all sites are admittedly present, and the geochemical data base for the sites varies with respect to the types as well as the amount of data. The definitive data for each site will be collected during site characterization. However, the data that are available are adequate for the purposes of the EAs. Geochemical data have been collectively evaluated in the preliminary performance assessments reported in Chapter 6 as the data relate to radionuclide solubility and retardation with respect to EPA standards (EPA, 1985) and NRC criteria (NRC, 1983).

Issue

A commenter criticized the DOE for its subjective treatment of available data to arrive at subjective conclusions as to which site is better than the other. Statistical procedures were then applied to the DOE's "subjectively determined data (rankings under each guideline)" to arrive at the best of five sites. The commenter also felt that the "subjective" conclusions were compounded by the ranking method.

Response

The DOE used the available data from each site, which includes site-specific data as well as regional data, plus professional judgment in order to perform a comparative evaluation of the sites against the guidelines. As already mentioned, the shortcomings of the ranking method used in the draft EA have been corrected.

Issue

The reviewer states that a major shortcoming with the draft EA for the Hanford site is that major concerns are evaluated "with short-term projections." Thus, the EA does not address the long-term problems that are posed by long-lived radionuclides (i.e., thousands of years).

Response

It is assumed that "major concerns" include waste-package lifetime, ground-water-travel time, and radionuclide release rate and retardation. Contrary to the impression of the reviewer, each of these concerns has been evaluated with respect to long-term waste containment and waste isolation. For example, the mean lifetime of the waste-package container is expected to be approximately 6,100 years $\pm$ 600 years on the basis of the corrosion rate.

Issue

One commenter said that the Hanford site does not have the advantages of salt. Salt provides excellent radiation shielding, is chemically active with regard to radiation-generated products, and has a higher thermal conductivity than basalt.

Response

Basalt and the associated ground water have significant advantages over salt (e.g., low oxidation-reduction potential, high sorptive capacity). It is true that salt and brine are chemically active when exposed to radiation; however, this reactivity makes salt somewhat less desirable than basalt. For example, gamma and alpha radiations produce more oxidizing products (from radiolysis) in a brine than in fresh water. In addition, rock salt is a poor sorbant for radionuclides. While it is true that salt has a higher thermal conductivity than basalt, the presence of water in the repository at Hanford would aid in the transfer of heat from the area.

Issue

One commenter felt that the salt sites should not be assigned a finding of "not present" for favorable condition 5 solely on the basis of data inadequacy. This party also questioned why such data needs were not investigated in the site-screening process that led to the identification of potentially acceptable sites.

Response

The mineralogic and chemical properties of salt deposits and the associated ground water are not conducive to the physical and chemical retardation of radionuclides (e.g., rock salt has poor sorption properties and brine further inhibits sorptive processes). On this basis, it was deemed conservative to assign the finding of "not present" for favorable condition 5.

Issue

One commenter noted that, even though high salinity inhibits the formation of colloids and particulates, the discussion for the Deaf Smith site suggests that all aquifers at the site contain saline water. It was noted that the upper aquifers contain fresh water.

Response

The discussion has been corrected in the final EA.

Issue

One commenter noted that the Deaf Smith site has no known radionuclide-sorbing minerals.

Response

Little work has been done on the mineral composition of the rock formulations at the Deaf Smith site. Preliminary work by the Texas Bureau of Economic Geology has shown that clay minerals may be present in the muds and mudstone interbeds of the Unit 4 halite of the San Andres Formation. However, because of the preliminary nature of this work, no credit is taken for sorption at the Deaf Smith site. This is noted in the final EA.

Issue

A commenter said that the Richton Dome site should be ranked lower than the Deaf Smith and the Davis Canyon sites for geochemistry because the "accessible environment" is defined as the edge of the salt stock and does not include adjacent aquifers and their retardation properties. Credit for the travel of radionuclides through the adjacent aquifers is irrelevant to the evaluation of the site.

Response

Because of the paucity of data for all of the salt sites, no credit is taken at present for the retardation characteristics of adjacent aquifers at any of these sites. While it is expected that additional retardation of radionuclides within these aquifers will take place, it is not possible to estimate the significance of such retardation effects without site-specific data. Thus, for the sake of conservatism, no credit for retardation in adjacent aquifers has been taken for any of the salt sites.

Issue

One reviewer noted that the radionuclide-complexing effects of carbonate are described in Chapter 7, mentioned only in passing in Chapter 3, and not mentioned at all in Chapter 6.

Response

A more balanced discussion of carbonate now appears in all three chapters.

Issue

One reviewer felt that the presence of carnallite, organic matter, and hydrocarbons at the Davis Canyon site and their absence at the Deaf Smith site should result in Davis Canyon being ranked lower than, or at least equal to, Deaf Smith.

Response

In the final EA, the Davis Canyon and the Deaf Smith sites are considered to have approximately equal geochemical properties. The uncertainties regarding organic materials (including hydrocarbons) are great because of the paucity of data for both sites. The available data indicate that carnallite may not be a problem at the Davis Canyon site because the carnallite-bearing zone apparently thins in the direction of Davis Canyon; however, this is also uncertain. Potential problems at the Deaf Smith site include the presence of mudstone interbeds and intercrystalline muds that contain clay minerals. Both carnallite and the muds and mudstone interbeds may provide high-magnesium brines during the lifetime of the repository.

Issue

A commenter expressed concern that a statement in Chapter 7 to the effect that the clays at the Swisher and the Deaf Smith sites would "strongly enhance" the sorption of radionuclides is not supported by the discussion in Chapter 6.

Response

In Chapter 7 of the final EAs no credit is taken for the sorptive properties of clays at either the Swisher or the Deaf Smith site.

Issue

One commenter noted that, in regard to favorable condition 2 of the geocemistry guidelines, Chapters 6 and 7 state that "brines will tend to promote the agglomeration of some types of colloids" and that the highly saline ground waters at the Richton Dome will inhibit the formation of colloids. On the basis of the evaluation in the draft EA, it cannot be unequivocally claimed that the evidence supports a favorable finding for this condition.

Response

It should be noted that favorable condition 2 covers a number of geochemical mechanisms, one of which is the formation of colloids. The final EA states that too little is known about particulates, colloids, and organics at each site to evaluate them at this time; favorable condition 1 is evaluated on the basis of other, and better-known, geochemical mechanisms.

Issue

A commenter pointed out that the Richton Dome is ranked lower than the bedded-salt sites, partly because the ground water at Richton is "less reducing than that of the bedded salt sites." The commenter claimed that the data do not support this statement.

Response

This discussion has been modified in the final EA. All three salt sites are now considered to be equal in terms of geochemical conditions, partly because of the paucity of data.

Issue

Some commenters noted that potentially adverse condition 3 of the geochemistry guideline (oxidizing conditions) is present at Yucca Mountain but was not considered in the overall evaluation of the five sites in Chapter 7.

Response

This omission is acknowledged. Potentially adverse condition 3, which is present only at Yucca Mountain, has been considered in the evaluation of the five sites in the final EA.

Issue

One reviewer suggested that, because the Yucca Mountain site is in the unsaturated zone and is not expected to become saturated with infiltrating surface water, the presence of oxidizing conditions (potentially adverse condition 3) is irrelevant. The lack of ground water in the Topopah Springs Member of the Paintbrush Tuff suggests that this condition does not apply to this site.

Response

This condition does apply because ground water, as defined in the guidelines, includes the water in the unsaturated zone whether transient or trapped in pore spaces.

Issue

A commenter noted that a statement in Chapter 7 indicates that no heat-induced alteration of zeolites in tuff at Yucca Mountain is expected. This is inconsistent with Chapter 6, which states that heulandite and smectite may be adversely affected by the heat emitted from the waste emplaced in the repository.

Response

This inconsistency has been corrected in the final EA.

C.3.4.1.4 Rock characteristics

Issue

Two commenters disagreed that "phenomena that could affect isolation... are not expected to have significant effects at any of the sites," as stated on page 7-27 of the draft EAs. One of them said that this statement revealed the DOE's intention of not using certain guidelines.

Response

The cited statement was poorly worded. It should have read "phenomena that could affect isolation...are not expected to produce effects exceeding regulatory limits at any of the sites." As can be seen from Chapters 6 and 7 of the draft and final EAs, each site was evaluated against every technical guideline, and every technical guideline was used in the comparative evaluation of sites.

Issue

One commenter felt that the summary section did not give a detailed explanation of the expected effects of brine migration at each site.

Response

Brine migration is discussed in Section 6.3.1.3.6 of each EA.

Issue

One commenter felt that on favorable condition 2 for postclosure rock characteristics all sites could be given a finding of "present," but should not be considered equal. The commenter felt that the salt sites should be given a higher rating because more of the three conditions specified--high thermal conductivity, low coefficient of thermal expansion, and sufficient ductility to seal fractures--have been demonstrated in salt.

Response

In the final evaluation of sites for recommendation for site characterization, the postclosure guideline on rock characteristics--including the cited favorable condition--is only one of the three guidelines grouped together in a major consideration that examines the effects of repository-induced heat.

Issue

One commenter asked whether rock porosity has been adequately measured.

Response

Since the largest specimens sampled to date are the cores from exploratory drilling, this is the size of specimens on which porosity has been measured. Larger-scale measurements of porosity can be made indirectly by geophysical logging techniques. Larger-scale measurements of porosity will be made during site characterization.

Issue

One commenter requested that the differences between the expected performance of the saturated and the unsaturated zones be mentioned in the discussion of postclosure rock characteristics in the EA for the Hanford site.

Response

The DOE recognizes that there are distinct and different advantages to each of these emplacement conditions. Since the candidate horizon at the Hanford site is in the saturated zone, it is inappropriate to describe the advantages of the unsaturated zone in the EA for the Hanford site.

Issue

One commenter requested that the magnitude of the thermal pulse be discussed in the EAs, to evaluate its significance for the postclosure guidelines.

Response

The effects of heat are described in Sections 6.3.1.3.4, 6.3.1.3.6, and 6.3.1.3.7 of the EAs. Not all the expected effects of heat are discussed in a particular section.

Issue

One commenter asked whether fractures can be thermally induced.

Response

Fractures can be thermally induced, but fractures have not been observed to be sizable under dry conditions. Thermally induced fractures usually occur from rapid increases or decreases in the heat content of a rock or through heat loadings that would be far more severe than those of a repository. Additional data on the potential effects of thermally induced fracturing on repository performance will be gathered during site characterization.

Issue

One party felt that, according to the results in Table 7-17, the basalt site (Hanford) should be ranked higher than the Deaf Smith site.

Response

In regard to Table 7-17 of the draft EAs, the commenter is correct.

Issue

A commenter disagreed with the finding for the Hanford site of "not present" for potentially adverse condition 2 of the rock-characteristics guideline, saying that "the potential for thermally induced fracturing and for the dehydration of fracture (infilling) material is present at the Hanford site, though it may occur only in areas near individual waste packages."

Response

The reasoning behind the finding of "not present" for potentially adverse condition 2 for this guideline is given in Section 6.3.1.3.6 of the final EA for the Hanford site.

Issue

One commenter questioned the basis for the statement that potential stability problems would not affect the containment and isolation capability of the Hanford site.

Response

At the Hanford site, all excavations would be backfilled before closure, but there would be some limits to the degree of rock adjustment that can take place. The Hanford site is not initially taking credit for the containment capability of the host rock and intends to demonstrate that the site performs acceptably without taking credit for travel through the dense interior.

Issue

One commenter felt that the evaluation of the Richton Dome site against the postclosure guideline on rock characteristics should consider the presence of anomalous zones.

Response

The DOE acknowledges this concern and has expanded Sections 6.3.3.2.1 and 6.3.1.3.2 in the final EA for the Richton Dome to discuss this topic.

Issue

One commenter asked why the Davis Canyon and the Deaf Smith sites were ranked close together on postclosure rock characteristics when the discussion for the preclosure guideline on rock characteristics indicates more-substantial differences between the sites.

Response

The term "flexibility" is considered to have a different meaning in the preclosure and the postclosure guidelines. Before closure, the DOE is concerned about whether a repository can be constructed. For the postclosure period, the DOE is concerned about how well the host rock (and other components) will isolate the waste from the accessible environment. Thus, the flexibility portions of the two guidelines are not equivalent. The preclosure and the postclosure evaluations are consistent with the intent of each guideline.

Issue

One commenter felt that insufficient credit has been given to the Davis Canyon site for the higher rock strength that results from a lack of clay insolubles in the host rock.

Response

Because of the lack of data from boreholes, rock strength at the Davis Canyon site is associated with a high uncertainty. Salt in general is a low-strength rock and is described as such in Section 6.3.1.3 of the EA for Davis Canyon. To claim an advantage for the Davis Canyon site at this time is not considered conservative.

Issue

One commenter stated that at the Davis Canyon site the carnallite contained in the rock salt would melt at repository operating temperatures, producing corrosive brine and volume changes.

Response

The corrosive effects of carnallite are discussed in Section 3.2.7 of the EA for Davis Canyon. The volume percentage of carnallite is small, and the effect of melting such a small volumetric fraction is not considered significant at present.

Issue

One commenter was concerned that at the Davis Canyon site the repository horizon would be the uppermost salt bed (salt cycle 6), and hence the salt barriers to the upward migration of radionuclides would be minimal.

Response

The significant Pennsylvanian and Permian strata overlying the host rock would provide an adequate barrier. Furthermore, the hydrologic gradients at the site are predominantly downward.

Issue

One comment about the Davis Canyon site said that thermal uplift will cause fracturing in the upper 625 feet of the overburden above the site, including extensive portions of the Cedar Mesa and the Elephant Canyon Formations, both of which supply water to wells and springs in the Canyonlands National Park.

Response

Thermal uplift has been calculated to provide a maximum lift of approximately 1 meter. Thermal dispersion would probably prevent this uplift from seriously displacing strata and interrupting aquifer continuity.

Issue

One commenter felt that the Yucca Mountain site should be ranked more highly on postclosure rock characteristics than the Deaf Smith site because Yucca Mountain appears to be more favorable in Table 7-3.

Response

The principal reason for this apparent discrepancy is explained in the fourth paragraph on page 7-27 of the draft EAs.

C.3.4.1.5 Climatic change

Issue

One reviewer questioned whether it is worth worrying about an increased precipitation and runoff in the next 10,000 years and the potential for perched water that might intersect the repository shaft.

Response

The DOE agrees. Such a scenario does not appear in the final EA.

Issue

A reviewer said that the Hanford site should be ranked lowest on the climatic-change guideline because of the potential for catastrophic flooding and lakes, as evidenced by recent catastrophic flooding.

Response

The Hanford site would not be affected by catastrophic flooding after repository closure because such flooding occurs on the surface and the shafts and boreholes would be sealed.

Issue

The reviewer inquired as to whether changes in surface-water conditions at the salt sites could increase salt dissolution and why these changes were not considered.

Response

This question is addressed in Section 6.3.1.4.2 of the draft and the final EAs for the salt sites.

Issue

One party noted that, in the climatic-change guideline, the conclusion for potentially adverse condition 1 for the Deaf Smith site is based on available data for the Quaternary Period. Yet the discussion on favorable condition 2 states that data for the Deaf Smith site are insufficient to determine the effects of changes on the hydrologic system.

Response

Potentially adverse condition 1 and favorable condition 2 are quite different. The latter states that climate changes have had little effect on the hydrologic system, whereas the potentially adverse condition states that climate changes could affect the ground-water flow system to significantly increase the transport of radionuclides to the accessible environment. Thus, the available data are adequate to address one, but not the other, condition.

Issue

One comment pointed out that an increase in the recharge and discharge of aquifers may not alter permeability within a salt sequence but might increase salt dissolution at the salt-rock interface and salt margins.

Response

While dissolution in these areas may be increased during times of increased recharge and discharge, the calculated rates of dissolution are conservative to account for any additional dissolution that may result from the increased availability of water.

Issue

The sites are ranked equally with respect to climatic change, yet Table 7-4 seems to rank Yucca Mountain slightly better than the other sites.

Response

In Table 7-4 of the draft EAs the Yucca Mountain site shows "not present" for a potentially adverse condition related to a potential rise in the water table. This applies only to Yucca Mountain; the other sites are below the unsaturated zone.

C.3.4.1.6 Erosion

A number of commenters expressed concern that the DOE has not adequately considered all information in the comparative evaluation of the sites against the guideline on erosion. The issues raised include changes in the ranking of sites, the relative importance of the potentially adverse and favorable conditions, and specific comments on erosion at Yucca Mountain and Hanford.

Issue

One commenter proposed that all sites except Yucca Mountain be ranked equal on the erosion guideline; Yucca Mountain should have a lower ranking because the repository would be closer to the surface.

Response

As stated in the draft EA, the objective of the erosion guideline is to ensure that erosional process acting on the surface will not be likely to lead to radionuclide releases greater than those allowed by regulations. The ranking evaluations in the draft EA were based on the qualifying, favorable, and potentially adverse conditions as they influence this objective.

Issue

One party argued that the favorable and potentially adverse condition for the erosion guideline are not of equal importance and should not be treated as equal.

Response

The DOE agrees. The qualifying condition relates to the requirements of 40 CFR Part 191, as implemented by the provisions of 10 CFR Part 60, and therefore the second favorable condition, if it is present, is the most significant because, according to 40 CFR Part 191, events with less than one chance in 10,000 over 10,000 years need not be considered in assessing postclosure performance. In general, if favorable condition 2 is present at a site, favorable condition 3 also is likely to be present and both potentially adverse conditions are likely to be absent. Because favorable condition 2 is present at all sites, all sites are rated equal with respect to the qualifying condition.

Issue

For the Hanford site, questions were raised regarding the proposed depth of the repository versus favorable condition 1 and the erosion depth from regional base levels discussed in favorable condition 2.

Response

Favorable condition 1 does not limit the depth of a repository; it merely says that ability to emplace waste at least 300 meters below the surface is favorable. The regional base levels in the draft and final EA for Hanford should be considered as bounding estimates, not as best estimates. Even under bounding estimates, Hanford was found to have favorable condition 2 and thus is rated the same as the other sites.

Issue

One commenter expressed concern that the evaluation of Yucca Mountain did not fully take into account portions of the repository whose depth is less than 300 meters.

Response

As reported in the draft and the final EA for Yucca Mountain, the minimum thickness of the overburden above the underground facility is about 230 meters, at the western edge of the primary area. However, for about 50 percent of Yucca Mountain the overburden is more than 300 meters thick. Because all of the repository would be at a depth greater than 200 meters, the site would not be disqualified. As stated in the draft EA, the fact that Yucca Mountain does not possess favorable condition 1 (waste emplacement below 300 meters) does not appear significant, because an evaluation of erosion rates for Yucca Mountain, applied to the 230-meter minimum depth, indicates that erosion would not significantly affect waste isolation over the next 10,000 years.

C.3.4.1.7 Dissolution

Issue

One reviewer felt that the draft EA did not consistently treat the favorable and the potentially adverse condition under dissolution for the three salt sites.

Response

The dissolution section in the final EAs has been revised to present a more consistent discussion of the two conditions for the salt sites.

Issue

One commenter objected to the statement that no significant dissolution has been identified at the Deaf Smith site because the statement is based on data from a well 3 miles from the site and seismic-reflection data that do not "cover" the site.

Response

While the available data from the area of the site do not unequivocally show that there is no dissolution at or near the site, data from boreholes, seismic-reflection measurements, as well as surface mapping have uncovered no evidence that significant dissolution occurred beneath the Southern Highlands at any time during the Quaternary Period.

Issue

One reviewer asked why the Pennsylvanian faults that occur 7 miles from the Davis Canyon site were not mentioned in the discussion on dissolution and whether the rates at which dissolution fronts are migrating could increase with the predicted increase in precipitation.

Response

The faults described by the reviewer die out in the lower part of the Paradox Formation; these faults have no surface expression. In addition, no indication of dissolution has been observed to be associated with these faults. In regard to the second question, no dissolution fronts have been identified in the study area. Discrete dissolution features like Lockhart Basin and Beef Basin may be affected by an increase in precipitation; however, the current rate of dissolution is not known.

Issue

One commenter objected to Yucca Mountain's receiving a finding of "not present" for the potentially adverse condition under the dissolution guideline. The repository would be near the breccia of the Solitario Canyon fault zone, which the draft EA does not discount as a dissolution phenomenon. Therefore, unless sufficient data are available to show that the fault is not related to caldera collapse, it should be assumed that the fault is a dissolution feature and the Yucca Mountain site should be considered as having this potentially adverse condition.

Response

The solubility of tuff in ground water is extremely low; furthermore, the hypothesis that the Solitario Canyon fault is a dissolution feature is not credible. Any breccia associated with the fault zone is of tectonic origin, and there is no logical reason to believe that the fault is the result of dissolution.

C.3.4.1.8 Tectonics

A number of commenters expressed concern that the DOE did not adequately consider all information in determining numerical ratings for the postclosure guideline on tectonics. Among the issues raised were the treatment of preexisting faults at the Deaf Smith site, the potential for diapirism in general and salt movement at the Gibson Dome as it relates to Davis Canyon, and the level of tectonic activity at the Yucca Mountain site.

Issue

One commenter wanted to know how preexisting faults at the Deaf Smith site were treated in the comparative evaluation against the postclosure guideline on tectonics.

Response

The evaluation of tectonic and igneous events is based on our understanding of those processes during the Quaternary Period. Faults that have been active during the Quaternary are more likely than older faults to be active now and for the next 10,000 years. The Deaf Smith site is different from the Davis Canyon site because Quaternary faults have been identified near Davis Canyon but not near Deaf Smith. Thus, Deaf Smith is more favorable with respect to Quaternary faults.

Issue

Some commenters asked why diapirism was not discussed in the comparative evaluation of sites, citing the Gibson Dome in Utah as a structure in which salt movement continues today.

Response

Potentially adverse condition 1 of the postclosure tectonics guideline is based on evidence of active tectonic processes, including diapirism. Although not explicitly discussed in Chapter 7, diapirism was evaluated in the draft EAs for the salt sites. As explained in Chapter 6 of the EAs, there is evidence that diapirism has not been active at any of the three salt sites during the Quaternary Period.

In regard to the Gibson Dome, the final EA for Davis Canyon explains that some degree of salt flow has occurred within the evaporite units near the Davis Canyon site, but the area of the site generally contains relatively undisturbed bedded salt.

Issue

Several comments pertained to the level of tectonic activity at the Yucca Mountain site and the treatment of tectonics in site evaluation.

Response

The evaluation of sites against the postclosure guideline on tectonics is primarily concerned with the effects of tectonic events on waste containment and isolation. As stated in the draft EA, the available data do not suggest that tectonic events at Yucca Mountain, Davis Canyon, and Hanford could both alter the hydrologic flow system and lead to radionuclide releases after repository closure. An accurate evaluation against the postclosure guideline on tectonics includes not only an assessment of the probabilities of events but also an assessment of whether an event could adversely affect the repository system.

In the final EA for the Yucca Mountain site, the discussion of repository performance has been expanded in Chapter 6 because the tectonic activity warrants additional discussion. The revised discussion adds perspective to issues on postclosure tectonics. It includes such factors as ground-water flux and travel time, waste-package integrity, the careful consideration during repository development of recognizable faults that appear to have any possibility of movement, and the geochemical capabilities of the site. While many studies remain to be completed, particularly with respect to probabilities, preliminary assessments of system performance suggest that tectonic events are not likely to lead to radionuclide releases in excess of regulatory limits.

Issue

One commenter argued that the DOE failed to identify or evaluate the seismic risk at Yucca Mountain (as shown in a map of seismic risk produced by the U.S. Geological Survey). The map clearly shows that Yucca Mountain is in a region of major seismic risk. The seismic risk in this region is much higher, in fact, than that at any of the other sites.

Response

The draft EAs recognize that the tectonic hazard at the Yucca Mountain site is higher than that for the other sites (page 7-116). Both the postclosure and the preclosure rankings (pages 7-44 and 7-115) reflect this relative comparison.

If the Yucca Mountain site is selected for characterization, site-specific estimates of seismic hazards will be made during characterization. In parallel with this, each site will be evaluated for the significance of tectonic hazards with respect to the total risk.

C.3.4.1.9 Natural resources

A number of commenters expressed concern that the DOE did not adequately consider all information in ranking the sites for the postclosure guideline on natural resources. The issues raised include the evaluation of future resources and the use of artificial markers as well as specific comments on resources at Deaf Smith, Davis Canyon, Hanford, and Yucca Mountain.

Issue

One commenter pointed out that the resources of today may not be the resources people will seek in the distant future.

Response

The evaluation of natural resources has been based on "reasonable projections of value, scarcity, and technology," as stated in the qualifying condition of the guideline. This statement is meant to reflect the NRC's 10 CFR Part 60, which states that the evaluation of the resource potential should consider whether economic extraction is currently feasible or potentially feasible during the foreseeable future. Thus the goal of natural-resource assessment is to ensure an acceptably low likelihood of postclosure human activities that would be detrimental to waste containment or isolation. This does not mean that the future development of a "new" resource can be absolutely ruled out, but, on the basis of our present understanding, this potential can be minimized. Furthermore, it is expected that permanent markers and records will also reduce the potential for human interference at the repository site.

Issue

One party commented that Chapter 7 of the draft EAs contained no more than a passing mention of artificial markers and asked whether there are any site-specific factors affecting the use of such markers.

Response

As stated in the qualifying condition for the postclosure guideline on natural resources, in assessing the likelihood of postclosure intrusion, the DOE will consider the estimated effectiveness of permanent markers and records. In evaluating the sites against the guidelines, the EAs qualitatively considered the effectiveness of markers and records in reducing the likelihood of human intrusion within the controlled area.

Issue

One party said that the Hanford site has a potential for ground-water resources and natural gas and should be disqualified for that reason.

Response

As discussed in the final EA for the Hanford site, the finding for potentially adverse condition 1 has been changed from "not present" to "present" because of the potential uses of ground-water resources and natural gas. It should be noted, however, that although source beds (for hydrocarbons) may exist beneath the basalt, present exploration activity has not found adequate evidence of significant concentrations of any mineral or rock that is unique to the Hanford site. The geothermal potential of the site is considered nonfavorable. The revised evaluation of the Hanford site is based on the latest information on the potential for hydrocarbon and other resources. As the potential for resource extraction is by nature speculative and the use of permanent markers and records will assist in reducing the likelihood of human intrusion within the controlled area to very low values, the Hanford site should not be disqualified because of the potential for natural resources.

Issue

One commenter suggested that the EA for Davis Canyon evaluate ground water and the Colorado River as valuable natural resources. Another commenter noted that, although Chapter 7 suggests that only minor aquifers exist above the host rock at Davis Canyon, the Cedar Mesa sandstone aquifer, which overlies the host rock, is used as a water supply for the Canyonlands National Park.

Resources

As discussed in the final EA for Davis Canyon, ground-water use in the area and vicinity of the site is minimal. Existing wells yield small quantities of ground water from the Glen Canyon Group as well as the Cedar Mesa and Cutler strata; however, these wells are less than 400 feet deep. As such, ground water is not expected to have an adverse effect on the ground-water flow system. Section 3.3.1.5 of the final EA discusses water availability and demand, including the amounts of water available from the Colorado River in a Davis Canyon region. Because the Colorado River is too far for its use to be practical, it was not considered significant as a potential resource that would directly affect the Davis Canyon site.

The commenter is correct in noting that the Cedar Mesa sandstone aquifer supplies water for Canyonlands; however, this aquifer is not highly productive at the Davis Canyon site. As summarized in Chapter 3 of the draft EA, this aquifer produced only a few gallons per minute from its entire thickness at well GD-1.

Issue

One party questioned the assessment of natural resources at Yucca Mountain, saying that the mineral potential had been ineffectually evaluated.

Response

As discussed in the final EA for the Yucca Mountain site, there are no energy or mineral resources for which economic extraction is feasible in the foreseeable future. The DOE does not agree that the mineral potential of the site has been ineffectually evaluated. The evaluation is based on a review of the literature, exploration and geologic mapping by the U.S. Geological Survey, and geochemical analyses of cores and cuttings taken from boreholes at and near Yucca Mountain.

C.3.4.1.10 Site ownership and control

Issue

The draft EA states that there is no basis for distinguishing among the sites in terms of site ownership and control at the beginning of the postclosure period, and therefore all sites were ranked equally on this guideline. One commenter asked why, if this is correct, land ownership is one of the guidelines.

Response

The postclosure guideline on site ownership and control is included in the siting guidelines to ensure consistency with the portion of NRC regulations in 10 CFR Part 60 that addresses the long-term control of the site by the DOE (10 CFR 60.121). In addition, this postclosure guideline is distinguished from the preclosure guideline on site ownership and control in two ways. First, the favorable condition for the preclosure guideline refers to the control of "...all surface and subsurface mineral and water rights by the DOE," whereas the favorable condition for the postclosure guideline refers to the "control of land and all surface and subsurface rights by the DOE." Second, the preclosure guideline is directed at the DOE's ability to control access to the site during repository operation, under the requirements of the system guideline for radiological safety. The postclosure guideline, in contrast, is a part of the human-interference guideline (960.4-2-8), which is intended to ensure that future generations will not compromise the integrity of the repository. Thus, although the DOE does not believe that there is currently a basis for discriminating among sites on the basis of postclosure site ownership and control, the guideline serves a necessary function in the siting process.

C.3.4.2 Comparison of sites on the basis of preclosure guidelines

The preclosure guidelines are divided into three groups, in order of decreasing importance: (1) preclosure radiological safety; (2) socioeconomics, environment, and transportation; and (3) ease and cost of siting, construction, operation, and closure. The issues raised in comments on the evaluation of the sites against these guidelines are summarized and addressed in this section.

C.3.4.2.1 Preclosure radiological safety

The preclosure guidelines on radiological safety consist of four separate guidelines: (1) population density and distribution, (2) site ownership and control, (3) meteorology, and (4) offsite installations and operations.

C.3.4.2.1.1 Population density and distribution

Issue

Many commenters stated that the evaluation of the Hanford site against the guideline on population density and distribution did not take into account the approximately 12,000 workers that the DOE and its contractors currently employ at the Hanford Site or the 3,500 of these 12,000 workers who work in the vicinity of the potential repository site. These commenters stated that the objective of the guideline is to protect the health and safety of both the public and repository workers and that the evaluation presented in the draft EA ignored the safety of the Hanford workers. Several of these commenters said that it is ridiculous to argue that the 3,500 Hanford workers in the vicinity of the site are "not members of the general public" as the draft EA states on page 7-57. Others insisted that the presence of these Hanford workers constitutes a high daytime population density for the site.

Response

The DOE agrees that the 3,500 Hanford workers must be considered members of the general public for the purposes of this evaluation. However, these persons work in the general vicinity of the site and not, as the guideline condition stipulates, "within the projected site boundaries."

Issue

One commenter noted that the draft EA reported the population density for the Hanford site as 43 persons per square mile and for the Richton Dome site as 40 persons per square mile, but nonetheless the Hanford site received a much higher score on this guideline than did the Richton Dome.

Response

The guideline on population density and distribution requires the DOE to evaluate the remoteness of the site from highly populated areas in addition to the population density of the general region of the site. While the population density is similar for both sites, the controlled area of a repository at the Richton Dome site would be adjacent to the town of Richton.

Issue

A few commenters stated that the evaluations of sites against the first favorable condition of the guideline on population density and distribution should consider transient populations. These commenters suggested that this condition might affect the population density given for the Davis Canyon site.

Response

Transient populations are explicitly considered by the first potentially adverse condition, which addresses high residential, seasonal, or daytime population densities within the projected site boundaries. Chapter 7 of the final EA also addresses such transient populations as users of offroad vehicles. These considerations do not significantly affect the population density for the Davis Canyon site.

C.3.4.2.1.2 Site ownership and control

Issue

Many commenters stated that the ranking of the Yucca Mountain and the Davis Canyon sites--both of which are on land owned by the Federal Government-- below the Richton Dome and Deaf Smith sites is indefensible and highly artificial. They insisted that to transfer land belonging to the Federal Government is easier than obtaining private land. One person said that persons who face the loss of their property will go through every legal means possible to keep their land. Another pointed out that the acquisition of private land is time consuming and expensive and that affected landowners have testified that they will not enter into voluntary leases or purchase-sell agreements; this commenter claimed that even identifying all of the affected owners of surface and subsurface rights will take time, given the large number of owners involved.

Two commenters noted that the Congressional action described as necessary in the draft EA for the Yucca Mountain and Davis Canyon sites would not be necessary until the time, or after, Congress approves the site for a repository, pursuant to Section 115 of the Act. They felt that it was ridiculous to argue that Congress would override a State veto of a site selection and then fail to expeditiously transfer land title to the DOE. All of these commenters therefore recommended ranking the Yucca Mountain and the Davis Canyon sites above the Richton Dome and the Deaf Smith sites because they believe that the transfer of land between Federal agencies is easier than obtaining private land.

One commenter stated that to obtain land at the Richton Dome site would create major, negative, and highly disruptive impacts for innocent citizens and that these impacts could be avoided at either the Yucca Mountain or the Davis Canyon site. Another party suggested that the Richton Dome site should be ranked below the Deaf Smith site because the privately owned land at Deaf Smith is agricultural land, of which there is no shortage.

<u>Response</u>

The guideline addresses only the complexity of procedures for acquiring the needed land. The complexity of these procedures does not necessarily reflect the value of the land or the associated social or economic impacts. The DOE is aware of the socioeconomic impact of acquiring lands, especially privately owned lands, and the socioeconomic aspects of land acquisition are considered under the socioeconomics guideline. For example, the DOE recognizes that the condemmation of privately owned lands could disrupt the lives of displaced landowners.

<u>Issue</u>

One commenter recommended that the Richton Dome site be ranked last, just below the Deaf Smith site, because there are more landowners at Richton Dome than at Deaf Smith.

<u>Response</u>

The DOE has not determined exactly how many landowners there are at the Deaf Smith and the Richton Dome sites. If one or both of these sites are recommended for site characterization, the DOE will identify the affected landowners as part of the formal land-acquisition process.

C.3.4.2.1.3 Meteorology

Issue

One commenter stated that it is not possible to make a comparative evaluation of the sites against the meteorology guideline, because of the lack of data and inconsistencies in the types and quantities of data available for the various sites.

Response

The siting guidelines acknowledge that complete data would not be available for all evaluations of the sites against the guidelines. The guidelines provide for evaluating sites on the basis of available data. In evaluating the sites against the meteorology guideline, the DOE used best estimates based on available data and conservative assumptions.

Issue

Several persons commented on population considerations under the guideline on meteorology. One commenter stated that the size of offsite populations has not been appropriately considered under the ranking. Another noted that site comparisons would be facilitated if all EAs expressed population density as "persons per square mile" rather than "population densities higher than average." Another commenter requested that the workers employed at the Hanford Site be considered under this guideline.

Response

The meteorology guideline is concerned primarily with meteorological conditions and events that could affect the transport of radioactive materials to persons beyond the boundaries of the site. The characteristics of offsite populations are considered separately under the guideline on population density and distribution. Meteorological information is combined with information about the population to evaluate the sites under the system guideline for preclosure radiological safety. If in comparing the sites against the meteorology guideline the DOE used population characteristics other than those specified by the guideline (i.e., location and density relative to regional density), double counting for population conditions would result.

The workers at the Hanford Site have been considered in determining the regional population density and in the final EA are specifically addressed under the guideline on population density and distribution.

Issue

Some commenters noted that the draft EAs for the Davis Canyon and the Hanford sites were inconsistent in the evaluation of the first potentially adverse condition of the meteorology guideline, and this inconsistency is reflected in the comparative evaluations of Chapter 7. The draft EA for Davis Canyon states that the town of Moab, 33 miles downwind, is close enough for the first potentially adverse condition to be present. However, the draft EA for Hanford says that the downwind city of Richland is sufficiently far from the site (22 miles) for the first potentially adverse condition to be not present. Similarly, the Hanford site, which appears to have more stagnation episodes than Davis Canyon, was ranked higher for dispersion conditions.

Response

The EAs have been revised to take a consistent approach on this condition. They define "prevailing meteorological conditions" to mean the most common annual average wind direction in any 22.5-degree sector and consider nearby population centers to be within a radius of 50 miles from the site, unless it is possible to document that atmospheric dispersion is sufficient to permit a smaller radius. As a result of this approach, the final EAs for both the Davis Canyon and the Hanford sites consider this potentially adverse condition to be present.

Issue

The Hanford site is not considered to have the second potentially adverse condition, which pertains to extreme weather, although Chapter 3 of the EA shows that part of the site would be inundated by the probable maximum flood and that the area has experienced a maximum snowfall of 24.5 inches.

Response

The second potentially adverse condition refers to the historical frequency of extreme weather. The probable maximum flood is a statistical worst-case flood. The DOE considers the 100-year flood to be an appropriately severe flood for this condition. The record snowfall occurred in 1916 and is not considered representative of recurrent conditions in the area of the site.

C.3.4.2.1.4 Offsite installations and operations

Issue

One person asked the DOE to explain how two sites with the same number of deleterious conditions can have different utility values. Another commenter suggested that the Hanford site be disqualified under this guideline because of conflict with nearby atomic-energy defense activities or, if it can be demonstrated that the conflict is not irreconcilable, that the ranking of the site be significantly lowered.

Response

Section 6.2.1.5 of the EA for the Hanford site demonstrates that there will be no irreconcilable conflict between a repository and nearby atomic-energy defense activities.

Issue

One party asked the DOE to identify the other nuclear installations that contribute to radioactive releases in the area of the Davis Canyon site.

Response

The contributing facilities are three uranium mines. They are discussed in Section 7.3.1.1.4 of the draft EA for the Davis Canyon site.

C.3.4.2.2 Environment, socioeconomics, and transportation

This group of preclosure guidelines consists of separate guidelines on (1) environmental quality, (2) socioeconomic impacts, and (3) transportation.

C.3.4.2.2.1 Environmental quality

Issue

A commenter requested that the sites be compared on the basis of their relative risk to water resources.

Response

The final EAs contain an evaluation of compliance with the ground-water protection requirements of the final EPA standards, 40 CFR Part 191 (EPA, 1985). These standards require that the repository may not cause the radionuclide concentrations in "a special source of ground water" to exceed specified limits for 1,000 years after waste emplacement.

The presence of sources of ground water suitable for crop irrigation or human consumption without treatment is potentially adverse condition 2 of the postclosure guideline on geohydrology. The comparative evaluation of sites did include this condition (see Sections C.3.4.1.2 and C.5.1 for comments on geohydrology). In addition, the comparative evaluation included in the disqualifying condition for the preclosure guideline on socioeconomic impacts pertains to significant effects on the quantity or the quality of water from major water supplies (see Sections C.3.4.2.2 and C.7.4).

Issue

One commenter contended that the EA for the basalt (Hanford) site should acknowledge the presence of potentially adverse conditions regarding (1) projected major conflicts with environmental requirements and (2) significant adverse environmental impacts that cannot be avoided or mitigated. This contention was based on claims of uncontained hazardous materials and controversy over the discharges of radioactive materials from DOE facilities at Hanford.

Response

The guideline on environmental quality is concerned with significant adverse environmental impacts at the repository site. It does not address the effects of unrelated activities.

Issue

One commenter stated that the DOE has not done the work to determine whether or not significant Yakima Indian cultural or religious resources would be adversely affected, especially in light of previous effects on Gable Mountain. He felt that the fifth potentially adverse condition should be considered present at the Hanford site.

Response

Parts of Gable Mountain have been examined by a reconaissance-level study that identified Gable Mountain and Gable Butte as having religious significance to local Indian groups. The DOE maintains that site characterization and repository development can be performed at the Hanford site without exerting any significant adverse effects on any significant Native American religious or cultural resources.

Issue

One person felt that the ranking of the Richton site should be lowered because environmental impacts would be experienced by the persons living at the site.

Response

The nearness of the town of Richton has been given due consideration in the evaluation of that site against the guideline on population density and distribution (see Sections C.3.4.2.1 and C.6.1 for comments on that guideline). To consider the population of Richton in evaluations against the guideline on environmental quality would result in double counting.

Issue

Several commenters said that greater emphasis should be placed on the proximity of the Davis Canyon site to the Canyonlands National Park.

Response

The guideline on environmental quality calls for an assessment of effects on any national parks and of irreconcilable conflicts with a park. The final EA for the Davis Canyon site presents such an evaluation for the Canyonlands National Park; the evaluation uses criteria developed by the National Park Service to test for irreconcilable conflicts. (See also Sections C.3.3 and C.7.1.)

Issue

One person said that the comparative evaluations should consider the uncertainties about the ability of the Deaf Smith site to comply with the requirements of the Texas Mine Shaft Act.

Response

The DOE acknowledges that uncertainties about compliance with environmental requirements should be considered in the comparative evaluation. The evaluation of the Deaf Smith site has been revised to address the uncertainty about compliance with the Texas Mine Shaft Act.

Issue

One commenter asked whether the DOE will guarantee protection of the Ogallala aquifer or, if not, how the DOE proposes to mitigate any releases into the Ogallala.

Response

It is the DOE's position that the quality of the environment at the Deaf Smith site can be adequately protected. Sections 4.2.1.4 and 5.2.2 of the Deaf Smith EA address protection of the Ogallala aquifer.

Issue

Several issues were raised about the Davis Canyon site. One commenter stated that air-quality impacts are double counted, being considered both under the environmental quality and the meteorology guidelines. Several commenters questioned the DOE's ability to determine the presence of an irreconcilable conflict with the Canyonlands National Park, since it appears that the DOE is not fully aware of the Park's designated uses. A commenter felt that, since neither favorable condition is present, the Davis Canyon site should possess both corresponding potentially adverse conditions. A commenter agreed that the site has the third potentially adverse condition, but believes it should have the fourth as well. It was noted by one commenter that the Davis Canyon site discussion should include the possibility of critical habitat. A commenter noted that the findings for the Davis Canyon site under the first and the third disqualifying conditions were based on insufficient data and questioned the statement that repository-related activities will be conducted within the park.

Response

The only evaluation of air-quality impacts occurs under the environmental quality guideline. The meteorology guideline is concerned primarily with radiological safety; it addresses only those meteorological conditions and phenomena that affect the transport of radioactive material to offsite areas.

The DOE has expanded the evaluation of Canyonlands National Park and possible impacts throughout Sections 4.2 and 5.2, with summaries presented in Sections 4.4.1 and 5.5.1. The results of the evaluations show that there will be no irreconcilable conflict with the uses of the park.

The guideline did not intend for the pairs of first and second conditions to be reciprocal. Each pair delineates a possible range for that condition. Therefore it is possible to not have either condition. For example, on the second set the favorable condition is not present because it cannot be projected that impacts will be mitigated to insignificant levels. The corresponding potentially adverse condition is not present, however, because it is projected that significant impacts can be mitigated to acceptable levels.

Because of potential effects on the Newspaper Rock State Historical Monument, the evaluation of the Davis Canyon site was revised to state that the fourth potentially adverse condition is present. A summary of possible critical habitats was added to the comparative evaluation, but the finding for the sixth potentially adverse condition was not changed.

The evaluation of potential effects on the Canyonlands National Park has been revised and expanded, but the finding that the site is not diqualified (see Section 6.2.1.6.4) was not changed. It remains the DOE's position that no repository-related activities will need to be conducted in the Park.

The DOE considers the revised comparative evaluation to place an appropriate emphasis on the proximity of the Davis Canyon site to Canyonlands National Park. This evaluation is supported by Sections 4.4.1 and 5.5.1, which have been added to the EA for the Davis Canyon site.

C.3.4.2.2.2 Socioeconomic impacts

Issue

One commenter stated that, in evaluating the sites on Federal land, acceptance by the local population at present should not be weighted too highly because the acceptance must persist for 1,000 to 10,000 years.

Response

Acceptance by the local population is not directly considered in the comparative evaluation of sites because it is not included in the siting guidelines. Public acceptance, however, may affect the degree of conflict between old and new residents and can be used as an indicator of social impacts. In this light, the DOE does consider public acceptance as a contributing factor to the potential for social impacts. The long duration of the repository is acknowledged by the siting guidelines, which assign primary importance to postclosure conditions.

Issue

One commenter expressed concern over the choice of Hanford as a site for characterization, saying that whether a repository would help to "stabilize general economic conditions" is not as important as the long-term safety of the site. The commenter stated that the Columbia River, which borders on the Hanford Site, is used for irrigation and that site characterization at Hanford could adversely affect the agricultural economies of the States of Washington and Oregon.

Response

In order to be considered for a repository, a site must meet the qualifying conditions of all the siting guidelines. Failure to meet even one condition will disqualify the site. The objective of the guidelines is to ensure that any site selected for a repository will meet all the regulatory requirements for the protection of the health and safety of the public and the quality of the environment. The ability to meet these requirements will have to be demonstrated to the satisfaction of the Nuclear Regulatory Commission, which will issue the authorization to construct the repository.

The DOE does not expect that site characterization for the Hanford site would adversely affect agriculture in the State of Washington or Oregon. Since no radioactive waste would be accepted at the site during this phase, there is no potential for radioactivity to enter the Columbia River through ground-water seepage.

Issue

One commenter suggested that the comparative evaluation of the Deaf Smith and the Richton sites against the guideline on socioeconomic impacts should rank Richton lower. This commenter stated that Deaf Smith's ranking was based on impacts to agriculture, but that we currently have more agricultural land in production than needed. Another commenter suggested that ranking the Deaf Smith site higher than Davis Canyon on socioeconomic impacts was arbitrary because the discussion states that in-migration requiring mitigation will occur at both sites and that effects on agriculture, a major sector of the economy of Deaf Smith County, are possible. Two commenters objected that the DOE had failed to consider any of the most important socioeconomic impacts.

Response

Chapter 7 of the final EAs presents a revised discussion of the comparative evaluation against the socioeconomics guideline, including the reasons the Richton Dome site is believed to be slightly more favorable in terms of socioeconomic impacts than the Deaf Smith site and why it is expected that socioeconomic impacts would be most severe at the Davis Canyon site. For example, Chapter 7 explains why the potential for effects on community services is greater at the Richton Dome site than at the Deaf Smith site and why in-migration would exert more severe effects at Davis Canyon site than at Deaf Smith. Chapter 7 also discusses the agricultural industry near the Deaf Smith site as an important primary sector of the economy that supports significant employment and business sales. The DOE does not believe that the evaluation of potential socioeconomic impacts at the Deaf Smith site can be based on the amount of agricultural land in production in the United States.

The guideline on socioeconomics addresses the most significant impacts that may be induced by a repository. The favorable and potentially adverse conditions of that guideline were widely reviewed by the States, affected Indian Tribes, Federal agencies, and the public during the consultation process for the guidelines.

Issue

Many commenters objected that the 1980 data presented in the draft EA for the Davis Canyon site are out of date and lead to a misrepresentation of the potential socioeconomic impacts of locating a repository in the area. One commenter stated that housing is available in the area, the vacancy rate being 15 to 20 percent. Other persons said that the current unemployment rate reported by the Utah Department of Unemployment Security is 23 percent whereas the draft EA reports 7 percent. Another commenter noted that the area has an abundance of water to sell and that the sewage-treatment plant was built to accommodate an increase in populations, but the area has recently experienced a decrease in population. Similarly, several other parties noted that, whereas in 1980 the area's population was booming, the area is losing population. Others explained that Grand and San Juan Counties had experience in handling "boom" conditions and had successfully handled two uranium and one oil boom. Many commenters pointed out that the testimony at the public hearings in Utah and Texas showed that some residents of southeastern Utah feel that the socioeconomic impacts would be both favorable and manageable, while the residents of the Texas Panhandle believe that the socioeconomic impacts on the town of Vega and the general agricultural economy would be dramatic and severe. All of these commenters, therefore, suggested that the Davis Canyon site should be ranked higher on the socioeconomics guideline and at least above the Deaf Smith site.

Response

Having considered and evaluated the comments and the information included in them, the DOE has revised the discussion of milling operations in the area of the Davis Canyon site. The recent suspension of mining and milling operations in the area has caused local socioeconomic conditions to change, with currently greater housing availability, higher unemployment rates, lower school enrollments, lower per capita incomes, and greater out-migration. Section 3.6 of the EA for Davis Canyon has been updated in regard to information on housing, personal income, unemployment rates, school enrollment, and the total population.

The DOE, however, does not believe that the Davis Canyon site should be considered more favorable than the Deaf Smith site for socioeconomics. Davis Canyon is still the only site where the analysis predicts significant repository-related impacts on community services, housing supply, and local government agencies in the affected area (see the evaluations of the sites against the first favorable and the first potentially adverse conditions of the socioeconomics guideline).

Issue

One commenter asked the DOE to clarify the first full paragraph on page 7-84. This paragraph, which discusses potentially adverse conditions for socioeconomics, states that "at Davis Canyon, water requirements are also not expected to adversely affect future development; however, this judgment is preliminary, as there is some uncertainty about potential short-term disruption of the area water supply during repository construction at this site." The commenter asked whether this statement implied disruptions of ground water at the site.

Response

The statement does not imply disruptions of ground-water systems at the site. The judgment is preliminary because it depends on the completion of two new reservoirs in the Blanding and Monticello areas. The San Juan Planning Council expects to build these two new reservoirs to take care of economic development needs and is willing to sell or lease part of its appropriations.

Issue

One commenter asked how the repository's effect on the High Plains aquifer in Texas would change if farmers move to dry-land crops or significant reductions in water use.

Response

Trends toward dry-farming could make the relative impact of withdrawing water for repository-related uses much more severe. The final EA does consider this trend and the potential for relatively more severe effects on water rights as well as consequent effects on future development near the Deaf Smith site.

Issue

One commenter recommended that the DOE use the disqualifying condition for the socioeconomics guideline to disqualify the Deaf Smith site; this disqualifying condition pertains to adverse impacts on water quality or quantity. The same commenter stated that, even if the DOE proceeded to rank the five nominated sites, it should not rank the Deaf Smith site as a preferred site.

Response

Because the DOE can mitigate or compensate for the adverse impacts on water quality and quantity, the Deaf Smith site is not disqualified on the basis of the socioeconomics guideline. The need to acquire water rights that could affect future development in the area was considered in the comparative evaluation of the five nominated sites against the socioeconomics guideline. The selection of preferred sites, however, depends on a comparative evaluation of the nominated sites against all of the siting guidelines.

C.3.4.2.2.3 Transportation

Issue

Several commenters stated that certain factors were not adequately accounted for in the relative ranking of the sites. Examples of such factors are cost, the emergency-response capabilities of affected States, and weather hazards. One commenter alleged that only distance was considered.

Response

All of the factors in the transportation guideline were considered during the comparative evaluation of sites. These factors include, but are not limited to, those mentioned by the commenters: cost, emergency-response capabilities, weather hazards, and distance. The evaluations of the favorable and potentially adverse conditions for each site in Section 6.2.1.8 of the final EAs discuss the information used to reach the findings on the guideline conditions.

Issue

Commenters noted that the draft EAs do not state what weight was given to the various conditions of the transportation guideline. It was also suggested that certain favorable conditions, such as cost and risk, should be weighted more heavily than others. These commenters contended that the DOE had stated publicly that national cost and risk would be weighted at half the total transportation ranking, but no similar statement is contained in published documents.

Response

The DOE agrees that national cost and risk should be weighted more heavily than the other factors in the transportation guideline. In the draft EA, the DOE considered national cost and risk (favorable condition 5 of the transportation guideline) to be weighted at 50 percent of the total importance of that guideline. A detailed explanation of the process used to evaluate the transportation conditions of the nominated sites for recommendation is contained in the multiattribute utility analysis of the nominated sites.

Issue

Several commenters expressed disagreement with the finding made by the DOE on the transportation-guideline conditions. They felt that, on the basis of the data presented, several of the findings for the favorable and potentially adverse conditions were unjustified. One commenter questioned that only the Richton site received a finding of "present" on favorable condition 5 (national cost and risk), and not Deaf Smith and Davis Canyon as well. Also noted were inconsistentcies in the data for the various sites.

Response

Several of the findings for the favorable and potentially adverse conditions of the transportation guideline have been revised in the final EAs. These revisions are based on responses to public comments, additional data, and additional analyses. To ensure consistency among the sites for the guideline-condition findings, a common set of criteria was applied. The DOE believes that all the findings reported under the transportation guideline in the final EAs are valid at this stage of the site-selection process. The rationale for each finding for each condition is presented in Section 6.2.1.8 of the final EAs.

Some of the favorable and potentially adverse conditions require a comparison among sites, and hence only one site can receive a finding of "present." These conditions are so noted in Section 6.2.1.8 of the final EAs. For example, favorable condition 5 contains the phrase "which are significantly lower than those for comparable siting options"; for this condition, only <u>one</u> site--the site with the lowest costs and risks--can receive the finding of "present." It should be noted, however, that in the comparative evaluation of sites all available data for each site for each guideline condition were considered.

C.3.4.2.3 Ease and cost of siting, construction, and closure

<u>Issue</u>

A commenter questioned why the DOE did not rank the sites with respect to the system guideline on the ease and cost of siting, construction, operation, and closure. The commenter argued that a "ballpark" figure would be useful and implied that the DOE avoided this because the result would be unfavorable to the Hanford site.

<u>Response</u>

As explained in this appendix and in the EAs, only preliminary assessments of performance against the system guidelines are possible at present (i.e., before site characterization), and the DOE feels that the results of such preliminary assessments would be inappropriate as bases for site-selection decisions.

<u>Issue</u>

Another commenter pointed out that the way that the EAs report costs makes ranking the sites on this basis difficult. The use of reference cases does not allow the site-specific construction and lifetime costs to be considered. The commenter was critical of the DOE's estimates of uncertainty, pointing out that cost overruns on some nuclear projects have exceeded 100 percent.

<u>Response</u>

The cost estimates in the EAs were based on the estimates of the total-system lifecycle costs that the DOE prepares annually each year for submittal to Congress as part of the fee-adequacy report. The repository is not comparable to nuclear power plants, some of which have indeed experienced large cost overruns. Furthermore, the DOE is financially accountable to Congress, and the expenditures of the repository program are audited by the General Accounting Office.

C.3.4.2.3.1 Surface characteristics

Issue

Some commenters felt that the interpretation of the potentially adverse condition of the guideline on surface characteristics was inconsistent in the various EAs and that the sites that are subject to potential flooding were not evaluated equitably: the Hanford, Yucca Mountain, and Richton sites were given credit for flood protection through engineering measures, whereas the Davis Canyon, Lavender, Cypress Creek, and Vacherie sites were not given credit for flood protection.

Response

The DOE has decided that flood protection through engineering measures cannot be considered in evaluations against the potentially adverse condition of this guideline because by allowing credit for such flood protection the DOE would eliminate a discriminating condition for this guideline. As a result, the Hanford, Yucca Mountain, and Richton sites were given a finding of "present" for this condition.

Issue

Some commenters pointed out that the Davis Canyon site was penalized in two guidelines (transportation and surface characteristics) for the rugged terrain that would be traversed by the access road and railroad. This penalty could be avoided by locating the surface facilities eastward in the flats away from the cliffs.

Response

Each site must be evaluated against every guideline regardless of any apparent duplication of penalties for site conditions. The Davis Canyon site contains rugged terrain; therefore, the favorable condition is not present. If the site is characterized, the plans for the layout of the surface facilities could be changed.

C.3.4.2.3.2 Rock characteristics

Issue

One commenter asked why the Hanford site was ranked lower on preclosure rock characteristics than the Deaf Smith and the Yucca Mountain sites.

Response

Since more exploration activity has occurred at the Hanford site than at the other sites, more data have been collected. Some of these data indicate that there are more conditions posing potential problems at this site than at the other sites. The conditions underground will not be adequately sampled until exploratory shafts have been sunk and underground excavations have been made at all sites.

Issue

One commenter asked whether a change in the buffer zone at Richton could change the degree of flexibility available at Richton and even require the use of a two-level design.

Response

Chapter 6 of the EA for the Richton Dome site has been revised to identify the assumptions and measurements made in claiming sufficient flexibility in preclosure rock characteristics. Several changes (not just the size of the buffer zone) could require the use of a two-level design at the Richton site.

Issue

One commenter questioned the Hanford site's being given a finding of "not present" for potentially adverse conditions 2 and 3.

Response

Chapter 6 of the EA for the Hanford site has been revised to explain the basis for these findings.

Issue

One commenter took issue with the small difference in rating between the Deaf Smith and the Davis Canyon sites for both preclosure flexibility and for ease of operation.

Response

Flexibility is only one of eight conditions considered in evaluating the sites on preclosure rock characteristics.

Issue

One commenter felt that the potential for high-pressure water inflow in regions of fractured rock will require "innovative engineering" and incur high costs at the Hanford site.

Response

The measures that would be required to mitigate these conditions are routinely used in mining. They are explained in Section 6.3.3.2.6 of the final EA for Hanford.

C.3.4.2.3.3 Hydrology

Issue

Several commenters questioned the appropriateness of the relative ranking of the five sites on the preclosure guideline on hydrology. One comment noted that the importance of the complexity of ground-water-control measures should not be equated with the potential for flooding or the availability of water. Another stated that the potentially adverse condition of ground-water conditions requiring complex engineering measures that are beyond reasonably available technology is present at Hanford, and therefore this site should be disqualified or heavily penalized in the relative ranking. A few comments stated that the relative rankings of Deaf Smith and Hanford were too favorable and should not be equal to those of Davis Canyon and Richton.

Response

As explained in Chapter 7 of the final EAs, the complexity of ground-water-control measures is indeed considered more important than the potential for flooding and the availability of water. The DOE does not agree, however, that the potentially adverse condition for the hydrology guideline is present at the Hanford site. The design features and construction techniques that would be used to minimize ground-water inflow into shafts and drifts at the Hanford site are based on mining experience under saturated conditions. The range of ground-water inflow conditions that are expected at Hanford can be accommodated with conventional design and construction methods; requirements for engineering measures beyond reasonably available technology are not expected. However, the relative complexity of ground-water-control measures at Hanford, as compared with the other sites, was taken into account.

Issue

One commenter noted that the Davis Canyon site was not correctly ranked on the hydrology guideline. Davis Canyon has enough flat land above the floodplain for construction and, unlike the other salt sites, has no large aquifers that require freezing for shaft sinking.

Response

The DOE agrees that, unlike the other two salt sites, the Davis Canyon site has no aquifers that require freezing for shaft sinking because only minor aquifers are present above the host rock. This favorable attribute was considered in the comparative evaluation of sites against the hydrology guideline. However, the location of the surface facilities of the repository is dictated by the need to mitigate visual aesthetic impacts to an acceptable level. Therefore, the DOE does not have the option of to locating a repository at the Davis Canyon site on flat land above the floodplain.

Issue

One commenter felt that the finding for favorable condition 3, the availability of water required for repository construction, operation, and closure, should be changed to "not present" for the Davis Canyon site. The estimated water requirements for the project do not include the water needed for mitigation measures, such as site revegetation and water sprays to suppress dust. Moreover, purchasing existing water rights would foreclose uses dependent on existing water rights and would adversely affect new development in the area.

Response

The DOE has revised the table on repository characteristics in Chapter 5 of the final EA for the Davis Canyon site to clarify the water-resource requirements for the repository. The DOE acknowledges that withdrawal from the Colorado River, if this resource is used, would contribute to the increasing demand on the region's sparse water resources.

Issue

One commenter asked what preliminary data indicate that at the Deaf Smith site adequate quantities of water can be obtained from the Dockum Group.

Response

Well yields in the vicinity of the Deaf Smith site are in the range of 400 to 900 gallons per minute.

Issue

One comment noted that Yucca Mountain is not as favorable as the text suggests and that the difference between Yucca Mountain and the other sites is not substantial.

Response

With respect to the Yucca Mountain site, the ability to locate the repository in the unsaturated zone, where minimal measures for ground-water control will be required, minimal potential for flooding, and an ample supply of water at the site for repository siting, construction, operation, and closure are favorable for this site. It is not clear from the comment what features of the Yucca Mountain site were considered adverse by the commenter with respect to the favorable ranking on the hydrology guideline.

C.3.4.2.3.4 Tectonics

Issue

A number of commenters expressed concern that the DOE has not adequately considered all information in ranking sites on the preclosure guideline on tectonics.

Response

The comparative evaluations of sites in the draft EAs were based on the information available for the qualifying, favorable, and potentially adverse conditions as they influence the potential for ground motion and fault displacement. The final EAs more explicitly discuss the expected effects of earthquake ground motion and fault displacement for each site; the discussion is based on the evaluations.

Issue

Some parties questioned the evaluation of the Yucca Mountain site, particularly with respect to the potential effects of nearby faults and in-situ stress, the derivation of ground-motion estimates, and the potential use of NRC criteria for nuclear reactors (10 CFR Part 100, Appendix A).

Response

As discussed in Chapter 7 of the final EA, there are uncertainties about potential ground motion and the time of the last movement on faults near the site. However, these uncertainties are not so large as to preclude the findings that must be made at this stage of the site-selection process. The data needed for higher-level findings will be collected during site characterization.

The NRC has said that (see page 103 of the NRC comments on the draft EA for Yucca Mountain) "at the present time, it is premature to state that the design requirements for nuclear power plants are the same as those required for a waste repository. The DOE should consider stating at this time that the design requirements of structures important to safety will comply with 10 CFR 60 and appropriate EPA regulations." The DOE agrees and has never intended or stated that reactor criteria would or should be used. The DOE is developing an approach to determining the appropriate earthquake inputs for repository design. An annotated outline of this approach was sent to the NRC for comment on June 20, 1985.

No quantitative statements about earthquake probability and magnitude can be made at present on the basis of stress data. In deriving estimates of potential ground motion for Yucca Mountain, the DOE did not ignore the nearby faults, but did not explicitly consider each fault because the magnitude and the probability of earthquakes on these are not known. The DOE's judgments are based on the data base for strong ground motion and on the type and levels of ground motion that other facilities have been designed for.

C.3.4.3 Decision method

The method used to identify the preferred sites for recommendation, described in Section 7.4 and Appendix B of the draft EAs, elicited many comments. As already mentioned in the introduction to Section C.3.4, the DOE, in response to these comments, developed a more formal decision-aiding methodology that was reviewed by the National Academy of Sciences. A detailed description of this methodology is presented in the multiattribute utility analysis of the nominated sites, which also shows how the methodology was applied in terms of the siting guidelines and identifies the sites preferred for recommendation. Thus, comments on the methodology applied in the draft EAs, the process used for identifying preferred sites, and the choice of preferred sites are not addressed here; only summaries of the various issues that were raised in these comments are presented in order to show the concerns of the commenters.

Among the comments was an objection to the statement in Section 7.1.2 of the draft EAs that "disqualifying conditions did not enter directly into the comparison of sites." This happened because the disqualifying conditions could not be used to discriminate between sites. Each of the potentially acceptable sites was evaluated against the disqualifying conditions (see Section 2.3 of the EAs), and no disqualifying conditions were found at any site. Had a disqualifying condition been found at any site, that site would have been removed from further consideration and would not have included in the evaluations of Chapter 7.

Many commenters said that the importance of individual guidelines in a group of guidelines should not be equal, and some suggested specific guidelines that should be considered more important than others in the same group. Some suggested that the importance of specific guidance should vary from site to site. These suggestions contradict the provisions of the implementation guidelines, which specify the relative importance to be assigned to each group of guidelines and state that, within a group, all guidelines are of equal importance.

The issues that were raised in the comments on the decision method are summarized below.

- The evaluation process described in Chapter 7 of the draft EAs is arbitrary and confusing.

- There is little correlation between the findings reported in Chapter 6 and the rankings in Chapter 7.

- The methodology is unsatisfactory, inadequate, undocumented, and biased. The averaging and the pairwise comparison methods are not satisfactory because the spread in rankings is artificially determined; the utility estimation method can be valid for comparisons against the preclosure guidelines but is not adequate for assessing postclosure performance.

- Aggregation procedures are valid only if the guidelines are complete and not redundant, but some guidelines are redundant (i.e., population is considered in the guidelines on population density and distribution, meteorology, environmental quality, socioeconomics, and transportation).

- The aggregation of rankings compounds the subjectivity of the application of the guidelines.

- Alternative decision methodologies might result in the identification of different sites as preferred for characterization.

- The methodology of comparison should be highlighted as a stand-alone issue.

- A sensitivity analysis should be performed and documented.
- The DOE should find a site adequate under the postclosure guidelines before considering its rank under preclosure guidelines.
- The aggregate ranking does not consider interactions among major factors.
- The weighting used for the various conditions of each guideline is not explained; hence the basis for the score on each guideline is not clear and cannot be replicated. Furthermore, if all conditions are of equal weight, then any one condition is not very important.
- The weighting of the postclosure guidelines with respect to the preclosure guidelines is too low and not justified.
- Because three postclosure guidelines cannot be used to discriminate among sites (climatic changes, erosion, and site ownership and control), the inclusion of these guidelines in the aggregate rankings reduces the weight assigned to the other postclosure guidelines.
- The weighting of 35:33:32 for the three groups of preclosure guidelines assigns similar weights to the three groups, contradicting the requirement of the implementation guidelines that the three groups be assigned a specified order of importance.
- Because the weighting was adopted without rulemaking proceedings, its use violates the public participation and rulemaking requirements of the Act, the DOE Organization Act, and the Administrative Procedures Act.
- Because the application of the methodology is contingent on the professional qualification and experience of the members of the evaluation team, the DOE should provide such information about every team member.

The DOE carefully considered these issues in the development and application of the decision-aiding methodology.

C.3.4.4 Miscellaneous comments on the nomination and recommendation process

The DOE received many comments that addressed various aspects of the process of site nomination and recommendation and the results reported in Chapter 7 of the draft EAs. Many of these comments approved of the sites identified as preferred for recommendation; one party submitted an independent evaluation that supported the choice of sites reported in Section 7.4. Many other commenters, however, disagreed with the sites identified as preferred. As already explained, the DOE developed a formal decision-aiding methodology for the ranking of sites. The results will be presented in the multiattribute utility analysis of the nominated sites and the recommendation of candidate sites, which are being issued separately.

Summarized and answered below are various other issues raised in comments on the nomination and recommendation process.

Issue

Some commenters said that four of the potentially acceptable sites should not have been excluded from the comparative evaluation in Chapter 7 because the exclusion of the four sites might have altered the outcome of the site rankings. Some parties also asked what happens to the four potentially acceptable sites that were not evaluated in Chapter 7.

Response

Section 112(b)(1)(E) of the Act requires each EA to include a reasonable comparative evaluation of the nominated site against the other sites and locations that have been considered. The siting guidelines (Section 960.3-2-2-3) require that the nominated site be evaluated against all other such sites. In this context "such sites" has been taken to mean other nominated sites. Therefore the comparative evaluation of sites against the guidelines considers the five sites proposed for nomination.

It is not true that the four remaining site have been excluded from a comparative evaluation against other potentially acceptable sites. As specified by the siting guidelines (Section 960.3-2-2-1), the selection of the preferred site in each geohydrologic setting that contains multiple sites was based on a comparative evaluation of the sites in that basin (see Section 2.4 of the EAs for the Davis Canyon, Deaf Smith, and Richton Dome sites).

The four sites not evaluated in Chapter 7 are not being recommended for characterization. They could, however, be considered again in the first-repository program if none of the characterized sites is accepted for repository development. They could also be considered in the second-repository program.

Issue

Commenters stated that the DOE should use the guidelines that do not require site characterization in selecting the preferred sites for characterization because the data are more available and more reliable. If this approach had been used, the rankings of the salt sites would have been different.

Response

The Act, in Section 112(b)(E)(i), requires that the sites be evaluated against all of the siting guidelines. Furthermore, many of the guidelines that require data from site characterization for the demonstration of compliance pertain to postclosure conditions that would affect the long-term safety of the repository.

Issue

A commenter applauded the DOE's use of conservative assumptions for preliminary performance assessments of the repository system and for present evaluations of potential environmental impacts, but suggested that the DOE should emphasize that actual repository performance at all sites is likely to be better than predicted because of these conservative assumptions. Commenters also noted that there are inconsistencies in the application of conservatism throughout the EAs.

Response

In its evaluations, the DOE used, where necessary, assumptions that approximate the characteristics or conditions considered to exist or expected to exist in the future at a site. These assumptions are realistic but conservative enough to underestimate the potential for a site to meet the qualifying condition of a guideline. The results of the analyses indicate that all of the sites are likely to meet the performance requirements. Given the limitations and uncertainty in the available information, statements that actual performance is likely to be better than predicted would be inappropriate. The DOE has attempted in the final EAs to ensure reasonable comparability among the sites in the degree of conservatism applied to similar analyses, such as ground-water-travel times.

Issue

Several commenters felt that nonconservative positions were taken when evaluating the sites against the guidelines in spite of a statement in Section 7.1.2 to the contrary. One commenter stated that a conservative assumption stated in Chapter 7, involving the vertical ground-water-travel time, was not implemented for the Davis Canyon site.

Response

The DOE feels that it has used conservative assumptions where insufficient data were available. It should be borne in mind, however, that at this stage in the site-selection process (i.e., nomination for site characterization) the qualifying and disqualifying conditions in the guidelines need only meet the tests that evidence does not support a finding that the site is disqualified or does not support a finding that the site is not likely to meet the qualifying condition.

Regarding the specific comment, the conservative assumption stated in Chapter 7 involves a time of vertical travel through the interbeds in the evaporite sequence. Chapter 6 does not indicate that anything other than zero was used in estimating travel time through the interbeds when the total travel time through the evaporite sequence was estimated.

Issue

Commenters were concerned because the DOE did not rank the sites on the system guidelines. Some suggested that the DOE delay ranking the sites until enough data for performance assessments are available and repository technology is more developed.

Response

The DOE described the basis for site evaluations in Section 960.3-1-5 of the guidelines. This section indicates that comparisons between and among sites shall be based on the system guidelines to the extent practicable, and, if the evidence is not adequate to substantiate such comparisons on the basis of the system guidelines, then the comparisons shall be based on the groups of tehnical guidelines. As discussed in the EAs, the results of preliminary evaluations based on the system guidelines were presented in the EAs, but the objective was to demonstrate the status of capability at this point in the program, not to provide the basis for recommending sites for characterization.

The information needed to develop system performance assessments with sufficient confidence to use them for applying the system guidelines can be gathered only during site characterization. This fact, together with the schedule mandated by Congress for repository development, makes it imperative that the sites to be characterized be chosen expeditiously.

Consistent with the Act, the applicable NRC regulations in 10 CFR Part 60, and the DOE's siting guidelines, the DOE believes that it is appropriate and prudent to proceed with site characterization in order to obtain the information needed for selecting one site for development as a repository, advancing the designs of the repository and the waste package, and completing a license application to the NRC.

Issue

Some commenters criticized the data bases for the analyses presented in the EAs.

Response

The DOE has met the intent of the Act to use available information to recommend sites for characterization (see Section 112(b)(3)) and has been consistent with the guidelines in making the findings required for nomination and recommendation (10 CFR Part 960, Appendix III).

Issue

Several commenters expressed concern over differences in the data bases for different sites.

Response

The information available for the various sites is admittedly nonuniform in accuracy and extent. However, it meets the requirements of the Act and of the siting guidelines for this stage of the site-selection process. The detailed data needed for later decisions will be collected during site characterization.

Issue

One commenter stated that the DOE does not have sufficient data to compare the Deaf Smith site with the other four nominated sites. The commenter cited a lack of site-specific data in many technical areas.

Response

The DOE recognizes that the data used in comparing the sites are not uniform. However, the DOE feels the data are sufficient to choose the sites for nomination and recommendation for site characterization; meet the requirements of the Act and of the siting guidelines.

Issue

One commenter remarked that site selection for characterization is pointed toward ease of public acceptance rather than the technical quality of the site. The commenter pointed to the proximity of DOE facilities to two of the sites as evidence that prior public acceptance of DOE installations was a major consideration.

Response

The process to be followed in recommending sites for characterization is specified in the Act. Included in that process is evaluation against the siting guidelines. In this evaluation, each site must be shown likely to meet all of the technical guidelines. Public acceptance is not directly considered. (It is considered indirectly as part of evaluations against the socioeconomics guideline). The proximity of DOE installations to two of the sites is, at least in part, a consequence of a Congressional mandate to search for sites on Federal lands dedicated to nuclear activities. That search led to the Hanford and the Yucca Mountain sites.

Issue

One commenter said that, whereas the Act requires a comparative evaluation in an EA for each nominated site, Chapter 7 compares only five sites. Therefore, only those five can be among the sites finally nominated. The commenter said that to nominate any other site would require new draft EAs or EA supplements for that site and new comparative evaluations.

Response

While Chapter 7 only compares five sites, the comparisons of sites within each geohydrologic setting, when taken together with Chapter 7, provide a comparison of all nine sites. The procedure of comparing sites in each geohydrologic setting to identify sites for nomination and then performing a compartive evaluation of the nominated sites follows the requirements of the siting guidelines, Section 960.3. New draft EAs will not be necessary unless there is a change in the preferred sites within a geohydrologic setting.

Issue

One commenter noted that no worst-case analyses were done for the sites, but courts have ruled that such analyses are required for demonstrating compliance with the National Environmental Policy Act.

Response

The EAs for geologic repositories are prepared under the statutory requirements of the Nuclear Waste Policy Act rather than the National Environmental Policy Act.

Issue

Several commenters suggested considerations that should be given the greatest importance in site evaluations. One said that the potential for harm to the Canyonlands National Park outweighs all other considerations. Another felt that safety is the most important criterion, followed by cost. Another commenter listed geologic stability, absence of ground-water intrusion, simple and regular transportation routes, and the ability to maintain repository integrity in spite of social upheaval as most important.

Response

The siting guidelines require that primary consideration be given to the postclosure guidelines. These include guidelines devoted to safety (postclosure), geologic stability, ground water (geohydrology), and long-term repository integrity. Furthermore, the preclosure guidelines are divided into three groups: radiological safety; environment, socioeconomics, and transportation; and EAs and cost of siting construction, operation, and closure. Those groups are specified to be in decreasing order of importance as listed above. It can be seen that the siting guidelines provide considerable constraint in the weighing, or at least in ranking the importance of, different factors used in evaluating and comparing sites.

Issue

One commenter felt that Chapter 7 did not explain how the evaluation of the favorable and potentially adverse conditions in the guidelines were related to the rankings given the sites.

Response

The approach used in the comparative evaluation of sites in Chapter 7 of the draft EAs was explained in Section 7.1.2, which discussed, among other things, the relationship between the favorable and potentially adverse conditions and the site rankings. It explained that the favorable and potentially adverse conditions, considered on balance and in relation to the qualifying condition, constitute the basis for ranking the sites.

Issue

One commenter suggested that all of the sites be characterized.

Response

Because of its high cost, the characterization of all nine sites would be an imprudent and unnecessary use of the funds collected from utility ratepayers.

Issue

A number of commenters stated that the waste should be disposed of at its point of origin and that the DOE should weigh regional considerations in siting the repository. Approximately 80 percent of the waste to be stored in a West Coast repository is generated east of the Mississippi, yet no States in the east are being considered for a repository.

Response

Among the nine sites found to be potentially acceptable for the first repository, and the five sites nominated as suitable for characterization is Richton Dome, which is in the State of Mississippi. In addition, the DOE is investigating potential repository sites in the north-central, northeastern, and southeastern regions. The study is investigating crystalline rocks of the eastern Appalachian region, but it was not sufficiently advanced to allow a crystalline-rock site to be included in the site-selection process for the first repository. The crystalline-rock program will be part of the effort to select a site for the second repository.

The Act requires consideration of regionality in selecting the second repository. Therefore, if the first repository is located in the west, the second repository may be located in a region closer to eastern nuclear power plants. However, it is important to remember that all sectors of the society benefit from nuclear power, either directly or indirectly, through the distribution of electrical power and decreases in the consumption of foreign and domestic oil. Therefore, the disposal of radioactive waste is a national problem. Although a State may not have a nuclear power plant within its boundaries, it is very likely that the State is, or will be in the future, consuming electricity produced by nuclear power plants outside the State. The paramount consideration in siting the repository is public health and safety, which cannot be sacrificed solely to ensure a regional distribution of repositories. If all host rocks and sites in the eastern United States were found unsuitable, then no repositories would be sited there.

Issue

Commenters were critical of the ability of DOE officials to make unbiased decisions. Some stated that political issues interfered with the site selection process. Specific concerns were stated as follows:

- Secretary Hodel's statements in Texas during the Congressional election race of Phillip Graham may have influenced site-selection decisions.

- The EAs were released one month after the election, rather than before, when they would have been a campaign issue. The commenter alleged that the schedule is being driven by politics.

- Political pressure may be brought to bear on the DOE to change the ranking of nominated sites. Several commenters felt that the residents of small towns and sparsely populated regions near the nominated sites do not have enough political clout to affect the choice of sites.

- Political and socioeconomic considerations should not outweigh safety and environmental considerations. Many commenters stated that the choice of Hanford was influenced by economic conditions in the region, and one commenter suggested that the government may be considering paying off the WPPSS bond in exchange for the State of Washington's agreement to locate the repository at Hanford. Other commenters stated that both the Yucca Mountain and the Hanford sites were recommended for characterization because, as federally owned sites, these would be less public opposition to these sites.

Response

Recognizing that the selection of a geologic repository should not be subject to political pressure, Congress specifically directed the DOE to issue guidelines to be used in selecting sites for a repository and specified the process to be used in site selections. The nomination and recommendation of sites for characterization were based on evaluation of the sites against the guidelines.

Former Secretary of Energy Donald Hodel did campaign in Texas on behalf of Representative Phillip Graham during the Congressional election of 1984. During that campaign, Secretary Hodel expressed his personal view that Mr. Graham would effectively represent Texans in the repository-development process. However, Secretary Hodel's participation in the 1984 campaign did not influence the evaluation of the potentially acceptable sites in the EAs. The identification of the Deaf Smith County as a preferred site for characterization was a technical decision that was not influenced by political considerations in view of the widespread opposition to a repository in Texas.

The collection and analysis of data for nine draft EAs was a complex and time-consuming process. The schedule was driven by the requirement of the Act for the DOE to prepare environmental assessments that include specific evaluations and analyses; the timing of the election had no influence on the schedule.

The DOE released the draft EAs for public comment and held briefings and hearings in the affected States. The DOE carefully considered the issues raised by individuals, public interest groups, States and Indian Tribes, and other Federal agencies submitted in writing or as testimony in the hearings.

The DOE is confident that all citizens had ample opportunity to comment on the EAs. Any change in the rankings of the nominated sites would be due to additional data leading to changes in guidelines findings, and not to political pressure.

The guidelines are structured to ensure that the protection of health and safety is heavily weighted in selecting sites for characterization. In no way do the economic conditions in an area override considerations of health and safety.

The Hanford site's close proximity to the WPPSS project has no influence on its nomination or recommendation for site characterization. The WPPSS program is an entirely separate program, and there has been no "tradeoff" agreement with the State of Washington.

While the DOE did initially look as Yucca Mountain and Hanford sites as part of its program to screen Federally owned sites, this is not the basis for nominating or recommending these sites for characterization. Each of these sites has been evaluated against the guidelines and has been found suitable for site characterization.

Issue

Some commenters observed that the draft EAs do not prove that the DOE has chosen the best sites for nomination and characterization. One commenter requested that the DOE repeat the ranking process for the nine potentially acceptable sites after site characterization completed, to make sure that the three sites characterized are the best sites.

Response

It is not necessary to choose the best sites for nomination and characterization; it is necessary to choose sites that are likely to meet all applicable regulatory requirements for the protection of public health and safety and would allow the geologic repository program to proceed in an expeditious and cost-effective manner.

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C.4 DATA BASE, PROPOSED ACTIVITIES, REPOSITORY DESIGN

This section addresses comments on the accuracy or adequacy of the baseline information about the repository system, site-characterization activities, and the reference repository location itself that is used to evaluate site suitability and the impacts of developing the site. It includes almost all comments on Chapter 3 and on Sections 4.1, 4.3, and 5.1 in this Environmental Assessment.

C.4.1 BASELINE CONDITIONS AT THE SITE

Discussions in this category are grouped under the following subsections:

- C.4.1.1, Geologic conditions.
- C.4.1.2, Hydrologic conditions.
- C.4.1.3, Environmental conditions.
- C.4.1.4, Transportation.
- C.4.1.5, Socioeconomic conditions.

Several concerns and issues pertaining to baseline conditions at the site were raised by reviewers of the Draft Environmental Assessment (DOE, 1984b). A clear understanding of current conditions at the Hanford Site is important because the impact analyses presented in Chapters 4 and 5 of this Environmental Assessment use current conditions as a basis to allow the estimation of changes resulting from site characterization or repository development. The first three categories of issues (geologic, hydrologic, and environmental conditions) are contained in this appendix section. However, the issues concerning transportation and socioeconomic conditions have been cross-referenced to more complete discussions of these topics in other portions of this appendix.

C.4.1.1 Geologic conditions

Many commenters were concerned with the description of geologic conditions at the reference repository location and vicinity as presented in the Draft Environmental Assessment. The comments are categorized into three issues:

- Additional information.
- Accuracy of discussion.
- Clarification of statements.

Issue: Additional information

Several commenters requested that additional information on geologic conditions of the reference repository location and vicinity be included in Sections 2.1.1 and 3.2 of the final Environmental Assessment.

Specifically, additional information was requested on (1) structural subprovinces, (2) faults on Gable Mountain, (3) catastrophic flooding, (4) recurrence intervals for a larger earthquake on the Rattlesnake-Wallula alignment, (5) other U.S. Department of Energy boreholes, (6) paleomagnetic polarity, (7) Vantage interbed, (8) physiography and geomorphology of the region, (9) definition of the term "paleosol," (10) geologic cross section through the reference repository location, (11) variability of basalt flow tops, (12) ground-water flow paths, (13) intraflow structures, (14) mineral resources, (15) tectonic investigations (also see Section C.5.7 of this appendix), and (16) basin analysis of the suprabasalt sediments.

Additional information on geologic conditions was also requested for specific guidelines in Chapter 6 and the siting process in Section 2.2 of the Draft Environmental Assessment and can be found in Subsection C.3.1.3, and Sections C.5.4, C.5.5, C.5.7, and C.5.8 of this appendix.

Response

The three informal structural subprovinces of the Columbia Plateau were briefly described in Subsection 2.1.1.2 of the Draft Environmental Assessment. It is agreed that the description of the structural provinces in the Draft Environmental Assessment did not include sufficient information for the reader to understand the basic structural relationships of the Columbia Plateau. To clarify concerns in the comments, the descriptions of the three subprovinces (which include the Yakima Fold Belt, Palouse, and Blue Mountains subprovinces) have been expanded in Subsection 2.1.1.2 of the final Environmental Assessment to include nature, style, and age of deformation in each region.

Faults on Gable Mountain are tear faults interpreted to be in response to folding. The lengths of the faults are controlled by second-order folds within the enclosure of a first-order fold (i.e., the Umtanum Ridge-Gable Mountain structure). Faulting on Gable Mountain was discussed in Subsection 3.2.3.2 and located in Figure 3-22 of the Draft Environmental Assessment. The interpretation of faulting on Gable Mountain is consistent with the structural analyses of Yakima folds presented in Subsection 3.2.3.8 of the Draft Environmental Assessment. Detailed discussion of the west fault and central Gable Mountain faults is presented in referenced documents (Bingham et al., 1970; Fecht, 1978; PSPL, 1982; NRC, 1982b).

Evidence for multiple catastrophic floods exists in the Pleistocene record of the central and eastern Columbia Plateau. This evidence was included in the Draft Environmental Assessment in Subsection 3.2.2.7, page 3-45, paragraph 1. An additional reference providing evidence for multiple catastrophic floods has been added to Subsection 3.2.2.7 of the final Environmental Assessment.

The average recurrence interval for a large earthquake (magnitude 6.5) on a 20-kilometer (12-mile) segment of the Rattlesnake-Wallula alignment has been estimated by the U.S. Nuclear Regulatory Commission (NRC, 1982b) to be greater than 50,000 years (Slemmons, 1982).

This information was discussed in Subsection 6.3.1.7.5 of the Draft Environmental Assessment. Further information is discussed in detail in the referenced document (NRC, 1982b). The statement concerning earthquake recurrence has been clarified and the U.S. Nuclear Regulatory Commission (NRC, 1982b) reference added to Subsection 6.3.1.7.10 of the final Environmental Assessment.

Data on the "700 other U.S. Department of Energy boreholes" discussed in Section 3.2.2 of the Draft Environmental Assessment are available through referenced documents; therefore, it is judged inappropriate to include this information in the final Environmental Assessment. References on additional U.S. Department of Energy boreholes have been included in Section 3.2.2 of the final Environmental Assessment.

The N_2 paleomagnetic polarity includes upper Grande Ronde Basalt flows as well as the Eckler Mountain member of Wanapum Basalt (see Swanson et al., 1979, Fig. 2). The stratigraphic position of the N_2-R_2 boundary in the Pasco Basin is identified in a report by Long and Landon (1981). Paleomagnetic polarity (i.e., magnetostratigraphy) of Grande Ronde Basalt flows were discussed in Subsection 3.2.2.1 of the Draft Environmental Assessment.

An extensive description of the Vantage interbed is judged to be beyond the scope of an environmental assessment; moreover, much of the work needed to describe the Vantage interbed in detail is yet to be completed and will be done as part of site characterization, should the reference repository location be selected.

The physiography and geomorphology of the region and reference repository location were described briefly in Section 3.2.1 of the Draft Environmental Assessment. The discussion concerning the reference repository location is adequate for the purpose of Subsections 6.3.1.4 and 6.3.1.5. Additional references for regional physiography and geomorphology are included in the final Environmental Assessment.

The term "paleosol" is defined as a buried soil horizon. This term has been added to the glossary of the final Environmental Assessment.

Although an expanded cross section might supply additional information, the purpose of the cross section was to provide only a general geologic view of the reference repository location, not to provide detailed data. Additional cross sections can be found in a report by Caggiano and Duncan (1983) (Fig. 2-4).

It is felt that flow-top thickness variations of the candidate horizons were adequately addressed for the purposes of the Environmental Assessment. More detailed discussions of variations in flow-top thicknesses are included in stated references (Long and WCC, 1984; Myers and Price, 1981).

Subsection 3.3.2.1 of the Draft Environmental Assessment discussed potential ground-water pathways. Figure 3-36 portrayed these features as possible influences on ground-water movement.

The Draft Environmental Assessment (see Section 2.1.1) presented discussions on intraflow structures of basalt flows, including data on fracture abundances and orientations. In addition, Figure 2-3 graphically illustrated examples of fracture patterns in cross sections of a hypothetical flow.

A discussion of mineral resources was presented in Subsection 6.3.1.8 of the Draft Environmental Assessment, and socioeconomic implications were addressed in Subsection 6.3.1.8.3. It does not appear necessary to repeat this information in other chapters.

The U.S. Department of Energy agrees it would be helpful to describe the number, nature, and scope of all previous tectonic investigations within the region of the Hanford Site and to make extensive use of tectonic and epicenter maps. Many of these investigations were referenced in the Draft Environmental Assessment. A complete discussion of tectonics investigations is beyond the scope of this document, since Chapters 2 and 3 of the Environmental Assessment are intended to provide information necessary to support the findings and positions taken in Chapter 6.

A basin analysis of the suprabasalt sediments was not included in the Draft Environmental Assessment because the distribution and stratigraphic analysis of these sediments is known only for very limited portions of the Pasco Basin. Further study of the suprabasalt sediments, including a basin analysis, would need to be considered during site characterization.

Issue: Accuracy of discussion

Several commenters questioned the accuracy of specific statements made in the Draft Environmental Assessment, others identified apparent inconsistencies, and still others recommended changes to inaccurate and inconsistent statements. The general topics included in this issue are (1) earthquake epicenter maps, (2) source dikes of the Wanapum Member, (3) relationship between the Cle Elum-Wallula Lineament and the Olympic-Wallowa Lineament, (4) location of the repository within the Cohassett flow, (5) stratigraphic position of the four proposed candidate horizons, (6) Umtanum fault, (7) data used to develop stratigraphic relationships, (8) use of the term "deformation," (9) thickness of the Cohassett flow, (10) thickness of the McCoy Canyon flow, (11) trend of the Pasco syncline, (12) dominant secondary minerals, (13) polarity of the Roza Member, (14) stratigraphy of the Frenchman Springs Member, (15) use of the term "intact rock," and (16) incorrect conversions on Figure 2-27 of the Draft Environmental Assessment.

Response

Changes have been made to two of the earthquake location figures in Chapter 2 of the final Environmental Assessment. Figure 2-9 now shows all earthquakes instrumentally recorded since 1969 that had a magnitude greater than 3.0 irrespective of depth. The purpose of Figure 2-9 is to present visual comparisons of the historical seismic record and the instrumentally recorded record. Figure 2-10 has been changed by adding the Wooded Island swarm activity that was inadvertently omitted, and by including a corresponding figure of deep events (i.e., greater than 4 kilometers (2.5 miles)).

The Draft Environmental Assessment erroneously stated in Subsection 2.1.1.1 that "source dikes for only three of the four Wanapum members have been identified in the eastern Columbia Plateau." Swanson et al. (1980) have identified source dikes for all four members. Subsection 2.1.1.1 of the final Environmental Assessment has been changed to reflect the findings in the Swanson et al. (1980) report.

The Draft Environmental Assessment did not discuss the relationship of the Cle Elum-Wallula Lineament and the Olympic-Wallowa Lineament. The Cle Elum-Wallula Lineament is part of the more regional Olympic-Wallowa Lineament as defined by Raisz (1945). This addition has been made to the final Environmental Assessment. Also, additional discussion of the Olympic-Wallowa Lineament was added to Subsection 2.1.1.2.

Current repository layout conceptual planning places the repository within the Cohassett flow interior. A statement has been added to Subsection 3.2.2.1.3 of the final Environmental Assessment concerning the placement of the repository in the Cohassett flow.

The basalt sequence to which the Rocky Coulee, Cohassett, and McCoy Canyon flows belong was incorrectly identified in Subsection 3.2.2.1 of the Draft Environmental Assessment. These flows are found in the Sentinel Bluffs sequence, not in the Schwana sequence. The correction has been made in the final Environmental Assessment.

The fault discussed on page 3-48, line 4 of the Draft Environmental Assessment is the Umtanum fault (see lines 4 and 7). The fault has been identified in the final Environmental Assessment.

Geophysical surveys have, for the most part, not been utilized as input to stratigraphy, but are utilized in interpreting the structure of the site. Therefore, six of the bulleted items in Section 3.2.2 of the Draft Environmental Assessment were misleading and have been moved to Section 3.2.3 of the final Environmental Assessment. This section describes the data sets used to assess structures in and around the reference repository location. Borehole geophysical logs are used in stratigraphy and have been retained in Section 3.2.2 of the final Environmental Assessment. Documents containing results of geophysical surveys were appropriately referenced and discussed in Section 3.2.3 of the Draft Environmental Assessment. Detailed discussion of geophysical surveys is judged to be beyond the scope of an environmental assessment; however, geophysical survey input to selection of the reference repository location was discussed in Section 2.2.1 of the Draft Environmental Assessment, particularly page 2-46, paragraph 5, and pages 2-50 and 2-51. Section 2.2.1 also provided references to more detailed descriptions of the siting process based on information available as of May 1980.

Deformation does not equate with vertical strain. Therefore, the wording in Subsection 3.2.3.8, paragraph 4, of the Draft Environmental Assessment was revised to clarify the statement and to delete the phrase "(i.e., vertical strain)." Also, the term "deformation" used in Subsection 6.3.1.7.4, paragraph 3, sentence 4, of the Draft Environmental Assessment specifically referred to faulting. The term "faulting" is used in place of the term "deformation" in this sentence in the final Environmental Assessment.

When the 1982 conceptual design (RKE/PB, 1983) was being written, information from borehole RRL-2, showing only 25.3 meters (83 feet) of flow interior, was not available. The RRL-2 data, however, was used for screening the proposed candidate horizons. The figure of 70 meters (223 feet) for the Cohassett flow interior is the total dense interior, including the upper and lower dense interiors and the vesicular zone. Table 5-5 of the Draft Environmental Assessment has been modified to show both the total flow thickness and flow interior thickness as utilized in different past design phases.

The Draft Environmental Assessment did contain an error in the thickness of the McCoy Canyon flow (see p. 7, par. 3, line 10). The total flow thickness should be 33.5 meters (110 feet). The error has been corrected in the final Environmental Assessment.

Subsection 3.2.3.6 of the Draft Environmental Assessment was in error regarding the trend of the Pasco syncline. The trend of the Pasco syncline (as shown in Fig. 3-22) is northwest. The text has been corrected in the final Environmental Assessment.

The listing of pyrite as a dominant secondary mineral (see Section 2.1.1 of the Draft Environmental Assessment) was an error. Pyrite has been deleted from the list of dominant minerals, and a sentence listing pyrite and calcite as less common secondary minerals was added to the final Environmental Assessment.

The reversed polarity "flow" of the Roza Member as described in the Draft Environmental Assessment was incorrect; the "flow" is actually a reversed polarity dike, probably the youngest unit of the Roza Member. The statement regarding the reversed polarity of the Roza Member has been corrected in the final Environmental Assessment.

The Ginkgo, Sand Hollow, and Sentinel Gap units of the Frenchman Springs Member have been added to the stratigraphic chart in Figure 3-6. A new stratigraphy that defines criteria for distinguishing basalt units in the Frenchman Springs Member has been published in a report by Beeson et al. (1985).

The use of the term "intact rock" to describe collectively the basalt flows in the Cold Creek syncline is incorrect since evidence suggests that at least minor structural discontinuities are present in the area. It was intended that the phrase "relatively intact rock" be used, as it was by Myers (1981). Subsection 3.2.3.3 of the final Environmental Assessment has been changed to read "relatively intact rock."

The values plotted on Figure 2-27 of the Draft Environmental Assessment represent elevations above mean sea level. This has been clarified in both the figure and in the text of the final Environmental Assessment. It is agreed that the "100-foot contour" does have an incorrect conversion and should read 30.5-meter (100-foot). This has been corrected in the final Environmental Assessment.

Issue: Clarification of statements

Several commenters requested statements in the Draft Environmental Assessment be clarified or elaborated on. The topics covered include (1) tiering within the dense interior of basalt flows, (2) glass content in the mesostasis, (3) inclinations from paleomagnetic data of core samples, (4) thinning of the Cohassett flow, (5) geologic cross sections, (6) faulting on Yakima Ridge, (7) thickest section of Wanapum Basalt in the central Pasco Basin, (8) location of vents for the Frenchman Springs Member, (9) core-sample logging and sampling, (10) surface versus subsurface characteristics of basalt flows, (11) candidate flow interior thicknesses, (12) complexity of geologic conditions, (13) leachate infiltration, (14) relationship between surface and subsurface structures and seismicity, (15) soil conditions, (16) tectonics (also see Section C.5.7 of this appendix), (17) suprabasalt sedimentary units of the Pasco Basin, (18) continental glaciation in eastern Washington, (19) classification of landforms, (20) age of last major catastrophic flood deposits, (21) geologic impacts from site characterization and construction, (22) future changes in the course of the Columbia River, (23) uppermost flow in the reference repository location, (24) uneven treatment of three major basalt formations, (25) thickness of the dense flow interiors, (26) "channels" or "caverns" in basalt flows, (27) structural setting, (28) intraflow structures, (29) relationship of tiering to other intraflow structures, (30) definition of "active" fault, and (31) naming of the reference repository location.

Response

Entablature-colonnade tiers within the dense interior of basalt flows are not necessarily correlatable from borehole to borehole in the reference repository location, but this is not expected to impact the design of a repository or adversely influence ground-water flow. The internal arrangement of entablature-colonnade tiers in the flow interior can be determined at any given borehole. It is known that tiering commonly occurs in the interiors of the Cohassett and Rocky Coulee flows. It is also known that internal tiering is probably laterally discontinuous. Two important facts should be noted. First, entablature and colonnade within the dense interior are believed to be attributable to differences in cooling rates of the lava. Changes from an entablature to a colonnade or vice versa, or aggradations are to be expected and are observed in outcrops surrounding the Pasco Basin. Second, hydrologic testing of dense interiors, including those with tiered entablature-colonnade, shows that the changes from entablature to colonnade are not associated with significant differences in hydrologic properties or with emplacement features such as flow-top breccia. Entablature-colonnade tiers, therefore, do not imply heterogeneities such as flow-top breccia or vesicular basalt. The final Environmental Assessment reflects borehole correlations of intraflow studies. Studies to better understand the nature of entablature-colonnade tiering within the dense interiors of flows will be considered during site characterization, should the reference repository location be selected for this activity.

The entablature contains more mesostasis (consisting of both glass and minute crystals and inclusions) than the colonnade portions of basalt flows. An increase in percentage of mesostasis is not necessarily attributable to a significant increase in the actual glass content. Section 2.1.1 of the final Environmental Assessment has been changed to include the prominent texture differences between entablature and colonnade (i.e., difference in percentage mesostasis).

The inclinations from paleomagnetic analysis of core samples from the Roza Member within the Pasco Basin probably do not indicate tectonic tilting of the section. All paleomagnetic inclinations except for the dike of Choiniere and Swanson (1979) fall within the error range of Rietman (1966). Tectonic tilting is one possible explanation; however, the Alpha 95's from both Van Alstine and Gillett (1981) and Packer and Petty (1979) overlay the mean and Alpha 95's from the flow (but not the dike) of Choiniere and Swanson (1979). Furthermore, the paleomagnetic data of Van Alstine and Gillett (1981) and Packer and Petty (1979) were corrected for structural tilt, suggesting the flow fed by the dike is not present in the Pasco Basin. The "oldest Roza flow" referred to in the Draft Environmental Assessment is actually "a Roza dike." The final Environmental Assessment has been reworded to reflect this change.

According to a report referenced in the Draft Environmental Assessment (Long and WCC, 1984), the thinning of the Cohassett flow in the southeast portion of the Hanford Site is thought to be related to the mechanics of flow emplacement, not to thinning over a topographic high, either structural or constructional. Several lines of evidence are provided in the referenced document (Long and WCC, 1984) to support this statement: (1) no present-day structures found in the vicinity account for this thinning; (2) underlying basalt between the Umtanum flow and the base of the Cohassett flow is no thicker than elsewhere in the basin, thus ruling out a constructional or structural topographic high; and (3) two flows overlying the Cohassett flow are thicker in the southeastern portion of the map area, indicating the presence of a topographic low in that area during emplacement of the two flows over the Cohassett flow.

It is agreed that a detailed understanding of stratigraphic continuity requires a knowledge of structural features in the area. The cross section presented in Figure 3-8 of the Draft Environmental Assessment was intended to be a generalization of stratigraphic relationships and correlations within the reference repository location. At the scale at which this cross section is presented, the faults of Cochran (1982) could not be realistically displayed. Because Figure 3-8 of the Draft Environmental Assessment was intended primarily to display stratigraphic relationships, the extension of the cross section onto the Yakima Ridge and Dry Creek is not required. This portion of the figure has been deleted in the final Environmental Assessment.

The northwest-trending fault discussed in Subsection 3.2.3.5 of the Draft Environmental Assessment was postulated to be present at the end of the Yakima Ridge by Myers, Price et al. (1979, pp. 111 through 142). The reference has been added to the final Environmental Assessment.

The Draft Environmental Assessment was not inconsistent with the most current published information on the thickest section of Wanapum Basalt in the central Pasco Basin. Reidel et al. (1980) indicated that the thickest section may lie below Rattlesnake Mountain. An updated report by Reidel and Fecht (1981) stated the thickest section of Wanapum Basalt is found in the central area of the Cold Creek syncline.

Vents for the Frenchman Springs Member are present slightly east of Wallula Gap in the central Columbia Plateau; therefore, the vents should have been described in Subsection 3.2.2.2 of the Draft Environmental Assessment as present on the east half rather than the east side of the plateau. The correction has been made in the final Environmental Assessment.

Core from cored boreholes is geologically logged before sampling is authorized. Logging involves measurement and description of the core for determination of engineering, lithologic, and discontinuity properties. It then may be selectively sampled for remnant paleomagnetism, whole-rock chemical analysis, and determination of physical properties. Core log pages are individually reviewed for technical accuracy by another geologist and an immediate manager or delegate. Adherence to logging procedures is routinely audited by Rockwell Hanford Operations quality assurance staff. Audits have also been performed by staff of the U.S. Department of Energy-Richland Operations Office and by U.S. Nuclear Regulatory Commission study groups. Data contained in the logs are entered into a central computer data file and may be accessed (but not changed) by users. After completion of a borehole, the original logs are filed and copies forwarded to the Basalt Waste Isolation Project Records Management Center.

Core sampled for whole-rock chemical analysis and remnant paleomagnetism is analyzed by subcontractor laboratories with established internal quality assurance programs. Results are reviewed by Basalt Waste Isolation Project technical staff, then compiled and issued as data packages. Data package issuance requires both peer technical and management review of the data. Information contained in data packages is available to data users as needed. Examples of data packages issued to date include reports written by Landon (1984) and Cross (1983). Core sampled for physical property determinations is analyzed in the Basalt Waste Isolation Project Basalt Materials Research Laboratory at 2101M, 200 East Area on the Hanford Site. Results are reviewed by Basalt Waste Isolation Project technical staff and issued through the Rockwell Hanford Operations controlled-documentation system as analytical reports or as experiment reports for use as supporting documents.

Basalts exposed at the surface are generally analogous to those at depth and are used for studies of intraflow structure, cooling fractures, and secondary fractures. Fractures at depth, however, are largely filled with secondary minerals, which results in the relatively low hydraulic conductivity of interiors of basalt flows beneath the Hanford Site. Fractures at the surface typically are enlarged by weathering, resulting in unstable rock conditions and the development of talus slopes below basaltic cliffs. Implications of these subsurface features were discussed extensively in Subsections 3.3.2.1 and 6.3.3.2 of the Draft Environmental Assessment. Long and Woodward-Clyde Consultants (Long and WCC, 1984, p. I-69) recognized that fracture abundance measured in core samples (from vertical boreholes) may be lower than fracture abundance measured from horizontal traverses at outcrop. They suggested that the fracture abundances are lower in core samples because of core orientation approximately parallel to the dominant fracture direction. In addition, the more narrow fractures may be more visible at outcrop due to accentuation by weathering. Statements concerning cooling fracture characteristics have been clarified in Subsection 2.1.1 of the final Environmental Assessment.

The cited Figure 6-9 of the Draft Environmental Assessment is a comparison of candidate flow dense interior thicknesses (Group II data for mean thickness values). The numerical values for Group II data (7 samples) used in Figure 6-9 to represent mean thickness of the Cohassett flow below the vesicular zone were given in Table 6-13 as 43.04 meters with a standard deviation of 4.54 instead of 11. The calculated (at 95 percent confidence) thickness below the vesicular zone was given as 34.22 meters with a student's t value of 1.943 (see Fig. 6-8 of the Draft Environmental Assessment). The 11-meter value apparently was taken from the sample mean thickness value of 61.59 meters for Group I data (17 samples) for the Cohassett flow interior below the flow top (see Table 6-13 of the Draft Environmental Assessment). Figure 6-9 of the Draft Environmental Assessment has been deleted from the final Environmental Assessment.

The U.S. Department of Energy does not consider the geology of the reference repository location too complex to be adequately characterized. Current geologic investigative methods and techniques have been proven effective in providing data and information necessary for the geologic evaluation of the Hanford Site and are expected to continue to be effective during site characterization, should the reference repository location be selected for this activity.

Methods to identify and deal with possible leachate infiltration were discussed in Subsection 4.2.1.2.1 of the Draft Environmental Assessment.

Three-dimensional studies of selected groups of earthquakes are under way to identify any relationship between seismicity and surface or subsurface folds and faults. Before additional studies are initiated, all greater Pasco Basin earthquakes will be relocated using the new velocity model obtained from the U.S. Department of Energy-U.S. Geological Survey refraction survey (Rohay et al., 1985).

Soil conditions were not considered in the Draft Environmental Assessment because they do not pose a threat to the construction, operation, closure, and isolation capability of a geologic repository in basalt. Soil conditions are considered adequate and are not expected to be a problem when constructing repository surface facilities, based on construction experience of other types of surface facilities in the 200 West Area in the reference repository location. The geomorphic and climatic controls on soil development and the long-term potential for wind and water erosion of soils were discussed in the Draft Environmental Assessment under Subsections 6.3.1.4 (Climatic changes) and 6.3.1.5 (Erosion).

The Draft Environmental Assessment devoted a total of 41 pages to the topic of tectonics of the Pasco Basin and surrounding areas. These discussions were included on the following pages of the Draft Environmental Assessment: 2-9 through 2-18, 3-45 through 3-56, 6-126 through 6-137, and 6-209 through 6-214.

Subsection 2.1.1.1 of the Draft Environmental Assessment was intended to serve as a general introductory section to the subject of suprabasalt sedimentary units in the Pasco Basin. A more detailed discussion of the stratigraphy and distribution of suprabasalt sediments was presented in Section 3.2.2 of the Draft Environmental Assessment.

There is no evidence to suggest that past continental glaciations have approached closer than 130 kilometers (80 miles) north of the Hanford Site. Even if at some future date a continental ice sheet did extend to the Hanford Site, baselevel control would prevent an ice sheet from scouring more than approximately 100 meters (328 feet) deep.

Land forms may be classified in several different ways. Figure 3-4 in the Draft Environmental Assessment represented only one classification scheme, based solely on differences in slope. No genetic interpretation of the underlying rock units was intended or provided using this method. An alternative type of land form classification that does differentiate rock unit types within the reference repository location was included in Figure 3-5 of the Draft Environmental Assessment.

The last major catastrophic flood deposits are dated at approximately 13,000 years before present as stated in Subsection 2.1.1.1 of the Draft Environmental Assessment.

The U.S. Department of Energy agrees that the drilling of the exploratory shafts and the possible construction of a deep geologic repository at the Hanford Site would constitute a geologic disturbance. However, as is the case with any mine construction, the disturbed area would be confined to the immediate mining operation site and would have no adverse impact on the "natural rock composition and structure" of the surrounding area.

It is true that during the Neogene, the course of the Columbia River changed in response to continuing tectonic deformation and in response to major volcanic episodes in the Cascade Range (Fecht et al., 1985; Tolan and Beeson, 1984). However, it is unlikely that similar events would occur during the lifetime of the repository (Johnpeer et al., 1981).

7 0 1 6 8 1 9 7 0

The Elephant Mountain flow was encountered in each borehole drilled in the area shown in Figure 2-27 of the Draft Environmental Assessment (except boreholes in the extreme northwest corner). This map was used in the site-selection process. Since site selection, additional boreholes have been drilled (see Fig. 3-7), which show that in the extreme northwest corner of the map the Elephant Mountain flow is absent and the Pomona flow is the uppermost flow of the basalt sequence. Therefore, the extreme northwest corner of the area represented in Figure 2-27 does not represent a true structural surface.

The statement that treatment of the three major formations is inconsistent in terms of time of emplacement, distribution, and thickness of units is unclear. The purpose of the stratigraphy discussions in the Draft Environmental Assessment was to present a broad overview of the stratigraphy of the Columbia Plateau.

The U.S. Department of Energy does not assume that the thickness of the flow interior of the proposed candidate horizons remains a constant thickness over a 3.2-square-kilometer (2-square-mile) area in the reference repository location, and this was not stated in the Draft Environmental Assessment. It was stated that there are dense-interior thickness variations with lateral position. It was further stated that there is sufficient thickness of dense rock in the Cohassett flow to provide significant design flexibility, and that sufficient lateral extent is apparent. Thus, while thickness variations exist, those variations are interpreted to not reduce the amount of available flow interior to a thickness unsuitable for repository emplacement. There was no discussion of anisotropy. Although such determinations have not been undertaken via geostatistics to date, geostatistical analysis is being considered if the reference repository location is recommended for site characterization. These analyses should provide some information on anisotropic conditions of Cohassett flow interior thicknesses in the reference repository location. However, anisotropy does not imply reduction of flow interior thickness to unacceptable limits.

No "channels" or "caverns" of the nature described have been observed or encountered within or between any basalt flows in or near the Pasco Basin. The occurrence of such features with any lateral extent seems highly unlikely given the emplacement history of the basalts in the Pasco Basin. The U.S. Department of Energy is not aware of any Columbia Plateau basalt flow named the "Cave Flow."

Figure 3-8 was presented in the Draft Environmental Assessment as a means of showing general structural setting and relationships among the candidate horizons and overlying formations. The figure was not intended to present details of the structure or stratigraphy of a particular basalt flow or formation, and the scale of the figure precluded any such presentation. Although a large number of boreholes have been drilled at the Hanford Site over the years, only approximately 20 boreholes penetrate to candidate horizon depths to provide information about the Grande Ronde Basalt. Approximately 9 of those 20 boreholes are located in or near the reference repository location. A cross section in any direction through the reference repository location would incorporate only three or four of the nine boreholes.

Features such as flow top breccia, vesicular zones, pillow palagonite zones, spiracles, faults, and shear zones have been observed in Columbia River basalts, including the Grande Ronde Basalt, and are discussed in numerous references. In particular, Myers and Price (1981) discuss the occurrence of such features.

Tiers of colonnade and entablature present in some candidate horizons do not necessarily relate to features of increased porosity such as spiracles, flow-top breccia, pillow zones, or vesicular zones. Although tiers cannot be readily correlated from borehole to borehole, features of increased porosity are generally recognizable within boreholes.

A report by the U.S. Department of Energy (DOE, 1984a) defines an active fault as "a fault along which there is recurrent movement, which is usually indicated by small, periodic displacements or seismic activity." In the Basalt Waste Isolation Project, the term active fault has been applied to faults with displacements of Quaternary age.

The reference repository location was named by the U.S. Department of Energy-Richland Operations Office during siting investigation, and the name has been used for the preferred site on the Columbia Plateau. It is not known why similar names were not adopted at the other sites.

C.4.1.2 Hydrologic conditions

This subsection contains responses to comments received on the ground-water and surface-water discussions in Chapters 2 and 3 of the Draft Environmental Assessment. Topics are divided into the following subsections:

- C.4.1.2.1, Surface water.
- C.4.1.2.2, Ground water.

C.4.1.2.1 Surface water

This subsection addresses comments received on the surface-water discussions in Chapters 2 and 3 of the Draft Environmental Assessment. These comments are divided into four basic categories:

- C.4.1.2.1.1, Flash flooding.
- C.4.1.2.1.2, Dam failure.
- C.4.1.2.1.3, Characterization activities.
- C.4.1.2.1.4, Miscellaneous.

C.4.1.2.1.1 Flash flooding

Flash-flood potential along the Cold Creek watershed (see Subsection 3.3.1.3.5 of the Draft Environmental Assessment) was the subject of several comments. One commenter asked why worst-case factors were not used in the analysis of flood potential along Cold Creek. Another questioned parameters used to determine the probable maximum flood and discussed the consequences of not understanding these parameters. This same commenter noted that Executive Order 11988 (ANS, 1981) concerning "Floodplain Management" had not been addressed. One commenter also suggested Table 6-2 (see p. 6-30 of the Draft Environmental Assessment) was in error since a flood plain may be modified. Another stated that the flash flood section should be expanded. One commenter wanted to see a larger scale map of the probable maximum flood area for Cold Creek and a discussion of flooding impact on drilling operations.

Response

The probable maximum flood, discussed in Subsection 3.3.1.3.5 of the Draft Environmental Assessment, described the worst-case basis for design purposes, in accordance with U.S. Nuclear Regulatory Commission Regulatory Guide 1.59 (NRC, 1977). This probable maximum flood is based on the best available information and may or may not be sufficient for the accurate estimate of the probable maximum flood required for an environmental impact statement. Because uncertainty exists in present analyses, a plan to produce a more detailed survey of Cold Creek watershed characteristics will be included in the site-characterization plan, should the reference repository location be recommended for further study.

Executive Order 11988 (ANS, 1981) defines flood plain as " . . . the lowland and relatively flat areas adjoining inland and coastal waters including flood prone areas of offshore islands, including at a minimum, that area subject to a one percent or greater chance of flooding in any given year (p. 728)." This is interpreted to be the 100-year flood. Skaggs and Walters (1981, p. 34) indicated the peak stage for the 100-year event is approximately 1.2 meters (4 feet) above the valley floor at valley mile 15.54 of Cold Creek. This corresponds to an elevation of approximately 191 meters (626 feet). The lowest elevation of the nearest surface facilities is approximately 195 meters (640 feet) (compare Fig. 3-7 and Fig. 3-31 of the Draft Environmental Assessment). Skaggs and Walters (1981, p. 33) state: "This rough approximation shows that at the lowest point of the reference repository location surface relative to flow depth, flooding depths of 5 feet will occur on the average once in every 200 years." Surface facilities are not planned within the flood plain as defined by Executive Order 11988 (ANS, 1981).

The effects of flooding on any drilling and exploratory shaft operation would be basically the same as the effects on repository surface operations: temporary service disruption, rerouting of traffic, and work schedule slips. Subsection 6.3.3.3 of the Draft Environmental Assessment briefly addressed surface-water systems that potentially could cause flooding of the repository area. Details supporting known flood characteristics of the Cold Creek Valley are found in Skaggs and Walters (1981), which was referenced in Chapter 3 of the Draft Environmental Assessment. As noted below, additional studies are planned to examine more closely the drainage and watershed characteristics of the Cold Creek Valley.

A new sentence has been added to Subsection 3.3.1.3.5 of the final Environmental Assessment to define the term "probable maximum flood." This term has also been added to the glossary. The American Nuclear Society (ANS, 1981) report has also been included in the reference list. Also, a new Subsection 4.1.1.7 has been added to the final Environmental Assessment acknowledging the need for additional flood studies in the Cold Creek Valley.

C.4.1.2.1.2 Dam failure

Issue

Several comments concerning the adequacy of using a 50-percent breach of Grand Coulee Dam referred to Subsection 3.3.1.3.3 of the Draft Environmental Assessment. Many commenters requested justification for use of a 50-percent breach and (or) a reevaluation of the original U.S. Army Corps of Engineers study. One commenter asked if failure of Grand Coulee Dam was accompanied by other dam failures, another if the referenced dam failure studies were consistent with commercial power reactor studies along the Columbia River. One commenter recommended that a 100-percent failure scenario be considered as more representative of the probable maximum flood.

Response

The use of a 50-percent breach of Grand Coulee Dam appears to be a valid assumption. The U.S. Army Corps of Engineers (COE, 1951) study was based on breaches of Grand Coulee Dam caused by "nominal atomic bomb" hits. A 50-percent breach was used for the maximum conceivable event. This original study has been reevaluated during the past 35 years, with one of the more recent analyses found in a report by the U.S. Energy Research and Development Administration (ERDA, 1976). This report noted that from 1951 through 1967 similar studies on the subject of a Grand Coulee Dam breach were performed by the U.S. Army Corps of Engineers and by New York University. The New York University study essentially confirmed the U.S. Army Corps of Engineers 1951 results. According to the U.S. Energy Research and Development Administration (ERDA, 1976), the U.S. Army Corps of Engineers published a January 1968 report essentially confirming the results of the 1951 study.

The U.S. Energy Research and Development Administration (ERDA, 1976) states, "It has been concluded in various studies that the damage to Grand Coulee under conditions judged to be conservatively severe would not be sufficient to cause a flow of greater than the 1,440,000 cfs Probable Maximum Flood (p. 11)." These conditions include seismic events causing failure of the dam. The flooded area for such a probable maximum flood event was shown in Figure 3-29 (p. 3-64) of the Draft Environmental Assessment. In addition, the Skagit-Hanford Nuclear Project Preliminary

Safety Analysis Report (PSPL, 1981) presented an upper limit to seismically induced failure that is represented by a flow of 150,000 cubic meters per second (5,370,000 cubic feet per second). This is approximately the same as a 25-percent breach scenario flow rate. Thus, the value for the 50-percent breach appears to be the largest realistically conceivable flow that requires analysis. This breach of Grand Coulee Dam is accompanied by concomitant failure of downstream dams.

Subsection 3.3.1.3.3 of the final Environmental Assessment has been expanded to state that the 50-percent scenario is believed to represent the largest realistically conceived flow resulting from a dam breach.

C.4.1.2.1.3 Characterization activities

Issue

Several comments included requests for additional surface-water data in the final Environmental Assessment. Most commenters questioned the adequacy of surface-water data base coverage. More information was requested on such items as Columbia River monthly flows, high and low flow analyses, water quality, and sedimentation, plus surface-water monitoring in the ephemeral Cold and Dry Creeks located west of the reference repository location. One commenter recommended a more detailed evaluation of ground-water and river-water exchanges so as to reduce the present "error band" regarding fluid exchange between surface and subsurface systems. One of the previously noted commenters also suggested further study of the soil and water infiltration characteristics of the Cold Creek drainage system as evaluated by Skaggs and Walters (1981).

Response

Understanding the characteristics and dynamics of surface-water systems was recognized in the Draft Environmental Assessment as an important factor. This is particularly true since ground-water discharge to surface waters can be a primary means for radionuclide transport off the Hanford Site. For this reason, the U.S. Environmental Protection Agency (EPA, 1985) specified strict control over radionuclide releases to the accessible environment at a close distance (5 kilometers (3 miles)) from the boundary of the repository.

In the Draft Environmental Assessment, 18 pages (2-18 through 2-21 and 3-57 through 3-72) were devoted to regional and site-specific surface-water discussions. While this discussion is brief compared to the length usually dedicated to an environmental impact statement, it is considered sufficient to meet the requirements of an environmental assessment as specified under the Nuclear Waste Policy Act of 1982. Additional surface-water studies are planned for the reference repository location and Hanford Site vicinity, and results would be included in the draft environmental impact statement issued should the Hanford Site be recommended for site characterization.

Section 4.1 of the Draft Environmental Assessment identified those site-characterization activities (e.g., borehole drilling, water discharges from pumping tests, and exploratory shaft construction) that might result in an environmental impact. These potential impacts were discussed in Section 4.2. Not all site-characterization activities (e.g., surface-water baseline monitoring) are expected to affect the environment. Nonetheless, an additional section will be added to Chapter 4 to identify surface hydrologic studies as part of the required characterization activities. Detailed plans will be identified in the site-characterization plan to be published if the reference repository location is recommended for further study. A summary of local river flow characteristics (e.g., discharges, water quality) can be found in the site-characterization report (DOE, 1982) referenced in the Draft Environmental Assessment.

A new subsection (4.1.1.7) has been added to the final Environmental Assessment acknowledging future surface-water hydrology characterization needs. Surface-water hydrology also is identified in Section 4.1.1 as an area for future work.

C.4.1.2.1.4 Miscellaneous

The following surface-water comments are discussed in this subsection because they are generally unrelated to other Subsection C.4.1.2.1 issues and (or) they require individual discussion due to the topic raised.

Issue: Figure 2-13 reference

One commenter suggested that Figure 2-13 would be a better reference than Figure 3-23 for the Yakima Reservoir discussion in Subsection 3.3.1.3.2 of the Draft Environmental Assessment.

Response

It is agreed that Figure 2-13 would be a better reference. This figure reference has been changed in Section 3.3.1.3.2 of the final Environmental Assessment.

Issue: Columbia River identification

One commenter noted that a portion of the Columbia River was misidentified in Figure 2-12 of the Draft Environmental Assessment and that the Flathead River should be connected to the Clark Fork.

Response

Figure 2-12 of the Draft Environmental Assessment misidentified a portion of the Columbia River. The Columbia and Flathead Rivers have been correctly identified in the final Environmental Assessment.

Issue: Landslide blockage of Columbia River

One commenter noted that landslides might occur northeast and east of the repository site and could cause temporary blockage of the Columbia River. Two additional sentences to page 3-61 of the Draft Environmental Assessment were suggested to note this point.

Response

The topic of landslide blockage along the Columbia River was addressed in Subsection 3.3.1.3 of the Draft Environmental Assessment. The existing text accommodates the thought offered.

Issue: Priest Rapids Dam flood-regulating capability

One commenter stated that the last sentence in paragraph 1 of Subsection 3.3.1.3.1 of the Draft Environmental Assessment incorrectly implied that Priest Rapids Dam has major flood-regulating capability. A suggested rewording was offered.

Response

It is agreed that Priest Rapids Dam has minimal flood-control-regulating capability. Subsection 3.3.1.3.1 of the final Environmental Assessment has been reworded to correctly state the flood-control capability of Priest Rapids Dam.

Issue: Yakima River flood discharge estimates for 1933

One commenter identified what appeared to be an inconsistency in the December 1933 Yakima River flood discharge estimates noted on page 3-61 (see Subsection 3.3.1.3.2 of the Draft Environmental Assessment). In paragraph 1, flood discharge was estimated to be 1,900 cubic meters (67,000 cubic feet) per second, and paragraph 2 stated 1,500 cubic meters (54,000 cubic feet) per second.

Response

The discharge measurement point for the first paragraph was Kiona, Washington and for the second paragraph measurement was Yakima, Washington. (Kiona is downstream from Yakima; therefore, river discharge at that point is greater.) This distinction was not made in the Draft Environmental Assessment. Subsection 3.3.1.3.2, paragraph 2, of the final Environmental Assessment has been reworded to identify Kiona, Washington, as the discharge measurement point.

Issue: Acknowledgment of manmade waterways

One commenter stated that five manmade waterways constructed in the Pasco Basin for water importation should have been acknowledged in Subsection 3.3.1.1, paragraph 2 of the Draft Environmental Assessment, because application of irrigation water has significantly affected local ground-water recharge. The commenter also stated " . . . to ignore the consequences of this importation results in a misrepresentation of the facts."

Response

The surface-water discussion in Subsection 3.3.1.1 referred to natural drainage systems and, as such, the paragraph in question was correct. The commenter is referred to Subsection 3.3.1.5, which addressed the topic of surface-water resource development and potential within the Pasco Basin. In that section, a Bell and Leonhart (1980) report was referenced that gives a detailed overview of the irrigation district boundaries, and the locations of canals, tunnels, siphons, wasteways, and drains for the Columbia Basin project. This report acknowledges the manmade waterways in question.

In regard to the statement concerning ignoring consequences (ground-water recharge) of water importation, the commenter is referred to Subsection 6.3.1.8.9 of the Draft Environmental Assessment. Here the potential impacts of water withdrawal and discharge were identified, and the potentially adverse condition concerning human activities that could alter the ground-water system was accepted as present at the Hanford Site. Therefore, the facts of water importation and potential impact were represented in the Draft Environmental Assessment.

Subsection 3.3.1.1 of the final Environmental Assessment has been reworded to identify the perennial streams as naturally occurring. A statement also was added acknowledging the manmade waterways addressed in Bell and Leonhart (1980).

Issue: Flooding and site suitability

One commenter suggested that flooding could result in water pollution, making the Hanford Site unsuitable for the proposed repository.

Response

While it is true that the potential for flash flooding exists, such flooding is not expected to make the Hanford Site unsuitable for a proposed repository. Section 3.3.1.3 (Surface flooding potential) and Subsections 6.3.3.1.5 (Potentially adverse condition under Preclosure surface characteristics) and 6.3.3.3.4 (second favorable condition under Preclosure hydrology) addressed the potential for flooding of the reference repository location. As stated in the referenced section and subsections, there is no potential for reference repository location flooding from dam failure or natural floods along the Columbia River. A temporary flash flood from the Cold Creek watershed might reach the surface facilities under probable maximum flood conditions. If such an event occurred, waste shipments would be curtailed and those casks or waste containers at the repository receiving facilities would be secured to a safe, above-water location. It is also important to recognize that wastes at the receiving location are protected by multiple barriers: the waste form is surrounded by a container that is, on receipt, enclosed within a shipping cask. These barriers should afford safe waste handling in the repository and movement, if necessary, to a safer location in case of a nonroutine (e.g., flooding) event. Thus, a flash flood is not expected to result in an increased radiation risk to man or the environment.

Issue: Dam failure and resultant flow rates

One commenter stated that the Draft Environmental Assessment did not address dam failure above the Hanford Site, or resultant flow rates.

Response

Potential flooding along the Columbia River was addressed in Section 3.3.1.3 (Surface flooding potential) of the Draft Environmental Assessment and included discussions of and references to dam failures upstream from the Hanford Site, plus resultant flow rates.

Issue: Two recent references on flooding

It was suggested that two more recent dam failure and probable maximum flood studies be substituted for the 1951 U.S. Army Corps of Engineers study (COE, 1951) referenced in the Draft Environmental Assessment. The references suggested by the commenter are the following:

COE (U.S. Army Corps of Engineers), 1982. Flood Emergency Plan, Chief Joseph Dam, Seattle District, Seattle, Washington.

DOI (U.S. Department of Interior), 1982. Emergency Preparedness Brief with Inundation Maps from Standard Operating Procedures, Grand Coulee Dam, Bureau of Reclamation, Pacific Northwest Regional Office, Boise, Idaho.

Response

The U.S. Department of Energy has reviewed the two referenced documents (COE, 1982; DOI, 1982) and has concluded that these studies do not add substantially new information beyond that contained in the original 1951 U.S. Army Corps of Engineers report.

The first reference noted above provides inundation maps for ". . . conditions of an extreme nature with essentially no probability of occurring. The flooding conditions shown on the maps represent the results of the occurrence of a spillway design flood (probable maximum flood) with and without a hypothetical dam failure." (p. 2). However, the extent of dam failure is not quantified in the reference. Examination of the inundation maps indicates that the flood area associated with all conditions is smaller than that shown on Figure 3-30 of the Draft Environmental Assessment.

The second reference presents inundation maps ". . . in the event of a very severe natural flood on the watershed which would require using most of the spillway capacity to safely pass the flood at Grand Coulee Dam" (p. 3). The inundation maps also indicate flood areas for a "sudden failure of Grand Coulee Dam." This "failure" is not quantified in the reference. Examination of the maps reveals that the flooded area appears less extensive than that shown in Figure 3-30 of the Draft Environmental Assessment.

It is concluded that Figure 3-30, based on 1951 data, is a more severe scenario than the two suggested substitutes and is adequate for flood potential estimates along the Columbia River.

Issue: Impact of flash flood

One commenter inquired about the expected impact a flash flood of Cold Creek would have on the repository.

Response

The impact expected is that of temporary curtailment of waste receipt and handling at the surface facility. Since the waste itself is in a low solubility waste form surrounded by a container and shipping cask, additional handling of these materials to remove them from a flooded area is not expected to result in any nonroutine radiation risk. The underground facilities would not be affected by a shallow flash flood, and underground shaft entrances would be protected from surface-water entry.

Issue: Flood impact of proposed Ben Franklin Dam

One commenter asked about flooding impact if the proposed Ben Franklin Dam were built.

Response

No formal study on this topic is known to exist; however, available information suggests little or no impact is expected. As discussed in Subsection 3.3.1.3.6 of the Draft Environmental Assessment, the previously proposed Ben Franklin Dam would have been a low-head dam. Reservoir elevation would be approximately 122 meters (400 feet). These backwaters would inundate lands having lower elevations adjacent to Columbia River (see Fig. 3-32 of the Draft Environmental Assessment). Providing the dam held, flood waters from upstream dam failures or a probable maximum flood would be diverted around the dam and would affect the reference repository location where land elevations range between 190 and 245 meters (625 and 800 feet).

Issue: Flooding during preclosure period

One commenter stated there was little mention of the possibility of flooding during the 50- to 60-year period preceding closure.

Response

The potential for flooding during the preclosure period was discussed in Subsections 3.3.1.3.5 (Flash-flood potential within the reference repository location), 6.3.3.1.5 (Preclosure surface characteristics), and

6.3.3.3.4 (Favorable condition under Preclosure hydrology) of the Draft Environmental Assessment. Each subsection referenced the 100-year flash-flood potential of Cold Creek across a portion of the reference repository location. For any one year, a one percent chance exists for such a flood. Therefore, for the 50- to 60-year period preceding closure, a 50 to 60 percent possibility exists for a 100-year flash flood. The flash-flood potential of Cold Creek is detailed by Skaggs and Walters (1981). The Draft Environmental Assessment also noted that the reference repository location lies above the flood plain of the Columbia and Yakima Rivers (see Subsections 3.3.1.3.1, 3.3.1.3.2, and 3.3.1.3.3).

Additional studies of the flash-flood potential of Cold Creek are needed. This has been mentioned in a new subsection (4.1.1.7) added to the final Environmental Assessment.

Issue: Failure of Grand Coulee Dam

One commenter stated that Grand Coulee Dam could be destroyed by a natural seismic event or by the explosion of a nuclear device. Should this occur, the commenter believes that all other Columbia River dams would be breached and the Hanford Site would be "scoured to bedrock, before being filled with debris."

Response

The failure of Grand Coulee Dam as a result of natural or man-induced events (including a nuclear detonation) and concomitant failure of downstream dams has been examined. The resultant flooding was discussed in Section 3.3.1 (Flood potential) of the Draft Environmental Assessment. The reference repository location lies above the level of such a potential flood, as does most of the Hanford Site; thus, the belief that the Hanford Site would be eroded to bedrock is incorrect. In fact, the reference repository location has been an area of sediment deposition for the last several million years, including that from the Lake Missoula flood event of 13,000 years ago. For additional information see Subsection C.4.1.2.1.2.

C.4.1.2.2 Ground water

This subsection addresses comments received on the ground-water discussions in Chapters 2 and 3 of the Draft Environmental Assessment. These comments are divided into five basic categories:

- C.4.1.2.2.1, Flow patterns.
- C.4.1.2.2.2, Hydraulic information.
- C.4.1.2.2.3, Hydrochemistry.
- C.4.1.2.2.4, Characterization activities.
- C.4.1.2.2.5, Miscellaneous.

C.4.1.2.2.1 <u>Flow patterns</u>

Comments on ground-water flow patterns are divided into the following issues, which are individually addressed:

- Large-scale ground-water flow patterns.
- Quasi-rectilinear ground-water flow and vertical versus horizontal hydraulic conductivity.
- Illustration of hydraulic head relationships.
- Ground-water discharge.
- Vertical ground-water flux.
- Accuracy and use of hydraulic head data.
- Hydraulic head changes.
- Treatment of vertical ground-water flow.
- Potentiometric surfaces in Figures 2-15 and 2-16.
- Definition of a slight vertical hydraulic head gradient.
- Ground-water discharge areas.

<u>Issue</u>: Large-scale ground-water flow patterns

Ground-water flow patterns as discussed in Chapters 2 and 3 of the Draft Environmental Assessment was the subject of numerous comments covering a range of topics including flow directions, lateral and vertical head gradients, ground-water recharge and discharge, reconnaissance-collected hydraulic head data, and specifics in referenced text pages and figures.

A few commenters questioned the supposition that within the reference repository location in the lower Cold Creek syncline, areal ground-water flow directions roughly conform to directions of bedrock dip. The commenter asserted that such a general supposition is an oversimplification and disregards three-dimensional aspects of ground-water flow. Ground-water flow does not have to follow bedrock dip directions and flow is determined by hydraulic gradient.

<u>Response</u>

Hydraulic head elevations are recognized as being the sum of two components: the elevation of the point of head measurement and the pressure head. In the Columbia Plateau, the combination of these two components creates a three-dimensional flow system in which ground water moves from high to low head and rock elevations.

7 0 1 6 8 1 9 8 2

It has been well established (Freeze and Witherspoon, 1967) that water-table configuration (surface topography) and subsurface permeability variations account for regionally developed patterns of steady groundwater flow. Upland areas are principal sites of recharge and lowland areas are principal discharge sites. Ground water flows from the former to the latter. In the Pasco Basin, a close relationship exists between surface topography and subsurface structure. Ridges in the western portion of the basin are formed by anticlines, valleys are formed by synclines. The general surface slope toward the Columbia River in the eastern portion of the Pasco Basin is underlain by a westward-dipping monocline. As a general rule, this correspondence between surface topography and layered basalt flow structure is also thought to identify approximate areal ground-water flow directions since higher rock elevations indicate recharge areas. Tanaka et al. (1979) present structure contour and water-level maps illustrating the general correspondence between structural dip and hydraulic gradient directions in the area of the Pasco Basin and across a large area of the State of Washington portion of the Columbia Plateau.

To say that areal patterns of ground-water flow in the deep basalts within the reference repository location may generally conform to large-scale bedrock structural configuration (and surface topography) is not an over-simplification, although it is a simplification. Such simplifications are commonly used to provide models that can be tested with available and (or) new information. (It is expected that local variations to this broad conceptualization exist.) Also, to state that a relationship between areal ground-water flow directions and subsurface structural configuration apparently exists does not deny that vertical flow within and between hydrogeologic units also occurs.

Areal ground-water flow does not necessarily follow bedrock dip; however, barring extreme areal anisotropy, it seems likely that ground-water flows would generally follow bedrock dip where surface topography strongly and directly reflects subsurface structure. Therefore, hydraulic heads (determined by the sum of an elevation and pressure component) will generally follow the direction of topographic slope. This concept is consistent with ground-water movement occurring from highlands surrounding the Columbia Plateau to the central lowlands. Basalt bedrock also slopes inward toward the central lowlands of the plateau.

To clarify the discussion on ground-water flow patterns and bedrock dip, the last sentence of the first bulleted item on page 3-79 (Section 3.3.2) of the Draft Environmental Assessment has been reworded and new sentences added.

Issue: Quasi-rectilinear ground-water flow and vertical versus horizontal hydraulic conductivity

Several commenters asserted that the concept of quasi-rectilinear flow, with largely horizontal ground-water flow in interflow zones and vertical ground-water flow in basalt flow interiors, is not supported by available data; that flow must be considered three-dimensional; and that horizontal and vertical permeabilities of flow interiors are nearly identical.

Response

The concept of three-dimensional flow, recharge-discharge relationships, and accompanying data and conceptualization uncertainty was acknowledged throughout the Draft Environmental Assessment (e.g., see Sections 2.1.4 and 3.3.2 and Subsections 3.3.2.2 and 6.3.1.1.6).

Available estimates of horizontal hydraulic conductivity in basalt interflow zones and flow interiors (e.g., Strait and Spane, 1984; Strait and Mercer, 1984) indicate that contrasts in hydraulic conductivity between the two types of intra-units are typically greater than two orders of magnitude. As the hydraulic conductivity ratio between near-horizontal layered units increases, the vertical upward or downward flow through an overlying low-permeability layer becomes more pronounced (Freeze and Witherspoon, 1967). In near-horizontal, layered aquifer-aquitard systems with hydraulic conductivity contrasts greater than approximately two orders of magnitude, flow patterns become almost rectilinear, with horizontal flow in the aquifers and vertical flow across the aquitards (Freeze and Cherry, 1979).

The U.S. Department of Energy agrees that the overall aspects of regional ground-water flow in the basalt sequence are three-dimensional because ultimately flow paths must descend from recharge areas, follow flow paths in the basin, and ascend to discharge areas. However, in layered rock with large hydraulic conductivity contrast between layers, descending and ascending flow will follow alternating near-horizontal and near-vertical paths. The strong conductivity contrasts ensure that marked refraction of flow (change in flow direction) will occur across unit boundaries. Only in homogeneous, isotropic material would one expect smoothly curvilinear flow paths from recharge areas to discharge areas in a regional ground-water flow system. The basalt sequence is clearly not homogeneous and the U.S. Department of Energy believes it is anisotropic in areal hydraulic property distribution.

Planned hydraulic testing using multiple wells is designed to measure the vertical hydraulic conductivity of flow interiors for comparison with single-hole estimates of horizontal conductivity. Because no really definitive information on vertical-horizontal conductivity contrasts in flow interiors at the Hanford Site (or Columbia Plateau) presently exists, the U.S. Department of Energy and others can only speculate within reasonable bounds based on available information.

The hydraulic head discussions in Section 3.3.2 of the final Environmental Assessment have been expanded to indicate new head data and to include tables on vertical and horizontal hydraulic gradients.

Issue: Illustration of hydraulic head relationships

Two commenters stated that illustrations of the head relationships discussed on page 3-80 of the Draft Environmental Assessment would be useful.

Response

It is agreed that a series of potentiometric maps illustrating head relationships would be helpful; however, other than for the Mabton interbed (DOE, 1982) and unconfined aquifer, such maps are not available, although they are planned for future publication. Therefore, a general text discussion is considered best at this time. Refer to issue on comparison of drill-and-test hydraulic heads with head values measured in new piezometers, under Subsection C.5.1.1 of this appendix, for a discussion of and maps showing hydraulic head values for individual stratigraphic units within the Wanapum and Grande Ronde Basalts. Potentiometric maps are not drawn, because data are considered too sparce.

The head relationships for individual wells discussed on page 3-80 of the Draft Environmental Assessment were illustrated in the references cited (Swanson and Leventhal, 1984; Swanson and Wilcox, 1985), which contain hydrographs over periods of several years for a number of boreholes and wells monitored on the Hanford Site.

The hydraulic head discussions in Section 3.3.2 of the final Environmental Assessment have been expanded to indicate new head data and to include several tables on vertical and horizontal hydraulic gradients.

Issue: Ground-water discharge

One commenter pointed out that in one context it was stated, "Ground-water drainage is to the Columbia River or its tributaries," and in another, the statement "the discharge area(s) for deep ground waters remains uncertain" is made. The reviewer asks which statement is correct.

Response

Both statements are correct in the context that they are used. The statement that "Ground-water drainage is to the Columbia River or its tributaries" (see Subsection 1.3.2.2 of the Draft Envrionmental Assessment) was made in the context of a discussion of the overall geohydrologic setting of the Hanford Site. In the overall geohydrologic setting of the Columbia Plateau, it generally is agreed that ground water drains ultimately to the Columbia River or its major tributaries. However, not all reaches of major streams may receive ground-water discharge. Some reaches may be losing water to the ground-water system. Therefore, on a local basis, one must begin to refine the interrelation between surface-water and ground-water flow to identify the places where ground water is discharged. The statement that "The discharge area(s) for deep ground waters remains uncertain" (see Section 3.3.2, p. 3-78 of the Draft Environmental Assessment) referred to a more local view, in the Hanford Site vicinity, where details of ground-water and surface-water interaction have yet to be explained. Thus, in the context of the above discussion, both statements are correct.

Issue: Vertical ground-water flux

Vertical head gradients across the basalt section would assist in estimating the vertical flux through the section, between shallow and deep basalt units, according to one commenter. Small vertical flow rates per unit area over large areas may be as important as large recharge rates over small outcrop areas, and both flow possibilities should be considered in gaining an understanding of the geohydrology of the Columbia River basalts.

Response

The commenter correctly summarized some of the many considerations to be dealt with in modeling ground-water flow. For example, on page 3-82 of the Draft Environmental Assessment it was stated " . . . it is recognized that over broad regions, ground-water movement (even across basalt flow interiors of apparently low-hydraulic conductivity) can be an important consideration in understanding flow dynamics and geochemical evolution." Measurements currently are being made, and more are planned, to further define vertical head gradients between basalt units of interest. These gradients and other information will be used in the Pasco Basin model to define three-dimensional patterns of ground-water movement. This definition will require development of an understanding of recharge-discharge mechanisms.

Issue: Accuracy and use of hydraulic head data

One commenter stated that the accuracy of hydraulic head measurements taken during the reconnaissance drill-and-test program has been questioned by critics; that one would not expect a constant gradient across the Cold Creek syncline; and that the use of head data alone to determine the amount of water movement, as described in Subsection 3.3.2.1.2 of the Draft Environmental Assessment, is inappropriate.

Response

While it is true that the accuracy of hydraulic head measurements taken during the reconnaissance drill-and-test program has been questioned, measurements recorded during that program have proved consistent with more recent measurements of head using specially constructed, multiple-level piezometers. (Refer to the issue on support of earlier concepts on hydraulic head distributions, under Subsection C.5.1.1 of this appendix, for details.) It is agreed that a constant gradient across the Cold Creek syncline would not be expected; an estimate of the central tendency of the hydraulic gradient in the syncline is given in the referenced paragraph. It is agreed that the use of head data alone to determine the amount of water movement is inappropriate. Such was not done in the Draft Environmental Assessment. Section 3.3.2 of the final Environmental Assessment was expanded to include new head data and tables on vertical and horizontal hydraulic gradients across the Cold Creek syncline.

Issue: Hydraulic head changes

One commenter pointed out that a sharp decrease in head associated with depth in the basalt sequence is the result of local geohydrologic conditions that may include the existence of a confining layer separating shallow and deep zones. Another commenter noted that a rapid water level rise in shallow confined aquifers could result from "vertical transmissivity."

Response

These comments reflect explanations given in Section 2.1.4 and Subsection 2.1.4.2 of the Draft Environmental Assessment for observing head changes with depth. The reviewer's concern that the water level rise is related to leakage is accommodated in the specific sentence reading, "This water-level rise is due to leakage of excess irrigation water from overlying unconfined aquifers across rock formations and probably along well casings and in open boreholes." The Draft Environmental Assessment also pointed out one of the major unknowns in regional geohydrologic studies—the amount of vertical ground-water movement occurring in the hundreds to thousands of irrigation wells open across multiple basalt layers. A related concern involves regional modeling studies and estimates of vertical leakage between flow systems in natural versus manmade conduits. Vertical leakage within open wells can make the basalt flow system appear more vertically permeable than it could be naturally. See issue on hydraulic conductivity measurement in vertical boreholes, under Subsection 4.1.2.2.2 of this appendix, for additional discussion.

Issue: Treatment of vertical ground-water flow

One commenter pointed out that it was stated in the Draft Environmental Assessment that ground-water mixing takes place across different basalt horizons, and evidence for vertical ground-water flow is given. The commenter asserted, "in most of the Environmental Assessment vertical ground-water flow is discounted," and asked how these differences were reconciled.

Response

The commenter was correct in stating that the Draft Environmental Assessment identified vertical ground-water mixing as part of the conceptual model for basalts. This model was well identified and illustrated in Section 3.3.2 and also was addressed in Chapters 2 and 6. The commenter statement that "Yet, in most of the Environmental Assessment vertical ground-water flow is discounted" is not understood in light of geohydrologic discussions in the Draft Environmental Assessment that acknowledge vertical mixing. It is also important to recognize that the system of subhorizontal layered basalt flows, which comprises the domain of most ground water to the depth of a candidate repository horizon at the Hanford Site, is composed of alternating flow interiors of apparently small hydraulic conductivity and interflow zones with small to moderate hydraulic conductivity. The general resistance to flow will be less within the flow tops parallel to the layering of the dense flow interiors than perpendicular to layering within the flow interiors. Hence, ground-water movement will be faster and easier in subhorizontal directions than in vertical directions. This is not to discount vertical ground-water flow, but to say that it is probably subordinate to horizontal flow in interflow zones in terms of speed and flux per unit of flow cross section. Refer to the issue on quasi-rectilinear ground-water flow, under this appendix subsection, for additional discussion.

Section 3.3.2 of the final Environmental Assessment has been expanded to include new hydraulic head and hydrochemical data supporting the concept of ground-water mixing.

Issue: Potentiometric surfaces in Figures 2-15 and 2-16

A few commenters addressed Figures 2-15 and 2-16 in the Draft Environmental Assessment. One commenter stated that Figures 2-15 and 2-16 did not contain data points, and bedrock configuration was not shown. The commenter also stated, "regional trends are important to develop an understanding of the hydrogeologic conceptual model" and it would be useful to know how closely the potentiometric surfaces are reflected by formational structural trends. Another commenter observed that Figure 2-15 appeared to indicate vertical gradients between the Wanapum and Saddle Mountains Basalts in the Pasco Basin and lateral gradients to the north. One commenter stated that the maps in Figures 2-15 and 2-16 were too small and that a contour map would be more illustrative. This commenter also stated that the section on regional ground-water hydrology should include a cross section of the Hanford Site showing potentiometric contours in the vertical plane.

Response

Figures 2-15 and 2-16 of the Draft Environmental Assessment were based on potentiometric surface maps found in reports by Tanaka et al. (1979) and Gephart et al. (1979). The reader is referred to those maps, which locate data control for the potentiometric surfaces. Also, the report by Tanaka et al. (1979) presented structural contour maps for the corresponding region so that correlation between bedrock structural configuration and potentiometric surfaces is possible. Figure 2-15 shows no head values in the Saddle Mountains Basalt to the north and northeast of the Pasco Basin because the Saddle Mountains Basalt does not extend that far north. The Wanapum Basalt is shown correctly (see Fig. 2-5 in the Draft Environmental Assessment); thus, there is no head data to report. The U.S. Department of Energy agrees that Figures 2-15 and 2-16 are small and that contour maps are more illustrative for a scientifically oriented audience. However, it is believed that these three-dimensional perspective maps may better illustrate broad areal head patterns to an interested lay audience. Updated cross sections of the Hanford Site showing potentiometric contours in the vertical plane are being developed for the site-characterization plan.

Issue: Definition of a slight vertical hydraulic head gradient

The question of what constitutes a slight vertical hydraulic head gradient was raised by one commenter.

Response

The upward gradients across the Wanapum and Grande Ronde Basalts vary between 10^{-3} and 10^{-4} depending on borehole location and stratigraphic zones selected for comparison. Such values are considered as a "slight" gradient. The U.S. Department of Energy agrees that it is best to quantify gradients in this portion of the Environmental Assessment rather than use the qualitative descriptions typical of the General Siting Guidelines (DOE, 1984a).

The vertical hydraulic head gradient values in Subsection 3.3.2.1.2 of the final Environmental Assessment were updated to reflect monitored head values reported since the Draft Environmental Assessment was issued. Specific head and gradient values are now given.

Issue: Ground-water discharge areas

One commenter claimed available data suggest ground-water discharge from the main part of the Hanford Site is to the Columbia River within the boundary of the Hanford Site, not farther south as indicated in the Draft Environmental Assessment. Because the amount of available data is limited, it is premature to give an estimate of lateral hydraulic gradient in basalt. The commenter also noted it would be reasonable to assume that the hydraulic gradient is variable, not constant.

Response

Available hydraulic head information supports the opinion that ground water from the Saddle Mountains Basalt and overlying sedimentary formations discharges to the Columbia River within the Hanford Site boundary. This concept was discussed in the Draft Environmental Assessment. Profiles of observed hydraulic head through the Saddle Mountains, Wanapum, and Grande Ronde Basalts near the Columbia River are available only in two boreholes located on the Hanford Site (DOE, 1982). These profiles, taken from boreholes DC-14 and DC-15, provide vertical head gradients. At borehole DC-14, a vertical downward gradient is observed from the Wanapum Basalt to the Grande Ronde Basalt, while at borehole DC-15, a vertical upward gradient is observed from the Grande Ronde Basalt to the Wanapum Basalt. The profile at borehole DC-15 indicates that discharge from the Wanapum and Grande Ronde Basalts to the Columbia River could occur at that location via vertical movement into shallow stratigraphic zones. The profile at borehole DC-14 does not support such a conclusion. As stated in Section 3.3.2 (see p. 3-81) of the Draft Environmental Assessment, "The above statements on hydraulic head patterns are not given as conclusions, but rather conceptualizations based on information available by researchers at the time of their studies."

While available hydraulic head data for basalt formations at various locations on the Hanford Site still are limited, it is reasonable to use those data to estimate the central tendency of lateral hydraulic gradients. As more head information becomes available, the estimate of the central tendency can be refined and unit and area variation defined.

Discussion on ground-water mixing, recharge, and discharge in Section 3.3.2 of the final Environmental Assessment has been expanded.

C.4.1.2.2.2 Hydraulic information

Comments discussed in this subsection are specific to hydraulic information and are divided into the following issues:

- Cause of water-level decline in borehole DC-1.
- Assumption of hydraulic test problems.
- Use of bentonite in well drilling.
- Criteria for well cleanup.
- Well completion reports.
- Pump testing of deep wells.
- Integrity of multiple completion wells.
- Testing rock zone sealed by cement.
- Tectonic stresses creating new fractures.
- Abundance of permeable fracture zones.
- Effects of drilling fluids on hydraulic conductivity values.
- Variability of U.S. Geological Survey hydraulic test values.
- Geologic origin of Cold Creek barrier.
- Geohydrologic baseline and environmental analysis details.
- Average thermal gradient.
- Well development during hydraulic test in borehole DB-2.
- Mud cake development in shallow versus deep boreholes.
- Transference of borehole DB-2 test results to other rock horizons.
- Effective thickness of a test interval.
- Identification of tracer test zone.
- Vertical hydraulic conductivity.
- Hydraulic conductivity measurement in vertical boreholes.

Several comments had multiple questions or concerns that may, depending on topic, be addressed elsewhere in this appendix.

Issue: Cause of water level decline in borehole DC-1

Two commenters inquired about the cause of the 1.5-meter (approximately 5-foot) decline in water levels recorded since 1978 at several DC-1 piezometers.

Response

As suggested in Section 3.3.2 (see p. 3-80) of the Draft Environmental Assessment, the 1.5-meter (approximately 5-foot) water-level decline is attributable to the construction of nearby borehole DC-2. To eliminate uncertainty concerning the factor responsible for the water-level decline, the final Environmental Assessment states the relationship of water-level decline in borehole DC-1 to the construction and completion design of borehole DC-2. The entire discussion of hydraulic heads in Section 3.3.2 has been revised and updated, including the discussion of heads in borehole DC-1.

Issue: Assumption of hydraulic test problems

Two commenters stated that, based on the assumption that the hydrologic test problems encountered in testing a basal fracture zone within the Umtanum Basalt at borehole RRL-2 " . . . occurred in every test of this type," these problems should be resolved using strict quality-control measures.

Response

The assumption that test problems identified in Strait and Spane (1983) for reconnaissance-level testing of a single test horizon at borehole RRL-2 occurred in every test of this type at the Hanford Site is not correct. Problems cited in Strait and Spane (1983) were primarily the result of an unexpected failure of the installed downhole pressure probe and lack of available onsite equipment replacements. Considerable improvements have been made in downhole pressure instrumentation since the 1982 field season, with the result that hydraulic characterization of test intervals now is rarely affected by the same type of equipment failure.

Issue: Use of bentonite in well drilling

The commenter asked if bentonite was used in drilling all wells on the Hanford Site.

Response

A variety of substances and additives commonly used in the well drilling industry have been utilized as drilling fluid components at the Hanford Site. These include bentonite and water, polymers, air, water, and aerated water. Most boreholes used for reconnaissance hydrologic testing and basalt core recovery have been drilled with a bentonite and water drilling fluid mixture.

Issue: Criteria for well cleanup

One commenter asked what criteria were used, other than time, to ensure that wells were clean of drilling fluid prior to testing and sampling.

Response

A number of development phases are commonly employed prior to hydraulic and hydrochemical characterization of individual test zones and are extended prior to final hydrochemical sampling to minimize the possibility of drilling fluid contamination. Development procedures are normally continued until monitored drilling fluid tracers (e.g., fluorscein, total organic carbon) have reached natural background levels; and (or) visual examination indicates the absence of drilling fluid within surface return flows; and (or) an acceptable ratio (approximately 5 to 1) of borehole fluid removed versus drilling fluid lost to the test interval has been attained.

Issue: Well completion reports

The commenter requested information regarding the number of wells completed in deep basalts and the availability of completion records.

Response

The number of boreholes completed in various deep basalts can be ascertained by examining Figures 3-9 through 3-19 in the Draft Environmental Assessment. Examination of the figures indicates that 18 deep boreholes penetrate formations of the Grande Ronde Basalt. Completion records are documented in a series of reports that describe the construction, completion, and testing history of specific borehole sites (e.g., Diediker (1984), Patterson (1984), and Wood et al. (1985)).

Issue: Pump testing of deep wells

One commenter asked for a description of problems that have occurred during pumping tests of deep wells on the Hanford Site.

Response

In all hydrologic studies, whether they are conducted at shallow or great depths, problems occur occasionally during the course of testing. To date, in excess of 200 separate stratigraphic intervals have been tested, for which multiple hydrologic tests (sometimes 3 to 5) have been performed. Most problems that have occurred during Hanford Site field studies can be ascribed to either test equipment failures (e.g., submersible pumps, downhole pressure probes, inflatable packers, surface electronic equipment) or lack of replacement test equipment. In most cases, equipment is replaced and the test rerun or continued depending on the nature and timing of the equipment failure.

Issue: Integrity of multiple completion wells

One commenter inquired about what measures were taken in multiple completion wells to ensure that no leakage occurred between zones.

Response

By multiple completion it is assumed that the commenter referred to nested piezometer installation well sites. Currently, there are four wells on the Hanford Site containing such piezometer installations, providing monitoring capability for multiple basalt zones. These are piezometer sites DC-19, DC-20, DC-22, and borehole DC-1. Details concerning the integrity of each installation are contained in Fenix and Scisson (1972) for DC-1, and Jackson et al. (1984) for piezometer sites DC-19, DC-20, and DC-22. To briefly summarize, a cement seal is used to isolate each monitored interval from other zones intersected by the borehole. Assessment of the integrity of the recently completed piezometer facilities (i.e., DC-19, DC-20, DC-22) was accomplished by examining cement-bond and fluid temperature geophysical surveys, pressure testing each piezometer string, performing stress tests after piezometer installation, and comparing long-term hydrologic response among piezometers (i.e., water levels, downhole pressure).

Issue: Testing rock zone sealed by cement

The commenter suggested it would be difficult to test a zone that is sealed by cement, with a vertical permeability less than the horizontal permeability of the formation.

Response

By " . . . a zone that is sealed by cement" it is assumed that the commenter refers to test intervals injected with cement (after hydrologic testing) to prevent significant drilling fluid loss during the course of subsequent borehole drilling. The U.S. Department of Energy usually does not test intervals that have been previously cemented.

To address the commenter's question specifically, it may be difficult to test zones sealed with cement. Factors controlling characterization of a zone in a severely cement-damaged borehole include permeability of the test formation, permeability of the emplaced cement, depth of cement invasion, test method used for hydraulic characterization, and test duration.

Issue: Tectonic stresses creating new fractures

A general observation was made by a commenter that tectonic stresses are likely to continually create fractures within basalt flow interiors that are not sealed by clay mineral alteration products. Some of these fractures might be interconnected. An example cited in the Draft Environmental Assessment was a high-permeability fracture zone (Strait and Spane, 1983).

Response

According to information presented in the Draft Environmental Assessment (see p. 3-53), the contemporary low rate of tectonic deformation appears consistent with estimated Neogene through Quaternary strain rates. This suggests that unless tectonic stresses change significantly, current field measurements of hydraulic conductivity for basalt flow interiors should remain essentially unchanged in the future. The following issue discusses the referenced high-permeability fracture zone.

Issue: Abundance of permeable fracture zones

According to one reviewer, insufficient evidence currently exists to support a statement that permeable fracture zones within flow interiors, such as the fracture zone at the base of the Umtanum flow at borehole RRL-2, are few in number.

Response

Concerning the example of a high permeability fracture zone within the Umtanum flow interior (Strait and Spane, 1983), it should be noted that this feature represents a fracture that occurs in the bottom 4.6 to 6.4 meters (15 to 21 feet) of the basalt flow. Due to problems cited by the authors, testing of this zone was limited. It appears, however, that this zone is a localized feature and is interconnected at this borehole site to the immediately underlying transmissive flow top.

Hydrologic results, both preliminary and final, have been obtained for a number of individual flow interiors in the immediate vicinity of the reference repository location and the surrounding Hanford Site. Results indicate that the hydraulic property determination obtained for the Umtanum fracture zone at borehole RRL-2 is considerably higher than Umtanum or other basalt flow interior test results. Therefore, the Draft Environmental Assessment statement (see p. 3-86) that this is "considered as a localized feature" appears to be justified. Nowhere in the Draft Environmental Assessment text was it stated that these types of transmissive features "are few in number," as suggested by the commenter.

In the final Environmental Assessment, Subsection 3.3.2.1.1 was revised to indicate possible interconnection of a local fractured zone found within a flow interior to a basalt flow top or bottom.

Issue: Effects of drilling fluids on hydraulic conductivity values

One comment concerns the validity of hydraulic conductivity values presented on page 3-88 of the Draft Environmental Assessment. These values were questioned previously by the U.S. Geological Survey because of the possible presence of drilling fluid.

Response

The presence of unknown amounts of drilling fluid in the test system or formation during testing should not affect hydraulic characterization. The effects of drilling fluid invasion, as indicated in numerous technical papers and textbooks (e.g., Matthews and Russell, 1967; Agarwal et al., 1970; Earlougher, 1977; Ramey, 1982), are manifest in early-time response data during transient testing. Late-time data (unaffected by drilling fluid invasion or borehole damage) are used in hydrologic analysis for the characterization of true formation properties.

As indicated in previous documents (e.g., Jackson, 1980; Strait et al., 1982; DOE, 1982), test zones are developed prior to hydrologic testing, employing several methods. Development phases are extended prior to final hydrochemical sampling. Future large-scale hydraulic stress tests are designed to avoid any affects from drilling fluids. This will be accomplished by using boreholes completed without drilling muds and tests conducted over a several-week period. See issue on criteria for well cleanup in this subsection for additional discussion.

Issue: Variability of U.S. Geological Survey hydraulic test values

One commenter stated that test results shown to the U.S. Geological Survey for a given test interval varied by several orders of magnitude depending on the analysis used. This variation should be mentioned in the final Environmental Assessment.

Response

Specifics regarding the comment need to be clarified, since the connotation that test results typically vary over "orders of magnitude" is incorrect. Nevertheless, a number of field test methods and analytical techniques are commonly used by the U.S. Department of Energy in the testing of individual test horizons. These have been described in reports by Jackson (1980), Strait et al. (1982), and U.S. Department of Energy (DOE, 1982). Each of the tests and analytical methods has limitations of application (e.g., permeability range, area of investigation, and inherent analytical assumptions).

Part of the U.S. Department of Energy field test program examines the correspondence of hydraulic property estimates obtained by different methods. For most test intervals, good corroboration of test results is obtained (e.g., Spane, 1981; Spane and Thorne, 1984; Thorne and Spane, 1985). However, in some cases where test and analytical methods are at their application limit, or because a specific test system problem arises, differences of an order of magnitude or greater may be exhibited (e.g., Strait and Spane, 1984). These differences and the reliability of estimates are discussed in the respective test completion reports. Hydraulic property values referenced in Section 3.3.2 (see p. 3-88) of the Draft Environmental Assessment were based on best-estimate calculations for hydrologic tests conducted for each test interval.

Issue: Geologic origin of Cold Creek barrier

A question was raised about the geologic origin of the Cold Creek geohydrologic barrier.

Response

As indicated in Subsection 3.3.2.1.3 of the Draft Environmental Assessment, the Cold Creek barrier is interpreted as a bedrock structural discontinutiy (i.e., fault). Additional geologic, geophysical, and hydrologic tests are planned to obtain information on the characteristics of this feature (e.g., orientation, hydrologic influence on ground-water flow patterns). Section 3.2 of the final Environmental Assessment has been expanded to include a geologic discussion of the existence of the Cold Creek barrier.

<u>Issue</u>: Geohydrologic baseline and environmental analysis details

Two commenters stated that in any geohydrologic baseline study or environmental analysis, it is important to present tables of data concerning well completions, water-quality data, and aquifer test results to help the reviewer interpret potential environmental effects.

<u>Response</u>

It is not the intention of the Environmental Assessment to serve as a baseline study or environmental analysis investigation, both of which would require the inclusion of a considerable amount of support data. Rather, the Draft Environmental Assessment focused on the site-selection process relative to satisfying the U.S. Department of Energy General Siting Guidelines (DOE, 1984a). Future documents (e.g., an environmental impact statement) would contain the level of support documentation mentioned in the comments.

<u>Issue</u>: Average thermal gradient

One reviewer inquired about average thermal gradient conditions beneath the Hanford Site.

<u>Response</u>

Average geothermal gradient conditions vary with depth across the Hanford Site. Average geothermal gradient data for basalt formations, as determined from individual borehole fluid-temperature surveys, are given in Table C.4-1.

These data will be documented in a future report that summarizes results of all fluid temperature surveys conducted in basalt boreholes on the Hanford Site.

Table C.4-1. Average geothermal gradient data for basalt formations

Formation	Number of boreholes surveyed	Geothermal gradient, F^o/ft
Saddle Mountains Basalt	27	1.95×10^{-2}
Wanapum Basalt	15	2.10×10^{-2}
Grande Ronde Basalt	13	2.22×10^{-2}

NOTE: 1 foot = 0.3028 meter, $F^o = 9/5\ C^o + 32$.

Issue: Well development during hydraulic test in borehole DB-2

A letter report to the U.S. Nuclear Regulatory Commission was referenced by a commenter, who stated that the report noted well development procedures used during field tests conducted in borehole DB-2 by Spane and Thorne (1984) were not the same as those used on other boreholes. Results of this test, therefore, could not be used to state that drilling fluid invasions have no adverse effect on hydraulic tests of deep basalts during single-hole tests.

Response

The DB-2 borehole and test interval were developed in a similar manner as those for other low-permeability basalt flow interiors on the Hanford Site (i.e., by flushing the borehole across the test interval with Columbia River water until surface-return flows were visibly clear of drilling fluid).

As indicated in Spane and Thorne (1984), field investigation was meant to examine the effects of drilling fluid on low-permeability basalt horizons (flow interiors). The effects of drilling fluid invasion on higher permeability basalt flow-top horizons will be addressed in future field studies as indicated in Subsection 4.1.1.3.4 of the Draft Environmental Assessment. The reader is also referred to the issue on criteria for well cleanup and the two following issues within this appendix subsection.

Issue: Mud cake development in shallow versus deep boreholes

Two commenters questioned whether or not the results of testing at shallow depths (i.e., approximately 400 meters (1,300 feet)) are applicable to deeper basalt horizons (i.e., to 1,200 meters (4,000 feet) or less). The concern expressed involved mud cake development in shallow versus deep boreholes due to temperature differences.

Response

The amount of mud-cake developed on a borehole wall and the depth of drilling fluid invasion that occurs in a test formation is primarily a function of test horizon permeability and exposure time. Extremely high temperatures, as experienced in deep wells drilled in oil provinces, can cause lime-based drilling mud to congeal if not circulated within the borehole. This condition is not present on the Hanford Site.

The fact the test section at borehole DB-2 has a permeability that occurs in the upper range of basalt flow interiors, and the manner in which drilling fluid was circulated in the borehole, favor the interpretation of limited drilling fluid invasion into the test section. While this study was not intended to be a final assessment of the effects of drilling fluid invasion, results are believed to provide insight into the effects of low-permeability horizons on hydraulic characterization. The effects of drilling fluid invasion in higher permeability basalt flow-top horizons will be addressed in future field studies, as was indicated in Subsection 4.1.1.3.4 of the Draft Environmental Assessment.

Issue: Transference of borehole DB-2 test results to other rock horizons

One reviewer stated that if mud was used during the drilling of borehole DB-2 prior to testing, the initial test results (i.e., Phase I testing) could have been lowered by an unknown amount. In addition, the commenter suggested that since the amount of drilling fluid loss could not be measured, transference of DB-2 test results to other test horizons is not justified, particularly for permeable interflows and sedimentary interbeds.

Response

As indicated in Spane and Thorne (1984), the test interval (as well as the overlying basalt flow) was drilled only with water from the Columbia River. The formations above these zones previously were drilled with a bentonite- and water-based drilling fluid mixture. These zones, however, were isolated from the open borehole utilizing a set casing string.

With regard to the second concern, the small permeabilities involved (10^{-11} to 10^{-10} meter per second (10^{-6} to 10^{-5} foot per day)), the large test system volume, and liquid thermal expansion effects made the measurement of small quantities of drilling fluid loss (e.g., less than approximately 4 liters (1 gallon)) extremely difficult. No transference of borehole DB-2 test results was ever intended to the more permeable interflows and sedimentary interbeds. As indicated in Subsection 4.1.1.3.4 of the Draft Environmental Assessment, this will be addressed in subsequent field studies.

Issue: Effective thickness of a test interval

One commenter made two observations on this subject. The first stated that the term "effective thickness" as used in the Draft Environmental Assessment appears inconsistent with the definition described during earlier data reviews and workshops at the Hanford Site. The second focuses on the Draft Environmental Assessment statement (see Section 3.3.2, pp. 3-88 and 3-89) that " . . . geophysical log traces indicate that ground-water movement is sometimes channeled along narrow intervals . . . as opposed to being averaged across the entire thickness of the flow top. Such intervals may have a higher local hydraulic conductivity than the 'equivalent' permeability of the 'effective thickness' of the flow top." The reviewer stated it is important that the proper effective thickness be selected when travel time estimates are being made.

Response

Prior to 1982, staff members did use the term "effective thickness" of a flow top to describe the section of the interval tested that contributed to the transmissivity calculated from a hydrologic test. This "thickness" calculation was based primarily on examination of borehole geophysical log surveys (e.g., neutron-epithermal), geologic description, and retrieved core. It was later recognized, however, that the term "effective thickness" was used by the technical community to describe the product of effective porosity and apparent thickness in tracer testing. This definition was adopted by the U.S. Department of Energy and agency subcontractors in 1982 and was utilized in the Draft Environmental Assessment (see Subsection 6.4.2.3.5). The term "effective test interval" currently is used to describe the section within the test interval that contributes to the transmissivity calculated for the interval isolated during testing.

With regard to the second comment, dynamic borehole fluid-temperature and flow velocity surveys conducted during air-lift pumping tests have indicated that ground-water inflow zones sometimes can be identified within an interval during testing. Because it is not possible to isolate these zones within a transmissive flow top, hydraulic property calculations for these discrete zones cannot be made. As for all other cases, an "equivalent hydraulic conductivity" is calculated based on the thickness of the effective test interval as defined above. The equivalent hydraulic conductivity is an average value of hydraulic conductivity for the entire effective test interval.

As indicated in all test interval reports, zones of higher and lower hydraulic conductivity may exist within the interval tested. Zones of high permeability within flow tops appear to be localized features and are not laterally continuous. For large-scale performance, the entire effective test interval is believed to be involved in ground-water transport. Additional information concerning the "effective thickness" of basalt flow tops will be obtained by planned large-scale interference and tracer tests mentioned in Subsections 4.1.1.3.1 and 4.1.1.3.3 of the Draft Environmental Assessment.

Subsection 3.3.2.1.2 of the final Environmental Assessment has been reworded to include the updated definitions of effective test interval thickness and equivalent hydraulic conductivity.

Issue: Identification of tracer test zone

One commenter identified an apparent inconsistency between the zone identified for tracer testing as described in Gelhar (1982) and that reported in the Draft Environmental Assessment.

Response

The approximate distance of the test zone above the Umtanum flow, as stated in Gelhar (1982), is incorrect. The Draft Environmental Assessment was correct.

Issue: Vertical hydraulic conductivity

One reviewer disagreed with estimates of vertical hydraulic conductivity as presented in the Draft Environmental Assessment. Specific comments are listed below.

1. The Draft Environmental Assessment did not support its statement that the vertical hydraulic conductivity is approximately the same order of magnitude as the horizontal hydraulic conductivity. This statement is based on results of one field test and two indirect analyses.

2. Studies question the usefulness of test results reported in the Spane et al. (1983) document. Alternative interpretations of the test results can provide estimates of vertical hydraulic conductivity several orders of magnitude greater than those cited.

3. The defensibility of vertical-to-horizontal hydraulic conductivity anisotropy ratios cited is questioned. The anisotropy ratio of 2 to 1 quoted from a report by the U.S. Department of Energy (DOE, 1982) appears misreferenced. In addition, the 3.5 to 1 ratio derived from a report by Sagar and Runchal (1982) should not be applied to Hanford Site basalt flow interiors in general, due to the site-specific nature of the fracture data used in the study.

Response

The following responses correspond to the numbered items in the above issue statement.

1. Field-derived values of the anisotropy ratio of vertical to horizontal hydraulic conductivity within basalt flow interiors are not available. Estimates based on ground-water model simulations and statistical analysis of fracture data are reported by the U.S. Department of Energy (DOE, 1982) to range between 3.5 to 1 and 10 to 1. Thus, once several field measurements become available, it is believed the vertical hydraulic conductivity of undeformed flow interiors likely will be within about a factor of 10 to horizontal conductivity values currently reported. The present uncertainty of these ratios is recognized and would be addressed during site characterization. (See Subsection 4.1.1.3 of the Draft Environmental Assessment.)

2. As noted in a report by Spane et al. (1983), the experimental field test at paired boreholes DC-4 and DC-5 was conducted to assess the applicability of the "ratio method" for determining vertical conductivity using inflatable straddle packer systems. Modifications to the "ratio method" test arrangement, as originally described by Neuman and Witherspoon (1972), are duly noted by Spane et al. (1983, p. 32).

With respect to alternative U.S. Nuclear Regulatory Commission interpretations of the vertical conductivity test results, it should be noted that a report by Golder (1984b, p. 3) stated that " . . . Williams . . . agreed with RHO . . . and suggested that the vertical hydraulic conductivity of the flow interior was actually less than the value calculated by RHO." Research by Golder Associates also states that test results may greatly overestimate the value for vertical hydraulic conductivity as reported by Spane et al. (1983) due to short-circuiting of flow around the bottom straddle packer (Golder, 1984a). The basis for the "greatly over-estimated value" is stated to be that hydraulic response during the test in paired boreholes DC-4 and DC-5 actually propagated only 0.9 to 1.2 meters (3 to 4 feet), not the 8 meters (26 feet) reported by Spane et al. (1983).

With respect to the greater distance (i.e., 8 meters (26 feet)) utilized in the analysis by Spane et al. (1983), it should be noted that the greater distance was selected as a measure of conservatism. If the smaller distance of 0.9 to 1.2 meters (3 to 4 feet) is utilized in the analysis, a much smaller, not higher, value of vertical conductivity is calculated. This is understood by examining the equation for vertical conductivity reported by Spane et al. (1983, p. 19). Therefore, the second concern expressed appears to be based on both a misunderstanding of what the U.S. Nuclear Regulatory Commission letter reports are documenting and a misquote of those documents.

3. The anisotropy ratio of 2 to 1 questioned in the comment is in error and should be 10 to 1, as indicated by the U.S. Department of Energy (DOE, 1982, p. 12.4-34). Whether the value of 3.5 as obtained from a general statistical study by Sagar and Runchal (1982) is representative of all Hanford Site basalt flow interiors will remain unknown until planned large-scale interference and exploratory shaft facility tests are performed. The values cited are believed to be generally consistent with values obtained from independent ground-water model simulations. (See Subsection C.5.1.2 of this appendix for additional details.)

Subsection 3.3.2.1.1 of the final Environmental Assessment has been reworded to give vertical to horizontal hydraulic conductivity ratios of 3.5 to 1 and 10 to 1. An additional paragraph has been added to the same subsection giving ratios reported in some non-U.S. Department of Energy documents. These same text modifications has been included in Subsection 6.3.1.1.6.

Issue: Hydraulic conductivity measurement in vertical boreholes

One reviewer submitted two comments concerning vertical hydraulic conductivity. The first related to the statement "It is well-known that vertical boreholes cannot provide a representative test of high angle fractures, and thus such tests will greatly underestimate the fracture transmissivity of flow interiors." The second stated "Evidence for significant vertical hydraulic continuity between basalt flows of the region was presented in the U.S. Geological Survey comprehensive review (Robertson, 1983), but was not cited in the Environmental Assessment."

Response

The U.S. Department of Energy recognizes the limitations of testing high angle fractures in vertical boreholes. If it were assumed all fractures were vertical and if a perfectly vertical borehole were drilled through a basalt flow interior, the commenter's statement would be valid. These assumptions are unrealistic, however, given the pattern of fracture distributions within flow interiors as determined in several U.S Department of Energy subcontractor reports (e.g., Long, 1978). It should also be recognized that most accepted analytical methods for determining vertical hydraulic conductivity are dependent on the use of vertical boreholes (e.g., Hantush, 1960; Weeks, 1969; Neuman and Witherspoon, 1972). Of special interest is a technique employing paired vertical boreholes recently reported to provide successful results in testing fractured granite (Hsieh et al., 1983). The possible application of this technique under Hanford Site test conditions is discussed by Spane et al. (1983).

With respect to the second comment concerning additional regional evidence provided by Robertson (1983) for significant hydraulic continuity between basalt flows, it is assumed that this refers to an observed increase in water levels for wells penetrating the Saddle Mountains and upper Wanapum Basalts located in the eastern and central sections of the Pasco Basin. This increase in water levels reported by Robertson (1983) (although no specific reports or well identifications were provided) is attributed to the onset of irrigation activities (well drilling and water application) in this area.

The effect of irrigation as a source of recharge to these basalt aquifers has been recognized and documented in the past by the U.S. Department of Energy and its subcontractors (e.g., Gephart et al., 1979, pp. III-161 and III-163; DOE, 1982, p. 5.1-101). The primary mechanism for transference of this recharge water is not completely understood, but may include a combination of the following: leakage to and through underlying basalt formations, conveyance losses along surface canals in areas of surficial basalt exposures, and direct recharge to underlying basalts through poor well construction practices and long open holes across multiple basalt flows. Based on available studies for the Pasco Basin, it is not possible to identify the primary recharge mechanism. It is reasonable to assume, however, that all three are operative, to varying degrees, in the Pasco Basin.

It may be of interest to note that U.S. Geological Survey and State of Washington Department of Ecology studies (e.g., Luzier and Burt, 1974; Luzier and Skrivan, 1973) have addressed this topic in the Odessa-Lind area, located immediately north of the Pasco Basin. In their study of basalt intercommunication in this area, Luzier and Burt (1974) state that although some natural hydraulic communication between shallow and deeper basalt flows exists, the completion of deep uncased wells in the area constitutes a major increase in the hydraulic connection. Concerning artificial recharge and associated intercommunication between basalt flows, Luzier and Burt (1974, p. 16) also noted that the formation of a recharge mound in shallow basalt aquifers without a corresponding response in deeper basalt zones " . . . exemplifies the poor vertical permeability and very slow crossbed leakage between the two aquifer zones."

A paragraph concerning artificial recharge to Saddle Mountains and upper Wanapum Basalt zones has been added to Section 3.3.2 of the final Environmental Assessment.

C.4.1.2.2.3 Hydrochemistry

Several comments were received regarding the hydrochemistry discussions in Chapters 2 and 3 of the Draft Environmental Assessment. These covered a range of topics including such items as evidence for vertical ground-water mixing, mud effects on water quality, ground-water chemical types, and critique of past hydrochemical data. Comments on hydrochemistry are divided into the following issues, which are individually addressed:

- Hydrochemical evidence for ground-water mixing near Cold Creek barrier.
- Possible effects of drilling mud on ground-water samples.
- Unconfined aquifer hydrochemistry.
- Use of hydrochemistry to address vertical ground-water movement.
- Hydrochemical parameters monitored.
- Hydrochemistry related to mineral alteration of Cold Creek barrier.
- Hydrochemistry detail.
- Iodine-129.

Issue: Hydrochemical evidence for ground-water mixing near Cold Creek barrier

Some commenters requested documentation of evidence for vertical mixing of ground waters near the Cold Creek barrier within the reference repository location. One commenter noted that the direction of flow is particularly relevant to performance assessment.

Response

The U.S. Department of Energy agrees that the hypothesized vertical mixing model associated with the Cold Creek barrier is important, both from the perspective of defining a conceptual flow model and for future performance assessment modeling.

To be responsive to the need for documentation, several new paragraphs have been added to the end of Section 3.3.2 of the final Environmental Assessment expanding on the ground-water chemistry in the reference repository location and vicinity. This includes alternative conceptualizations for ground-water chemical evaluation.

Issue: Possible effects of drilling mud on ground-water samples

One commenter expressed concern about the possible effects of drilling mud on ground-water chemistry. This concern was directed toward organic constituents but is applicable to all chemical components. Future use of drilling fluids that minimize organic contamination was recommended. The commenter suggested that the anion to cation balance serve as a check on sample representativeness.

Response

As stated in Subsections 6.3.1.2.4 and 6.3.1.2.8 of the Draft Environmental Assessment, data on the organic component of ground waters are limited and future studies are directed at correcting this deficiency. However, as also noted in Subsection 6.3.1.2.8, available data for extensively pumped boreholes seem to indicate background levels of organic carbon of less than 1 milligram per liter.

Obtaining representative samples (both for inorganic and organic constituents) is a goal of the U.S. Department of Energy, and recent studies by Graham et al. (1985) and Halko (1984) sought to characterize drilling fluid additives and assess the importance of such additives on ground-water sample quality during a controlled test in borehole DC-14. Furthermore, a report by Early et al. (1985) discusses a variety of evaluation tools that can be used to test for sample representativeness. These tests have been applied to all currently available hydrochemical data collected by the U.S. Department of Energy.

Until relatively recently, most boreholes drilled by the U.S. Department of Energy used mud rotary techniques in which the use of organic polymers was common. In boreholes of this type, contamination of ground water with organic carbon has been observed. Currently, an air rotary drilling technique is in use and it is anticipated that fewer contamination problems will result.

The anion to cation balance is an excellent screening tool for checking the completeness of the chemical analysis, but it does not address the issue of representativeness. A sample may be profoundly contaminated but a good analytical laboratory will report analyses from which an excellent change balance can be computed.

Subsection 6.3.1.2 of the final Environmental Assessment has been changed to reflect the fact that data are not available to fully quantify concentrations of organic complexes.

Issue: Unconfined aquifer hydrochemistry

Information about the overall hydrochemical nature of the shallow unconfined ground water at the Hanford Site was requested by one reviewer.

Response

The overall hydrochemical nature of the unconfined aquifer ground water is that of a dilute calcium-bicarbonate chemical type. General hydrochemical information relative to the unconfined aquifer was contained within the Draft Environmental Assessment in Section 3.3.2 (see pp. 3-72 and 3-77). More detailed chemical data can be found in references cited on these pages.

Issue: Use of hydrochemistry to address vertical ground-water movement

One commenter suggested that hydrochemical data be used to address the question of vertical communication between basalt flows where piezometers are located.

Response

The U.S. Department of Energy agrees that, in principle, vertical differences in hydrochemistry might suggest a low component of vertical flow and, therefore, little cross-formational leakage. Many factors are involved in this assessment (e.g., time, rock-water reactions) and hydrochemical data must be supplemented by other studies.

Additional hydrochemical information concerning vertical ground-water mixing at and near the reference repository location has been added to Section 3.3.2 of the final Environmental Assessment, as noted in the first issue of this appendix subsection.

Issue: Hydrochemical parameters monitored

One commenter requested information regarding which chemical parameters other than major cations and anions are monitored for both shallow and deep ground water.

Response

The U.S. Department of Energy does not have a hydrochemical baseline monitoring program for the basalts in which specific boreholes are resampled routinely. However, nonroutine resampling of selected zones in some boreholes has occurred. Site-characterization plans would establish a baseline monitoring program for both unconfined and confined aquifers.

Samples collected by the U.S. Department of Energy are subjected to routine analysis for major cations and anions, a selection of trace metals, stable isotopes of hydrogen, carbon, oxygen, and sulfur, dissolved gases, and radioactive isotopes (i.e., carbon-14, chlorine-36, and tritium).

Analyses of samples from the unconfined aquifer are performed by the Pacific Northwest Laboratory and are restricted to major cations and anions and some trace constituents (see Eddy et al., 1983, referenced in Chapter 3 of the Draft Environmental Assessment). The U.S. Department of Energy recently initiated a sampling program for this aquifer in selected boreholes. This will provide more comprehensive analyses than presently are available.

Issue: Hydrochemistry related to mineral alteration of Cold Creek barrier

One commenter asked if the hydrochemical observations in the reference repository location could be resulting from mineral alteration within the Cold Creek hydrologic barrier and if large vertical head gradients are associated with the barrier.

Response

The U.S. Department of Energy has no definitive information on the structural and mineralogic properties of the barrier; however, the vertical geochemical gradients observed in ground water from the reference repository location are significant. Table C.4-2 summarizes some pertinent data.

Table C.4-2. Approximate observed values for selected hydrochemical parameters in reference repository location boreholes[a]

Parameter	Saddle Mountains Basalt	Wanapum Basalt	Grande Ronde Basalt
Na (mg/L)	50	130 (U)[b] to 350 (L)[c]	350
Cl (mg/L)	5	100 (U) to 450 (L)	450
^{18}O (o/oo)	-18	-17 (U) to -11 (L)	-11
D (o/oo)	-145	-138 (U) to -110 (L)	-110

NOTE: mg/L = milligrams per liter, o/oo = parts per thousand.

[a]Source of data: From boreholes DC-16A and RRL-2 as reported by Early et al. (1985).

[b]U = upper part of formation.

[c]L = lower part of formation.

Given the known mineralogy of basalt, it is difficult to conceive of a mechanism by which mineral-water reactions within the barrier might control the concentration of chloride; isotopic gradients are so large as to rule out solid-liquid reaction as a causal mechanism. The U.S. Department of Energy believes that these geochemical gradients result from mixing two ground waters from different source regions.

The Cold Creek barrier separates upper Cold Creek Valley from the reference repository location. Head data are taken from McGee well and borehole DB-11 west of the barrier, and from three clusters of piezometers located in the reference repository location. Table C.4-3 summarizes some of the available head information.

Issue: Hydrochemistry detail

One commenter questioned the lack of discussion of ground-water chemistry in the Draft Environmental Assessment compared to that in the site-characterization report (DOE, 1982). The commenter also claimed that the treatment of hydrochemistry in the site-characterization report was "largely discredited" by the U.S. Nuclear Regulatory Commission (NRC, 1983).

Response

The Environmental Assessment was not intended to be a technical status report; rather, its purpose was to evaluate the suitability of a potential waste disposal site according to specific preclosure and postclosure guidelines (DOE, 1984a). Consequently, detailed discussion of hydrochemistry or other technical data is not appropriate. However, summaries of relevant hydrochemical data are utilized to support ground-water flow models referenced in the Draft Environmental Assessment (see pp. 3-81 through 3-83 and 3-90). In addition, references to specific hydrochemical properties that may affect radionuclide isolation for a repository in basalt were included in discussions of certain favorable and potentially adverse conditions under the geochemistry qualifying condition (see Subsection 6.3.1.2 of the Draft Environmental Assessment). Also, refer to the first issue under this appendix subsection for additional hydrochemistry information added to the final Environmental Assessment.

The second part of this comment referred to an evaluation of the site-characterization report (DOE, 1982) prepared by the U.S. Nuclear Regulatory Commission (NRC, 1983). It is unnecessary and inappropriate to provide a detailed defense of the site-characterization report in this response. An initial response is contained in a report by Rockwell (1983). However, the following observations are offered.

It is acknowledged within the site-characterization report and pointed out by the U.S. Nuclear Regulatory Commission that insufficient hydrochemistry data were available for reaching final conclusions on ground-water flow models. For example, evaluation of the stable isotopic composition of local precipitation, the effects of drilling fluid contamination on apparent carbon-14 ages and other hydrochemical parameters,

Table C.4-3. Approximately observed hydraulic heads[a] relative to mean sea level.

Borehole	Location relative to barrier (nearest mile)	Saddle Mountains Basalt (feet)	Wanapum Basalt (feet)	Grande Ronde Basalt (feet)
Upper Cold Creek Valley				
McGee well	2 mi west	ND[b]	960 (U)[c], 661 (L)	590 to 601
DB-11	1 mi west	670 to 680 (L)[d]	735 to 742 (U)	ND[b]
Reference repository location				
DC-22	1 mi east	442 (U)[c], 410 (L)	400 (U), 400 (L)	397 (U), 402 (L)

NOTE: 1 mile = 1.6 kilometers; 1 foot = 0.3028 meter

[a]Sources of data: McGee - Wood et al. (1984)
DB-11 - Swanson and Leventhal (1984)
DC-22 - Bryce and Yeatman (1985).

[b]No data.

[c]U = upper part of formation.

[d]L = lower part of formation.

and nearly all hydrochemical data from boreholes in the reference repository location were unavailable until after publication of the site-characterization report. To a significant extent, deficiencies in the treatment of hydrochemistry in the site-characterization report derive from an inadequate data base, a shortcoming recognized by the U.S. Department of Energy and others.

Issue: Iodine-129

One commenter noted that trace concentrations of iodine-129 found in ground-water samples beneath the Hanford Site might be of use in inferring ground-water dynamics and assessing ground-water travel time estimates. Two references were given that relate to this subject.

Response

The Draft Environmental Assessment listed one reference (Gephart et al., 1976) that reported on iodine-129 concentrations in the Saddle Mountains Basalt near Gable Mountain Pond and West Lake. (Refer to Fig. 3-26 in the Draft Environmental Assessment for specific locations.) Three additional U.S. Department of Energy-cleared reports containing iodine-129 data (Brauer and Rieck, 1973; Strait and Moore, 1982; Graham et al., 1984) have been added to the final Environmental Assessment. Collectively, these reports indicate low levels of iodine-129 are present in the shallow ground water near the above-mentioned water bodies.

Available iodine-129 data may or may not be suitable for use as a manmade tracer to assist in flow system conceptualization or evaluation of ground-water travel times. To assess the potential use of these data the U.S. Department of Energy will carry out a technical review to evaluate published and unpublished iodine-129 information. The support role iodine-129 data might have in addressing ground-water travel times must await completion of this review. As in the resolution of any technical question, facts are first assembled and data quality understood before conclusions are drawn.

One of the documents referenced by the commenter was not used in the Draft Environmental Assessment because it was never issued as a final report. New paragraphs were added to Section 3.3.2 of the final Environmental Assessment to identify additional reports and to discuss iodine-129 concentrations found in the shallow basalts, as addressed in these reports. The Brauer and Rieck (1973) report has also been added to the final Environmental Assessment.

C.4.1.2.2.4 Characterization activities

Issue

Many comments received on Chapters 2 and 3 of the Draft Environmental Assessment dealt with the need for additional ground-water data. A few comments pertained to the importance of understanding the extent and continuity of high permeability fracture zones or other interflow or intraflow features such as those addressed in the last paragraphs of pages 3-78 and 3-86, and stated that knowledge of such zones is important in evaluating ground-water travel times and radionuclide transport. One commenter questioned the reasonableness of a fracture zone being "localized" as was stated in the last paragraph of page 3-86. Several comments centered on the need for additional regional ground-water quality data, identification of well water withdrawals by individual aquifers, listing of well ownerships and completion designs, and (or) the necessity of making long-range ground-water consumption estimates. Two commenters said that the Draft Environmental Assessment text in Section 2.3.1 should have stated that not enough data are present to fully describe the ground-water flow system. Two commenters also asked for a description of plans for future hydraulic testing of the deep basalts.

Response

It is agreed that the extent and continuity of any high permeability fracture zone(s) that could affect waste isolation should be evaluated. The importance of understanding the potential hydraulic influence of such zones was the basis for incorporating Figure 3-36 and support text into the Draft Environmental Assessment and for taking a "present" position for the third potentially adverse condition under postclosure geohydrology (DOE, 1984a; 960.4-2-1(c)(3)) (see Subsection 6.3.1.1.10).

Regarding the comment questioning the reasonableness of the Umtanum fracture zone being "localized," it is stated in the last paragraph on page 3-86 and the top of page 3-88 that this feature "is presently considered as a localized feature because at other borehole sites tested, the same stratigraphic zone possesses a much lower hydraulic conductivity typical of other basalt flow interiors studied." This implies that the feature is interpreted as localized in the Umtanum flow because a much lower hydraulic conductivity is measured in surrounding boreholes. This seems to be a responsible interpretation based on available data; with further data, interpretations may or may not change. In either case, future site-characterization plans will establish a research approach toward understanding the hydraulic characteristics of intraflow or interflow discontinuities important to waste isolation. See issue on abundance of permeable fracture zones in Subsection C.4.1.2.2.2 of this appendix for additional discussion.

The U.S. Department of Energy agrees that new regional ground-water quality data, some on a stratigraphic-specific basis, should be collected and existing data fully reported. Subsection 2.1.4.1 of the Draft Environmental Assessment broadly treated the topic of regional ground-water chemistry. In fact, in the referenced discussion it was stated, "Overall, regional hydrochemistry is only preliminarily understood." The same discussion acknowledges weaknesses in the existing data base. Understanding aspects of the regional hydrochemical evaluation is important in evaluating site-specific shallow and deep ground-water chemistry. These data needs would be addressed during site characterization.

Subsection 2.1.4.2 referenced many of the available data sources regarding water-well withdrawals, ownerships, completions designs, and projected ground-water consumption. While this treatment was brief compared to discussions required for an environmental impact statement, it is considered sufficient to meet the requirements of an environmental assessment as specified within the Nuclear Waste Policy Act of 1982.

It is agreed that insufficient data are available to fully describe the ground-water flow system. These data needs were acknowledged in many sections of the Draft Environmental Assessment (e.g., Subsection 2.1.4.1, Sections 3.3.2 and 4.1.1, and Subsection 6.3.1.1.11.3). Data acquired during future studies will be used to define waste isolation capabilities of the ground-water system.

Hydrologic test plans for investigating the deep basalt will be included in the upcoming site-characterization plan if the reference repository location is recommended for further study. Although the Environmental Assessment does not function as a planning document, a broad approach outline to future ground-water studies was included in Section 4.1.1 of the Draft Environmental Assessment.

The last full paragraph in Subsection 3.3.2.1.1 of the final Environmental Assessment has been modified to include the possibility of a localized fracture zone being interconnected to a basalt flow top or bottom. In addition, Subsection 4.1.1.5 has been changed to reflect the need for regional hydrochemical data.

C.4.1.2.2.5 Miscellaneous

Numerous comments received for Chapters 2 and 3 of the Draft Environmental Assessment were not easily incorporated into previous ground-water discussions in this appendix due to subject matter, topic breadth, and (or) emphasis of the comment concerns. These comments are discussed individually as issues.

Issue: Definition of aquifer and aquitard

One commenter noted that caution should be used in quoting former investigators who classify flow tops as more permeable than interiors. Definitions of what constitutes an aquifer or aquitard is dependent on perspective and water need.

Response

The U.S. Department of Energy agrees with the comment.

Issue: Current ground-water monitoring

One commenter asked "what is current ground-water monitoring?"

Response

This is interpreted to mean water-level monitoring. Water-level data and borehole descriptions for monitoring wells used are detailed in Swanson and Leventhal (1984) and Swanson and Wilcox (1985). The first report was referenced in Chapter 3 of the Draft Environmental Assessment; the second report has been added to the final Environmental Assessment. These reports note that ground-water levels are monitored in basalt at 35 separate locations on the Hanford Site. In addition, semiannual reports are issued on the results of water-table monitoring in approximately 210 wells penetrating the unconfined aquifer on the Hanford Site (Schatz, 1984).

Two new references detailing hydraulic head monitoring in the unconfined aquifers and basalt flow system have been added to Section 3.3.2 of the final Environmental Assessment.

Issue: Umtanum fracture zone description

One commenter noted that on page 3-86, paragraph 5 of the Draft Environmental Assessment, there was an inconsistency of numbers reported for the Umtanum fracture zone. The Draft Environmental Assessment gave a value of 10^{-4} meter per second (10^{1} feet per day) while the Strait and Spane (1983) reference stated 5.2 x 10^{-4} meter per second (147 feet per day). Zone thickness (1 versus 2 meters (3 versus 6 feet)) also was questioned.

Response

The commenter has found an error in the Draft Environmental Assessment resulting from rounding all metric units to the nearest conservative order of magnitude (5.2 x 10^{-4} meter per second is rounded to 10^{-4} meter per second). The rounded number later was converted back into English units (10^{-4} meter per second equals 28 feet per day--or 10^{1} feet per day, as the text gave). For this specific fracture zone quoted from a report by Strait and Spane (1983), the exact, nonrounded numbers will be given. The quote of a 3-foot thickness instead of 6 feet was an error. These corrections have been incorporated into Subsection 3.3.2.1.1 of the final Environmental Assessment.

Issue: Use of dispersivity values

One commenter stated that dispersivity values are a function of test scale and should not be "plugged into" regional models.

Response

The U.S. Department of Energy agrees with the comment. Dispersivity values are carefully selected and their uncertainty qualified.

Issue: Basalt flow leakage

One commenter asked, "How can the U.S. Department of Energy say that basaltic flows are not going to leak?"

Response

The U.S. Department of Energy did not state that basalt flows are "not going to leak." For example, the commenter is referred to Subsection 3.3.2.1 of the Draft Environmental Assessment regarding potential ground-water pathways, Subsection 3.3.2.2 on alternative ground-water flow concepts, and the last several paragraphs of Section 3.3.2 relative to hydrochemical evidence for vertical ground-water mixing. Field quantification of the degree of leakage across basalt flow interiors will be a major thrust in upcoming studies (see Subsections 3.3.2.2 and 4.1.1.3.1 of the Draft Environmental Assessment).

Issue: Questions about Table 3-7

Two commenters asked identical questions about Table 3-7 of the Draft Environmental Assessment. The first requested a definition of the term "best estimate"; the second inquired why the table does not include other Grande Ronde Basalt flow top hydrologic test results.

Response

The term "best estimate" was used by the referenced authors (Jackson, 1982; Wilson, 1983) to indicate their professional judgment as to the most characteristic test value obtained. This is an important interpretation because a range of possible values (as given in Table 3-7) is possible using different standard analytical techniques.

Other individual Grande Ronde Basalt flow top test results were not similarly compared in Table 3-7 because such specific comparisons were not known to be completed and documented for reference.

Issue: Regional ground-water chemistry

One commenter expressed concern that little is known regarding regional ground-water chemistry, especially from the deeper (Grande Ronde) basalt flows. Regional water samples are commonly mixtures of ground waters from more than one stratigraphic unit. Quality control on regional ground-water chemical data is needed.

Response

The above observations also were made in the Draft Environmental Assessment. For example, Subsection 2.1.4.1, sentence 1, pages 2-28 and 2-29 stated, "Ground-water chemical analyses available for the Columbia Plateau are usually composite and represent water samples obtained from a number of hydrogeologic units penetrated at the sampled well site." Subsection 2.1.4.1 stated, "Overall, regional hydrochemistry is only preliminarily understood. This results from the scarcity of three-dimensionally distributed hydrochemical data."

Quality control measures on ground-water sampling and hydrochemical analyses are enforced by the U.S. Department of Energy, contractors, and agency subcontractors. A discussion of these procedures is found in a report by Early et al. (1985). Procedures for classifying the quality of historical regional data collected by organizations not responsible to the U.S. Department of Energy will be completed in the future.

It is agreed that water samples from the Grande Ronde Basalt are needed in the reference repository location and vicinity to postulate likely ground-water flow paths. A plan outline for collecting critical regional hydrochemical data will be included in the site-characterization plan, should the reference repository location be recommended for further study.

Issue: Areal distribution of vertical hydraulic conductivity

One commenter noted that the distribution of vertical hydraulic conductivity may vary significantly in the reference repository location and vicinity based on structural and other types of basalt discontinuities.

Response

This observation agrees with statements made in the Draft Environmental Assessment. For example, the first sentence on page 3-79 stated, "The specific hydraulic effect of major geologic structures on ground-water flow patterns, such as anticlines crossing portions of the Columbia Plateau, is currently unanswered but is being addressed (see Section 4.1)." Also, the second bullet on page 3-79 addressed possible hydraulic influences major structural features (Cold Creek barrier and Umtanum-Gable Mountain anticline) may have on the reference repository location and vicinity.

Issue: Concern over permeable fractures and basalt leakage

Concern was expressed by several reviewers about permeable fractures and porous zones existing in basalt. Such features were said to offer avenues for ground-water movement, making it impossible to assume no water interchange takes place between deep basalt layers or that a "no leak" scenario exists.

Response

The Draft Environmental Assessment did not imply a "no leak" scenario or that water leakage between basalt layers does not take place. For example, Sections 2.1.4 (Regional ground-water hydrology) and 3.3.2 (Ground water) and Subsection 3.3.2.2 (Alternative ground-water flow concepts) collectively addressed such topics as vertical leakage, three-dimensional recharge-discharge relationships, geologic structures acting as vertical conduits, and alternative flow concepts, which include the possibility of basalt units that have high vertical permeability. The document also outlined data uncertainties and field studies requiring completion to answer geohydrologic issues critical to understanding the suitability or nonsuitability of basalt for waste isolation. Examples of these discussions were included in Section 4.1.1 (Field studies) and Subsection 6.3.1.1.11.3 (Reducing data uncertainty).

Contrary to the commenter's apparent perception, not all basalt zones are highly porous and (or) permeable to ground-water flow. The locations of aquifers (i.e., the more transmissive basalt flow tops and sedimentary interbeds) were identified (see Subsection 6.3.3.3.3 of the Draft Environmental Assessment) and their permeabilities summarized (see Subsection 3.3.2.1.2). Some flow tops and interbeds have high permeabilities; others are very low. Basalt flow interiors separating flow tops or interbeds appear to have very low transmissive characteristics (see Subsection 3.3.2.1.1).

The U.S. Department of Energy agrees that natural fractures exist in basalt rock. It was stated in Section 2.1.1 of the Draft Environmental Assessment that fracture abundances in rock core samples range from approximately 1 to 40 fractures per meter (less than 1 to 12 fractures per foot). Most of these fractures have narrow widths (less than 0.5 millimeter (0.02 inch)) filled with multiple generations of secondary minerals. The volume of filled fractures in dense basalt interiors is typically large—greater than 99 volume percent. Thus, most fractures formed from cooling and shrinkage of the original molten rock mass are now essentially sealed, rather than open to fluid movement.

It is only natural that much of the public perception of the basalt "obvious open fracture network" results from viewing rock exposed at land surface. However, these outcrops have been subjected to thousands to millions of years of weathering. The once-filled fractures are now open because the original secondary minerals were chemically removed. This phenomenon has not taken place deep underground.

The objective of the basalt studies is identification of the natural, at-depth characteristics of basalt rock, including measuring the permeability of basalt flow interiors, flow tops, and interbeds to determine if radioactive waste can be safely isolated from man and the environment.

<u>Issue</u>: Water level rise in basalt associated with irrigation

One commenter referred to the text discussion in Subsection 2.1.4.2 of the Draft Environmental Assessment regarding rise in water levels within upper Columbia River basalts in the eastern Pasco Basin as a result of the Columbia Basin Irrigation Project. The reviewer questioned whether or not water levels will continue to rise and become contaminated by radioactive materials already contained in the soils beneath the Hanford Site.

Response

The water-level rise of 6 to 12 meters (20 to 40 feet) mentioned in the Draft Environmental Assessment referred to "shallow" aquifers in an area of the Pasco Basin east of the Hanford Site. Because of the distance separating the Hanford Site from this area of irrigation-related recharge, water-level increases for confined aquifers within the upper Columbia River basalts on the Hanford Site would be considerably less.

The water-level rise described refers to a hydrostatic response in water level within a cased (i.e., lined) monitoring well. Water level increases or decreases in such structures are attributable to variation in formation water pressure within a confined aquifer, and do not represent actual movement of water within formations above the monitored horizon. In essence, water-level measurements within cased wells can be visualized as a manometer (or piezometer) that reflects formation pressure variations within a confined or isolated well-aquifer system.

In summary, increases in formation pressure within confined aquifers would be reflected by an increase in water levels within a cased well, but would not cause contamination of the confined aquifer water by radionuclides entrained in soils on the Hanford Site.

Issue: Grande Ronde Basalt ground-water recharge and discharge

One commenter paraphrased from the first paragraph on page 2-24 of the Draft Environmental Assessment, which stated that the Grande Ronde Basalt can receive ground-water recharge or discharge water along margins of the Columbia Plateau, at rivers, and from leakage of other basalt formations. The commenter's belief is "that isn't a good indication of a restricted ground-water horizon in the waste level of the stratigraphy."

Response

As outlined in the above-mentioned paragraph, the Grande Ronde Basalt is part of a large-scale flow system in which water enters, moves, and exits. As discussed in Section 2.1.4 (Regional ground-water hydrology) of the Draft Environmental Assessment, surface recharge most likely occurs at higher elevations where precipitation is greater and the Grande Ronde Basalt crops out or is near the land surface. In like fashion, rivers are well known as discharge and (or) recharge boundaries. The important considerations to the waste isolation issue are the hydraulic and hydrochemical characteristics of the Grande Ronde Basalt some 1,000 meters (approximately 3,000 feet) beneath the Hanford Site and how these relate to the surrounding geohydrologic setting. These characteristics will determine how quickly and in what quantity ground water moves, and the natural sorptive properties of the geochemical environment.

Issue: Ground-water age dating in regional wells

One reviewer quoted from page 2-31 of the Draft Environmental Assessment " . . . Absolute ground-water ages cannot be reliably calculated from these regional data because of ground-water mixing across different basalt horizons in the sampled boreholes . . . " The commenter concluded this statement does not support the idea that "the waste horizon is a separate hydrologica (sic) aquifer and is separated from the ground-water layers above."

Response

Ground-water mixing results from a well open to more than one flow top or interbed. Therefore, the water sample collected is some unknown composite from multiple rock zones. A ground-water age analysis on such a sample provides little useful information. On the other hand, carbon-13 and -14 analyses on water samples from an individual flow top or interbed are valuable. The commenter also omitted the last phrase of the sentence in question which provides a second reason regional ground-water ages are not reliable (i.e., the lack of carbon-13 (dead carbon) corrections in the carbon-14 analyses).

Issue: Onsite well drilling in basalt

One commenter stated that the U.S. Department of Energy has drilled over 40 "site-specific" boreholes and coreholes, plus a total of 3,000 boreholes across the Hanford Site. Despite this intense drilling, compared with few holes drilled at other sites considered for repository development, it appears there are few conclusions on ground water. Therefore the commenter concluded that the hydrology at the Hanford Site apparently is a difficult problem to understand.

Response

While it is true many wells have been drilled on the Hanford Site, only a small percentage of these wells have been completed in support of the basalt project or for hydrologic investigation purposes.

Over the last 60 years, approximately 2,900 wells have been drilled in the area now called the Hanford Site (McGhan et al., 1985). Of these, 2,500 wells still exist with approximately 900 wells (36 percent of the total) completed into or below the water table.

Most of these wells have been constructed for a variety of purposes related to water supply, facility construction, environmental monitoring of sediments below waste management facilities (tanks and cribs), geologic and seismic studies, unconfined aquifer ground-water monitoring, and associated hydraulic data collection.

Since the beginning of the Basalt Waste Isolation Project in 1976, 58 holes have been drilled or cored in support of basalt studies. These are distributed across a large portion of the 1,500-square-kilometer

(570-square-mile) Hanford Site to address a range of geotechnical questions including: basalt-sediment stratigraphy, structure, and tectonics; basalt permeability, hydraulic heads, and ground-water chemistry; and mining safety and engineering design considerations. These 58 holes account for 2 percent of the total holes at the Hanford Site. Considering the environmental importance of ensuring a technically sound selection for a waste isolation medium, this is not a large number of holes.

Development of a geotechnical basis for answering waste isolation issues at any geologic site will require extensive drilling. Some geologic sites have drilled boreholes to examine site-specific characteristics, others have not (see Subsection 7.2.1.1 of the Draft Environmental Assessment). Each of the five recommended sites (basalt, tuff, and three salt have a "not present" position relative to the third favorable condition under postclosure geohydrology (DOE, 1984a; 960.4-2-1(b)(3)) ("sites that have stratigraphic, structural, and hydrologic features such that the geohydrologic system can be readily characterized and modeled with reasonable certainty"). The difficulty of such studies is recognized as a commonality for all sites (Meyer, 1985).

Issue: Merit of future borehole drilling

One commenter referred to a discussion in the Draft Environmental Assessment (see Section 3.3.2) on conceptualization of ground-water flow within deep Hanford Site basalts (i.e., Grande Ronde Basalt). The commenter questioned whether " . . . if after 40 holes on (the) Reference Site, the information is not available to make a scientific decision on the hydrology--then how can we be sure that 40 more holes will give information on the safety of this site?"

Response

The comment embodies several misconceptions. Hydrologic data for conceptualization of ground-water flow within the Grand Ronde basalts are available for only seven sites within the reference repository location (boreholes DC-3, paired DC-4 and DC-5, DC-20, DC-22, RRL-2, RRL-6, and RRL-14). Of this total, only five provide hydrologic information for more than one Grand Ronde Basalt flow. Therefore, considerably fewer than 40 boreholes have been hydrologically evaluated in the reference repository location.

Site safety is dependent on a number of factors, of which ground-water flow direction is only one element. Other major research areas are geochemistry, geology, rock characteristics, and repository design, and each has characterization needs requiring shallow or deep borehole drilling. Such is common to any geology studied for waste isolation potential. As discussed on page 3-82 of the Draft Environmental Assessment, finalization of the conceptual ground-water flow within deep basalts in the reference repository location, as well as other factors that require assessment, can only be evaluated after site-characterization activities are completed. These activities were outlined in Section 4.1 of the Draft

Environmental Assessment. The number of boreholes needed for completing site characterization (should the reference repository location be recommended for characterization) is unknown at this time.

<u>Issue</u>: Hydraulic head values, vertical flow, and spring discharge

One commenter expressed the following four basic concerns.

- Test-well data shown in the site-characterization report (DOE, 1982), but not in the Draft Environmental Assessment, indicate high hydraulic head values for portions of the Wanapum and Grande Ronde Basalts.

- When water-level readings taken from different basalt members reach the same elevation, this is an indication these members are hydraulically connected.

- There is no assurance significant vertical flow will not take place.

- Rockwell Hanford Operations geologists have suggested that interbeds overlying the Grande Ronde Basalt may discharge ground water as springs along the south bank of the Columbia River a few miles north of the reference repository location.

<u>Response</u>

In response to the first comment in this issue, the commenter is in error. The site-characterization report (DOE, 1982) data were frequently referenced in the Draft Environmental Assessment and used either in numerical form or as a basis for ground-water flow computation (e.g., see Section 3.3.2 and Subsection 6.3.1.1.6). Note that Table 6-5 summarized previously reported hydraulic head values. Additionally, see page 3-78 (last full paragraph) for a discussion of water under artesian and flowing artesian conditions. Such discussions and information are common to both reports.

All flow systems are hydraulically connected; the question is how much interconnection exists. This focuses on the topic of head distributions and vertical hydraulic conductivity of basalt flow interiors. In a three-dimensional flow field, hydraulic heads decrease with depth in recharge areas, increase with depth in discharge regions, and are relatively uniform (no head change with depth) between. Available evidence appears to support the concept that in and near the reference repository location, the shallow Saddle Mountains Basalt is being recharged and the deep Grande Ronde Basalt is discharging into the overlying Wanapum Basalt. Across the Wanapum Basalt, vertical hydraulic heads are low (10^{-4} meter per meter or less (10^{-4} foot per foot)). The question of how the Grande Ronde Basalt is interconnected to the overlying basalts remains unanswered and unquantified. The apparent low hydraulic conductivity across flow interiors (see Subsection 3.3.2.1.1 of the Draft Environmental Assessment) suggests a low degree of interconnection. In areas containing stratigraphic and (or) structural discontinuities, higher vertical interconnection is expected (see Subsection 3.3.2.2) versus areas of nondeformed and accordantly layered basalts. Hydrologic testing from surface boreholes and the exploratory shaft facility (see Subsections 4.1.1.3 and 4.1.1.6) are designed to quantify the vertical hydraulic conductivity of basalt flow interiors.

As noted above and in the Draft Environmental Assessment, the question of vertical hydraulic conductivity across basalt flows is an unanswered question. Preliminary information does not resolve the question of how much vertical ground-water movement takes place. This issue needs to be fully field analyzed as was noted in Subsections 3.3.2.2, 4.1.1.3, 6.3.1.1.11.3, and 6.3.1.1.12 of the Draft Environmental Assessment.

Throughout the Pasco Basin, springs are known to flow from basalt outcrops along major anticlinal ridges. Umtanum Ridge, northwest of the reference repository location, is such an anticline. The stratigraphic section from which springs flow depends on the basalt formation exposed. For example, along Rattlesnake Mountain, southwest of the reference repository location, Saddle Mountains, Wanapum, and some Grande Ronde Basalts crop out. Springs issue at specific locations throughout these exposures (Schwab et al., 1979; Gephart et al., 1979). The chemical composition of these spring waters is that of a dilute (low total dissolved solids concentration) calcium-magnesium-bicarbonate chemical type. A geologic consultant to the U.S. Department of Energy (Goff, 1981) reported similar ground-water chemistry from Juniper Springs, located along the northern flank of Umtanum Ridge northwest of the reference repository location.

In discussing all spring and irrigation well waters sampled, Goff (1981, p. 79) said, "The water chemistry and pH of all eight samples are strikingly similar, although they issue from a variety of depths and geologic settings. The waters are dilute and of good drinking quality . . . Juniper Springs issues from the Juniper Springs landslide complex that covers a probable fault. The most obvious aquifer that might supply the spring (if it is not merely a landslide spring) is the Vantage sandstone interbed, which crops out 770 meters to the east." The chemistry reported (Goff, 1981) for Juniper Springs (values in parts per million) is given below.

Field pH	= 5.9	K^+	= 6.25
SiO_2	= 55	HCO^{-*}	= 148
Mg^{+2}	= 13.3	SO_4^{-2}	= 7.5
Ca^{+2}	= 19.5	Cl^-	= 5.75
Na^+	= 20	F^-	= 0.62

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*It is assumed the chemical designation HCO^- reported by Goff (1981) is a typographical error. The proper symbol for bicarbonate is HCO_3^-.

Water chemistry, such as that identified above, resembles a shallow ground water or a spring locally recharged by precipitation infiltering overlying rocks. The commenter should compare the above chemical analyses with those typical of basalt sampled on the Hanford Site. (Page 3-83 of the Draft Environmental Assessment contained a summary table; Early et al. (1985) give details on well and spring sample analyses.) The fluoride, chloride, and sodium concentrations of typical deep mineralized ground waters beneath the reference repository location are clearly distinct from any spring samples collected at Juniper Springs. Thus, the source of Juniper Springs waters is not the deep basalts lying farther east on the Hanford Site.

The hydrochemistry discussion at the end of Section 3.3.2 of the final Environmental Assessment has been expanded by several paragraphs to include a discussion of spring occurrence and water chemistry. Updated hydraulic head data have also been added to Section 3.3.2.

Issue: Documentation of post-1982 information

One commenter stated that the Draft Environmental Assessment did not include information other than that in the site-characterization report (DOE, 1982), and therefore did not contain sufficient information regarding favorable or unfavorable ground-water conditions.

Response

The commenter is incorrect. A quick review of Section 3.3.2 (Ground water) alone turned up the following new hydrologic-related references and reports not published in the site-characterization report.

Bentley, 1982
DOE/NRC, 1983
Eddy et al., 1983
Gelhar, 1982
Gephart et al., 1983
Graham et al., 1982
Jackson, 1982
LBL, 1982
Long and WCC, 1984
Newcomb, 1982
NRC, 1983
PNL, 1983
Spane and Thorne, 1984
Spane et al., 1983
Strait and Spane, 1983
Strait et al., 1982
Swanson and Leventhal, 1984
Wilson, 1983
Yeatman and Bryce, 1984a, 1984b

In addition, the above reports reference many other documents not referenced in the site-characterization report. Since approximately 1 year has elapsed between publication of the Draft Environmental Assessment, many new hydrologic references have been added to the final Environmental Assessment in addition to those given above. It should also be noted that an environmental assessment is a broad, summary-type document, not a bibliography listing all related reports. Otherwise, the reference list would be greatly enlarged. Much post-1982 geohydrology information was contained throughout the Draft Environmental Assessment. The commenter is invited to compare reference lists of the two documents.

Issue: Three perceptions on hydrology discussion in Draft Environmental Assessment

One commenter made a number of statements about the Draft Environmental Assessment, including that textbook understandings of hydrologic flow have been ignored; implications were made that water does not move under the Hanford Site and does not flow into the Columbia River; and contentions were made that basalt has only low permeability.

Response

The statement that "textbook understandings" were ignored is a non-specific statement but one with which the U.S. Department of Energy does not agree.

The Draft Environmental Assessment did not state or imply that water does not move in the basalt beneath the Hanford Site. Stratigraphic intervals and intraflow features having high or low fluid conductance were acknowledged in the document throughout the geohydrologic discussions. The commenter is encouraged to review Sections 2.1.4 (Regional ground-water hydrology) and 3.3.2 (Ground water) and Subsections 6.3.1.1 (Geohydrology) and 6.3.3.3 (Hydrology). Subsection 6.3.3.3.3 specifically identified several aquifers lying between the land surface and the repository candidate horizons.

The Draft Environmental Assessment did not imply that ground water does not discharge to the Columbia River. Mention of basalt ground-water discharge into the Columbia River was included, for example, on page 7 (last two sentences), page 3-77 (first partial paragraph), page 3-78 (second paragraph), and page 3-80 (last paragraph).

The commenter indicated that the Draft Environmental Assessment stated all basalt has very low permeability. The document did not so state. The document identified basalt zones having a wide range of permeabilities—including stratigraphic horizons that are considered as aquifers.

Issue: Ground-water steady-state condition and flow paths

One commenter said that Basalt Waste Isolation Project scientists tend to assume the ground-water system is in a steady state and interbeds provide the major principal path for ground-water movement.

Response

The onsite scientists do not assume the ground-water system is in steady state or that sedimentary interbeds are the principal aquifers. For example, Section 3.3.2 (see p. 3-80 of the Draft Environmental Assessment) described monitored water-level changes in the Saddle Mountains and upper Wanapum Basalts; Subsection 2.1.4.2 addressed water-level declines in the upper Wanapum Basalt over the past 50 years resulting from ground-water withdrawal. Water-level changes occurring over the last decade in the deep (mostly Grande Ronde) basalts also were noted in Section 3.3.2.

In early 1984, three new piezometer suites (DC-19, DC-20, and DC-22) were installed in and around the reference repository location. Each borehole site has nine piezometers monitoring water levels from the lower Ringold Formation to the flow top of the Umtanum flow of the Grande Ronde Basalt. Details of this monitoring are included in the final Environmental Assessment. In summary, these data appear to confirm earlier concepts that water levels in the Wanapum and Grande Ronde Basalts change very slowly in the reference repository location.

The discussion in Subsection 3.3.2.1 began with the sentence "Ground-water movement in basalt likely occurs along pathways found in three groups of features: (1) discontinuities within flow interiors, (2) flow contacts and sedimentary interbeds, and (3) bedrock structures (Gephart et al., 1983)." Several pages of support documentation followed that introduction. Thus, the Draft Environmental Assessment stated that more than just sedimentary interbeds contribute to ground-water movement. Additionally, Subsection 6.3.3.3.3 identified principal aquifers that include both sedimentary interbeds and basalt flow tops.

Issue: Statement of three potential errors in Draft Environmental Assessment

One commenter cited three potential errors in the Draft Environmental Assessment.

In Subsection 3.3.2.1.1, last paragraph, the Strait and Spane (1983) report was said to assign a hydraulic conductivity of approximately 5.2×10^{-4} meter per second (1.5×10^{2} feet per day) and a thickness of 2 meters (6 feet) to the Umtanum fracture zone--not 10^{-4} meter per second (10^{1} feet per day) and 1 meter (3 feet) thickness.

In Subsections 3.3.2.1.1 and 6.3.1.1.6, the Sagar and Runchal (1982) report was said to present an example calculation related to future permeability, which was intended as illustrative example on hydraulic conductivity. This calculation was cited in the Draft Environmental Assessment to justify a near-isotropic condition of the basalt interior.

In Subsection 6.3.1.1.6, last paragraph, Gelhar (1982) and Leonhart et al. (1982) estimates of effective porosity for the McCoy Canyon basalt flow were given as 0.02 and 0.04 percent. The Draft Environmental Assessment cited these papers to support an effective porosity of 1.0 to 0.01 percent.

Response

Relative to the Strait and Spane (1982) report, the commenter found an error resulting from rounding all metric units to the nearest conservative order of magnitude; 5.2×10^{-4} meter per second was rounded to 10^{-4} meter per second. Later conversion of this rounded number back to English units resulted in 10^{-4} meter per second being rounded to 28 feet per day--or 10^{1} feet per day as given in text. For this specific fracture zone quoted from Strait and Spane (1983), the exact, nonrounded number (147 feet per day) will be given. The quote of a 3-foot thickness instead of 6 feet also was an error. This also has been corrected in the final Environmental Assessment. See issue on Umtanum fracture zone description under this appendix subsection for a similar comment.

The Sagar and Runchal (1982) reference was cited in the Draft Environmental Assessment. The 3.5 to 1 anisotropic ratio given on pages 3-85 and 6-71 was used as an example of what might exist in the subsurface, not a justification for isotropic conditions. The paragraph containing the above reference began by stating "In lieu of many direct measurements, estimates of the anisotropic ratio . . . . " This uncertainty regarding the vertical-to-horizontal anisotropic ratio was stated in other sections of the Draft Environmental Assessment including Subsections 3.3.2.2. (Alternative ground-water flow concepts), 4.1.1.3.1 (Large-scale hydrologic stress tests), and 6.3.1.1.12 (Conclusions on qualifying condition). A support discussion can be found in the issue on vertical hydraulic conductivity in Subsection C.4.1.2.2.2 of this appendix.

The commenter said of the reports by Gelhar (1982) and Leonhart et al. (1982), "They estimate the zone has an effective porosity of 0.02 to 0.04 percent." Such numbers are not found in these references. In fact Gelhar and Leonhart give values only for longitudinal dispersivity and effective thickness. They do not conclude an effective porosity value or range--most likely because, as Gelhar (1982) stated on page 14, the "tested zone does not behave as a homogeneous, constant-thickness aquifer." This makes it less than reliable to simply divide the effective thickness value (calculated directly from tracer tests) by the test interval thickness. Other possible explanations that may have prompted the comment: the commenter calculated an effective porosity value from information contained by the references, then attributed the value to the authors; or the commenter may have confused effective porosity with the dispersion parameter(s) discussed by both Gelhar (1982) and Leonhart et al. (1982).

As a side note, an effective porosity value of 4.3×10^{-4} was given by Gelhar (1982 p. E-31), where a test report from Science Applications Incorporated was reproduced. Science Applications Incorporated is quoted: "Using the thickness of the straddled interval b = 49.8 feet, we get an effective porosity of 4.3×10^{-4}. It is preferred to use the product nb, however, since the flow may be taking place through a much smaller section of the formation." This quote reflects the same interpretation caution expressed by Gelhar.

The important consideration in this discussion is that Gelhar (1982) and Leonhart et al. (1982) recognized the uncertainty in performing a "simple" effective porosity calculation from effective thickness and test interval thickness numbers. The Draft Environmental Assessment also acknowledged and identified the need for a better understanding of flow top and flow interior effective porosities (e.g., see Subsections 4.1.1.3.3 (Tracer tests), 4.1.1.6.3 (Hydrologic characterization), 6.3.1.1.11.3 (Reducing data uncertainty), and 6.3.1.1.12 (Conclusions on qualifying condition).

The corrections noted in paragraph 1 of this response have been incorporated into Subsection 3.3.2.1.1 of the final Environmental Assessment.

Issue: Impact of drilling activities on radionuclides existing in soil column

Three commenters posed interrelated questions.

- "What is the impact of shaft-drilling activities during site characterization on the suspended radionuclides in the soil column beneath the waste disposal cribs and trenches at the 200 Areas?"
- "What is the possibility of the disposal of waste-water from repository construction and site characterization on these wastes?"
- "What is the possibility of upward migration of ground-water into these suspended radionuclides as a result of shaft construction?"

Response

No impact is expected because shaft drilling would not take place above or through any cribs or trenches having soil columns contaminated by radionuclides. As stated in Section 2.2 of the Draft Environmental Assessment (see pp. 2-41, 2-50, and 2-51), areas of contaminated soil were avoided in the site-selection and screening process for identification and location of the principal borehole for the exploratory shaft and proposed surface facilities. Also, whenever a new borehole is planned, an environmental evaluation is written. This report and a site-excavation permit must be approved by the radiological monitoring staff of Rockwell Hanford Operations prior to site preparation and drilling to ensure that a borehole is not drilled through a soil column known or suspected to be contaminated. As noted in Subsection 4.2.1.3.6 of the Draft Environmental Assessment, no major impacts are expected from site-characterization activities.

The possibility of ground-water mounding from shaft construction is very low to nonexistent for several reasons, including close management of mud losses, shaft completion with steel liner and grout emplacement, and lining of the surface mud pit with low-permeability bentonite. Given the above measures to minimize fluid losses, and location of the shaft outside of contaminated areas, it is very unlikely that water would mound up to resuspend radionuclides.

Issue: Critique of hydrochemistry plans

One commenter noted that on page 3-82 mention was made of outside critique of hydrochemistry plans. The commenter requested the results of this review and asked why such a critique was not considered in the Draft Environmental Assessment.

Response

The results of several technical reviews of U.S. Department of Energy plans and documentation were referenced and factored into the Draft Environmental Assessment. In addition to the Bentley (1982), Lawrence Berkeley Laboratory (LBL, 1982), and Pacific Northwest Laboratory (PNL, 1983) documents listed on page 3-82, several references and quotes from U.S. Geological Survey and U.S. Nuclear Regulatory Commission critiques of the site-characterization report (DOE, 1982) were also used in the Draft Environmental Assessment (Robertson, 1983; NRC, 1983). Geohydrologic studies outlined in Chapter 4 factor in many of the data needs noted in the above reports. These outside reviews have helped the U.S. Department of Energy focus on technical concerns of the scientific community at an early stage in the site-evaluation process. Details of these reviews may be found in the referenced documents.

Issue: Proof of geohydrologic conclusions

One commenter expressed the opinion that many of the geophysical, geochemical, and hydrologic sections of the Draft Environmental Assessment put forth conclusions that cannot be proven now or in the future.

Response

The comment is all-encompassing and does not provide examples of any exceptions to the data bases or preliminary conclusions given in the Draft Environmental Assessment. Therefore, a specific response cannot be offered. In general, the commenter should note that the Draft Environmental Assessment included few final conclusions on geohydrologic issues because of the very preliminary nature of available information. Discussions under postclosure geohydrology in Section 6.3.1 were commonly introduced by the phrase "A final conclusion of this favorable (or potentially adverse) condition for . . . cannot be made at this time based on available data . . . " In addition, the U.S. Department of Energy believes that the technology exists or can be developed to resolve technical issues facing the proposed geologic disposal of radioactive waste.

Issue: Concern over unconfined aquifer contamination and future repository waste leakage

Two commenters expressed three concerns. The first was that basalt is very porous and contains many fractures and discontinuities; therefore, the rock is not conducive to waste storage. The second concern related to existing ground-water contamination in the unconfined aquifer from onsite waste disposal over the last 40 years. The belief was expressed that unconfined aquifer contamination portends future leakage of radioactive waste from a repository built in basalt. The third concern was that water disposal ("fluid injection") from the 200 West Area on the Hanford Site should have been mentioned in Subsection 2.1.4.2 of the Draft Environmental Assessment.

Response

While it is true that some portions of basalt flows are porous and possess high permeabilities, most of the basalt volume is very dense and apparently has a low permeability. Section 3.3.2 of the Draft Environmental Assessment addressed the hydraulic characteristics of basalt including differences between brecciated, vesicular flow tops and the much lower permeable flow interiors. Several references from independent agencies were given that recognized these distinctions. A repository would not be constructed in any rock having a high permeability that would permit radioactive waste to contaminate aquifers.

There is no similarity between the waste storage and disposal practices that have led to the contamination of the unconfined aquifer beneath the Hanford Site and the proposed engineered design of a commercial waste repository. Waste process waters containing low-level contamination have been routinely released into ponds and ditches on the Hanford Site for the last 40 years. Extensive ground-water monitoring over this period has traced the resultant contaminant movement. The references (Eddy et al., 1983; Prater et al., 1984) given in the Draft Environmental Assessment provide details on existing contaminant plumes and analyses routinely conducted. Such environmental surveillance reports are issued yearly. The low-level contamination of these waters has been a reported consequence of onsite water disposal practices. Discharge of these waters into the Columbia River does not pose a significant risk to local or regional inhabitants. This is addressed in a report by Price et al. (1984), which is also referenced in the Environmental Assessment.

On the other hand, the proposed repository is an engineered facility built deep underground and designed with multiple barriers to prohibit radionuclide releases for the first thousand years and to permit only slow releases thereafter. The primary barriers to waste movement from the repository are the natural chemistry of basalt rock, secondary minerals filling fractures, the surrounding ground water, and the hydraulic characteristics of the rock itself. The engineered barriers include the low solubility waste form, metal container, and backfill material (refer to Subsection 5.1.3.2 of the Draft Environmental Assessment for details). These barriers work in concert to retain short-lived radionuclides until their hazard is reduced to insignificant levels; most long-lived radionuclides will be adsorbed on rock surfaces near the repository. Radionuclides not readily adsorbed must be shown to be released in sufficiently small quantities to present no unacceptable risk to man and the environment. If this cannot be done for a geologic setting proposed for repository development, a repository will not be built at that site.

To summarize, discharge of waste waters on the Hanford Site has resulted in low-level contamination of the shallow aquifers. This contamination has been monitored and the migration predicted. No significant hazard exists for the general public. On the other hand, a repository would be designed to intentionally hold radionuclides in place, deep underground, for thousands of years and allow only small quantities to be released thereafter. This is accomplished by natural and engineered barriers.

Relative to the comment about including a discussion of the Hanford Site water disposal activities in Subsection 2.1.4.2, it should be noted that this subsection addresses only ground-water use activities. Hanford Site cooling and waste processing waters are pumped from the Columbia River; ground water is not relied on. Water disposal on the Hanford Site was mentioned in Subsection 3.3.1.2 and Section 3.3.2 of the Draft Environmental Assessment.

Issue: Ground-water monitoring near shallow solid waste burial grounds

One commenter noted that LaSala and Doty (1975) identified the need for additional ground-water monitoring points to determine the source of radionuclide contamination in ground water beneath the Hanford Site.

Response

The report referenced was an evaluation of the suitability of near-surface solid waste burial grounds on the Hanford Site for long-term storage of radioactive waste. The greatest concern expressed by LaSala and Doty (1975) was the possibility of precipitation infiltrating the soil column and transporting buried radionuclides to the underlying water table. It was concluded that none of the burial grounds was sufficiently instrumented with monitoring devices to determine if radionuclide leaching was occurring. It was recommended that environmental studies be undertaken to determine the long-term suitability of radionuclide storage in solid-waste burial grounds.

A study addressing the long-term environmental impacts of waste disposal on the Hanford Site will be issued in the future by the U.S. Department of Energy. It will address the final disposal strategy for high-level and transuranic wastes generated during national defense activities and stored on the Hanford Site. The document will be a draft environmental impact statement and, on release, will be available for public comment. Although it is agreed that existing knowledge of moisture movement beneath solid waste burial grounds is limited, the above study should correct this situation. It is believed that this study and environmental impact statement will address the central issues raised in LaSala and Doty (1975).

Issue: Dewatering ground-water system

One commenter was concerned about the U.S. Department of Energy undertaking onsite activities that would result in ground-water dewatering. In such a situation, the commenter said the State of Washington Department of Ecology would intervene to control ground-water usage.

Response

The only site-characterization activity planned that would require temporary, production of large quantities of water are pumping tests. The total water production from these tests, conducted over several years, is similar to that of the annual production of a typical single-pivot irrigation system covering 53 hectares (130 acres) with 150 centimeters

(60 inches) of water. (Refer to issue on timing of large-scale pump tests, under Subsection C.4.2.1.4 of this appendix, for more detail.) Therefore, there is no large-scale dewatering concern. It is also important to point out that many of the rock intervals planned for testing are very low water producers (less than a few gallons (several liters) per minute).

C.4.1.3 Environmental conditions

Many comments were received regarding the inadequacy and (or) insufficiency of the environmental baseline presented in the Draft Environmental Assessment. Most reviewers stated that this inadequacy resulted in the inability of the U.S. Department of Energy to perform a credible assessment of the impact of site-characterization activities. These comments are addressed in the following categories:

- C.4.1.3.1, Land use.
- C.4.1.3.2, Ecosystems.
- C.4.1.3.3, Air quality and weather.
- C.4.1.3.4, Noise.
- C.4.1.3.5, Aesthetic resources.
- C.4.1.3.6, Archaeological, cultural, and historical resources.
- C.4.1.3.7, Background radiation.

C.4.1.3.1 Land use

Activities at the Hanford Site other than those related to site characterization or repository development were the subject of many comments. These dealt primarily with defense activities. Several commenters requested an expanded discussion of other Hanford Site activities, others were concerned over the past record of Hanford Site activities, and a few were concerned about container leaks and the impact of defense activities on the long-term repository performance monitoring. These concerns have been addressed in Section C.6.4, Offsite installations.

Several commenters were concerned with an apparent conflict in land use between site-characterization and repository activities and the State of Washington-leased land (U.S. Ecology, Inc.). Others suggested that more information be presented regarding the Big Bend Alberta Company mineral leases and the U.S. Army Yakima Firing Center. These concerns have been addressed in Section C.6.2, Site ownership and control.

C.4.1.3.2 Ecosystems

Many comments were received regarding the inadequacy and (or) insufficiency of the ecological database presented in the Draft Environmental Assessment. The commenters questioned the data base relating to the flora and fauna of the Hanford Site, including: threatened, endangered and State-protected species; soils at the Hanford Site; surface water at the reference repository location; and the Columbia River and its biotic resources.

Issue: Inadequate baseline information

Several commenters stated that the Draft Environmental Assessment did not present an adequate baseline information on plant communities, mammals, and birds on the reference repository location or Indian reservations and the ceded areas adjacent to the Hanford Site.

Response

The baseline of flora and fauna of the Hanford Site are fairly well known and adequately described for the purposes of the Environmental Assessment. The reference repository location is not congruent with any Indian reservation; hence, certain biotic associations (e.g., Douglas forest and ponderosa scrub forest on Indian reservations) do not occur on the Hanford Site.

The U.S. Department of Energy, as part of the repository siting environmental impact statement scoping process, will undertake a program to indentify those areas both on and off the Hanford Site that could be impacted from repository-operation activities. An environmental baseline program will then be implemented to further characterize those potentially impacted areas. This baseline program will include the study of ecosystems, air quality, noise, aesthetic conditions, archaeology and cultural resources, and background radiation.

Issue: Threatened, endangered, and protected species

Many reviewers felt that the Draft Environmental Assessment lacked sufficient information on threatened, endangered, and State-protected species on the Hanford Site.

Response

As it was written, the Draft Environmental Assessment leads to confusion regarding the occurrence of sensitive, threatened, and endangered species at the reference repository location and the Hanford Site. These concerns, along with concerns regarding the impact to sensitive, threatened, and endangered species, are addressed in Subsection C.7.2.2 of this appendix.

Issue: Elk herd

One reviewer stated that the Draft Environmental Assessment did not provide sufficient information on the elk herd on the Hanford Site. Concern was also expressed that the elk herd may increase and possibly spread into areas near the reference repository location.

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Response

The concern of the reviewer is valid. Subsection 3.4.2.2 has been changed in the final Environmental Assessment to reflect that, in the future, the elk herd may increase and possibly spread into areas near the reference repository location.

Issue: Shrub-steppe environment

One reviewer felt the statement in the Draft Environmental Assessment that the shrub-steppe is a "nonfragile" physical environment is incorrect.

Response

The reviewer is correct. Section 3.4.2 of the final Environmental Assessment has been revised to indicate that the natural shrub-steppe environment is in fact more easily affected than some other ecosystems.

Issue: Sagebrush-bunchgrass habitat

One commenter suggested that the Draft Environmental Assessment misclassified the Hanford Site as a sagebrush-bunchgrass habitat.

Response

Although the Hanford Site lies within the Artemisia tridentata/Agropyron spicatum habitat classification scheme (Daubenmire, 1970), the predominant vegetation associate is Artemisia/Bromus tectorum. In Daubenmire's classification scheme, the habitat type is not always the vegetation association that dominates the landscape. There are edaphic and topographic influences that alter the vegetation association. The highly sandy soils of the lower elevations of the Hanford Site do not support Agropyron but do support Bromus. Thus, Bromus is the dominant grass of lower elevations.

The habitat composed of sagebrush and cheatgrass is attractive to wildlife. The term wildlife is used to mean "all" wildlife, nongame and game alike. Lizards, snakes, insects, small birds, and mammals all use cheatgrass and sagebrush plant communities.

Issue: Surface-water resources

The adequacy of the data provided addressing surface water at the reference repository location is inadequate according to several reviewers.

Response

There are no naturally occurring surface waters at the reference repository location. West Lake, a natural alkaline pond, is more than 10 kilometers (16 miles) from the reference repository location. Cold Creek is an ephemeral, discontinuous, and normally dry creek below Rattlesnake Springs. In some years, excess runoff results in surface water in the lower portion of the valley, but this is an infrequent and temporary phenomenon. Since that portion of the drainage below Rattlesnake Springs is normally dry and is essentially a terrestrial habitat, water-quality data are not available. Data are available for Rattlesnake Springs, but since site-characterization activities and potential construction and operation of a repository at the reference repository location are not expected to impact either Rattlesnake Springs nor West Lake, these resources are not described in the final Environmental Assessment.

Issue: Inadequacy of soils-related data

Several reviewers stated that the Draft Environmental Assessment did not provide sufficient description of soils at the Hanford Site including thickness, infiltration, geotechnical characteristics, potential for movements by wind, radionuclide concentrations, and evapotransportation data.

Response

For the purposes of the Draft Environmental Assessment, the soils of the Hanford Site are adequately described in Section 3.2.1. Further description of soil thickness, infiltration, and geotechnical characteristics may be found in Hajek (1966). Radionuclide concentrations of soils are listed in Gutknecht et al. (1980). The potential for soil movements by wind, as it relates the potential resuspension of radionuclides, would be considered during site characterization.

Issue: Columbia River water-quality monitoring data

Several commenters felt that the Draft Environmental Assessment provided insufficient information with regards to the monitoring of Columbia River water for both radiological and nonradiological water-quality parameters.

Response

The Columbia River and its biotic resources are briefly described in Subsection 3.4.2.6 of the Draft Environmental Assessment and references to more detailed data are provided. Except for more water-quality detail, this information is considered adequate for the purposes of the final Environmental Assessment.

The Pacific Northwest Laboratory (for the U.S. Department of Energy) conducts routine monitoring of the Columbia River water quality for both radiological and nonradiological water-quality parameters (Price et al., 1985).

River-water samples are currently collected from locations upstream and downstream of the Hanford Site as part of the routine surveillance program. Radiological analyses include alpha, beta, tritium, strontium-89, strontium-90, natural uranium, plutonium-238, plutonium-239-240, iodine-129, and a gamma scan. A summary of annual average concentrations of radionuclides of primary significance in the river has been included in Subsection 3.4.2.6.3 of the final Environmental Assessment.

Nonradiological sampling in the Pacific Northwest Laboratories routine program is supplemented by sampling performed by the U.S. Geological Survey upstream and downstream of the Hanford Site. Nonradiological analyses include pH, turbidity, nitrates, dissolved oxygen, fecal coliform, biochemical oxygen demand, hardness, suspended and dissolved solids, chloride, iron, chromium, and total organic carbon. The U.S. Geological Survey publishes their data in annual reports (USGS, 1982). Additionally, all direct discharges to the Columbia River are monitored for various parameters according to the provisions of National Pollutant Discharge Elimination System permits.

The ranges for radiological and nonradiological water-quality parameters have been added to Subsection 3.4.2.6.3 of the final Environmental Assessment.

C.4.1.3.3 Air quality and weather

Many commenters were concerned about the overall air quality of the Hanford Site. These comments included the need for information on downwind air quality, atmospheric stability, dispersion, diffusion, and joint frequency distributions. Several commenters felt the Draft Environmental Assessment needed to present more data on severe meteorological conditions.

Issue: Air quality conditions at the Hanford Site

Several commenters expressed concerns related to an inadequate discussion of air quality at the Hanford Site.

Response

At the Hanford Site, one type of air pollutant, total suspended particulates, has been monitored routinely for many years. For the past few years, another pollutant, nitrous oxides, has been monitored at several locations at the Hanford Site. No current ambient monitoring exists for other air pollutants such as sulfur oxides, carbon monoxide, or ozone. However, these pollutants have been briefly monitored at other locations within southcentral Washington in the recent past. Because there has not been a comprehensive program to monitor all nonradiological pollutants in the Hanford Site, the discussion in Subsection 3.4.3.5 of the Draft Environmental Assessment is somewhat limited.

Little emphasis has been placed on performing detailed monitoring of nonradiological air pollutants in the region because the air quality in the area is perceived to be good. This perception is supported by the results of the monitoring that has been conducted. The only pollutant that has been shown to occasionally exceed current ambient air-quality standards at the Hanford Site is total suspended particulates. This violation is attributed to blowing dust and sand rather than anthropogenic emissions. In addition to current monitoring activities, emission inventories from signficant sources of pollution in the region indicate that current levels of emission are well below the levels that would raise serious concerns about the ambient air quality of the area.

In the Skagit/Hanford Draft Environmental Impact Statement (NRC, 1982a), which is referenced in Subsection 3.4.3.5 of the Draft Environmental Assessment, the nonradiological air quality of the area is characterized using limited data from the 1970's through the early 1980's. The data indicate that air quality during this period met all Federal, State, and local ambient air-quality standards (except for total suspended particulates occasionally exceeding short-term standards during dust storms). This monitoring also showed air quality to be improving with time, as construction activities on the Hanford Site and in neighboring towns decreased, the acreage used for dryland agriculture was reduced, and the use of pollution-control devices increased.

Table 3-11 in the Draft Environmental Assessment has been modified as Table 3-23 in the final Environmental Assessment to include background concentrations.

Issue: Atmospheric stability and dispersion characteristics

Several commenters stated that the Draft Environmental Assessment lacked specific information on atmospheric stability, dispersion, and joint frequency distributions.

Response

Specific information on atmospheric stability, dispersion, and joint frequency distributions of wind speed category wind direction sector and stability class are presently available (Stone et al., 1983). Because of the ready availablility of site-specific information on atmospheric stability, dispersion, and joint frequency distributions in numerous publications, it is not deemed necessary to present this detailed information in the final Environmental Assessment.

Issue: Climatological extremes

It was stated by several reviewers that the Draft Environmental Assessment lacked specific information on record high-wind speeds and other climatological extremes.

Response

Extreme weather, as it relates to the second potentially adverse condition under meteorology (DOE, 1984a; 960.5-2-3(c)(2)) is not present at the Hanford Site. The 62 centimeters (24.5 inches) of snowfall measured in February 1916 is more than double the second highest snowfall reading. Therefore, the 62-centimeter (24.5-inch) snowfall measured by a volunteer weather observer is considered to be either a meteorological anomaly or an inaccurate measurement. Since no snowfall has even approached 33 centimetrs (13 inches) in the 69 years since the record and because the average monthly snowfall is only 13.5 centimeters (5.3 inches) in the "snowiest" month of the year, snowfall at the Hanford Site is classified as being very low for a state located in the northern half of the United States. Locally intense precipitation and flooding does not occur at the Hanford Site.

Severe meteorological conditions are currently evaluated in detail in a previous report by Stone et al. (1983) and other publications (environmental reports and environmental impact statements for various Hanford Site projects). The meteorology of the Hanford Site and region will be addressed in detail as part of site characterization if the reference repository location is recommended for characterization. Further information can be found in Subsection C.7.2.3, Air quality.

Issue: Diffusion conditions at the Hanford Site

One concern was that the data base presented in the Draft Environmental Assessment is incomplete as it relates to diffusion conditions at the Hanford Site.

Response

Diffusion conditions at the Hanford Site, as stated in the Draft Environmental Assessment, are generally good. As stated in the Draft Environmental Assessment, poor diffusion conditions can and do occur at the Hanford Site, especially during the winter. Climatologically, wind speeds are less than 7 kilometers (4 miles) per hour approximately 40 percent of the time in December (37 percent in January, dropping to 30 percent in February) and very stable conditions exist near the surface approximately 26 percent of the time (moderately stable conditions exist about 40 percent of the time) (Stone et al., 1983). Periods of below average diffusion in the winter are characteristic of most locations in the United States, as reduced levels of solar radiation result in more stable atmospheric conditions and weaker diurnal circulations. However, considering conditions throughout the entire year, it is correct to state that diffusion conditions at the Hanford Site are "generally good."

During the winter of 1984-1985, diffusion conditions at the Hanford Site were much below normal. For example, in January 1985 wind speeds averaged 4.6 kilometers (2.9 miles) per hour, a full 5.6 kilometers (3.5 miles) per hour below the normal average of 10.3 kilometers (6.4 miles) per hour. Also, in January, the average mixing level height was lower than normal. Occasional periods during which dispersion conditions were below seasonal averages is consistent with the natural variability of conditions at the Hanford Site. However, the winter of 1984-1985 is not indicative of the typical dispersion characteristics of the area.

Issue: Mixing layer climatology

One commenter felt that the Draft Environmental Assessment presented insufficient information on mixing-layer climatology at the Hanford Site.

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Response

Mixing layer thickness is a very difficult parameter to measure. Only 50 to 60 radiosonde launch sites throughout the country can accurately measure this parameter under all conditions. At the Hanford Meteorological Station, mixing layer thickness at altitudes less than 600 meters (1,968 feet) is measured using tower sensors and acoustic sounders. Mixing layer thickness is estimated by using radiosonde data from Spokane, Washington.

The two-year averages provided in Table 3-10 of the Draft Environmental Assessment are representative of the climatology and are sufficient for dispersion modeling.

Issue: Local particulate sampling data

One reviewer felt that the location of the Benton-Franklin-Walla Walla County Air Pollution Control Authority particulate sampler is suspect.

Response

The Benton-Franklin-Walla-Walla County Air Pollution Control Authority particulate sampler is a component of a State-wide program to measure ambient particulate concentrations. It is not intended to measure particulates from any specific facility at the Hanford Site.

C.4.1.3.4 Noise

Several commenters suggested that the final Environmental Assessment provide more information on the impact of noise, including that resulting from construction and operation of road and railroad access on the general public and the noise impacts on transportation on wildlife. These concerns are addressed in Subsection C.7.2.5, Noise.

C.4.1.3.5 Aesthetic resources

Several reviewers commented that the Draft Environmental Assessment should mention the potential repository as an aesthetic resource. Others felt that the Draft Environmental Assessment did not sufficiently address the impact of a potential repository waste pile on the aesthetic value of the reference repository location. These concerns are addressed in Subsection C 7.2.4, Aesthetic conditions.

C.4.1.3.6 Archaeological, cultural, and historical resources

Many comments were recieved regarding the current status of archaeological, cultural, and historical resources both on and near the reference repository location. These concerns and those that question the impact to these subjects due to site-characterization activities and potential repository construction and operations have been addressed in Subsection C.7.2.6, Archaeological, cultural, and historical resource.

C.4.1.3.7 Background radiation

Several commenters requested an expanded discussion on background radiation as a result of other activities at the Hanford Site. These concerns and the concerns that deal primarily with the radiological impacts of defense activities have been addressed in Subsections C.6.4.2.3, Offsite installations radiological impact, and C.6.4.2, Offsite installations radiological conditions description.

C.4.1.4 Transportation

Comments assigned to this subsection have been cross-referenced to and discussed in Section C.7.3.

C.4.1.5 Socioeconomic conditions

Comments assigned to this subsection have been cross-referenced to and discussed in Section C.7.4.

C.4.2 ACTIVITIES PROPOSED FOR SITE CHARACTERIZATION

Comments responded to in this section pertain to Section 4.1 of the Draft Environmental Assessment. Section 4.1 provided a brief description of the major activities related to site characterization at the Hanford Site. This description was intended to provide a general basis for a subsequent discussion of the environmental effects of conducting site-characterization activities. Consequently, a number of comments were received requesting a more detailed description of the planned activities. While additional detail has been provided in this appendix and the final Environmental Assessment in response to comments, Section 4.1 of the final Environmental Assessment still provides only a brief description of site-characterization activities. An extensive description of these activities will be included in the site-characterization plan, should the reference repository location be recommended for characterization.

Comments in this section were divided into four major categories paralleling the structure of the Draft Environmental Assessment:

- C.4.2.1, Field studies.
- C.4.2.2, Exploratory shafts.
- C.4.2.3, Other activities.
- C.4.2.4, Alternative activities.

Comments were received only for the first two categories.

C.4.2.1 Field studies

This subsection addresses comments received on Chapter 4 of the Draft Environmental Assessment. The comments are grouped into the following subdivisions:

- C.4.2.1.1, Ground-water characterization activities.
- C.4.2.1.2, Surface-water characterization activities.
- C.4.2.1.3, Hydrochemical characterization activities.
- C.4.2.1.4, Miscellaneous.

C.4.2.1.1 Ground-water characterization activities

Comments on ground-water characterization activities are divided into several issues that are individually addressed.

- Need for better understanding of ground-water system.
- Quality and validity of hydrologic data.
- Potential for geohydrologic studies to affect rock integrity.

Issue: Need for better understanding of ground-water system

Numerous comments were received regarding ground-water characterization activities related to Chapter 4 of the Draft Environmental Assessment. Most comments pointed to the need for a better understanding of local and regional ground-water flow patterns, discharge to the Columbia River, hydraulic influence of structural discontinuities, and (or) the need to reduce data uncertainty and address outstanding issues. One reviewer questioned quality control and data screening; another asked whether or not site-characterization studies will affect the geologic integrity of the reference repository location and proposed repository, and commented that studies should be done objectively and in a manner that satisfies the needs of the scientific community. The commenter stated that plans to store or process radioactive waste on the Hanford Site should not be implemented before the scientific community at large is assured that waste disposal in basalt is acceptable. One commenter noted that additional detailed characterization plans are expected in the site-characterization plan.

Response

It is agreed that the geologic, hydrologic, and performance assessment studies conducted by the U.S. Department of Energy should be done objectively, scientifically, and openly. Only such an approach to the question of geologic disposal of nuclear wastes can answer critical site-characterization and waste-isolation questions so as to instill public and scientific community confidence in decisions made.

As acknowledged throughout the Draft Environmental Assessment, evaluation of ground-water flow patterns both near and away from geologic discontinuities, areal property hydraulic distinctions, and hydrochemistry are in a preliminary state of understanding (e.g., see Sections 3.3.2 and 4.1.1, and Subsection 6.3.1.1.11.3). Details concerning research activities and schedules to address remaining issues will be included in the site-characterization plan, should the reference repository location be recommended for this activity. The Environmental Assessment provides information relative to the site-selection process specified in the General Siting Guidelines (DOE, 1984a); it does not serve as a characterization plan or an environmental impact statement.

The U.S. Department of Energy believes that an understanding of the geohydrologic influence of major structures surrounding the reference repository location and vicinity (i.e., Umtanum-Gable Mountain anticline, Yakima Ridge anticline, and the Cold Creek barrier) is essential to developing a reliable conceptual model of ground-water movement in the basalts. Section 3.3.2 of the Draft Environmental Assessment included discussions on potential geohydrologic influences of known stratigraphic and structural features in and surrounding the reference repository location.

The U.S. Department of Energy agrees that a site-specific and regional perspective of the ground-water flow system in basalt is important. For this reason, the Draft Environmental Assessment (e.g., Section 4.1.1) acknowledged the need to collect regional data. The word "limited" was used in Subsection 4.1.1.3 to address the number of wells that may be drilled or tested off the Hanford Site because (1) primary site-characterization focus and waste isolation must be ensured in close proximity (5 kilometers (3 miles)) of a repository, (2) critical information gaps in the regional data base may require drilling and (or) testing of some limited (versus unlimited) number of offsite wells, and (3) a defensible estimate of the number and locations of such regional wells is not yet available. Relative to the comment that the Indian Tribes "are concerned that the proposed (site-characterization) program will not begin to address the ground water contamination potential of the repository on ground water within the ceded lands area . . . ", the U.S. Department of Energy will objectively and scientifically address the "ground water contamination potential" for all lands potentially affected by a repository.

Issue: Quality and validity of hydrologic data

Two commenters posed the following three questions.

- Will the hydrologic investigator determine if data are good or will it be decided in the field by another investigator?
- What quality control will be implemented during site investigations?
- What screening technique will be used to determine if data are valid?

Response

All site-characterization data, "good" or otherwise, would be reported, should the reference repository location be recommended for further study. This information would be published and made available for review by interested organizations.

Quality control would be applied to all types of data collection, including site-characterization activities involving borehole design and construction, instrumentation used for data collection, and data handling and storage. Internal operating procedures currently are in place to cover existing data-gathering activities. These procedures are regularly updated and (or) expanded to meet programmatic quality-assurance needs.

All data collected would be reported. Data validity is based on how closely information approximates reality. One of the best methods for evaluating data validity is to approach desired information from several angles. For example, the question of vertical hydraulic conductivity of basalt flow interiors would be addressed through large-scale hydraulic stress tests, single-hole tests, and testing in an underground exploratory shaft facility. The combined results should be sufficient to bound real values of vertical conductivity and associated uncertainty. Data from these activities would be available for review and analysis by the scientific community. Through this approach of data collection, application of multiple interpretations, and data analyses by members of the scientific community, the U.S. Department of Energy believes data validity can be objectively assessed.

Issue: Potential for geohydrologic studies to affect rock integrity

One commenter asked whether or not site studies could affect the reference repository location.

Response

It is assumed that the commenter refers to an effect on the waste-isolation potential. The commenter has touched on a vital concern at any geologic site under present or future consideration for repository studies. A careful balance must be maintained between the need to adequately understand subsurface conditions and the need to not unintentionally damage the natural isolation potential offered by a geologic setting. The approach believed suitable involves several factors:

- Minimizing boreholes drilled in or adjacent to the proposed repository underground layout area. Other borehole drilling should be carried out only as needed to answer critical characterization questions.

- Developing a borehole plugging program to have technology in place for permanently sealing research and monitoring holes once the objectives have been fulfilled.

- Relying on large-scale hydraulic tests to examine geohydrologic property distributions over wide areas or, for example, in the case of remote sensing, to assess geologic structural trends without the need for extensive borehole drilling. These activities help minimize the number of borings required to address characterization questions.

- Conducting numerical model studies on the potential long-term effects of sealed boreholes or sealed borehole failures to waste isolation. Results would be factored into the decision process for final site selection and waste-isolation potential.

Through the above approach, the U.S. Department of Energy and other interested organizations can address independently the question of potential site-characterization effects on waste isolation. It is important to note that future resource development and any associated drilling activities may also impact waste isolation. Such potential was used in the General Siting Guidelines (DOE, 1984a) as a discriminator between geologic settings.

C.4.2.1.2 Surface-water characterization activities

Issue

Two comments were received regarding surface-water monitoring and measures proposed to gather additional data on surface-water flow and quality. Both commenters said that no information was provided in Subsection 4.1.1.3 concerning such monitoring. The surface-water data base maintained by State and other organizations should be explained and flood potentials on Cold and Dry Creeks should be studied in more detail. Finally, the commenters felt radionuclide transport models should be developed for surface water.

Response

The commenters are referred to Subsection C.4.1.2.1.3 of this appendix. This discussion identifies a new subsection (see Subsection 4.1.1.7) that has been included in the final Environmental

Assessment to broadly outline future surface-water studies. Studies include a finer definition of the flash-flood potential for the reference repository location and vicinity.

For an environmental impact statement, all details regarding radionuclide transport models and analysis results would be reported, including any credible accident scenarios in which radionuclides could be introduced into surface waters. The extent of future involvement of the State and other organizations in maintaining a surface-water data base is not an appropriate topic for the U.S. Department of Energy to include in the Environmental Assessment.

C.4.2.1.3 Hydrochemical characterization activities

Issue

Two comments addressed questions about hydrochemical sampling and analysis activities. One reviewer suggested that the effects of drilling mud contamination on sample quality should be considered. The second commenter stated that a complete analysis of organic carbon and methane gas in ground water is required for compliance with the second favorable condition under the postclosure geochemistry guideline (DOE, 1984a; 960.4-2-2(b)(2)).

Response

The U.S. Department of Energy has published a hydrochemistry data base (Early et al., 1985), including a tabulation of currently available hydrochemical data and an evaluation of data quality. This data base and the evaluation tools presented therein will be updated periodically.

The effects of drilling mud contamination on ground-water composition have been addressed in detail (Graham, 1984; Graham et al., 1985). Results of these analyses are being incorporated into future hydrochemical data evaluation. For example, the amount of tritium and organic carbon are sensitive indicators of drilling mud contamination and are used as screening tools for assessing data quality (Early et al., 1985).

It was pointed out that the Draft Environmental Assessment did not provide detailed plans concerning a ground-water monitoring program, new borehole locations, and chemical parameters to be determined. This omission was intentional; the Environmental Assessment is not a document for discussion of detailed future plans. These questions will be addressed in the site-characterization plan, if the reference repository location is recommended for further study.

Subsections 6.3.1.2.4 and 6.3.1.2.8 both acknowledged limitations in the hydrochemical data base with respect to organic constituent characterization. The extent and significance of organic complexants with respect to radionuclide transport remains to be quantified. Studies to provide detailed organic analyses for ground water at the Hanford Site are either in progress or planned. Results from these new studies will permit a more complete assessment of potential radionuclide movement in the ground-water system.

For a discussion of potential radionuclide complexation and effects on transport, the commenters are referred to Subsection C.5.2.2 of this appendix.

C.4.2.1.4 Miscellaneous

Many comments received regarding site-characterization activities discussed in Chapter 4 of the Draft Environmental Assessment are discussed individually below because of subject matter, topic breadth, and (or) emphasis of the comment concerns.

Issue: Definition of hydrologic term

A definition or clarification was requested for the term "vertical transmissivity" as noted in Subsection 4.1.1.3.1.

Response

The phrase in question should read "vertical leakage." The term "vertical leakage" has been inserted into Subsection 4.1.1.3.1 of the final Environmental Assessment.

Issue: Timing of large-scale pump tests

A suggestion was made that large-scale hydrologic pump tests be properly timed to minimize any environmental impact from salt buildup in soil.

Response

Test timing and the size of area selected for discharged water retention and infiltration will be chosen to minimize any environmental impact and possible interference with other site-characterization activities. The commenter is also referred to Subsection C.7.1.1.2 of this appendix, which addresses discharged water impacts. In this discussion it is concluded that based on existing knowledge of soil infiltration and water evaporation rates, minimal dissolved mineral precipitation is expected from the waters discharged during site characterization.

One commenter noted that approximately 290 metric tons (318 tons) of salt (from dissolved solids in ground water) would be discharged onto land surface from the twelve pumping tests identified in Subsection 4.2.1.2.1 of the Draft Environmental Assessment. The commenter's calculation apparently assumes no surface runoff or soil infiltration of salts—simply salt buildup. Such an event would not be realistic yet is certainly highly conservative.

While 290 metric tons (318 tons) may seem significant, it is important to put such a number in perspective. For example, while also not assuming credit for surface runoff or infiltration, one can calculate salt accumulation occurring from ground-water application in the Pasco Basin surrounding the Hanford Site or for the Columbia Plateau. To roughly estimate such numbers, the following data were used: mean regional basalt ground-water total dissolved solids concentration (from Table 2-1 of the Draft Environmental Assessment) is 325 milligrams per liter; Pasco Basin annual irrigated water use (Leonhart, 1979) is 5.82×10^7 cubic meters (47,760 acre-feet); and Columbia Plateau (State of Washington portion) annual irrigated water use (Leonhart, 1979) is 2.17×10^8 cubic meters (177,803 acre-feet).

For ground-water use in the Pasco Basin, approximately 19,000 metric tons (21,000 tons) of salt are discharged annually. This value increases to nearly 71,000 metric tons (78,000 tons) for ground-water discharge in the State of Washington portion of the Columbia Plateau. In other words, the quantity of salt discharged as a result of several years of site-characterization activities is a very small percentage (1 percent or less) of that annually delivered in the Pasco Basin or surrounding Columbia Plateau from crop irrigation.

In fact, the conservative salt volume of 290 metric tons (318 tons) calculated by the commenter is approximately equal to the salt volume discharged by a single "typical" pivot irrigation system covering 53 hectares (130 acres) with an annual irrigation volume of 150 centimeters (60 inches). The resultant yearly salt discharge would be approximately 260 metric tons (290 tons).

Therefore, the pump tests scheduled for site characterization would discharge very limited volumes of naturally dissolved salts, much smaller than annual salt productions from surrounding irrigation systems.

Subsection 4.2.1.2.1 of the final Environmental Assessment has been expanded to include a discussion of salt production during site characterization.

Issue: Baseline monitoring and effect of mud losses

One commenter stated that the Draft Environmental Assessment should have given a higher priority to baseline monitoring because of possible water-level interference from shaft construction, and that drilling mud loss from shaft construction might make representative hydraulic testing near the reference repository location difficult to conduct. The reviewer also asked if the baseline monitoring program was nearing completion.

Response

The baseline monitoring program in the deep basalts within and near the reference repository location began in spring 1984 with drilling completion and monitoring of boreholes DC-19, DC-20, and DC-22. The additional monitoring needed for site characterization (see Subsection 4.1.1.4

of the Draft Environmental Assessment) will be outlined in the site-characterization plan, should the reference repository location be recommended for this activity.

The Environmental Assessment is a site-selection document and as such does not place "priorities" on data needs. As seen in Section 4.1, ground-water monitoring is one of several critical characterization activities. The importance of establishing a baseline monitoring program before shaft drilling was acknowledged in Subsection 4.2.1.2.2, and was one reason the DC-19, DC-20, and DC-22 monitoring holes were installed.

Although drilling fluid losses could interfere with flow top permeability measurements in the vicinity of the shafts, this interference is not expected to be significant. Mud losses will be minimized and large-scale hydrologic tests, which will integrate hydraulic values across hundreds to a few thousand meters (feet), should not be significantly affected by expected drilling fluid losses. However, this potential impact has been acknowledged in the final Environmental Assessment. Section 4.2.1.2.2 of the final Environmental Assessment includes mud losses as a potential impact from shaft drilling.

Issue: Wide range of comments on site-characterization plans

Two reviewers offered a wide range of comments involving geohydrologic, ecological, transportation, and socioeconomic studies. The geohydrologic concerns involved requests for information on the plans for determining "basement characteristics," surface-water data, and regional well drilling and testing.

Response

Plan outlines covering the above topics will be included in the site-characterization plan, should the reference repository location be recommended for characterization. The Environmental Assessment is a site-selection document comparing various geologies against the General Siting Guidelines (DOE, 1984). The site-characterization activities identified in Section 4.1 of the Draft Environmental Assessment are those activities that may impact the surrounding environment. The section was not intended as a listing or an outline of all characterization research needed to evaluate the suitability or nonsuitability of basalt for safely storing radioactive waste.

Issue: Shaft disturbance of hydrologic baseline

One commenter paraphrased from page 4-22 (see Subsection 4.2.1.2.2) of the Draft Environmental Assessment regarding potential ground-water impacts from shaft drilling. These impacts relate to the measurement of baseline ground-water levels and possible creation of a vertical conduit (via poor shaft seal) for ground-water exchange between previously confined aquifers. Another commenter noted that shaft construction could alter local ground-water movement for short time periods.

Response

These two possibilities have been identified in the Draft Environmental Assessment. Subsection 4.2.1.2.2 (Ground-water impacts) addressed a basic approach to eliminating or reducing such impacts.

Issue: New regional ground-water wells

A reviewer quoted the Draft Environmental Assessment statement, "If wells are unavailable outside the Hanford Site where head data are considered critical, then new wells may be drilled" (see p. 4-8, Subsection 4.1.1.4.2), and asked how this critical data would be determined if new wells were not drilled.

Response

The phrase "may be" was originally inserted to accommodate those times when approval of or access to a specific drill site is unavailable. However, under such conditions, the nearest approved site would be drilled. Therefore, under either situation, drilling would take place in or near areas considered critical.

Subsection 4.1.1.4.2 of the final Environmental Assessment was reworded to indicate regional well drilling where needed.

Issue: Drill and test hydrologic technology

A statement was made that many in the scientific community deplore the use of "drill and test" methods and the use of inflatable packer technology to acquire hydraulic information. Based on this statement, the commenter questioned why such high reliance is placed on these methods.

Response

Contrary to the opinion expressed in the comment, the acquisition of hydraulic property information from boreholes using the "drill and test" method and inflatable packer technology is widely used and accepted in the scientific community, and represents the only effective means of testing and characterizing a series of individual test horizons intersected within a well or research borehole.

Examples of other scientific groups, private companies, or governmental agencies utilizing the "drill and test method" and (or) packer technology are given below.

- U.S. Geological Survey at the Nevada Test Site (Blankennagel, 1968) and the Waste Isolation Pilot Plant in New Mexico (Dennehy and Mercer, 1982).

- Atomic Energy Canada, Limited at various crystalline rock sites within Canada (Davison et al., 1982).

- Swedish Geological Survey at various granite sites in Sweden (Carlsson and Olsson, 1982).

- Various private engineering and petroleum companies investigating a variety of sedimentary and crystalline rock formations (Thackston et al., 1984; Earlougher, 1977).

Issue: Maintenance of drilling fluid circulation

One commenter addressed a specific paragraph in Subsection 4.1.1.6.1 of the Draft Environmental Assessment that discussed the use of various drilling fluids during exploratory shaft construction. The commenter stated that use of these fluids will not guarantee maintenance of drilling fluid circulation, and concluded that once circulation is lost, it cannot be "reinstituted" rapidly enough, even in small boreholes, to save hole or drilling tools.

Response

The discussion in Subsection 4.1.1.6.1 was intended to describe general aspects of the construction phase of the exploratory shaft. Nowhere in this section was it stated that use of drilling fluids will "guarantee" or provide "proof" that circulation will never be lost.

With regard to the commenter's conclusion that the hole or drilling tools would be lost upon loss of drilling fluid circulation, extensive borehole drilling experience on the Hanford Site does not support this contention. Subcontractors for the U.S. Department of Energy have drilled more than 30 deep basalt boreholes on the Hanford Site. Most of these boreholes had sections drilled within basalt for which no fluid circulation could be maintained. The loss of drilling fluid circulation did not cause a loss of the borehole or tools. The following description provided by Fenix and Scisson (1978, p. 7) is typical of borehole construction conditions on the Hanford Site:

" . . . Partial loss of drilling fluid was experienced within the 1,676 - 1,747 ft interval and total lost circulation occurred at 1,747 ft. The addition of particulate lost circulation material to the drilling mud and the setting of cement plugs restored partial circulation only temporarily, and coring was continued to 2,638.7 ft with 100 percent lost circulation. No significant problems were encountered that affected the coring operations and percentage core recovery . . . "

Issue: Borehole lining

One commenter stated that if lining (i.e., well casing) of a borehole is deferred until the bottom is reached, there will be a great chance for rock burst, cave-in, or similar occurrence, with a resultant loss of hole and equipment. The commenter also implied that unlined boreholes could cause drilling fluid to leak into surrounding strata.

Response

In response to the first concern, the U.S. Department of Energy subcontractors involved in drilling and testing research boreholes on the Hanford Site utilize standard construction procedures for well structures. To minimize problems of borehole stability, a series of telescoping well casings commonly is installed during well construction. In addition, drilling fluids are used during construction to mitigate the potential for borehole cave-in.

Another factor that influences borehole stability is the strength of the rocks encountered. Because of the high strength characteristics of basalt, borehole stability is enhanced.

In response to the second concern, the potential for drilling fluid movement into strata surrounding an unlined borehole is primarily a function of formation permeability and the hydraulic head difference between the borehole fluid column and test interval in question. During borehole construction, hydraulic head differences are commonly established with fluid flowing either into or out of formations intersected depending on the head gradient condition. Such occurrences are inherent in borehole drilling. For those situations where drilling fluid enters a formation, the fluid is removed utilizing a series of development procedures prior to hydraulic and hydrochemical characterization of the test interval.

Issue: Detail of site-characterization activities

One commenter emphasized that, with exception of the exploratory shaft, site-characterization activities identified in Section 4 of the Draft Environmental Assessment were very general. Though these activities appear justified, it is not possible to determine if existing data gaps will be filled or what environmental effects will result from this characterization. It is believed that critical geohydrologic information should be obtained from small-diameter borings prior to exploratory shaft drilling. Details are expected in the site-characterization plan, should the reference repository location be recommended for characterization.

Response

The commenter is correct in stating that characterization details would be contained in the site-characterization plan. This plan will outline an approach for collecting geohydrologic information using both surface boreholes and the exploratory shaft facility. Shaft drilling and testing have beneficial aspects as well as a potential negative impact on other characterization activities. The positive side includes in situ hydraulic tests within a basalt flow interior. These prototypical tests are designed, for example, to quantify water seepage into large underground openings and the hydraulic conductivity tensor within a flow interior, estimate near-field solute dispersion and effective porosity, and evaluate fracture patterns, widths, and infilling. These data are important to a technically sound characterization program, as is information gathered from surface boreholes.

The negative side of shaft facility construction is possible interference with other characterization work (see Subsection 4.2.1.2.2 of the Draft Environmental Assessment). Such impacts might include water-level baseline disturbance and (or) vertical interconnection between aquifers if the shaft seal is poor. Suggested solutions to these problems were given in Subsection 4.2.1.2.2 of the Draft Environmental Assessment.

Since data from both surface boreholes and the exploratory shaft are needed to address characterization issues, both types of facilities will be in operation. By conducting a properly scheduled and integrated program, interferences can be minimized.

Issue: Adequacy of existing hydraulic head measurements

One comment asked if hydraulic heads have been adequately measured.

Response

Collection of much more hydraulic head information is necessary to characterize potentiometric surfaces in the Wanapum and Grande Ronde Basalts (Gephart, 1985). This issue was addressed in Section 3.3.2 (Ground water) and Subsection 4.1.1.4 (Ground-water monitoring) of the Draft Environmental Assessment.

Issue: Boreholes interconnecting aquifers

The possibility of boreholes interconnecting different aquifers concerned one commenter. This in conjunction with pump tests "could cause acceleration of existing radionuclide plumes toward the Columbia River and their migration down river in previously unaffected aquifers."

Response

The commenter appeared concerned that boreholes drilled into basalts would act as vertical conduits for radionuclides present in the shallow unconfined (sediment) aquifers to migrate into the basalt aquifers. Boreholes drilled for basalt studies are designed to avoid this possibility. In all deep basalt wells the upper sediments are both cased and cemented. In addition, basalt formations and (or) specific stratigraphic zones not planned for monitoring or future testing are cased and cemented to avoid ground-water movement along the borehole. Some research wells used to characterize the shallow basalts may be cable tooled and shallow sediments cased off. These holes have a cement plug installed between the sediments and basalt. Following research use, boreholes will be filled with cement, and possibly bentonite, to minimize or eliminate their acting as a vertical flow path.

A good example of some recent borehole completion designs is found in Jackson et al. (1984). Boreholes DC-19, DC-20, and DC-22 were designed to provide well facilities for multilevel water-level monitoring across the reference repository location. These holes are used for piezometer baseline monitoring and large-scale hydraulic stress testing. As part of the documentation process, Jackson et al. (1984) described the design and installation of the piezometers. This effort involved the drilling of 11 boreholes (total footage drilled: 5,638 meters (approximately 18,500 feet)); installing 27 piezometer tubes in 9 monitoring boreholes (total length of piezometer tubing: 16,946 meters (approximately 55,600 feet)); and placing 73 cubic meters (2,600 cubic feet) of filter pack material and 570 cubic meters (20,113 cubic feet) of neat-cement seals to secure and isolate piezometer tubes and casings.

Issue: Adequacy of rock porosity measurements

Two reviewers asked if rock porosity has been adequately measured.

Response

By porosity, it is assumed the commenters refer to interconnected porosity (i.e., effective porosity). As discussed in the Draft Environmental Assessment, few values of effective porosity are available; therefore, a large uncertainty is associated with this parameter (see Section 3.3.2 and Subsection 6.3.1.1.11.3). Additional tracer tests are required in both surface boreholes and in the exploratory shaft facility (see Subsections 4.1.1.3.3 and 4.1.1.6.3).

Issue: Depth coverage of existing hydrologic data

According to one commenter, the U.S. Department of Energy has insufficient data to characterize the ground-water flow system in the upper 900 meters (3,000 feet) of the Columbia River Basalt Group. In addition, almost no information is available to characterize the lower 70 percent (2,100 meters (7,000 feet)) of ground-water system the commenter believes exists below the proposed repository location.

Response

The U.S. Department of Energy agrees that an extensive site-characterization program is needed to collect the geohydrologic information necessary to address site suitability or nonsuitability. However, the U.S. Department of Energy questions the commenter's apparent emphasis on extensively evaluating the geohydrology for thousands of meters (feet) below the proposed repository depth.

Should the reference repository location be recommended for site characterization, geohydrologic studies will center on answering basic site suitability questions (e.g., head distributions, vertical leakage across flow interiors, structural influences on flow patterns, hydrochemical evolution) and thoroughly examining likely ground-water flow paths. Existing data suggests that ground-water flow paths (and consequently solute migration routes) will be outward and upward from a repository. Basalt at depths comparable to or shallower than the repository have research priority since their properties determine likely flow paths to the accessible environment. Though some very deep drilling may be completed to address questions on basement (below basalt) characteristics, these data needs are viewed as less critical than shallower characterization efforts.

Issue: Quotes from U.S. Geological Survey Circular 779

One reviewer provided selective quotes from the U.S. Geological Survey circular 779 (Bredehoeft et al., 1978):

" . . . given the uncertain state of our knowledge, the uncertainties associated with hot wastes that interact chemically and mechanically with the rock and fluid system appear very high . . . Although the geometry of a fracture system may be known in the vicinity of an underground working, it seems difficult, if not unfeasible to know this in sufficient detail at any distance from the few bore holes or workings likely to be permitted near a repository . . . In addition to natural fractures, manmade boreholes in the vicinity of the repository as well as in the repository itself, present problems. They must, even during hundreds of years, be considered as potential short-circuit pathways that could permit water flow from the repository horizon upward to shallow aquifers that may be utilized by man."

Response

Though these quotes are taken from pages 6 and 8 of Bredehoeft et al. (1978), they do not, as excerpted, necessarily represent the perspective on geologic disposal expressed in the referenced publication. The message communicated by Bredehoeft et al. (1978) is that while acceptable geologic repositories can be constructed, there are many uncertainties and technical problems to overcome. The U.S. Department of Energy agrees. Consider the following quotes from Bredehoeft et al. (1978).

"Because the authors are confident that acceptable geologic repositories can be constructed, this paper should not be construed as an attempt to discredit the concept of geologic containment or the work done in the 1960's and early 1970's. However, the earth-science problems associated with disposal of radioactive wastes are not simple, nor are they completely understood. The many weaknesses in geologic knowledge noted in this report warrant a conservative approach to the development of geologic repositories in any medium. Increased participation in this problem by earth scientists of various disciplines appears necessary before final decisions are made to use repositories. Basic philosophical, as well as technological, issues remain to be resolved." (p. iii)

"It is generally accepted that repositories in geologic media can provide the most certain safe containment of radioactive waste." (p. 2)

"The authors of this Circular are confident that the steps outlined above can be carried out in such a way that the ultimate decision on the acceptability of a given site and waste-handling procedure will have a strong scientific and technical foundation. However, some key geologic questions are unanswered, and answers are needed before the risk associated with geologic containment can be confidently evaluated." (p. 3)

"This Circular has dealt largely with the difficulties and uncertainties connected with the geologic disposal of high-level radioactive waste because, from our viewpoint, these are significant potential stumbling blocks that need critical attention. In emphasizing these problems, we do not intend to slight the extensive effort currently going forward to find safe repositories. Significant progress is being made. We offer the following suggestions for research efforts and emphasis in the hope that they will prove constructive . . . " (p. 12)

Issue: U.S. Geological Survey ground-water monitoring network

It was noted that the last paragraph on page 4-8 of the Draft Environmental Assessment read, "Existing regional wells outside the Hanford Site that are suitable for monitoring also have been identified and integrated into the existing U.S. Geological Survey regional ground-water monitoring network." No plans exist to remeasure water levels in these new wells.

Response

It is agreed that wells added to the existing U.S. Geological Survey monitoring network were only for the duration of the Regional Aquifer System Analysis Project. Details for further regional ground-water monitoring are not yet established.

The quoted sentence has been modified to remove any connotation of these new wells being part of the established, routine monitoring network of the U.S. Geological Survey.

Issue: Demonstrating the feasibility of waste isolation

One commenter asked if any degree of site characterization could successfully demonstrate the feasibility of isolating waste in basalt. Guidelines were suggested for identifying the end point of characterization studies.

Response

The end point of site characterization is being approached from two directions. The first involves the characterization process itself; the second addresses overall repository performance allocation and risk acceptance.

Each geologic site recommended for characterization must undergo a rigorous, multi-year, site-specific evaluation of geologic, hydrologic, and geochemical properties. This information forms the basis for estimating confidence probabilities for site property distributions and for the past or future occurrence of natural events. These studies are carried out by contractors responsible to the U.S. Department of Energy. Data collected and conclusions drawn are made available for critique by all interested State, Federal, Indian, and private parties. This approach to identifying the end of site characterization is concluded when critical rock properties and processes are understood to an acceptable confidence level, or additional gain in site property knowledge is unwarranted. As stated in Peck (1985), "When the process has proceeded far enough for modeling efforts to yield verifiable future predictions, the characterization process can be considered adequate."

The initial decision as to whether or not site-characterization data are sufficient to answer critical waste isolation issues rests with the U.S. Department of Energy. Upon publication of the required environmental, safety, and licensing reports, other agencies will assess independently the technical bases for conclusions drawn on repository performance and risks considered acceptable.

C.4.2.2 Exploratory shafts

Comments received on the exploratory shafts are responded to in this subsection. These comments are addressed as outlined below.

- C.4.2.2.1, Exploratory shaft design and construction.
- C.4.2.2.2, Other uses of the exploratory shaft facility.
- C.4.2.2.3, Exploratory shaft testing.

C.4.2.2.1 Exploratory shaft design and construction

The explanation and clarification of activities associated with the design and construction of the exploratory shaft facility is covered by the following eight issues:

- Exploratory shaft drilling.
- Exploratory shaft construction details.
- Exploratory shaft sealing.
- Examination of the exploratory shaft seal.
- Volume of material to be excavated from the exploratory shaft.
- Exploratory shaft design.
- Exploratory shaft costs.
- Exploratory shaft facilities design.

Issue: Exploratory shaft drilling

One reviewer was concerned whether biodegradable mud additives would be used in shaft drilling and was also concerned that shaft dewatering was not sufficiently addressed for uncased drifts.

Response

Potential mud additives and their respective chemistries are identified below and a contingency plan to deal with treatment, storage, or discharge of mine waters is discussed.

The drilling fluid (mud) additives are as follows:

- Bentonite (1-1/2 to 2 percent of volume).
- Lost circulation material (0 to 5 percent of volume).
- Caustic soda (1/8 pound per barrel of mud).
- Lime (less than 1/8 pound per barrel of mud).
- Cellulose (less than 1/8 pound per barrel of mud).

Bentonite is a montmorillonite-type clay formed by the alteration of volcanic ash. When mixed with water, it is highly colloidal and plastic and is used to thicken drilling muds. Bentonite is not readily biodegradable, and the mud will require proper disposal after the shafts have been completed.

The lost circulation material (a mixture of cedar chips, shredded tree bark, and shredded newspaper) is used whenever a lost circulation condition is expected or encountered. Caustic soda and lime are used to control the pH of the drilling fluid to minimize corrosion of the drilling tools. The caustic soda and lime are rapidly expended and must be added continuously to the drilling fluid to maintain a controlled pH. The cellulose derivative is one used in foodstuffs; it is used in drilling muds to control viscosity and to enhance caking of the bentonite on the rock wall.

The drilling mud additives proposed for the Hanford Site are identical to those used in drilling domestic water wells that do not receive special treatment prior to producing drinking water.

There is no plan to deal with the treatment, storage, or discharge of mine water. The deep ground water at the Hanford Site is uncontaminated by past practices, and the need for treatment or storage is not foreseen at this time.

Water produced during the drift mining operations, plus water used for drilling and dust control, will be drained to the shaft and pumped to the surface through two 17.8-centimeter- (7-inch-) inside-diameter utility lines attached to the outside of the liner. The Exploratory Shaft-Phase I dewatering system consists of two 12.6-liter-per-second (200-gallon-per-minute) pumps.

Issue: Exploratory shaft construction details

One reviewer requested that the thickness of the shaft liner be provided and that potential geophysical methods to investigate for voids be discussed.

Response

The 183-centimeter- (72-inch-) inside-diameter shaft liner and stiffener ring materials are comprised entirely of American Society for Testing and Materials A-588-80, "High-Strength, Low-Alloy Structural Steel with 50,000 psi (Pounds per Square Inch) Minimum Yield Point to 4-inches Thick."

The 183-centimeter- (72-inch-) inside-diameter shaft liner plate thicknesses and stiffener ring sizes and spacings are shown in Table C.4-4.

The "voids" referenced in this comment were assumed to be voids in the grout seal, since there will not be any voids in the annular space between the casing and the shaft liner. Any discontinuities in the grout will be filled with either broken rock, drilling fluid, or ground water, since the drill hole is not evacuated prior to, or during, the grouting period.

The drill hole is 1,036 meters (3,400 feet) deep, and the liner is 1,018 meters (3,340 feet) long. The 18-meter (60-foot) interval below the liner serves as a trash sump and will provide space for rocks dislodged from the drill-hole walls while installing the casing, as well as for cuttings remaining in the drilling fluid following completion of the drilling operation.

Once drilling has been completed, the drill bit will be raised slightly off bottom, and the hole will be circulated for a period of 4 to 8 hours to remove the remaining cuttings. The circulating time is determined by the drilling superintendent, and is based on field observations of samples of the drilling fluid as it flows out of the blooie (discharge) line at the surface. Circulation is completed when the drilling fluid is free of cuttings.

The grouting operations will be continually monitored by use of cement bond logs and geophysical density logs. The density logs can assist in identifying any voids present by indicating contrasting zones in the vicinity of the grout lines.

Issue: Exploratory shaft sealing

One reviewer was concerned that vertical leakage along an imperfectly sealed shaft could result in communication of hydrologic zones at different depths, sufficient differential loading to cause shaft collapse, and increased hazards to workers involved in shaft activities.

Response

The drill hole is 1,036 meters (3,400 feet) deep, and the liner is 1,018 meters (3,340 feet) long. The 18-meter (60-foot) interval below the liner serves as a trash sump and will provide space for rock particles dislodged from the drill-hole walls while installing the casing, as well as for cuttings remaining in the drilling fluid following completion of drilling operations.

Once drilling has been completed, the drill bit will be raised slightly off bottom, and the hole will be circulated for a period of 4 to 8 hours to remove the remaining cuttings. The circulating time is determined by the drilling superintendent and is based on field observations of samples of the drilling fluid as it flows out of the blooie (discharge) line at the surface. Circulation is completed when the drilling fluid is free of cuttings.

Table C.4-4. Specifications for the exploratory shaft liner

Depth from surface, ft	Plate thickness, in.	Stiffener ring size, in.	Stiffener ring spacing, in.
0-300	1/2	3x3	76
300-420	1/2	3x3	57
420-620	5/8	3x3	45.6
620-820	5/8	4x3	45.6
820-1,020	5/8	4x3	38
1,020-1,420	3/4	4x3	28.5
1,420-1,620	7/8	4x3	28.5
1,620-1,860	1	5x3	28.5
1,860-2,220	1-1/8	5x3	28.5
2,220-2,500	1-1/4	5x3	24
2,500-2,940	1-3/8	5x3	24
2,940-3,260	1-1/2	5x3	24
3,260-3,300	1-5/8	5x3	24
3,300-3,340	1-3/4	[illegible]x3	24

NOTE: Specifications and drawings are in English units. To convert from feet to meters, multiply by 0.3048. To convert from inches to centimeters, multiply by 2.54.

When the hole has been cleaned, the casing is installed and grouting commences. The grouting is carried out in stages. Each stage of the grouting operation will be preceded by pumping a predetermined quantity of chemical flush material followed by fresh water to clean the interval being grouted. The circulating and washing operations will minimize the potential of an imperfect grout seal. When grouting is completed, no communication between aquifers can occur.

Experience gained from numerous boreholes drilled at the Hanford Site indicates little sloughing occurs after drilling. The difference between the diameter of the holes drilled to date and shaft diameter excavations is expected to produce some additional sloughing. Drilling procedures and mitigating factors including support offered by the drilling fluid will assist in mitigating most rock dislodgement. Following drilling, the drill tools will be "tripped" the full distance of the shaft to work loose rock blocks to intentionally dislodge this material and remove it from the excavation before a shaft liner is installed. An 18-meter (60-foot) interval below the liner has been provided to accommodate wall rock dislodged during liner emplacement. The 18-meter (60-foot) interval below the liner will accommodate adequately all wall rock sloughed from the shaft walls during the casing installation.

As stated in the issue concerning exploratory shaft construction details in this subsection, the 183-centimeter- (72-inch-) inside-diameter shaft liner and stiffener ring materials consist entirely of American Society for Testing and Materials A-588-80, "High-Strength, Low-Alloy Structural Steel with 50,000 psi (Pounds Per Square Inch) Minimum Yield Point to 4-Inch Thick."

The 183-centimeter- (72-inch-) inside-diameter shaft liner plate thicknesses and stiffener ring sizes and spacings were presented in Table C.4-4.

The liner design incorporated a 1.5 safety factor over its entire length. It was assumed that the greatest load imposed on the liner will occur during grouting operations while the grout remains in the fluid state. Once the grout hardens, it too will complement the liner in resisting static and hydrostatic loading. Therefore, shaft collapse would be highly unlikely.

The hazards of underground operations were considered in detail prior to the selection of the blind boring and lining techniques proposed by the U.S. Department of Energy. Since no personnel are in the shaft as it is being drilled and lined, worker safety hazards are decreased. Blind boring and lining techniques have been used extensively at the Nevada Test Site for providing shafts through which mining operations are (were) conducted. A blind-bored and lined shaft was used on Amchitka Island, Alaska, for mining at far greater depth and hydrostatic pressure than will be encountered at the Hanford Site.

Numerous liquified petroleum gas storage caverns have been constructed through blind bored and steel-lined shafts. The mining industry has also employed this construction method for providing shafts in ground where high volumes of water and (or) poor rock conditions are known to occur. Admittedly, these shafts are not as deep as the proposed shafts at the Hanford Site. However, the persons working in and below these shafts are exposed to similar hazards; therefore, the shafts are designed to maximize personnel safety. The design of the surface and underground facilities at the Hanford Site are also designed to be safe.

Issue: Examination of the exploratory shaft seal

One commenter felt that the effectiveness of the grout seal is not a function of grout continuity alone and that plans for testing the grout through portholes would not provide a representative data base. Regarding the grout seal, it was further asserted that the presence of drilling mud could affect the ability of the grout to seal to the rock wall. The use of porthole tests would have to be extensive to reduce uncertainties in grout continuity.

Response

The final test to determine the effectiveness of the cement grout seal will be to core holes drilled through specially designed portholes in the casing. Other tests will be conducted during the grouting operations. An effective seal with the rock wall is important to seal integrity. Chemical flush materials, followed by water to further cleanse the rock wall, will allow a strong bond to be formed by the grout at the rock wall.

The grout will be emplaced in stages. During the grouting operations, cement-bond logging and density logging operations will be conducted to determine grout characteristics over the entire casing length.

The porthole testing program has been designed to validate the efficiency of the grout seal above, through, and below the proposed mining horizon. Porthole testing will provide a direct confirmation of the integrity of the grout-to-rock wall bond.

The grout program for the exploratory shafts has not been finalized at this time. It is proposed, however, to utilize an expanding cement in the interval between 1,018 and 813.8 meters (3,340 and 2,670 feet) below surface, except as noted. Two special chemical seal rings, one below and one above the mining horizon, will be installed in this interval. A dense Class G cement will be used to grout the interval between 813.8 meters (2,670 feet) and the surface.

The current porthole testing program is expected to confirm the effectiveness of the cement grout seal above and below the mining horizon. This program is designed to provide a representative data base on seal integrity.

Issue: Volume of material to be excavated from the exploratory shaft

An apparent conflict was noted by one reviewer concerning the volume of material to be removed from the exploratory shaft facility. It was requested that additional information be provided including bulking factors, amount to be used for backfill, and differentiation between shaft drilling and test drilling volumes.

Response

The volume of material to be removed from the shaft (based on Figure 4-2 of the Draft Environmental Assessment) is shown in Table C.4-5.

Table C.4-5. Volume of material to be removed from shaft

Depth from surface		Hole diameter		Volume	
m	ft	m	ft	m^3	ft^3
0-31.7	0-104	4.87	16	591.5	20,900
31.7-195	104-640	3.65	12	1,715.8	60,589
195-1,207	640-3,960	2.43	8	4,723.7	166,797
Total				7,031.4	248,286

Additionally, there will be a shaft station constructed during Phase I. The material excavated will have a drift size of 2.7 meters by 3.9 meters (9 feet by 13 feet), a length of 15.2 meters (50 feet), and a volume of 165.5 cubic meters (5,850 cubic feet).

Therefore, the total volume removed will be 7,197 cubic meters (254,136 cubic feet), the number that should have appeared on page 4-25. However, since the Draft Environmental Assessment was issued, it has been determined that the Cohassett flow is the candidate horizon. Therefore, the shafts will now be drilled to a depth of 1,034 meters (3,393 feet), which results in a rock volume of 6,400 cubic meters (225,000 cubic feet).

A bulking factor of 100 percent was used to obtain the 14,000 cubic meters (500,000 cubic feet) stated on page 4-25 of the Draft Environmental Assessment for the size of the spoils pile.

There are no plans to use any of the excavated material in the grout for the exploratory shaft.

The volume of material to be excavated from the exploratory shaft has been corrected in Subsection 4.2.1.3 of the final Environmental Assessment.

Issue: Exploratory shaft design

One concern was expressed regarding whether the design of the exploratory shaft was feasible and if the facility would be safe for underground workers.

Response

The design for the exploratory shaft program has been prepared in two parts: Phase I consisting of the first shaft, breakout station, and supporting equipment; and Phase II consisting of the second shaft, underground facility, and supporting equipment. The Phase I design has been completed and the conceptual design for Phase II has been completed. The construction methods necessary to implement the design are considered standard industry practices, which have been successfully employed on similar construction projects.

The design of the exploratory shaft will meet or exceed the system and hardware industrial health and safety requirements of the U.S. Department of Energy. The U.S. Department of Energy requires that the design reflect the most stringent of many Federal and State safety and health regulations (e.g., including provisions for protection of employees against such events as fire, explosions, rockfalls, equipment failures, and water inrush). Life safety systems, such as hoisting and ventilation, are provided with backup electrical power. Additionally, formal operational readiness checks of all equipment and systems will be conducted by engineering and operations personnel prior to manned entry underground to ensure that all designed systems work as designed.

Issue: Exploratory shaft costs

One reviewer requested that a cost breakdown of each of the shaft-sinking alternatives be provided in the final Environmental Assessment.

Response

The Basalt Waste Isolation Project, through engineering studies, has selected blind boring as the method to be used in construction of the exploratory shaft. This type of cost data is not considered appropriate for documentation in an environmental assessment.

Issue: Exploratory shaft facility design

A concern was expressed that poor planning regarding the placement of mud pits and cutting pits could affect foundation conditions for surface facilities.

Response

This consideration has been taken into account in the preparation of surface layouts for the exploratory shaft and for the repository.

C.4.2.2.2 Other uses of the exploratory shaft facility

The use of the exploratory shaft facility after site characterization is addressed in the following two issues:

- Other uses of exploratory shaft facility.
- Use of exploratory shaft surface facilities.

Issue: Other uses of the exploratory shaft facility

One commenter quoted the Draft Environmental Assessment statement that the exploratory shafts could be "preserved for other uses," requested that these uses be defined, and questioned why they were not discussed in the Draft Environmental Assessment.

Another commenter stated, "In case Hanford proves unsuitable as a repository, the exploratory shaft facility, the EA says at 4-15, would be either decommissioned or preserved for other uses. What would those other uses be and, if outside the repository program, how and to what extent would the new user reimburse the Nuclear Waste Fund for the greater than 100 million dollar cost of the Exploratory Shaft Program?"

Response

The ultimate use of the exploratory shaft facility, in the event that the reference repository location is not selected for repository construction, has not been established at this time. Potential uses of the facility are outlined below. The phrase "preserved for other uses," which appeared in Subsection 4.1.1.6.5 of the Draft Environmental Assessment, has been deleted.

At completion of all tests identified in the exploratory shaft test plan (Rockwell, 1983a), the Exploratory Shaft-Phase II layout will be capable of supporting, or accommodating, one or more of the following options:

- Continued use as a test facility.
- Decommissioning at repository startup by plugging and sealing.
- Incorporation into the repository.

Subsequent to the completion of tests outlined in the exploratory shaft test plan (Rockwell, 1983a), it is likely that the performance of a number of ongoing or additional tests will be desirable. The expansion capabilities of the Exploratory Shaft-Phase II layout will readily accommodate the extension or addition of areas off the main drift.

If it is decided to decommission and seal the Exploratory Shaft-Phase II facility at the time of the repository startup, a certain sequence of actions will be required. Generally, the decommissioning sequence would begin with the test drifts, followed by the main drift, and finally the two exploratory shafts.

Backfilling or sealing of the test drifts and the main drift may or may not be necessary, and is dependent on the expected performance of the Exploratory Shaft-Phase II layout as it relates to the repository.

Sealing of the two exploratory shafts is mandated by the decommissioning requirements of the adjacent repository shafts. Although the design does not preclude the option for decommissioning, the details for this effort have not been identified.

Certain expansion alternatives of Exploratory Shaft-Phase II provide for incorporation of the Exploratory Shaft-Phase II layout within the repository. Depending on the orientation of the Exploratory Shaft-Phase II within the finalized design for the repository shaft pillar area, the main drift could be extended north and (or) south to connect with appropriate repository drifts. Otherwise, rock mechanics drift number 1, the hydrology drift, eventually could become a part of the ventilation returns by proper location and alignment of the Exploratory Shaft-Phase II layout. Selection of the actual means of repository connection is dependent on the future use of the Exploratory Shaft-Phase II layout and expected ventilation needs.

Connection of the layout to the repository will provide added ventilation capacity needed to support any expansion of the Exploratory Shaft-Phase II. Connection to the repository also will require upgrading of the Exploratory Shaft-Phase II layout to ensure repository compatibility based on the presence and proximity of stored waste. The exploratory shaft facility would not be used as part of the waste storage or handling. Installation of filter banks and airlocks as a part of the Exploratory Shaft-Phase II layout system may be necessary to protect personnel as well as repository integrity.

Planned incorporation of the Exploratory Shaft-Phase II within the repository also would have the advantage of providing an early site for limited repository development. Staging of certain repository drifts from the Exploratory Shaft-Phase II would provide some reduction in the overall initial development schedule of the repository.

Issue: Use of exploratory shaft surface facilities

One commenter asked, "At p. 11, the EA says, 'DOE . . . will construct support structures on the surface . . . ' Does this mean permanent support facilities? Will these structures be used as part of repository development if Hanford is chosen the site of the first repository? If so, this seems to be in conflict with NRC licensing criteria forbiding permanent surface structures (except foundations) prior to Construction Authorizations. Does BWIP contemplate applying for a Limited Work Authorization (LWA) from NRC?"

Response

The structures referred to are not considered permanent nor is their use considered for repository development at this time.

C.4.2.2.3 Exploratory shaft testing

Exploratory shaft testing rationale and methodology are covered in the following five issues:

- Exploratory borehole drilling.
- Exploratory shaft testing sequence.
- Characterization of the reference repository location.
- Exploratory shaft porthole locations.
- Suitability of the exploratory shaft site.

Issue: Exploratory borehole drilling

One commenter stated that according to the U.S. Department of Energy, a 304.8-meter- (1,000-foot-) horizontal hole will be drilled within the dense interior. The commenter requested an explanation of the technology to be used to keep a hole perfectly horizontal for 304.8 meters (1,000 feet) and stated that a deflection of 0 degrees 17 minutes would place the end of the hole in a flow top at 304.8 meters (1,000 feet).

Response

The centerline of the breakout horizon will be at a depth of approximately 964.4 meters (3,164 feet). The flow tops above and below the breakout horizon are at depths of approximately 912.3 and 983 meters (2,993 and 3,225 feet), respectively. Therefore, the closest flow top will be approximately 27.4 meters (90 feet) vertically from the collar of the horizontal boreholes, and an average deviation of 5 degrees from horizontal would be required to intersect the flow top in a 304.8-meter (1,000-foot) borehole.

To maintain the borehole as close to horizontal as possible, the borehole will be surveyed at regular intervals and wedging techniques will be used to correct deviations.

Issue: Exploratory shaft testing sequence

One commenter asked, "At p. 4-10, if two 2.8 meter shafts are a necessary part of the Exploratory Shaft Program in order to comply with DOE safety requirements and to assure personnel safety, why is downhole testing and characterization going to take place prior to construction of the second 'safety' shaft? If this is indeed the case, it appears the second shaft will be completed for reasons other than safety. To expedite repository construction perhaps?"

Response

The only types of testing that will take place prior to the connection to the second shaft is in the following areas:

- Testing to ensure worker safety (e.g., porthole drilling prior to breakout to ensure that the liner is properly sealed).

- Installation of monitoring equipment to ensure the openings being excavated are stable and safe for the workers.

- Collection of construction data that would be lost if not recorded in conjunction with the actual construction process.

Issue: Characterization of the reference repository location

One commenter stated, "The actual characteristics of the basalt at the depth of the repository is impossible to characterize without actually building the repository. We are unlikely to know more about the site than we do now."

Response

The characterization of the repository area is the overall objective of the Basalt Waste Isolation Project site-characterization program, if the reference repository location is recommended.

The integration of data from exploratory shaft testing, surface boreholes, hydrology testing, and geophysical testing will provide an estimate of the variability of the preferred horizon. The repository design will provide a degree of flexibility for mitigating the variability of the preferred horizon. For those features that are considered likely to be present in the preferred horizon, based on the characterization data, construction contingency plans will be prepared. If the combination of these items does not provide an acceptable level of confidence, then additional data in the reference repository location, increased flexibility in repository design, and (or) additional contingency plans will have to be provided.

Issue: Exploratory shaft porthole locations

One reviewer asked if the U.S. Nuclear Regulatory Commission had guidelines on frequency and spacing of port holes along shaft.

Response

The U.S. Nuclear Regulatory Commission does not have guidelines on porthole locations at this time. The portholes were located based on stratigraphy and testing needs.

Issue: Suitability of the exploratory shaft site

One commenter observed, "I could go on, say a little something about the suitability of the site, again, I had a chance to go through the basalt tubes at Gable Mountain. My experience in the salt (sic) tubes is I had water rain down on me. I don't believe that's a solid structure. I was in it, I went down those tunnels, I saw the water dripping. It was on a day when it hadn't rained. Water is deposited on top of the mountain and comes down. It rains through the tunnels. I don't know whether I'd believe it's a safe place to put things."

Response

The use of the Near-Surface Test Facility as an example of the suitability of the site (the reference repository location) is not technically sound. The locations (structurally and at depth), the deformation histories, the geologic properties, and the hydrology of the Near-Surface Test Facility and the reference repository location are different.

C.4.2.3 Other activities

No comments were assigned to this category.

C.4.2.4 Alternative activities

No comments were assigned to this category.

C.4.3 THE REPOSITORY

This section addresses comments on the Draft Environmental Assessment regarding design and construction of repository surface and subsurface facilities. These comments are categorized into the five subsections listed below.

- C.4.3.1, Waste isolation.
- C.4.3.2, Environmental controls.
- C.4.3.3, Repository design basis.
- C.4.3.4, Alternative repository design.
- C.4.3.5, Shaft construction.

C.4.3.1 Waste isolation

This section addresses comments relating to the long-term waste isolation capability of the repository. These comments are grouped into the following three issues:

- Effect of waste form on design and performance.
- Long-term monitoring of repository conditions.
- Postclosure sealing.

Issue: Effect of waste form on design and performance

Two commenters requested additional detail regarding the properties of the nuclear waste to be stored and their impact on design and long-term performance of the repository. Both commenters stated that such information was necessary to better understand the subsequent site-characterization program.

Response

Additional detail relating to the properties of the waste form and their effect on waste package and repository design are provided in several of the references listed at the end of Chapter 5 of the Draft Environmental Assessment (RKE/PB, 1983, 1984a,b,c,d,e; Rockwell, 1984; Westinghouse, 1985; DOE, 1984c). The heat load from the waste containers is a function of waste age, type of waste (e.g., spent fuel from commercial nuclear reactors, defense high-level waste, or reprocessed commercial high-level waste), and quantity of waste. The heat load is a factor in design of emplacement borehole spacing, emplacement room geometry, and the ventilation system. The composition of the waste (i.e., quantity of various radionuclides) is a factor in the design of the engineered barriers (i.e., the waste package and the repository seals). Radioactivity levels for the waste forms to be emplaced are factors in the design of handling systems and shielding for personnel safety during operations. Therefore, characteristics of the wastes to be stored are important elements in the design process for the repository.

Issue: Long-term monitoring of repository conditions

Two commenters stated that long-term monitoring techniques to be used during the 90-year preclosure period and monitoring to be conducted during the postclosure period are not discussed in the Draft Environmental Assessment. Both commenters stated that definitive monitoring programs for the reference repository location must be developed during the site-characterization phase.

Response

As stated in the Generic Requirements Document (DOE, 1984c), during the preclosure phase, radiation monitoring shall be done to meet U.S. Nuclear Regulatory Commission requirements as specified in 10 CFR 60.131(a) (NRC, 1985a); performance confirmation shall be done to meet the requirements of 10 CFR 60, Subpart F. Additional information on instrumentation and monitoring techniques for the subsurface facility during the preclosure phase is provided in the 1982 conceptual design (RKE/PB, 1983) listed in the references at the end of Chapter 5 of the Draft Environmental Assessment. Monitoring programs for the postclosure phase will be developed in accordance with the requirements of 10 CFR 60 (NRC, 1985a) and 40 CFR 191, Subpart B (EPA, 1985). At the current time, however, there are no such requirements.

Issue: Postclosure sealing

Comments were received relating to postclosure shaft sealing. Two commenters questioned the conclusions regarding the first potentially adverse condition under rock characteristics (DOE, 1984a; 960.4-2-3(c)(1)), which relates to rock conditions that may require "engineering measures beyond reasonably available technology" for long-term sealing of the repository to minimize ground-water flow and radionuclide migration. One commenter stated that information should be provided relating to procedures for placement of permanent seals, long-term performance of sealing materials including testing and monitoring to be performed, and sealing of interfaces between the liner and rock and within rock fractures. Some commenters questioned the constructibility and long-term durability of bulkheads and grout curtains under the thermal, chemical, and stress conditions expected and the applicability of grouting experience at dam sites (see Subsection 6.3.1.3.5 of the Draft Environmental Assessment) to grouting in a repository shaft. Additional commenters expressed general concerns relative to the ability to isolate radionuclides in a repository constructed in the saturated zone.

Response

The discussion in Subsection 6.3.1.3.5 of the Draft Environmental Assessment presented a preliminary, conceptual shaft-seal design. Design and construction requirements for shaft sealing will be developed during the site-characterization phase, should the reference repository location be recommended for characterization. Installation of shaft seals would involve the removal of the shaft liner and the grout placed between the liner and excavated rock and the subsequent placement of sealing materials in the space provided. The primary sealing materials currently being considered for shafts and boreholes is a mixture of crushed basalt and a "swelling" clay such as bentonite. Such a material would provide low hydraulic conductivity, chemical stability over long time periods, and plastic response to loads and deformations imposed over the 10,000-year design lifetime.

Concrete or grout may be used for sealing components if application techniques, mix designs, and long-term performance can be demonstrated. Grouting to seal fractures in the damaged rock zone may be appropriate for sufficiently large fractures. The techniques involved in injecting grout into fractures would be similar to techniques used in dam construction. The conditions under which grout would be installed and the performance requirements for such grout installation would be different, however, than for dam construction. The final Environmental Assessment has been revised to indicate that materials and techniques to be used for sealing the damaged rock zone, if required, would be based on engineering studies and development testing to be conducted during the site-characterization phase.

Current concepts and programs for defining shaft seal requirements will be provided in the site-characterization plan if the reference repository location is recommended for characterization. The site-characterization plan will also describe a program for assessing the long-term durability of cementitious materials. Performance assessment of the repository seals, discussed in Section 6.4.2 of the Draft Environmental Assessment, suggests that the cumulative radionuclide release to the environment, attributable to migration through the repository seals system, would be well within U.S. Environmental Protection Agency (EPA, 1985) limits even if fractures in the damaged rock zone around the shafts are not sealed or grouted. Test programs to be conducted during the site-characterization phase will provide a basis for finalizing repository seal design and construction requirements.

Subsections 6.3.1.3.5 and 6.3.4.1.2 in the final Environmental Assessment were modified to clarify that materials and installation methods for repository sealing would be developed during site characterization.

C.4.3.2 Environmental controls

This section addresses comments relating to design features to promote occupational health and safety, and safety of the general public. These comments were grouped into the following three issues:

- Occupational and public health and safety.
- Ventilation system design.
- Facility-generated radioactive waste treatment and disposal.

Issue: Occupational and public health and safety

Two commenters stated that the increased occupational risks due to airborne dust and heat radiated from waste containers need to be evaluated. One commenter asked what the impact of radon releases during construction and operation of the repository would be.

Response

Air quality and air temperatures affecting construction and operating personnel are considered in the design of the ventilation system for the underground facility. The ventilation system will be designed and operated to maintain air temperature and humidity in working areas in accordance with limits set by the American Conference of Government Industrial Hygienists (Rockwell and RKE/PB, 1982). The ventilation system is also designed to control airborne particulates by a combination of filtration and limiting air velocities.

The effect of radon releases due to repository construction was evaluated by the U.S. Department of Energy (DOE, 1980, listed in the references for Chapter 5). As indicated in Subsection 5.2.1.3.6 of the Draft Environmental Assessment, this evaluation concluded that no health effects are expected.

Issue: Ventilation system design

Two commenters questioned how underground ventilation problems would be handled considering the potentially high air temperatures expected at the repository horizon. One commenter was concerned with the cooling load for the repository. Two commenters expressed an opinion that there was a lack of apparent coordination in preparing a comprehensive overall design package and a concern that evaporation and other factors influencing ventilation had not been addressed.

Response

Ventilation schemes for the repository can be found in a report by Raymond Kaiser Engineers, Inc./Parsons Brinckerhoff Quade & Douglas, Inc. (RKE/PB, 1984e), which was included in the list of references for Chapter 5 of the Draft Environmental Assessment. The primary ventilation fans are located on several shafts. Other ventilation controls, which exist underground, can be approached from the upstream side and necessary repairs or changes can be effected advancing from the shafts in cooled air.

The projected cooling loads for the repository are shown in Table C.4-6.

Table C.4-6. Maximum cooling and refrigeration loads*

Phase	Cooling load		Refrigeration load	
	Refrigeration tons	Kilowatts	Refrigeration tons	Kilowatts
Initial development	2,267	7,974	1,768	6,220
Operations	4,402	15,484	3,318	11,670
Caretaker	2,268	7,979	984	3,463
Backfill	2,405	8,461	1,044	3,672

*Taken from Raymond Kaiser Engineers, Inc./Parsons Brinckerhoff Quade & Douglas, Inc. (RKE/PB, 1984e).

The ventilation system designs for the engineering studies discussed or referenced in the Draft Environmental Assessment were conceptual and were developed for scoping purposes. As such, some factors may have been considered of secondary importance for such purposes, and therefore not included. Later stages of design, up to final design for construction, will include details omitted at earlier stages. Such designs will include design reviews and design verification, consistent with quality assurance program requirements for systems and components important to radiological safety.

Issue: Facility-generated radioactive waste treatment and disposal

Some comments were received regarding the treatment and disposal of facility-generated solid, liquid, and gaseous radioactive wastes. One commenter asked if repository-generated solid low-level waste would be disposed of at the reference repository location, or if existing U.S. Department of Energy facilities would be used for disposal. Some commenters expressed concerns regarding possible radiological impacts as a result of generating these wastes. Additionally, some commenters were concerned with the impact of system failure if the high-efficiency particulate air filter system should fail on detection of airborne radioactive or toxic materials in the ventilation system.

Response

The comments related to facility-generated radioactive waste treatment and disposal have been grouped into two general areas for response. These areas are radwaste treatment and radiological impacts from normal facility operations.

Radwaste treatment. The Generic Requirements for a Mined Geologic Disposal System (DOE, 1984c, Section 1.2.2.2), states " . . . The processing and packaging facility will monitor, collect, process, and package radioactive wastes generated during waste handling operations. This waste shall be processed and packaged according to the criteria developed for waste of similar radionuclide content, received from offsite, such that it can be disposed of onsite or safely transported to an alternative disposal site, in accordance with any applicable regulations." This same criterion is stated in 10 CFR 60.132(d) (NRC, 1985a). As yet, no decision has been made as to whether solid low-level radioactive wastes generated onsite would be disposed of onsite or offsite. This question will be evaluated during later design stages. The surface facilities will be designed to control the release of radioactive materials in effluents during normal operations so as to meet the performance objective of 10 CFR 60.111(a) (NRC, 1985a).

In the current design concept, liquids are transferred by gravity mains and force mains from the radwaste sources to a 144-cubic-meter (30,000-gallon) storage tank below grade. The tank contents are sampled and, if found to be uncontaminated, pumped to the surface percolation pond. Liquids in which radioactivity exceeds percolation disposal limits are pumped through an etched disc filter, then through a mixed bed ion exchanger. The purified effluent can then be pumped to the percolation pond. The semipurified effluent is routed to the radwaste immobilization system. Contaminated spent resin beads are sent to the radwaste incinerator.

The gaseous radwaste system of the current design concept collects and purifies gaseous radwastes from gas-emitting sources of the facilities. Purification consists of removal of droplets of radioactive liquid and radioactive particles. Two purification trains are provided, one of which is a redundant standby train. The following description covers one train. Source gases are routed to a gas blower, which then forces the air through the purification equipment and the 102-millimeter (4-inch) transfer gas piping. This discharges to a cooler, then in sequence to a moisture entrainment separator, a caustic scrubber, a heater, a prefilter, and a high-efficiency particulate air filter. The high-efficiency particulate air filter discharge is routed to the primary confinement ventilation system of the waste-handling building, which in turn exhausts waste air and gases through high-efficiency particulate air filters to the exhaust stack. Radwaste gases are collected from the sources through suction piping routed to the blower in the two gaseous radwaste rooms at the northeast corner of the waste-handling building. Each room contains a purification train. The blower discharges gas to an air-to-water heat exchanger that cools the gas to 38°C (100°F) for subsequent discharge to a moisture entrainment separator. The cooled and dried gas is then routed to a caustic scrubber for iodine removal. Scrubbed gas is routed through an electric heater to warm the air so that condensation and clogging does not occur in subsequent filters. The piping system is arranged so that gases may bypass the caustic scrubber and pass directly to the electric heater if it is determined that the gases do not contain iodine. The heated gases pass through a prefilter and a high-efficiency particulate air filter and are discharged to the waste-handling building primary confinement ventilation system.

Radiological impacts from normal facility operations. Requirements invoked by reference in 10 CFR 60.111(a) (NRC, 1985a) pertain to protection against radiation exposure and release of radioactive material (see Subsection 6.4.1.2 of the Draft Environmental Assessment). These are minimum requirements. Requirements pertaining to protection against radiation exposure and release of radioactive material are also given in 10 CFR 20.101, 10 CFR 20.103, 10 CFR 20.105, 10 CFR 20.106 (NRC, 1985b), and 40 CFR 191, Subpart A (EPA, 1985). Specified safety design criteria are prescribed by the U.S. Nuclear Regulatory Commission to provide reasonable assurance that the radiation exposure and radiological release requirements contained in 10 CFR 20 (NRC, 1985b) and 40 CFR 191 (EPA, 1985) are met. These requirements are delineated in 10 CFR 60.131(a), 10 CFR 60.131(b), 10 CFR 60.132, 10 CFR 60.133, and 10 CFR 60.135 (NRC, 1985a). Design of radiation-monitoring systems, radioactive waste treatment and disposal systems, and radiation-protection systems for operating personnel and the general public will be in compliance with these requirements.

The ventilation exhaust system will be capable of controlling the discharge of airborne radioactive materials to the environment within the limits established under 10 CFR 20, Appendix B, Table II (NRC, 1985b) and 40 CFR 191 (EPA, 1985). The design will preclude the release of radionuclides greater than established limits by incorporating redundant, sequential, or backup systems to those systems necessary for mitigation of radionuclide releases.

Operational and accident scenarios that may impact system safety are identified and described as part of preclosure safety analysis. Scenarios considered are those that can result in potential occupational radiation exposure or offsite radiological release. The Draft Environmental Assessment (see Subsection 6.4.1.4) discussed analysis of releases under routine operations and under postulated accident conditions. For normal operating conditions, the radiation dose to a member of the general public was estimated to be approximately 0.001 millirem per year. For a fuel cask drop accident, estimated to be a bounding accident case, the calculated radiation dose to a member of the public was 0.3 millirem. Both values are well within allowable limits.

C.4.3.3 Repository design basis

This section addresses comments relating to repository design features, the repository design basis and criteria, and the effect of changes in the design basis. The issues addressed in this subsection are as follows:

- Repository design features.
- Retrieval option period.

Issue: Repository design features

Some commenters asked general questions regarding repository characteristics and design features. These questions related to the repository depth, ventilation in the repository, the time period required to emplace waste in the repository, and a general comment regarding the nature of the repository. One commenter stated that the length of the double-security fence should be provided. Another commenter stated that when the amount of water needed for the facility operation is known, it should be included within the project description.

Response

Information pertaining to repository characteristics and design features is contained in Section 5.1 of the Draft Environmental Assessment. Greater detail is provided in the references listed at the end of Chapter 5.

Based on the 1982 conceptual design (RKE/PB, 1983), the length of the outside security fence is approximately 4,600 meters (15,000 feet). This may change with subsequent designs.

Issue: Retrieval option period

One commenter stated that the 35-year retrieval option period identified for the two-phase repository (following completion of the 50-year operation and maintained retrieval period) may result in room and borehole rock stability problems that were not addressed in the Draft Environmental Assessment. Another commenter stated that the bar chart (see Fig. 5-1 of the Draft Environmental Assessment) should be clarified to indicate the period of time that rock support systems must be maintained.

Response

Specifications for rock support and maintenance requirements are based on the need to provide opening stability for construction, operation, and retrieval (i.e., for the entire preclosure period up to permanent closure). Any or all of the emplaced waste must be retrievable for a period of 35 years starting at any time up to 50 years after waste-emplacement operations are initiated. This period of time is indicated in Section 5.1 of the Draft Environmental Assessment as taking approximately the same amount of time as that devoted to construction of the geological operations area and the emplacement of wastes (NRC, 1985a; 10 CFR 60.111(b)) (i.e., approximately 34 years). Since the decision to retrieve the wastes could be made at the end of the 50-year retrievability period, which starts at initial waste emplacement (approximately 6 years after the start of construction), the total preclosure period as indicated in the bar chart in Figure 5-1 of the Draft Environmental Assessment is approximately 90 years. Design of the rock-support system and plans for its maintenance are discussed in Subsections 6.3.3.2.4 and 6.3.3.2.7 of the Draft Environmental Assessment. Figure 5-1 represents a scenario wherein the decision is made to retrieve emplaced wastes. If the decision is made at the end of the 50-year retrievability period to leave the wastes emplaced, backfilling and sealing of the repository would begin at that time. For the last areas of the underground facility to be backfilled, the time period during which rock support system would need to remain functional may approximate that of the retrieval scenario.

The text of Section 5.1 in the final Environmental Assessment was revised to clarify the application of Figure 5-1 in the Draft Environmental Assessment. Also, clarification was provided in Chapter 5 as to the current plans of the U.S. Department of Energy for developing design, construction, operational, and maintenance requirements for retrievability.

C.4.3.4 Assessment of alternative repository designs

Nineteen comments related to alternative design concepts or the bases for repository design that were either discussed in Chapter 5 of the Draft Environmental Assessment or, in the opinion of the commenter, should be evaluated and discussed. These comments were grouped into the following four issues:

- Design assumptions regarding high-level waste.
- Interim storage, retrieval, and decommissioning.
- Design description.
- Natural phenomenon.

Issue: Design assumptions regarding high-level waste

Some comments were received pertaining to potential impacts of changes in conditions and requirements relative to high-level waste. One commenter questioned the effect of the "29% increase in size" (assumed to mean the increase in size from the 1982 conceptual design (RKE/PB, 1983) to the more recent 70,000 metric ton (77,000 ton) capacity). Another commenter stated that although the Draft Environmental Assessment indicated in some sections that defense high-level waste may be received, no discussion of its impact was included. One reviewer stated that commingling defense waste, commercial high-level waste, and spent fuel would have more than a nominal impact. One commenter questioned whether the Federal Government planned to store defense high-level waste in the repository. Another commenter asked what the effect on repository design concepts would be if certain assumptions changed (e.g., inclusion of defense waste, capacity, receipt rate, waste age, and prepackaging of waste). A question was raised as to whether designing the repository to accept waste aged 10 years or longer would impact decommissioning schedules for power reactors. One reviewer asked what the effect due to increasing the repository capacity would be on the environment.

Response

Section 5.2 of the Draft Environmental Assessment discussed the environmental-, socioeconomic-, and transportation-related effects of constructing and operating a repository at the Hanford Site. These assessments were based primarily on the 1982 conceptual design (RKE/PB, 1983), which was based on a repository built to contain 47,400 metric tons (52,000 tons) of heavy metal. Other design studies also have been performed, as discussed in Section 5.1. Among these are studies of a larger (70,000 metric tons (77,000 tons) of heavy metal) repository and a two-phase repository. Table 5-1 provided a comparison of repository concepts that have been evaluated and presented an assessment of the changes in environmental impacts associated with the alternative concepts. In addition, comments received on draft environmental assessments by the other candidate high-level nuclear waste projects relating to design alternatives has prompted a decision by the U.S. Department of Energy to require that all projects address, in a modified Table 5-1, the issue of potential impacts of various design alternatives on environmental, socioeconomic, and transportation concerns.

Chapter 5 of the final Environmental Assessment has been modified to discuss the possible inclusion of spent fuel aged as little as 5 years, emplacement of defense wastes, and to include a revised Table 5-1 which addresses environmental, transportation, and socioeconomic impacts of alternative designs.

Issue: Interim storage, retrieval, and decommissioning

One commenter stated that the role of monitored retrievable storage in the repository program was not adequately addressed. Another commenter asked what the impact of the decommissioning phase and terminal phase would have on the conclusions drawn in the Draft Environmental Assessment, since these were not specifically included in the 1982 conceptual design (RKE/PB, 1983).

Two reviewers stated that more information regarding the requirement (DOE, 1984a) to provide 3-month surge capacity to minimize the impact of interruptions in repository operations should be presented in Chapter 5 of the final Environmental Assessment. Two commenters stated that plans and procedures should be developed for retrieving emplaced wastes if monitoring revealed that radioactive materials were escaping into the environment. One commenter questioned the use of facilities that would be acquired from Washington Public Power Supply System for interim storage and handling of waste, which was considered in the two-phase repository study.

Response

Surge capacity would be provided in a surface storage facility. The 1982 conceptual design (RKE/PB, 1983) did not include provisions for a 3-month interim storage capacity. This requirement will be included in the conceptual design phase to be conducted in parallel with site-characterization. Storage capacity will be provided in surface facilities and would be dry for waste already encapsulated in emplacement containers and wet or dry (to be determined) for waste forms not yet in such emplacement containers. Radiation monitoring and treatment for such temporarily stored wastes will be in compliance with U.S. Environmental Protection Agency (EPA, 1985) and U.S. Nuclear Regulatory Commission (NRC, 1985a) requirements applicable to repository operations. Therefore, provision of a 3-month surge capacity would not constitute a significantly higher level of risk than if temporary storage were not required. If, during the preclosure period, radiation monitoring indicated that containers were leaking, such containers would be identified and retrieved or repaired prior to permanent closure. Current plans do not include acquisition of terminated Washington Public Power Supply System facilities for storage or handling of waste.

Chapter 5 of the final Environmental Assessment was modified to refer to plans for incorporation of a monitored retrievable storage facility for interim handling and storage of high-level nuclear waste, and also discusses the plans of the U.S. Department of Energy to develop criteria for retrievability.

Issue: Design description

Two commenters questioned why the 1982 conceptual design (RKE/PB, 1983) was mentioned in such great detail in the Draft Environmental Assessment since it had been updated by later engineering studies. One comment questioned why the shaft diameters and numbers were inconsistent in various sections of Section 5.1.

Response

The purpose for providing the design details for the 1982 conceptual design (RKE/PB, 1983) is because that was the basis for the detailed assessments of environmental, socioeconomic, and transportation impacts. Differences in the number of shafts and the sizes of those shafts, as presented in various sections of Section 5.1, are associated with the different concepts that were evaluated.

Issue: Natural phenomenon

One commenter asked about the impact of the design basis tornado on the repository. Another commenter asked what impacts volcanic ash from Mount St. Helens would have on repository design.

Response

Volcanic ash from Mount St. Helens was not considered in previous repository designs, but roof loads from such ash will be considered in the conceptual design forming the basis for the site-characterization program. Tornado loads were also considered in the design of surface facilities.

C.4.3.5 Shaft construction

This subsection addresses comments relating to shaft constructibility and the choice of construction method for the repository shafts. These comments were combined into the following two issues:

- Applicability of previous drilling experience.
- Choice of construction method.

Issue: Applicability of previous drilling experience

Some reviewers questioned the applicability of case histories and previous drilling experience cited in the Draft Environmental Assessment to the drilling of large-diameter shafts at the Hanford Site. Two commenters expressed doubt about the applicability of the 2.3-meter- (7.5-foot-) diameter Amchitka shaft drilling experience to drilling a 4.6-meter- (15-foot-) diameter shaft at the Hanford Site. One commenter also implied that structural problems encountered in drilling the 4.3-meter- (14-foot-) diameter Agnew shaft may be evidence of significant technological problems for drilling at the reference repository location. One commenter identified an inconsistency between Tables 6-20 and 6-21 regarding the drilled-hole diameter of shafts at Summer Falls, Washington. Another commenter stated that small-diameter drilling experience at the Hanford Site should not be cited as evidence of shaft constructibility, since large-diameter shafts would intersect more fractures, encounter a larger volume of water inflow, and require drilling equipment with considerably larger capacity than for small-diameter boreholes. Two reviewers stated that, due to the uncertainties inherent in extrapolating from the large-diameter drilled-hole case histories at other locations and the small-diameter drilled holes in the Hanford Site basalt formations, the U.S. Department of Energy should revise its position that engineering measures beyond reasonably available technology would not be required for construction of the shafts and underground facility. One commenter expressed concerns with the lack of shaft-drilling experience in basalt to the depth and diameter required at the Hanford Site. Two commenters also noted that no shafts with drilled diameters as large as those proposed at the Hanford Site had ever been constructed in basalt to the depth required at the Hanford Site, and that discussion of potential technical problems that may be encountered in construction was inadequate.

Response

Even though some uncertainty exists in extrapolating experience from drilling small-diameter boreholes at the Hanford Site and large-diameter shafts at other locations, this experience supports the conclusion that engineering measures required for constructing shafts at the Hanford Site are not beyond the limits of reasonably available technology.

Applicability of small-diameter borehole experience at the Hanford Site. The geologic and hydrologic conditions affecting the drilling of small-diameter boreholes at the Hanford Site are expected to be nearly identical for large-diameter shafts. Larger-diameter shafts will intersect more fractures than do smaller-diameter boreholes, but this alone should not affect constructibility. The presence of fractures enhances the comminution of basalt and allows for relief of in situ stress, therefore reducing the likelihood of spalling (Morrison-Knudsen, Co., Inc., 1983b). The frequency of slabbing, which may occur due to the collapse of partially drilled portions of vertically oriented columnar basalt, would be greater in a larger-diameter shaft than in a small-diameter borehole; however, this is considered to be an infrequent occurrence and such slabs are expected to be crushed by the drill assembly (Morrison-Knudsen, Co., Inc., 1983b). Common industry practice is to use a properly formulated drilling fluid for control of sloughing (Morrison-Knudsen, Co., Inc., 1983a). In the event drilling fluid fails to control sloughing, concrete plugs may be placed in zones of unstable rock, or slabs that are too large to be crushed can be extracted with appropriate tools (Morrison-Knudsen, Co., Inc., 1983a).

The potential for a larger volume of water inflow due to drilling a large-diameter shaft is not considered to be a problem since the in situ hydraulic head is offset by the head due to the depth of the drilling fluid. Control of potential water inflow would be no different for larger-diameter shafts than for small-diameter boreholes. Artesian conditions have not been encountered during drilling at the reference repository location and are not expected to exist during construction of the shafts (Morrison-Knudsen, Co., Inc., 1983b). Such conditions, if present, could be controlled by increasing the density of the drilling fluid. Following shaft liner installation, the annulus between the liner and the excavated rock is filled with grout to seal off and isolate aquifers; thus, water inflow would not be a problem following shaft breakout.

For construction of the large-diameter shafts, drilling equipment with considerably larger capacity than equipment used for boreholes will be required. Several studies (Morrison-Knudsen, Co., Inc., 1983b, 1984; RKE/PB, 1984b) have evaluated conditions at the Hanford Site and previous drilling experiences in making preliminary recommendations on large-diameter shaft drilling equipment. The drill rig mechanical and load-carrying components for the shafts at the reference repository location will be sized based on the higher torque loads and higher rig-hook loads required for drilling a large-diameter shaft. The circulation system design for removal of cuttings from under the bit would be optimized based on experience gained from other large-diameter drilling operations. The cutter design, size, and loads will be similar, however, to cutters used in drilling smaller-diameter boreholes. Techniques to predict shaft- and tunnel-boring performance and optimize boring-equipment design, based on empirically derived statistical relationships between rock properties (e.g., compressive strength, rock hardness) and such equipment parameters as penetration rates and cutter consumption, are commonly used in mining excavation (Tarkoy, 1979). Such relationships, extrapolated from previous experience, are used in the mining industry to specify drilling equipment machine design parameters such as thrust, torque, horsepower, number of cutters, cutter diameter and spacing, and cutterhead rotational rate. The application of small-diameter drilling experience in the Hanford Site basalt formations to the selection of techniques and equipment for large-diameter shaft drilling at the reference repository location is considered to be a similar extrapolation and therefore consistent with standard industry practice.

The most recent small-diameter drilling experience at the reference repository location included drilling a 44-centimeter- (17.5-inch-) diameter borehole to 850 meters (2,800 feet), then continuing with a 30-centimeter- (12-inch-) diameter borehole to 1,040 meters (3,400 feet). This operation was completed in 35 days with no problems encountered.

Differences in hole diameters and drilling equipment between existing experience at the Hanford Site and large-diameter blind boring experience elsewhere introduce some uncertainties in extrapolating experience and existing technology for the selection of equipment and methods. These uncertainties primarily are associated with the efficiency and economy of drilling and the degree of confidence in estimates of cost and schedule (RKE/PB, 1984b).

Applicability of large-diameter shafts at other locations. Further evidence for constructibility of large-diameter shafts by blind boring at the Hanford Site is provided by large-diameter blind boring operations at other locations. In addition to those shafts cited in Table 6-20 of the Draft Environmental Assessment, a 3-meter- (10-foot-) diameter hole was blind bored through breccias and basalts to 1,390 meters (4,550 feet), at a rate of 4.75 meters per day (15.6 feet per day), at Amchitka (RKE/PB, 1984b). At the Agnew shaft, where drilling was stopped short of the projected depth due to equipment failure, the cause of such failure was concluded to be preventable by design and to be repairable; however, the remoteness of the Agnew shaft location favored completion of the shaft by conventional methods. The diameter of the Agnew shaft (4.3 meters (14 feet)) closely approximates the 4.6-meter- (15-foot-) diameter shafts proposed for the Basalt Waste Isolation Project. The Agnew shaft was drilled through actinolite-gneiss, phlogopite-schist, and metagabbro rocks. The metagabbro was tested by Rockwell Hanford Operations and by the Colorado School of Mines (RKE/PB, 1984b) and yielded unconfined compressive strengths in the range of the basalts at the Hanford Site. While it is not possible to identify case histories of previous blind boring experience where conditions exactly simulate those at the Hanford Site, those experiences cited do provide strong evidence of constructibility with reasonably available technology.

Issue: Choice of construction method

Some commenters questioned the choice of the blind-hole drilling method as the preferred technique for shaft construction at the reference repository location. Some commenters recommended that additional discussion be provided in the final Environmental Assessment supporting the decision for blind-hole drilling the shaft. Other commenters recommended that additional discussion be provided relating to the drill-and-blast method or other methods as alternative construction techniques that may have certain advantages over the blind-hole drilling method or may be required to recover a jammed drill bit. Two commenters stated that the assumptions regarding sloughing of small blocks of rock from the sides of the shaft excavation (see Subsection 6.3.3.2.6.1 of the Draft Environmental Assessment) as a potential cause of jamming the drill bit may have underestimated the potential problem. Two reviewers stated that contingency plans should be presented for the sealing of abandoned shafts in the event of unforeseen technical problems associated with shaft drilling.

Response

The advantages and disadvantages of blind-hole drilling and drill-and-blast construction techniques, as well as rationale, potential problems, and uncertainties associated with the method selected for the reference repository location, are presented in Subsection 6.3.3.2.6.1 of the Draft Environmental Assessment and the references cited therein.

The principal factors favoring the blind-hole drilling method over the drill-and-blast method for shaft construction are personnel safety and schedule. While the basalt at the Hanford Site is considered to have high rock strength, it also has excellent drillability characteristics since it exists as a glassified brittle form. Potential technical problems cited for the blind-hole drilling method (e.g., recovery of jammed drill bit, sloughing of rock, sealing of aquifers) were considered in the comparative evaluation of shaft-sinking methods. Such technical problems either are considered to be resolvable by existing methods or to entail less risk to cost, schedule, and personnel safety than conventional drill-and-blast techniques for shaft-sinking and freezing methods for aquifer sealing. Long-term repository performance also is considered to be enhanced by the blind-hole drilling technique, since damage to the rock is expected to be less than that caused by blasting.

In the event that partially drilled shafts had to be abandoned and they were of sufficient depth to represent a credible pathway for migration of radionuclides, they would be sealed in accordance with provisions developed for the completed and decommissioned repository shafts.

C.4.4 WASTE PACKAGE

Comments on waste package topics resulted in ten separate issues. These issues include the following:

- Appropriateness and accuracy of calculations of container lifetime given in the Draft Environmental Assessment.
- Chemical stability of bentonite in packing material.
- Values of packing material transport parameters used in calculating radionuclide releases.
- Whether or not the solubility and chemical reactivity of engineered barriers (DOE, 1984a; 960.4-2-2(c)(1)) was adequately addressed in the Draft Environmental Assessment.
- Dissolution and mechanical erosion of the waste form.
- Thickness and physical properties of damaged and disturbed rock adjacent to the repository.
- Justification of the wall thickness at which the container will collapse.
- Selection of low-carbon steel for the waste container.
- Ground-water resaturation of the waste package.
- Effects of ground-water temperature on corrosion and solubility of the waste package.

In addition, a number of comments addressed miscellaneous concerns unrelated to any of the aforementioned issues. These comments were grouped into a subsection titled "Miscellaneous."

Issue: Container lifetime calculations

A number of commenters questioned the calculations of container lifetime given in the Draft Environmental Assessment. Reviewers stated that processes other than uniform corrosion must be considered in these calculations. These processes include thermal stresses, lithostatic loading, elastic and plastic deformation, brinnelling, ductile rupture, brittle fracture, fatigue, and wear. Concern that the containers will eventually leak was also expressed.

Response

The container lifetime calculations given in the Draft Environmental Assessment were based on preliminary models developed from extremely limited data obtained under simulated repository environment conditions.

Steps have been taken to expand the data base (under relevant repository conditions), which will be used to improve the models and obtain more realistic and statistically significant container lifetime estimates.

The waste-package design will accommodate all expected stresses (no lithostatic stresses are expected under nondisruptive conditions based on current knowledge of rock properties and waste package-repository design) and thereby address all structural and mechanical considerations for the container by applying design rules similar to the American Society for Mechanical Engineers Boiler and Pressure Vessel Code (ASME, 1983). This will provide a conservative container wall thickness for thermal, hydrostatic, and handling stresses. A corrosion allowance will be added to the structural thickness, as well as any additional thickness needed to reduce radiation dose rates to below a level of concern from a radiolysis standpoint, to establish the total overall thickness of the container. All active degradation modes will be considered in both the design and the performance assessment of the waste-package container.

The approach to predicting long-term corrosion behavior starts with the identification and understanding of the active corrosion processes in a repository environment by means of a detailed test-and-analysis program. Container-material behavior models can then be developed based on an understanding of the observed corrosion processes in materials and environmental conditions specific to a repository in basalt. Confidence in the long-term predictive capabilities of the resulting computer codes is generated by the following activities:

- Testing in accordance with accepted procedures.
- Testing under truly representative environmental conditions.
- Generating a large, statistically significant data base.
- Analyzing all data in accordance with accepted standard practices.
- Developing an understanding of the active corrosion processes.
- Constructing corrosion models based on the data and an understanding of the active corrosion processes.
- Developing computer predictive codes that are validated by appropriate engineering-scale tests.
- Obtaining expert review and concurrence on each of the above activities.

The analysis of container failure has not been changed for the final Environmental Assessment. However, a more complete explanation of assumptions used in this analysis and its limitations is given in Subsection 6.4.2.3.3.

Issue: Stability of packing material

Numerous concerns were raised about the chemical stability of bentonite and the effects that alteration may have on desired bentonite performance as a part of the packing components of the engineered barrier system. Specifically, there is concern that bentonite will convert to illite or albite. Another concern is that the steam transport through bentonite in the packing will irreversibly reduce the swelling capacity of bentonite, thereby substantially increasing the permeability of the packing.

Response

Both hydrothermal alteration of bentonite to illite and a reduction of swelling capacity of bentonite by steam treatment are potential causes of increased packing permeability and loss of diffusional control of mass transport.

Packing material-ground water experiments have been conducted by the Basalt Waste Isolation Project (Wood et al., 1982, 1984) and others (Peacor et al., 1984; Anderson et al., 1984). The Basalt Waste Isolation Project data show that substantial reactions occur primarily at 300°C (572°F) and relatively small amounts of reaction occur at lower temperatures. In the experiments with basalt, bentonite, and ground water, the major secondary phases formed are iron-rich smectites and zeolites. Bentonites are slightly enriched in potassium, which may indicate incipient transformation to illite. However, the alteration of bentonite to illite has not been clearly identified. Another possible reaction is the alteration of bentonite to iron-rich smectite. Anderson et al. (1984) performed experiments at 150°C (302°F) in the system containing basalt, bentonite, steel, and ground water, which was saturated with methane or irradiated or both. The x-ray diffraction analyses of the solid phases showed some changes in the bentonite peaks, which are probably the result of cation exchange (e.g., calcium and magnesium for sodium). As with the Basalt Waste Isolation Project experiments, an iron-rich smectite (nontronite) was formed. Peacor et al. (1984) performed bentonite groundwater experiments from 300 to 460°C (572 to 860°F) and observed substitution of calcium for potassium in the bentonite at 300°C (572°F). These data are relatively consistent and, when combined with observations of secondary minerals formed in the natural basalt environment, indicate that loss of swelling capacity and increase in permeability are unlikely to result from hydrothermal reactions. The major mechanism for loss of swelling capacity should be the conversion of bentonite to illite. The potassium-poor basalt environment, the observed partioning of potassium into other secondary minerals (e.g., zeolite), and the scarcity of mixed layer smectite-illite clays in the host rock (Benson and Teague, 1982) support the hypothesis that illite alteration is unlikely to be a significant reaction in the packing. Furthermore, substantial reactions of basalt glass to iron-smectite are expected to occur that will offset the effects of nonswelling illite clay, should it form.

Couture (1985) steam-treated packing-material mixtures (75 percent basalt and 25 percent bentonite, by weight) up to 250°C (482°F) and then measured the permeabilities of these mixtures. Increased permeabilities as a function of increased steam temperatures were observed. Permeabilities of 1 x 10^{-18} square meter (1.8 x 10^{-17} square foot) and 1 x 10^{-14} square meter (1.8 x 10^{-13} square foot) were measured for unsteamed and steamed packing materials, respectively, with an initial density of 1.7 grams per cubic meter (106 pounds per cubic foot). These values correspond to hydraulic conductivities of 1 x 10^{-9} and 1 x 10^{-5} centimeter per second (3.9 x 10^{-10} and 3.9 x 10^{-6} inch per second). At a density of 2.1 grams per cubic centimeter (131 pounds per cubic foot), a hydraulic conductivity of approximately 1 x 10^{-7} centimeters per second (3.9 x 10^{-8} inch per second) was measured for steamed packing. Following the experiments, the packing materials were allowed to expand freely in water and a significant loss of swelling capacity was reported, resulting in the increased permeability.

At present, the mechanism for the observed reduction in swelling capacity is not known. No definite phase alteration occurred during the experiments and work is in progress to determine if the loss of swelling capability is truly irreversible.

The following analysis has been done to determine what effects these large increases in permeability, assuming they are permanent, may have on the ability of packing to maintain diffusional control of radionuclide transport. Measured diffusion coefficients for inert elements in packing material at 1.8 grams per cubic centimeter (112 pounds per cubic foot) at 90°C (194°F) are 1 x 10^{-5} square centimeter per second (1.55 x 10^{-6} square inch per second) (Relyea et al., 1985). Using the approach of Relyea and Wood (1984), a hydraulic conductivity of approximately 1 x 10^{-4} centimeter per second (3.9 x 10^{-5} inch per second) is necessary for diffusion to be the primary transport mechanism affecting fractional release rates. For cumulative release over 10,000 years, assuming no sorption, the necessary conductivity is approximately 1 x 10^{-7} centimeter per second (3.9 x 10^{-8} inch per second). Thus, for a packing material with a density of 2.1 grams per cubic centimeter (131 pounds per cubic foot), steam treatment will not increase permeability enough to eliminate diffusional control of radionuclide transport.

A brief discussion of the potential for packing-material alteration and possible effects on waste-package performance has been added to Subsection 6.3.1.2.8 of the final Environmental Assessment. Papers by Haire and Beall (1979) and Couture and Bane (1984) on the alteration of bentonite under repository conditions will be addressed.

Issue: Values of packing-material parameters

Transport parameters used in the calculations of radionuclide transport and release through packing material should be characteristic of packing-material properties. It appears that the values used for hydraulic conductivity (10^{-12} meter per second (3.3 x 10^{-12} foot per second)) and radionuclide diffusion coefficients (10^{-6} square centimeter per second

(1.6 x 10^{-7} square inch per second)) in the Draft Environmental Assessment analysis of radionuclide transport and release are not conservative (i.e., too low), leading to nonconservative estimates of release rates.

Response

The importance of the hydraulic conductivity and diffusion coefficient values of packing material on predicted radionuclide releases must be evaluated separately.

Hydraulic conductivity of packing material was not used in the Draft Environmental Assessment because only diffusional transport was assumed in the analysis. The hydraulic conductivity of 1 x 10^{-10} centimeter per second (3.9 x 10^{-11} inch per second) was listed in the Draft Environmental Assessment because it is a representative value for fresh packing-material at a density of 2.1 grams per cubic centimeter (131 pounds per cubic foot) and because it is a value which more than meets the packing-material performance requirements to maintain diffusional control of mass transport. Measured diffusion coefficents for inert elements in packing material with a density of 1.8 grams per cubic centimeter (112 pounds per cubic foot) at 90°C (194°F), are approximately 1 x 10^{-5} square centimeter per second (1.55 x 10^{-6} square inch per second) (Relyea et al., 1985). Using the approach of Relyea and Wood (1984), a hydraulic conductivity of approximately 1 x 10^{-4} centimeter per second (3.9 x 10^{-5} inch per second) or less will result in diffusion being the primary radionuclide transport mechanism that determines fractional release rates. For cumulative releases over 10,000 years, assuming no sorption, the necessary conductivity is approximately 1 x 10^{-7} centimeter per second (3.9 x 10^{-8} inch per second) or less. Recent work by Couture (1985) indicates that steam treatment of packing material with a density of 2.1 grams per cubic centimeter (131 pounds per cubic foot) at 250°C (482°F) increases the hydraulic conductivity through packing material to approximately 1 x 10^{-7} centimeter per second (3.9 x 10^{-8} inch per second). Thus, even if steam treatment affects packing in the manner reported by Couture (1985), hydraulic conductivity values in the packing are sufficient to maintain diffusional control of mass transport in a packing material with a density of 2.1 grams per cubic centimeter (131 pounds per cubic foot).

Emplacement of packing material with a sufficient density is being addressed in the waste-package-design program. It is desirable to minimize void space, although some void space is inevitable in the emplaced waste package. Use of prefabricated blocks of packing and package assembly prior to borehole emplacement are two examples of processes which might be used to achieve limited void space and an acceptable overall packing-material density. Laboratory tests are being conducted to determine the feasibility of compacting large blocks of packing material to required densities, and field tests are planned to test emplacement methods.

Recent measurements (Relyea et al., 1985) of tritium and chloride diffusional transport in packing indicate that a reasonable diffusion coefficient at 90°C (194°F) is approximately 10^{-5} square centimeter per second (1.55 x 10^{-6} square inch per second). The value of 10^{-6} square centimeter per second (1.55 x 10^{-7} square inch per second) in the Draft Environmental Assessment was used because this information was not available. However, packing-material diffusion does not significantly influence release-rate calculations. The controlling diffusion coefficient which determines calculated release rates is that of the rock (Relyea and Wood, 1984). At present, there are no applicable data to define the diffusion coefficient of inert elements in fractures. However, given the possibility for matrix diffusion and the potential tortuosity factor, a value of 10^{-6} square centimeter per second (1.55 x 10^{-7} square inch per second) is reasonable. Future work will be completed to measure the diffusion coefficients of inert elements in fractures. Plans for this work will be discussed in the site-characterization plan for the Hanford Site, should the reference repository location be recommended for characterization.

Issue: Discussion of Guideline 960.4-2-2(6)(1) (DOE, 1984a)

A commenter stated that the U.S. Department of Energy failed to address the pertinent issue of the first potentially adverse condition under geochemistry in the General Siting Guidelines (DOE, 1984a; 960.4-2-2(c)(1)) by failing to describe how the "ground water conditions may effect (sic) the 'solubility or the chemical reactivity of the engineered barrier system.'"

Response

It is apparent that there was a difference of interpretation of the stated condition between the author of this guideline discussion and the reviewer. After receiving clarification of the intent of the guideline, it is clear that discussion of this guideline in the final Environmental Assessment should include expected ground-water interactions with the waste form, container, and packing material of the engineered barriers system. Interactions should include (1) dissolution and leaching of the waste form, (2) corrosion of the container, and (3) alteration of the packing material. Ground-water conditions that affect these processes and the resulting influences on performance of the engineered barriers are addressed in Subsection 6.3.1.2.8 in the final Environmental Assessment. Discussions of radionuclide complexation and migration have been deemphasized.

Issue: Dissolution of the waste form

Several commenters stated that ground water could come into direct contact with the waste form and become contaminated. The reviewers bring into question how resistant the waste forms are to dissolution or mechanical erosion by the ground water.

Response

The effects of Hanford Site ground water on waste-form durability are not considered in the Draft Environmental Assessment because no credit is given to the waste form as a barrier to radionuclide migration. This assumption provides a conservative basis for determining the total inventory of contaminants that might be released to the engineered barriers (see Subsection 6.4.2.3.5 of the Draft Environmental Assessment) and eliminates the need to measure leach rates of the waste forms.

Issue: Physical properties of disturbed rock

A commenter questioned the thickness and physical properties of damaged and disturbed layers of host rock adjacent to the repository as shown in Figure 6-17. The reviewer states that this information is not known and that in situ testing will be required to obtain the data.

Response

As stated in Tables 6-26 and 6-28 of the Draft Environmental Assessment, the dimensions and transport properties for damaged and disturbed rock that were used in waste-package-performance analyses were assumed values. No actual measurements exist for these parameters. Obviously, these measurements must be made during site characterization to improve the accuracy of future performance analyses. Plans for obtaining these data will be described in the site-characterization plan for the Hanford Site, should the reference repository location be recommended for characterization.

Issue: Calculation of container wall thickness

Justification of the calculation of the wall thickness at which the waste container will collapse was requested.

Response

The thickness value of 0.79 centimeter (0.31 inch) at which spent-fuel container collapse was assumed to occur was calculated using the following assumptions. The container was assumed to be a thin-walled cylinder. This assumption is justified since the diameter-to-thickness ratio at the end of the corrosion period is greater than 10. The low-carbon steel container material was assumed to have a minimum yield strength of 2.0×10^8 pascals (30,000 pounds per square inch). The pressure exerted on the low-carbon steel container at the repository horizon (the Cohassett flow) was assumed to be due to the hydrostatic pressure, which is 9.0×10^6 pascals (1,325 pounds per square inch). The thickness of the container to support a hoop stress of 2.0×10^8 pascals (30,000 pounds per square inch) was calculated using the hoop stress equation below.

$$\text{Hoop stress} = pD/2t \qquad \text{(C.4-1)}$$

where:

p = hydrostatic pressure,
D = outside diameter,
t = thickness.

Thus, the thickness, t, from Equation C.4-1 was calculated to be 0.79 centimeter (0.31 inch).

The intent is to refine the structural thickness calculations for the future waste-package designs. The calculations are expected to be more realistic and conservative.

Issue: Low-carbon steel waste container

Concern was expressed relative to the selection of the reference container material, low-carbon steel.

Response

Low-carbon steel was chosen as the reference container material after extensive review of literature surveys of material behavior in potential repository environments and review of screening tests. The selection basis for the alloys were (in order of weighting from the highest importance): (1) corrosion resistance in the expected repository environment, (2) fabricability, and (3) availability and cost. Resistance to corrosion by environmentally assisted cracking was considered most important because of the difficulty of demonstrating freedom from cracking during long exposure times. Evidence in the literature for environmentally assisted cracking in a particular material would eliminate the material from further consideration, unless it could be clearly shown that expected service conditions would not support cracking. Other forms of corrosion (uniform or pitting corrosion) could be tolerated during waste-package service if their predicted rates were acceptable.

Low-carbon steel has a firm basis for the assumption of a high degree of corrosion resistance in the low-oxygen, aqueous environment expected in a repository constructed in basalt; studies of archeological artifacts have consistently shown that iron- and copper-based materials have lasted for millenia with acceptable corrosion rates in low-oxygen, aqueous environments. Other alloy systems were considered and rejected using the selection basis described earlier. Both titanium and zirconium alloys can be susceptible to hydride formation and subsequent embrittlement, and welding of those alloys requires close environmental control to prevent embrittlement. Thus, titanium and zirconium alloys were rated lower than iron or copper alloys using the corrosion resistance and fabricability basis. Stainless steels were considered as a separate alloy class from other iron alloys, since their chromium content results in differing resistance to aqueous corrosion. Stainless steels and other high-chromium alloys were felt to be inherently susceptible to environmentally assisted cracking and, therefore, less corrosion-resistant than the chosen container material. Nickel alloys are very corrosion-resistant but the cost penalty (the third selection basis) was felt to be too great to justify the incremental increase in corrosion resistance compared to iron alloys.

Four candidate container materials are presently in the testing program; low-carbon steel is the current reference, but the data base is insufficient to justify exclusion of other promising materials. The final reference material will be chosen in fiscal year 1988, prior to the start of license application design.

Issue: Resaturation of the waste package

Several comments dealt with resaturation of the waste package by ground water. Two commenters stated that the purpose of the siting procedure was to find a site where the packing would not become saturated with ground water. One commenter was concerned that resaturation will lead to contamination of ground water. Another concern was that resaturation will lead to contamination of ground water and will necessitate extensive water-quality monitoring programs.

Response

The post-emplacement function of the packing material is to limit ground-water intrusion to the container and to reduce radionuclide release by maintaining ambient reducing conditions. It is not required that the packing remain dry throughout the lifetime of the repository.

Radionuclides must be contained by preventing contact with ground water for a minimum period of between 300 to 1,000 years (as specified by the U.S. Nuclear Regulatory Commission (NRC, 1985a) in 10 CFR 60). The component of the waste package that is to provide the primary containment function is the container. A design for the container is being used based on a minimum containment period of 1,000 years (see Subsection 5.1.4.2 of the Draft Environmental Assessment). Following the containment period, any radionuclides that are released from the waste form are to be attenuated through interactions with the packing material or the basaltic host rock. The function of the packing material and host rock is to control the release rate of radionuclides to the accessible environment to levels specified in Section 960.4-1 of 40 CFR 191 (EPA, 1985) and from the engineered barrier system, using reasonably available technology (10 CFR 60.113; (NRC, 1985a)).

The purpose of the waste package, therefore, is to reduce the migration of radionuclides to acceptable levels. Preventing contact of ground water with the waste form throughout the lifetime of the repository is not mandated under current regulations, nor under the General Siting Guidelines (10 CFR 960) (DOE, 1984a).

The duration and cost of any long-term, water-quality monitoring program is an issue that is not specific to the proposed repository at the Hanford Site. Any proposed site must contend with this question.

Issue: Temperature effect on corrosion

Several comments stated that the reference repository location is located in a water-saturated or ground-water area. The water temperature at this location is approximately 60°C (140°F), therefore increasing the water corrosivity or materials solubility characteristics.

Response

It is correct to state that container corrosion and general materials solubility are increased at 60°C (140°F) over that expected at ambient temperatures. Corrosion data will be collected on container materials under conditions expected at the waste package container to allow development of predictive techniques and waste package designs for safe containment of high-level nuclear waste.

C.4.4.1 Miscellaneous

A few comments were received that dealt with the waste package, but did not conveniently fit into any of the previously mentioned areas. These concerns are as summarized below and are addressed individually under this issue.

- Evidence of new technology on waste forms.
- Ambiguous wording in descriptions of packing materials function.
- Length of waste package.
- Effects of cladding damage.

Issue: Evidence of new technology on waste forms

The reviewer questions the status and application of new technology for developing alternative waste forms. Specifically, the reviewer cites a lack of evidence of new technology for alternative waste forms such as glass "pellets."

Response

Research and development of alternative waste forms have been active for many years. Technical reports concerning this effort are available to the public. A good source of information on this subject is the published symposia proceedings of the annual Materials Research Society meetings.

Issue: Ambiguous wording of packing material function

This comment concerns ambiguity in statements related to the function of the packing surrounding a waste container. The reviewer points out that Subsection 6.4.2.2.1 of the Draft Environmental Assessment suggests that the function of the packing is to maintain reducing conditions in the repository, whereas, in Subsection 5.1.4.3, it is stated that the function of the packing is to control ground-water Eh. The reviewer notes that the latter suggests that the packing is imposing redox conditions on the system that are different from "ambient."

Response

The function of the packing material is to maintain reducing conditions in the repository. The packing is not meant to impose a reducing environment (on the system) that does not otherwise already exist.

The wording in Subsection 5.1.4.3 of the final Environmental Assessment has been changed from "controlling ground water Eh and pH providing . . . " to " . . . maintaining ambient reducing conditions in the repository and providing . . . "

Issue: Waste package length

This commenter raises two points concerning the design length of the waste package. The first asserts that shorter packages (than currently planned for) would aid retrievability of the waste should earthquakes or rock falls change the orientation of boreholes during the 50-year "caretaker period." The second suggests that shorter packages may offer a greater long-term ability to contain the waste.

Response

Design length for waste containers given in the Draft Environmental Assessment (see Table 5-9) are 411 centimeters (162 inches) for spent fuel and 325 centimeters (128 inches) for commercial high-level waste. The reviewer cites a length of "3.3 feet" for the waste "package" (cited, according to the reviewer, on p. 5-34 of the Draft Environmental Assessment). This figure could not be found in our inspection of the Draft Environmental Assessment. It is not clear to us where the reviewer obtained this number for the length of the waste package. Nevertheless, the scale of damage caused by earthquakes or rock falls is commonly measured on the order of at least hundreds of meters (feet) and it is therefore unlikely that by reducing the length of the containers, retrievability of the waste would be any less affected by disturbances to the repository.

The suggestion by the reviewer that shorter containers may increase the ability to contain waste is evidently related to the preceding discussion on retrievability. It is not clear how else shorter containers would enhance the containment function. The reviewer acknowledges that shorter containers would increase the amount of handling required before emplacement. In addition, shorter containers would probably necessitate a larger repository, which may possibly lead to a reduction in its mechanical stability.

Issue: Effects of cladding damage

The effects of cladding damage on release rates of radionuclides are questioned by the reviewer. In addition, the reviewer notes that cladding damage may potentially cause corrosive constituents like water, oxygen, and other oxidizing chemicals to be released within the container. These may act to corrode the interior of the container. The question is raised as to how this might influence the release of the radionuclides.

Response

Currently, no containment function is credited to the zircaloy cladding in the waste-package performance assessment (i.e., it is assumed that no cladding exists). Thus, while damage to the cladding would influence radionuclide release rates and the quantitative relationships between the nature of the damage and rates of release have not yet been determined. Ignoring the existence of the cladding is a conservative assumption.

Container corrosion caused by oxidizing materials trapped within failed fuel rods has not been studied in detail by the U.S. Department of Energy. This is because the amounts of oxidizing materials released are likely to be extremely small relative to the amount of container material (due to the typically very small size of the breach in the cladding). In addition, even if the container itself were breached by corrosion, the oxidizing conditions within the containers should become reduced through interactions with the low-Eh environment in the waste package.

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C.5 POSTCLOSURE PERFORMANCE

This section includes comments on the condition and performance of the repository over the long term, after it is closed and sealed. With the exception of issues related to climatic change and long-term site ownership, all these comments address the geologic or hydrologic features of the reference repository location. From another perspective, comments in this category address the postclosure system guideline and all the suitability analyses for individual guidelines that support the evaluation of the system guideline. These include all analyses in support of the U.S. Environmental Protection Agency and U.S. Nuclear Regulatory Commission regulations governing the long-term performance of the repository (40 CFR 191 (EPA, 1985) and 10 CFR 60 (NRC, 1985)). Many of these guidelines cannot be fully evaluated until after site characterization, and this section therefore includes many comments that address some of the most contentious uncertainties about the repository system.

C.5.1 POSTCLOSURE GEOHYDROLOGY

This section addresses comments received on the geohydrologic discussions in Chapter 6 of the Draft Environmental Assessment (DOE, 1984b). Topics are divided into the following subsections:

- C.5.1.1, Flow patterns.
- C.5.1.2, Hydraulic information.
- C.5.1.3, Ground-water quality.
- C.5.1.4, Geohydrologic system changes.
- C.5.1.5, Complexity.
- C.5.1.6, Characterization activities.
- C.5.1.7, Miscellaneous.

C.5.1.1 Flow patterns

Numerous comments were received regarding questions, concerns, and statements about ground-water flow patterns discussed in Chapter 6 of the Draft Environmental Assessment. Topics cover a wide range of subject matter such as head gradients, hydraulic head values, ground-water flow dynamics, and water-discharge impacts. Several text-specific comments were given.

Topics are divided into the issues listed below and are individually addressed within the text.

- Ground-water pathway analogy.

- Existence of vertical discontinuities and Vantage interbed permeability.

- Ground-water flow directions.
- Three-dimensional ground-water movement.
- General comments on temperature and pressure distributions.
- Hydraulic head gradient between boreholes RRL-2 and DC-15.
- Vertical hydraulic heads in deep basalts.
- Reference to two previous comments.
- Hydraulic head gradients and the fourth favorable condition under postclosure geohydrology (DOE, 1984a; 960.4-2-1(b)(4)).
- Support of earlier concepts on hydraulic-head distributions.
- Comparison of drill and test hydraulic heads with head values measured in new piezometers.
- Hydraulic heads, hydraulic tests, and hydraulic properties.
- Vertical ground-water movement.

Issue: Ground-water pathway analogy

One commenter examined ground-water flow pathways and travel times from the reference repository location to the Columbia River. The travel time of the tritium plume from the 200 East Area to borehole 699-2-3 was estimated by the commenter to be 21 years, and was said to be a crude estimate of the travel time that might be expected for the horizontal leg of a sedimentary pathway connecting the repository to the Columbia River. The assumption seems to have been made that most vertical movement in the basalt flows follows localized ground-water pathways of high hydraulic conductivity. Further, it was assumed that if vertical pathways of high hydraulic conductivity do exist over the reference repository location, travel time to the Columbia River might be as little as 21 years. "The presumedly (sic) local recharging of the deep aquifers at Hanford would imply reciprocal, upward flows to the surface aquifer as well."

Response

The analogy proposed compares flow systems with different hydrologic characteristics and is therefore inappropriate. For example, the hydraulic conductivity of the Hanford Formation sediments through which the tritium plume has migrated ranges between 10^{-3} to 10^{-2} meter per second (10^2 to 10^3 feet per day) (Gephart et al., 1979). The hydraulic conductivity for sedimentary interbeds lying in the Saddle Mountains Basalt ranges between 10^{-4} to 10^{-9} meter per second (10^1 to 10^{-4} feet per day) with a mean of 10^{-6} meter per second (10^{-1} foot per day) (Gephart et al., 1979). Lower in the stratigraphic section, the Vantage interbed (where it exists beneath the Hanford Site (see Section 3.3.2 of the Draft Environmental Assessment)) has a hydraulic conductivity of between 10^{-6} and 10^{-13} meter per second (10^{-1} to 10^{-8} foot per day) with a mean on the order of 10^{-7} to 10^{-8} meter per second (10^{-2} to 10^{-3} foot per day). Therefore, sedimentary interbeds are typically orders of magnitude less permeable than the overlying shallow unconfined sediments. Also, the tritium plume has been "driven" over the last 40 years by ground-water recharge from water disposal mounds located in the 200 Areas of the Hanford Site. Differences in sediment hydrology, thickness, continuity, and interconnected porosity are additional factors making a direct analogy between sedimentary interbeds and shallow sediments properties inappropriate.

Recharge to shallow basalt units occurring at depth in the Cold Creek syncline is interpreted to take place in uplands associated with the Yakima Fold Belt west of the Hanford Site (see Section 3.3.2 of the Draft Environmental Assessment). Basalts at this location are at or near the surface and water gains entry with relative ease. At depth in the lower Cold Creek syncline, vertical upward flow does occur between basalt units. This flow, however, is laborious because it takes place across dense flow interiors having apparently low hydraulic conductivity.

Localized pathways of high vertical hydraulic conductivity may exist within the Grande Ronde Basalt. Site-characterization studies would address this issue. Presently, such pathways are considered to be scarce in the areas of the Cold Creek syncline studied.

In summary, it is unlikely that ground-water travel times from a repository in the Grande Ronde Basalt to the Columbia River would approximate ground-water travel times in the shallow unconfined aquifer.

Issue: Existence of vertical discontinuities

One comment began with the assumption that vertical fractures or faults (i.e., vertical discontinuities) are associated with large vertical conductivity values and provide paths for easy vertical ground-water flow. The comment concluded it is likely that a repository will intersect a major vertical discontinuity. The evidence the commenter provided to support such an intersection was (1) the Cold Creek flow impediment (barrier) identified west of the reference repository location, (2) general descriptions of Columbia Basin basalt outcrops and observations from roadways that reveal major vertical discontinuities in distances shorter than the scale of the repository, and (3) general consideration of plate failures that suggests fracture spacing on the order of plate thickness (330 meters (less than 1,000 feet)). In devising hypothetical ground-water flow paths from a repository, the Vantage interbed was considered by the commenter to be a highly permeable zone (i.e., to have a "hydraulic conductivity similar to the surface aquifer").

Response

The majority of cooling fractures in basalt flow interiors apparently are sealed by secondary mineralization and confining forces (see Section 2.1.1 of the Draft Environmental Assessment). The hydraulic conductivity of the flow interiors is very low according to hydraulic test results. The U.S. Department of Energy is uncertain why a fault cutting vertically through a flow interior would necessarily be any more conductive than cooling fractures. Depending on fault age and movement specifics, gouge materials and secondary minerals would likely fill or line fault-related fractures. In fact, faults and fault zones at depth in flow interiors may or may not represent preferred ground-water flow pathways at all. One of the site-characterization goals, if the reference repository location is recommended for site characterization, is to better understand the hydraulic influence and characteristics of fault-related features.

The reference repository location lies within a gently formed syncline where structural inclination of the basalt is only a few degrees (see Section 2.2 of the Draft Environmental Assessment). Therefore, the descriptions of Columbia Basin basalt outcrops (which are biased toward sharp anticlinal folds in many areas) and observations from roadways revealing major structural discontinuities may not be relevant to the structural style and fracture frequency of the Cold Creek syncline. The Cold Creek barrier apparently acts as an impediment to lateral ground-water flow (see Subsection 3.3.2.1.3 of the Draft Environmental Assessment). The structural nature and vertical conductivity of the barrier are not determined, but no evidence yet points to the barrier being a major conduit for vertical flow.

Overall, the commenter provided an interesting scenario and range of assumptions for envisioning ground-water flow paths from the repository. Yet, because Figure 3-36 of the Draft Environmental Assessment was identified as hypothetical, with no horizontal or vertical scales intended, no modification of the figure was required. The commenter's modification of the same figure was also hypothetical.

The hydraulic conductivity of the Vantage interbed beneath the Hanford Site ranges between 10^{-6} and 10^{-13} meter per second (10^{-1} to 10^{-8} foot per day) (Strait and Mercer, 1984; DOE, 1982). The coarser sediments comprising the unconfined (surface) aquifer have a hydraulic conductivity of generally 10^{-2} to 10^{-3} meter per second (10^{3} to 10^{2} feet per day) (see Section 3.3.2 of the Draft Environmental Assessment). This is orders of magnitude larger than that locally typical of the Vantage interbed.

Two paragraphs have been added to Section 3.3.2 of the final Environmental Assessment addressing the origin and hydrologic characteristics of the Vantage interbed. Additional discussion has been included in Section 3.2 on the topic of structural discontinuities possibly existing in and near the reference repository location.

Issue: Ground-water flow directions

One comment stated that Figure 2-16 of the Draft Environmental Assessment apparently indicated a southerly gradient in the basalt formations at the Hanford Site while Table 6-3 " . . . shows that almost all the calculations of ground-water travel times, including the latest by the U.S. Department of Energy, are based on flow to the north."

Response

Figure 2-16 of the Draft Environmental Assessment was a graphical summary of potentiometric surface maps presented by Tanaka et al. (1979). The purpose of Figure 2-16 and the maps on which it is based was to provide some insight into regional ground-water flow patterns in the Pasco Basin and vicinity. The figure and maps were not intended to provide a detailed picture of the potentiometric surface for basalt formations of the Hanford Site in general or the reference repository location specifically. Examination of the maps on which Figure 2-16 was based, however, shows that the Pasco Basin occupies the lowest hydraulic point in the State of Washington portion of the Columbia Plateau. Recharge appears to enter the Pasco Basin from northern, eastern, and western directions. Overall, once inside the Pasco Basin, ground-water flow directions generally turn south. Geologic structures can locally affect these flow patterns. Table 6-3 simply displayed ground-water travel time estimates, efforts to develop modeling technology, and examinations of data uncertainty. It was not a critique of ground-water flow direction knowledge, as was implied by the commenter.

Two of the earliest estimates of ground-water travel time given in Table 6-3 associated the ground-water flow from the reference repository location and vicinity with a northerly direction (LATA, 1981; Dove et al., 1981). Another of the earliest estimates associated flow with a southeasterly direction (Arnett et al., 1981). The remaining four ground-water travel time estimates did not associate flow with a particular compass direction. Also, the latest travel time estimates given in Table 6-3 did not presume a particular flow direction. The assumption of northerly flow in the first two travel time estimates of Table 6-3 might be viewed as a conservative estimate of travel time to the Columbia River at its closest approach to the reference repository location, regardless of available evidence suggesting a more southerly flow direction.

Available evidence and flow concepts suggest that ground water in deep basalt formations in the Cold Creek syncline moves with a substantial east-to-southeast component (see Section 3.3.2 of the Draft Environmental Assessment). As new hydraulic head distributions are estimated from piezometric data, an updated conceptual understanding of ground-water flow will be used in future modeling simulations of travel times and flow directions.

Issue: Three-dimensional ground-water movement

One commenter stated "significant vertical mixing" of ground waters is likely and that ground-water flow in the Pasco Basin is three-dimensional, moving upward near the Columbia River. Two other comments stated that ground-water flow in basalt is three-dimensional, not two-dimensional or horizontal.

Response

The U.S. Department of Energy agrees that ground water moves three-dimensionally. The Draft Environmental Assessment did not state ground-water flow is only horizontal or two-dimensional. The existence of vertical hydraulic heads, vertical basalt "leakage," and (or) ground-water recharge of and discharge from basalt was addressed in several areas, including Sections 2.1.4 and 3.3.2, and Subsection 6.3.1.1.6.

Additional discussion of three-dimensional ground-water flow can be found in the flow patterns issue, under Subsection 4.1.2.2 of this appendix.

It is true that the overall aspect of regional ground-water flow in the basalt sequence is three-dimensional because ultimately flow paths must descend from recharge areas, follow subhorizontal flow paths in the interior of the Pasco Basin, and ascend to discharge areas. Certainly the Saddle Mountains Basalt discharges to the Columbia River. Although only limited hydraulic head evidence currently supports this assumption, the Wanapum and Grande Ronde Basalts also likely discharge (directly into or indirectly across overlying basalt flows) to the Columbia River in and (or) near the Pasco Basin.

The system of subhorizontal, layered basalt flows that comprises the ground-water environment at the depth of the candidate repository horizon is composed of alternating flow interiors of apparently very small hydraulic conductivity, and interflow zones with small to moderate hydraulic conductivity. Resistance to flow will be less within interflow zones (flow tops) parallel to layering of the dense flow interiors than in those perpendicular to this layering. Hence, ground-water movement should be slower in vertical directions than in subhorizontal directions. This is not to disregard vertical ground-water flow (and vertical mixing), but to say that vertical ground-water movement is likely subordinate to horizontal flow in interflow zones in terms of speed and flux per unit of flow cross section.

Hydraulic tests planned for the Hanford Site using multiple wells are designed to measure the vertical hydraulic conductivity of flow interiors. These and other hydraulic measurements are necessary to provide adequate information on which to base decisions regarding the suitability of the Hanford Site for a nuclear waste repository.

Issue: General comments on temperature and pressure distributions

According to one commenter, the basalt formations under the Hanford Site are "fissured" and cracked in many places, temperature and pressure differ from place to place, and " . . . given a few decades the ground-water will migrate up and down from level to level."

Response

The basalt formations do contain a great number of cooling cracks largely filled with secondary minerals (Long and WCC, 1984). Temperature and pressure do vary from place to place in the basalt formations in response to the natural geothermal gradient and the laws of hydrostatics, respectively. Other than the few sentences given above, it is difficult to respond to the commenters statements that ground water will migrate from level to level in a few decades without knowing the distance between points of reference. The commenter is referred to Subsections 6.3.1.1.3, 6.3.1.1.11.1, and 6.4.2.3.5 of the Draft Environmental Assessment for information regarding ground-water travel time estimates.

Issue: Hydraulic head gradient between boreholes RRL-2 and DC-15

One comment maintained that a direct line gradient between borehole RRL-2 and borehole DC-15 is inappropriate because the head derived from borehole DC-12 is greater than the head in either of the other two boreholes.

Response

Borehole DC-12 is located south of the southern extension of the Yakima Ridge anticline structure, not in the Cold Creek syncline as are boreholes RRL-2 and DC-15. Because of the apparent relationship between ground-water flow directions and regional bedrock dip, a direct relationship would not be expected between heads measured in borehole DC-12 and those measured in boreholes RRL-2 and DC-15 located in another structural compartment (i.e., Cold Creek syncline). Thus, it was more appropriate, under prevailing geohydrologic concepts, to provide a direct line gradient between borehole RRL-2 and borehole DC-15.

In addition, hydrochemical data presented before the U.S. Nuclear Regulatory Commission (Early et al., 1985) strongly suggests that the ground-water flow pattern probably conforms to the structural dip of the Cold Creek syncline (i.e., from the reference repository location toward borehole DC-15).

Section 3.3.2 of the final Environmental Assessment has been expanded to include additional discussions on lateral and vertical head gradients in addition to hydrochemical mixing of ground waters.

Issue: Vertical hydraulic heads in deep basalts

Several comments pointed out that the hydraulic gradient in deep basalt formations (the proposed host rock and immediately surrounding geohydrologic units) is not predominantly horizontal or downward in the reference repository location and vicinity. It was further stated that the upward flux of ground water through the basalt flow interiors must be assessed. One commenter said, "Thus ground-water movement in the basalts at the reference repository location is predominantly upward over most of the basalt and for several hundred feet above the suggested repository depth."

Response

Recent observations of hydraulic head in the three piezometer clusters in and near the reference repository location indicate that the lateral hydraulic gradient in Grande Ronde Basalt flow tops is approximately 10^{-4}. The same observations show that the vertical hydraulic gradient across the Grande Ronde Basalt above the Umtanum flow is directed upward with a magnitude of approximately 10^{-3} within the reference repository location. A vertical hydraulic gradient greater than the horizontal gradient is thought related to greater resistance to vertical flow across the flow interiors compared to lateral flow in interflow zones. Plans are being prepared (see Subsection 4.1.1.3.1 of the Draft Environmental Assessment) to measure the vertical hydraulic conductivity of flow interiors to provide a basis to estimate upward flux of ground water. Finally, it is presumed that the statement quoted above applies to vertical ground-water movement only, otherwise the use of head data alone to determine the amount of water movement is inappropriate.

The commenter is also referred to issues on hydraulic heads, hydraulic tests, and hydraulic properties under this appendix subsection for discussion on lateral head gradients within the reference repository location.

Lateral and vertical hydraulic head gradients given in Section 3.3.2 of the final Environmental Assessment have been updated to include new piezometric information collected since Spring 1984. This write-up includes several new tables and one figure. These data support lateral gradients of 10^{-4} meter per meter (10^{-4} foot per foot) and vertical head gradients among the deep basalts of 10^{-4} to 10^{-3} meter per meter (10^{-4} to 10^{-3} foot per foot). This same information also has been incorporated into Subsection 6.3.1.1.6, and credit is no longer taken for the second subpart (ii), since the deep vertical gradients are neither downward nor predominantly horizontal. The second bullet in Subsection 6.3.1.1.12 has been revised to reflect these new data on head gradients.

Issue: Reference to two previous comments

One comment simply referred to two previously given comments. No further detail was offered.

Response

Refer to issue on statements about ground-water discharge, under flow patterns issue, Subsection C.4.1.2.2; and to the issue below.

Issue: Hydraulic head gradients and the fourth favorable condition under postclosure geohydrology

One comment pointed out that vertical upward hydraulic gradients exist across the host rock and immediately surrounding geohydrologic units. In fact, the comment concluded that a "present" position was not taken for either favorable condition (DOE, 1984a; 960.4-2-1(b)(4ii,iii)) in Subsection 6.3.1.1.6 of the Draft Environmental Assessment. The commenter asked if this would disqualify the Hanford Site. Further, it was stated that the definitions of predominantly horizontal and low hydraulic gradient must be set forth and detailed hydraulic head data must be collected. The commenter asked "What is a slight upward gradient?" and then remarked that the accuracy for head values in Table 6-5 is 0.5 meter (1.6 feet). The commenter concluded that the " . . . collected data do not have sufficient accuracy to assist analysis of the site." Based on data in Table 6-5, it was said that an upward gradient of 10^{-2} existed in borehole RRL-2 as well as in borehole DC-15, and that a downward gradient of 10^{-2} existed in borehole RRL-14. The commenter stated that these data do not support findings that gradients are slightly upward or horizontal. Finally, the commenter stated that the downward hydraulic gradient in shallow basalts may be an artificial phenomenon caused by infiltration of water ponded at the surface on the Hanford Site.

Response

The issue on vertical hydraulic heads in deep basalts, under this appendix subsection, gives results of recent hydraulic head observations in and near the reference repository location. These data indicate a vertical upward hydraulic gradient across the Grande Ronde Basalt. The vertical gradient has a magnitude of approximately 10^{-3}. In fact, the response given in the following issue of this appendix lists head data showing the vertical upward gradient across the Grande Ronde Basalt to vary from 1×10^{-3} to 4×10^{-4}. It is agreed that favorable condition (4)(ii) does not exist at the reference repository location. Favorable condition (4)(iii) does exist at the reference repository location because low lateral hydraulic gradients exist in the host rock (10^{-4} horizontal gradient) and between the host rock and immediately surrounding geohydrologic units (10^{-3} or less vertical gradient). As was discussed in the issue on vertical hydraulic heads in deep basalts, the response to this subpart of the fourth favorable condition has been changed in the final Environmental Assessment.

If neither favorable condition (4)(ii) nor (4)(iii) were present, the reference repository location would not be disqualified because the fourth favorable condition is not a disqualifying condition. Disqualifying conditions in the General Siting Guidelines (DOE, 1984a) were summarized in Section 2.3 of the Draft Environmental Assessment.

A predominantly horizontal gradient is one that is of greater magnitude than apparent gradients in other directions. It would be larger than the vertical gradient, for example. A low hydraulic gradient is taken to be one of magnitude 10^{-3} or less. Ground-water flux is influenced, of course, by parameters other than the hydraulic gradient. The vertical flux across Grande Ronde Basalt flow interiors is influenced by apparently low hydraulic conductivity as well as by the vertical hydraulic gradient. Detailed hydraulic head data are being collected in three recently constructed piezometer clusters in the reference repository location and vicinity. Other piezometers are planned.

Upward gradients of 10^{-3} have been measured across the Grande Ronde Basalt. These vertical gradients are considered to be small. The head values given in Table 6-5 of the Draft Environmental Assessment were reported to the nearest 0.5 meter (1.6 feet). These values, taken during the drill-and-test program, are of limited accuracy and utility, particularly for estimation of vertical hydraulic gradients. They should be used only to obtain rough estimates of lateral hydraulic gradients. This was emphasized throughout the Draft Environmental Assessment (see Section 3.3.2 and Subsections 4.1.1.4 and 6.3.1.1.6). More accurate measurements of hydraulic head currently are being made in the piezometer clusters in and near the reference repository location. These data provide the basis for the present 10^{-4} to 10^{-3} estimate of vertical hydraulic gradient and 10^{-4} estimate of lateral hydraulic gradient in and across units of the Grande Ronde Basalt. The accuracy of the current measurements of hydraulic head between piezometer clusters in and near the reference repository location is approximately 0.05 meter (0.2 foot) at a given piezometer cluster. The accuracy of head measurements is substantially greater. The minimum vertical hydraulic gradient that can be measured is 5×10^{-5}. The head data obtained from these piezometer clusters should be of sufficient accuracy to permit site geohydrologic characterization.

The downward gradient in shallow basalts (Saddle Mountains Basalt) in the vicinity of the reference repository location may be caused in part by infiltration of water ponded at the surface on the Hanford Site. Recharge from surface runoff in the western part of the Hanford Site is considered important in establishing the downward hydraulic gradient presently measured in shallow basalts. The relative importance of these two mechanisms in establishing and maintaining vertical downward hydraulic gradients in the western portion of the Hanford Site is not yet determined. It was acknowledged in Section 3.3.2 of the Draft Environmental Assessment that some controversy exists concerning the hydraulic effects of surface wastewater disposal on the Hanford Site. This issue requires resolution.

Section 3.3.2 of the final Environmental Assessment has been revised to include recently collected hydraulic head data. Subsection 6.3.1.1.6 has also been updated to include these new head data.

Issue: Support of earlier concepts on hydraulic head distributions

One commenter stated that earlier concepts of the hydraulic head distribution in the reference repository location are not being supported by new results from piezometers at boreholes DC-19, DC-20, and DC-22. In particular, earlier concepts indicated that head declines in the vertical direction from the Wanapum Basalt to the upper Grande Ronde Basalt and then increases, while results from the nested piezometers at boreholes DC-19, DC-20, and DC-22 indicate flow is upward from the deep basalts to the uppermost Wanapum Basalt flow.

Response

The commenter is in error in terms of the earlier concepts of vertical head distribution as well as in some aspects of recent results from the nested piezometers regarding vertical flow. Earlier concepts of hydraulic head distribution in the reference repository location are summarized in Table 5-50 of the site-characterization report (DOE, 1982). That table lists expected vertical head distributions for the Saddle Mountains, Wanapum, and Grande Ronde Basalts. It was expected, based on head values derived from the drill-and-test program, that heads decrease with depth in the Saddle Mountains Basalt, change little with depth in the Wanapum Basalt, and are uniform to increasing with depth in the Grande Ronde Basalt. The results of recent measurements in the three piezometer nests in the reference repository location and vicinity show that head decreases with depth through the Saddle Mountains Basalt, as expected; head changes little with depth in the Wanapum Basalt, as expected; and that head increases slightly with depth in the Grande Ronde Basalt, as expected. These relationships are illustrated in Table C.5-1.

The concepts of hydraulic head distribution held at the time of writing of the site-characterization report (DOE, 1982) supported vertical flow downward through the Saddle Mountains Basalt to the Wanapum Basalt and vertical flow upward through the Grande Ronde Basalt to the Wanapum Basalt. Recent head measurements at the piezometer clusters generally support these concepts. More refined and longer-term head measurements in the piezometer clusters have provided better resolution of this vertical pattern. In some cases (e.g., in boreholes DC-19 and DC-22), it appears that flow downward from the Saddle Mountains Basalt and flow upward from the Grande Ronde Basalt converges in the upper Wanapum Basalt. In borehole DC-20, heads in Wanapum Basalt interflow zones are essentially identical. Thus, it appears that earlier concepts of the vertical hydraulic-head distribution in the reference repository location are supported by recent observations. Additional information from these piezometers and future piezometers will provide the basis for refining flow concepts.

Subsection 6.3.1.1.5 of the final Environmental Assessment has been revised and a new paragraph added to summarize support for previous concepts on head distributions as compared with new data.

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Table C.5-1. Vertical hydraulic head gradients calculated from observed water levels at piezometer cluster sites DC-19, DC-20, and DC-22

Stratigraphic interval monitored	Observed hydraulic head, m above MSL[a]	Vertical interval separating designated monitored zones, m[b]	Apparent vertical head gradient across basalt formations
Borehole DC-19			
Saddle Mountains Basalt			3×10^{-2} (down)
Rattlesnake Ridge interbed	134.4	220	
Mabton interbed	128.5		
Wanapum Basalt		70	4×10^{-4} (up)
Priest Rapids Member	122.0		
Sentinel Gap flow	122.1	240	
Ginkgo flows	122.1		
Grande Ronde Basalt		115	4×10^{-4} (up)
Rocky Coulee flow	122.4		
Cohassett flow	122.3	250	
Umtanum flow	122.5		
Wanapum and Grande Ronde Basalts			8×10^{-4} (up)
Borehole DC-20			
Saddle Mountains Basalt			4×10^{-2} (down)
Rattlesnake Ridge interbed	135.5	218	
Mabton interbed	126.3		
Wanapum Basalt		68	0 (no gradient)
Priest Rapids Member	122.4		
Sentinel Gap flow	122.4	243	
Ginkgo flows	122.4		
Grande Ronde Basalt		109	1×10^{-3} (up)
Rocky Coulee flow	123.3		
Cohassett flow	123.3	249	
Umtanum flow	123.6		
Wanapum and Grande Ronde Basalts			2×10^{-3} (up)
Borehole DC-22			
Saddle Mountains Basalt			4×10^{-2} (down)
Rattlesnake Ridge interbed	134.8	231	
Mabton interbed	125.1		
Wanapum Basalt		61	8×10^{-4} (up)
Priest Rapids Member	122.1		
Sentinel Gap flow	122.2	257	
Ginkgo flows	122.3		
Grande Ronde Basalt		91	1×10^{-3} (up)
Rocky Coulee flow	122.9		
Cohassett flow	123.1	261	
Umtanum flow	123.2		
Wanapum and Grande Ronde Basalts			2×10^{-3} (up)

NOTE: 1 meter = 3.28 feet.

[a]Data taken from Bryce and Yeatman (1985).
[b]Data taken from Jackson et al. (1984).

Issue: Comparison of drill-and-test hydraulic heads with head values measured in new piezometers

One commenter indicated that the picture of ground-water movement presented in the first part of paragraph 2, page 6-72 of the Draft Environmental Assessment, might be contradicted in the last part of the same paragraph. According to the commenter, the only head data indicating direction of vertical movement in the basalts are those for the piezometers at boreholes DC-19, DC-20, and DC-22. No other unquestioned data exist. The flow pattern most supported by the available data is one of downward flow near the anticlines (to include flow in the deep basalts) and upward flow near the Columbia River. Upward flow in the deep basalts appears to begin west of the reference repository location. Finally, the commenter indicated that the hydraulic head data gathered during the drill-and-test period of data collection present a confusing picture of vertical and horizontal water movement. Also, another commenter stated that combining head data from the drill-and-test program with that from boreholes DC-19, DC-20, and DC-22 for each major flow top yields " . . . no straight forward pattern of flow." A similar thought was expressed in a third comment which stated that data do not suggest any uniformity in flow direction.

Response

The ground-water movement discussed in the first part of the referenced paragraph is said to take place in the shallow basalts (Saddle Mountains Formation), while that discussed in the last part is said to occur in the deep basalts (Wanapum and Grande Ronde Formations). If this distinction is recognized, there is no contradiction.

The general pattern of vertical head variation in the basalt formations at the Hanford Site was originally based on drill-and-test head data (Gephart et al., 1979; DOE, 1982). As was pointed out in the previous issue, this pattern generally has been confirmed by more accurate head measurements in the three nested piezometer clusters in and near the reference repository location. The assertion that " . . . the only head data that indicate the direction of vertical movement in the basalts are those for piezometers at DC-19, 20, and 22 . . . " is unsupported. Careful use and interpretation of head measurements taken during the drill-and-test program have been helpful in defining broad lateral and vertical head distributions. As long as the obvious shortcomings of the drill-and-test head measurements are taken into account, they are useful and appropriate for reconnaissance hydrologic study. The drill-and-test head data are considerably less accurate than information obtained from permanent well and piezometer installations. This was recognized in the Draft Environmental Assessment (see Section 3.3.2 and Subsections 4.1.1.4.1 and 6.3.1.1.6).

It is agreed that the general pattern of ground-water movement supported by available data includes downward flow into the active zone of circulation near the major anticlines (major topographic uplands) and upward flow in major topographic lowlands. Small upward gradients exist in the Grande Ronde Basalt in the area of the reference repository location, as well as near the Columbia River. However, the river may not act as a line sink for the deep basalts. Vertical upward ground-water movement through the Grande Ronde Basalt beneath the Hanford Site area may be more areally distributed.

Figures C.5-1 through C.5-6 depict the areal hydraulic head distribution in six specific stratigraphic units of the Wanapum and Grande Ronde Basalts. Potentiometric maps are not drawn on these figures because of data scarcity and the mixture of both monitored and drill-and-test head data. Head values are taken from measurements in piezometers at boreholes DC-19, DC-20, and DC-22 in addition to boreholes drilled and tested since the late 1970s. Only reasonably well-equilibrated heads from borehole measurements are shown. Borehole DC-12 is located south of the Yakima Ridge anticlinal axis, and borehole DC-14 is located north of the Gable Butte-Gable Mountain anticline. Heads in these two boreholes are thought to reflect conditions in different "structural compartments" of the Pasco Basin and therefore should not be directly compared to hydraulic heads measured in the Cold Creek syncline. Heads in the remaining boreholes reflect conditions in the Cold Creek syncline.

In general, head data indicate flow is from the north side of the Cold Creek syncline to the south side and from northwest to southeast along the synclinal axis. As shown, the axis of the Cold Creek syncline lies close to the Yakima Ridge anticlinal axis. Large head values west of the upper Cold Creek flow impediment (Cold Creek barrier) reflect the resistance to southeasterly flow provided by the impediment. Thus, contrary to the commenter's statements, head data from the drill-and-test program combined with that from boreholes DC-19, DC-20, and DC-22 for the major flow tops do provide a reasonable, general areal pattern of ground-water flow in the Cold Creek syncline. Head data gathered during the drill-and-test program do not present a confusing picture with regard to movement of water as long as one uses values that were well equilibrated.

Relative to the concept that the Columbia River in the Pasco Basin is a line sink (receives upward ground-water flow) for shallow and deep ground-water discharge, it is important to recognize major geomorphic differences between the course of the river in different Columbia Plateau basins. For example, in a high plateau, deep canyon terrain, the Columbia River flows directly on basalt, the course essentially entrenched for millions of years. In such locations, one would expect basalt structures to directly offset surface drainage and also have major influence on subsurface flow patterns. In such a setting, the Columbia River would have a high likelihood of acting as a line sink for shallow and possibly deep basalt flows. On the other hand, topographic and structural control of the Columbia River is less important in the Pasco Basin. There, the river generally flows on a thick deposit of sediments less than 6 million years old, rather than on a basalt sequence. There exists no single paleochannel. The present course of the Columbia River in the Pasco Basin has developed over a long period of time (14.5 million years ago to present). This course is a product of events controlled by a westward-tilting paleoslope, a subsiding basin since the Miocene, growth of Yakima fold structures, infilling of the Pasco Basin with sediments, control

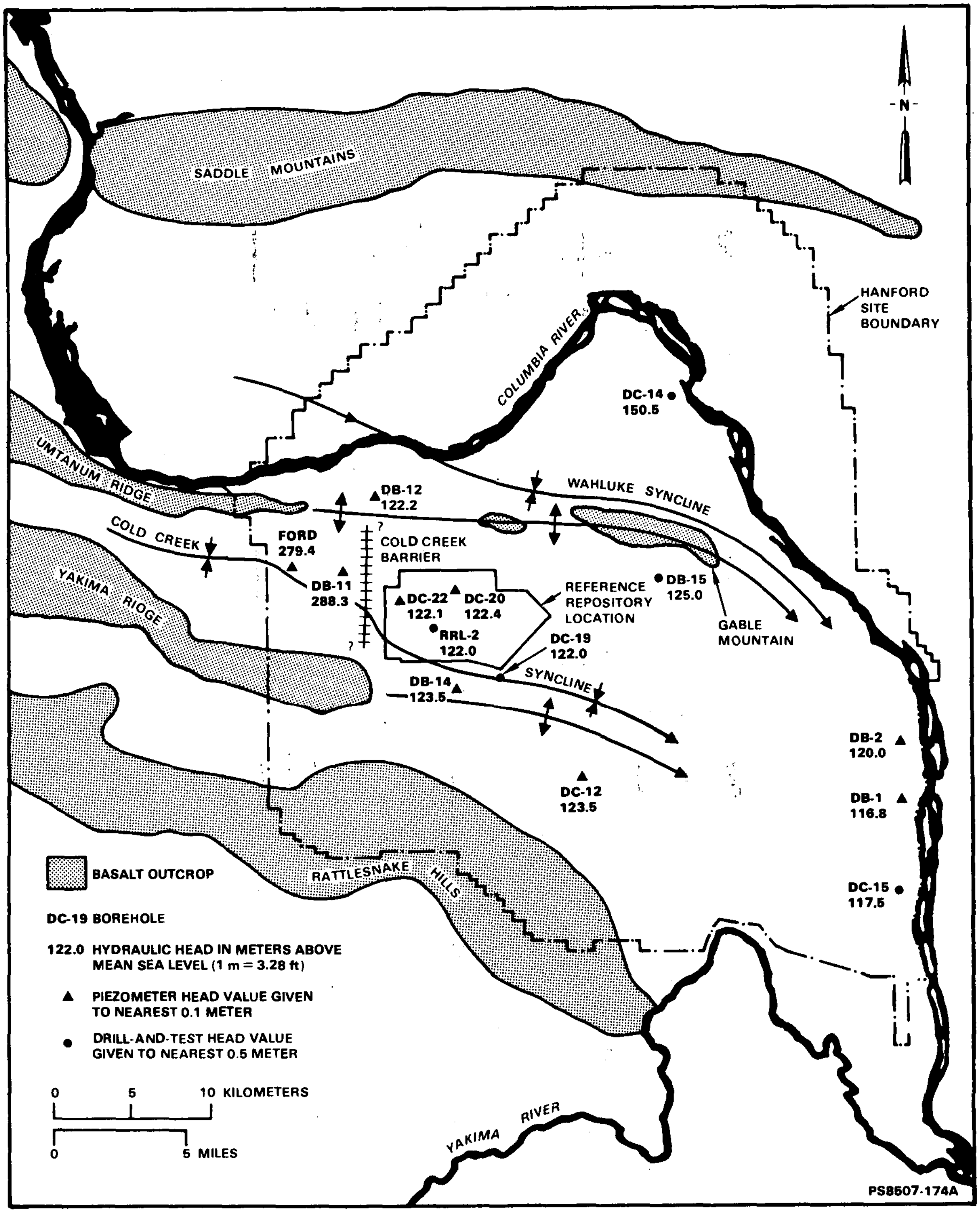

Figure C.5-1. Hydraulic head potential in the Priest Rapids flow top of the Wanapum Basalt.

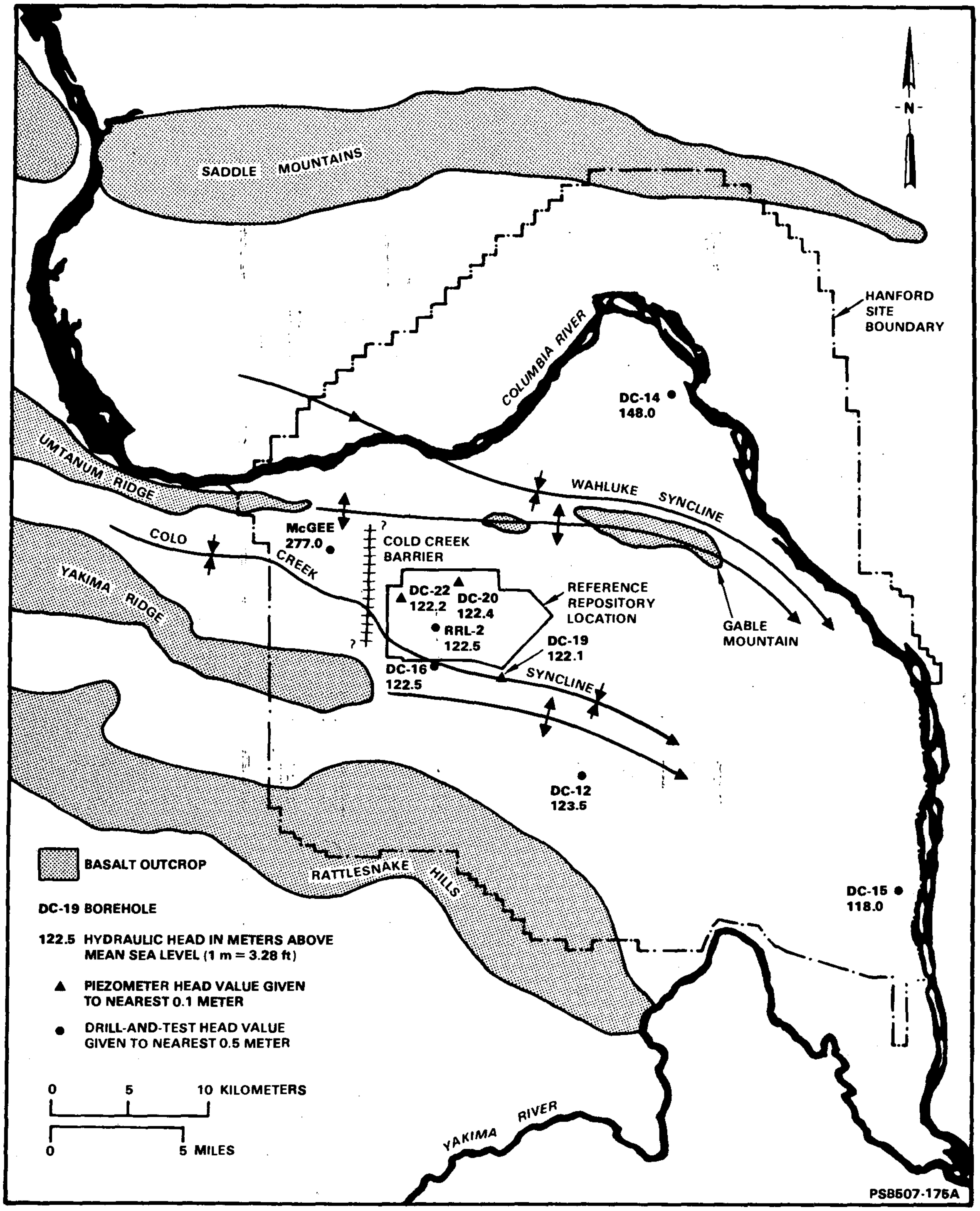

Figure C.5-2. Hydraulic head potential in the Sentinel Gap flow top of the Wanapum Basalt.

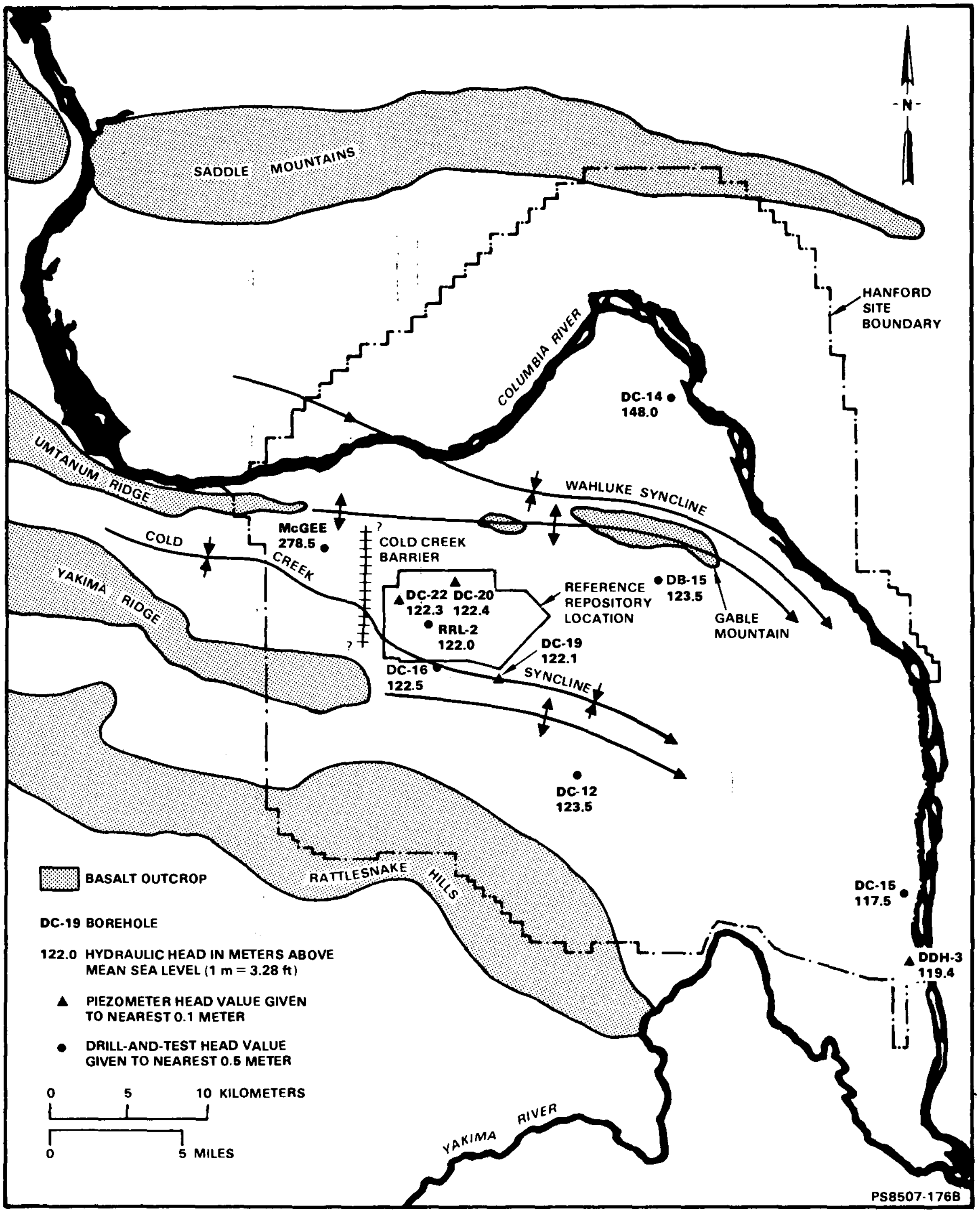

Figure C.5-3. Hydraulic head potential in the Ginkgo flow top of the Wanapum Basalt.

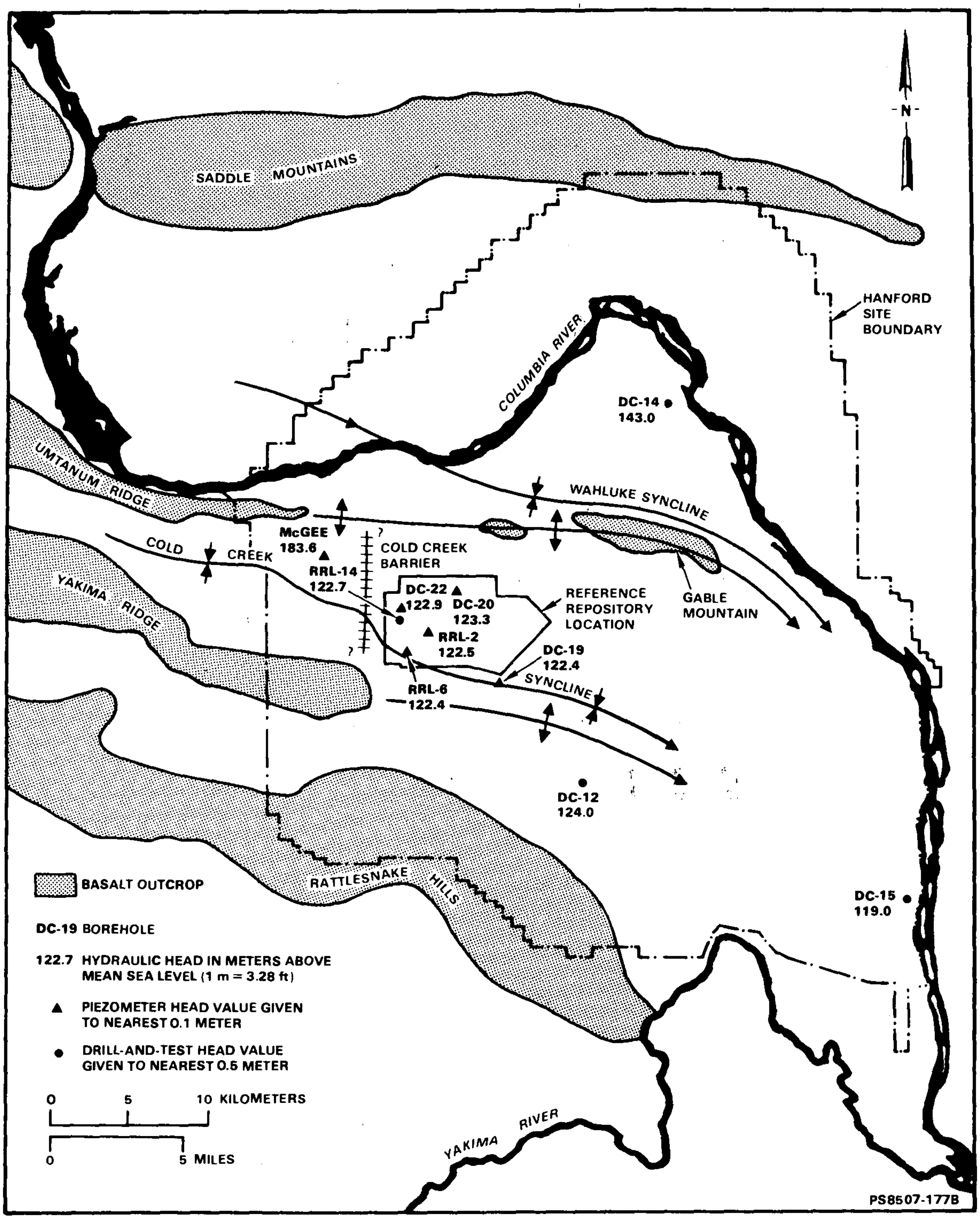

Figure C.5-4. Hydraulic head potential in the Rocky Coulee flow top of the Grande Ronde Basalt.

7 0 1 6 8 8 2 1 2 3

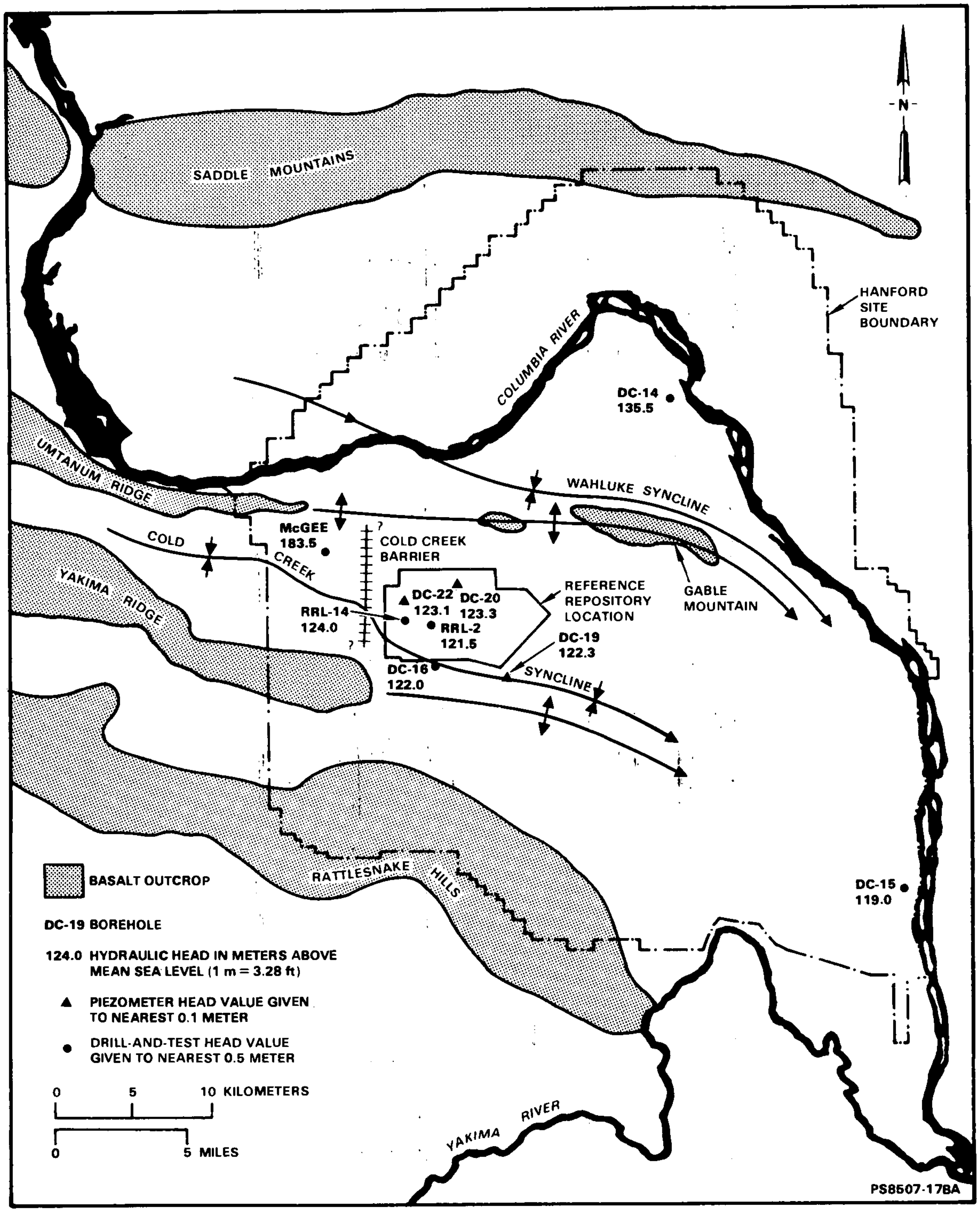

Figure C.5-5. Hydraulic head potential in the Cohassett flow top of the Grande Ronde Basalt.

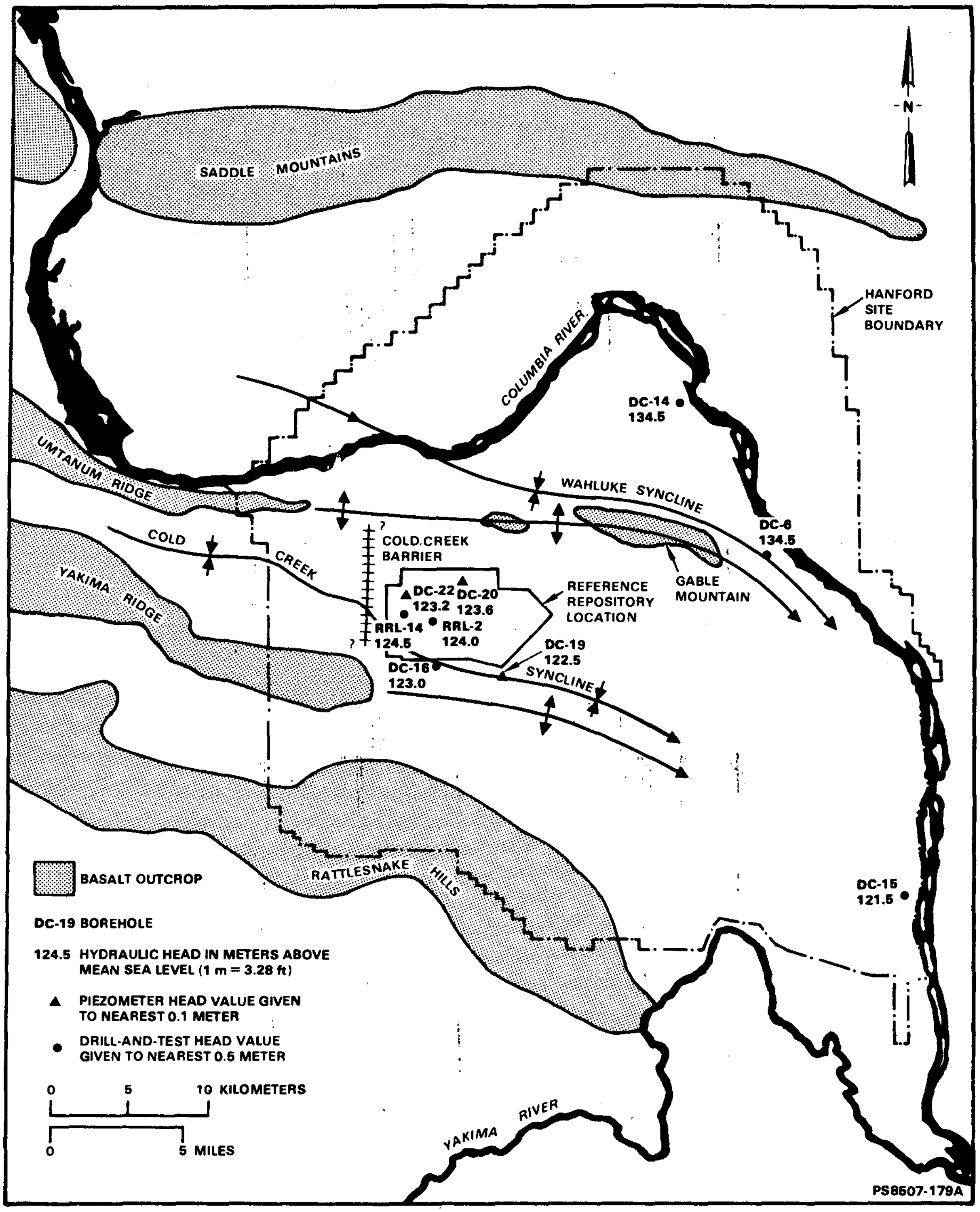

Figure C.5-6. Hydraulic head potential in the Umtanum flow top of the Grande Ronde Basalt.

of surface drainage by numerous basalt flows, and surface-water flooding during the Pleistocene. Therefore, it is conceptualized that discharge of deep basalt ground water is influenced more by the local structural and stratigraphic setting than by the present Columbia River location, which has changed frequently over recent geologic time (Fecht et al., 1984).

Issue: Hydraulic heads, hydraulic tests, and hydraulic properties

Two commenters questioned findings for the fourth favorable condition under postclosure geohydrology (DOE, 1984a; 960.4-2-1(b)(4)), as identified in Subsection 6.3.1.1.6 of the Draft Environmental Assessment. Specifically, one comment stated that " . . . there may be substantial uncertainty in the support for this finding (i.e., favorable condition status). The evidence is inconsistent, and alternative findings on these subconditions are possible with existing data."

For example, a number of U.S. Nuclear Regulatory Commission letters and letter reports (e.g., Golder, 1984a, 1984b) were referenced that described a variety of specific concerns regarding hydraulic test results. These concerns are categorized below and are responded to by the identifying number.

1. This commenter questioned the reliability of posthydraulic test results, on the basis of problems identified in previous U.S. Nuclear Regulatory Commission letters. These problems include irregularities in test procedures; improper test analysis; effects of temperature, dissolved gas, and dissolved solids; and effects of large- and small-scale heterogeneities.

2. The representativeness of single-hole tests was also questioned. A test result within a Grande Ronde Basalt flow interior, reported by Strait and Spane (1983a), was provided as exemplifying the concern that reported values may not be representative of certain significant anomalous zones of higher hydraulic conductivity.

3. Results of an initial vertical hydraulic conductivity test conducted on a Grande Ronde Basalt flow interior, reported by Spane et al. (1983), were also questioned. These concerns focused on the appropriateness of the test arrangement selected and the fact that alternative interpretations of test results are possible that could provide an estimate of vertical hydraulic conductivity up to two orders of magnitude greater than that calculated.

4. The defensibility of the vertical to horizontal hydraulic conductivity anisotropy ratios cited in the Draft Environmental Assessment was questioned. The anisotropy ratio of 2 to 1 cited from the site-characterization report (DOE, 1982) appears to be

misreferenced. Secondly, the 3.5 to 1 ratio derived from Sagar and Runchal (1982) should not be applied to Hanford Site basalt flow interiors in general, due to the site-specific nature of the fracture data used in the study.

The commenter also pointed out that vertical hydraulic gradients across the Grande Ronde Basalt are upward. It was noted that downward gradients in the upper basalts and upward gradients in the deeper basalts require that a sink be available to move water laterally after it has moved down from above and up from below. The commenter asserted that the magnitude of the hydraulic gradient in and between the host rock and surrounding geohydrologic units may be estimated to be greater than 10^{-3}. The basis for this belief is that the gradients calculated and listed in Table 6-5 of the Draft Environmental Assessment were obtained between well pairs and therefore could represent apparent gradients of magnitude less than the true gradient. The commenter also asserted that the direction of the gradient cannot be determined at this time.

5. The comment noted that statements relative to subparts (ii) and (iii) of Subsection 6.3.1.1.6 on ground-water gradient directions appeared contradicted on page 6-231, where it was stated that a slight upward natural gradient exists across the preferred candidate horizon.

6. A suggestion was made that the phrase "radionuclide movement would have taken place in basalt layers having both low and high effective porosities" be reworded to read "radionuclide movement would have taken place in layers having both higher and lower effective porosities."

Response

The following responses correspond to the numbered items in the above issue statement.

1. Questions identified in the referenced U.S. Nuclear Regulatory Commission letters were answered previously in response letters from the U.S. Department of Energy-Richland Operations Office to the U.S. Nuclear Regulatory Commission (DOE, 1984c). In these letters the appropriateness of various test and analytical methods was discussed, perceived changes in test procedures were examined, and the effects of transient and heterogeniety factors on test results were examined. Based on the discussion presented in the U.S. Department of Energy-Richland Operations Office letters, no change in the favorable condition status identified in the Draft Environmental Assessment is warranted, and the statements given stand supported. In addition, discussions concerning some of the problems identified under Comment 1 are contained in reponses to issues raised (see issues on well development during hydraulic test in borehole DB-2

(Subsection C.4.1.2.2.2), vertical hydraulic conductivity (Subsection C.4.1.2.2), and basalt flow interior permeability values (Subsection C.5.1.2) of this appendix).

2. The representativeness of single-hole tests and the use of such tests in hydrologic investigations were discussed in the Draft Environmental Assessment. The referenced letter (DOE, 1984c) stated that " . . . values obtained from previous single-well tests are defensible and representative of conditions for the test intervals in the vicinity of the borehole site. When used collectively, areal information obtained from single-well tests can provide insight as to variability and heterogeniety of various hydrologic properties of aquifer systems within a region . . . Information obtained from single-well tests is appropriate, not only in the qualitative planning for future tests, but in the manner presented in the site-characterization report (DOE, 1982)." Characterization studies which integrate information obtained from areally located single borehole and multiple borehole sites are best suited for addressing far- and near-field hydrologic relationships. This is consistent with other hydrologic investigations that depend on both single- and multiple-borehole-derived data, conducted at other regional sites in the United States.

   With regard to the example for high permeability zones within flow interiors as reported in Strait and Spane (1983a), it should be noted that this feature represents a fracture that occurs in the bottom 4.5 to 6.5 meters (15 to 21 feet) of the basalt flow. Due to constraints and problems cited by the authors, testing of this zone was limited. It appears, however, that this zone is a localized feature and is interconnected at this borehole site to the immediately underlying transmissive flow top. The final Environmental Assessment has been amended to reflect this relationship.

   Hydrologic results, both preliminary and final, have been obtained for a number of individual flow interiors in the immediate reference repository location vicinity (e.g., boreholes RRL-6, RRL-14, and DC-3) and the surrounding Hanford Site. Results from these tests show that the hydraulic property determinations obtained for the Umtanum fracture zone at borehole RRL-2 is considerably higher than other Umtanum or other basalt flow interior test results. Therefore, the observation that this may be considered as a localized feature appears to be justified. See issue on abundance of permeable fracture zones, in Subsection C.4.1.2.2.2, for additional discussion.

3. This review comment previously was answered in the issue on vertical hydraulic conductivity in Subsection C.4.1.2.2.2. As noted in that response, the experimental field test at boreholes DC-4 and DC-5 was conducted to assess the applicability of the "ratio method" for determining vertical conductivity using

inflatable straddle packer systems. Modifications to the "ratio method" test arrangement, as originally described in Neuman and Witherspoon (1972), were duly noted in Spane et al. (1983, p. 32).

With respect to alternative U.S. Nuclear Regulatory Commission interpretations of the vertical conductivity test results, it should be noted that Golder Associates (Golder, 1984b, p. 3) states that " . . . Williams . . . agree(s) with RHO . . . and suggested that the vertical hydraulic conductivity of the flow interior was actually less than the value calculated by RHO." Research by Golder Associates also states that the test results may greatly overestimate the value for vertical hydraulic conductivity as reported by Spane et al. (1983), because of short-circuiting of flow around the bottom straddle packer (Golder, 1984a, p. 3). The basis for the "greatly over-estimated value" is stated to be that the hydraulic response during the dual borehole DC-4 and DC-5 test actually propagated only 1 to 1.2 meters (3 to 4 feet), not the 7.9 meters (26 feet) reported by Spane et al. (1983). With respect to the greater distance (i.e., 7.9 meters (26 feet)) utilized in the analysis by Spane et al. (1983), it should be noted that the greater distance was selected as a measure of conservatism. If the smaller distance of 1 to 1.2 meters (3 to 4 feet) is utilized in the analysis, a much lower, not higher, value of vertical conductivity is calculated. This can be readily understood by examining the equation for vertical conductivity reported by Spane et al. (1983, p. 19).

4. This comment was previously answered in the appendix issue referenced above. As noted in the response, the anisotropy ratio of 2 to 1 questioned in the review comment was misquoted and should be 10 to 1, as indicated in the site-characterization report (DOE, 1982, p. 12.4-34). Whether the value of 3.5 to 1 as obtained from a general statistical study by Sagar and Runchal (1982) is representative of all Hanford Site basalt flow interiors will remain unknown until planned large-scale interference and exploratory shaft facility tests are performed.

It is acknowledged that vertical hydraulic gradients across the Grande Ronde Basalt are upward. This subject has been discussed in some detail in the responses in issues on vertical hydraulic heads in deep basalts and support of earlier concepts on hydraulic head distributions in this appendix subsection. A working hypothesis currently being tested is that water moving down from the Saddle Mountains Basalt and moving up from the Grande Ronde Basalt converges in a unit or units of the Wanapum Basalt and flows laterally. Units in the upper Wanapum Basalt have relatively large hydraulic conductivity and could act as drains for the Saddle Mountains and Grande Ronde Basalts.

Recently, the local (within and immediately adjacent to the reference repository location) lateral hydraulic gradient in units of the Wanapum and Grande Ronde Basalts was calculated based on near-equilibrium head values from piezometers in boreholes DC-19, DC-20, and DC-22. Table C.5-2 lists these true gradient magnitudes. These gradient magnitudes compare closely with those estimated by comparing head values in wells or boreholes judged to lie along the path of ground-water flow in the Cold Creek syncline. Use of a reasonable conceptual flow model provides the basis for a shortcut gradient estimation that compares well with true gradients calculated from multiple data points. Finally, the direction of the local lateral hydraulic gradient in the reference repository location can be determined at this time. The equilibration of borehole RRL-2C, completed in mid-1985, will provide a fourth multiple piezometer nest in the reference repository location area.

5. Regarding the suggestion that the hydraulic gradient discussion in Subsection 6.4.2.2.3 of the Draft Environmental Assessment possibly contradicted that given in Subsection 6.3.1.1.6, the commenter is in error. Both portions of the Draft Environmental Assessment included the statement supporting the presence of an upward hydraulic gradient in the deep basalts where the candidate horizons lie. For example, page 6-72, paragraph 1, sentence 1, states:

   "Existing hydraulic head data for addressing favorable condition 4(ii) in the Cold Creek syncline near the reference repository location suggest that the head gradient in the shallow basalts is downward while that in the deeper basalts (where the host rock exists) is either horizontal or slightly upward."

   Page 6-231, last paragraph, sentence 1, states:

   "The flow top of the perferred candidate horizon is a likely lateral ground-water flow path because of the existence of (1) a slightly upward hydraulic head gradient (natural and thermally induced) across the horizon . . . "

6. The suggested wording change is gramatically ambiguous (e.g., higher and lower than what?).

Subsections 3.3.2.1.1 and 6.3.1.1.6 of the final Environmental Assessment have been reworded to reflect the statement on anisotropy ratios given in Response 4. In addition, the discussion of the Umtanum fracture zone in Subsection 3.3.2.1.1 was revised to indicate the possible interconnection of the zone to a basalt flow bottom or top.

Issue: Vertical ground-water movement

One commenter noted that the Draft Environmental Assessment stated there is "very little vertical movement of ground water." The commenter believes there is much vertical movement, both shallow and at depth. The commenter continued by saying the U.S. Department of Energy based its opinion on the fact that cooling fractures of the basalt were mineralized.

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Table C.5-2. Hydraulic head gradient in the reference repository location as determined from three points (boreholes DC-19, DC-20, and DC-22)

Flow top or interbed	True horizontal gradient, m/m (ft/ft)
Priest Rapids Member	9.5×10^{-5}
Sentinel Gap flow	6.6×10^{-5}
Ginkgo flows	5.7×10^{-5}
Rocky Coulee flow	2.2×10^{-4}
Cohassett flow	1.5×10^{-4}
Umtanum flow	1.8×10^{-4}

Response

The commenter apparently did not understand discussions in the Draft Environmental Assessment concerning vertical ground-water movement. For example, the following paragraphs are quoted from Subsection 3.3.2.2 (Alternative ground-water flow concepts):

> "There has been controversy concerning what constitutes the details of a conceptual model for basalt (NRC, 1983). However, in a broad sense, the layered geology at the reference repository location consists of alternating basalt flows containing high-to-low conductivity intraflow units. Such heterogeneity forces essentially rectilinear ground-water movement to occur with lateral movement in flow tops and interbeds (potential aquifers) and vertical movement across flow interiors (aquitards). The U.S. Department of Energy believes this to be the overall conceptual model of which details remain to be quantified during site characterization (Section 4.1). Such details would specify a model having little vertical leakage across undeformed flow interiors (see Concept A in Fig. 3-37) or pronounced leakage (see Concept C in Fig. 3-37). The role of leakage along structural discontinuities (see Concepts B and D in Fig. 3-37) also would be addressed during site characterization."

The fourth sentence is especially appropriate. The U.S. Department of Energy stated quantification of vertical leakage remains an issue (although concepts exist) until site-characterization activities (see Section 4.1.1) are initiated.

It is agreed that secondary minerals now infilling or lining fractures are a result of basalt and water interactions. However, the commenter appeared to mix past processes with present characteristics. The general sequence of events resulting in basalt interior properties as observed today were probably basalt outflow and cooling, fracture formation, surface and ground-water infiltration, and fracture mineralization. Mineral infilling indicates past mineral formation from basalt-water interactions. The fact that most fractures are now lined or filled with secondary minerals argues against the existence of open fracture networks such as those that existed in the original formation and cooling of the basalts.

C.5.1.2 Hydraulic information

Comments received on Chapter 6 of the Draft Environmental Assessment were grouped under this subsection. A wide range of topics was covered, including tracer tests, hydraulic conductivity values, leakage, hydraulic test difficulty, and the effects of future borehole drilling.

The hydraulic information subsection is divided into the issues listed below, which are individually addressed.

- Hydraulic properties in a fractured rock mass.
- Upward ground-water movement to Columbia River.
- Definition of hydrologic term and identification of a stratigraphic zone used for tracer testing.
- Review of and need for additional tracer tests.
- Basalt flow interior permeability values.
- Suggested statement for inclusion in Environmental Assessment.
- Value of further borehole testing.
- Planned site-characterization tests.
- Correspondence between F. A. Spane, Jr. and P. A. Witherspoon.
- Hydrologic effects from future borehole drilling.

Issue: Hydraulic properties in a fractured rock mass

This commenter's previous petroleum industry experience with fractured reservoirs suggests that estimates of ground-water production from fractured basalts (obtained from well tests) may not be accurate. Ground-water flow rates within basalts, therefore, may not be calculated accurately, because fracture characteristics are not and will not be adequately understood.

Response

For large-scale applications, heterogeneous fractured rock masses, such as those occurring in permeable basalt flow tops, may be treated as porous media equivalents. This analogy reduces the dependence in requiring detailed information of fracture system characteristics (e.g., orientation, aperture, fracture roughness). This information can be obtained readily from field well tests. For small-scale application, such as near-field repository performance, a greater degree of information concerning fracture properties is needed. This type of fracture characterization will be obtained from chamber and borehole tests conducted at depth within the exploratory shaft facility.

Textbooks and journal articles that discuss fracture flow analysis of well tests, both in the petroleum industry and in hydrologic science, include work by Gringarten et al. (1975), Streltsova (1976), and Van Golf-Racht (1982).

Issue: Upward ground-water movement to Columbia River

This commenter had two concerns: the first that radionuclides might migrate to the nearby Columbia River; the second that the Draft Environmental Assessment did not address the possibility of upward movement of ground water, which may rule out the safe containment of high-level radioactive wastes.

Response

The fact that the Hanford Site has a major surface-water body (i.e., the Columbia River) crossing its boundary is a concern and driving force behind the scientific studies conducted. The distance from the reference repository location to the Columbia River is, however, only one parameter considered in assessing the potential for radionuclide migration. Other factors include the permeability (horizontal and (or) vertical) of various basalt and sedimentary formations; hydraulic head gradients (horizontal and vertical); and radionuclide retardation, diffusion, and dispersion characteristics. These types of studies are in progress and require completion to evaluate the suitability or nonsuitability of basalt to safely isolate waste from the Columbia River.

Information from these studies serves as input to numerical models used to estimate ground-water travel times. Modeling results of radionuclide transport times from prospective repository horizons to the accessible environment were summarized in Section 2.2.3 and Subsection 6.3.1.1.11 of the Draft Environmental Assessment.

The Draft Environmental Assessment did discuss the potential for and factors that influence the vertical movement of ground water through basalt formations (see Section 3.3.2 and Subsection 3.3.2.1).

The potential for upward ground-water movement primarily is influenced by the vertical hydraulic head gradient. As indicated on page 3-80 of the Draft Environmental Assessment, "In deep basalt flows (principally Wanapum and Grande Ronde Basalts), available hydraulic head data indicate either generally uniform heads or a slight upward gradient, . . . " and "Close to the Columbia River, heads either increase with depth or have a variable pattern suggesting potential discharge." Section 3.3.2 has been updated with new hydrochemical and hydraulic head data that further outline the evidence for vertical ground-water movement. The major unresolved question is the rate of this vertical ground-water movement. Refer to issues on three-dimensional ground-water movement, vertical hydraulic heads in deep basalts, and hydraulic head gradients and the fourth favorable condition under postclosure geohydrology, under Subsection C.5.1.1 of this appendix, for additional discussions on vertical ground-water movement.

Issue: Definition of hydrologic term and identification of a stratigraphic zone used for tracer testing

Two commenters made two observations. The first pointed out a perceived inconsistency in the definition of the term "effective thickness" between that used in previous data gathering and workshop meetings with Hanford Site personnel and that used in the Draft Environmental Assessment. The second questioned the identity of the stratigraphic zone selected for tracer testing at paired boreholes DC-7 and DC-8, as described in Gelhar (1982) and the Draft Environmental Assessment.

Response

For discussion of these comments, see Subsection C.4.1.2.2.2 of this appendix.

Issue: Review of and need for additional tracer tests

One commenter stated that tracer tests referenced on page 6-75 of the Draft Environmental Assessment should be reviewed in detail. In addition, more tests, including flow metering throughout the length of the borehole while pumping, would be useful.

Response

With respect to the first observation, tracer tests referenced in the Draft Environmental Assessment have been thoroughly analyzed by subcontractors and consultants of the U.S. Department of Energy. These analyses were published in a number of reports (e.g., Bakr, 1980; Gelhar, 1982; Leonhart et al., 1982, 1985). These reports have been reviewed in the technical community and commented on by the U.S. Nuclear Regulatory Commission and the U.S. Geological Survey.

Concerning the second observation, the Draft Environmental Assessment acknowledged the need for additional tracer testing. This intent was stated in Subsection 6.3.1.1.6 and discussed in Subsection 4.1.1.3. As indicated in previous documents by subcontractors of the U.S. Department of Energy (e.g., Strait and Spane, 1982a, 1982b, 1983a, 1983b), borehole fluid velocity and fluid temperature surveys performed during air-lift pumping can provide insight as to the location of localized ground-water producing zones within a given test interval. These types of surveys were used in the test previously described by Leonhart et al. (1985) and will be used in future tracer testing.

Issue: Basalt flow interior permeability values

One comment contained five concerns related to the possibility that vertical and horizontal permeability values cited in the Draft Environmental Assessment for basalt flow interiors may have been too low and (or) incorrect. Unidentified U.S. Geological Survey ground-water modeling reports of selected areas of the Columbia Plateau were said to provide estimates for vertical permeability of basalt flow interiors ranging between 1.2×10^{-7} meter per second to 6.0×10^{-6} meter per second (3.5×10^{-2} foot per day to 1.7 feet per day). These values are considerably higher than those described in the Draft Environmental Assessment. Specific comments are listed below.

1. Point measurements for horizontal permeability measured at the Hanford Site are far too small.

2. There is a great variability in vertical permeability values.

3. The concept that the ratio of horizontal-to-vertical permeability is approximately 2 to 1 is in error.

4. Vertical movement across flow interiors is controlled by phenomena not yet tested at the Hanford Site.

5. Statements that the vertical permeabilities of the flow interior are very small should be reevaluated based on the available data for the Columbia River basalts as a whole.

Response

With respect to the referenced vertical permeability values (obtained from unidentified U.S. Geological Survey ground-water modeling reports) of approximately 10^{-7} to 10^{-6} meter per second (10^{-1} to 10^{0} foot per day), no such values are known to be reported. In examining available U.S. Geological Survey open-file reports and studies done in cooperation with the State of Washington Department of Ecology (e.g., Tanaka et al., 1974; Luzier and Burt, 1974; Luzier and Skrivan, 1973; MacNish and Barker, 1976), vertical permeability values reported commonly fall within the range assumed by the U.S. Department of Energy. For example, reports by Tanaka et al. (1974, p. 24) for the Columbia Basin Irrigation Project, and MacNish and Barker (1976, p. 5) for the Walla Walla River Basin give values of 3×10^{-12} to 1×10^{-10} meter per second (1×10^{-6} to 3.7×10^{-5} foot per day) and values of 1×10^{-8} meter per second (4×10^{-3} foot per day), respectively. The values cited by the commenter may have been mistaken for values of vertical leakage rates (e.g., Luzier and Skrivan, 1973, p. 23). The two parameters are not the same. The values reported in the Draft Environmental Assessment appear comparable to vertical permeabilities determined by these modeling simulations. The representativeness of the above estimates will be examined during large-scale hydraulic stress tests and research conducted from within the exploratory shaft facility.

It is important to consider that the vertical permeability values noted above were derived from numerical model studies. The U.S. Department of Energy conducted the first field vertical-permeability tests in the basalts of the Columbia Plateau, and no other similar field-measured values are known to exist. If other organizations have conducted such large-scale tests across a basalt flow interior, the U.S. Department of Energy is interested in seeing the well construction, test results, and analysis details.

Responses to specific comment concerns are listed below.

1. The values are considered representative of the rock volume tested. Point measurements of horizontal permeability in other Hanford Site boreholes for basalt flow tops generally are consistent with values reported in other Columbia Plateau regions, as discussed in the site-characterization report (DOE, 1982) (pp. 5.1-46 and 5.1-47). Values for basalt flow interiors also fall within the range for crystalline and argillaceous rock types as reported by Brace (1984).

2. With respect to the variability of vertical permeability in flow interiors, no definitive field-measured values exist; therefore, the comparative variability of flow interior permeabilities is still unknown. Such field tests would be scheduled for completion during site-characterization activities (see Section 4.1.1 of the Draft Environmental Assessment). Based on geohydrologic observation and geologic fracture studies conducted on the Hanford Site and surrounding area, vertical permeability is expected to display variability, especially between structurally deformed and less deformed areas, as addressed in the Draft Environmental Assessment (see Section 3.3.2).

3. The Draft Environmental Assessment discussed the vertical to horizontal permeability ratio of flow interiors, not "horizontal to vertical" as stated in the comment. As noted in Subsection 6.3.1.1.6, the cited anisotropy ratios were determined from statistical and model-calculated estimates, in lieu of any in situ field determinations. The acceptability of these estimates can only be evaluated when vertical permeability measurements are obtained from field tests. Planned tests to obtain representative vertical permeability measurements include large-scale

interference testing in the reference repository location and vicinity, plus testing in chambers and boreholes constructed from the exploratory shaft facility (see Section 4.1.1 of the Draft Environmental Assessment).

4. Phenomena that control the vertical ground-water flux through a given section of basalt flow interior are vertical hydraulic head gradient and vertical hydraulic conductivity. Vertical head measurements have been obtained at a number of boreholes and piezometer sites within the reference repository location and surrounding area. As indicated in response 3 above, hydrologic tests are planned, including large-scale interference testing and tests conducted in the exploratory shaft facility. In addition, a wide range of interflow and intraflow discontinuities that can affect the hydraulic properties of basalt were addressed in the Draft Environmental Assessment (see Subsection 3.3.2.1). Thus, major characteristics that control vertical water movement across flow interiors have been discussed in the Draft Environmental Assessment.

5. The estimated small values of vertical permeability reported in the Draft Environmental Assessment are believed consistent with available data, including vertical permeability values computed from ground-water models, field-derived horizontal permeability values, vertical permeability values obtained from laboratory core analyses, and inferences obtained from basalt core-fracture studies.

Issue: Suggested statement for inclusion in Environmental Assessment.

One commenter suggested the following statement be added to the first bullet in Subsection 6.3.1.1.5 of the Draft Environmental Assessment:

> ". . . the study of well hydraulics has become a well-established discipline in the last 30 years and its techniques are far more advanced than theoretical approaches to predicting flow in fractured media."

Response

The referenced section of the Draft Environmental Assessment discussed future site-characterization tests designed to reduce uncertainty in modeling the geohydrological system. One such test discussed in the text and in the identified bullet on page 6-69 is the planned large-scale hydraulic test. While the commenter's addition is factual, inclusion of the wording in this section of the final Environmental Assessment would not provide additional support information or clarification.

Issue: Value of further borehole testing

One commenter addressed the discussion in Subsection 6.3.1.1.5 of the Draft Environmental Assessment that focused on available hydrologic data and future site-characterization tests designed to reduce data uncertainty.

The commenter questioned whether or not more boreholes and "more testing and studies" conducted in the reference repository location will reduce this uncertainty. "Perhaps the problem is too complex."

Response

Data uncertainty is expected to be reduced to an acceptable level and the reference repository location is believed to have a high likelihood of being characterized. See response in issue on merit of future borehole drilling in Subsection C.4.1.2.2.5 of this appendix for additional related discussions.

Issue: Planned site-characterization tests

One commenter made a number of statements concerning the discussion of planned site-characterization tests designed to reduce data uncertainty in the reference repository location (see pp. 6-68 and 6-69 of the Draft Environmental Assessment). The comments, which will be responded to separately, are identified below.

1. " . . . it is unclear how DOE intends to proceed with hydraulic testing . . . "

2. The U.S. Nuclear Regulatory Commission reference cited in the bulleted items in Subsection 6.3.1.1.5 is irrelevant and incorrectly referenced and should be NUREG 0960, p. 3-5.

3. The U.S. Department of Energy reliance on theory (i.e., "developed saturated-flow hydraulic theory") and the absence of actual measurements, as well as quantitative data, have been criticized in the past by the U.S. Nuclear Regulatory Commission.

Response

The following responses correspond to the items listed in the above issue statement.

1. General aspects of planned hydrologic tests designed in support of site-characterization were discussed in Section 4.1 (Site Characterization Activities) of the Draft Environmental Assessment. The Environmental Assessment is a support document for the site-selection process, not a planning document. Detailed descriptions of the design, performance, and analysis of these planned tests will be published in U.S. Department of Energy subcontractor reports prior to test implementation. Overall program plans will be issued in the site-characterization plan, should the reference repository location be recommended for characterization.

2. The introduction to the U.S. Nuclear Regulatory Commission reference cited required expansion for placing the support statement in proper context. The intended meaning was that the primary approach adopted by the U.S. Department of Energy for

site characterization (i.e., large-scale interference testing) is supported by the U.S. Nuclear Regulatory Commission technical position for site-characterization studies on the Hanford Site. The introduction has been modified.

The reference and page number cited in the Draft Environmental Assessment are correct. Note: the reference cited in the Draft Environmental Assessment is NRC (1983a) not NRC (1983c), the designation used by the commenter.

3. The commenter apparently has misunderstood the intent of large-scale interference testing. Actual measurements and quantitative data derived from these tests can be interpreted with analytical methods developed from saturated-flow theory. This approach is supported by the U.S. Nuclear Regulatory Commission, and is the standard test-analysis procedure used by the scientific community. The Draft Environmental Assessment did not advocate theory substitution for actual data. Both play an essential role in addressing waste-isolation issues in any geologic medium.

The second bullet under Subsection 6.3.1.1.5 has been reworded to reflect the thought expressed in the first paragraph of Response 2 above.

Issue: Correspondence between F. A. Spane, Jr. and P. A. Witherspoon

One commenter contended that " . . . it was expedient for U.S. Department of Energy/Rockwell Hanford Operations to reduce the minimum thickness of 200 feet in 1979 to 70 feet in the draft E.A. just so the Hanford Site would qualify." To support this contention, letter correspondence from Dr. F. A. Spane, Jr. (Rockwell Hanford Operations) to Dr. Paul A. Witherspoon (Lawrence Berkeley Laboratory, University of California) was referenced (Spane, 1979). The comment quoted Dr. Spane as stating " . . . Hanford is a good candidate site because the basalt flows are greater than 200 feet thick (thus indicating 200 feet is a safe and preferred minimum)." (Parenthetical statement added by commenter.) The comment continued that "Dr. Witherspoon's contention at that time was that it was much less than 200 feet . . . Subsequent drilling showed that Dr. Witherspoon, not Dr. Spane, Jr. from Rockwell International, was correct."

Response

The contention that the U.S. Department of Energy and its subcontractors reduced the minimum thickness value of 61 meters (200 feet) to 21 meters (70 feet) so that the Hanford Site would qualify as a repository candidate is incorrect. No such change took place. Perhaps the commenter has confused total flow thickness versus flow interior thickness, or metric and English units. A basalt flow is composed of (in descending order) a vesicular zone and brecciated flow top, dense flow interior (consisting of entablature and colonnade sections), and flow bottom. The thickness percentage for each flow component varies areally for each flow. For most thick flows, flow interiors commonly comprise the thickest section. It is not uncommon, however, that flow tops comprise the largest thickness within an individual basalt flow. Refer to Sections 2.1.1 and 3.2.2 and Subsection 6.3.3.2.3 of the Draft Environmental Assessment for discussions of basalt flow thicknesses, variations, and other characteristics.

Concerning the thickness of entire basalt flows (e.g., flow tops, flow interiors), Dr. Spane stated in his letter to Dr. Witherspoon that " . . . the thickness of Columbia River Basalts varies considerably between individual basalt flows, with thicknesses ranging from a few tens to over 400 feet. . . . " Dr. Spane's observations were based on borehole, geophysical, and surface outcrop studies available in 1979, and have been corroborated by data collected since that time.

The 21-meter (70-foot) minimum thickness criteria for housing a repository in basalt was specifically stated in the Draft Environmental Assessment (see Subsection 6.3.3.2.3) to apply only to basalt flow interiors. Therefore, no conflict between thickness values exists between the 1979 letter and the Draft Environmental Assessment.

As an additional point of correction, nowhere in the letter correspondence does Dr. Spane state that "Hanford is a good candidate Site." The intent of the letter was to clarify statements made by Dr. Paul Witherspoon and to invite his staff to visit the Hanford Site for technical discussions.

Issue: Hydrologic effects from future borehole drilling

Several commenters questioned the effect future borehole drilling may have on the hydrology and (or) ground-water flow patterns on the Hanford Site. One of the commenters also questioned the effect of earthquakes, and another the impact of the exploratory shaft construction on the local Hanford Site hydrologic conditions.

Response

As indicated by studies conducted on the Hanford Site, the drilling and activities associated with borehole construction can cause temporary changes in formation pressure and provide a localized site for vertical movement between test intervals intersected by the borehole.

Due to pressures maintained within a borehole during construction, formation pressures and hydraulic head distributions within individual basalt formations may be temporarily altered. The magnitude and duration of this effect for a given area is a function of the duration of borehole construction, magnitude of applied stress maintained during borehole construction, and hydraulic characteristics of the intersected test formations. For basalt aquifers possessing a medium to high transmissivity, in situ conditions equilibrate rapidly (i.e., within a time frame approximately equal to or less than the duration of hole construction) when construction activities cease.

Open, uncased boreholes also can provide pathways for the vertical movement of fluids between intersected aquifers. The magnitude or quantity of fluid transported between zones is a function of the hydraulic characteristics and vertical hydraulic head gradients for the respective formations. Following completion of characterization activities, boreholes in the reference repository location will be abandoned and filled with cement, have basalt formations isolated within the borehole using a combination of cement and packers, or be completed as isolated monitoring structures (piezometers).

Earthquakes that do not cause permanent formation damage produce only transitory effects on the hydrologic conditions within an area. Seismic waves induced by earthquakes cause formation pressures and water levels within wells to oscillate; this effect rapidly diminishes (within seconds or minutes) to equilibrium levels upon cessation of the earthquake. An example of a study that investigated this type of induced response is given in Cooper et al. (1965).

When earthquakes cause permanent formation damage, long-term changes in the local ground-water hydrologic conditions may result. The cause-and-effect relationship in these situations may be difficult to establish, due to the varying degree of deformation possible. However, changes to the local ground-water hydrology attributable to earthquake scenarios can be effectively modeled if the deformation effect to the respective formations can be quantified. Such modeling is planned during site characterization, should the reference repository location be recommended.

Potential effects of exploratory shaft construction were discussed in Subsection 4.2.1.2.2 of the Draft Environmental Assessment. As indicated, the baseline ground-water conditions and selected areal hydraulic characteristics in the reference repository location will be determined prior to shaft construction. Measurements recorded during shaft construction, as well as replicate tests conducted following shaft construction, will provide a means of quantifying any temporary or long-term effects.

C.5.1.3 Ground-water quality

Several comments were received concerning ground-water quality as related to the second potentially adverse condition under geohydrology (DOE, 1984a; 960.4-2-1(c)(2) (see Subsection 6.3.1.1.9 of the Draft Environmental Assessment) and the ground-water chemistry summary as given in Table 3-6. According to some reviewers, the quality of ground waters along likely flow paths between a repository and accessible environment does not preclude use of these ground waters for agriculture or for some future purpose. Two commenters recommended that specific data be presented and compared with various water-quality standards, and questioned the source of fluoride in the water. A comparison was requested between the deep water quality beneath the Hanford Site and that from other areas of the Columbia Plateau.

Response

Throughout the entire Columbia Plateau, ground water used for irrigation is of distinctly lower salinity than that found in the Grande Ronde and lower Wanapum Basalts in the vicinity of the reference repository location. This is true even of Wanapum and Grande Ronde Basalt ground water in the upper Cold Creek syncline, west of the hydrologic and geochemical anomaly occurring along the Cold Creek barrier (see Section 3.3.2 of the Draft Environmental Assessment). Sodium and chloride concentrations for waters from these two areas are plotted in Figure C.5-7. Ground water in the Columbia Plateau, excluding the Hanford Site, is characterized by low chloride (generally 10 parts per million or less) and sodium concentrations (ranging from near zero to slightly greater than 100 parts per million) (U.S. Geological Survey WATSTOR data base). The shallow Saddle Mountains Basalt ground water at the Hanford Site has similar characteristics. Water with these characteristics is found at all depths in the region for which data are available.

There appears to be no increase in salinity with depth in the Columbia Plateau region even though irrigation water is pumped from the Grande Ronde and Wanapum Basalts. (These basalts are generally at shallower depths in the Columbia Plateau outside of the Hanford Site.) However, at the Hanford Site, the salinity of ground water increases with depth in the Wanapum Basalt and reaches a maximum in the Grande Ronde Basalt, where the salinity is uniformly high with most specific conductivities between about 1,500 and 2,000 micromho per centimeter and sodium and chloride concentrations on the order of 350 and 450 parts per million, respectively (Early et al., 1985). Therefore, water found in the vicinity of the reference repository location is distinctly different from irrigation waters used elsewhere in the Columbia Plateau even though they are located in the same stratigraphic horizons.

The type of saline ground water found in the Wanapum and Grande Ronde Basalts at the Hanford Site is not used for irrigation elsewhere in the Columbia Plateau. This is because these saline waters do not exist in the same formations in the rest of the Columbia Plateau and also because of the presence of high-quality surface waters in the Columbia, Snake, and Yakima Rivers, and high-production, good-quality shallow aquifers. Therefore, locally there appears to be no incentive to use the deeper saline waters, especially those waters in the low-production flow tops of the Grande Ronde Basalt found in the reference repository location and vicinity.

Assuming that in the future an economic or cultural incentive arises that would cause someone to use the deeper saline waters beneath the Hanford Site for agricultural purposes, the suitability of these waters is still dependent on such factors as the crop produced, infiltration and drainage characteristics of the soil, and irrigation management practices. Because soils at the Hanford Site are, in general, coarse textured and have reasonably good drainage characteristics, it appears that the opportunity exists, with a proper water budget and deep leaching programs, for

7 0 1 6 8 2 1 4 2

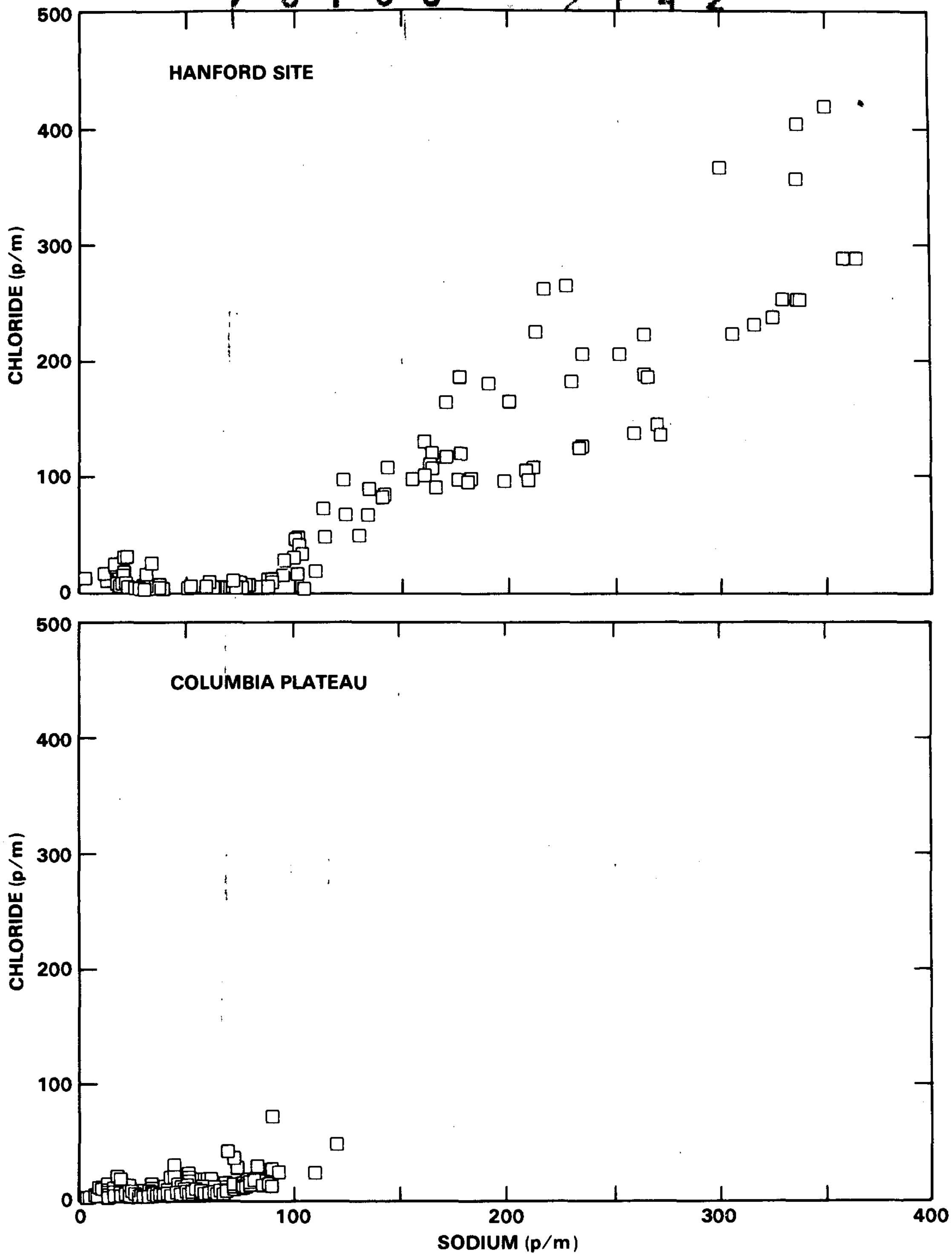

Figure C.5-7. Sodium and chloride concentrations for the Hanford Site and Columbia Plateau region. Data for the Hanford Site were collected by the Basalt Waste Isolation Project, and data for the Columbia Plateau region were collected by the U.S. Geological Survey WATSTOR data base.

the higher salinity waters to be used in production of the more salt-tolerant crops. This may seem even more realistic in light of the fact that waters of similar and even higher salinity are used for irrigation elsewhere in the arid United States. However, the use of salinity comparisons alone can be misleading.

There are two aspects of the salinity question that should be addressed:

- The total dissolved salt content of the irrigation water and the physiological influence on plants.

- The ionic composition of the dissolved salt as it influences soil structure and drainage.

The specific conductivity of the Grande Ronde Basalt waters places them in the high salinity class, as previously stated. This means that only the more salt-tolerant crops could be grown and only if strict water management practices were implemented. Soils on which waters of such high salinity are used require frequent deep leaching to prevent salt accumulation in the root zone (Israelsen and Hansen, 1962; Allison, 1964). This requires that the soils have good drainage characteristics. The composition of dissolved salts, specifically the ratio of sodium to calcium plus magnesium, influences soil drainage. A parameter called the sodium adsorption ratio is used as an indicator of this water-quality condition. Even for the most saline irrigation waters used in the arid western United States, sodium adsorption ratio values are not greater than 20 (Allison, 1964, p. 144). As noted earlier, the sodium adsorption ratio of Grande Ronde waters is in the 30's and 40's. For Wanapum Basalt ground water within and adjacent to the reference repository location, the sodium adsorption ratio ranges from the high 20's to the low 40's.

The significance of this ratio is that with long-term use, the natural calcium carbonate in the soils would be leached away. The soils would be dominated by sodium and would lose the existing good structure, resulting in plugging of soil pores. Deep leaching to remove salts would be precluded. The only alternatives to this situation would be to periodically add gypsum to the soil or to reclaim the soil with a low-sodium adsorption ratio, high-salt water as is done in California where seawater is used. In essence, the deeper saline waters beneath the reference repository location and vicinity could not be used for irrigation without considerable treatment of the water or soils.

In addition to the sodium and salinity hazards, boron and fluoride are of special importance. As noted earlier, Wanapum and Grande Ronde Basalt ground waters in the reference repository location contain fluoride concentrations ranging from 4 to 44 milligrams per liter and boron concentrations from 0.4 to 3.5 milligrams per liter. (Most Grande Ronde Basalt ground waters range from about 2 to 3.5 milligrams per liter boron. Within the upper and middle Wanapum Basalt, boron concentrations are about 0.5 milligram per liter. This value increases to about 1.5 milligrams per liter in the lower Wanapum Basalt ground water.) Boron concentrations in Grande Ronde Basalt ground waters places them, depending on the classifications used, in the poorest classes for this parameter (Israelsen and Hansen, 1962, p. 226; Allison, 1964, p. 142). Only the most boron-tolerant crops could be grown, and then only with a good deep leaching program.

The U.S. Environmental Protection Agency guidelines for human consumption of water recommend fluoride levels below 2.4 milligrams per liter in climates with air temperatures less than 12°C (54°F), and below 1.4 milligram per liter where temperatures are greater than 27°C (80°F) (EPA, 1972). A single lethal dose of fluoride is considered to be 14 to 70 milligrams fluoride per kilogram of body weight in an adult human (Gosselin et al., 1977). A person weighing 70 kilograms (154 pounds) would have to consume between 55 and 250 liters of water containing 20 milligrams fluoride per liter (average Grande Ronde Basalt composition) for a lethal dose. Nausea accompanies ingestion of as low as 7 milligrams of fluoride per liter and acute vomiting would occur at ingestion of fluoride levels approaching 29 milligrams per liter (Leland et al., 1980). Thus, an average adult human would have to consume 0.35 liter (0.1 gallon) of water containing 20 milligrams fluoride per liter to become nauseated, and 1.5 liter (0.4 gallon) of the same water to experience vomiting. Chronic endemic fluorosis due to high concentrations of natural fluoride in ground waters is characterized by symptoms such as mottling of teeth, weakening of bones, and nervous disorders (Gosselin et al., 1977). Thus, ground waters beneath the Hanford Site that contain fluoride in excess of U.S. Environmental Protection Agency guidelines (approximately 1.4 milligrams per liter) are not suitable for general human consumption.

In summary, Grande Ronde and lower Wanapum Basalts ground waters in the reference repository location are considered unsuitable for agricultural use without treatment. High salinity, fluoride, and boron concentrations directly affect the quality of the crop grown, and the high sodium adsorption ratio affects the ability of the farmer to maintain good soil drainage characteristics required to leach salts from the root zone. These waters could be used for selected crops, with special treatment of the water and soil.

Regarding the source of fluoride in the ground water, the U.S. Department of Energy believes that fluoride could result from rock-water interactions, but does not exclude external sources. A typical fluoride value reported for the Columbia River Basalts rock analyses is 540 parts per million fluoride. Unpublished fluoride data for the Cohassett and Rocky Coulee flows indicate that fluoride concentrations between 350 and 500 parts per million are present. Recent studies at the Hanford Site indicate that fluoride concentrations on the order of 20 parts per million can be generated by reacting deionized water with crushed basalt at 300°C (570°F) for 2 weeks. These data lead one to believe that the 40 parts per million fluoride concentrations can be generated by rock and water interaction.

One comment questioned the reliability of using current water-quality standards for future generations (next 10,000 or 100,000 years). With advancement of biogenic engineering accompanied by depleting and degrading water quality, future generations will probably rely on water sources considered poor by current health standards. This is an interesting topic, though one that is so uncertain as to be difficult to address. To apply the second potentially adverse condition under postclosure geohydrology (DOE, 1984a; 960.4-2-1(c)(2)) (see Subsection 6.3.1.1.9 of the Draft Environmental Assessment) as a discriminator between geologic sites, some water-quality standard is needed. This standard is based on current knowledge of health risks as defined by the U.S. Environmental Protection Agency or other agencies.

Two commenters requested a comparison of water "chemical parameters" to drinking-water standards. A summary of the major concerns regarding water consumption and irrigation use was included in Subsection 6.3.1.1.9 of the Draft Environmental Assessment. This subsection has been expanded as noted below. Since the guidelines do not require a comparison of all water chemical parameters to applicable drinking water standards, only those parameters identified as major problems were noted. For an overview discussion of surface-water and unconfined aquifer-water quality beneath the Hanford Site and vicinity, refer to the surveillance reports by Price et al. (1984) and Eddy et al. (1983) listed in Chapter 3 of the Draft Environmental Assessment. A more recent report by Prater et al. (1984) concerning unconfined aquifer ground-water monitoring has been added to Section 3.3.2 of the final Environmental Assessment.

Most of the above response, with exception of the last three paragraphs, has been added to the end of Subsection 6.3.1.1.9 of the final Environmental Assessment.

C.5.1.4 Geohydrologic system changes

Of the comments received in this category, many focused on geohydrologic changes induced by human activities such as water application or withdrawal. This subsection is divided into two issues:

- First potentially adverse condition under postclosure geohydrology.
- Manmade changes to ground-water system.

Issue: First potentially adverse condition under postclosure geohydrology

The first potentially adverse condition under postclosure geohydrology (DOE, 1984a; 960.4-2-1(c)(1)) refers to expected changes in geohydrologic conditions sufficient to significantly increase radionuclide transport compared to pre-waste-emplacement conditions. Several comments emphasized the need to include human interference (e.g., water application, ground-water pumpage) and (or) thermal-loading effects into the application of this adverse condition. Not factoring in such activities was interpreted as either an inappropriate application of the guideline or an inconsistency between interpretations of the postclosure geohydrology and human interference (DOE, 1984a; 960.4-2-8-1) guidelines. One commenter noted a possible inconsistency in climate-change discussions between page 6-86 (" . . . climate would not change for the next 100,000 years . . . ") and page 6-116 (" . . . the next glacial advance will occur 15,000 years from now. . . "). Another reviewer said that climatic changes over the next 100,000 years could significantly alter surface and near-surface hydrologic systems. However, the commenter added, changes to the deep hydrologic system would not be significantly altered.

Response

Subsection 6.3.1.1.8 (Postclosure geohydrology) is intended to refer only to naturally induced changes (e.g., geomorphic, climatic) to the geohydrologic system. Subsections 6.3.1.8.9 (the fifth potentially adverse condition under human interference (DOE, 1984a; 960.4-2-8-1(c)(5)) and 6.3.3.2.8 (the fourth potentially adverse condition under rock characteristics (DOE, 1984a; 960.5-2-9(c)(4)) referred to system changes resulting from human activities and thermal effects, respectively. The human interference potentially adverse condition was considered present (i.e., no credit is assumed for absence of condition). The noted rock characteristics potentially adverse condition also is considered present because of potential difficulties in retrieving waste canisters. Thus, the U.S. Department of Energy concurs with the commenter's opinions that selected human activities could alter the geohydrologic characteristics near the proposed repository. Natural changes to the flow system, however, are not expected to significantly alter the isolation potential of the reference repository location, based on available data and understanding of geomorphic, tectonic, and climatic processes (see Subsection 6.3.1.1.8 of the Draft Environmental Assessment). Also, it is agreed that any major climatic changes and (or) ice advance over the next 100,000 years will likely alter the surface and near-surface hydrologic systems see Subsection 6.3.1.1.4). This is one of the reasons the proposed repository would be located deep underground.

Subsection 6.3.1.3.6 of the Draft Environmental Assessment discussed thermal buoyancy effects resulting from waste emplacement.

Subsection 6.3.1.1.8 of the final Environmental Assessment has been reworded to clearly indicate that this first potentially adverse condition under postclosure geohydrology only pertains to naturally induced changes. References have been added to indicate where the effect of thermal loading and man-induced changes on the ground-water system are addressed elsewhere in the General Siting Guidelines (DOE, 1984a). Also, Subsection 6.3.1.1.8 will be expanded to include the concept that glaciation during the next 35,000 years may create ice dams and surface flooding.

Issue: Manmade changes to ground-water system

Concern was expressed by several reviewers over possible changes to the ground-water system resulting from such processes as water extraction, water application, oil or gas withdrawal, and (or) alteration of surface-drainage patterns. One commenter said that ground-water system changes associated with water use must be included as part of the repository-selection process. Another commenter stated that neither ground-water extraction nor the effects of basalt erosion were considered in the Draft Environmental Assessment. The question "What impact would rock bursts have upon the ground-water regime?" was also asked.

Response

The potential for and effects of future water application and withdrawal on ground-water flow and radionuclide movement is not yet fully addressed. For this reason, the fifth potentially adverse condition under human interference (DOE, 1984a; 960.4-2-8(1)(c)(5)) (see Subsection 6.3.1.8.9 of the Draft Environmental Assessment) is present at the reference repository location. Specifically, the first paragraph of Subsection 6.3.1.8.9 stated:

> "There is a potential for foreseeable human activities, particularly ground-water withdrawal for the purposes of irrigation and discharges of significant quantities of waste water to the unconfined system in and around the reference repository location (see Section 2.1.4). However, insufficient data are presently available to reasonably determine if such human activities could adversely change portions of the ground-water flow svstem, which is important to waste isolation. Therefore, it is assumed that this potentially adverse condition could be present at the reference repository location."

This specific potentially adverse condition does factor geohydrologic system changes from man-induced activities into the repository-selection process.

Discussions of sediment and basalt erosion were included in the Draft Environmental Assessment. Subsection 6.3.1.5 addressed favorable and potentially adverse conditions related to erosion.

Rock bursts result from the sudden yielding and failure of rock slabs within an underground mine and are a mine safety issue rather than a hydrologic concern. Minor rock failure would have no expected effects on the local ground-water system. The failure of a large mine opening (from massive rock burst) could create a water-storage cavity, possibly connected to a basalt flow top; otherwise, rock burst should not significantly impact the ground-water system away from the immediate repository vicinity.

C.5.1.5 Complexity

A variety of topics were raised on the issue of site complexity and are summarized below.

1. A complex site makes it easier to bias data.

2. The presence of discontinuities will make characterization difficult; however, a layered stratigraphy, as exists in basalt, permits ready identification, evaluation, and demonstration of discontinuities using existing investigative techniques.

3. Many uncertainties will need to be resolved to understand ground-water systems and adequately model isolation potential, should characterization proceed. The costs and time to gain such knowledge may be prohibitive.

4. The geology and hydrology of the reference repository location are complex and not easily modeled.

5. The reference repository location defies characterization, according to a U.S. Geological Survey staff member.

6. Site safety will be difficult to ascertain, because the reference repository location has the most complex geology and hydrology.

7. Final siting guidelines call for site disqualification if characteristics are too complex to analyze with reasonable confidence. This would make valid site characterization impossible.

8. No one knows the reference repository location well enough to assure safety as a repository.

9. It is doubtful the reference repository location can be well enough understood using present investigative technology and reasonable costs to have a high confidence that waste could be safely stored.

10. The Hanford Site should not be in the top three sites recommended for characterization, since the ground-water regime has not yet been characterized.

11. Site complexity may not allow credit to be taken for a confidence level 2 for the postclosure geohydrologic disqualifying condition on ground-water travel time even after site characterization.

Response

The following responses correspond to the items listed in the above issue statement.

1. The Nuclear Waste Policy Act of 1982 establishes an open, formal review process for all site-characterization data. This is a first step in assuring technical excellence. All geologic sites, whether perceived as geohydrologically simple or complex, will receive technical scrutiny.

2. The U.S. Department of Energy agrees that a layered stratigraphy such as basalt might permit more ready identification of structural and (or) stratigraphic discontinuities than possible in a non-layered svstem. This was acknowledged in Subsection 6.3.1.1.5 of the Draft Environmental Assessment.

3. While a 100-percent guarantee of resolving all critical site-characterization issues is not possible, a research program would be carried out to answer all major issues. If data essential for reasonably assuring waste isolation cannot be collected for technical or site-complexity reasons, or the time and cost of acquiring such information are prohibitive compared to other likely geologic storage sites, basalt will be reconsidered as a possible storage medium.

4. As stated in Subsection 6.3.1.1.5 of the Draft Environmental Assessment, characterization of the reference repository location is not expected to be easy. If characterization were easy, the geohydrology of the site would likely make it unfavorable for waste isolation (e.g., high hydraulic head gradients, large rock permeabilities, shallow characterization depths, and oxidizing ground waters). However, such characteristics are not favorable to long-term waste isolation. The scheduled large-scale pumping tests, additional piezometer emplacements, and exploratory shaft test program (see Section 4.1.1 of Draft Environmental Assessment) are essential activities for understanding the degree of hydrologic "complexity" inherent in the reference repository location.

5. The U.S. Department of Energy has no knowledge of such a statement being made by a member of the U.S. Geological Survey. The commenter's statement does not appear to reflect the position of the U.S. Geological Survey. For example, in correspondence between the U.S. Geological Survey and a House of Representatives subcommittee on the topic of past critical reviews of U.S. Department of Ener y plans, the U.S. Geological Survey states " . . . present investigative plans should address adequately the issues raised both by the USGS and the report 'Heat, High Water and Rock Instability at Hanford' . . . " (Peck, 1985). (The U.S. Geological Survey critique was written by Robertson (1983) and the report title given above is from Makhijani and Tucker (1985)). The U.S. Department of Energy does believe that the reference repository location has a high likelihood of being characterized so as to address important geohydrolgic waste-isolation questions (see Subsection 6.3.1.1.5).

6. At this stage, comparable data bases are not available for the five nominated geologic sites; therefore one site cannot be established as more or less complex than any other. Each rock medium is unique and will offer potential difficulty in characterization. The U.S. Department of Energy acknowledges

site-characterization difficulties at each site under study. The Draft Environmental Assessment stated this in Section 7.2.1.1:

"Favorable condition 3 is the presence of stratigraphic, structural, and hydrologic features such that the geohydrologic system can be readily characterized and modeled with reasonable certainty. This favorable condition is not present at any of the sites because it is likely that all the sites have stratigraphic, structural, and hydrologic features which may render them more difficult to characterize than the term "readily" implies. Nonetheless, the sites can be compared in relation to this favorable condition as follows: on the basis of very limited information, the three salt sites appear to have less complex stratigraphic and structural frameworks than the Hanford and Yucca Mountain sites. However, as site-specific data from geophysical surveys and boreholes are collected at the salt sites, it is likely that additional complexities will be identified that may increase the difficulty in characterization."

7. Whether or not a site can meet the third favorable condition under postclosure geohydrology (DOE, 1984a; 960.4-2-1(b)(3)) (sites that have stratigraphic, structural, and hydrologic features such that the geohydrologic system can be readily characterized and modeled with reasonable certainty) does not itself suggest qualification or disqualification.

   If the geohydrologic characteristics of a site are not defined, for whatever reason, waste-isolation safety guidelines cannot be adequately answered. This would result in qualifying and (or) disqualifying conditions remaining open. Since the siting guidelines specify that a site must meet each qualifying condition and avoid each disqualifying condition, the inability to fully address any one category would disqualify a site.

8. It is true that at this time the basalt environment is not sufficiently understood to assure development of a safe repository. Such confidence can be gained only through completion of a technically sound site-characterization program.

9. As addressed in Subsection 6.3.1.1.5 of the Draft Environmental Assessment, the U.S. Department of Energy believes available investigative technology can define those basalt characteristics critical to answering waste isolation questions. The term "reasonable costs" is undefined. Any such definition would have to factor in the risk of leaving radioactive waste in an interim or less secured state compared to permanent storage if less expensive alternatives are not suitable. Only then can "reasonable" be qualified.

Relative to cost comparisons between sites, the Draft Environmental Assessment, in Subsection 7.3.3.2, stated:

"In view of the current status of repository designs and the potential range of cost variation due to uncertainty in the cost estimates, such estimates do not provide a reasonable basis for discriminating among sites by host rock. Furthermore, site-specific cost estimates for each of the five sites compared in this chapter would involve similar ranges of costs and would lead to a similar conclusion."

10. As addressed in Subsection 7.2.1.1 of the Draft Environmental Assessment, no site under consideration in the civilian waste-management program is expected to be easily characterized. Each medium (basalt, tuff, bedded salt, and dome salt) is expected to have unique characterization difficulties. Acquisition of data permitting technically sound decisions for any geologic medium will be time-consuming and costly.

11. The U.S. Department of Energy believes that following site characterization, a Level 2 statement will be made on ground-water travel times.

C.5.1.6 Characterization activities

Numerous comments were received related to site-characterization data needs identified in postclosure geohydrology (see Section 6.3.1) in the Draft Environmental Assessment. These comments do not include those regarding ground-water travel time, which are discussed in Section C.5.11 of this appendix.

Topics raised in the above comments included such items as the need to understand, or uncertainties associated with, the following:

1. Lateral and vertical hydraulic property distributions.

2. Vertical hydraulic conductivity.

3. Effective porosity.

4. Ground-water flow patterns.

5. Ground-water discharge areas.

6. Effects of geologic features or any high-conductivity zones on ground-water movement.

7. Reliable conceptual models.

8. Regional ground-water models.

9. Predevelopment, current, and future ground-water use conditions.

10. Steady-state versus transient ground-water conditions.

11. Hydraulic boundaries for numerical models.

12. Impact from future "geologic movement" on ground-water system.

13. Possible effect of site-characterization holes on ground-water movement.

Two commenters made a general statement that "more data is required to determine if the site is suitable." Two other reviewers stressed that "questionable data should be identified and used cautiously." One commenter expressed the concern that evaluation of potential water contamination should be based on data, not on "abstract computer models." The same commenter urged that the U.S. Department of Energy delay drilling the "borehole," if such excavation would disrupt water flow patterns, "until such time as all data are collected."

Response

The above bulleted items identify a number of hydraulic properties, conceptual model inputs, and numerical model simulations important to assessing the suitability of a geologic medium for waste isolation. Site-characterization research will focus on these types of items. Additionally, reasonable predictions are needed of future ground-water demand and development patterns. Many of the same needs were expressed in the Draft Environmental Assessment (e.g., see Sections 3.3.2 and 4.1.1 and Subsections 6.3.1.1.11.3 and 6.3.1.1.12).

Portions of a few of the above comments require additional response. One commenter also was concerned about the effects of heat on ground water and rock geochemistry. It is agreed that such concerns are important and should be addressed. Current understanding of thermal loading effects was included in Subsection 6.3.1.3 (Postclosure rock characteristics) of the Draft Environmental Assessment.

One commenter quoted a U.S. Geological Survey letter (Robertson, 1983) that said, "We do not believe that the hydraulic conductivity, head gradient, and effective porosity data are sufficient or reliable enough to allow velocity calculations to be made with an accuracy of greater than approximately 2 or 3 orders of magnitude." The quote cited was given in the Draft Environmental Assessment (see Subsection 6.3.1.1.11.3). The use of such quotes or opinions expressed by review agencies underlies the emphasis the U.S. Department of Energy is placing on development of a technical consensus on topics of data adequacy and ground-water system conceptualization. The U.S. Department of Energy believes that an adequate understanding of the deep geohydrologic environment beneath the Hanford Site is not yet available to answer some critical waste-isolation issues. This is reflected in the Robertson quote and is the reason for conducting a site-characterization program.

Assuming that the above quote is referring to uncertainty in travel time estimates, the U.S. Department of Energy agrees that uncertainties in hydraulic properties produce large uncertainties in ground-water travel time estimates. As discussed in Subsection 6.4.2.3.5 of the Draft Environmental Assessment, the U.S. Department of Energy has developed and used a predictive methodology for estimating ground-water travel time that accounts for data uncertainty. This is accomplished by using probabilistic representations of known and unknown hydraulic property values (hydraulic conductivity, head gradient, and effective porosity).

One commenter is referred to Subsections C.4.1.2.2.2 and C.5.1.2 of this appendix regarding comments on past critiques of onsite data. The statement "two tests for measuring effective porosity were of questionable validity" is unsupported. These tracer tests have been widely reported (Bakr, 1980; Gelhar, 1982; Leonhart et al., 1982, 1985) and reviewed by the technical community. Validity beyond that normally associated with tracer technology is not a concern.

Another commenter stated that a discussion of present and future ground-water demand was lacking, and future demand could influence the migration of radionuclides. Present ground-water demand in the Pasco Basin and Columbia Plateau is outlined and extensively referenced in Subsection 2.1.4.2 of the Draft Environmental Assessment; however, the reviewer is correct in stating that future ground-water use was not discussed in the document. These studies are planned. The U.S. Department of Energy agrees that such demand on water resources could affect radionuclide migration; this point was addressed in Subsection 6.3.1.8.9. The first paragraph of that section read:

> "There is a potential for foreseeable human activities, particularly ground-water withdrawal for the purpose of irrigation and discharges of significant quantities of waste water to the unconfined system in and around the reference repository location (see Section 2.1.4). However, insufficient data are presently available to reasonably determine if such human activities could adversely change portions of the ground-water flow system, which is important to waste isolation. Therefore, it is assumed that this potentially adverse condition could be present at the reference repository location."

Both quality data and computer models are needed to evaluate the potential suitability of a site for waste isolation. Field data are needed in order for a computer model to perform numerical simulations. Otherwise, as one commenter suggested, the model is an abstraction. The question of isolation requires an analysis of geohydrologic properties and processes existing today and the reasonable extrapolation of these into the future. One cannot solely rely on field data, or waste-isolation experiments would require thousands to tens of thousands of years to conduct. Technically sound extrapolations are prerequisite knowledge.

Understanding the geohydrologic system requires that information be collected from both surface boreholes and an exploratory shaft. (The commenter's word "borehole" is interpreted to mean the exploratory shaft.) Both types of facilities are needed to address unresolved questions (e.g., vertical hydraulic conductivity, water flow into a mine, rock stability, and subsurface fracture characteristics). As noted in Subsection 4.2.1.2.2 of the Draft Environmental Assessment, construction of the shaft facility potentially could interfere with other characterization work. Such impacts might include water-level baseline disturbance and (or) vertical interconnection between aquifers if the shaft seal is not of high quality. Suggested solutions to these possible problems were given in the referenced subsection.

Another commenter stated that hydraulic head distributions were irregular and unpredictable. The U.S. Department of Energy does not agree. The commenter is referred to Subsections C.4.1.2.2 and C.5.1.1 of this appendix for discussions on hydraulic head distributions.

Since data from both surface boreholes and the exploratory shaft are needed to address characterization issues, both types of facilities will be in operation. By conducting a properly scheduled and integrated program, interferences can be minimized or avoided.

C.5.1.7 Miscellaneous

Many comments received under postclosure geohydrology did not conveniently fall into broad classifications or were identified for separate reasons, and therefore are being treated individually or in small groupings.

Issue: Change in water table elevation due to irrigation

In the opinion of one commenter, the Draft Environmental Assessment should have contained a discussion of possible changes to the water table due "to agricultural usage or surface flows."

Response

Subsections 2.1.4.2, 3.3.1.4, and 3.3.1.5 included information pertinent to the comment. In addition, Subsection 6.3.1.8.9 addressed the potentially adverse condition on foreseeable human activities (e.g., water withdrawal or application) (DOE, 1984a; 960.4-2-8-1(c)(5)) that could change the ground-water flow system.

Issue: Quote from 1981 Hydrology Overview Committee Report

Two commenters referenced a 1980 Hydrology Overview Committee Report (Rockwell, 1981). The two sentences in question were, "There is really only one solid justification for studying this site and it is the sociopolitical fact that the land is a U.S. nuclear reservation. From a hydrogeologic perspective, the Columbia River Basalt Group as a whole is not well suited for a high-level waste repository."

Response

The above sentences express the opinion of the Hydrology Overview Committee as written in 1980 (Rockwell, 1981). Committee comments were documented after reviewing the geology and hydrology integration reports (Myers, Price, et al., 1979; Gephart et al., 1979), planning documents, and other materials requested by the committee.

Since this quote is a point of historical interest, it is important to review a fuller context of the above sentences, plus that which preceded and followed the initial issuance of the report. All of the quotes provided below can be found in Rockwell (1981).

October, 1979--Hydrology Integration Report (PI-1 and I-2)

> "The National Waste Terminal Storage Program is coordinated for the U.S. Department of Energy by the Office of Nuclear Waste Isolation. As part of this program, a number of different geologies are being studied in a number of different locations throughout the United States. One of the geologic settings being considered is the basalt underlying the Hanford Site of the U.S. Department of Energy. This site is being studied because of the present and future commitment of this land to nuclear waste management activities and because of the favorable geology of this site. The Basalt Waste Isolation Project is responsible for these studies within the National Waste Terminal Storage Program."

June 1980--Hydrology Overview Committee Report (Introduction, Section A1, and Concluding Statement Section)

> "The comments contained in this report are based on a level of understanding of the Hanford Site and ongoing investigative program obtained from the Geology and Hydrology Integration Reports, the Planning Documents of December, 1979 and May 7, 1980, and various other documents requested by members of the Overview Committee. This information has been supplemented by discussions with and presentations by Rockwell staff actually performing the work. These presentations were conducted on a highly professional basis and the Rockwell staff is to be commended for their candid and frank approach in discussing the hydrologic aspects of the Hanford Site.
>
> "With regard to these hydrologic aspects, two tasks are identified and addressed in this report. The first deals with our own preliminary hydrologic assessment of the Hanford Site. These discussions admittedly focus on the negative component of our reponse along with some serious questions that require further assessment. This is not meant to be a site suitability analysis in that we recognize that hydrology is only one part of the technical attributes of a potential repository, political, social, and engineering feasibility being others. In this section, we restrict ourselves to our respective areas of professional competence and focus only on those hydrologic conditions that are considerably less than ideal insofar as a repository location is concerned . . . .
>
> "On page I-2 of the Hydrology Integration Report, it is stated that the Hanford Reservation is under study 'because of the favorable geology of the site.' We trust that this is not a representative

attitude. There is really only one solid justification for studying this site and it is the sociopolitical fact that the land is a U.S. nuclear reservation. From a hydrogeologic perspective, the Columbia River Basalt Group as a whole is not well suited for a high-level waste repository. It may well be that with further data and/or careful engineering design it can be shown to be acceptable, but it cannot be stated that the 'geology is favorable.'

" . . . After reviewing the comments cited above, a logical conclusion might be 'reasonably good program, potentially unfavorable hydrogeology.' Although the Overview Committee is in general accord with this statement, it should be recognized that technical experts of good and equal competence and of good will might, without prejudice, arrive at very different conclusions based upon their experience and upon how risk-adverse they may or may not be . . .

"But, on a generic basis (which is not a satisfactory way of specifying a site), one would expect certain rock types to have certain inherent advantages over other rock types. Consequently, if all the other processes that go into determining the location of a repository were to be excluded, then one would try, at firt, to locate the repository within a certain rock type. Under these conditions, fractured basalt would not rank very high. However, the other conditions cannot be excluded, and, consequently, it is worthwhile, as the President has suggested, to look at a variety of rock types. But one should bear in mind that there are inherent differences between rock characteristics of the different rock types.

"At this stage of the investigation of the Columbia River basalts, the program is still within the drill hole phase of Figure 3 and, from the point of view of hydrological attributes, the envelope of confidence lies within the pessimistic region. There is one solid reason for this, namely, that "proving" the Hanford site is equivalent to "proving" the integrity of the individual basalt flow in which the repository is to be emplaced, in this case, most likely the Umtanum. That is to say, the main line of defense against radionuclide transport (other than the engineered repository) would appear to lie in the basalt flows themselves. We do not believe that such "proving" can be accomplished by drilling alone. It is unlikely that the scientific community, or the public, will be persuaded as to site suitability without a deep test facility; i.e., embarking on the exploratory shafts, tunnels, drifts, and in situ testing of the type shown on Figure 3 and espoused by Dr. P. A. Witherspoon in his letter of November 23, 1979, to Colin Heath."

<u>September 1981 (Rockwell 1981)--Rockwell Response to June 1980 Hydrology Overview Committee Report, pages IV-4 and IV-5</u>

"The Committee is referred to NRC 10CFR60, paragraph 60.122 (c) for the intended scope and meaning of the term 'favorable' as implied in regulatory guidelines and intended on page I-2 of the HIR. We are cognizant of the Committee's concern of the word 'favorable' and should have clarified it better in the HIR . . .

"We believe the Hanford Site is suitable for study as a possible waste storage site because of both land commitment and geology. Specific geologic factors favorable from a waste isolation and regulatory standpoint include flow thickness and lateral continuity, dense internal structure, geochemical stability of basalt rock with certain canister materials and a relatively stable tectonic area . . .

"In the fourth sentence of the second paragraph, page 1, the Committee states "This (the report) is not meant to be a site suitability analysis in that we recognize that hydrology is only one part of the technical attributes of a potential repository, political, social, and engineering feasibility being others. Herein the Committee recognizes the interdependence of geology, hydrology, engineering barriers, waste forms and engineering design in determining the suitability of basalt for waste isolation. This thought is reflected in 10CFR60 when it is stated 'The effect of potentially adverse human activity or natural condition is compensated by the presence of favorable characteristics in Paragraph 60.22(c) of this Section.' . . . Research is now underway to evaluate the strengths and weaknesses of the hydrogeologic environment into which a repository might be constructed. Only the integrated results of such an effort can adequately address the question of environmental isolation of radioactive wastes.

1981--Hydrology Overview Committee Response to Comments from Rockwell Hanford Operations (Section A1)

"Rockwell argues with our lack of support for their statement that the 'geology is favorable' by listing a series of favorable attributes of the site. In order for the site to have a truly favorable geology, these favorable attributes must outweigh the unfavorable attributes. No such unfavorable aspects are mentioned. It is our contention that potential site liabilities should be tacitly recognized by the hydrologists conducting the site investigation. We believe that the data demonstrates that certain liabilities do indeed exist, and are sufficiently serious so as to render many of the cited 'attributes' as secondary. We note further that we did not engage in any premature site condemnation and stated that '. . . with further data and/or careful engineering design, it (the site) may be shown to be acceptable.' But it cannot be stated that the 'geology is favorable.'"

Summary

There are several conclusions that outline the principal thoughts contained in the above quotes.

- The term "favorable geology" should have been better clarified in the 1979 hydrology integration report (Gephart et al., 1979) to reflect the intended meaning of the report as established by rules and regulations of the U.S. Nuclear Regulatory Commission (NRC, 1983a). These regulations address "favorable" and "potentially adverse conditions" which later evolved into the U.S. Department of Energy General Siting Guidelines (DOE, 1984a). "Favorable geology" was not intended to mean "without weakness or uncertainty."

- The site geology has favorable and unfavorable attributes, the interpretation of which is open to honest differences of judgment.
- Hydrologic investigations to resolve technical questions require the use of surface boreholes and an exploratory shaft facility.
- Hydrology is one of many considerations in selecting a suitable repository site.
- The hydrology overview comments were not meant to be a site-suitability analysis but rather opinions on hydrologic conditions.

The U.S. Department of Energy agrees with the above summary statements. The Draft Environmental Assessment accommodates many of the concerns expressed by the above quotes from the Hydrology Overview Committee report (Rockwell, 1981). These involve items such as acknowledging data strengths and weaknesses, recognizing the interdisciplinary nature of waste-isolation questions, and planning an integrated surface borehole and underground facility exploratory program.

The U.S. Department of Energy does not agree with the 1980 Hydrology Overview Committee statement that land ownership is the only basis for pursuing repository studies on the Hanford Site. Land ownership is only one of the many site-selection factors in the General Siting Guidelines (DOE, 1984a). Chapter 7 of the Draft Environmental Assessment detailed the U.S. Department of Energy opinion relative to the favorable and potentially adverse conditions of locating a repository on the Hanford Site.

Issue: Reliance on hydrologic testing

One commenter raised two points:

- The analysis and performance of large-scale hydraulic tests "may have" to be developed beyond current state-of-the-art technology. The phrase "developed saturated flow hydraulic theory" (see Subsection 6.3.1.1.5 of the Draft Environmental Assessment) might require revision.
- The U.S. Nuclear Regulatory Commission citation in the same subsection regarding reliance on direct hydraulic testing of the basalt site may have been taken out of context--" . . . however, if cited, the Nuclear Regulatory Commission draft Site Technical Position should be correctly referenced as 'draft.'"

Response

The word "developed" was not intended to imply that all analysis tools possibly needed for evaluation of large-scale tests were available, but rather that the basic theory of test conductance and analysis is an established science. This clarification is necessary in order to make a distinction between hydraulic testing in the saturated environment beneath the Hanford Site and geologies where even the basic test approach to measuring critical hydraulic parameters is more complex or not known to exist. To eliminate confusion, the word "developed" has been deleted.

The U.S. Nuclear Regulatory Commission quote is considered appropriate to the topic discussed. The word "draft" will be added to the U.S. Nuclear Regulatory Commission reference (NRC, 1983a).

Issue: Likelihood of site characterization

Reference was made by one commenter to the sentence in Subsection 6.3.1.1.5 of the Draft Environmental Assessment that read: "Although the specifics of this understanding will change as data are collected, the principals involved believe that the reference repository location has a high likelihood of being characterized." The commenter stated, " . . . the NRC has not taken a position on the likelihood of the site being characterizable."

Response

As used in the context of the paragraph in quesion, the word "characterized" implied development of an adequate data base to evaluate the ground-water flow system. This appears consistent with the U.S. Nuclear Regulatory Commission statement (NRC, 1983a, page 12), "The hydraulic testing strategy that is described in this document is not necessarily the only approach that would lead to an acceptable hydraulic data base and performance assessment." Nevertheless, a word change has been made without losing the intended meaning.

Subsection 6.3.1.1.5 has been reworded to eliminate the connotation that the U.S. Nuclear Regulatory Commission supports characterization likelihood. Instead, data base development is emphasized.

Issue: Geochemistry and solubility discussion in geohydrologic disqualifying condition write-up

One commenter stated that the discussion of geochemistry and radionuclide solubility in Subsections 6.3.1.1.11.2 and 6.3.1.1.11.3 of the Draft Environmental Assessment did not appear to relate to the disqualifying condition discussion of ground-water travel time.

Response

The discussion focus in Subsection 6.3.1.1.11 was on ground-water travel time and the achievement of this condition without credit for solubility. However, the disqualifying statement included the phrase "along any pathway of likely and significant radionuclide travel." Thus, it was considered appropriate to include a short discussion on radionuclide solubility and accompanying uncertainty so that the reader would have a more complete treatment of all issues raised by the disqualifying statement itself. Radionuclide sorptive characteristics and waste-form solubilities are critical factors in determining solute migration within a ground-water system.

Issue: Geochemistry discussion in geohydrology qualifying condition writeup

One comment concerned the topic of geochemistry being cited as a contributing factor in meeting the qualifying condition under geohydrology (DOE, 1984a; 960.4-2-1(a)) (Subsection 6.3.1.1.12). The commenter stated, " . . . the qualifying condition deals with geohydrology, not geochemistry."

Response

The qualifying condition dealt with a wider range of topics than did the five favorable conditions, three potentially adverse conditions, and one disqualifying condition identified. It also entailed information on geochemistry, radionuclide transport and releases from the material and engineered barrier system, and geologic setting. Therefore, the inclusion of geochemical information in responding to the qualifying condition was both appropriate and necessary. For reference, the entire qualifying condition, as given in Subsection 6.3.1.1.1 of the Draft Environmental Assessment, is quoted below:

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

Issue: Statement about geohydrology qualifying condition

A summary statement by one commenter referenced several of the commenter's previous concerns relative to the conclusions on the qualifying condition under geohydrology (DOE, 1984a; 960.4-2-1(a)). In short, the commenter stated that consideration of the following four points "seems appropriate before making a finding on the presence of this qualifying condition."

1. There is reasonable doubt about a 10,000-year ground-water travel time to the accessible environment.

2. The statement in the second bullet of Subsection 6.3.1.1.12 seemed to contradict the previous statement in Subsection 6.3.1.1.5 regarding ease of site characterization and modeling.

3. Hydraulic gradients may be higher or lower than 10^{-4} depending on the well pair used.

4. Human- and repository-induced changes could affect deep hydrogeologic system. These concerns were not expressed in Subsection 6.3.1.1.8.

Response

The following responses correspond to the items listed in the above issue statement.

1. The 10,000-year ground-water travel time for the first favorable condition appears to be met based on available information. Refer to Section C.5.11 of this appendix for details.

2. The statements noted were in agreement. In Subsection 6.3.1.1.5 it was stated:

   "This favorable condition does not appear to be present because the reference repository location and surrounding geohydrologic system are not expected to be easily (readily) characterized and modeled. A program has been developed with the U.S. Nuclear Regulatory Commission and is being implemented to investigate the reference repository location with the confidence needed for repository licensing." The second bullet in Subsection 6.3.1.1.12 reads, "The geohydrologic system is expected to be characterized and modeled with the required confidence needed for licensing decisions."

   (The above-referenced sections both state that site characterization will not be easy but it is believed that the certainty needed for making licensing decisions is achievable.)

3. A lateral hydraulic gradient of 10^{-4} appears appropriate using wells within the Cold Creek syncline for reference. Refer to issue on hydraulic heads, hydraulic tests, and hydraulic properties under Subsection C.5.1.1 of this appendix for details.

4. The commenter has mixed different guidelines that individually deal with natural (see Subsection 6.3.1.1.8 of the Draft Environmental Assessment) versus human- or repository-induced changes (see Subsections 6.3.1.8.9 and 6.3.1.3.6).

Issue: Use of professional judgment and the need for high quality data

Two reviewers questioned whether or not "substantial interpolation and judgment" is a valid method in developing a realistic model." The commenters expressed the need to reduce data uncertainty, understand regional ground-water flow, ensure "good data acquisition," and ensure quality control of ground-water sampling and analysis.

Response

The U.S. Department of Energy agrees with each of the above comments, as reflected in the philosophy and content of the Draft Environmental Assessment. Interpolation and judgment will always be part of model development regardless of data available. The degree of such technical subjectivity depends on the problem being addressed, data abundance, and complexity of the geohydrologic system.

Issue: Quote from Wilson and Kanehiro report

One commenter quoted from Wilson and Kanehiro (1983), "It should be recognized that no hydrologic model can directly address all of the uncertainties." The commenter stated, "The EA reports that geohydrologic favorable condition b,2 (p. 7-6) is not present. Wilson and Kanehiro imply that no model can directly address the uncertainties. Thus, this would indicate that further characterization and modeling effort would be useless."

Response

The above quote from Wilson and Kanehiro (1983) was taken out of context and an unsupported conclusion was drawn.

The title of the Wilson and Kanehiro (1983) report is "Updated Recommendations for Standard Problems and Sensitivity Studies for Modeling the Groundwater System in the Pasco Basin." As the title itself implies, the report centered on developing realistic hydrologic models and sensitivity studies. "In this way, the preliminary model can be used as a vehicle for achieving consensus on the hydrologic behavior of the Pasco Basin" (Wilson and Kanehiro, 1983, p. 1, par. 2). The report outlined work priorities, data base classifications, available data base information, modeling approaches, and other considerations for developing a regional ground-water numerical model. Nowhere did the report suggest that "further characterization and modeling effort would be useless."

In fact, the Wilson and Kanehiro report suggested just the opposite. For example the last paragraph of the report (p. 45) reads:

> "The sensitivity studies will help identify major uncertainties in our understanding of groundwater movement within the study area, clarify the significance of uncertainties associated with the input parameters, and guide the effort required for resolution. In most cases, additional information will be required to resolve significant uncertainties. The types of information required, and the most advantageous locations of measurement, should be indicated by the

> results of the studies. The methods adopted to obtain the required information may be varied. They include well surveys, geophysical studies, borehole drilling, hydrochemical studies, and hydrological testing. The decision to implement this work should be based upon the importance of resolving the identified uncertainties to demonstrating the suitability of the site for nuclear waste disposal."

It also is important to present the entire paragraph from page 2 of the report from which the commenter selectively quoted.

> "It should be recognized that no hydrologic model can directly address all of the uncertainties raised by the Working Group. Uncertainties related to field measurement techniques, vertical hydraulic gradients, use of hydrochemical data to interpret groundwater flow patterns, and the assumption that groundwater in the Pasco Basin is in steady state will probably require additional field data for resolution."

As can be seen in the paragraph, uncertainties relate to a wide range of questions involving much more than numerical modeling simulation, including field measurement techniques, data interpretations, and hydrochemical data. Of course, no model can handle all such questions; each is dealt with individually by an appropriate combination of data, technical consensus, and (or) numerical simulation. The commenter is also referred to the last words in the Wilson and Kanehiro (1983) report: " . . . will probably require additional field data for resolution." The word "resolution" connotes finding answers through data collection and modeling.

Thus, nowhere in the report is it suggested that "further site characterization and modeling effort would be useless." In fact, the opposite is supported (i.e., further field measurements and modeling will resolve significant uncertainties).

Issue: Vertical interconnection in ground-water system

The possibility of vertical interconnections occurring in the ground-water system concerned two commenters. The logic followed was generally " . . . the head data in well DC-20 . . . show evidence of a strong interconnection between the Cohasset (sic) and Rocky Coulee flow tops . . . RHO stated . . . that they believe the interconnection to be due to rock character . . . Although this does not constitute a legitimate sampling population . . . it does demonstrate the real possibility that a vertical pathway may provide the most direct access to the accessible environment." The commenters concluded that " . . . vertical connection possibilities in the system, as well as the complex heterogeneities in the flow tops, must be assessed."

Response

The commenters were correct in noting the Rockwell Hanford Operations interpretation of the borehole DC-20 hydraulic head data. As stated in Sections 3.3.2 (Ground water) and 4.1.1 (Field studies) and Subsection 6.3.1.1.11.3 (Reducing data uncertainty) of the Draft Environmental Assessment, an evaluation of vertical flow interconnections and flow-top permeabilities will be essential activities during site-characterization research. The U.S. Department of Energy agrees with the commenters that data from boreholes DC-19, DC-20, and DC-22 " . . . does not constitute a legitimate sampling population from which any probabilistic judgments could be made . . . ." If a vertical pathway does exist, such "may provide the most direct access" to the accessible environment. This is one of several reasons why extensive geohydrologic research of the reference repository location and vicinity is planned should the reference repository location be recommended for site characterization.

Issue: Potential for increased rock hydraulic conductivity

Two commenters stated, "The EA should also address the potential for increased hydraulic conductivity caused by increased rock fracturing from glacial activity, rock mass yielding, and microearthquake swarms."

Response

These processes were accounted for under selected tectonic favorable and potentially adverse conditions discussed in Subsection 6.3.1.7 of the Draft Environmental Assessment.

Issue: Preliminary nature of existing geohydrology data base

Two reviewers made a variety of statements such as the existing data base is not sufficient to form defensible conclusions regarding ground-water travel times or directions (or may not be sufficient even after site characterization). Also, major problems were said to exist in determining an acceptable conceptual model, acquiring reliable hydrologic data, and choosing a numerical modeling technique.

Response

The U.S. Department of Energy agrees that the existing data base is insufficient to form defensible final conclusions. This was stated throughout the Draft Environmental Assessment and is the reason a site-characterization program is planned. The U.S. Department of Energy believes that the available hydrologic data base is good, and acceptable conceptual models have been and will continue to be developed. The statement regarding choice of numerical modeling techniques "that must be resolved" is unclear. In addition, it is believed that following site-characterization research, the ground-water flow system will be sufficiently understood to make reasonable estimates of ground-water travel times and flow directions.

Issue: Repository effect on water table and irrigation

A commenter asked if siting the repository would have any effect on the water table. Another commenter was concerned that repository siting might affect ground-water extraction for irrigation from the upper basalts.

Response

It is assumed that "effect" relates to water-level elevation change. Outside the immediate geographic area of repository construction, no major water-level rise or fall is expected.

Repository siting is not expected to affect irrigation practices in the shallow basalts. For example, hydraulic head changes due to shallow water irrigation in the Cold Creek Valley apparently are not transmitted across the Cold Creek barrier and into the reference repository location. The barrier forms a hydraulic impediment between the proposed repository site and the closest irrigated lands. East and north of the Columbia River, irrigation in the Columbia Basin Irrigation Project should not be affected due to the distance from the reference repository location, repository depth, and the fact that site-characterization research (e.g., borehole and shaft drilling) will not result in large water productions.

Issue: Characterization confidence

One commenter made two statements and posed one question:

- Characterization with confidence "will be difficult, time consuming, and costly."
- "The combination of values of low horizontal gradient with hydraulic conductivities of interiors is misleading since it was stated earlier that flow in interior zones is vertical."
- What confidence is required for characterization?

Response

In response to the first statement, see response in Subsection C.5.1.5 of this appendix.

The second statement is unclear. The second bullet in Subsection 6.3.1.1.12 of the Draft Environmental Assessment lists three separate flow-system characteristics not necessarily dependent on each other.

In response to the third statement, the confidence required presently is unspecified for any geologic medium. It is expected that this will be clarified as the Civilian Radioactive Waste Management Program proceeds into licensing. Perhaps part of the answer to knowing what confidence is required was touched on in a report by Peck (1985, p. 3) of the

U.S. Geological Survey, which stated, "When the process has proceeded far enough for modeling effects to yield verifiable future predictions, the characterization process can be considered adequate."

Issue: Thermal gradients

One commenter asked in what manner the topic of thermal gradients was addressed in the Draft Environmental Assessment, and stated that thermal gradients were not mentioned on page 3(ii), 3-72, or 6-76.

Response

Thermal gradients were not discussed on the referenced pages because those pages addressed the natural ground-water flow system, excluding the effects of human interference or thermal loading. Thermal effects were treated in Subsection 6.3.1.3.6 (Postclosure conditions for rock characteristics).

Issue: Acknowledging unknowns in geohydrologic data base

According to one commenter, page 6-68, paragraph 3, sentences 2 and 3 of the Draft Environmental Assessment were misleading because so little data on spatial permeabilities, heat gradients, and effective porosity are known, some information has not been measured, and a reasonable ground-water flow model is not yet developed.

Response

The paragraph in question (see Subsection 6.3.1.1.5) adequately addressed, in broad terms, the knowns and unknowns of the geohydrologic data base. For clarity, the entire paragraph should be read. A majority of the paragraph is quoted below.

> "Knowledge of the subsurface hydrology of the reference repository location and vicinity is less advanced than the knowledge of geology. As addressed in Section 3.3.2, reconnaissance testing has already identified preliminary hydraulic properties of basalt flow tops, flow interiors, and sedimentary interbeds, as well as broad hydraulic head distributions. In addition, a range of reasonable conceptual ground-water flow models has been developed. Because of the preliminary nature of available hydrologic information, a large uncertainty is associated with the data. For this reason, several data-gathering activities have been completed/planned, such as the installation of additional piezometers, large-scale pumping (stress) tests, more tracer testing, and an Exploratory Shaft Program (see Section 4.1). . ."

Issue: Data uncertainty and past criticism

It was stated by one commenter that the presentation of permeability values in the last paragraph on page 6-71 was made without the necessary qualifying remarks. Also, "this entire set of data has been severely questioned in the U.S. Geological Survey review of the site-characterization report and during the followup visit to Hanford in June 1983."

Response

The commenter is referred to the last sentence in the paragraph under question that stated "the general uncertainties of these numbers are addressed in Subsection 3.3.2.1." This subsection was given for cross-reference.

The commenter also is referred to the issues and responses in Subsection C.5.1.2 of this appendix, which addressed a variety of topics including possible interference of drilling muds with test results and variability of calculated hydraulic conductivities due to application of different analytical interpretations. It is believed that this subsection adequately addresses the commenter's concern relative to past criticism of data. In addition, numerous U.S. Geological Survey and U.S. Nuclear Regulatory Commission technical discussions were held with the U.S. Department of Energy during the last 2 years to address questions of data validity.

In recent correspondence between the U.S. Geological Survey and a House of Representatives Subcommittee on the topic of past critical reviews of U.S. Department of Energy plans, the U.S. Geological Survey stated, " . . . present investigative plans should address adequately the issues raised both by the USGS and the report 'Heat, High Water and Rock Instability at Hanford'" (Peck, 1985). (The U.S. Geological Survey critique was written by Robertson (1983) and the report title given above is from Makhijani and Tucker (1985).)

Issue: Conclusions given in geohydrology qualifying condition

One commenter referred to Subsection 6.3.1.1.12 of the Draft Environmental Assessment and stated, "Based on previous comments, the major conclusions are believed to be too positive and in some cases inaccurate."

Response

Overall, the conclusions given in Subsection 6.3.1.1.12 were considered neither too positive nor inaccurate, and as the first sentence in the subsection stated, "A final conclusion on the qualifying condition for geohydrology cannot be made based on currently available data." It should be noted that previous pages identified many data uncertainties underlying conclusions drawn; therefore, the preliminary conclusions given appear properly positioned in light of unknowns.

Issue: Concern over statement on extensiveness of existing data base

One reviewer commented, "The statement that an extensive data base exists on which to base major conclusions given on pages 6-85 and 6-86 seems very inappropriate. In fact, little is known about the spatial values that are needed to characterize the site with regard to ground-water flow rate and direction. The general lack of data is actually identified later in the same paragraph in the last half of page 6-86 in which specific uncertainties are listed."

Response

The commenter apparently has quoted the Draft Environmental Assessment out of context. The specific quote from Subsection 6.3.1.1.12 of the Draft Environmental Assessment is, "The above statements are based on an extensive, though preliminary, data base, and a general understanding of ground-water movement in and around the reference repository location that remains to be confirmed. Uncertainties are identified in the data sections of this environmental assessment, as well as in the guideline evaluation section of Chapter 6 and the performance assessment (Section 6.4.2) . . . " Therefore, the context of the whole quote was correct

Issue: Statement on basalt permeability, geochemistry, and volcanic potential

One commenter stated that although basalt has great strength, it lacks the low permeability required for long-term isolation. This factor raises questions about the statement " . . . the likely geochemical reactions between the basalt rock, ground water, and the materials that would be placed in the repository are favorable for long-term isolation . . ." (see p. 1-11 of the Draft Environmental Assessment). This is especially true, the commenter continued, if the assumption of a low volcanic potential is questionable.

Response

This comment covers a wide range of topics; each will be briefly addressed. Available data on basalt flow-interior permeability suggest these intrabasalt features do have low permeabilities--on the order of 10^{-11} meter per second (10^{-6} foot per day) or less (see Subsection 3.3.2.1.1 of the Draft Environmental Assessment). In addition, many Grande Ronde Basalt flow tops also have low permeabilities. An interesting indication of the low permeability of selected Grande Ronde Basalt flow tops is the very slow water-level recovery in the deep piezometers at wells DC-19, DC-20, and DC-22 (see Yeatman and Bryce (1984a, 1984b), referenced in the Draft Environmental Assessment). While shallow water levels quickly recovered from testing and drilling, water levels in the Grande Ronde Basalt piezometers were still recovering more than a year after emplacement. This and other data suggest the existence of a ground-water system comprised of low-permeability aquitards separated by even lower permeability aquicludes. Since uncertainty exists in the quantification of flow-interior permeabilities and large-scale flow top permeabilities, an extensive field-test program is planned (see Subsections 4.1.1.3 and 4.1.1.6.3 of the Draft Environmental Assessment).

Subsection 6.3.1.2 (Postclosure geochemistry) detailed the geochemical environment within and surrounding the proposed repository. This included discussions on geochemical processes and conditions expected to promote radionuclide retardation. Both strengths and weaknesses of the existing data were recognized. The overall conclusion was that basalt appears to offer an exceptional geochemical environment for waste isolation.

A summary of the volcanic and tectonic processes operating within and near the Columbia Plateau was included in Subsection 6.3.1.7.4 of the Draft Environmental Assessment. As discussed therein, the Columbia Plateau is considered to have been volcanically inactive for nearly the last 2 million years (over Quaternary Period). This lack of activity is expected to continue.

Therefore, available information suggests the reference repository location has favorable geochemistry and zones of low permeability, which can be conducive to long-term isolation.

The reference repository location is set in a geologic framework of inactive volcanism. Therefore, a low potential for volcanic activity exists.

Issue: Presence of aquifers as a concern in repository site selection

One commenter said that according to the Draft Environmental Assessment, the presence of aquifers is not conducive to siting a repository.

Response

The U.S. Department of Energy agrees with the commenter's statement. In applying the siting guidelines and comparing strengths and weaknesses of different geologic settings, credit was not taken by the Hanford Site or by seven of the other candidate sites for the presence of aquifers (see Subsections 6.3.3.3.3 and 7.3.3.1.3 of the Draft Environmental Assessment). Only the Yucca Mountain site in Nevada is located above the water table and therefore does not have aquifers lying between the land surface and the proposed repository depth.

Issue: Hanford Site suitability

One reviewer stated another branch of government had completed a study that determined the Hanford Site was unsuitable for a repository because of the "Columbia aquifer."

Response

The term "Columbia aquifer" is interpreted to mean aquifers within the Columbia River basalts. Also, the branch of government addressed is interpreted to be the U.S. Geological Survey, and the report is interpreted to be by Robertson (1983).

In 1983, the U.S. Geological Survey issued an analysis of the U.S. Department of Energy site-characterization report (DOE, 1982). Comments focused on earth-science issues such as geohydrologic data availability, interpretation, and uncertainty, but did not address suitability or nonsuitability of basalt for waste isolation. This is a U.S. Department of Energy responsibility as addressed by the Draft Environmental Assessment.

The question of the suitability of a site for waste isolation can only be answered with extensive field-collected data. This is reflected by recent statements by the U.S. Geological Survey, " . . . the issue of the geologic suitability of the Hanford Site is complex, just as it is for all of the sites being considered . . . The process laid out in the Nuclear Waste Policy Act requires sites to be nominated for characterization, and DOE is now at that stage in the process. The answer to the questions concerning geologic and hydrologic suitability can only be answered by the characterization process itself . . . " (Meyer, 1985).

The presence of aquifers in the Columbia River basalts was discussed in the Draft Environmental Assessment and is considered an unfavorable condition (e.g., see Subsection 6.3.3.3.3).

Issue: Concern over underestimating three long-term hazards

The evaluation summary against postclosure guidelines (see Section 6.2 of the Draft Environmental Assessment) neglected or underestimated several problems with long-term hazards, according to one commenter. These are unknown vertical ground-water flow characteristics, candidate horizons located below unconfined and confined aquifers, and poorly understood ground-water travel times and aquifer discharge.

Response

There appears to be some confusion over the location of certain information in Chapter 6 of the Draft Environmental Assessment. Section 6.2 contained evaluations against guidelines that do not require site characterization. Section 6.3 addressed guidelines that do require characterization. Therefore, Section 6.3, specifically Subsections 6.3.1.1 and 6.3.3.3, addressed data knowns and unknowns on the topics of vertical ground-water movement and hydraulic conductivity, repository siting relative to overlying aquifers, and ground-water travel times.

Issue: Presence of aquifers and long-term rock deformation

One commenter expressed concerns that basalts are geologically unstable, and that the Hanford Site has aquifers that discharge into the Columbia River.

Response

The basalts are not considered geologically unstable. The Columbia Plateau is considered to have been volcanically inactive during the Quaternary Period (approximately the last 2 million years), and the long-term, low average rate of deformation of the central Columbia Plateau is not expected to affect waste isolation (see Subsection 6.3.1.7.3 of the Draft Environmental Assessment).

The presence of aquifers between the proposed candidate horizons and land surface was discussed in the Draft Environmental Assessment (see Subsection 6.3.3.3.3). Such horizons of high permeability were identified because a repository would not be constructed within or adjacent to an area that could become an avenue for contaminant release and rapid movement.

Issue: Modeling confidence discussion in third favorable condition under geohydrology

One commenter stated that although Subsection 6.3.1.1 of the Draft Environmental Assessment admitted uncertainty exists in defining the hydrologic regime, it still concluded "the geohydrologic system is expected to be modeled with the required confidence needed for licensing decisions" and "the median ground-water travel time to the accessible environment is estimated to be in excess of 10,000 years." The commenter further stated that these conclusions contradicted judgments of other observers, and quoted the U.S. Geological Survey:

> "We do not believe that the hydraulic conductivity, head gradient, and effective porosity data are sufficient or reliable enough to allow velocity calculations to be made with an accuracy of greater than about 2 or 3 orders of magnitude . . . Overall, the (hydrologic) system appears to be very leaky . . . "

Response

The above comment raises several points that will be individually addressed. First, the U.S. Department of Energy agrees that Subsection 6.3.1.1 identified uncertainties in the geohydrologic data base. Throughout the Draft Environmental Assessment, data strengths and weaknesses were acknowledged. Unresolved questions on critical hydrologic issues can only be answered through a technically sound characterization program involving surface and subsurface exploration. In recognition of these data uncertainties, it is important to note that ground-water travel times presented in the Draft Environmental Assessment (see Subsections 6.3.1.1.3, 6.3.1.1.11, and 6.4.2.3.5) were also acknowledged to be uncertain. Notice in Figure 6-22, the range of travel time uncertainty (from approximately 1 to 100 percent cumulative probability) varies over six orders of magnitude. Travel times, as defined, range from approximately 100 to 1 million years with a median travel time estimated to be 81,000 years. Thus, the conclusions of the Draft Environmental Assessment did not contradict the quote referenced from the U.S. Geological Survey report (Robertson, 1983) (refer to Subsection C.5.1.6 of this appendix for more discussion of the Robertson (1983) quote). In fact, taken at face value, the range of travel times given in the Draft Environmental Assessment may be magnitudes more conservative than suggested in Robertson (1983). Nowhere in the Draft Environmental Assessment was it proposed that ground-water travel times are known; rather it was emphasized that much additional data collection and monitoring are required to adequately define basalt hydraulic conductivity, effective porosity, and hydraulic gradients.

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Second, Robertson (1983) did state "overall, the system appears to be very leaky" (p. 13). This was followed by a qualitative evaluation of the term:

> "Application of surface water on the unconsolidated deposits in the Columbia Basin Irrigation Project area of the Pasco Basin has resulted in water level increases of over 300 feet in the Saddle Mountains Basalt and 200 feet in the Wanapum Basalt. Increases of over 100 feet in both formations have occurred throughout large areas in other parts of the Columbia Basin Irrigation Project as a result of surface water irrigation. These results and other studies by the U.S. Geological Survey document the 'leaky' nature of the basalts." (pp. 13 and 14)

The above statement leaves the term "leaky" unquantified and undefined. It is assumed that use of the term was intended to establish a relative indication of vertical hydraulic conductivity. To this end, the U.S. Department of Energy has examined some available U.S. Geological Survey open-file reports and studies done in cooperation with the State of Washington Department of Ecology (Tanaka et al., 1974; Luzier and Burt, 1974; Luzier and Skrivan, 1973; MacNish and Barker, 1976). The vertical hydraulic conductivity values reported tend to fall within the range commonly assumed by the U.S. Department of Energy. For example, Tanaka et al. (1974) for the Columbia Basin Irrigation Project and MacNish and Barker (1976) for the Walla Walla River Basin report values of 3×10^{-12} to 1×10^{-10} meter per second (1×10^{-6} to 3.7×10^{-5} foot per day) and values as high as 1×10^{-8} meter per second (4×10^{-3} foot per day), respectively. The values reported in the Draft Environmental Assessment were within this range of vertical permeabilities estimated by independent modeling simulations. The representativeness of the above estimates will be examined during large-scale hydraulic stress tests and research conducted within the exploratory shaft test facility, should the reference repository location be recommended for characterization.

The vertical hydraulic conductivity values noted above are derived from numerical model studies. No such field-measured values are known to exist; however, the U.S. Department of Energy currently is planning the first field vertical permeability tests in the Columbia Plateau basalts. If other organizations have conducted such large-scale tests across a basalt flow interior, the U.S. Department of Energy would welcome the opportunity to closely examine the well construction, test results, and analysis details.

In adequately interpreting the cause for water-level rises in basalts resulting from water application, it is important to consider the full range of contributing factors, including vertical leakage through or across basalt flow interiors, well casings, open holes, and geologic structures. For example, water leakage across basalts, along well casings, and especially within the many open holes existing in heavily irrigated regions of the Columbia Plateau can significantly contribute to water-level rises (see issue on hydraulic conductivity measurement in vertical boreholes in Subsection C.4.1.2.2 of this appendix). Unless such effects are specifically subtracted from any modeling evaluation of "natural basalt leakage," the results will be inaccurate.

Third, the U.S. Department of Energy stands behind the statement, "The geohydrologic system is expected to be characterized and modeled with the required confidence needed for licensing decisions" (see Subsection 6.3.1.1.12). The commenter is referred to Subsection 6.3.1.1.5 for rationale addressing the referenced statement.

Issue: The Vantage interbed, short ground-water travel times, and technological fixes

Included in one comment were a number of interwoven concerns and concepts:

1. The Draft Environmental Assessment did not consider three-dimensional flow paths or the presence of the Vantage interbed, which forms an excellent ground-water conduit.

2. It is estimated that because of ground-water travel times, waste could reach the river in a matter of weeks.

3. The installation of pumps to remove contaminated water is a technological fix. There is no way of assuming pump operations would continue for thousands of years.

Response

The following responses correspond to the items listed in the above issue statement.

1. The Draft Environmental Assessment did address three-dimensional ground-water flow. Such a concept is a fundamental aspect of ground-water movement. The commenter is referred to the issue on flow patterns under Subsection 4.1.2.2 and to Subsection C.5.1.1 of this appendix for discussions on this topic.

   Beneath the Hanford Site, the Vantage interbed does not act as an aquifer, because locally, the interbed is mostly thin or absent, and where present, consists of low-permeability clays and silts. The concept of a water-productive Vantage interbed is correct when applied to the western portion of the Columbia Plateau. There, the Vantage sediments are commonly sands and gravels.

2. The concept that waste moving with ground water could reach the Columbia River in a matter of weeks is unfounded. Based on preliminary information, likely ground-water travel times are thousands to tens of thousands of years (see Subsections 6.3.1.1.3 and 6.3.1.1.11 and Section 6.4.2 of the Draft Environmental Assessment). Radionuclide transport along these flow paths would be even slower due to the natural sorptive (retardation) capacity of the basalt rock and secondary minerals infilling fractures

(see Subsection 6.3.1.2). A discussion of radionuclide releases from a repository and the meeting of release limits was included in Section 6.4.2 of the Draft Environmental Assessment.

3. The U.S. Department of Energy does not intend to use water pumps as a "technological fix" to permit selection of a site otherwise unsuitable for long-term waste isolation. Such a concept was not stated or implied in the Draft Environmental Assessment. The suitability of a site for repository development must be determined according to the waste-isolation capability of the local geology rather than engineered design.

A discussion of the Vantage interbed and the interbed hydrologic characteristics has been included in Section 3.3.2 of the final Environmental Assessment.

Issue: Rock stresses and ground-water flow patterns

One commenter made two assertions: the first stated basalt is subject to "extreme stresses"; the second emphasized that basalt structures would produce unfavorable ground-water patterns.

Response

At repository depth, in situ rock stresses are considered to be within design and safe-operating limits. Subsection 6.3.3.2.10 of the Draft Environmental Assessment discussed rock characteristics as applicable to repository construction, operation, or closure. It stated:

"Available geomechanics data from laboratory, field, and in situ testing, and from case history studies of underground construction projects similar to that expected at the basalt site, suggest that the effects of potentially hazardous conditions on the construction, operation, and closure of a repository are not expected to cause significant risk to the health and safety of personnel. This takes into account mitigating measures that use reasonably available technology."

While the comment that basalt structures produce unfavorable ground-water patterns is not clearly understood, Section 6.4.2 of the Environmental Assessment contains information on ground-water travel time that might assist the commenter.

Issue: Uncertainties given under geohydrology qualifying condition

One commenter stated that the uncertainties listed after the conclusions in Subsection 6.3.1.1.12 of the Draft Environmental Assessment tended to downgrade the conclusions, specifically relative to ground-water travel times and geologic discontinuities.

Response

Conclusions written for qualifying conditions were designed to provide the reader with an outline of support findings and associated uncertainties to remind the reader that some siting guideline findings are preliminary and should not be taken as conclusionary statements. Though this treatment may give the impression of downgrading conclusions, it is nevertheless important to emphasize unknowns.

Issue: Influences on ground-water flow characteristics

One reviewer noted there are many influences on ground-water flow characteristics that are variables and considered uncertain. Some of these include gas, oil, and ground-water withdrawal, plus geologic movement and surface-water application from expansion of the Columbia Basin Phase II irrigation program.

Response

The U.S. Department of Energy agrees with the commenter. These types of influences were included in discussions under Subsection 6.3.1.1.8 for natural (e.g., geologic) geohydrologic system changes and Subsection 6.3.1.8.9 for man-induced (e.g., water withdrawal or application) influences. Because of uncertainty of these influences, the Draft Environmental Assessment stated:

> " . . . insufficient data are presently available to reasonably determine if such human activities could adversely change portions of the ground-water flow system, which is important to waste isolation. Therefore, it is assumed that this potentially adverse condition could be present at the reference repository location . . . " (p. 6-144)

Issue: Geohydrologic concerns includin~ ~eochemistry, ground-water flow, travel times and site complexity

One commenter listed a variety of topics.

1. The U.S. Department of Energy "consciously ignored geochemical data which indicates excessive vertical movement of the ground water."

2. Ground-water flow in the Pasco Basin is three-dimensional.

3. The U.S. Geological Survey states the whole basalt system is "leaky."

4. Vertical ground-water travel times increase the possibility of waste moving faster than the horizontal paths assumed.

5. Basalts are so complex and heterogeneous, analysts have stated that 20 years of study would be insufficient to determine critical parameters.

Response

The following responses correspond to the items in the above issue statement.

1. The statement that the U.S. Department of Energy ignored geochemical data is untrue. For example, a few quotes from Section 3.3.2 of the Draft Environmental Assessment are given below.

   The last paragraph addressing ground-water chemistry (p. 3-81) states:

   "Some locations of potential mixing of ground waters have also been identified using these data. However, the rate of any mixing is unknown."

   The second-from-last paragraph in the section (p. 3-82) states:

   "However, it is recognized that over broad regions, ground-water movement (even across basalt flow interiors of apparently low hydraulic conductivity) can be an important consideration in understanding flow dynamics and geochemical evolution. Future geochemical modeling is directed toward evaluating hydrochemical zonations."

   Subsection 3.3.2.2, second-from-last paragraph reads:

   "There has been controversy concerning what constitutes the details of a conceptual model for basalt (NRC, 1983). However, in a broad sense, the layered geology at the reference repository location consists of alternating basalt flows containing high-to-low conductivity intraflow units. Such heterogeneity forces essentially rectilinear ground-water movement to occur with lateral movement in flow tops and interbeds (potential aquifers) and vertical movement across flow interiors (aquitards). The U.S. Department of Energy believes this to be the overall conceptual model of which details remain to be quantified during site characterization (see Section 4.1). Such details would specify a model having little vertical leakage across undeformed flow interiors (see Concept A in Fig. 3-37) or pronounced leakage (see Concept C in Fig. 3-37). The role of leakage along structural discontinuities (see Concepts B and D in Fig. 3-37) also would be addressed during site characterization."

   Because additional hydrochemical data have been reported since issuance of the Draft Environmental Assessment, several new paragraphs have been added to Section 3.3.2 of the final Environmental Assessment.

2. It is agreed that ground-water flow is three-dimensional. This concept was carried within the geohydrology discussions of the Draft Environmental Assessment. Refer to Subsections C.4.1.2.2.1

and C.5.1.1 of this appendix for expanded discussions on this topic as well as cross-references to Draft Environmental Assessment text.

3. Refer to the issue on modeling confidence discussion in third favorable condition under geohydrology, in this appendix subsection, for a discussion of the term "leaky" as used in the U.S. Geological Survey critique (Robertson, 1983) of the site-characterization report (DOE, 1982b). In summary, the term "leaky" was undefined in Robertson (1983), and vertical hydraulic conductivity values generated by the U.S. Geological Survey in numerical model studies are generally comparable with values used by the U.S. Deparment of Energy. The first hydrologic tests conducted in the Columbia Plateau specifically addressing the question of vertical hydraulic conductivity of basalt flow interiors are being planned by the U.S. Department of Energy in consultation with the U.S. Geological Survey and the U.S. Nuclear Regulatory Commission.

4. If vertical hydraulic conductivity values for basalt flow interiors are larger than flow-top conductivities, this might be a true statment. Available preliminary information suggests flow interiors are hydraulically much tighter (horizontally and vertically) than typical flow tops. Therefore, vertical ground-water travel times would be slower. The site-characterization activities discussed in Subsections 4.1.1.3 through 4.1.1.6 of the Draft Environmental Assessment are designed to collect data needed to define likely ground-water flow paths and travel times.

5. Heterogeneities and anisotropic conditions ("complexity") exist in all geologic sites considered for site characterization. A wide range of study-completion times has been and will likely continue to be proposed. The important consideration is that comparable, detailed site-characterization plans, schedules, and budgets are developed for all geologies under study to address critical site-characterization issues.

Issue: Proximity of Columbia River to proposed repository site

One commenter expressed a concern regarding the proximity of the Columbia River to the reference repository location. If ground-water travel times are inaccurate, river proximity becomes a very important criterion.

Response

The U.S. Department of Energy agrees with the comment, although proximity to the Columbia River also must be evaluated relative to ground-water flow directions. If deep ground-water movement is southward as available data across the Cold Creek syncline suggests (see Section 3.3.2), the 10 kilometers (6 miles) separating the northern boundary of the reference repository location from the closest approach of the Columbia River may be more of an academic or political concern than a real waste-isolation issue. Nevertheless, because of the proximity of a major water body to a proposed repository site, ground-water and surface-water interactions must receive close technical scrutiny.

Issue: Concern over lack of solid rock

One commenter wrote, "Can you tell me that's solid rock for a mile deep below halfway between Rattlesnake and the Columbia?" and "I'll bet you a thousand bucks it isn't solid rock and it's indicated that way here."

Response

Solid rock is interpreted to mean a rock without fractures, vesicles, and flow top or flow interior layering. The Draft Environmental Assessment did not portray basalt stratigraphy in that fashion, whether the topic addressed was geology, hydrology, or rock characteristics. The proposed site consists of numerous individual basalt flows, some separated by sedimentary interbeds. Basalt flow interiors, flow contacts, and bedrock structures create an anisotropic, heterogeneous rock system (see Subsection 3.3.2.1 of the Draft Environmental Assessment). This was well displayed in Figure 3-36.

Issue: Uncertainty in knowledge about ground-water flow

One commenter stated that serious questions already have been raised regarding the suitability of the Hanford Site for a repository, some of these by the Draft Environmental Assessment. At this point, any conclusions about ground-water flow are just educated guesses.

Response

Before definitive site-characterization data are available to answer unresolved geotechnical issues, conservative, technical estimates of site characteristics and processes are necessary. Perhaps in popular terminology, this is called "educated guesses."

The General Siting Guidelines (DOE, 1984a; 960.3-1-4-2) recognized that both data and conservative assumptions would be applied to the nomination of any site for characterization. The Civilian Radioactive Waste Management Program is currently in this nomination and recommendation stage.

Issue: Concerns about vertical ground-water movement, presence of fractures, hydrologic test scales, and the need for more hydrologic data

One commenter listed four concerns said to be taken from a U.S. Geological Survey analysis.

1. Features associated with basalt cooling margins, basalt and water interactions, and cooling joints could result in considerable

vertical hydraulic communication and produce flow pattern complications.

2. Possible presence of buried canyon wells, faults, and sheer zones is significant because such zones could be relatively permeable to vertical water movement.

3. There is a lack of information on fractures in basalt. Vertically drilled holes will not adequately define these fractures. Tunnels and horizontally drilled holes from within an exploratory shaft facility would address the problem only on a small scale.

4. The most significant lack of information and data is reflected in geohydrology. Evaluation of the ground-water system and effects imposed on it by man will not be possible until the ground-water system of the entire Pasco Basin is quantitatively defined.

Response

The following responses correspond to the items listed in the above issue statement.

1. It is agreed that such failures, if present, could result in vertical communication and make characterization difficult. This possibility was discussed in the Draft Environmental Assessment in Subsection 6.3.1.1.10. The first sentence of that subsection stated, " . . . stratigraphic and structural features that could contribute to the difficulty of characterizing or modeling the geohydrologic system of the reference repository location have been identified in the geologic setting (Columbia Plateau)."

2. The U.S. Department of Energy agrees with the commenter. See response above.

3. It is agreed that much additional information is needed on the at-depth distribution of possibly significant vertical fractures. However, an investigative program using surface boreholes and an exploratory shaft facility is believed adequate to reduce much of the present uncertainty regarding critical site-characterization issues such as vertical hydraulic conductivity in a basalt flow interior, mine-water inflow, rock stability, and large-shaft drilling feasibility in a basalt terrain. There will be some uncertainty in scaling up the resultant conceptualization of geologic features to a repository size facility; however, this is common for any geologic medium studied for waste isolation.

4. It is agreed that much additional geohydrologic information is required although it is not believed that the flow system beneath the entire Pasco Basin requires the same level of quantification. The uncertainty of available hydrologic knowledge was acknowledged throughout the hydrologic sections of the Draft Environmental Assessment (see Section 3.3.2 and Subsection 6.3.1.1). With

distance from the proposed repository site, data needs become less critical and more general. For example, within and adjacent to the reference repository location, a thorough understanding of hydraulic conductivity, values, hydraulic head gradients, effective porosities, and geologic structures and stratigraphy is needed, and (or) good conservative uncertainty bounds should be applied. At the scale of the larger Pasco Basin, more general data needs are appropriate.

Issue: Competing water-use interests and radionuclide movement from repository

It was stated by one commenter that the U.S. Department of Energy has failed to recognize the importance of competing interests for ground-water use. An example of water rights and historical dewatering was given for the Hermiston-Umatilla, Oregon area. By the year 2000, it is likely irrigators will be drilling to depths of 600 to 900 meters (2,000 to 3,000 feet). The U.S. Department of Energy must demonstrate that contaminant releases from the repository will not be reached in the basalt sequence downstream from the Hanford Site.

Response

It is agreed that the U.S. Department of Energy must demonstrate that contaminant releases from the repository will not move far from the repository. The U.S. Environmental Protection Agency and U.S. Nuclear Regulatory Commission regulations (EPA, 1985; NRC, 1985) specify that waste isolation must be reasonably assured within a few kilometers (few miles) radius of the repository itself. Any geologic medium unable to isolate waste from significantly contaminating ground water many tens of kilometers (tens of miles) away is not acceptable for repository development.

Issue: Concerns over ground-water contamination

Several reviewers expressed broad concerns regarding possible radioactive contamination. One commenter stated that it was not in the best interests of the Pacific Northwest to jeopardize farm lands, recreational lands, and commercial development. Another concluded that it was doubtful ground-water contamination could be prevented. A third commenter stressed that ground-water contamination would move to the Columbia River, which flows into the ocean.

Response

A repository will not be built in any geologic medium if it cannot be reasonably assured to be an environmentally safe and technically sound decision for present and future generations. This is the basis and intent of the Civilian Radioactive Waste Management Program. Projections of radionuclide releases from a repository built in basalt were addressed in Section 6.4.2 of the Draft Environmental Assessment.

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Issue: Water-bearing zone in borehole DC-1

One reviewer quoted from a document by the U.S. Energy Research and Development Administration (ERDA, 1975, p. II.3-31, Vol. I):

"Some data on the aquifer properties of the various confined aquifers are available from the ARHCO deep drilling well ARH-DC-1. This well was drilled to a depth of 5661 feet and is located near well 699-49-48 in Figure II.3-21 (just north of the 200 East area.) . . . There is one significant water-bearing zone, 10 feet thick, occurring at 3230 feet depth with a transmissivity of 68 ft^2/day . . . " (emphasis added by commenter).

The commenter noted that the depth listed for this confined aquifer corresponds to the "dense interior" of the candidate horizon. The 3-meter- (10-foot-) thick confined aquifer at 984-meter (3,230-foot) depth could impact postclosure guideline positions. The final Environmental Assessment must reflect data found in U.S. Energy Research and Development Administration (ERDA, 1975).

Response

Two basic concerns were expressed in the above comment:

1. The 984-meter (3,230-foot) depth of the noted water-bearing zone is located in the dense interior of the candidate horizon.

2. This 3-meter- (10-foot-) thick confined aquifer could impact postclosure guideline positions for geohydrology taken in the Draft Environmental Assessment.

In response to the first concern, the commenter is in error. A depth of 984 meters (3,230 feet) corresponds to the flow bottom (not interior) of the Umtanum unit of the Grande Ronde Basalt. The candidate horizon (Cohassett flow) lies between the depth of 716 and 800 meters (2,349 and 2,626 feet), according to core samples recovered in adjoining hole DC-2 (Landon, 1985). Note: the U.S. Energy Research and Development Administration reference was published in 1975, not 1976 as the commenter had indicated.

In response to the second concern, the zone in question would not affect postclosure positions taken in the Draft Environmental Assessment. As addressed by Gephart (1985), the existence of the zone has been known and well documented over the last 14 years (e.g., ERDA, 1975).

In the final Environmental Assessment, additional sentences have been added to Subsections 3.3.2.1.2 and 6.3.1.1.6 to indicate the full range of hydraulic conductivity values reported.

Issue: Repository proximity to Columbia River and avoidance of outside criticism

One commenter expressed several concerns about the Hanford Site including the fact that the reference repository location is 10 kilometers (6 miles) from the Columbia River, aquifers exist in the basalts, and the U.S. Department of Energy did not include any outside criticism (such as that from the U.S. Geological Survey) in the Draft Environmental Assessment because such criticism would reflect negatively on the Hanford Site.

Response

The northern boundary of the reference repository location is actually 6 kilometers (4 miles) from the closest reach of the Columbia River. This is a factor in evaluating the possible suitability of the proposed site for waste isolation. However, the critical siting issue is not river proximity to the reference repository location, but rather the direction and rate of ground-water movement. Available information suggests ground-water flow is southward, away from the closest approach of the Columbia River. Refer to Section 3.3.2 of the Draft Environmental Assessment for supporting details. In addition, in order for the basalt site to become a licensed repository facility (if it reaches such a stage) the site would have to meet radionuclide release limits established by the U.S. Environmental Protection Agency (EPA, 1985). These limits apply to radionuclide releases at a 5-kilometer (3-mile) distance from the repository.

While it is true that aquifers exist in the basalts, it is also true that all basalt is not a highly permeable, water-bearing rock. Section 3.3.2 of the Draft Environmental Assessment addressed the hydraulic characteristics of basalt flows including differences between brecciated, vesicular flow tops and the dense, low permeability flow interiors. Numerous references given were published by various agencies that recognize these distinctions. The Draft Environmental Assessment also summarized information on typical fracture occurrence in basalt flows and intraflow variations for repository candidate horizons (e.g., Sections 2.1.1 and 3.2.2). The important consideration is identification of aquifers and potential ground-water flow paths that could serve as conduits for radionuclide movement. The Draft Environmental Assessment acknowledged the presence of aquifers and identified the stratigraphic locations (see Subsection 6.3.3.3.3). In addition, geologic features that might exist in or around the reference repository location that could serve as high-permeability conduits or complicate subsurface geohydrologic studies were discussed in Subsection 3.3.2.1. Thus, the U.S. Department of Energy is cognizant of the need to study the geologic and hydrologic properties of the basalt rock. Resolution of critical subsurface siting issues is possible only after completing a detailed site-characterization program as outlined in Section 4.1.1 of the Draft Environmental Assessment.

The U.S. Department of Energy does not agree with the commenter's statement that outside criticism was not referenced in the Draft Environmental Assessment. In fact, the specific critique mentioned by the commenter appears to have been taken from the U.S. Geological Survey evaluation of the site-characterization report (DOE, 1982). This critique was issued as Robertson (1983) and was both referenced and quoted in Chapter 6 of the Draft Environmental Assessment. For example, in Subsection 6.3.1.1.11.3, the following quote from Robertson (1983, p. 5) was used to express U.S. Geological Survey concern over the lack of data for use in performing defensible ground-water travel time analyses: "We do not believe that the hydraulic conductivity, hydraulic head, and effective porosity data are sufficient or reliable enough to allow velocity calculations to be made with an accuracy greater than approximately 2 or 3 orders of magnitude." In like manner, the U.S. Nuclear Regulatory Commission critique (NRC, 1983a) of the U.S. Department of Energy report (DOE, 1982) also was referenced and quoted in the Draft Environmental Assessment. Other critiques of previous work are referenced in the Draft Environmental Assessment (e.g., Golder, 1983b; Burnham, 1983).

Issue: Work scope of Interagency Hydrology Working Group

One commenter stated that the Interagency Hydrology Working Group has the single objective of resolving hydrologic differences in the conceptualization of ground-water flow in the Pasco Basin. The group is not involved in generating any information for site characterization or ground-water travel times. The Draft Environmental Assessment should have reflected this purpose. The commenter referenced the first paragraph on page 6-82.

Response

The U.S. Department of Energy agrees with the above-stated objective. For this reason, the second sentence of the first paragraph on page 6-82 stated, after listing working group members, " . . . who are sharing data and conducting computer model studies to more closely define hydrologic properties and ground-water flow dynamics within and surrounding the Pasco Basin." Nothing was mentioned about generating site-characterization data, including input to travel time analyses. To further reinforce this distribution, the paragraph has been modified.

Subsection 6.3.1.1.11.1 of the final Environmental Assessment has been reworded to accommodate the concern expressed regarding the work scope of the Interagency Hydrology Working Group.

Issue: Access to information from Interagency Hydrology Working Group

Several comments were received regarding lack of documentation access and participation within the Interagency Hydrology Working Group. This group consists of representatives from the U.S. Geological Survey, Pacific Northwest Laboratory, and the Basalt Waste Isolation Project. The basic concerns expressed in the comments are given below.

- Other outside agencies or interested parties are excluded from the group. This frustrates fulfillment of the consultation and cooperation process.

- Group-generated information was not used in calculating ground-water travel times given in the Draft Environmental Assessment.

- Group documentation is not available for public access.

Response

The U.S. Department of Energy and the U.S. Geological Survey have a formal intergovernmental agency agreement designed to protect proprietary data known to the U.S. Geological Survey and used in the Interagency Hydrology Working Group. This information is supplied by private sources (landowners and corporations) and pertains to areas outside the Hanford Site. These sources share data with the U.S. Geological Survey with the understanding that it will not be made publicly available. Otherwise, water rights and other legal questions could arise. Therefore, information shared by the U.S. Geological Survey in the working group and the informal documentation of modeling results generated using this information are not presently available to the public. For this reason, working group references were not given in the Draft Environmental Assessment and are not part of the data input to ground-water travel time calculations.

Historically, the U.S. Geological Survey has fostered an excellent working relationship with private data sources; the U.S. Department of Energy supports this role and will work to maintain it.

The need to establish a regional ground-water modeling program outside the auspices of the Interagency Hydrology Working Group is recognized, and this task is now being undertaken. All information used in this new program and modeling results obtained will be available to any interested organization. In this fashion, the full intent of consultation and cooperation can be exercised.

C.5.2 GEOCHEMISTRY

Comments regarding geochemistry concerns are addressed in this section. Subsection C.5.2.1 deals with redox conditions in the repository and basalt formations. Subsection C.5.2.2 discusses other geochemistry issues as outlined below.

- Extent of radionuclide sorption on basalt minerals.
- Effects of ground-water components on radionuclide mobility.
- Radiation effects on waste-package performance and design.
- Lack of geochemical data for site selection.
- Transport of radionuclides as particulates.
- Limited solubility data for radionuclides.
- Process used for selection of key radionuclides.
- Possibility of postclosure criticality.
- Omission of geochemical data in the Draft Environmental Assessment.
- Dissolution of basalt rock and secondary minerals.
- Possibility of a methane explosion.

C.5.2.1 Redox conditions

Comments regarding the existence of reducing conditions in a basalt repository and surrounding basalt formations fall into four issues. The following concerns are addressed in the issues:

- Lack of convincing data that would prove the existence of reducing conditions.
- The possibility that radionuclides will not be reduced by the basalt environment because of slow redox reactions.
- The use of an Eh value of -0.3 volts for radionuclide solubility calculations.
- The use of crushed basalt rather than fractured surfaces in experiments where redox conditions were determined.

Issue: Lack of convincing data

Reviewers were concerned that the assumption of reducing conditions was based on insufficient data and optimistic, nonconservative assumptions, that some data (Eh measurements and the presence of hematite) did not support the position that preemplacement ground water is nonoxidizing, that oxygen introduced during excavation and operation of the repository will result in an oxidizing environment, and that the possible absence of equilibrium for several redox reactions (magnetite-secondary minerals and sulfate-sulfide and methane-carbonate couples) was not considered.

Response

Three approaches were used to determine the redox state of the preemplacement repository environment: (1) secondary mineralogy in basalt flows, (2) concentration measurements of both the reducing and oxidizing species of several redox couples dissolved in ground water, and (3) platinum electrode measurements.

The first approach in determining the redox state of a geochemical system is the secondary mineralogy, in particular the iron-bearing secondary minerals. The presence of secondary pyrite occurring as a fracture-filling mineral sets an upper bound on the redox state of the system, since pyrite is stable only in a reducing environment.

Benson et al., (1979) may have identified hematite within a smectite "at Hanford." Even if this identification is substantiated, it is germane to note that hematite is stable in a reducing environment at the same pressure and temperature conditions of the repository (see Garrels and Christ, 1965, for 25°C (77°F) data).

The second approach used to define the redox state of the site system is the direct measurement of the concentrations of both the reducing and oxidizing species of redox couples dissolved in the ground water.

The concentrations corresponding to each redox couple are theoretically related to the oxidation potential by the Nernst equation. The potential calculated using different redox couples will be in agreement only if the couples are in equilibrium with each other. However, the potentials calculated will, as a whole, provide qualitative information on the redox environment.

There are five redox couples for which either quantitative or qualitative concentration data are available. These are sulfide/sulfate, iron(II)/iron(III), methane/carbon dioxide, methane/inorganic carbon, and methane/carbon monoxide.

The sulfide (as either HS^- or $S^=$)/sulfate (as either $SO_4^=$ or HSO_4) couple has been commonly used as a redox indicator for natural ground waters. At the ambient repository temperatures and pH values, the $HS^-/SO_4^=$ species will dominate (Garrels and Christ, 1965, pp. 213 through 218).

The kinetics of the uncatalyzed redox reaction between sulfide and sulfate are extremely slow at ambient repository conditions (Ohmoto and Lasaga, 1982, pp. 1727 through 1745). For this reason, the sulfate/sulfide couple may not be at equilibrium in the ground water samples obtained. The presence of redox-sensitive mineral surfaces and certain bacteria may, however, help to catalyze this reaction.

Most of the sulfur occurs as sulfate in Grande Ronde Basalt ground water, with a typical value of 6 x 10^{-5} mole per liter in the reference repository location. Sulfide is not alwavs detected, but concentrations as great as 1.3 milligrams per liter have been measured in Grande Ronde Basalt ground-water samples using ion-selective electrodes. The presence of any sulfide in solution is strong evidence for reducing conditions.

Table C.5-3 lists Eh values calculated from available concentration data using the Nernst equation.

The data represented here show good agreement with an average value of -0.4 volts for Eh.

The second redox couple investigated was the iron(II)/iron(III) couple. The measurement of ferrous iron concentrations has been initiated only recently and little data have been obtained to date. However, measured ferrous iron concentrations were obtained in wells associated with ground water at depths of less than 610 meters (2,000 feet). At depths greater than 610 meters (2,000 feet) (reference repository depth is 915 meters (3,000 feet)), significant concentrations of sulfide were measured but only trace amounts of ferrous iron were detected. Where ferrous iron is present, it accounts for over 90 percent of the total iron detected. This, along with the presence of sulfide at depths greater than 610 meters (2,000 feet), is qualitatively indicative of a reducing environment.

Table C.5-3. Eh calculations based on sulfide/sulfate equilibria

Date	Borehole	Eh (volts)
November 16, 1982	DC-16A	-0.41
November 19, 1982	DC-16C	-0.38
February 18 1983	DC-14	-0.37
February 22, 1983	DC-14	-0.38
March 1, 1983	DC-14	-0.38
March 4, 1983	DC-14	-0.38
March 15, 1983	DC-14	-0.40
April 11, 1984	DC-6	-0.40

The third redox couple investigated was the equilibrium between dissolved methane and carbon dioxide according to the half reaction

$$CH_4 + 2H_2O = CO_2 + 8H^+ + 8e^- \quad (C.5\text{-}1)$$

Eh values calculated from measured concentrations of these components using the Nernst equation yield values that range from -0.42 to -0.52 volts over a pH range of 9 to 10 at a temperature of 55°C (131°F). (It is recognized that the kinetics of this reaction are slow and may represent disequilibrium conditions and, thus, should be interpreted in concert with other couples.)

The fourth reaction investigated was the equilibrium between dissolved methane and inorganic carbon (as bicarbonate) according to the reaction

$$CH_4 + 3H_2O = HCO_3^- + 9H^+ + 8e^- \quad (C.5\text{-}2)$$

Average concentrations of methane and bicarbonate measured in Hanford Site ground-water samples are 0.044 mole per liter and 0.0016 mole per liter, respectively. The Eh calculated from these concentrations is -0.45 volt.

The fifth redox couple considered was the equilibrium between methane and carbon monoxide according to the reaction

$$CH_4 + H_2O = CO + 6H^+ + 6e^- \qquad (C.5\text{-}3)$$

Carbon monoxide concentrations are generally below detection limits in Grande Ronde Basalt ground water; therefore, an upper Eh limit can be calculated. This calculation yields an upper limit of -0.38 volt at 55°C (131°F).

The third approach used to evaluate the redox environment in basalt ground water is the direct measurement of Eh with a platinum electrode. The range of values measured at the Hanford Site, as presented in Figure C.5-8, is +0.3 to -0.2 volt.

The platinum electrode measurements reported are subject to question because the electrodes can react with oxygen and sulfur species in ground water, leading to spurious Eh values (Garrels and Christ, 1965, pp. 135 through 139; Morris and Stumm, 1967, pp. 282 through 283; Langmuir, 1971, pp. 518 through 621; Whitfield, 1969, pp. 547 through 549; Whitfield, 1974, pp. 857 through 865). The data also reflect measurements of repository ground water at ground level, not at repository depth.

Exposure of the sample to the more oxidizing surface environment (atmospheric oxygen) and contamination of the ground water with drilling muds will potentially lead to more oxidizing surface measurements and may explain the wide range of measured Eh values. The redox processes responsible for the measured electrode responses have not been definitively identified, leaving the possibility that the measurement represents true changes in the aqueous composition (e.g., sulfide content, iron content) of the ground water.

The reasonable expectation is, therefore, that all directly measured Eh values are more oxidizing (i.e., displaced toward more positive values) than the actual Eh values of the ground water at the Hanford Site. This displacement cannot be quantified because of the uncertainties in electrode response and an unknown degree of possible contamination. The recorded Eh values can be used in a qualitative manner. The predominance of negative Eh values in Figure C.5-8 (i.e., reducing conditions) is clearly shown.

The results of Eh calculations using the methods previously discussed are shown in Table C.5-4. Although some of these reactions are quite slow, the agreement between the Eh values calculated using several different independent techniques strongly suggests that a close approach to equilibrium between these couples has been achieved and that the ground water is indeed reducing.

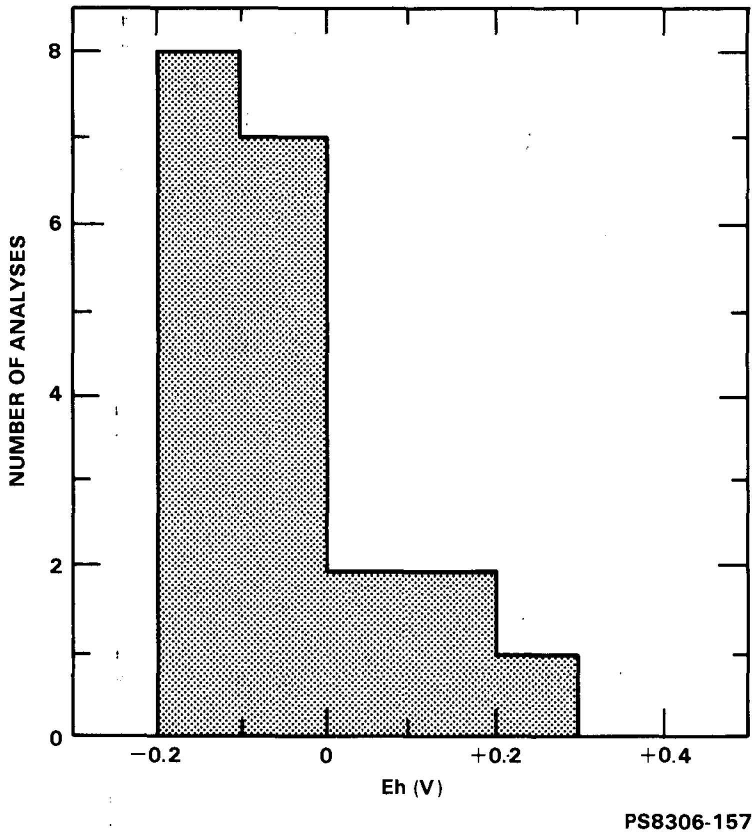

Figure C.5-8. Histogram of measured Eh values for Grande Ronde Basalt groundwater samples at the Hanford Site in boreholes DC-6, DC-7, DC-12, DC-14, and DC-15.

Table C.5-4. Calculated potentials for redox couples

Technique	Eh, volts
Presence of secondary pyrite	less than -0.2
Sulfate/sulfide	-0.37 to -0.41
Ferrous/ferric iron	less than 0.0
Methane/carbon dioxide	-0.42 to -0.52
Methane/bicarbonate	-0.45
Methane/carbon monoxide	-0.38
Platinum electrode	+0.3 to -0.2

Lindberg and Runnells (1984) indicate that there is no means to measure a "master" Eh for a ground-water system. They indicate that the kinetic inhibition of redox equilibration requires that the redox state of a system not be cavalierly quoted based on a single measured value or calculated from a single measured couple. They certainly do not imply that a redox "state" does not exist for a given system, only that some species react much more slowly to the conditions than do others and, therefore, problems can be encountered in quoting a "master" value from a couple that may not have attained equilibrium. Lindberg and Runnells further state that the best way to estimate a redox state for a given system is to use as many independent means as possible, estimating the redox state according to each. If the quantitative values obtained from these independent means agree, this strongly implies that equilibrium has been attained and the value is reasonable. This is the approach used by the U.S. Department of Energy in concluding that the redox conditions are "reducing," and it is clear that the preponderance of evidence points to that conclusion. A conclusion that "oxidizing" conditions prevail would be contrary to the best evidence available.

Oxygen will be introduced into the repository during excavation and operation phases. It is expected that oxygen will be removed in a very short time after closure by reaction with minerals in the backfill that contain iron(II). The amount of iron(II) available will be more than adequate to remove the oxygen (Lane et al., 1983).

Discussions in Subsection 6.3.1.2.2 of the final Environmental Assessment have been expanded to summarize evidence for reducing conditions in the repository and surrounding basalt formations.

Issue: Non-equilibrium redox reactions

Several reviewers stated that slow redox reactions may prevent reduction of radionuclides, and that these radionuclides would not be released in their least-soluble, most-sorptive form.

Response

The effect of the redox environment on radionuclide speciation must be experimentally determined for each radionuclide of interest to repository performance. This is because the redox equilibrium for each radionuclide involves specific chemical reactions that may be kinetically inhibited at the expected temperatures. This is one reason the U.S. Department of Energy has an experimental waste-barrier-rock interaction program under way. Initial experiments that reacted uranium-, neptunium-, plutonium-, and technetium-bearing waste forms with basalt and ground water (Coles, 1984; Myers et al., 1984) indicate that those elements are only slightly soluble in the ground water. These results are supported by researchers at Oak Ridge National Laboratory (Kelmers et al., 1984a, 1984b, 1985) who found high sorption coefficients for technetium and neptunium using Hanford Site basalt and ground water. Reduced species of neptunium and technetium have been identified in experiments where solutions of these radionuclides (in high oxidation states) were reacted with crushed basalt (Meyer et al., 1984; Susak et al., 1983). Current plans call for additional tests to determine the behavior of every key radionuclide in the repository environment; however, experimental data thus far obtained support the contention that redox-sensitive radionuclides will assume a reduced valence state in the repository environment.

It should be noted here that, although virtually all the evidence points to the presence of reducing conditions, the U.S. Department of Energy does not plan to use calculated solubilities and sorption properties of radionuclides in its ultimate performance assessment. Experiments are under way to assess the behavior of radionuclides, individually and collectively, in site-specific systems. Steady-state solution concentrations of radionuclides achieved in a relatively short time in the presence of site and waste-package constituents will be used to predict their behavior in a repository. Results to date indicate that redox-sensitive species are reduced in the presence of basalt (Coles, 1984).

Further research is being done (by D. Runnells at the University of Colorado) to assess the kinetics of reduction in the basalt-ground-water system and the reversibility of redox reactions in the basalt-ground-water system.

Issue: Calculation of radionuclide solubility

Reviewers expressed concern that a redox potential of -0.3 volt was used to estimate radionuclide solubilities. The reviewers claim that a redox potential of -0.3 volt is not conservative and is not supported by sufficient evidence.

7 0 1 6 8 2 1 9 2

Response

Radionuclide solubilities given in the Draft Environmental Assessment were not based on a redox potential of -0.3 volt. These solubility values represent best estimates based on experimental evidence (where it exists for measurements at expected repository conditions) and on theoretical calculations (Salter and Jacobs, 1983). In addition, curves showing calculated solubilities versus Eh for key, redox-sensitive radionuclides (Early et al., 1984) suggest that there is no difference in calculated solubilities between Eh values of -0.3 and -0.1 volt.

Issue: Experiments were not realistic

According to several commenters, experiments that resulted in reducing conditions were not realistic because crushed basalt was used rather than fractured surfaces and because large ratios of surface area to volume were used.

Response

The high ratio of surface area to volume is used to enhance the kinetics of reactions that normally would occur. In this way, long-term effects can be reproduced on an observable time scale. Two comments are relevant here.

1. The use of finely divided materials of the redox-controlling material (basalt) cannot be proven to reproduce the exact conditions that would occur in the natural system. The agreement of measured Eh values from the experiments using crushed material with nearly all the measured and calculated values has been good. Therefore, the basalt appears to have imposed these reducing conditions on the water currently there, whatever the basalt ratio of surface area to volume.

2. Even though data on fracture density in the reference repository location are not available, it is clear that the volume of basalt relative to the volume of water is overwhelming; therefore, experiments using finely divided materials are realistic. To produce results in a reasonable time, finely divided materials must be used.

Experiments are under way to investigate the effects of varying rock-to-water ratios and surface-area-to-volume ratios on reactions of radionuclides.

Response

Extensive data are available providing evidence of the strong sorption of most important radionuclides on minerals and rocks found in basalt formations. Existing data cover wide ranges of expected conditions of temperature, ground-water composition, sorbent composition, and radionuclide species. These data have been obtained by several different laboratories using a variety of experimental methods. Radionuclide sorption measurements on various basalts (e.g., different flows, flow tops, entablatures, weathered basalts, secondary minerals) were reported by Ames and McGarrah (1980a, 1980b, 1980c), Barney (1981), Barney et al. (1983), Barney and Brown (1979), Salter et al. (1981a, 1981b), Meyer et al. (1984), Kelmers et al. (1984a), Vandegrift et al. (1984), and many others. In addition to basalts, sorption data have been obtained for secondary minerals (Salter et al., 1981b; Barney, 1981), interbed materials (Barney, 1982, 1984), and packing materials (Barney et al., 1985). Results of these studies show that radionuclides that exist as metallic ions in basalt ground-water solutions are strongly and irreversibly sorbed (their sorption and desorption isotherms are different) by chemisorption mechanisms onto the basalt, secondary mineral, interbed material, or packing material surfaces. Radionuclides that are present only as nonmetallic anions are either sorbed weakly (e.g., selenium) or are not significantly sorbed (e.g., iodine and carbon).

The U.S. Department of Energy considers flowthrough (column) measurements of sorption processes essential to complement and verify the batch data obtained under static conditions. These experiments will also allow the identification of multiple species of radionuclides in ground-water solution (if these species are not in equilibrium with other sorbed species).

Most radionuclide sorption measurements have been conducted over a temperature range of 23 to 90°C (73 to 194°F); a smaller number have been performed at 150°C (302°F) and 300°C (572°F). The lower temperature range represents conditions in the far field and can also be applied to the repository if radionuclide release from the containers occurs after approximately 5,000 years, as expected (see Fig. 6-5 of the Draft Environmental Assessment). The higher temperature data will only be relevant for a low-probability, early failure of the container.

Some sorption measurements have been performed using air-saturated ground-water solutions. These experiments are attempts to represent an extreme boundary of radionuclide oxidation states. Radionuclides in these experiments will be in their highest possible oxidation states (for this system) and will be sorbed to the least extent (Ames and McGarrah, 1980b; Barney, 1984); therefore, these experiments define the worst possible sorption behavior with regard to radionuclide release and transport.

Although the representation of distribution coefficients by K_d values implies equilibrium constants, equilibrium is rarely achieved in laboratory sorption measurements because most ground-water and rock systems are not in equilibrium. The K_d values given in the Draft

C.5.2.2 Other geochemistry issues

This subsection deals with the numerous comments received regarding geochemistry concerns other than redox conditions in the repository and basalt formations. These comments are divided into the following issues:

- Sorption of radionuclides.
- Effects of ground-water components.
- Radiation effects on waste package.
- Lack of geochemical data.
- Transport of radionuclide particulates.
- Limited solubility data.
- Selection of key radionuclides.
- Postclosure criticality
- Omission of geochemical data.
- Dissolution of the host rock.
- Methane explosion.

Issue: Sorption of radionuclides

Commenters stated that no defensible evidence exists to prove that radionuclides are strongly sorbed on basalts or basalt-alteration phases and that the experimental conditions used thus far in measuring sorption are not representative of repository conditions. Concerns related to experimental conditions and methods are as follows:

1. Batch sorption measurements do not distinguish among various radionuclide species.

2. Temperatures used in measurements were too low and too oxidizing, and equilibrium was not reached.

3. No consideration was given to ground-water alteration due to hydrothermal or radiolytic interactions.

4. Sorption was measured using crushed basalt instead of flat surfaces of basalt (representing fractures).

5. Sorption values measured by the U.S. Department of Energy are significantly different from those reported by the U.S. Nuclear Regulatory Commission.

6. The validity of sorption measurements using hydrazine to maintain radionuclides in the reduced state is questioned.

7. No results of radionuclide desorption experiments or technetium isotherms have been reported.

Finally, two commenters stated that details of planned radionuclide transport studies were not presented in the Draft Environmental Assessment.

Environmental Assessment are "steady-state" values obtained over weeks or months of equilibration time. These values are considered to be conservative since longer equilibration times increase sorption (Barney et al., 1983).

Effects of ground-water composition variations on radionuclide sorption have been determined by statistically designed experiments (Barney, 1981, 1982, 1984; Barney et al., 1985). Wide ranges of possible ground-water compositions were examined in these experiments.

Sorption measurements have been performed on a variety of geologic materials in a number of geometric configurations, including flat basalt surfaces. Each of these experiments is representative of an expected situation along a postulated ground-water flow path from the waste to the accessible environment. Data from these measurements will be used as required by performance assessment models.

For several radionuclides, sorption values measured by the U.S. Nuclear Regulatory Commission were different than the "conservative best estimates" reported in the site-characterization report (DOE, 1982). This is not surprising since, in the work sponsored by the U.S. Nuclear Regulatory Commission, the basalt samples and methods used to measure sorption were different than those used in the site-characterization report. In any case, the values used in analyses reported in the Draft Environmental Assessment were obtained from a published data base (Salter and Jacobs, 1983) that periodically is reviewed and updated, not from the site-characterization report. These are very conservative values that are valid even under oxidizing conditions and for sorption on the least sorptive geologic solids. The distribution values measured by the U.S. Nuclear Regulatory Commission are well within the ranges of values used in the analyses reported in the Draft Environmental Assessment.

Hydrazine was chosen as a reducing agent for radionuclides in some sorption experiments because it

- Is soluble and chemically stable at the pH and temperatures of the experiments.
- Reacts rapidly with most radionuclides of interest to repository performance to produce low oxidation states in solution.
- Does not form complexes with radionuclides at the pH and temperatures of the sorption measurements (complexation would likely decrease sorption, whereas the addition of hydrazine increases sorption of radionuclides that can be reduced in solution).
- Produces innocuous reaction products (N_2 and water) that do not interfere with sorption reactions.

The U.S. Department of Energy does recognize several potential problems associated with addition of hydrazine to sorption measurement systems. Kelmers et al. (1984a) have suggested a number of potential problems relative to the use of hydrazine in these experiments. They have implied that radionuclide reactions with hydrazine may not yield the same reduced species as reactions with reducing agents present in the ground-water flow path. Although this may be true for some radionuclides with multiple lower-oxidation states, most of the radionuclides of interest to repository performance have only one stable reduced state that is soluble in aqueous solution. This reduced state can be predicted with confidence from studies reported in the literature (Table C.5-5). Reduction kinetics for several of these reactions are also available. Additional evidence for reduction is the significant increase in sorption observed when hydrazine is present. For several radionuclides that cannot be reduced in aqueous solution (e.g., $^{90}Sr^{2+}$, $^{226}Ra^{2+}$, $^{137}Cs^{+}$), hydrazine actually decreases sorption due to ion exchange reactions such as

$$N_2H_5^+ + \binom{\text{mineral}}{\text{surface}}\text{---}Cs = \binom{\text{mineral}}{\text{surface}}\text{---}N_2H_5 + Cs^+ \qquad (C.5\text{-}4)$$

(Barney, 1984).

Kelmers et al. (1984a) have also suggested that hydrazine may attack secondary minerals present in sorption experiments and alter their structures. However, if secondary minerals are altered to any significant extent, sorption of radionuclides that are not reduced by hydrazine, such as ^{241}Am(III), should also be affected. However, Barney (1984) has shown by statistically designed experiments that sorption of ^{241}Am(III) on interbed materials that contain secondary minerals is not significantly affected by the presence of hydrazine. It can be concluded that the mineral surfaces involved in radionuclide sorption are not significantly altered by the presence of hydrazine.

As pointed out in Kelmers et al. (1984a), hydrazine is a base and will increase ground-water pH. In the U.S. Department of Energy experiments, small amounts of hydrochloric acid were added to the synthetic ground-water solutions to neutralize the solutions to desired pH levels. Chloride does not affect radionuclides sorption reactions (Barney, 1984). The formation of hydrazine carbonate by reaction of bicarbonate with hydrazine in experimental solutions, as suggested in Kelmers et al. (1984a), seems unlikely. The carbonate has been prepared only by reaction of carbon dioxide gas with hydrazine in strongly basic solution (Staal and Faurholt, 1951). This reaction product decomposes in water to form hydrazine and carbon dioxide.

Because of the potential problems associated with using hydrazine, a second method of radionuclide oxidation state control has been adopted by the U.S. Department of Energy. The results of this new method will be used to confirm (or reject) the sorption results obtained by the above techniques. The new method consists of removing enough oxygen from the ground water and atmosphere above the ground-water-solid mixture so that the solids and dissolved redox couples (e.g., iron(II)/iron(III)) control oxidation states.

Table C.5-5. Oxidation states of radionuclides reduced by 0.01 mole per liter hydrazine in ground-water solutions

Element	Starting species	Reduced oxidation state	References
Uranium	UO_2^{2+}	Uranium(IV)	Kalnins and Gibson (1959)
Neptunium	NpO_2^+	Neptunium(IV)	Keller (1971); Koltunov and Tikhonov (1973)
Plutonium	PuO_2^+	Plutonium(IV) or plutonium(III)	Koltunov and Zhuravleva (1974)
Technetium	TcO_4^-	Technetium(IV)	Spitsyn et al. (1983)
Selenium	SeO_3^{2-}	Selenium(-II)	Benzing et al. (1958)

No chemical that does not naturally occur in ground water is added to the system. It is, however, more difficult to perform laboratory sorption measurements at very low oxygen concentrations. Oxygen must be removed from experimental systems to very low levels, and this requires the use of air-tight chambers and inert atmospheres of very low oxygen concentration. Also, this method of oxidation-state control may suffer from very slow reaction rates at low temperatures. Reactions between radionuclides and reducing species (such as iron(II) species) at the surface of the solids or dissolved from the solid into the ground water are expected to be slow. Crushed basalt has been reported to control ground-water Eh at negative values (as measured by a platinum electrode) in deoxygenated synthetic ground water (Jantzen, 1983) at 60°C (140°F). However, the fresh, unaltered surfaces of crushed basalt are likely to be more reactive than solids found in the (far-field) system.

Results of desorption measurement have been reported in several U.S. Department of Energy publications (Barney, 1981, 1982, 1984; Barney et al., 1983, 1985), with desorption isotherms described for a number of radionuclides.

Technetium sorption and desorption isotherms have been reported in the publications listed above. Since technetium(VII) does not sorb measurably on any of the geologic materials studied, isotherms were measured only for reduced technetium.

Detailed plans for future radionuclide sorption studies will be presented in the site-characterization plan for the Hanford Site should the reference repository location be recommended for characterization. These detailed plans are beyond the scope of this Environmental Assessment.

A more detailed discussion of radionuclide sorption issues and findings has been added to Subsection 6.3.1.2.7 of the final Environmental Assessment.

Issue: Effects of ground-water components

Reviewers stated that the presence of fluoride, carbonate, and fulvic acids in Grande Ronde Basalt ground water will increase the mobility of radionuclides by reacting with them to form stable complexes that are more soluble and more weakly sorbed than other radionuclide species. In addition, two commenters stated that the presence of sodium, potassium, and calcium ions decrease sorption of radioisotopes of cesium, strontium, and radium. Other commenters stated that unspecified organic compounds found in Grande Ronde Basalt ground water will decrease sorption of americium and neptunium.

Response

Recent evidence shows that fluoride complexes of important radionuclides are not significant in determining transport properties of the radionuclides. Nash and Cleveland (1984) have measured the formation constants of 1:1 and 1:2 plutonium(IV)-fluoride complexes and found that hydrolysis reactions of the plutonium(IV) predominate above a pH of approximately 6 in the presence of 0.002 molar fluoride. This observation is in agreement with published estimates of fluoride and hydroxide complexes of actinides (Apps et al., 1982; Allard, 1982) that report formation constants for hydroxide (and carbonate) complexes that are orders of magnitude larger than fluoride complexes. The inability of fluoride to complex radionuclides explains the insignificance it has in affecting radionuclide sorption from basalt ground waters (Barney, 1984; Barney et al., 1985). These data show that the relatively high plutonium solubility in basalt ground water observed by Cleveland et al. (1983) cannot be explained by the formation of fluoride complexes.

Carbonate, on the other hand, does complex some radionuclides in basalt ground water. Sorption of neptunium, uranium, and technetium is decreased in the presence of carbonate due to complex formation. This effect is relatively small, however, at the carbonate-bicarbonate concentration levels (approximately 50 to 200 milligrams per liter) found in Grande Ronde Basalt ground waters.

Preliminary estimates of naturally occurring organics in Grande Ronde Basalt ground water indicate that organic carbon concentrations are less than approximately 1 milligram per liter. This estimate may be high because of difficulties involved in obtaining deep ground-water samples that are not contaminated with drilling fluids. Drilling fluids contain organic compounds that are difficult to remove completely from the borehole. The potential for naturally occurring organic materials in basalt ground waters to complex radionuclides is, therefore, not well understood. Several recent publications have suggested that dissolved organic carbon concentrations less than 1 milligram per liter have little influence on plutonium sorption (Nelson et al., 1984) and on americium and neptunium sorption (Boggs and Seitz, 1984). Detailed plans for determining effects of dissolved organics on sorption will be presented in the site-characterization plan should the reference repository location be recommended for characterization.

Several radionuclides are at least partially sorbed by cation exchange reactions. These are radionuclides that are not strongly complexed in Grande Ronde Basalt ground waters (e.g., cesium, strontium, and radium). As might be expected, the extent of sorption of these radionuclides depends on the ionic strength of the ground waters. Increases in sodium, potassium, or calcium concentrations decrease sorption. At the ionic strength of Grande Ronde Basalt ground water, these radionuclides are strongly sorbed.

A discussion of fluoride, carbonate, and organic complex formation with radionuclides has been added in Subsection 6.3.1.24 of the final Environmental Assessment. Recent results of U.S. Geological Survey measurements of plutonium fluoride formation constants are addressed.

Issue: Radiation effects on waste package

Comments in the area of radiolysis can be summarized as follows:

- The radiolytic formation of hydrogen and organic polymers will detrimentally affect waste-package performance.
- The effect of radiation on the design of the waste package (waste form and container-canister material) has not been determined.
- Alpha and gamma radiolysis can affect radionuclide solubility.

Response

The formation of hydrogen will occur if ionizing radiation is present. The yield, however, is not large (on the order of 5 moles per waste container for the whole containment period) and is approximately 6×10^{-10} mole per rad of radiation absorbed. This, coupled with the use of a material (low-carbon steel with low-yield strength) with little susceptibility to hydrogen embrittlement, plus a thermal environment (temperatures well above 25°C (77°F)) that minimizes the effects of hydrogen embrittlement, does not indicate a significant problem.

The formation of polymers reported by Gray (1984) represented results obtained at dose rates 100 to 1,000 times higher than expected in the repository and in the absence of waste package components (basalt, bentonite, and iron). Recent results indicate that the presence of these components inhibits polymer formation. A significant amount of polymer formation is not expected to occur under repository conditions.

The current reference waste form for commercial high-level waste is spent fuel. This currently is being extensively studied and characterized. Part of this effort will be an evaluation of the effect of radiation on the integrity and performance of the waste form. Defense high-level waste and West Valley waste will be in a borosilicate glass. As indicated in the comment, a significant amount of testing has been done on this waste form. The effect of radiation on the selected canister and container material is established from literature data and review of the work that has been done in research related to nuclear reactor performance.

The statement that the solubility of radionuclides can be affected by radiolysis is true. The potential of ionizing radiation to affect radionuclide solubility and speciation has been established in radiochemical research. These effects can be both detrimental and beneficial to waste-package performance in that radiation produces strongly oxidizing and reducing species. The net effect in room temperature experiments with actinides is that reduction is generally favored over oxidation until the +4 or +3 oxidation state is reached. The U.S. Department of Energy currently is conducting investigations to determine the effect of radiation under repository conditions.

A brief discussion of radiolysis effects on radionuclide solubility, sorption, and mobility has been added in Subsection 6.3.1.2.4 of the final Environmental Assessment.

Issue: Lack of geochemical data

Several commenters expressed a general concern that there is insufficient data available to make a selection of sites based on geochemistry. Some of the commenters refer to studies that may invalidate conclusions reached by the U.S. Department of Energy. Other commenters speak of the general insufficiency of data available on which to base conclusions or arrive at a siting decision.

Response

It is felt that the basis for this group of comments is true in principle but not appropriate to the scope and purpose of an environmental assessment. The scope and purpose of the Draft Environmental Assessment was to provide guidance in the determination of sites for further evaluation. The conclusions (recognized as tentative by at least several of the commenters) are reached in good faith by the scientific personnel, as reasonable deductions based on the data available. In the opinion of the U.S. Department of Energy, the geochemistry of the Hanford Site appears favorable to waste isolation. More complete studies will be conducted should the reference repository location be recommended for characterization.

Issue: Transport of radionuclide particulates

Several commenters stated that the Draft Environmental Assessment did not adequately consider transport of radionuclides as particulates or colloids suspended in ground water.

Response

The Draft Environmental Assessment states (see Subsection 6.3.1.2.8) that the existence of naturally occurring colloids in deep ground waters has not been demonstrated. Determination of colloids must await planned pump tests in boreholes drilled without the use of drilling fluids. Detailed plans for determining the significance of radionuclide transport by colloids will be presented in the site-characterization plan, should the reference repository location be recommended for characterization.

Issue: Limited solubility data

Several comments were received about the use of solubility limits of radionuclides as source concentrations in performance assessment calculations. Reviewers expressed the following concerns:

- Solubility limits for the radionuclides are not accurately known for conditions expected in the repository, and the limits are sensitive to the composition of the solid phase, pH, Eh, temperature, presence of complexants, and concentration of electrolytes.

- Several solubility values (those for neptunium and plutonium) used in the Draft Environmental Assessment performance analyses may be nonconservative since they are lower than reported experimental values.

Response

Uncertainties do exist in the solubility limits for the radionuclides of concern. These uncertainties are reflected in the wide range of solubility for each radionuclide (2 to 5 orders of magnitude) given in Table 6-27 of the Draft Environmental Assessment. These values represent best estimates of solubilities based on experimental evidence (where it exists for measurements at expected repository conditions) and on theoretical calculations. The justification for using these values is given by Salter and Jacobs (1983). Certainly, much additional experimental data will be required to reduce uncertainties. These data are presently being obtained by the U.S. Department of Energy. Detailed plans for performing solubility measurements during site characterization will be presented in the site-characterization plan should the reference repository location be recommended for characterization. These plans conform to recommendations by the U.S. Nuclear Regulatory Commission for determination of radionuclide solubility (NRC, 1984a).

The solubility values used in the Draft Environmental Assessment performance analyses for neptunium and plutonium were based on recent high temperature (200°C (392°F)) measurements of radionuclide concentrations in hydrothermal solutions. These solutions were generated by reacting a synthetic waste glass with ground water in the presence of basalt (Coles, 1984). The resulting solubility values are lower than observed previously in lower-temperature measurements (60 through 90°C (140 through 194°F)). To assure that conservative values are used in performance assessment calculations, the higher solubility values for plutonium and neptunium (Salter and Jacobs, 1983) will be used to repeat these analyses.

Solubility values for neptunium and plutonium in Table 6-27 of the final Environmental Assessment have been changed to the higher values reported by Salter and Jacobs (1983). This will result in changes in fractional release rates and cumulative releases for neptunium and plutonium given in Figures 6-18 and 6-19, respectively, and in Tables 6-29 and 6-30.

Issue: Selection of key radionuclides

Commenters stated that the procedure for selection of key radionuclides in Subsection 6.4.2.3.2 of the Draft Environmental Assessment should be reviewed to ensure that significant radionuclides are not ignored. Consideration should be given to the following:

- The inventory criterion of 1.0 percent of the cumulative release limit (given in 40 CFR 191 (EPA, 1985)) may not include radionuclides that could exceed the release rate limit (given in 10 CFR 60 (NRC, 1985)).
- Eliminating radionuclides with half-lives of 100 years or less should be justified.
- The chemical form of the radionuclides will affect the solubility and sorption criteria used.

Response

It is recognized that radionuclides that have low inventories could exceed release rate limits if the radionuclides are highly soluble and are not sorbed by engineered barriers under repository conditions. However, the U.S. Environmental Protection Agency criteria (cumulative releases) were considered to be the overriding safety criteria for the purpose of selecting radionuclides for detailed analysis in the Draft Environmental Assessment. Radionuclides with inventory fractions less than 1.0 percent are not likely to contribute significantly to the total release.

As stated on page 6-236 of the Draft Environmental Assessment, the screening process was based on the assumption of containment for 5,000 years. A radionuclide with a half-life of 100 years would decay to 10^{-13} percent of its original inventory after this time. Even under the most pessimistic conditions allowed by the Federal regulations (300-year containment and 1,000-year travel time), the inventory of the radionuclide would be reduced by a factor of 10^{-4}. Thus, elimination of radionuclides with half-lives less than 100 years seems justified for analyses based on undisrupted conditions.

The solubilities and sorption properties of radionuclides used in the selection process were conservative estimates for radionuclide species expected to exist in the repository. No elemental species were assumed for any of the radionuclides.

Because of reviewer comments (see Section C.5.11 of this appendix), radium-226 and americium-241 have been added to the list of radionuclides requiring detailed analysis.

Issue: Postclosure criticality

Several comments were received concerning the possibility of post-closure criticality. The reviewers note that adsorption processes within the repository could concentrate radionuclides along certain ground-water flow paths. Reconcentration of the fissile elements in this way might lead to a critical mass being generated. The reviewers suggest that while this is probably extremely unlikely, the subject of postclosure criticality should be discussed in the final Environmental Assessment.

Response

It is agreed that the probability of postclosure criticality being achieved within the repository is extremely small. To quantify this probability more precisely, however, more information on the sorption properties of the fissile radionuclides is required. This is because an assessment of the potential for criticality must consider the presence and concentration of neutron poisons as well as the relative concentration of fissile materials being adsorbed (Gore and Jenquin, 1981). The spatial and temporal distributions in concentrations of the fissile elements and neutron poisons should be predictable from models (as described in Subsection 6.4.2.3.1 of the Draft Environmental Assessment) once the sorption data on all of the pertinent elements are obtained. It is felt, therefore, that a quantitative assessment of the potential for criticality in the proposed repository should await this information.

Issue: Omission of geochemical data

A number of commenters stated concerns about omissions of geochemistry data from the Draft Environmental Assessment. A suspicion of deliberate omission of data was expressed by one reviewer. Specific areas that commenters felt there was a lack of specific geochemical information include radiochemistry, reaction rates, equilibria, temperature effects, adsorption isotherms, and surface area calculations. Several reviewers suggested that only peer reviewed papers in the "open" literature be cited in the final Environmental Assessment and that summaries of data obtained in-house be presented in the final Environmental Assessment.

Response

Presentation in the final Environmental Assessment of all available geochemical data relevant to a repository in basalt would not be practical because of the excessively large amount of space required in the document and the great amount of time and expense involved. The scope of geochemical data presentation in the Draft Environmental Assessment was limited to information required to evaluate the Hanford Site using the postclosure and preclosure siting guidelines (DOE, 1984a). For more detailed information, the references cited in the Draft Environmental Assessment must be consulted. In addition, a more in-depth discussion of the geochemistry issues that are important for a repository in basalt will be presented in the site-characterization plan should the reference repository location be recommended for characterization.

The majority of the references cited in the Draft Environmental Assessment are in-house government or contractor reports. All of these reports are available to the public. The Draft Environmental Assessment relied heavily on these reports because (1) information in these reports is generally more applicable than papers in the open literature since they were generated to fill gaps in the understanding of relevant geochemical issues and (2) they contain more up-to-date information since they can be published more quickly than journal articles (which may take over a year for publication).

Issue: Dissolution of the host rock

Several reviewers raised questions about the dissolution of the host rock (basalt) and (or) the dissolution of secondary minerals with line fractures, joints, and faults in the host rock. Specifically, the reviewers note that higher temperatures will be imposed on rocks near the repository and that the increased temperatures might cause the basalt or secondary minerals to dissolve. This raises a concern that the permeability of the host rock will be increased, causing more rapid resaturation of the repository and greater potential for ground-water contamination. Each of the reviewers suggests that the current state of knowledge about the geochemistry of host rock and water interactions is inadequate and should be investigated in more detail.

Response

The comments are concerned with the relationship between two processes: mineral dissolution or precipitation and changes in the permeability of fractures in the host rock. The inferred relationship between the two processes is that dissolution of the host rock will increase the permeability of the fractures. This implies that a substantial net reduction in the mass of the host rock and secondary minerals will be caused by dissolution.

The dissolution behavior of basalt from the Hanford Site has been investigated experimentally. The experiments have been conducted to investigate the hydrothermal interactions between basalt and ground water under repository-relevant conditions and at temperatures as high as 300°C (572°F) (Grandstaff et al., 1984). The results indicate minimal changes in the amounts of basalt present following reactions with the ground water. Even the most reactive, glassy portion of the basalt (the mesostasis) was present in almost original amounts after reactions at 300°C (572°F) for up to 7,000 hours. This suggests that the net loss in mass of the basalt will probably be minimal following a temperature rise in the repository host rock where temperatures are expected to be much lower than 300°C (572°F).

The thermal stability of secondary minerals formed by hydrothermal interactions between basalt and ground water also has been investigated. Secondary minerals that were produced at 300°C (572°F) in the experiments described by Grandstaff et al. (1984) are similar to the alteration minerals that line fractures in basalts at the Hanford Site (formed at temperatures near 60°C (140°F)) and elsewhere in basaltic geothermal fields where temperatures exceed 100°C (212°F). The stabilities of the secondary minerals, thus, do not appear to be strongly influenced by changes in temperature in the range expected for the repository (see Subsection 6.3.1.2.5 of the Draft Environmental Assessment). The secondary minerals should, therefore, persist despite the rise in temperature of the repository.

The experimental investigations of basalt-water interactions together with available field evidence do not indicate major dissolution of basaltic host rocks that could lead to significant increases in permeability. Further experimental characterization of reaction products in the basalt-ground-water system is planned by the U.S. Department of Energy. This will help to further quantify the net changes in mass involved in these reactions.

A brief discussion of expected effects of elevated temperature on basalt and secondary mineral dissolution is included in Subsection 6.3.1.2.5 of the final Environmental Assessment.

Issue: Methane explosion

A comment was received that states concern about the possibility of a methane explosion in a repository in basalt.

Response

As stated on pages 6-187 and 6-188 of the Draft Environmental Assessment, methane found in the repository will be diluted with ventilation air to concentrations below 0.25 percent. This concentration is far below the concentration required to form explosive mixtures.

C.5.3 ROCK CHARACTERISTICS

Many commenters questioned the suitability of the host basalt for the repository. Despite their diversity, the comments actually fall into three broad topics and one miscellaneous category. These topics and associated subsections are given below.

- C.5.3.1, Influence of thermally induced fracturing on hydraulic conductivity.
- C.5.3.2, Flexibility as to the depth, configuration, and location of the underground repository.
- C.5.3.3, Waste emplacement thermal density.
- C.5.3.4, Miscellaneous.

Additional comments and responses on rock characteristics appear in Section C.8.2 of this appendix.

C.5.3.1 Influence of thermally induced fracturing on hydraulic conductivity

Numerous comments were received dealing with thermally induced fracturing and hydraulic conductivity. These comments are divided into the five following issues, each of which are addressed in this subsection:

- Thermally induced fracturing.
- Thermal shrinkage of fracture infill materials.
- Abundance of fracture infill materials.
- Influence of stress change on fracture conductivity.
- Thermal fracturing of vesicles.

Issue: Thermally induced fracturing

Commenters were concerned that hydraulic conductivity would likely increase due to thermally induced fractures.

Response

Most comments on thermally induced fracturing and the potential increase in hydraulic conductivity implied that this increase in itself was sufficient grounds for concern or disqualification. These comments did not take into account the conservative assumption in the performance assessment that, even if the waste were instantaneously released in the flow top, the reference repository location would meet the U.S. Department of Energy siting guidelines. Hence, fracturing in the flow interior may occur, but it does not violate the ability of the reference repository location to isolate the waste.

Some commenters questioned the philosophical approach in the Draft Environmental Assessment in discussing the rock characteristic postclosure qualifying condition in Subsection 6.3.1.3.2 and the conclusions in Subsection 6.3.1.3.8. The Draft Environmental Assessment (p. 6-109) states that " . . . as credit is not presently taken for the isolation potential of the Cohassett flow dense interior, thermally induced fracturing around the emplacement borehole or emplacement rooms, therefore, would not adversely affect the projected ability of the host rock to provide isolation." The commenters suggested that the isolation characteristics of the flow interior should be assessed in establishing a position with regard to the qualifying condition.

These comments also challenged the accuracy of the discussion on the potentially adverse condition discussed in Subsections 6.3.1.3.5 and 6.3.1.3.7 (DOE, 1984a; 960.4-2-3 with regard to the significance of the isolation potential of the flow interior. They suggest that the heat generated by the waste and thermally induced fracturing could significantly decrease the isolation provided by the host rock.

The U.S. Environmental Protection Agency rule on the definition of the distance to the accessible environment has been modified (from 10 to 5 kilometers (4.5 to 2.27 miles)) since the Draft Environmental Assessment was released. In light of this modification, the U.S. Department of Energy has reevaluated isolation requirements of the host rock and the results, presented in Subsection 6.4.2.6, indicate that travel time through the host rock augments, but is not essential to, isolation capability. The revised position resulting from the interpretation of the U.S. Environmental Protection Agency final rule is that the repository design should incorporate at least 10 meters (33 feet) of undamaged dense interior between the repository excavations and the flow top. This requirement dictates that thermally induced fracturing, as well as excavation-induced fracturing, be limited to the immediate vicinity of the excavation.

Thermally induced fracturing is not expected to impact waste isolation between the repository and the accessible environment. Significant decrease in the isolation characteristics of the host rock would involve thermal fracturing of the 10-meter (33-foot) zone of dense interior basalt and reduction in the retardation characteristic of the basalt in the dense interior and flow top. The interior of the Cohassett flow is sufficiently thick to ensure at least 10 meters (33 feet) of undisturbed interior host rock, and thermally induced fracturing is expected to be limited to within the excavation-induced damage zone around the openings. Change to the flow top is not expected because this zone is not significantly thermally stressed.

Changes have been made in Subsections 6.3.1.3.2, 6.3.1.3.5, and 6.3.1.3.7 to reflect the provision of 10 meters (33 feet) of undamaged dense interior between the repository excavation and the flow top.

<u>Issue</u>: Thermal shrinkage of fracture infill materials.

Concern was raised that permeability would increase with increasing temperature due to volume decrease of fracture-filling secondary materials.

Response

The impact of elevated temperature on the fracture-filled secondary minerals has been investigated by oster van Groos (1981) and has shown that the temperature of dehydration of smectites (the predominant clay infill mineral group) is significantly increased with the presence of water vapor or pressure. Thermal studies have also shown (e.g., Fig. 6-5 in the Draft Environmental Assessment) that the temperature change above and below the repository rapidly decreases, with temperature changes in the dense interior-flow top contacts, approximately 30 meters (100 feet) above and below the repository, of 70°C (126°F). Absolute temperatures at these locations are approximately 120°C (248°F), which is below the dehydration temperature (200°C, (392°F)) of smectites at the expected fluid pressures in the flow tops. At these contacts, the fluid pressures will be significantly higher than ambient, possibly as high as the initial pressure of 9.5 megapascals (1,400 pounds-force per square inch).

Subsection 6.3.1.3.6 of the final Environmental Assessment has been expanded to quantify the expected impact of thermal loads on thermally induced fractures and to discuss the potential for steam-generated fractures. Also included in this section is a descriptive summary of expected joint condition and infill materials.

Issue: Abundance of fracture infill materials

Commenters stated that the Draft Environmental Assessment is unclear as to whether or not most fractures in the host rock are filled.

Response

Joint infill characteristics have been studied during core drilling programs and surface mapping (Long and WCC, 1984) and recently by Lindberg (1986). These studies suggest that most naturally occurring joints have some infill material, usually thin coatings or partial coatings of clay-like minerals. The infill material with the Cohassett flow is primarily (80 percent) clay (Long and WCC, 1984, p. I-124). Of the fractures studied, 50 percent had thicknesses less than 0.10 millimeter (0.004 inch) with width fractures greater than 1 millimeter (0.04 inch) constituting less than 2 percent of all fractures (Long and WCC, 1984, pp. I-84 to I-88). Lindberg (1986) notes that virtually all (99.4 percent) cooling joints in the Cohassett flow are filled completely with clay, silica, or zeolite.

Further details on the joint properties and infill materials appear in Subsection 6.3.1.3.6 of the final Environmental Assessment.

Issue: Influence of stress change on fracture conductivity

Several commenters stated that the opening and closing of existing fractures and their influence on fracture conductivity because of stress changes during shaft and tunnel construction has not been addressed and quantified in the Draft Environmental Assessment.

Response

The opening and closing of existing fractures during shaft and tunnel construction is expected to be limited to the immediate vicinity of the excavation in the damaged rock zone. This zone is limited to 1 to 2 meters (3.3 to 6.6 feet) around the excavation and is supported by rock bolts, shotcrete, or the shaft liner. Release of radionuclides to the accessible environment through this potential pathway has been evaluated in Section 6.4 of the Draft Environmental Assessment and is not the controlling or dominant release mechanism. Away from the damaged rock zone, stress changes will be small and predominantly compressive, which leads to joint closure and reduction in permeability or joint hydraulic conductivity. No credit is taken in the performance assessment for the reduction in joint hydraulic conductivity because of stress increases.

Issue: Thermal fracturing of vesicles

A concern was stated that fluid-filled vesicles might expand, fracture the vesicle walls, and create additional permeability.

Response

The potential for fluid-filled vesicles to expand and fracture the vesicle walls is considered remote because of the strength of the intact basalt relative to the pressure increase, the low temperature gradient away from the immediate vicinity of the canister, and pressure dissipation by flow through the intact basalt to nearby hydraulically connected joints.

No evidence has been found indicating thermal expansion of fluid-filled cavities produce fracturing in basalt during past field or laboratory studies. The full-scale heater tests at the Near-Surface Test Facility were conducted in Pomona Member basalt that contained natural ground water. The water was converted to steam in some of the instrumentation holes and in the heater hole. Post-test coring and laboratory testing of cores indicated no significant change in physical and mechanical properties and mapping of the heater test hole indicated no new fracture development. If expansion of water had induced fracturing, some reduction of the strength of core would be expected and some new fractures would be detectable at the heater wall. The temperatures generated during the full-scale heater tests were up to 635°C (1,175°F), significantly higher than that expected at the repository horizon (200°C (392°F)).

Laboratory studies have been conducted on cores of basalt under dry and saturated conditions with and without heating. No reports have been recorded of basalt cracking, popping, or splitting as a result of heating. However, a detailed, specific study of this potential phenomena has not yet been conducted.

To theoretically evaluate the potential for fracture development by thermal expansion of fluid-filled vesicles, a simplified representation of a vesicle has been analyzed. This analysis represented a vesicle as a long cylindrical hole in a rigid, impermeable rock and assessed the pressure developed in the fluid from thermal expansion and compression of the fluid. Later, the rate of flow of fluid from the circular cylinder to a nearby fracture was considered to show that due to the slow buildup of temperature, excessive pressure could be dissipated by flow from the vesicle throu h the rock matrix to a nearby fracture.

The pressure buildup in a water-filled vesicle in an incompressible solid due to a temperature increase depends on the bulk thermal expansion coefficient and the bulk compressive modulus of water. The bulk thermal expansion coefficient of liquid water is approximately 6×10^{-4} per degree Celsius, which is aproximately 30 times that of basalt. Therefore, if there were a closed vesicle, pressure would be developed with heating in the fluid-filled vesicles. The compressibility of water (2.3 gigapascals (3.3×10^5 pounds-force per square inch)) is, however, significantly lower than basalt (80 gigapascals (11.6×10^6 pounds-force per square inch)), but even so, high ressures could be developed in the vesicles at relatively low temperatures. For example, a temperature change of 30°C (118°F) could cause a pressure increase of approximately 36 megapascals (5,220 pounds-force per square inch) in sealed vesicles. This would be sufficient to induce horizontal fractures that would propagate in the basalt until either sufficient new volume was created to lower the pressure, or an adjacent vesicle or fracture were intersected. Such fractures would be short and not significantly impact the vertical permeability of the rock mass.

For the conditions typical for the Cohassett flow, darcian flow through the unfractured basalt to nearby hydraulically connected joints would dissipate this pressure, thereby reducing the potential for thermally induced fracturing. Analyses indicate that for a pressure differential of 1 megapascal (145 pounds-force per square inch), sufficient water volume would flow within 1 year to a joint 5 centimeters (2 inches) away to be produced by the thermal expansion of water up to 300°C (572°F). This suggests that for the temperature changes expected around the repository, water pressures in the vesicles will be dissipated by darcian flow rather than fracturing.

C.5.3.2 Flexibility as to the depth, configuration, and location of the underground repository

Numerous comments were received on the general area of flexibility, most dealt with the thickness of the host basalt while the remainder dealt with the lateral extent of the host basalt.

C.5.3.2.1 Thickness of host basalt

Several comments were received dealing with the thickness of the host basalt. These comments fall into the following six issues, each of which is addressed in this subsection:

- Variation in thickness of the Cohassett flow.
- Rock-support requirements and maintenance for excavation through the vesicular zone.
- Availability of three other flows to provide flexibility.
- Change in minimum thickness requirements.
- Postclosure favorable condition 1.
- Statistical significance of regional thickness data.

Issue: Variation in thickness of the Cohassett flow

Commenters stated concerns that the thickness of the Cohassett flow would vary much more than the Draft Environmental Assessment indicated; the implication was that unexpectedly thin areas would prevent construction of the repository.

Response

The thickness of the Cohassett flow has been observed in 8 holes in the reference repository location and at a total of 22 locations in the vicinity of the reference repository location. The average thickness of the 8 holes in the reference repository location is 71.7 meters (235 feet) but if all 22 holes are included, the mean thickness is 62.1 meters (204 feet). The required interior flow thickness is 27 meters (89 feet) from postclosure and preclosure considerations. The possibility of a small area having less thickness than either of these limits cannot be discounted, but at this time it appears unlikely that the flow interior of the Cohassett flow will be thinner than 27 meters (89 feet). If a region with a thin flow interior is encountered during repository development, either waste will not be emplaced, or a change in the repository layout will be made to avoid the thin area. Additional data would be available from site-characterization testing and an in situ observation of the flow characteristics.

Changes have been made in Subsections 3.2.2.3, 6.3.1.3.3, and 6.3.3.2.3 of the final Environmental Assessment to present new data on the Cohassett flow thickness and to provide a clear definition of the 27-meter (89-foot) thickness requirements.

Issue: Rock-support requirements and maintenance for excavation through the vesicular zone

Commenters were concerned that excavations in the vesicular zone in the Cohassett flow would demand excessive rock-support requirements and maintenance requirements.

Response

The Draft Environmental Assessment did not address the rock support requirements for excavations in the vesicular zone. This zone has been studied and found to be suitable for excavation (Barton, 1986). The rock-support requirements are similar to those required in the dense interior and the same as those recommended for the colonnade.

Changes have been made in Subsections 6.3.3.2.4 and 6.3.3.2.7 of the final Environmental Assessment to include a description of the expected conditions, rock support, and maintenance in the vesicular zone.

Issue: Availability of three other flows to provide flexibility

Commenters stated that the other three flows (Rocky Coulee, McCoy Canyon, and Umtanum) are not viable options for the siting of the repository.

Response

The other three flows (Rocky Coulee, McCoy Canyon, and Umtanum) have been previously considered as potential candidate horizons. However, the Cohassett flow appears to be significantly more favorable than the other flows because of its consistent flow interior thickness.

Subsequent to the issuance of the Draft Environmental Assessment, a U.S. Department of Energy decision established that the Cohassett flow be considered during site characterization (DOE, 1985). This decision caused the final Environmental Assessment to be written to reflect only the Cohassett flow as a candidate horizon (see Subsection 2.2.3.2).

Changes have been made throughout the final Environmental Assessment to delete specific mention of the other three flows as potential candidate horizons.

Issue: Change in minimum thickness requirements

Commenters felt that the minimum required thickness of the basalt flow had changed from the earlier 61 meters (200 feet) to only 21 meters (69 feet). Commenters further stated that this change was made to allow the Hanford Site to qualify. Another commenter asked for the rationale behind the selection of 24 meters (79 feet) as the required thickness of the flow interior.

Response

In preliminary site-screening exercises, a minimum thickness of 24 meters (78 feet) of dense interior flow was selected; whereas, in the Draft Environmental Assessment (Subsection 6.3.3.2.3, pp. 6-153 through 6-157), a minimum thickness of 21 meters (69 feet) was used.

With subsequent changes in the U.S. Environmental Protection Agency requirements for the accessible environments, the thickness requirement for postclosure is now estimated to be 27 meters (89 feet). This difference results from the evolutionary process of the site-screening process. The 24-meter (78-foot) thickness was developed before the General Siting Guidelines (DOE, 1984a) were developed, and represented a preliminary screening criteria. For the General Siting Guidelines, flexibility, and for some conditions "significant" flexibility, must be demonstrated, which caused the U.S. Department of Energy to redefine the minimum thickness, and hence, what constitutes significant flexibility. The current subsurface repository design for basalt uses horizontal emplacement from rooms approximately 3 meters (10 feet) high. Some dense, competent basalt is required to form a stable roof and floor; therefore, the minimum thickness of basalt was selected as 21 meters (69 feet) (as described in Fig. 6-7 of the Draft Environmental Assessment). Around the shafts, a greater thickness is required. For postclosure considerations, it is considered desirable and prudent to maintain a 10-meter (33-foot) buffer zone of undisturbed dense interior basalt between the repository opening and the flow interior and flow top contact. This buffer zone is not required to satisfy either the 10,000-year ground-water travel time requirement or to ensure waste isolation, but would enhance both. To ensure that this 10 meters (33 feet) remains undisturbed during the postclosure period, a further buffer of 5 meters (16.4 feet) has been established to account for the damaged rock zone around the excavations. The thickness of dense interior basalt below the repository is maintained at 9 meters (30 feet) for preclosure conditions. This translates into a minimum flow interior of 27 meters (89 feet) to conservatively meet the postclosure flexibility requirements.

Changes have been made in Subsection 6.3.1.3.3 of the final Environmental Assessment to explain the 27-meter (89-foot) thickness requirement.

Issue: Postclosure favorable condition

A comment was made that the "not present" recorded in Subsection 6.3.1.3.3 of the Draft Environmental Assessment would seemingly prevent a finding of "present" in Subsection 6.3.3.2.3.

Res onse

In the Draft Environmental Assessment (Subsection 6.3.1.3.3), the postclosure favorable condition (DOE, 1984a; 960.4-2-3(b)(1)) considering host-rock thickness and lateral extent was taken as "not present." The preclosure favorable condition (DOE, 1984a; 960.5-2-9(b)(1)) was taken as "present."

The apparent inconsistency between preclosure and postclosure favorable conditions results from different criteria being applied for different guidelines when considering the differing time frames and performance aspects of the repository operations (preclosure) and functions (postclosure). Thus, the technical position for one guideline does not necessarily influence the technical position adopted for the other.

Current understanding of the reference repository location indicates that sufficient thickness and extent of the Cohassett flow exist to physically locate a repository within the dense portions of the flow interior. The degree of flexibility indicated through geologic reconnaissance establishes that significant flexibility exists to safely house the repository within the flow interior with a contingency factor for natural variability and the damage that may result from excavation and thermal effects.

However, a concern based on the presence of a vesicular zone of potentially reduced hydraulic conductivity within the interior portion of the Cohassett flow has influenced the postclosure finding. Uncertainty as to the hydraulic conductivity of the intraflow feature has warranted a conservative finding that significant flexibility be taken as "not present." The hydraulic conductivity values are not considered sufficiently high to present difficulty to the excavation or operation of the repository, nor do they represent the worst case of the expected repository excavation conditions, assumed for preclosure safety assessment. The utility of the vesicular zone to store waste during the postclosure period has not yet been established with confidence. Performance analysis of the repository is not sensitive to the use of the vesicular zone and indicates that the ground-water travel time criteria would be met even without consideration of the retardation provided by the host flow interior, including the vesicular zone. However, because the Cohassett flow vesicular zone hydraulic conductivity cannot be established with confidence, the conservative finding that the favorable condition was not present for postclosure guideline considerations was adopted.

Changes have been made in Subsections 6.3.1.3.3 and 6.3.2.3.3 of the final Environmental Assessment to define the thickness requirement and to discuss the uncertainty in hydraulic conductivity of the vesicular zone.

Issue: Statistical significance of regional thickness data

A commenter stated that the data base is so variable as to be statistically unreliable, so any choice of the Cohassett flow is premature.

Response

Comments were received on the statistical significance of the data used to argue the thickness of the flows. It is recognized that the data base in flow thickness is sparse, and insufficient for detailed design. A more complete definition of the thickness of the flow interior of the repository horizon can be expected with more confidence during site characterization. At present, core hole data and inference from outcrops of the flows is sufficient to support the conclusions presented in the Draft Environmental Assessment on flow continuity and thickness.

Subsection 6.3.3.2.3 of the final Environmental Assessment has been modified to present additional data from newer holes, with more emphasis placed on data from the reference repository location and from within 5 kilometers (2.3 miles) of the reference repository location.

C.5.3.2.2 Lateral extent of host basalt

Ten comments were received dealing with the lateral extent of the host basalt. These comments are divided into the following two issues:

- Intraflow stratigraphy.
- Repository extent as a result of defense waste.

Issue: Intraflow stratigraphy

According to a commenter, given the limited data, the intraflow stratigraphy or uniformity of the host basalt may limit the lateral flexibility open for construction of the repository.

Response

There are no known structures that cross basalt flows, such as faults, that would seriously impact lateral flexibility in siting the repository within the reference repository location.

Intraflow structures such as pillow palagonite zones and a thickened flow top have not been observed at outcrop in the Cohassett flow, but have been observed in other flows in the Sentinel Gap area (some 25 kilometers (16 miles) from the reference repository location). These intraflow structures have not been detected in core holes in the reference repository location. The character and thickness of the flow top, flow interior, and flow bottom of the Cohassett flow are not expected to change significantly from that observed in core holes. The internal character of the Cohassett flow and tectonic features in the reference repository location are discussed in Chapter 3. Intraflow structures could be significant if they represent zones of poor rock quality or zones of higher hydraulic conductivity and may produce higher water inflow than is currently expected of the flow interior.

The reference repository location area provides over five times the area required for subsurface facility construction; therefore, should adverse geologic features be encountered, other areas within the reference repository location are available for construction. The exposure of rock conditions during the Exploratory Shaft Test Facility and drilling from the shaft and test area will provide significant additional data to reduce the uncertainties identified with these comments.

No change is required in the final Environmental Assessment as a result of this comment. However, a more complete description of the Cohassett flow characteristics has been included in Subsection 6.3.3.2.9.

Issue: Repository extent as a result of defense waste

Commenters stated that estimates of repository size ignore the possibility that defense waste may need to be stored in the repository. With the added defense wastes, the projected lateral extent of the repository may be insufficient. The effect of defense waste on the lateral availability of suitable host rock was also questioned.

Response

The effect of defense waste on the repository size will be assessed when specific quantities and heat generation rates for the defense wastes are known. The mix of commercial wastes and age at placement presently are not known; therefore, repository size has been estimated assuming all waste is 10 years old. A significant portion of the waste received is expected to be older than 10 years, which could allow closer spacings between waste canisters, and hence, a reduced repository size. At present, it is unlikely that additional defense waste will significantly change the size of the repository, thereby impacting the lateral availability of suitable flow interior host rock.

C.5.3.3 Waste emplacement thermal density

Issue

One reviewer commented on a discrepancy in the Draft Environmental Assessment. Figure 6 5 reads " . . . 8.2 watts per cubic meter, . . . "

whereas the text reads " . . . 8.2 watts per square meter." This same reviewer stated that there is no reference regarding how much waste this "8.2" refers to.

Response

This discrepancy is the result of a mislabeled figure. The caption for Figure 6-5 should have read " . . . 8.2 watts per square meter." The calculation is based on a completed repository areal extent and full storage. Because of other changes in the text in response to comments, this figure has been deleted.

C.5.3.4 Miscellaneous

Sixteen comments on rock characteristics were received that do not fall into any of the previously discussed classifications. These comments pertain to the following issues, each of which is addressed in this subsection:

- Unsuitability of basalt.
- Steam generation.
- Evaluation of alternative mining techniques.
- Other phenomena.
- Partial glass dissolution.
- Influence of drilling on basalt.
- Rock characteristic uncertainties.

Issue: Unsuitability of basalt

Commenters felt that the fractured basalt is not safe or the basalt could fold up; the stability and permeability of the basalt is questionable; basalt is seamy, discontinuous, and interlaced with water courses; and basalt is not good for long-term stability.

Response

The general comments that basalt is not safe (i.e., seamy or unstable) were made without specific reference to time frames or phenomena. One commenter was concerned that " . . . large amounts of underground water and unsolid rock makes it a very dangerous site." While most deep, hard rock excavations are "unsolid" to some degree, the Draft Environmental Assessment presented a preliminary determination based on current data and commonly applied methods that indicated it is feasible to construct a repository at the proposed location within the Cohassett flow under safe working conditions that meet the regulatory guidelines with regard to radionuclide release. The response provided with regard to the issues in Subsections C.8.2.1, Water inflow, and C.8.2.5, Worker safety, also relates to this group of comments.

Issue: Steam generation

Commenters were concerned that the waste may produce steam and the heat and water pressures could affect the storage areas.

Response

The question of steam generation is related to the potential for water inflow to the canister-storage holes. Water inflow is expected to be minimal (on the order of 0.0063 cubic meter per second (100 gallons per minute)) for the entire repository. During the retrievable storage phase, some steam will be produced. The full-scale heater tests at the Near-Surface Test Facility generated some steam, which had only a minor effect on heat transfer but did affect the response of some thermocouples (Gregory and Kim, 1981). After closure, resaturation of the repository horizon is expected. During the resaturation period, steam will continue to be produced, but eventually the full preexisting piezometric head will be reestablished, raising the boiling point of water above the repository temperature and, hence, inhibiting the generation of steam. No steam is expected to be vented to the atmosphere during this resaturation period because of the sealing and backfilling in the repository and shaft.

Issue: Evaluation of alternative mining techniques

The adequacy of mining techniques, including radiological factors was questioned.

Response

Alternative mining techniques for the shaft and underground openings have been evaluated and will continue to be reevaluated as construction experience is gained at the reference repository location. The exploratory shafts will be blind-hole drilled, whereas conventional drill-and-blast techniques will be used for the exploratory shaft facility drift excavation. Mechanical boring machines have been evaluated for mining portions of the subsurface developments, but present plans only include the use of conventional drill-and-blast techniques. Technological development before construction begins or during repository development could result in the selection of alternative technologies in the future.

Issue: Other phenomena

One commenter stated that the statement " . . . there are no known physical, chemical, or radiation related phenomena that are expected to adversely affect the Cohassett flow dense interior . . . " is not known with the degree of certainty required for the final Environmental Assessment.

Response

The comment refers to the first sentence of paragraph 4, page 6-107 of the Draft Environmental Assessment, which reads in part " . . . phenomena that are expected . . . "

The above phrase has been modified in Subsection 6.3.1.3.6 of the final Environmental Assessment to read as follows: " . . . phenomena, other that those noted above, that are expected . . . "

Issue: Partial glass dissolution

A commenter stated that experimental studies have not evaluated variable mineralogical suites to obtain optimum zones of repository location relative to resultant basalt strength after partial glass dissolution.

Response

The effect of partial glass dissolution on rock mass strength has not been evaluated at this time, but neither has it been demonstrated that this factor should be used as a significant parameter for ascertaining the optimum zone for repository location. Further studies of this effect would be included in site-characterization studies, if such studies appear warranted.

Issue: Influence of drilling on basalt

A concern was raised that drilling into the basalt will affect the characterization of the basalt.

Response

Drilling is expected to be used for reconnaissance and shaft-sinking (physical access) purposes. Reconnaissance drilling is a necessary part of geologic assessment and the changes this activity imparts to the rock mass are expected as part of the characterization process. Standard industry practices are relied on to reduce the influences drilling may have on the tests or observations being performed. The relative degree of disturbance to the host rock compared to the areal extent of the repository is not considered a problem in terms of repository integrity. Also, shaft drilling into the basalt in itself is not considered a problem from the waste isolation point of view. Golder (1983a) showed that for a repository in basalt, only 0.1 to 2.0 percent of the vertical ground-water flow entering the repository area would move laterally and enter the vertical shafts at the repository level. Performance assessment calculations (see Subsection 6.4.2.3.4 of the Draft Environmental Assessment) have assumed a more conservative value of 10 percent in evaluating the effectiveness of repository shaft seals in controlling the cumulative radionuclide release to the accessible environment. A seal system will be relied on to provide an engineered barrier against waste migration from the underground openings to the shafts (see Subsection 6.4.2.2.2 of the Draft Environmental Assessment). Drill holes in or around the reference repository location will be sealed prior to waste emplacement, and because of their small diameter and favorable capacity to be sealed, these holes are not considered credible pathways for radionuclide releases. Even so, the number of exploratory drill holes will be minimized to reduce the potential for leakage from these holes.

No change is required for the final Environmental Assessment with regard to drilling processes. Changes have been made in Subsection 6.4.2.2.2 of the final Environmental Assessment in regard to repository seal subsystems.

Issue: Rock characteristic uncertainties

A comment was made that the rock characteristics section would benefit from a concise overall discussion of assessment results and relevant uncertainties.

Response

The uncertainties in rock characteristics are, in general, high and are expected to be reduced by exploratory excavation and testing at depth at the potential repository horizon. Uncertainties exist as to the applicability of rock-support design methodologies for the interlocking jointed basalts under high horizontal stresses. The constructibility issues (preclosure) can only be resolved by exploratory excavation. The long-term isolation characteristics of the reference repository location are ensured by not relying solely on the impermeable nature of the dense interior; hence, uncertainties related to thermal degradation or fracturing of the basalt do not control the ability of the reference repository location to meet the siting guidelines on radionuclide releases. Should the reference repository location be recommended for characterization, the site-characterization phase will include studies and tests to reduce the uncertainties associated with safe construction and radionuclide containment and isolation.

C.5.4 CLIMATIC CHANGES

Numerous comments dealt with climatic changes discussed in the Draft Environmental Assessment. Comments for this section are discussed in three issues:

- Glacial events.
- Migration of Columbia River.
- Miscellaneous.

Issue: Glacial events

According to several commenters, glacial events, such as those that occurred during the Pleistocene Epoch or that are predicted for the future, probably would affect the ground-water flow system or the isolation of waste at a repository in the reference repository location. These findings are contrary to positions taken in the climatic changes guideline (DOE, 1984a; 960.4-2-4) discussed in Subsection 6.3.1.4 of the Draft Environmental Assessment. The comments suggested likely effects on the repository would include loading and unloading of glacial flood-waters or a continental ice sheet that would be expected to cause perturbations in ground-water flow, increase fracturing in the basalt sequence, and (or) reactivate existing structures.

Response

Future climatically induced changes, both short-term catastrophic flooding and long-term regional changes in recharge and discharge, are not expected to adversely affect the deep ground-water flow system or waste isolation in the reference repository location. Changes in pressure and recharge associated with catastrophic flooding are not expected to have a significant effect on the deep ground-water flow system within the reference repository location. Long-term regional changes to the recharge-discharge areas are not expected to adversely affect the deep ground-water flow system in the reference repository location. The reason climatic changes are not expected to adversely affect the deep ground-water system is that associated changes are judged to be transient, shallow and (or) local, so only changes to the shallow ground-water flow systems should occur. There is uncertainty in this assessment that can only be resolved during site characterization.

The development of fractures or the reactivation of tectonic structures, perhaps due to rapid loading and unloading of catastrophic flood waters, has been reported in nearby surface exposures (Farooqui, 1979; PSPL, 1982). However, fractures or reactivated structures are not expected to propagate downward to repository depths due to confining pressure at depth. The U.S. Department of Energy believes that the Draft Environmental Assessment contained sufficient information, based on the present knowledge of climatic changes over the Quaternary Period, to support the preliminary positions on the climatic changes guideline and conditions.

Future warming (i.e., "super interglacial") through man-induced increases in atmospheric carbon dioxide was not considered in the Draft Environmental Assessment. While such a change is not expected to adversely alter the hydrologic system in the next 10,000 years, the possibility will be considered in future studies, should the reference repository location be recommended for site characterization. Climatic changes between possible future major glacial advances will be studied for potential effects on the ground-water flow system.

Issue: Migration of Columbia River

Three commenters suggested that migration of the Columbia River as a result of aggradation of a future proglacial outwash plain, landslides off the White Bluffs east of the site, or reduced flow in the Columbia or Yakima Rivers could alter ground-water flow and thus bring wastes closer to the accessible environment. The Draft Environmental Assessment also was considered inadequate in the evaluation and substantiation of expected geohydrologic changes caused by future manmade or natural warming and cooling trends.

Response

The potential for significant futher incisement of the Columbia River within the Pasco Basin is not considered likely based on sedimentary records since the late Miocene. The potential for incisement of the Columbia River was discussed in detail in Subsection 6.3.1.5 of the Draft Environmental Assessment.

A discussion of the potential for the diversion of the Columbia River was not addressed in the Draft Environmental Assessment and has been added to Subsection 6.3.1.4.3 of the final Environmental Assessment.

Issue: Miscellaneous

Other commenters (1) questioned the future climatic changes based on the model in Craig et al. (1983), (2) requested additional information on the effects of an ice age during the period when waste is still hot, (3) suggested that wastes could be leached under present meteorological conditions, (4) stated that renewed catastrophic flooding was dismissed by a dam-breach scenario, (5) found inconsistencies of catastrophic flood durations, (6) found an erroneous reference, (7) questioned inconsistent or inaccurate wording of the rates of geomorphic processes expected over the next 100,000 years, and (8) asked why Brets (sic) floods were ignored and inquired about the possibility of future catastrophic floods.

Response

A preliminary model of future Pleistocene catastrophic flooding presented by Craig et al. (1983) that predicts the next glacial maximum in approximately 15,000 years is not certain because large uncertainties are associated with the data and assumptions on which the model is based. According to the modeler, there is a 75-percent chance that the model is correct and a 25-percent chance it is incorrect. Refinement and confidence in climatic models will be gained as more data are collected and as computer models become more sophisticated.

Waste is expected to be sufficiently cooled before the next ice age, thousands of years from now, because most of the heat generated by a repository will have dissipated with the decay of the shorter-lived isotopes. Furthermore, heat generated at proposed repository depths should not affect the ground surface or change the weather, because of the insulating effect of the overlying sequence of basalt and sediments (approximately 900 meters (3,000 feet) in thickness).

Rainfall and dampness will not leach wastes into the soil. It is important to note that a repository in basalt would be beneath the water table and 900 meters (3,000 feet) below the ground surface. At this depth, surficial processes including the effects of rainfall would not have an adverse effect. The potential for leaching or dissolution of wastes in ground water was discussed in Subsection 6.3.1.6 of the Draft Environmental Assessment.

The Draft Environmental Assessment made no association between Pleistocene catastrophic floods and a breach of the Grand Coulee Dam, two types of flooding that could adversely affect the reference repository location. The potentially adverse effects of flooding during the pre-closure period (approximately 100 years) were evaluated on the basis of a 50-percent breach of Grand Coulee Dam. Because it takes many thousands of years for ice buildup and advance, the potential for the second type of flooding, catastrophic proglacial, is not a credible disruptive scenario for the preclosure period.

The words "less than 2 weeks" in Subsection 6.3.1.4.6 of the Draft Environmental Assessment may be an underestimate of maximum flood duration. A more appropriate and less-restrictive estimate of "weeks or less" was presented in Subsection 6.3.1.4.3. In Section 6.3.1.4.6 of the final Environmental Assessment, the maximum flood duration has been changed to "weeks or less." An erroneous reference to Brown (1970, p. 29) in Subsection 6.3.1.4.2 has been deleted.

A statement in Subsection 6.3.1.1.12 stated that there is " . . . no evidence to suggest . . . current rates of geomorphic processes are expected to change within the central Pasco Basin over the next 100,000 years." To be made consistent with Subsection 6 3.1.4, the words "current rates" have been replaced by "long-term rates." In Subsection 6.3.1.4.7, the word "significant" has been changed to "extreme."

Catastrophic Pleistocene floods discussed throughout the climatic changes section are the same as Bretz's floods. Other names for the Pleistocene floods (i.e., Bretz, Spokane, Missoula floods) have been added to Section 6.3.1.4.2.

C.5.5 EROSION

Several comments were received concerning the erosion guideline. Issues addressed include the following:

- Extreme erosion.
- Depth of erosion.
- Changes to ground-water system.

Issue: Extreme erosion

One commenter stated that because extreme erosion by Pleistocene catastrophic floods has occurred in the geologic setting during the Quaternary Period, isolation of wastes over the next 10,000 years is not assured.

Response

The first potentially adverse condition under erosion (DOE, 1984a; 960.4-2-5(c)(1)) (see Subsection 6.3.1.5.6 of the Draft Environmental Assessment), stating " . . . a geologic setting that shows evidence of extreme erosion during the Quaternary Period, . . . " was interpreted to be not present in the Draft Environmental Assessment because erosion that carved the Channeled Scablands is not considered extreme. This interpretation was based on the fact that although erosion of coulees and channelways associated with the Channeled Scablands was dramatic and areally extensive, the results were relatively shallow (up to approximately 100 meters (300 feet)) when compared to the proposed repository depth (900 meters (3,000 feet) below the ground surface) at the reference repository location.

Changes have been made concerning the first potentially adverse condition to strengthen the argument that extreme erosion has not occurred on the Columbia Plateau during the Quaternary Period.

Issue: Depth of erosion

Another commenter stated that erosion of the upper Ringold unit within the Pasco Basin was not documented.

Response

Erosion of the upper Ringold unit in the Pasco Basin was documented in the Draft Environmental Assessment (see Subsections 3.2.2.5 and 6.3.1.4 and Fig. 3-23), although it was not specifically referred to in Subsection 6.3.1.5.6. Additional information has been added to Subsection 6.3.1.5.6 of the final Environmental Assessment to further document and constrain the timing of post-Ringold incision.

Issue: Changes to ground-water system

Other comments claimed the evaluation process did not address potential changes in ground-water discharge near the reference repository location or increased infiltration to deep aquifers from erosion.

Response

No significant changes to ground-water discharge are expected near the reference repository location. The Columbia River is expected to remain in approximately its present position in the Pasco Basin for at least the next 10,000 years; therefore, river migration is not expected to adversely affect the ground-water discharge to the deep ground-water systems of the Cold Creek syncline.

The Columbia River, in the northern part of the Pasco Basin, is presently confined to the Wahluke syncline, a structural basin bounded by the Saddle Mountains to the north and Umtanum Ridge-Gable Mountain to the south. In the southern Pasco Basin, the Columbia River flows in a north-south direction from Gable Mountain to Wallula Gap near the axis of the Pasco syncline. For the Columbia River to be diverted south across the Umtanum Ridge-Gable Mountain structure, the river would have to flow through a structural and topographic low at the gap located between Gable Mountain and Gable Butte. This low is approximately 25 meters (80 feet) above present river level. The existing landforms (i.e., principally the bounding basalt ridges and the intervening sediment plain) and expected future erosional and aggradational processes (other than catastrophic flooding) are not expected to result in a diversion of the Columbia River from its present position through the gap within the next 10,000 years. Therefore, discharge from either the deep or shallow ground-water flow systems is not expected to change appreciably because the potential for erosion and movement of the Columbia River within the Pasco Basin is confined to near its present location north of the Umtanum Ridge-Gable Mountain structure. While there is potential for movement of the Columbia River through aggradation by proglacial outwash in the next 10,000 years, this aggradation is not expected to exceed the 25 meters (80 feet) required to divert the Columbia River into the Cold Creek syncline.

The information presented in the Draft Environmental Assessment, with additional discussion on the future effects of the Columbia River, is considered sufficient to support the preliminary position for the erosion portion of the General Siting Guidelines (DOE, 1984a; 940.4-2-5). Further studies are being considered to better understand the extent to which ground-water recharge occurs around the margins of the Pasco Basin and what effects, if any, shallow erosion and short-term recharge have on the deep ground-water flow system.

A discussion on the possibility of river diversion leading to erosion or changes in the ground-water flow system has been added to Subsections 6.3.1.5.2 and 6.3.1.4 of the final Environmental Assessment. Supplementary information also has been added to Subsection 6.3.1.5 9.

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C.5.6 DISSOLUTION

Comments assigned to this section have been cross-referenced to and discussed in Section C.5.2.

C.5.7 TECTONICS

Over 200 comments were received that dealt with various aspects of tectonics. One major concern expressed was that inadequate descriptions of deformation in the reference repository location and vicinity were provided in the Draft Environmental Assessment. Another major concern was that the Draft Environmental Assessment provided an overly favorable view of the tectonic setting and possible effects of tectonics on waste isolation. To address the comments on tectonics, this section has been divided into four subsections:

- C.5.7.1, Structures in and around the reference repository location.
- C.5.7.2, Geophysical surveys in the vicinity of the reference repository location.
- C.5.7.3, Seismicity.
- C.5.7.4, Stability.

C.5.7.1 Structures in and around the reference repository location

The discussion of structures in and around the reference repository location is divided into the following issues:

- Top-of-basalt structural features.
- Northwest-trending strike-slip faults.
- Small-scale strain features.
- Vantage analog study.
- Details of Umtanum Ridge structure.
- "White" fault.
- Remote sensing studies.

Issue: Top-of-basalt structural features

Several commenters were concerned that structural features depicted on top-of-basalt maps were not included in the Draft Environmental Assessment.

Response

The reference repository location is in the west central part of the the Cold Creek syncline on the Hanford Site (see Fig. 3-1 in the final Environmental Assessment). The Cold Creek syncline is generally a flat-lying syncline (see Fig. 3-8 in the final Environmental Assessment) situated between Yakima Ridge and Umtanum Ridge, with the syncline axis passing through the southwest portion of the reference repository location. Basalt within the reference repository location area of the syncline ranges in dip from 0 to 5 degrees. Myers (1981) interpreted the presence of smaller-scale structures superimposed on the predominant pattern, but acknowledged the uncertainty of these features; these features and the uncertainties are further discussed below. Also discussed below is the degree of deformation in the reference repository location and the uncertainty associated with it.

Myers (1981) constructed an interpretive top-of-basalt map from borehole data and geophysical data. Geophysical data included seismic reflection, multilevel aeromagnetic, ground magnetic, and gravity profiles.

The Myers (1981) map was purposely very conservatively interpreted for siting studies. Many of the subtle structural features depicted on this map fall within the expected variation among data sets used to construct the top-of-basalt surface. The top-of-basalt map was determined from boreholes drilled in the Hanford Site area since the 1920's. Variations in the elevation of the bedrock surface determined from boreholes can stem from four sources: (1) borehole elevations, (2) basalt-sediment contact, (3) borehole deviation, and (4) normal variation from the planar surface of a basalt flow top.

The first variation in the elevation of the bedrock surface is borehole elevation. Elevation measurements made at the borehole are assumed to be accurate to within 0.3 meter (1 foot). The point on the borehole casing where the measurement is taken can be one of three positions, with the difference between points being as much as 1 meter (3 feet).

The second variation in elevation, related to the basalt-sediment contact or to definition of the bedrock surface, stems from the criteria used to establish the bedrock surface. A variety of drilling techniques have been used to construct boreholes on the Hanford Site since the 1920's and different types of information have been collected from these boreholes by numerous organizations. Defining the basalt-sediment contact in core samples from diamond-drill core holes is objectively accomplished by examining the core. However, for rotary-drilled and cable-tool-drilled holes, accurately defining the basalt-sediment contact may not be easy or possible. Often only a descriptive log is available to define the bedrock surface. The variation in picking the bedrock surface is known to be as much as 7.6 meters (25 feet). This variation can be decreased by use of core hole data or through careful examination of rotary hole samples coupled with data from borehole geophysical logs.

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The third area of variability in boreholes that may affect the elevation of the bedrock surface is borehole alignment or deviation. This could be as great as 3 meters (10 feet) at 150 meters (500 feet) drilled depth. This variation can be reduced by conducting borehole-elevation surveys.

The fourth factor to consider is the normal variation from a planar surface of the flow top. Reidel (1984, p. 970) estimated the normal thickness variation of a basalt flow (1 standard deviation) to be approximately 4 meters (13 feet), based on data from five closely spaced boreholes in the Cold Creek syncline. This variation would be primarily at the top of the flow. This does not include any potential error resulting from erosion of the flow that could be identified only in core.

An estimate of the total possible variation in elevation of the basalt-sediment contact for boreholes other than precisely surveyed core holes on the Hanford Site is the summation of these factors: 1 meter (3 feet) for borehole elevation, 7.6 meters (25 feet) for defining bedrock contact, 3 meters (10 feet) for borehole deviation from the surface, and 4 meters (13 feet) for deviation of the flow top from a planar surface, totaling approximately 15.5 meters (51 feet). This means that features interpreted in the borehole top-of-basalt map that are less than 15 meters (50 feet) from the norm could be a combination of normal flow variation plus error in measuring the elevation of the basalt-sediment contact. The quality of the borehole data must be considered before interpreting a subtle structure; in most cases, a precisely measured and logged borehole in the reference repository location currently allows the uncertainty to be reduced to an estimated 8 meters (26 feet). Also, the total possible expected variation is a bounding value and it is likely that the individual variations compensate for each other.

On the top-of-basalt map, Myers (1981) interpreted several possible folds in the reference repository location that occur within the best possible control from contour lines. Myers interpreted several folds or potential folds with less than 15.2 meters (50 feet) of structural relief and, in many cases, less than 7.6 meters (25 feet) of structural relief in the reference repository location. These features fall into the uncertainty area discussed above because they are not controlled by precisely surveyed and logged boreholes. With present borehole data, no folds or faults have been interpreted on the top of basalt in the reference repository location with the level of uncertainty discussed above; the structures interpreted by Myers (1981) are based on geophysical data available at that time. Since that report, new data have been collected that allow refinement and reinterpretation of these features as discussed in Subsection C.5.7.2.

Additional supporting information on the generally flat-lying nature of the top of basalt in the reference repository location has been incorporated into Subsection 3.2.3.3 of the final Environmental Assessment.

Issue: Northwest-trending strike-slip faults

Several commenters stated that northwest-trending strike-slip faults are likely to trend through the reference repository location.

Response

Two principal types of faults have been identified in the western half of the Columbia Plateau: (1) east-trending high-angle reverse and (or) thrust faults that occur on the limbs of the large anticlinal ridges and (2) vertical to near-vertical faults with northerly trends and having reverse, normal, and (or) strike-slip movement.

The U.S. Geological Survey (Swanson et al., 1979) has mapped northwest-trending strike-slip faults on the western portion of the Columbia Plateau that transect the anticlinal ridges and extend for many kilometers (miles). The first indications of northwest-trending faults were provided by Newcomb (1969, 1970), who identified northwest-striking, dextral strike-slip faults north of the Columbia River and west of the Pasco Basin. Subsequently, Kienle and Newcomb (1973) implied that a series of northwest-trending aligned doubly plunging anticlines in the Arlington, Oregon, area were wrench-generated, although no strike-slip faults were mapped. Regional reconnaissance mapping of The Dalles 2 degree quadrangle by the U.S. Geological Survey identified more than 100 faults (Swanson et al., 1979, 1981). Many of these are dextral strike-slip faults oriented north 20 to 60 degrees west.

Strike-slip faults, often called wrench faults, typically have the following characteristics on the Columbia Plateau:

- Genetically related en echelon folds.
- Conjugate en echelon folds.
- Reverse of apparent normal separation along strike (scissoring).
- En echelon normal, antithetic, and synthetic faults.
- Subparallel synthetic strike-slip faults (Riedel shears).
- Lateral offset of pre-existing structure and stratigraphy.
- Horizontal to subhorizontal striae.
- Relatively straight trace for several to a few tens of kilometers (miles).

The northwest-trending faults of the western Columbia Plateau are steeply dipping with several meters to several tens of meters (feet to tens of feet) of dip-slip displacement and various amounts of strike-slip displacement (Bentley et al., 1980; Gardner et al., 1981; Swanson et al., 1979). The length may range up to 100 kilometers (60 miles). Without steeply dipping stratigraphic marker horizons, the amount of strike-slip movement, if any, on these faults has not been firmly established (Caggiano, 1983). Many resemble tear faults and may be confined to anticlines.

One of the most obvious features associated with these northwest-trending wrench faults in The Dalles area is the presence of relatively small, aligned, anticlinal hills. These folds are often doubly plunging domical or elongated structures that range from 1 to 5 kilometers (0.6 to 3.1 miles) and are usually less than 1 kilometer (0.6 mile) wide. These anticlinal domes generally have several hundred meters (feet) of structural relief and have consistent asymmetric steepness on the northeast limbs due to faulting.

The Rattlesnake-Wallula alignment that forms the southern margin of the Pasco Basin has been argued to have dextral strike-slip movement, as the result of north-south compression (Laubscher, 1977; Davis, 1981). The Rattlesnake-Wallula alignment is approximately 6.4 kilometers (4 miles) from the reference repository location at the nearest point. A series of anticlinal domes occurs along the trend in the southeast part of the basin; these domes are referred to as the "rattles" and resemble the domes along the northwest-trending faults in The Dalles 2 degree sheet. Structural development of the "rattles" and Rattlesnake Mountain on the Rattlesnake-Wallula alignment is contemporaneous with the Yakima folds. Strike-slip movement has been observed on the Wallula Gap fault along this trend (Gardner et al., 1981) and supports at least some dextral movement. Continuous exposure of 12-million-year-old basalt along the Yakima River where it crosses the Rattlesnake-Wallula alignment near the Hanford Site has shown no strike-slip displacement (Fecht et al., 1984). Studies of the growth of Rattlesnake Mountain (Reidel et al., 1983) show that this structure along the Rattlesnake-Wallula alignment developed under north-south compression in a manner similar to other Yakima folds. Paleomagnetic data (Reidel et al., 1984) independently support this. Because the Rattlesnake-Wallula alignment has a northwest trend, some amount of dextral movement is compatible with fold growth under north-south compression and, therefore, some component of strike-slip faulting is expected along the alignment. However, field data limit the amount and, in areas such as along the Yakima River, the age of movement.

No strike-slip faults have been observed crosscutting the Pasco Basin (Myers, Price et al., 1979, Plate III-1). Anticlinal ridges that bound the Pasco Basin have been mapped in detail and, except for the component of dextral movement on the Rattlesnake-Wallula alignment discussed above, no strike-slip faults have been observed similar to those on The Dalles 2 degree sheet (also discussed above). Tear faults have been observed along the major anticlinal ridges at boundaries between geometrically coherent segments of the structures, as in the Saddle Mountains (Reidel, 1984); but these faults are confined to the individual structure and developed as different geometries developed in the fold. Similar type faults have been mapped on Gable Mountain and studied in detail (Fecht, 1978; PSPL, 1982); these features are also interpreted as tear faults that are a response to folding. One potential strike-slip fault is the eastern edge of the Pasco Basin where the Ice Harbor dikes intruded along a northwest-trending inferred fracture zone (Reidel, 1984, p. 955). However, evidence of movement has not been observed on the Ice Harbor dikes which have been dated at 8.5 million years.

In the Cold Creek syncline there is sufficient structural control on the top-of-basalt map to identify anticlinal domes with structural relief commonly associated with strike-slip faults on The Dalles 2 degree sheet. No such features have been detected in the reference repository location, indicating that strike-slip faults of this type are probably not present. One potential fault west of the reference repository location may be the Cold Creek Barrier. Tests are under way to determine the exact nature of this feature. Should the reference repository location be recommended for site characterization, additional studies will be conducted to reduce the uncertainty regarding strike-slip faults in the Cold Creek syncline.

A discussion of northwest-trending structures in the Cold Creek syncline has been added to Subsection 3.2.3.3 of the final Environmental Assessment.

Issue: Small-scale strain features

Several commenters had concerns about small-scale strain features that were not discussed in the Draft Environmental Assessment.

Response

Two types of features have been identified in the Cold Creek syncline and reference repository location that indicate the north-south compressional stress has produced some strain features. These strain features, tectonic breccia and discing, are discussed below.

Moak (1981) summarized the zones of tectonic breccia in drill core from the Pasco Basin. He found that the breccia zones are infrequent in all the thousands of meters (feet) of core drilled and that most zones are from the Wanapum and Grande Ronde Basalts. The breccia zones are generally intact and less than 10 centimeters (4 inches) thick, although some are up to 30.5 centimeters (1 foot) thick. For example, core hole DB-10 on the south flank of Gable Mountain has breccia associated with two faults that repeat a section of Saddle Mountains Basalt (Myers, Price et al., 1979). No other breccia zones in the Cold Creek syncline have been identified as having displacements that repeat stratigraphic section. Two zones of tectonic breccia have been encountered in the upper Frenchman Springs flow in borehole RRL-6, which is located in the southwestern portion of the reference repository location. The zones are between the depths of 647 and 655 meters (2,123 and 2,149 feet) and each is 1 meter (3 feet) in apparent thickness.

Field studies have shown the relationship between characteristics of breccia zones and geologic structures. Major reverse faults along anticlinal ridges generally are associated with very thick breccia zones. Reidel (1984, pp. 951-952) found that breccia zones associated with the Saddle Mountains fault are very distinct and at Sentinel Gap consist of a fault zone of shatter breccia several hundred meters (feet) thick. In some areas (e.g., Smyrna Bench) the fault zone may be as much as 400 meters (1,300 feet) wide. Goff (1981) and Price (1982, p. 53) also found that breccia zones on Umtanum Ridge are very thick, and similar zones were found by Gardner et al. (1981) at Wallula Gap in the Horse Heaven Hills. An examination of the anticlinal ridges for most Yakima folds illustrates that thick breccia zones are typical of anticlines. This can be seen in the Columbia Hills along State Route 14 east of John Day Dam. In all cases, significant stratigraphic offsets can be demonstrated.

Price (1981, 1982) and Reidel (1984) observed that the greatest deformation occurs in the hinge areas of the anticlinal ridges and decreases with distance from that area. Studies of south-dipping limbs of north-vergent anticlines support these observations. To quantify these relationships, Price (1981, 1982) completed a detailed study of strain features on Umtanum Ridge and a detailed examination of specific areas on limbs of other folds. Price was the first to examine these features and no other study as detailed and complete has been made of the Yakima folds. Price found that the degree of brecciation is related spatially to the dip of the layering (Price, 1981, pp. 119 and 159). The greatest amount of tectonic jointing and faulting occurs in the hinge zone and in steeply dipping beds. On the flanks of the folds, Price observed low dips to the faults and often saw conjugate shear zones. The greatest amount of faulting and tectonic jointing occurs in the hinge zone and decreases to the gently dipping limbs. For example, on the well-exposed south limb of the Frenchman Hills along the Columbia River, Price (1981, pp. 151 and 152) observed numerous faults and shear zones that are only locally developed, but widely disseminated. Almost all the faults have low dips and occur in conjugate sets. These features typically have small displacements; an apparent maximum displacement of 1 to 2 centimeters (0.4 to 0.8 inch) dissipates to no recognizable displacement at a lateral distance of 1 meter (3 feet) on small shear zones (Price, 1982, pp. 7 through 16). Faulting primarily is confined to the individual basalt layer in which it occurs.

Price (1981) interpreted the greatest strain in the hinge area of the fold and decreasing strain away from this zone with small fault zones and shear zones on the flanks of the folds. Price also observed that there is relatively little deformation, other than steeply dipping tectonic joints, immediately adjacent to the hinge zone in the anticlinal crest (Price, 1982, pp. 7 through 17). He noted that synclinal troughs in the Burbank Creek syncline and in the syncline north of Umtanum Ridge near Priest Rapids Dam exhibit the least strain of any parts of the fold. These troughs do not show pervasive tectonic jointing or small-scale faulting related to folding. The study by Reidel et al. (1984) also examined strain features in folds by using paleomagnetism. This study showed the same results as Price's study: the greatest vector rotation occurred in the anticlinal ridges, with decreasing amounts of vector rotation down the flanks of the fold and little or no vector rotation in the synclines. This study independently supports the strain interpretation of Price (1981, 1982). It further supports Price's interpretation that the syncline shows the least strain effects.

Price (1982) examined the breccia zones described by Moak (1981) in the core drilled from the Pasco Basin to determine if the limited strain effects he observed in the field were present in core from the syncline. He noted that the largest breccia zone (taken from core hole DB-10) came from the flank of a fold, and that breccia zones in the synclines are fewer and thinner than those on the anticlinal flanks. He interpreted these breccia zones to represent localized minor faults in the syncline and did not observe any breccia zone that suggested a significant zone of faulting.

Core discing has long been known to be an indicator of high stress. Core discing has been described by Moak (1981) and Long and Woodward-Clyde Consultants (Long and WCC, 1984, p. I-230). Kim et al. (1984) have summarized the following conclusions on discing on the Hanford Site:

- The saddle-shaped discing is the result of nonaxisymmetrical horizontal stresses.

- Oriented core from holes producing saddle-shaped discs indicates that the maximum horizontal stress is generally north-south.

Kim et al. (1984) concluded that stress ratios calculated from the results of hydraulic fracturing tests are in general agreement with an analysis of core discing at the Hanford Site as presented by Myers and Price (1981) and Lehnoff et al. (1982).

A discussion of small-scale strain features (i.e., tectonic breccias and discing) has been added to Subsection 3.2.3.3 of the final Environmental Assessment.

Issue: Vantage analog study

Several commenters suggested that faults present in the Vantage analog study area could be present in the reference repository location.

Response

Synclinal areas within the Yakima Fold Belt commonly contain thick accumulations of sediments; the Cold Creek syncline is one such sedimentary basin. These synclinal basins have collected sediments throughout the Neogene and allows a determination of the rate and timing of folding and faulting. However, in most cases it is not possible to directly observe the basalt bedrock within these synclinal basins without drilling boreholes.

The Vantage area, a synclinal area between the Frenchman Hills and the Saddle Mountains, was chosen because it was well exposed. Unfortunately, the Vantage area appears to be not totally analogous to the Cold Creek syncline because it has been folded and uplifted by forces that produced the Hog Ranch-Naneum Ridge anticline and is also cut by major cross structures. The Vantage area lies on the flank and extends to the anticlinal crest of this major fold. The Hog Ranch-Naneum Ridge anticline is a major geologic structure that originates in the North Cascades and can be traced several hundred kilometers (miles) south to the Horse Heaven Hills, just north of the Washington-Oregon border (Swanson et al., 1979; Mackin, 1961; Hagood, 1985). This anticline forms the western structural boundary of the Pasco Basin and is situated approximately 29 kilometers (18 miles) west of the reference repository location. Many major structural faults and folds are associated with this anticline, which has caused uplift of the area. Farther east along the synclinal trend in the central Vantage area, mapping by the U.S. Geological Survey (Swanson et al., 1979) has shown a gentle dip slope similar to that interpreted for the Cold Creek syncline. No faults have been mapped in that syncline by the U.S. Geological Survey. As is the case with most synclines, lack of exposure precludes a detailed study of the area.

The Vantage study will produce useful information for determining the properties of faults and tectonic fractures, even though such zones may not be directly related to a syncline environment. In the Vantage analog area, faults can be characterized and geophysical surveys can be run to determine fault properties. This will provide data that will be useful for interpreting the results of similar work conducted in the reference repository location and surrounding area.

Issue: Details of Umtanum Ridge structure

Several commenters were concerned about the spatial relationship between the reference repository location and the Umtanum Ridge structure.

Response

Anticlines of the Yakima Fold Belt form the north and south margins of the Cold Creek syncline. These ridges have faults that dip generally south. Goff (1981, p. 66) inferred the Umtanum fault, a south dipping fault, to be north of the overturned and vertical basalt strata along the face of eastern Umtanum Ridge. Although not determining the age of this fault (p. 67), Golf observed no offset of Quaternary deposits and found that the Umtanum uplift is apparently older than the deformation zone coincident with the Olympic-Wallowa lineament.

In a more recent and detailed study, Price (1982, p. 55) constrained the dip of the Umtanum fault, based on two core holes, to be dipping south at not less than 20 degrees but possibly as much as 60 to 70 degrees. Additional drilling by Golder Associates (Price, 1982, p. 56) constrained the fault to have a minimum dip of 30 degrees with 45 degrees as most realistic. Price (1982, p. 170) further suggested that the fold geometry developed along eastern Umtanum Ridge is that expected if basalt is mechanically continuous and not disrupted by unknown faults within the Pasco Basin.

Although no data are available to show conclusively the presence of the Umtanum fault east of the eastern Umtanum Ridge (Gable Butte-Gable Mountain area), such a fault dipping between 30 and 60 degrees would pass under the northern boundary of the reference repository location at approximately a 2.77- to 8.32-kilometer (1.73- to 5.20-mile) depth and under the southern boundary at approximately a 6.46- to 19.39-kilometer (4.04- to 12.12-mile) depth.

Issue: "White" fault

Several commenters were concerned that a fault discussed by D. A. White of the U.S. Geological Survey was not discussed in the Draft Environmental Assessment.

Response

The presence of a fault that White (1983) describes as being 25 kilometers (15 miles) from the Hanford Site was based on a personal communication from D. A. Swanson in July 1981. A fault 25 kilometers (15 miles) southeast of the Hanford Site could lie on Rattlesnake Mountain, in the Horse Heaven Hills, or along the doubly plunging anticlines of the Rattlesnake-Wallula alignment. Extensive mapping by the Washington Public Power Supply System (WPPSS, 1981), Bond et al. (1978), the U.S. Geological Survey (Bingham et al., 1970, pp. 71 through 77), and Fecht et al. (1984) have not identified such a feature in these areas. Continuing studies are planned to map these areas in more detail, should the reference repository location be recommended for site characterization. Such studies would reduce the uncertainty associated with the existence of this fault.

Issue: Remote sensing studies

According to several commenters, remote sensing studies were not discussed in the Draft Environmental Assessment.

Response

A remote sensing study conducted by Pacific Northwest Laboratory (Sandess et al., 1979) covered a major portion of the Columbia Plateau. The data from this study were included in the Draft Environmental Assessment considerations. Within the reference repository location, all lineations were found to be related to nontectonic features.

Reference to the remote sensing study has been made in Subsection 3.2.3.3 of the final Environmental Assessment.

C.5.7.2 Geophysical surveys in the vicinity of the reference repository location

Several commenters were concerned that geophysical data were not used in the Draft Environmental Assessment for describing the geologic structures in and around the reference repository location. This subsection summarizes the most current analysis of geophysical anomalies in the vicinity of the reference repository location, and is divided into the following issues:

- General information on geophysical surveys.
- Specific geophysical anomalies.
- Deep structure.

Issue: General information on geophysical surveys

A number of commenters requested general information on geophysical surveys, including the objectives of the surveys and the types of surveys conducted.

Response

The reference repository location and the Cold Creek syncline have very limited bedrock exposure; therefore, identification and characterization of geologic structure in bedrock within the syncline is heavily dependent on geophysical and borehole data. The prime objective of the initial geophysical studies conducted by Basalt Waste Isolation Project staff at the Hanford Site was to provide reconnaissance-level information focused on locating areas that are relatively free of potentially adverse geologic structures. These reconnaissance geophysical studies, in addition to a few site-specific studies, were used in siting the reference repository location (Myers, 1981). Geophysical data sets were used to identify geophysical anomalies, defined here as departures of the geophysical character for a specific area from that of the surrounding area. Geophysical anomalies are not always readily depicted from geophysical data maps and cross sections, and do not necessarily represent geologic structures. Under most circumstances, the identification of geophysical anomalies is subjective and dependent on analytical techniques and (or) interpretation.

There are numerous analytical techniques (e.g., Werner deconvolution) that can be used to identify discrete anomalies. The results of these techniques must be used cautiously since anomalies can be produced that are a function of processing techniques rather than a representation of real geologic features. Processing techniques may also deemphasize relatively major features and enhance minor features. In most cases, a geophysical anomaly has no unique geologic explanation, although the number of possible explanations can be limited by integrating geophysical data from several techniques with geologic data. A unique solution can be verified only through direct observation (i.e., drilling or trenching).

The principal geophysical data types used in the initial site-screening studies of the Cold Creek syncline and reference repository location were seismic reflection, magnetic, and gravity. Care was taken where possible in these initial surveys to collect data that later could be included in more detailed, higher-resolution data sets to aid in detailed studies.

Seismic reflection surveys. Seismic reflection surveys conducted by Seismograph Service Corporation (SSC, 1979, 1980) used survey parameters tuned to optimize reflections from a depth of approximately 900 meters (3,000 feet) at the unavoidable expense of obtaining something less than optimally resolved data from the shallower horizons (Holmes and Mitchell, 1981). Analysis of the data shows that information from the deeper horizons around 900 meters (3,000 feet) is limited because of the attenuative nature of the suprabasalt sediments, the numerous reflectors in the basalt sequence, and the lack of strong reflectors (good velocity contrasts) in the deeper basalts (i.e., Wanapum and Grande Ronde Basalts). Several anomalous areas in the data were identified by Seismograph Service Corporation (SSC, 1979, 1980) and interpreted to be the result of faulting. Holmes and Mitchell (1981) concluded that several of the anomalous areas in the seismic sections were due to processing error, such as incorrect velocity statics, rather than structure, but they also concluded that several anomalies were caused by geologic features. The data were not of high enough quality to resolve the type of structure, if any, associated with the anomalies.

In May 1984, after the reference repository location had been selected as a candidate repository site and while the Draft Environmental Assessment was being prepared, Berkman (1984) reprocessed and reinterpreted portions of the seismic reflection data from the vicinity of the reference repository location. The primary objective of the study was to determine if the resolution of the original data could be enhanced by different processing techniques. New velocity layering information (Weston, 1983), and lithologic and geophysical logs from boreholes (Bjornstad, 1984; Robbins et al., 1983), acquired after the original processing, were used to construct synthetic seismograms and to add insight regarding the source of many reflections (i.e., suprabasalt reflectors, basalt flow tops or bottoms). The reprocessing did not significantly improve the seismic sections.

A structural interpretation of the reference repository location was made, with emphasis on detecting features in the suprabasalt sediments and Saddle Mountains Basalts (Berkman, 1984). The interpretation was intentionally conservative; that is, more structural significance was attributed to slight variations in the data than probably is warranted. (Subsequent use of the term "conservative" implies similar meaning.) This was done to ensure subsequent, detailed characterization of areas in and around the reference repository location where the original data showed variations. Some of the data variations will likely prove to be the result of data acquisition and processing techniques rather than real structural or stratigraphic variations in the rocks. Though the seismic reflection data quality generally was poor, several anomalous zones, including some possible minor faults, were postulated to exist in the vicinity of the reference repository location.

Aeromagnetic surveys. The Aeroservice (1980) multilevel aeromagnetic survey data discussed by Holmes and Mitchell (1981) was used extensively in siting the reference repository location (Myers, 1981) and as a guide in mapping areas of suspected geologic complexity (e.g., eastern extensions of Gable Mountain and Yakima Ridge). The total magnetic field contour map depicts a general east-west-striking magnetic field in the reference repository location. The gradient decreases from north to south, becoming fairly flat in the southern half of the reference repository location (Holmes and Mitchell, 1981). South of the reference repository location, the total magnetic field begins increasing in a steep, east-west-striking gradient. The magnetic field appears to correlate reasonably well with the interpreted top of basalt, the field also dips from the north into the broad Cold Creek synclinal axis and then rises sharply at the northern flank of the buried Yakima Ridge south of the reference repository location.

The Werner deconvolution method was applied to the aeromagnetic data as a preliminary aid in the identification of magnetic anomalies. The method computes depths, susceptibilities, and dips of hypothetical tabular bodies, based on individual flight-line profiles (Hartman et al., 1971). The geometric solutions determined by Werner deconvolution are expressed in three forms that have misleading geologic connotations: (1) fault-like solutions, (2) dike-like solutions, and (3) structural disturbances.

A fault-like solution indicates that a termination of a horizontal magnetic source was modeled by the automated Werner algorithm. In the Pasco Basin, horizontal terminations of magnetic sources are most likely related to basalt features such as the thinning of a basalt flow, pinching out of a basalt flow(s), erosional characteristics, changes in magnetic properties within a flow, and anticlinal and synclinal flanks and faults. Differentiating among these features is difficult at best, because magnetic data have poor resolution without ample supporting data from other geophysical methods, geologic studies, or quantitative analysis of the magnetic data via modeling and magnetic parameter studies of the basalt flows.

Similarly, dike-like solutions are not synonymous with geologic dikes, even though a true geologic dike may have a dike-like solution. Most of the dike-like solutions depicted by the Werner method are over known anticlinal structures. Structural disturbances are generally solutions that do not meet completely the criteria for either dike-like or fault-like solutions. For example, structural disturbances may exist where the Werner algorithm resolves a dike-like solution on one level of the aeromagnetic survey and one or two fault-like solutions on a lower survey level.

Many assumptions and simplifications (e.g., that the body is orthogonal to the flight line and is positive-polarized) are required in the Werner deconvolution computations. However, the earth, and especially a basaltic terrain, is a three-dimensional environment with complex and variable magnetic properties; therefore, the interpretations of the Werner solutions are not unique. Geologic significance should not be given to single solutions without careful examination and integration with other geophysical and geologic data.

Airborne magnetic surveys may be biased in revealing the shape of anomalies because of the acquisition of data along lines. Werner deconvolution solutions also can be affected by this flight-line bias. The orientation of some of the anomalies is not consistent with the general fabric of the plan-view, mapped data; therefore, questions exist regarding the true orientation of the anomalies and whether a causative body or geologic feature actually exists, and whether an anomaly is an artifact of processing and interpretive techniques.

Most of the anomalies interpreted by Myers (1981, Fig. 8-8) are based primarily on Werner solutions. Myers took a conservative approach when using the Werner solutions by assuming they were all geologically significant and therefore avoiding them as much as possible in siting the reference repository location. Should the reference repository location be recommended for site characterization, existing magnetic data will be closely re-examined in conjunction with new geophysical data and the known geology.

Gravity surveys. Gravity data on a 152.4-meter (500-foot) station-spacing grid are currently being collected (80% complete) and analyzed. The gravity data respond to density contrasts and therefore complement the magnetic (magnetic intensity) and seismic (velocity) data. Gravity data are useful for identifying density variations within the suprabasalt sediments, fluctuations on the top of basalt, and gross subbasalt features. The density variations identified as anomalous are interpreted in the context of geologic structure by thoroughly integrating the data with other geophysical and geologic data.

Gravity data are used to identify relief in the top of basalt after the effect of the suprabasalt sediments is calculated, modeled, and subtracted from the gravity field (i.e., stripped).

Issue: Specific geophysical anomalies

Many commenters suggested that geophysical anomalies were not used in establishing the geologic conditions in Chapters 2 and 3 of the Draft Environmental Assessment.

The more significant structural and topographic features such as the Gable Mountain-Gable Butte anticline, the buried extension of Yakima Ridge, and the eastward terminus of Yakima Ridge (see Fig. 3-20) are clearly depicted from the geophysical data sets. In and more immediate to the reference repository location the geophysical character is much more subdued and does not suggest any throughgoing faults or folds in the reference repository location. Because of the subtle nature of the data, geophysical anomalies that have been identified cannot be reliably or clearly delineated as can the structural and topographic features bounding the reference repository location; this suggests that features, if present, are relatively small. Figures C.5-9 through C.5-11 show the geophysical anomalies that have been identified in the proximity of the reference repository location. Table C.5-6 summarizes the status of these anomalies.

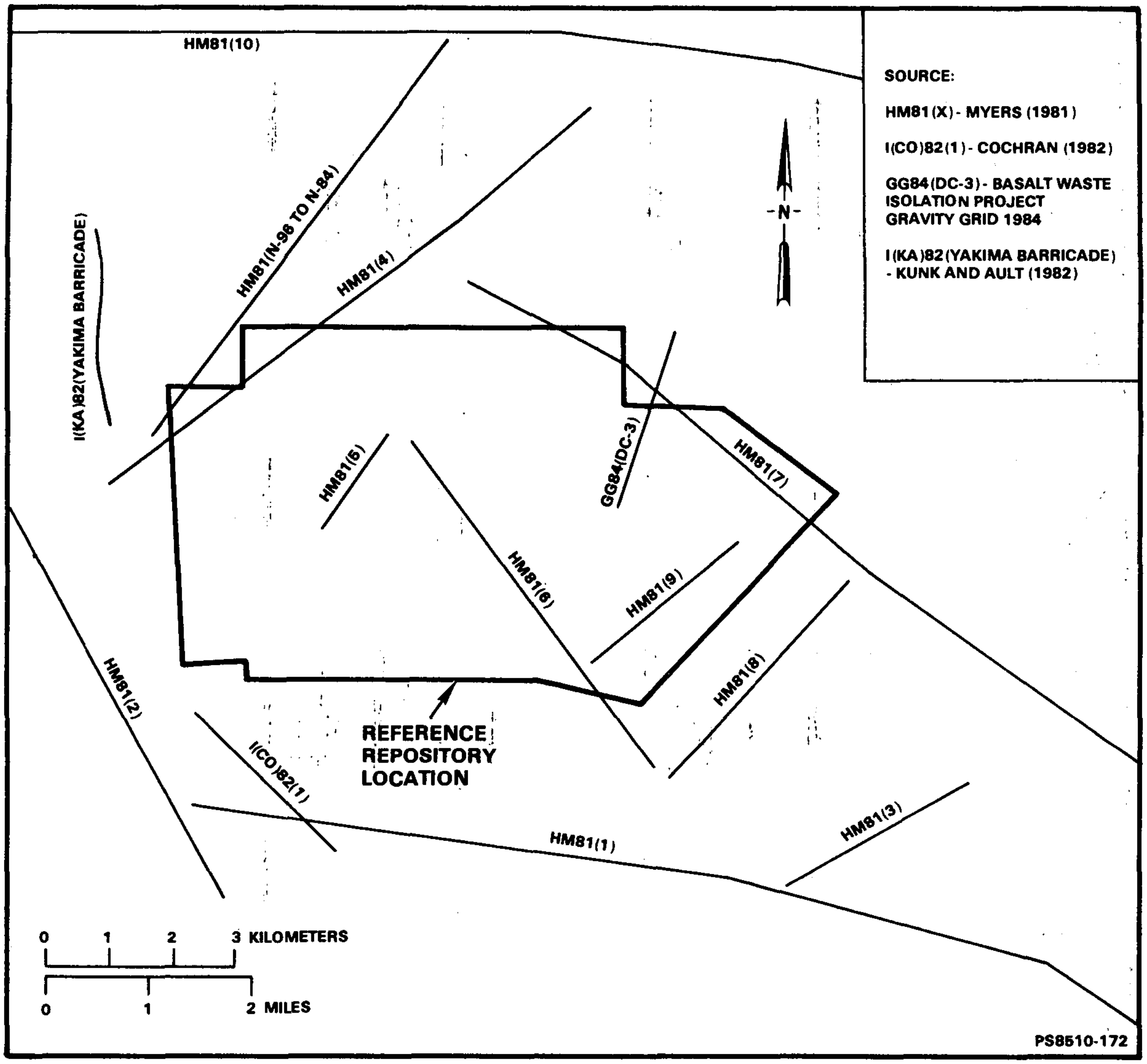

Figure C.5-9. Location map of potential-field geophysical features in and around the reference repository location.

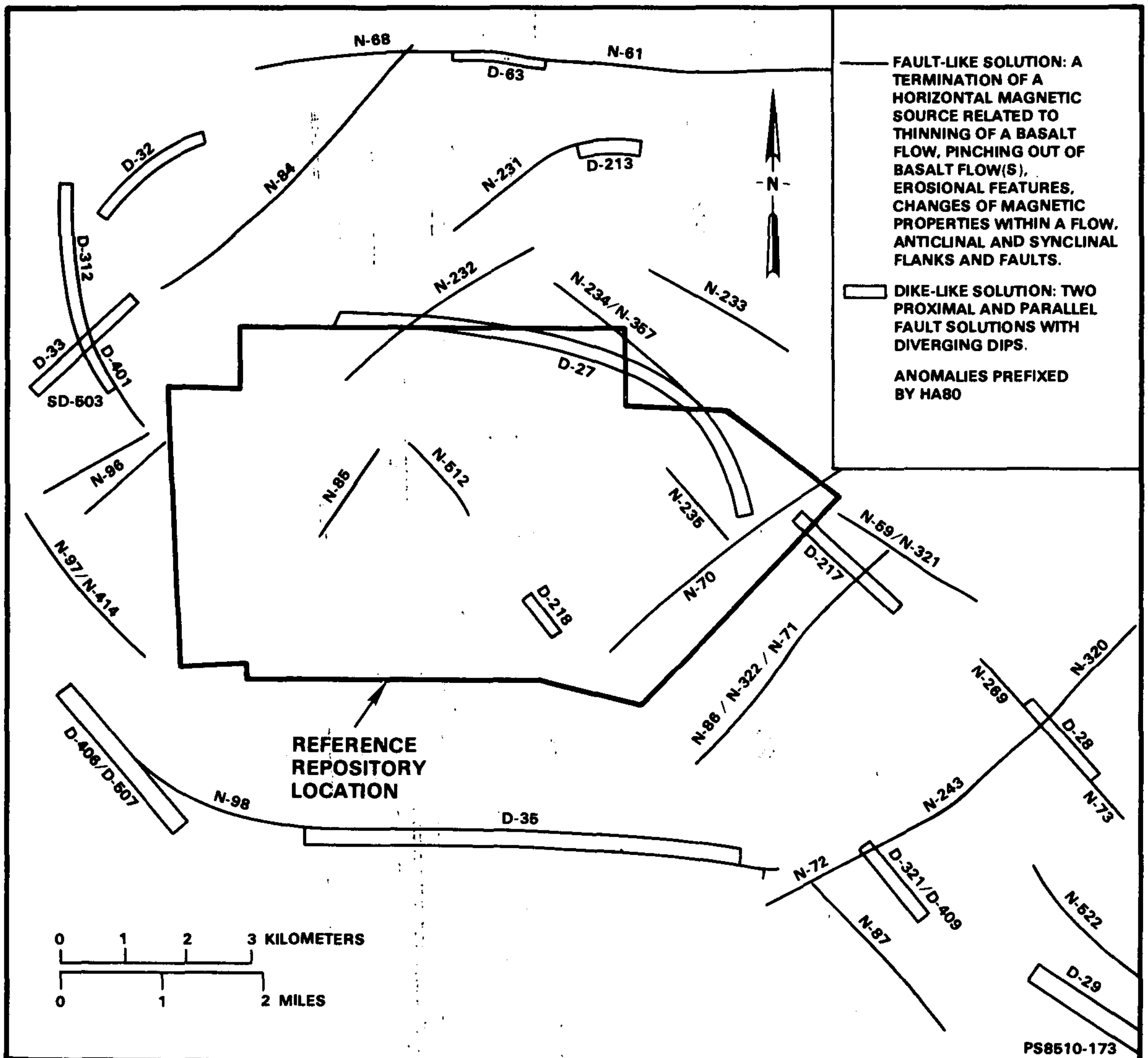

Figure C.5-10. Location map of aeromagnetic Werner deconvolution solutions identified in and around the reference repository location (taken from Aeroservice, 1980).

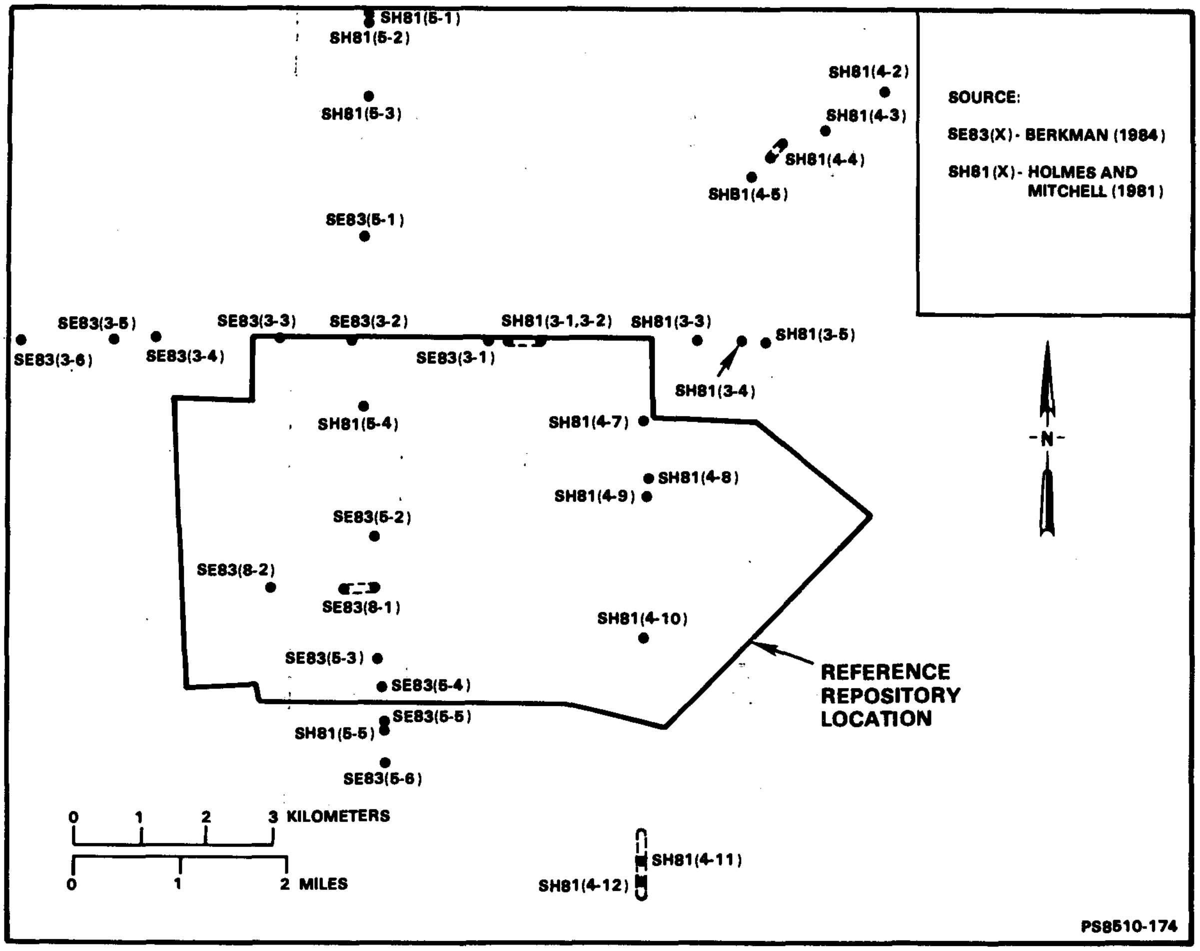

Figure C.5-11. Location map of seismic reflection features in and around the reference repository location.

Table C.5-6. Geophysical features in and around the reference repository location (sheet 1 of 7)

Geophysical features	Source	Comments
HM81 (1)	Myers (1981)	Bounding feature during initial reference repository location siting process.
Coincident Werner solutions*		
HA80 (D-321) HA80 (D-409) HA80 (N-98) HA80 (D-35) HA80 (N-72) HA80 (N-87) HA80 (D-29) HA80 (N-522)	Holmes and Mitchell (1981)	Werner deconvolution solutions corresponding to buried eastern extension of Yakima Ridge structure. Associated faults are expected but not verified.
Coincident seismic features		
SE83 (5-4) SE83 (5-5) SE83 (5-6)	Berkman (1984)	Anomalous zones identified and interpreted by Berkman (1984) could be related to faulting on the buried extension of Yakima Ridge but data quality is poor. The seismic anomalies are affected by static velocity-static correction errors.
SH81 (5-5) SH81 (4-11) SH81 (4-12)	Holmes and Mitchell (1981)	
Other		
I (CO)82 (1)	Cochran (1982)	Reinterpreted to be a north-south tear fault on buried portion of Yakima Ridge.
HM81 (2)	Myers (1981)	Topographic termination of Yakima Ridge structure.
Coincident Werner solutions		
HA80 (D-406) HA80 (D-507) HA80 (N-414) HA80 (N-97) HA80 (N-98)	Holmes and Mitchell (1981)	Werner solutions responding primarily to the topography of the Yakima Ridge structure.

Table C.5-6. Geophysical features in and around the reference repository location (sheet 2 of 7)

Geophysical features	Source	Comments
HM81 (3)	Myers (1981)	Defined by Werner solutions.
Coincident Werner solutions		
HA80 (N-243) HA80 (N-320) HA80 (N-72) HA80 (D-321)	Holmes and Mitchell (1981)	May be related to the buried extension of Yakima Ridge.
HM81 (4)	Myers (1981)	Used to help define the northern boundary of the reference repository location during the siting process based on Werner solutions. The extreme northern and southern ends are possibly related to minor structure such as buried erosional channels in the Hanford and (or) Ringold Formations. The central portion does not appear to be related to any geologic features.
Coincident Werner solutions		
HA80 (N-96) HA80 (N-231) HA80 (D-213)	Holmes and Mitchell (1981)	
Coincident seismic features		
SE83 (3-2)	Berkman (1984)	Probably due to erosional features in the Hanford and (or) Ringold Formations.
HM81 (5)	Myers (1981)	Defined by single Werner solution.
Werner solution		
HA80 (N-85)	Holmes and Mitchell (1981)	Interpreted to be responding to the west-striking magnetic gradient reflecting, in part, the southern dip of the northern limb of the Cold Creek syncline. The northeast strike of HA80 (N-85) may be due to flight-line orientation or to a change in direction of the gradient to the east of the plotted solution.

Table C.5-6. Geophysical features in and around the reference repository location (sheet 3 of 7)

Geophysical features	Source	Comments
HM81 (6)	Myers (1981)	Defined by Werner solutions.
Coincident Werner solutions		
HA80 (N-512) HA80 (D-218)	Holmes and Mitchell (1981)	The southern end is interpreted to coincide with a low-amplitude anticline, but the size of the anticline is smaller than the error of the borehole accuracy. The northern end corresponds with the dipping basalt of the northern limb of the Cold Creek syncline.
HM81 (7)	Myers (1981)	Defined by Werner solutions and consists of three magnetically unique segments. A boundary feature in the reference repository location siting process.
Northern segment		
Coincident Werner solutions		
HA80 (D-27) HA80 (N-234) HA80 (N-357)	Holmes and Mitchell (1981)	Werner solutions responding to a 30-gamma low with highs to the east and west.
Coincident seismic features		
SH81 (3-1) SH81 (3-2)	Holmes and Mitchell (1981)	Probably a function of shallow sediment velocity variations causing stacking velocity correction errors.
Middle segment		
Coincident Werner solutions		
HA80 (N-69) HA80 (N-321) HA80 (D-217)	Holmes and Mitchell (1981)	Magnetic field relatively flat. Werner solutions are interpreted to be caused by minor perturbations in the magnetic field that are not clearly related to either the northern or southern segments of HM81 (7).

Table C.5-6. Geophysical features in and around the reference repository location (sheet 4 of 7)

Geophysical features	Source	Comments
HM81 (7) (cont.)		
Southern segment		
Coincident Werner solutions		
HA80 (N-269) HA80 (D-28) HA80 (N-73)	Holmes and Mitchell (1981)	Werner solutions are not consistent with the magnetic total field contour maps.
HM81 (8)	Myers (1981)	Inferred "Deep structure" based on Werner solutions.
Coincident Werner solutions		
HA80 (N-71) HA80 (N-86) HA80 (N-322)	Holmes and Mitchell (1981)	Interpreted to be a response to a northeast-trending structural high across the axis of the Cold Creek syncline. Depths calculated by the Werner method are doubtful.
HM81 (9)	Myers (1981)	Inferred "Deep structure" based on Werner solutions.
Coincident Werner solutions		
HA80 (N-70)	Holmes and Mitchell (1981)	Werner depths are likely in error because the Werner profiles are not perpendicular to a more westerly striking gradient that is interpreted to be responding to a south-dipping basalt on the northern limb of the Cold Creek syncline.
Coincident seismic features		
SH81 (4-10)	Holmes and Mitchell (1981)	Interpreted to be associated with time-static processing problems.

Table C.5-6. Geophysical features in and around the reference repository location (sheet 5 of 7)

Geophysical features	Source	Comments
HA81 (10)	Myers (1981)	Bounding feature during initial siting process.
Coincident Werner solutions		
HA80 (N-68) HA80 (D-63) HA80 (N-61)	Holmes and Mitchell (1981)	Werner deconvolution solutions corresponding to Umtanum Ridge-Gable Mountain structure.
Coincident seismic features		
SH81 (5-1) SH81 (5-2)	Holmes and Mitchell (1981)	Related to the faulting and (or) folding of the Umtanum Ridge-Gable Mountain structure.
HM81 (N-96 to N-84)	Myers (1981)	Boundary feature in the reference repository location siting process.
Coincident Werner solutions		
HA80 (N-84) HA80 (N-96)	Holmes and Mitchell (1981)	These magnetic features are responding to an 80- to 100-gamma magnetic gradient that is coincident to a segment of the Nancy Linear (Weston, 1978).
I(KA)82 Yakima Barricade	Kunk and Ault (1982)	North-south Cold Creek barrier. Magnetic and gravity data indicate a north-south linear. Hydrologic head differences, particularly in the Wanapum Basalts. Termination of the Elephant Mountain Member. Elevation difference of 122 meters (400 feet) between correlatable Pomona Member over a half mile east-west distance.
Coincident Werner solutions		
HA80 (N-84) HA80 (D-33) HA80 (D-312) HA80 (D-401) HA80 (SD-503)	Holmes and Mitchell (1981)	Several Werner solutions responding to a variety of magnetic gradients, highs, and lows.

Table C.5-6. Geophysical features in and around the reference repository location (sheet 6 of 7)

Geophysical features	Source	Comments
I(KA)82 Yakima Barricade (cont.)		
Coincident seismic features		
SE83 (3-4) SE83 (3-5) SE83 (3-6) SE83 (3-7)	Berkman (1984)	Poor data quality probably due to thick deposits of the Hanford Formation. Indications of faulting or other reflection discontinuities.
GG84 (DC-3)	Kunk (1984)	A north-northeast-trending gravity anomaly that is interpreted to be responding to Hanford Formation infilling of an erosional scarp in the middle Ringold Formation.
Coincident seismic features		
SH81 (4-8) SH81 (4-9) SH81 (3-3)	Holmes and Mitchell (1981)	These seismic anomalies are probably related to stacking velocity-static correction errors that could in part be related to variable sediment velocities.
Miscellaneous Werner solutions		
HA80 (N-235)	Holmes and Mitchell (1981)	Interpreted to be a shallow feature.
HA80 (N-232)		May be related to an interpreted broad-open anticline (Myers, 1981).
HA80 (N-233)		Small northwest-striking gradient of approximately 20 gammas.

Table C.5-6. Geophysical features in and around the reference repository location (sheet 7 of 7)

Geophysical features	Source	Comments
Miscellaneous seismic features		
SE83 (5-3) SE83 (8-2)	Berkman (1984)	Small, broad depression in the upper basalt seismic reflectors, making the absolute location of the Cold Creek syncline axis difficult. The total magnetic field (Holmes and Mitchell, 1981) exhibits a spatially coincident magnetic low with about the same orientation.
SE83 (5-2) SE83 (8-1)	Berkman (1984)	The seismic reflectors are flat lying and have no significant time offset on the two sides of a seismic character change. Nearby boreholes and borehole gravity indicate intermittent high-density layers in the middle Ringold Formation. The seismic anomaly appears to be due to variable properties in the middle Ringold Formation.
SH81 (3-4) SH81 (3-5) SH81 (4-2) SH81 (4-3) SH81 (4-4) SH81 (4-5) SH81 (4-7) SH81 (5-3) SH81 (5-4)	Holmes and Mitchell (1981)	These seismic anomalies are not spatially related but are grouped together because they are all interpreted to be a result of stacking-velocity correction problems. Variable suprabasalt sediment velocities contribute to these processing problems.
SE83 (3-2) SE83 (3-3)	Berkman (1984)	These anomalies appear to be responding to velocity variations in the sediments, probably due to cut-fill features in the Hanford and Ringold Formations.
SE83 (3-1) SE83 (5-1)	Berkman (1984)	Possibly a low-amplitude anticline with minor associated faulting.

*Coincident, as used in this table, is defined as describing different geophysical anomalies that are spatially close together.

Issue: Deep structure

Several commenters requested that a discussion of subbasalt strati-graphy and structure be included in the final Environmental Assessment to support the tectonics and human interference guidelines in Chapter 6.

Response

The Columbia River basalt overlies a geologically diverse terrain as judged from the age, lithology, and structure of rocks exposed along the plateau margin. There are no exposures of rocks beneath the thick basalts, and few boreholes have penetrated these rocks; therefore, the age of the rocks, rock types, and structures that might be present beneath the central Columbia Plateau must be inferred from extrapolation of exposures along the margins of the plateau. The diversity of lithology and structure along the plateau margins does not permit simple extrapolation. Therefore, geophysical techniques have been used extensively to study the rocks and structure beneath the basalt. The magnetotelluric method has proven the method best suited for deep exploration in the Columbia Plateau. Like most geophysical techniques, interpretation of magnetotelluric data is dependent on geologic and other geophysical information.

The observed character changes associated with the magnetotelluric data in the central Columbia Plateau are interpreted to represent five primary rock units. From the surface down are (1) low-resistivity (5-to-50 ohm-meter) rocks, (2) high-resistivity (100-to-200 ohm-meter) rocks, (3) low-resistivity (2-to-20 ohm-meter) rocks, (4) a more resistive (100-to-1,000 ohm-meter) electrical basement, and (5) a deep (5-to-15 ohm-meter) lower crustal layer. The upper rock unit (rock unit 1) can be related to the suprabasalt sediments (primarily Hanford and Ringold Formations), and the interbedded sediments (Ellensburg Formation) between the Saddle Mountains Basalt flows. Rock unit 2 can be correlated to the Columbia River Basalt Group. The correlations of the first and second rock units are based on geologic mapping, borehole data, and the general electrical properties of the observed rocks.

Rock unit 3 is interpreted to be a sedimentary unit that ranges in age from lower Miocene through Cretaceous (Campbell, 1985). The rock unit has been subdivided into two subunits, based on borehole data from outside the Pasco Basin (Orange and Berkman, 1985). These boreholes include the Standard Kirpatrick No. 1 well (T.4S., R.21E., sec. 6) in north-central Oregon, and three Shell Oil Company wells (Yakima mineral 1-33 and 2-33, T.15N., R.19E., sec. 33; and Bissa 1-29, T.18N., R.21E., sec. 29) in central Washington State. The sedimentary rocks encountered immediately beneath the basalt are interpreted to be lower Miocene and Oligocene strata with resistivities of 1 to 4 ohm-meters. These rocks are of continental origin and consist primarily of volcaniclastic units with interbedded basalts, pyroclastics, tuffs, and epiclastic deposits. Underlying these 1-to-4 ohm-meter rocks are Eocene and (or) Cretaceous strata with resistivities of 10 to 20 ohm-meters. The Eocene and Cretaceous rocks consist primarily of continental fluvial sandstones with interbedded carbonaceous shales. Marine sandstones and shales were encountered near the base of the Bissa well.

Electrical basement, rock unit 4, could correlate with a variety of geologic terrains observed around the edges of the Columbia Basin. In all cases, the unit resistivities range from 100 to 1,000 ohm-meters. A metamorphic basement would relate to resistivities of approximately 100 ohm-meters and a granitic basement would relate to resistivities closer to 1,000 ohm-meters; in the vicinity of the Pasco Basin, the resistivities are closer to 100 ohm-meters. The electrical basement also might contain older, more resistive sediments similar to those cropping out in the Blue Mountains.

The lower crustal layer, rock unit 5, consisting of low-resistivity crustal materials is deep and is not detected on most magnetotelluric data. The rock types of this rock unit are not known.

Data suggest the thickest accumulation of basalt is found centered around the Pasco Basin, where the basalt forms an asymmetric basin with a steep west flank and a more gently dipping east flank. There presently is insufficient high-quality data to reliably interpret the relationships of the observed shallow basalt structures to the deep basalts and subbasalt structures, and the relationships of faults to folds. Data on deep structural features such as the Rattlesnake-Wallula alignment and the Pasco Basin will be collected during future studies, should the reference repository location be selected for site characterization.

A discussion of the pre-Columbia River basalt stratigraphy has been added to Section 3.2.2 of the final Environmental Assessment.

C.5.7.3 Seismicity

This subsection is divided into two issues:

- Seismic monitoring and earthquake evaluation.
- Swarm activity at or near the reference repository location.

Issue: Seismic monitoring and earthquake evaluation

Several commenters considered the Draft Environmental Assessment description of seismicity in the reference repository location to be misleading and therefore inadequate. Commenters stated that (1) data presented in Figures 2-9, 2-10, 3-24, and 3-25 were misleading, (2) seismicity of the reference repository location is not low, (3) questions exist concerning weightings given earthquakes of the same size, (4) evidence suggests that the cause of swarm earthquakes may be different than the cause of other earthquakes, (5) graphs are needed to depict recurrence at given distances from the reference repository location, (6) apparent patterns exist for seismicity associated with the Rattlesnake-Wallula alignment, and (7) potential is present for a magnitude 6.5 earthquake on the Rattlesnake-Wallula alignment.

Figure 2-10 has been modified to show the location of the Wooded Island earthquake swarms, which were inadvertently omitted from the original figure (see Fig. 2-11 of the final Environmental Assessment). So many small earthquakes were located using a detailed network at Wooded Island that plotting of this earthquake cluster was impractical. All earthquakes plotted on Figures 2-9, 2-10, 3-24, and 3-25 of the Draft Environmental Assessment were objectively selected based on different magnitude and spatial groups (see Fig. 2-10, 2-11, 3-22, and 3-23 of the final Environmental Assessment). Figures 3-24 and 3-25 have been modified to accurately illustrate the western boundary of the reference repository location, which was plotted to the east of its actual location (see Fig. 3-22 and 3-23 of the final Environmental Assessment).

The seismicity (i.e., the seismic hazard) of the reference repository location is considered relatively low because of the history of "small" earthquakes (3 to 5 magnitude) in and around that particular area. The Columbia Plateau is considered a region of "moderate" seismicity, since one earthquake registering 5.75 on the Richter scale did occur in 1936 near Milton-Freewater. "Moderate" signifies that earthquakes with magnitudes of 5 to 7 have occurred.

No statements were made in the Draft Environmental Assessment to imply that "more or less weight is given to an earthquake of the same size." Earthquakes of the same magnitude release approximately the same energy.

There is no conclusive evidence to support a theory of multiple causes for earthquake swarms. Further studies of earthquake swarms will be conducted if the reference repository location is recommended for site characterization.

A graph depicting earthquake recurrence versus distances from the reference repository location would show only the relative distances of past swarms from the reference repository location. Data for recurrence of a swarm (or any specific number of events) or for energy release may be useful in the future, but at this time, the cause and spatial relationships of swarm events are still being studied.

There are no concentrated alignment or patterns of earthquakes either parallel to the strike of the Rattlesnake-Wallula alignment or near the alignment. No earthquake event focal mechanisms along the Rattlesnake-Wallula alignment have the same strike as the Rattlesnake-Wallula alignment. Seismicity close to the Rattlesnake-Wallula alignment includes a 6-event swarm in September 1979 (largest event was 2.4 magnitude) and a 15-event swarm in November 1984 (largest event was magnitude 1.2).

The Washington Public Power Supply System nuclear power plant study at the Hanford Site (WPPSS, 1981) assigned a postulated 6.5 magnitude event for the Rattlesnake-Wallula alignment based on an assumed fault length and geometery. No events of this magnitude have been reported for the Columbia Plateau. The postulated magnitude was assigned based on topographic expression of the Rattlesnake Hills and the linear trend of other hills to the southeast. If the Rattlesnake-Wallula alignment is actually a continuous, capable fault as postulated, and it is assumed to be unless proven otherwise, then there could be an impact on the reference repository location during the postclosure period.

1. If a magnitude 6.5 event did occur on the Rattlesnake-Wallula alignment, the closest distance to the proposed exploratory shaft site would be approximately 10 to 13 kilometers (6 to 8 miles). There would be high accelerations at the surface facilities and lesser ground motion at repository depth. Expected maximum displacements, accelerations, and velocities from this ground motion would be provided for use in the engineering design of a repository. A moderate earthquake on the Rattlesnake-Wallula alignment would necessitate proper design of facilities for construction safety and structural integrity prior to closure. Postclosure ground motion probably would not affect repository integrity, but associated displacement could have an effect on ground-water flow. Effects on ground-water flow will be addressed during site characterization, if the reference repository location is recommended for this activity.

2. If splays from the Rattlesnake-Wallula alignment passed through the reference repository location, the potential would exist for a moderate earthquake to occur within the reference repository location. Aftershocks from a magnitude 6.5 main event could occur on these splays of a fault, resulting in fault movements within the repository and causing changes in the hydrologic regime. The possibility of these splays actually being present in or near the reference repository location is judged unlikely, but the presence of such splays will be investigated should the reference repository location be recommended for site characterization. The risk of such splays on repository operations and waste isolation would also be addressed during site characterization.

Issue: Swarms at or near the reference repository location

Several commenters were concerned that earthquake swarm activity in the reference repository location and vicinity was inadequately described in the Draft Environmental Assessment and contained errors in figures.

Response

The following information on seismicity is included to address commenter concerns.

In late 1969, closely spaced seismograph stations were installed around the Hanford Site area; this system was expanded to cover the entire eastern Washington area in 1975. Since 1969, several earthquake swarms have been recorded. Most of these occur along the flank of the Saddle Mountains anticline, but none are known to occur on mapped faults. These swarms are concentrated activity of events between magnitudes 1.0 and 3.0, but a few small events up to a maximum magnitude of 4.4 have occurred.

The U.S. Department of Energy presently is studying past swarms in detail with the purpose of identifying causative processes and characterizing them. The potential for a swarm, or swarms, to occur in the reference repository location is not known at this time but a detailed study is planned to assess the possibility of such an occurrence and to identify associated problems. Potential problems related to swarms during preclosure include compromise of construction activities, waste storage safety, and waste retrievability. Postclosure swarm activity possibly could alter ground-water travel times or flow paths between the repository and the accessible environment.

Swarms usually occur in the basalts, although a few are located below basalt depth. The majority of swarms appear to be related to anticlines, but some appear to be nonanticlinal (e.g., Wooded Island and Coyote Rapids swarms). Further study is required to resolve the issue of swarm potential.

Eight high-quality, shallow-hole seismometers have been installed in the top of basalt in the reference repository location for specific studies related to engineering design and reference repository location analysis, including swarm studies. In addition, a deep-hole, high-gain accelerometer is being installed at repository depth. These instruments and the baseline, bedrock surface seismic array surrounding the reference repository location will gather data on all events greater than magnitude 0.0 in and near the reference repository location. This data, along with data from magnitude 1.0 and larger events already being recorded, will be used to determine the seismological characteristics of the reference repository location and surrounding area. These data will be integrated with continuously gathered seismological data from the University of Washington eastern Washington array to form as complete a picture as possible of seismic activity.

Seismicity within the boundaries of the reference repository location has been limited to two periods of activity below the basalts. In November 1969, two events occurred in the central reference repository location, and two just south of the reference repository location. One of the events south of the reference repository location occurred in the basalt; the other has a large depth error and may have been in the basalt or below. These four events were as follows:

- Magnitude 2.2 at depth of 10.3 kilometers (6.4 miles).
- Magnitude 1.6 at depth of 7.5 kilometers (4.7 miles).
- Magnitude 1.4 at depth of 6.6 kilometers (4.1 miles).
- Magnitude 1.3 at depth of 3.0 kilometers (1.9 miles).

Relocation with a new velocity model (Rohay et al., 1985) and reinspection of first arrivals of phases will be completed during site characterization, if the reference repository location is recommended for characterization.

The other period of subbasalt activity within or on the borders of the reference repository location occurred between March and September 1971. Seven events were centered in a small area near the central northern border of the reference repository location. These events were as follows:

- Magnitude 0.8 at depth of 7.1 kilometers (4.4 miles).
- Magnitude 0.6 at depth of 7.2 kilometers (4.5 miles).
- Magnitude 0.4 at depth of 7.4 kilometers (4.6 miles).
- Magnitude 1.0 at depth of 6.5 kilometers (4.0 miles).
- Magnitude 0.8 at depth of 7.3 kilometers (4.5 miles).
- Magnitude 0.1 at depth of 14.3 kilometers (8.9 miles).
- Magnitude 1.1 at depth of 8.0 kilometers (5.0 miles).

Shallow swarm seismicity in the vicinity of the reference repository location includes two clusters of activity. One swarm cluster of 67 events is located between 10 to 15 kilometers (6.2 to 9.3 miles) north of the reference repository location, on and near the Columbia River. This cluster of seismic activity is the result of two earthquake swarms that occurred in March 1969 and October 1983. The locations of these events appear to have an east-northeast trend. The two largest events were magnitude 3.8 at approximately 1.0-kilometer (0.6-mile) depth and magnitude 3.0 at probably less than 1-kilometer (0.6-mile) depth (depth in question). The other area of shallow swarm seismicity is approximately 5 to 8 kilometers (3.1 to 5.0 miles) south of the reference repository location. There were two periods of activity in this zone, July to November 1979, and August 1981. A total of 15 events occurred at this location during the two swarms and all were less than 5 kilometers (3.1 miles) deep. The largest event was magnitude 2.4.

Table 3-6 in the final Environmental Assessment provides a list of all located events in or near the boundaries of the reference repository location between 46.51 degrees to 46.60 degrees north and 119.53 degrees to 119.75 degrees west. See Figure 3-22 in the final Environmental Assessment for a map showing these events.

The earthquake record for the reference repository location and vicinity is one of small or "micro" size earthquakes, which indicates this is an area of low seismicity. The closest moderate-size (magnitude 5 to 7) earthquake was the 1936 Milton-Freewater event at magnitude 5.75, located 122 kilometers (75 miles) south of the reference repository location. The only other possible event of moderate size was a 1893 earthquake that occurred near Umatilla, Oregon. This earthquake had a maximum modified Mercalli intensity of VI and was estimated to be not greater than magnitude 5.0. This event occurred approximately 75 kilometers (47 miles) south of the reference repository location.

Section 3.2.4 of the final Environmental Assessment has been expanded to clarify various parts of the Draft Environmental Assessment discussion on seismicity and to address inadequacies noted by commenters. A numerical analysis was added to Subsection 6.3.1.7.3 of the final Environmental Assessment to help support the presence of the favorable condition.

C.5.7.4 Stability

Many comments were received on the subject of the tectonic stability of the reference repository location and surrounding region. Commenters expressed concerns that (1) the Draft Environmental Assessment provided an overly favorable view of the tectonic setting and possible effects of tectonism on waste isolation, and (2) the positions taken in the tectonic guidelines (postclosure and preclosure) were inadequately supported by data and analyses.

Comments reflecting similar or identical concerns were made in reference to several issues by reviewers who apparently did not relate information or qualifiers specified for one guideline to all guidelines, as was intended. To facilitate responses, the comments are divided into 3 issues:

- Faulting.
- Volcanism.
- Tectonic stability.

Several comments are addressed under each subissue: for example, evidence given by reviewers for the possible presence of faults in the reference repository location consists of geologic mapping, microseismicity, tectonic breccia in cores taken from the reference repository location, geophysical anomalies (seismic reflection and magnetic linears), tectonic models, and the presence of certain mapped structures in a candidate analog area. The various lines of evidence given by reviewers to support possible interpretations are discussed under each subissue. By responding to comments in this manner, reviewer concerns are addressed without having to repeat responses to identical or related comments.

A number of commenters referred to the inadequacies of the present data and the use of those data in making assessments relative to the General Siting Guidelines (DOE, 1984a). The Environmental Assessment is intended to be a screening method to determine which sites are best suited for further characterization for the first high-level nuclear waste repository. Many uncertainties remain and will be addressed by further data collection, interpretation, and analyses should the reference repository location be recommended for site characterization. The interpretations and assessments given in the Draft Environmental Assessment were made with available data. Because available data are not adequate to make final evaluations, differences stemming from interpretation of data are likely to cause disagreements regarding the ability of the Hanford Site to meet site recommendation guidelines. Resolution of such differences will require further data, interpretation, and analysis.

Issue: Faulting

Many commenters were concerned with the presence or possible presence of faults in and near the reference repository location, the possible youthful geologic age of such faults, the potential for future slip on existing faults, or the development of new faults. Other reviewers stated that the presence of faults in or near the reference repository location is an adverse condition, or that such presence was underestimated by the U.S. Department of Energy in arriving at the positions taken in the Draft Environmental Assessment. According to these commenters, the presence of faults in the reference repository location is suggested by (1) the possible extension or extrapolation of faults beyond areas where faults now are mapped, (2) the geometry and spacing of anticlinal ridges, (3) tectonic breccia encountered in boreholes, (4) anomalies in profiles interpreted from seismic reflection lines, (5) linears interpreted on aeromagnetic maps, (6) the occurrence of microearthquakes within the vicinity of the reference repository location, (7) possible tectonic models for the development of Umtanum Ridge-Gable Mountain and Yakima folds in general, and (8) studies of possible analog areas of the Cold Creek syncline in which the reference repository location is situated. Several commenters stated concerns about the apparent youthful age of faults on Gable Mountain and the Rattlesnake-Wallula alignment, and about frequent microseismic activity in the region. Others were concerned about the potential for future fault activity.

Response

The subject of faulting was discussed in Sections 2.1.2 and 3.2.3 of the Draft Environmental Assessment. A discussion of faulting in the postclosure period was included in Subsections 6.3.1.7.3, 6.3.1.7.4, and 6.3.1.7.10. Faulting in the preclosure period was discussed in the Draft Environmental Assessment in Subsections 6.3.3.4.2, 6.3.3.4.3, and 6.3.3.4.4. The following discussion provides additional information.

In the General Siting Guidelines (DOE, 1984a), the presence of faults is considered to be a potentially adverse condition. The presence of one or more faults in the area of the candidate repository site is not considered potentially detrimental to a repository, unless the characteristics of such faults preclude the design and construction of a safe repository or the isolation of the waste in the repository. The effect of the condition, not the presence, is significant, and is the reason the presence of faults in the area of the candidate repository site constitutes a potentially adverse condition. If faults are present or suspected, it is the degree of adversity for development of a repository that must be evaluated. The presence or suspected presence of a fault does not necessarily make a site unsuitable for a repository; the size, width, extent, and degree of activity determines whether or not a fault makes a site unacceptable. However, an unfaulted volume of rock would preclude any analysis of the effects of a fault on repository construction, operation, and isolation, and may be preferred.

Several lines of evidence suggest possible faults in and near the reference repository location. A northwest-trending, steeply dipping fault mapped on Rattlesnake Mountain is considered part of the Rattlesnake-Wallula alignment. If this or a similarly oriented fault were to be present beyond Snively Basin, where the trend of the Rattlesnake Hills changes from northwest to approximately east-west, the Rattlesnake-Wallula alignment, or splays from the alignment, might be present in or near the reference repository location. The geomorphic expression of the eastern end of Yakima Ridge suggests that the structural relief may be reduced by dip-slip motion along a fault near the exposed eastern end. To assume an extension of the Rattlesnake-Wallula alignment beyond Snively Basin at this time seems premature because of the change in trend of the Rattlesnake Hills at that locality, and the suggestion that the style of faulting may change at Snively Basin from high-angle faults south of the basin along Rattlesnake Mountain to thrust faults in the basin area.

The U.S. Nuclear Regulatory Commission agreed that only domains I and II of the Cle Elum-Wallula lineament, extending from the Blue Mountains of Oregon to the Snively Basin at the north end of Rattlesnake Mountain, constituted a part of the Rattlesnake-Wallula alignment (NRC, 1982a).

A detailed study of the alignment, especially the northern part, is planned should the reference repository location be recommended for site characterization. This study would address such subjects as the style and amount of displacement along associated faults; interdependence, if any, of segment slip and differences in recurrence and slip rates; the ages of fault movement; and the kinematic relationship of deformation to the development of Yakima folds.

Because the continuity of geologic structures along the Rattlesnake-Wallula alignment north of The Butte is not established but merely suggested based on geomorphic evidence and similarity of trends, it seems premature to further extend an already hypothetically extended fault. While the possibility of northwest-trending faults in the area north of Snively Basin does exist, the existence of faults, and the relationship of such faults to the Rattlesnake-Wallula alignment are so uncertain at this time as to not warrant extending the Rattlesnake-Wallula alignment beyond Snively Basin. The extension of the alignment beyond Snively Basin as an active fault is pure speculation, but is a hypothesis that will be evaluated in further studies.

The similarity of the geometric shape and spacing of the Yakima folds west of Priest Rapids Dam to an "imbricate south-dipping thrust zone of primary origin" merely suggests that the Yakima folds result from folding and thrust-faulting at the leading edge of thrust faults ramping upward from a detachment zone deep in the stratigraphic section. Such a hypothesis is based on the similarity of the asymmetrical shape and vergence of the Yakima folds, along with the width, as compared to spacing, and will be tested during further studies. To speculate that such faults exist in the deeper basalt stratigraphic section, and to extrapolate that these faults may occur beyond where thrusting on Umtanum Ridge can be reasonably mapped from surface exposures and evidence, is pure conjecture. Microearthquakes that occur south of but near Umtanum Ridge do not align in a manner that suggests the presence of a fault. Focal mechanism solutions of a few microearthquakes in the area suggest that the rupture producing the earthquakes is occurring on nearly east-west, steeply dipping faults, which disagrees with the sense of displacement of such a hypothetical fault.

Tectonic breccia has been reported in some deep boreholes in the reference repository location. Such breccias might reasonably be predicted in synclinal areas using the model for the evolution of Umtanum Ridge developed by Price (1982), and could indicate local shearing of basalt during deformation. The presence of breccias does not necessarily signify the existence of major faults that could be a part of the Rattlesnake-Wallula alignment, as suggested by the U.S. Nuclear Regulatory Commission (see Subsection C.5.7.1 of this appendix). To make predictions of major structures purely on the basis of limited occurrences of breccia in core is speculation, even with the acknowledgment that vertical boreholes will miss steeply inclined, breccia-filled fracture zones unless boreholes are fortuitously located. Such breccias merely suggest that structures of unknown extent, geometry, and dimensions may be present.

Without bedrock exposure, and with only limited data from geophysical investigations (see Subsection C.5.7.2 of this appendix) conducted at the ground surface and from boreholes, faults of limited length, displacement, and area that may be present in the reference repository location could remain undetected until excavated. Contingencies in the design of a repository should be able to accommodate such features with limited adverse effects. Should such features be encountered during underground excavation, decisions will be made as to where waste should be emplaced (and whether or not it should be emplaced) to assure tunnel stability and waste retrievability, and to maximize waste isolation after closure.

Seismic reflection anomalies, similar to other geophysical anomalies, merely indicate a contrast in travel time of seismic waves due to contrast in properties of materials along the path of propagation. Reflections are produced at interfaces between horizons where materials of significant velocity contrast are superposed or juxtaposed. In the reference repository location, differences in travel time from source to reflector and back to receiver may be due to differences in the elevation of a reflecting horizon in the basalt, or to a difference in the time it takes compressional waves to penetrate highly variable materials in the sediments overlying the basalt, or both. Because of the highly variable nature of fluvial sediments of the Ringold and Hanford Formations that overlie the basalt, the difference in travel times may result from passage through these contrasting materials. If this is the case, the seismic reflection anomalies merely indicate contrasting velocity propagation (and thus travel time) along travel paths that result from primary characteristics of sediments unrelated to tectonic deformation (see Subsection C.5.7.2 of this appendix).

Seismic reflection anomalies were liberally interpreted by Berkman (1984) in order to focus further studies on areas where differences in travel times were determined for nearby geophones. The reason for such differences remains to be determined. Thus, seismic reflection anomalies are merely another type of suggestive evidence that structures may be present in the reference repository location; however, current interpretations are not final and should not be treated as unequivocal evidence of the presence of faults or other geologic structures.

Linear features on aeromagnetic maps may result from gradients between two adjoining materials of different magnetic susceptibility. Juxtaposition of materials of different magnetic susceptibility result from the termination of a stratigraphic unit by pinching out or erosion, changes in magnetic properties of a stratigraphic unit, or from geologic structure (e.g., fold and faults). Thus, linears defined by gradients in magnetic susceptibility may have several possible geologic interpretations. Aeromagnetic linears are one of several types of suggestive evidence that may reveal the presence of faults in the reference repository location. Further analysis of the possible geologic causes of such anomalies will be made if the reference repository location is recommended for site characterization.

Earthquakes, however small, indicate that slip is occurring on fractures. These fractures may be newly generated during the earthquake or may have existed prior to the earthquake. These planar fractures are faults. Because of the occurrence of microearthquakes in the vicinity of the reference repository location, it is reasonable to conclude that rupture and (or) slip is occurring on faults. Rupture and slip that produce microearthquakes occur on very small faults or very limited parts of larger faults. If these microearthquakes were occurring on limited segments of larger faults, other evidence of the existence of such major faults should be present, and possibly could be detected geologically or geophysically. Because major faults have not been detected, it seems reasonable to conclude that the fractures that produce such events are areally limited. The existence of such small fractures is suggested by different focal mechanisms for several small events in a swarm, as well as seismic moments of such events (see Subsection C.5.7.3 of this appendix).

Microearthquakes are another type of evidence that suggests the possible presence of faults in the reference repository location. Microseismicity in the reference repository location and vicinity is currently being monitored and will be studied further to determine possible causes, sizes, and proximities of faults in relationship to a repository in the reference repository location, and the possible effects of such activity on repository operations and waste isolation.

Sediments of the Ringold and Hanford Formations that overlie the basalt prohibit direct observation of the basalt in the Cold Creek syncline. Geologic structures that may be present in the reference repository location are thus hidden from view and must be interpreted from limited borehole data and geophysical surveys conducted from the ground surface. Because of these limitations, a search for possible areas analogous to the Cold Creek syncline was initiated for the purpose of conducting studies of exposed synclines and any structures that might be present in the synclines.

The syncline lying between the Saddle Mountains and Frenchman Hills originally was chosen as a possible analog to the Cold Creek syncline because of proximity to the Cold Creek syncline, probable similarity of geologic history (and, therefore, possible similarity of geologic structure), and presence of basalt exposures along the Columbia River and adjacent areas. Mapping in this area near Vantage, Washington has revealed geologic cross structures not previously identified in reconnaissance geologic mapping at scales of 1 to 62,500 (WPPSS, 1977) and 1 to 250,000 (Swanson et al., 1979). Detailed geologic mapping and study of fault zones, including materials filling fault zones, is being conducted. The Vantage study is under way, and it is premature at this stage to use data and information developed in that study to derive any final conclusions regarding the presence and extent of geologic structures in the Cold Creek syncline. Because of the proximity of the Vantage analog area to the Hog Ranch axis to the west, and because of the possible presence of a major fault oblique to an anticlinal axis that may segment the Saddle Mountains at Sentinel Gap, the syncline in the Vantage study area and the Cold Creek syncline is not analogous, and therefore cannot be directly compared (see Subsection C.5.7.1 of this appendix).

The evidence discussed above and in Subsection C.5.7.1 of this appendix suggest that faults and shears exist in the reference repository location. This evidence will be examined further to provide more data for better interpretations of possible causes. Much of the evidence given by commenters is speculative and merely suggests working hypotheses that remain to be evaluated and tested. If speculative evidence of this type were considered grounds for eliminating a repository candidate site, all sites would be eliminated. Comparisons of sites where data have been gathered over a number of years with sites where very little data exist allow for more speculative "what if"-type questions and can lead to an uneven treatment of sites.

The age of faulting in the reference repository location and vicinity was discussed in the Draft Environmental Assessment in Subsections 6.3.1.7.4, 6.3.3.4.2, and 6.3.3.4.3.

The age of fault activity on Gable Mountain and along the Rattlesnake-Wallula alignment was studied during investigations for licensing of the Washington Public Power Supply System operating plant WNP-2 on the Hanford Site. This plant is located some 25 kilometers (15.5 miles) southeast of the reference repository location. During studies for the plant, emphasis was placed on the potential for faults to slip and generate earthquakes and concomitant ground motion during the design life of the facility.

The central fault on Gable Mountain (discussed in Subsection 6.3.1.7.4 of the Draft Environmental Assessment) has been interpreted to be a capable (NRC, 1984b, Appendix A terminology) tear fault that displaces Pomona, Rattlesnake Ridge, and Elephant Mountain Members of the Saddle Mountains Basalt. This northeast-trending fault occurs in a topographic low that separates the north-verging from the south-verging anticlines on Gable Mountain. The fault plane continues along the trend into the overlying glaciofluvial sediments that correlate with 12,000-year-old catastrophic flood deposits. This fault has been geologically active during the Quaternary Period, but no earthquakes have been recorded along this fault during the 15 years of instrumental monitoring of earthquakes at the Hanford Site. Long-term average slip rates calculated for this fault are very low; however, slip rates for this structure and recurrence rates for earthquakes generated by such slip remain to be determined. Based on the average low slip rate and the relationship to the Gable Mountain anticline, the central fault on Gable Mountain has been provisionally assigned a maximum credible earthquake of approximately magnitude 5 to 5.5 (Slemmons, 1982).

In the absence of definitive geologic evidence to the contrary, the Rattlesnake-Wallula alignment has been assumed to be a continuous, capable, 120-kilometer- (75-mile-) long, right lateral strike-slip or right-oblique slip fault (see Subsection C.5.7.1 of this appendix). There is some evidence of fault capability of parts of this feature east of the Columbia River toward the Hite Fault and west of the Columbia River near Wallula Gap. The trend of the Wallula Fault System is continued northwestward from The Butte to Snively Basin by a series of northwest-trending, asymmetrical, doubly plunging anticlines, on some of which faults have been mapped. Because of this geomorphic continuity, the Rattlesnake-Wallula alignment has been assumed to be a continuous feature. Further studies will address various aspects of the Rattlesnake-Wallula alignment, especially age and continuity. Slemmons (1982) has assumed that because of very low slip rates, recurrence intervals for events as large as magnitude 6.5 may be 50,000 years or longer. Relative inactivity of this feature is suggested by the general absence of microearthquakes along the length during 15 years of instrumental monitoring, and by the absence of any fault scarps suggesting displacement since the latest catastrophic flood some 12,000 years ago. Holocene scarps should be well-preserved in a desert climate such as that of the Pasco Basin, in a manner similar to the preservation of Holocene scarps along the Lost River Fault System in east-central Idaho, the source structure for the 1983 Borah Peak earthquake.

Scarps have been identified by Campbell and Bentley (1981) on Toppenish Ridge, a Yakima fold located approximately 65 kilometers (40 miles) west of the reference repository location. Members of the Grande Ronde, Wanapum, and Saddle Mountains Basalts have been folded and faulted on this asymmetrical ridge. A zone of discontinuous scarps along the north side of the ridge continues for approximately 32 kilometers (20 miles), with the longest individual scarp being approximately 9 kilometers (6 miles) in length. Scarps of up to 4 meters (13 feet) in height displace the ground surface and appear to mark the trace of vertical planes along the face of the ridge. A curving scarp continues intermittently for several kilometers (miles) at the base of the slope and appears to represent the topographic expression of thrusting at the base of the slope. These scarps have been assumed to be tectonically produced, although other hypotheses have not been adequately tested. Geomorphic expression of the scarps has led to the provisional designation of these features as a capable fault on which a magnitude 7.4 earthquake could occur (Slemmons, 1982). However, Slemmons acknowledges that the scarps could be nontectonic in origin and therefore not seismogenic.

Excavation for construction associated with Interstate 82 near Yakima, Washington, revealed a north-dipping reverse fault that strikes north 88 degrees west and dips 43 degrees north. This fault was only temporarily exposed during construction and is now covered by a concrete retaining wall. Investigation has revealed that the fault displaces older Yakima River terrace gravels of unknown age but did not offset Touchet Beds (slackwater sediments associated with the Missoula Floods). No slickensides were found to indicate the true slip, but some strike-slip displacement was suspected by Bentley (1980).

Clear evidence of late Quaternary, tectonically produced surface faulting has not been found, but the evidence listed above indicates that deformation has been ongoing, at least episodically, during the Quaternary Period. Such deformation is in accordance with continuing deformation of Yakima folds since their inception in the Miocene Period; however, the mechanics of deformation, specifically the relationship of folding and faulting, remain to be determined. Locations with evidence that suggests Quaternary Period faulting are not obvious when examining the record of instrumentally recorded seismicity over the last 15 years or in examining the historic earthquake record. The relationship of seismicity to geologic structure, and the nature, rates, and mechanisms of deformation remain to be determined. Long-term, average low rates of deformation appear to have been in effect in the central Columbia Plateau since the Miocene Period, but the episodic nature of this deformation, including slip and recurrence rates, requires further study.

The level, pattern, and distribution of microseismicity, along with other geologic and geodetic data, supports the interpretation of continuing deformation at long-term, average low rates. While microearthquakes may occur on limited length segments of major faults, the record of microearthquakes and seismicity for the central Columbia Plateau during historic time does not support the occurrence of long, major faults similar to the San Andreas and other strike-slip faults in California. The assumed, continuous, 120-kilometer (75-mile) length of the Rattlesnake-Wallula alignment is not confirmed. Based largely on geomorphic evidence and the absence of specific geologic evidence to the contrary, the Rattlesnake-Wallula alignment has been assumed to be a continuous capable structure, and extending this feature any farther based on further speculation seems unwarranted. It does not seem likely that the Rattlesnake-Wallula alignment comes within 1.6 kilometers (1 mile) of the reference repository location. In addition, the alignment is notable for the general absence of microseismicity during the 15-year period of instrumental monitoring. Detailed studies of the Rattlesnake-Wallula alignment and the possibility that related structures exist in the vicinity of the alignment near the reference repository location will be addressed should the reference repository location be recommended for site characterization. See Subsection C.5.7.1 of this appendix for additional discussions of the Rattlesnake-Wallula alignment.

The known and interpreted pattern, style, and chronology of deformation, along with microearthquake seismicity and geodetic measurements of strain, suggest that the present regime of tectonic deformation was under way in the Miocene Period and will probably continue for at least another 10,000 years. Questions and uncertainties regarding the detailed mechanics and chronology of deformation will be addressed during planned studies; however, the pattern of an average long-term, low rate of deformation under nearly north-south compression suggests, in comparison with other active orogenic areas, that the area is relatively stable. The role of faulting in the deformation, the slip rate and slip per event, and the recurrence rate for fault slip will be studied in the near future. All these data, along with the presence of core discing, borehole spalling, and focal mechanisms, suggest that future fault activity will be of the thrust or reverse fault variety and probably will occur on existing geologic structures rather than produce new, first-order geologic structures. Compressional deformation would be expected to continue during preclosure operational and postclosure waste isolation periods of a repository.

Although present data are too preliminary to make any specific predictions of continued tectonic activity and effects, these data, in conjunction with the performance assessment analysis presented in Subsection 6.3.1.7.3 of the Draft Environmental Assessment, suggest that repository construction, operation, and waste isolation in the reference repository location are possible. However, detailed analysis of the effects of future tectonic processes, when such effects are known in more detail and with greater certainty, will be conducted to assess the future safety of a repository in the reference repository location during the period of construction, operation, and waste isolation.

As discussed above, there is uncertainty regarding development of Yakima folds and associated faulting that will require further study should the reference repository location be recommended for site characterization. These studies should address such subjects as the style and amount of displacement along faults; interdependence, if any, of segment slip and differences in recurrence and slip rates; age of fault movement; and the kinematic relationship of deformation to development of Yakima folds. Given the uncertainty of faults associated with Yakima folds, it is not presently possible to rule out that the frequency or magnitude of earthquakes on the Columbia Plateau could increase during the postclosure period. Therefore, the position on this third potentially adverse condition of the postclosure tectonics guideline (DOE, 1984a; 960.4-2-7(c)(3)) will be changed from "not present" to "present."

Issue: Volcanism

Several commenters expressed concerns that past and potential future volcanism (and accompanying effects such as earthquakes) might impact repository operations.

Response

The specific concerns of the commenters were unclear; therefore, the following response addresses concerns for both preclosure and postclosure periods.

Volcanic (igneous) activity was addressed in the Draft Environmental Assessment for both the preclosure and postclosure periods. For the postclosure period, see Subsections 6.3.1.7.4, 6.3.1.7.4, 6.3.1.7.8, and 6.3.1.7.11. For the preclosure period, see Subsections 6.3.3.4.2 and 6.3.3.4.8. Information on volcanism that produced the Columbia River basalt can be found in Section 2.1.1.

Calc-alkaline lavas from Cascade Range volcanic eruptions have neither reached nor come near the Pasco Basin during the Quaternary Period and are not expected to reach the Pasco Basin during the foreseeable future. Therefore, lavas from Cascade Range volcanism are not expected to be a concern during preclosure or postclosure time. The only product of Cascade Range volcanism known to have reached the Pasco Basin during geologic time is volcanic ash from volcanic eruptions such as Mount St. Helens. At most, a few centimeters (inches) to a few tens of centimeters (inches) of ash might reach the Pasco Basin. Such ash could affect surface operations for a repository during the preclosure period, but the effect would be temporary (a few days to a few weeks depending on the volume of ash).

The western margin of the Columbia Plateau occurs approximately 112 kilometers (70 miles) west of the western boundary of the reference repository location, where the margin adjoins the Cascade Range. Mount St. Helens is located in the Cascade Range approximately 192 kilometers (120 miles) west of the western boundary of the reference repository location, in a distinct volcanic and geologic province that is different from the Columbia Plateau. The Cascade Range has resulted from Tertiary and Quaternary volcanism. Cascade volcanoes have erupted in historic time and will continue to do so episodically in the future. Earthquake activity associated with the 1980 eruption of Mount St. Helens, including the magnitude 5.5 event that immediately preceded the eruption, has not been felt in the Pasco Basin. A postulated magnitude 6.5 earthquake on the Rattlesnake-Wallula alignment at a distance of approximately 10 kilometers (6 miles) from the reference repository location is larger and closer than any known earthquake activity associated with Cascade Range volcanism. This postulated event was used in the design of the

Washington Public Power Supply System operating plant WNP-2 on the Hanford Site, and will strongly influence the seismic design of facilities for a nuclear waste repository in basalt. Earthquake activity was discussed more fully in Subsection 6.3.3.4 of the Draft Environmental Assessment.

The Hanford Site is located between Yellowstone National Park in Wyoming (more than 640 kilometers (396 miles) east-southeast of the reference repository location) and Mount St. Helens (192 kilometers (120 miles) west of the reference repository location). Earthquake, volcanic, and hydrothermal activity has occurred in both areas during the Quaternary Period, and continues to occur. Yellowstone National Park and Mount St. Helens are in distinct geologic provinces that are very different from the Columbia Plateau in which the Hanford Site and the reference repository location are located. Activity in these two distinct geologic provinces is not known to be related to any geologic processes currently operating on the Hanford Site, other than the movement of large lithospheric plates, which appears to have had a negligible effect on the reference repository location during the last 15 million years.

Issue: Tectonic stability

A large number of comments were received concerning the tectonic stability of the reference repository location and vicinity. Specific concerns were (1) the potential for seismicity, (2) the effects of ground motion from earthquakes on a repository and on waste isolation, (3) inadequate discussions of seismic design, (4) the prediction of future seismicity, (5) the proximity to and possible effects of a lithospheric plate boundary and any associated earthquakes, (6) the rates of deformation, (7) the use and utility of geodetic data, and (8) continuous versus episodic deformation.

Response

Information on geologic structure, seismicity, and tectonics as it relates to tectonic stability can be found in Sections 2.1.1, 2.1.2, 3.2.3, and 3.2.4 of the Draft Environmental Assessment. Tectonic stability as it relates to the postclosure period was discussed in Subsection 6.3.1.7; tectonic stability during the preclosure period was discussed in Subsection 6.3.3.4.

The potential for seismicity. A seismic surveillance system has been installed in the reference repository location area to supplement the earthquake monitoring being conducted for the Hanford Site and region by the University of Washington and the Washington Public Power Supply System (see Subsection C.5.7.3 of this appendix). This system has been designed to detect and locate events down to magnitude 0 and to a location precision of a few tens of meters (feet). Such a system will gather data to better understand the mechanisms producing microearthquakes, especially swarms, in the reference repository location and vicinity. Specific items to be addressed using the data gathered by this system include (1) possible structural control of such events, (2) causative mechanisms,

(3) the size of areas rupturing during such events (i.e., a local moment-magnitude scale), (4) ground motions produced during such events, (5) recurrence of events, and (6) propagation characteristics of strain energy in the area of the reference repository location. Data and interpretations derived from these studies will be used to assess the potential for future seismic activity within and near the reference repository location, and to assess the effects of such events and ground motions on repository operations, safety, and waste isolation.

The instrumental record of earthquakes for eastern Washington dates back to the early decades of the twentieth century. Early seismometers, less sensitive to ground motions than instruments in current use, were deployed in Spokane and Seattle, Washington, and Vancouver, British Columbia. The instruments deployed at these locations were sufficient to detect earthquakes of approximate magnitude 4.5 and above, events considered moderate by current standards. The records from Spokane, Washington for the July 1936 earthquake of magnitude 5.75 near Milton-Freewater, Oregon, and an earlier earthquake of approximate magnitude 4.5 in November 1918 near Corfu, Washington provide some constraints on the location of these earthquakes. However, the records of these events were inadequate to provide precise locations and depths such as can be provided with modern seismometers. Magnitudes for these events were assigned much later after the magnitude scale was developed by Richter for local events in California in 1935. Thus, the brevity of the instrumental record of earthquakes is not unique to the area surrounding the Hanford Site. Accounts of some nineteenth century earthquakes felt in the Hanford Site area extend the earthquake record back further, but these accounts are highly qualitative and subjective as they are for all historical earthquakes, particularly for those occurring in an area as sparsely populated as eastern Washington in the nineteenth century.

Because of the brevity of the historical and instrumental record of seismicity, the potential for future earthquake activity also is being assessed by evaluating the geologic record of deformation. Because earthquakes are more likely to occur along geologic structures that have ruptured during geologically recent time, exposed geologic structures are being evaluated to determine the age of most recent deformation and the history of deformation of structures. In an arid climate such as exists in the Hanford Site area, geologically recent faulting that may have produced earthquakes is often expressed in the topography and can be detected during field studies and aerial overflights. While much data have been gathered already by these methods, additional geologic data on the timing and chronology of deformation will be gathered during site characterization should the reference repository location be recommended for detailed study. These data will supplement the record of historical and instrumental seismicity used to assess the potential for future earthquakes and deformation that may possibly affect repository construction and (or) waste isolation.

Ground motion, seismic design, and future seismicity. Without additional data, it is premature to discuss seismic design or to speculate on potential effects of such events and ground motion on a nuclear waste repository in basalt in the reference repository location. When appropriate ground-motion data are available, detailed analyses will be made of tunnel stability under projected earthquake loads, along with analyses of radionuclide transport, which will consider the effects of tectonic change on ground-water travel times and pathways for the no-disruption base case and for disruptive scenarios involving faulting and earthquakes. In making preliminary assessments that were the basis for positions taken in the Draft Environmental Assessment, available data and some quantitative analyses (see Subsection 6.3.1.7.3 and Section 6.4) were used to make qualitative professional judgments about probable effects of earthquakes and seismicity on repository design and waste isolation. These judgments assumed that the processes currently ongoing have been ongoing for some time and will continue to be operative at approximately the same rates for an unknown period into the future. The geologic record of these processes influenced these judgments.

The basis for the seismic design of the Washington Public Power Supply System operating plant WNP-2 on the Hanford Site was reviewed. The design is based on a hypothesized magnitude 6.5 earthquake occurring on the Rattlesnake-Wallula alignment. The Rattlesnake-Wallula alignment is the eastern boundary of a zone of topographic and structural features extending from the Snively Basin at the north end of Rattlesnake Mountain to the northeast-trending Hite Fault along the front of the Blue Mountains of Oregon (see issue on faulting under this appendix subsection). The part of this alignment extending east-southeastward from Wallula Gap to the Blue Mountains is a fault that has been determined to be capable by criteria given by the U.S. Nuclear Regulatory Commission (NRC, 1984b, Appendix A).

This trend continues northwestward from Wallula Gap along a series of doubly plunging anticlinal structures that are aligned northwesterly, along which there are faults of similar trend. It is not known whether the mapped faults on these ridges are segments of a longer fault that is not expressed at the surface, or if they are independent faults. The similarity of trend and topographic expression has resulted in the U.S. Nuclear Regulatory Commission assuming that the total trend from Snively Basin to the Hite fault is continuous for purposes of establishing a potential maximum magnitude earthquake. Using several techniques, a maximum magnitude of 6.5 was hypothesized as the maximum event that might occur along this alignment. This is larger than any historical event known to occur in the Columbia Plateau and larger than the magnitude 5.75 earthquake that occurred near Milton-Freewater, Oregon, in 1936. The Milton-Freewater earthquake has been assumed to have occurred along the Rattlesnake-Wallula alignment, even though focal mechanism solutions and the alignment of aftershocks suggest that this earthquake occurred on a northeast-trending structure with an orientation similar to that of the Hite fault. No magnitude 6.5 earthquake is known to have ever occurred along the Rattlesnake-Wallula alignment and certainly not within a few kilometers (miles) of the reference repository location. The 1936 Milton-Freewater earthquake occurred near the junction of the west-northwest trending Wallula fault zone (part of the Rattlesnake-Wallula alignment) and the northeast-trending Hite fault. For purposes of developing the construction permit seismic design of Washington

Public Power Supply System operating plant WNP-2, the Milton-Freewater event has been assumed to have occurred along the Rattlesnake-Wallula alignment, even though focal mechanism solutions and the trend of aftershocks suggest that the event occurred on a fault with northeast trend.

In selecting a candidate site for a repository in the Cold Creek syncline (location of the reference repository location), a decision was made to avoid mapped structures and any potential structures known from data available at the time of site selection (1981) (see Subsections C.3.1.3 and C.5.7.2 of this appendix). The Rattlesnake-Wallula alignment was not postulated to extend beyond Snively Basin because the evidence to support the existence of such an extension is purely speculative. Effects of earthquakes on underground facilities are minimal except where the rupturing fault intersects the excavated opening. The postulated extension of the Rattlesnake-Wallula alignment beyond Snively Basin is not presently accepted; therefore, the reference repository location is considered to be beyond the zone likely to experience near-field effects of earthquakes, assuming such events were to occur at the northern extreme of the Rattlesnake-Wallula alignment. The length and segmentation of the Rattlesnake-Wallula alignment are topics to be addressed during future studies.

In making recommendations to the architect-engineer for a repository in basalt, it is recommended that a 0.25-gravity peak horizontal ground acceleration be used as a starting point for the design of category 1-type surface facilities, with the understanding that this value might change because of the difference in distances between the reference repository location and the Rattlesnake-Wallula alignment, and between the Washington Public Power Supply System operating plant WNP-2 and the Rattlesnake-Wallula alignment (as stated in Subsection 6.3.3.4.5 of the Draft Environmental Assessment). Even allowing that this value of peak horizontal ground acceleration might increase, the design acceleration for surface facilities for a nuclear waste repository in basalt still probably would be less than for some nuclear powerplants west of the Cascade Range and significantly less than for some nuclear powerplants in California. While still less than the seismic design basis for some nuclear powerplants, the seismic design basis for surface facilities for a repository in basalt cannot be significantly less than all other licensed nuclear powerplants, regardless of age. Therefore, the favorable condition for the preclosure tectonic guideline (DOE, 1984a; 960.5-2-11(b)) is not present because the seismic design for facilities in the reference repository location would not be significantly less than for many other nuclear facilities. The seismic design for a repository in basalt will not, in all likelihood, involve ground motions in excess of that which seismic design has successfully accommodated elsewhere in past experience. Expected ground motions in the subsurface are presently considered to be not detrimental to openings, but this judgment will be reevaluated using earthquake and design data that will become available during future studies.

Proximity to and possible effects of a lithospheric plate boundary and any associated earthquake. The reference repository location is situated more than 300 kilometers (186 miles) east of the lithospheric plate boundary between the North American and Juan de Fuca Plates. The nature of the interaction between these two plates is one of general convergence and subduction, but the angle and rate of subduction and the degree of segmentation of the subducting plate are currently being investigated, along with the possible maximum size of earthquake to be expected along such a zone. Heaton and Kanamori (1984) suggest that events as large as magnitude 8 and above might occur along this zone. However, previous events as large as magnitude 7 that occurred in the Puget Sound area in 1949 and 1965 have barely been felt in the Hanford Site area. Therefore, this experience suggests that large earthquakes, as have been historically associated with the Juan de Fuca subduction zone, apparently would not create any significant ground motion in the reference repository location.

Several recently proposed tectonic models for the Pacific Northwest and the northern part of the North American Cordillera have suggested that seemingly anomalous geologic terranes, called suspect terranes, were not formed in place. Instead, these terranes are pieces of oceanic plateaus, volcanic island arcs, or continental fragments that migrated slowly with time on the oceanic crust on which they were "riding." Upon collision with a continental margin, such terranes became accreted to the continent, were subsequently displaced by transcurrent faults, leading to present distribution in widely separated masses in elongate zones along the western margin of the North American continent. The Olympic Mountains of Washington and the Coast Range of Oregon are examples of such terranes. Pieces of the Blue Mountains in Oregon have been interpreted as pieces of accreted terranes.

Columbia River basalt overlies an older terrane of unknown stratigraphy and structure. Rocks exposed to the north, west, south, and east of the basalt are different. Projecting these rocks and structures into the subbasalt basement beneath the central plateau does not allow clear understanding of the rock types and structures that may be present beneath the basalt. While there currently is no reason to suspect accreted terranes may underlie Columbia River basalt, the existing data do not allow for dismissal of such a working hypothesis. The presence of one or more accreted terranes underlying Columbia River basalt is not suggested by existing earthquake or geophysical data. Thus, it appears unlikely that if such terranes are present, they would be bounded by seismogenic faults that could generate ground motion and therefore potentially affect a high-level nuclear waste repository in Columbia River basalt in the reference repository location.

Rates of deformation. Several commenters expressed concern regarding the long-term, average low rate of deformation presented in the Draft Environmental Assessment in assessing potentially adverse conditions. Discussions of current interpretations of deformation, the data on which such interpretations are based, and the uncertainties of these interpretations using currently available data were included in Subsections 3.2.3.8, 6.3.1.7, and 6.3.3.4 of the Draft Environmental Assessment. Subsection 6.3.1.7.11 specifically addressed the uncertainty of the current preferred interpretation and the possibility of more episodic deformation. The interpretations presented in the Draft Environmental Assessment were those most strongly supported by available data; alternative working hypotheses will be evaluated during further studies, including the commonly expressed view that deformation is much more episodic than long-term average rates would imply. The magnitude and effects of these episodic movements may be significant to repository operations and to waste isolation; therefore, the topic of episodic deformation will be studied in more detail should the reference repository location be recommended for site characterization.

Use and utility of geodetic data. Geodetic data are merely suggestive evidence that support the interpretation that the reference repository location and Hanford Site area are undergoing deformation at very low rates. The measured strain is within the range commonly experienced by the crust during earth tides. The axes of strain, determined geodetically, have varied with time because of the nature of the data and the actual amount of change in length of surveyed lines. The fact that the amount of measured strain is very small after 8 surveys conducted over 12 years, and that the data allow different interpretation of the strain axes suggests that minimal deformation currently is occurring. These data are merely cited to suggest a long-term pattern that appears to be present, and indicate that a number of different lines of evidence support the pattern of deformation given in the Draft Environmental Assessment.

The mechanics of deformation, specifically the role of basement (i.e., subbasalt) rock type and structure in the development of the Yakima folds, the role of folding and faulting in the development of the Yakima folds, and the chronology of deformation, remain to be defined should the reference repository location be recommended for site characterization. Price (1982) interpreted the thrust and reverse faults on Umtanum Ridge to be secondary to folding after the folds had become "locked." However, the geometry and spacing of the Yakima folds suggest they may be the leading edge of thrust-faulted ramps branching upward from a detachment zone at some depth within the strata. Testing of this latter hypothesis will require drilling of boreholes and acquisition of data on the subsurface extent of folds and faults.

The pattern of deformation interpreted to date proposes deformation at average low rates of strain from the Miocene to the present. This would suggest that such a pattern continued throughout the Quaternary; however, the Quaternary Period stratigraphic record is limited, especially in areas of anticlinal deformation where deformation has been most studied. In synclinal areas where a Quaternary stratigraphy may be preserved, deformation in the basalt is masked by sediments younger than the basalt, so deformation must be interpreted from limited geophysical and borehole data. Therefore, insufficient available data have precluded detailed interpretation of the record of deformation during the Quaternary Period, other than postulation that the pattern and rate under way in the Miocene continued through the Pliocene and Quaternary.

Because of this data uncertainty, tectonic models specific to the Yakima folds will be evaluated and tested as new data become available. Tectonic models for the development of the Columbia Plateau and vicinity have been reviewed by Duncan (1983) and will continue to be evaluated as new data and interpretations become available. All relevant tectonic models will be reviewed and evaluated, including the models specified by the commenter. Review and evaluation of the more than 40 tectonic models that may be applicable to the reference repository location and Columbia Plateau area is beyond the scope of an environmental assessment. Tectonic models are important to the development of predictions of possible tectonic effects after repository closure and will continue to receive attention should the reference repository location be recommended for site characterization.

Microearthquakes are judged to have a reasonable likelihood of occurrence in the reference repository location during the postclosure period, even though the rates of tectonism in the Pasco Basin are considered low. Therefore, a numeric analysis was deemed necessary to support a contention that the favorable condition and the qualifying condition under the postclosure tectonics guideline (DOE, 1984a; 960.4-2-7(a) and (b)) are likely to be met. Detailed site characterization and scenario definition are required to support an analysis suitable for use in a licensing procedure, but a simplistic analysis based on the present qualitative judgment regarding potential impacts has been used to indicate a low likelihood of significant radionuclide releases to the accessible environment resulting from microseismic activity in and around the reference repository location. The simplistic numerical analysis is presented in the discussion of the tectonics favorable condition in Subsections 6.3.1.7.3 of the final Environmental Assessment.

General concerns about earthquakes and faulting have been addressed earlier in this response and are addressed in Sections 3.2.3 and 3.2.4 and Subsection 6.3.1.7 (postclosure) and Subsection 6.3.3.4 (preclosure) of the Draft Environmental Assessment.

The location of the Hanford Site between the Hegben Lake, Montana, and Borah Peak, Idaho, areas and the San Andreas fault is unrelated to the potential for future earthquakes and tectonic instability. Both the Borah Peak and Hegben Lake areas are regions of repeated earthquake activity, as documented in geologic and historic records of earthquakes. Both areas occur in the intermountain seismic belt and in a branch of this feature that extends westward into Idaho, and are located in tectonic provinces unique and distinct from the Columbia Plateau in which the Hanford Site is located.

The San Andreas fault is a transform fault separating the North American and Pacific Plates, which are continually slipping past one another. The plate boundary nearest the Hanford Site is the Juan de Fuca-North American plate boundary, which occurs several hundred kilometers (miles) to the west of the reference repository location, off the coast of the State of Washington. The subducted ocean crust extends eastward beneath Puget Sound but is not known to extend beneath the Hanford Site.

Available geologic, geodetic, and seismologic data have been interpreted to indicate that deformation under nearly north-south, nearly horizontal compression began at least 15 million years ago in the Miocene Epoch, is continuing today, and will continue at least through the period of waste isolation (Caggiano and Duncan, 1983). This stress regime is responsible for the development of the Yakima folds and associated faults, the microseismicity currently observed in the vicinity of the reference repository location, and the strain being measured by geodetic surveying. Development rates of geologic structures appear to be geologically very low, leading to infrequent, moderate-level earthquakes with long recurrence times. While such earthquake activity indicates relief of stress and resulting strain, the impact of this activity on a nuclear waste repository remains to be determined during further studies.

Much of the microseismicity that has occurred since the installation of a network of seismometers in 1969 would not have been detected had sensitive instruments not been deployed. Although the pattern of microseismicity presumably existed prior to 1969, it was not detected because these microearthquakes are too small to be felt. The evaluation of tectonic stability constitutes a significant research effort should the reference repository location be recommended for site characterization. Monitoring systems to determine levels of stress release and strain are in place and would continue to gather data during that process. These data, along with data from geologic studies of faults and folds, would be used to determine any effects of such ongoing activities on the construction, operation, and waste isolation of a nuclear waste repository in basalt in the reference repository location.

C.5.8 HUMAN INTERFERENCE

Numerous comments dealt with human interference as it relates to the natural resource portion of the postclosure human interference guideline (DOE, 1984a; 960.4-2-8). Most of the comments were concerned with inadequate documentation for hydrocarbon resource potential of the central Columbia Plateau and reference repository location. The remaining comments addressed geothermal and ground-water resource concerns.

Issue: Hydrocarbon resources

Comments regarding the Draft Environmental Assessment discussion of hydrocarbon resource potential generally can be summarized as follows: (1) natural gas traps other than those associated with anticlines and synclines were not considered and structures in basalt are not necessarily reflected in structures beneath the basalt; (2) the buried Yakima Ridge extension, an anticlinal ridge and possible hydrocarbon exploration target, is near the reference repository location; (3) natural gas is present in ground-water samples from the Cold Creek syncline and may have originated beneath the basalts; (4) the economic value of resources in the region of the reference repository location may be substantially underestimated; (5) the assumption that natural gas resources do not exist