NRC STAFF COMMENTS

ON THE

DOE FINAL ENVIRONMENTAL ASSESSMENTS

DECEMBER 22, 1986

DIVISION OF WASTE MANAGEMENT

U.S. NUCLEAR REGULATORY COMMISSION

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INTRODUCTION

Background

The Department of Energy (DOE) issued for public comment nine draft Environmental Assessment (EA's) on December 20, 1984. The Nuclear Regulatory Commission (NRC) reviewed the nine draft EA's and gave DOE comments on March 20, 1985 (SECY-85-114). Subsequent to the public comment period, DOE prepared revisions to the draft EA's in response to comments received from Federal and State agencies, Indian Tribes, various interest groups and members of the public. In accordance with the repository siting guidelines (10 CFR Part 960) the Secretary of Energy on May 28, 1986 issued five final EA's and nominated five sites that he determined suitable for site characterization from the original nine potentially acceptable sites. The five sites nominated are Davis Canyon, Deaf Smith, Hanford, Richton Dome, and Yucca Mountain (the same sites proposed for nomination in the draft EA's). The Secretary of Energy also recommended three of the five sites for site characterization: Deaf Smith, Hanford, and Yucca Mountain (the same sites proposed for recommendation in the draft EA's). The President has approved this recommendation. DOE also issued two other documents titled: "A Multiattribute Utility Analysis of Sites Nominated for Characterization for the First Radioactive-Waste Repository - A Decision-Aiding Methodology" (DOE/RW-0074, referred to below as the Methodology Document) and "Recommendation by the Secretary of Energy of Candidate Sites for Site Characterization for the First Radioactive-Waste Repository" (DOE/S-0048, referred to below as the Recommendation Document). Together with the final EA's these documents provide the support for the DOE nomination and recommendation decisions.

NRC Staff Review

The NRC staff has reviewed and prepared comments on all five final EA's. The staff conducted its review according to the NRC Division of Waste Management's "Standard Review Plan for Final Environmental Assessments" (March 18, 1986), which states that the final EA review is being done 1) to inform the Commission of any major concerns the staff may have with the final EA's and 2) to support NRC's ongoing effort to identify major concerns important to NRC's prelicensing consultation with DOE. The Nuclear Waste Policy Act (NWPA) and NRC regulations governing licensing of the geologic repository provide for consultation between DOE and NRC staffs prior to formal licensing to assure that licensing information needs and requirements are identified at an early time. The final EA's give current information and revised DOE conclusions regarding the sites after considerable evaluation by DOE of numerous comments on the draft EA's. Therefore, they provide current DOE positions and a foundation upon which DOE's project planning (including preparations for the Site Characterization Plans (SCP's) and draft Environmental Impact Statement (EIS)) will be developed for those sites recommended for site characterization.

These NRC staff comments on the final EA's are part of the continuing interface between the staffs of the DOE and NRC which will lead to early identification of potential licensing issues. In the short term our comments should assist the DOE in preparing high quality SCP's. In its concurrence action on the siting guidelines, the Commission found that the guidelines are consistent with the requirements of its own regulations on geologic repositories (10 CFR Part 60). Therefore, while the staff has not identified how its comments relate to the specific requirements of 10 CFR Part 60, the NRC staff considers that they serve to identify open items which are relevant to potential licensing of each site based on information currently available and which will need to be resolved during site characterization. Therefore, we believe that the opportunity afforded by the final EA's for early interaction between NRC and DOE will be beneficial to the progress of the repository program.

The objectives of the NRC staff review are as follows:

1. Identify and document any major concerns with DOE's responses to the NRC major comments on the draft EA's and certain detailed comments (i.e. those referenced by major comments and other detailed comments that now appear to warrant the same attention as the major comments based on the ongoing review of DOE's program). In other words identify residual major concerns not adequately addressed by DOE.

2. Become aware of as well as identify and document any major concerns with new data and information resulting from revisions/additions to the draft EA's by DOE.

3. Identify and document any major concerns with changes to the findings and supporting material in the final EA's.

4. Identify and document major concerns with the technical evaluations in Chapter 7, the Methodology Document, and the Recommendation Document including inconsistencies in use of data, interpretations, etc., between Chapter 7, the Methodology Document, the Recommendation Document and supporting final EA chapters. This does <u>not</u> include a review of the evaluation methodology or the ranking of the sites.

5. Identify and document any inconsistencies between the evaluation methodology in Chapter 7, the Methodology Document, and the Recommendation Document and the siting guidelines as concurred in by the Commission (including whether or not the evaluation methodology is an interpretation of the guidelines).

The final EA review is not a review like that of the draft EA; it is not a comprehensive and detailed review effort to identify every concern and document these concerns as major and detailed comments. The final EA review, as indicated above, focuses only on documenting major concerns in the form of major comments. Detailed comments, which were developed for the draft EA reviews to improve the information provided in the final EA's, were not developed since the EA's are now final. Furthermore, identifying only major concerns sharply focuses on high priority concerns needing attention in the SCP development.

Just as in the draft EA review, the NRC staff has not performed a detailed review with regard to the site characterization plans described in Chapter 4 or the repository descriptions in Chapter 5 of the final EA's. The staff only commented on the plans for characterizing the geohydrological regime beneath Canyonlands, National Park, (close to the Davis Canyon site) because it was a major comment on the draft EA, and because of the potential impact on the park. Site characterization plans and repository descriptions will be reviewed by the NRC staff upon receipt of the SCP's, and comments will be documented in NRC's Site Characterization Analyses.

Because of the limited time available for review relative to the amount of information existing for the five sites, the staff prepared for the final EA reviews long before their receipt. Preparations included 1) reviewing selected new or revised final EA references containing significantly different information, 2) reviewing draft EA comments from States, Indian Tribes, and other Federal agencies, 3) conducting technical meetings with DOE, States and Indian Tribes on selected technical concerns identified in draft EA comments, and 4) conducting selected data reviews and site visits. This early preparation and familiarization with the existing data base has allowed the staff to better determine if the conclusions in the final EA's are consistent with the available data.

Contents

The attached comments describe only major concerns resulting from the review of the final EA's. Therefore, "no comment" merely indicates that no major concerns were identified. Table 1 lists for each final EA the major comments resulting from both the draft and final EA reviews thus indicating in which areas major concerns remain. Major comments are grouped for each of the five final EA's. Within the group of comments for each separate final EA the order is governed by the fact that some comments, which help the reader understand others, come first.

The heading for each comment contains a reference to the appropriate draft EA comment for ease in tracking the staff's concerns back to the original comment. Also identified in the heading for organizational purposes are the relevant guideline conditions. Each comment consists of 1) a statement of the original concern with the draft EA; 2) those portions of the original concern that have been resolved; 3) the remaining major concern(s); 4) the basis for the remaining concern with reference to appropriate sections in the final EA; and 5) the significance of the remaining concern.

Comments that appear nearly identical for the different sites reflect information that was presented in the final EA's that was very similar among sites. Similar comments do, however, take into consideration differences resulting from site-specific information.

CONCLUSIONS AND RECOMMENDATIONS

It is apparent that significant efforts were made by DOE to respond to the NRC staff major comments on the draft EA's, and in fact many of these comments have been resolved. However, for each of the final EA's our review identified remaining concerns many of which are the same type of concerns identified in our review of the draft EA's such as 1) not identifying the range of uncertainties associated with the existing limited data base, 2) not identifying the range of alternative interpretations and assumptions that can be reasonably supported by existing data, and 3) not incorporating a reasonable range of uncertainties and alternative interpretations into evaluations and conclusions. Based on the above we believe that some conclusions in the final EA's are still overly favorable or optimistic for the areas of comment.

In accordance with our review plan, the NRC staff also reviewed aspects of the Methodology Document. As mentioned earlier the NRC staff did not evaluate the ranking of the sites or the ranking methodology itself. Just as was done for the draft EA's, the review focused on the existing data and how that data was used in the evaluations in the final EA's and the Methodology Document. From this review it was clear that evaluations and conclusions regarding site conditions presented in the final EA's were factored into the evaluations of scenarios and their consequences presented in the Methodology Document. Therefore, conclusions on repository performance in the Methodology Document that were derived from evaluations and conclusions in the final EA's, that are considered in our comments to be overly optimistic, are likewise considered to be overly optimistic. Some examples for the Hanford Site are 1) insufficient consideration of flow along large, discrete faults and fracture zones that may exist within dense flow interiors, including consideration of fracture flow as an "unexpected" feature rather than an "expected" one, and 2) inadequate consideration of alternative assumptions regarding pumping for the small-scale exploratory drilling scenario. Some factors which were not given sufficient consideration for the salt sites are 1) effects of host rock mass heterogeneities and 2) shaft and repository sealing concerns related to thermally inducted salt creep and differential uplift. An example from the Yucca Mountain Site is the lack of consideration that hydrothermal activity could be a future source of fluid important to waste package corrosion. For all sites, the effects of alternative corrosion mechanisms were not factored into waste package lifetime analyses. Finally, considering the examples noted above, it is overly optimistic to state on p. 3-41 of the Methodology Document that "When placed on a scale where a zero can be interpreted as performance at the minimum level required by the primary-containment requirements of the EPA standards and 100 is perfection, all of the sites have expected utilities of 99.7 or higher."

The significance of the above concerns is to DOE's ongoing preparation of the SCP's and eventually to site characterization activities, since both the general over optimism as well as the specific concerns could result in inadequate testing programs and inadequate information at the time of licensing. Should the range of uncertainties and alternative interpretations and assumptions that can be reasonably supported by the existing data not be considered in the SCP development, the SCP could be deficient in the identification and description of 1) the site including the range of uncertainties in known site conditions; 2) the issues and information needed to resolve issues; 3) the issue resolution strategies; 4) the performance allocation (i.e. the definition of performance goals and desired, associated confidence levels for various components of the repository system); 5) the investigation and study plans (tests and analyses); and 6) the rationales for investigations and studies with consideration to various sources of uncertainty. To the extent necessary for demonstrating compliance with 10 CFR Part 60, site characterization tests should lead to narrowing the range of uncertainties and eliminating alternative interpretations and confirming or revising assumptions on the basis of new data and analyses. This narrowing process will not be effective unless the test plans recognize the range of uncertainties and alternative interpretations and assumptions that can be reasonably supported by the existing data. It is important to note that because our comments are only related to the material which we reviewed in the final EA, they are not a complete list of our concerns important to the SCP development. We have identified such concerns in our correspondence and technical meeting summaries with DOE.

Over the past few years we have identified the need for recognizing uncertainties and alternative interpretations in the DOE program as reflected in our comments on the BWIP Site Characterization Report (NUREG-0960), the draft EA's, and the draft Project Decision Schedule. In addition, the NRC and DOE staffs have met numerous times over the past few years to discuss this subject. While we feel that these interactions have resulted in final EA's which exhibit some progress in these areas, we consider that further improvement in recognition of uncertainties and alternative interpretations is still needed. In addition, further progress has been made recently by DOE and NRC agreeing on how uncertainties and alternative interpretations will be considered in the SCP's and supporting study plans (NRC/DOE meeting on Level of Detail in the SCP, May 7-8, 1986). For the above reasons we are providing our comments for DOE's consideration. Furthermore, we recommend that because of the difficulties encountered in the past in addressing uncertainties and alternative interpretations we consider it important that the NRC and DOE staffs discuss representative comments in these areas as part of our pre-SCP interactions to agree on how they will be considered in the development of test plans.

TABLE 1 SUMMARY OF CONCERNS WITH THE FINAL EA'S

FINAL EA	DRAFT EA MAJOR COMMENT	CONCERN WITH FINAL EA RESOLUTION*
Hanford	1. Groundwater travel time	Groundwater travel time (5)**
	2. Changes that could affect the geohydrologic regime	No major concern
	3. Geochemical environment	Redox conditions (6)
		Microbial/Organic Complexes and Radionuclide Retardation (new comment based on new information) (7)
	4. Tectonic stability	Potential fault activity (2) Rate and style of deformation (3)
		Seismicity (4)
	5. Natural resources	No major concern
		Potential geothermal resources (new comment based on new information) (1)
	6. Thickness of host rock	No major concern
	7. Shaft construction	No major concern
	8. Waste package lifetime	Waste package lifetime (8)
	9. Surface flooding	No major concerns
	10. Comparative evaluation of sites	No major concerns

*The concerns found with the final EA resolutions represent a range from essentially no resolution to resolution of all but a few of the original draft EA concerns. It is important to note that even where major concerns remain, some of the original concerns were addressed and in many cases improvements were evident in the final EA's.

**The number in parenthesis is the final EA comment number.

TABLE 1 (CONTINUED) SUMMARY OF CONCERNS WITH THE FINAL EA'S

FINAL EA	DRAFT EA MAJOR COMMENT	CONCERN WITH FINAL EA RESOLUTION
Yucca Mountain	1. Fault activity	Fault activity (1) Northeast trending faults (2) Detachment faulting (3)
	2. Volcanism/hydrothermal activity	Hydrothermal activity (4) Natural resources data relevant to the evaluation (5)
	3. Groundwater travel time calculations	Groundwater travel time (7)
	4. Free drainage of host rock	No major concerns
	5. Groundwater chemistry of the unsaturated zone	No major concerns
	6. Retardation of radionuclides	Retardation of radionuclides (8)
	7. Mineral stability	No major concerns
	8. Radionuclide transport increase due to changes in geohydrologic and climatic conditions	Radionuclide transport increase due to changes in geohydrologic and climatic conditions (6)
	9. Surface flooding	No major concerns
	10. Waste package postclosure performance	Waste package postclosure performance (9)
	11. Comparative evaluation of sites	No major concerns

TABLE 1 (CONTINUED) SUMMARY OF CONCERNS WITH THE FINAL EA'S

FINAL EA	DRAFT EA MAJOR COMMENT	CONCERN WITH FINAL EA RESOLUTION
Davis Canyon	1. Tectonics and structural discontinuities	Structure and tectonics (1)
	2. Dissolution	Dissolution (2)
	3. Groundwater travel time	Groundwater travel time (3)
	4. Hydraulic gradient	No major concern
	5. Host rock carnallite	Decomposition of carnallite (4)
	6. Radionuclide mobility	Redox conditions (5)
	7. Effects of host rock mass heterogeneity	Effects of host rock mass heterogeneity (6)
	8. Retrievability	No major concern
	9. Shaft sealing	Shaft sealing (7)
	10. Waste package performance predictions	Waste package performance prediction (8)
	11. Controlled area	No major concern
	12. Potential field studies in Canyonlands National Park	Potential field studies in Canyonlands National Park (9)
	13. Surface flooding	No major concern
	14. Comparative evaluation of sites	No major concern

TABLE 1 (CONTINUED) SUMMARY OF CONCERNS WITH THE FINAL EA'S

FINAL EA	DRAFT EA MAJOR COMMENT	CONCERN WITH FINAL EA RESOLUTION
Deaf Smith	1. Structural discontinuities 2. Dissolution	Dissolution (1)
	3. Groundwater travel time	Groundwater travel time (2)
	4. Host rock clay content and dehydration	No major concerns
	5. Radionuclide mobility	Redox conditions (3)
	6. Effects of host rock mass heterogeneity	Effects of host rock mass heterogeneity (4)
	7. Retrievability	No major concerns
	8. Shaft sealing	Shaft sealing (5)
	9. Waste package performance predictions	Waste package performance predictions (6)
	10. Controlled area	No major concerns
	11. Surface flooding	No major concerns
	12. Comparative evaluation of sites	No major concerns

TABLE 1 (CONTINUED) SUMMARY OF CONCERNS WITH THE FINAL EA'S

FINAL EA	DRAFT EA MAJOR COMMENT	CONCERN WITH FINAL EA RESOLUTION
Richton Dome	1. Fractures and anomalous zones	No major concerns
	2. Dissolution	No major concerns
	3. Groundwater travel time	No major concerns
	4. Radionuclide mobility	Redox conditions (1)
	5. Effects of host rock mass heterogeneity	Effects of host rock mass heterogeneity (2)
	6. Shaft sealing	Shaft sealing (3)
	7. Retrievability	No major concerns
	8. Waste package performance predictions	Waste package performance predictions (4)
	9. Controlled area	No major concerns
	10. Surface flooding	No major concerns
	11. Comparative evaluation of sites	No major concerns

MAJOR COMMENTS

ON

HANFORD SITE

Comment 1

Potential Geothermal Resources

Guidelines on Natural Resources - 10 CFR 960.4-2-8 (b)(1) and (c)(1)(i)

The analysis presented in the final EA (Section 6.3.1.8.3, page 6-175, last paragraph) on natural resources does not consider new geothermal resource information acquired and evaluated by the Bonneville Power Administration and published in June 1985. This new information considers applications of resources at geothermal temperature gradients equivalent to and less than the Hanford site's gradient of 38°C per kilometer (162°F per mile) (final EA, Section 6.3.1.8.3, page 6-175, last paragraph, and page 6-176, top of page). Available data indicates that the average geothermal gradient at the Hanford site may support low temperature geothermal resource utilization as described in the above-referenced report (BPA, 1985).

The final EA (page 6-175, last paragraph, and page 6-176, top of page) concludes, based on measurements obtained from 15 boreholes drilled in the Pasco Basin, that the geothermal gradient at the Hanford site is approximately 38°C per kilometer (162°F per mile). This is considered insufficient for space heating (final EA, Section 6.3.1.8.3, page 6-176) because space heating requires a geothermal gradient exceeding 45°C per kilometer (182°F per mile). However, the final EA does not consider the potential for the commercial utilization of geothermal resources with temperature gradients lower than those required for space heating. This includes applications for industrial processes, agriculture and aquacultural production (BPA, 1985, Volume 1, page 293, Figure 9-1) which require temperatures ranging from approximately 18°C (65°F) (BPA, 1985, Volume 1, page 293, Figure 9.1) to 44°C (111°F) (BPA, 1985, page 300).

The Bonneville Power Administration, Department of Energy, released the above-referenced report in June 1985, evaluating and ranking the geothermal resource sites in Washington and the three adjacent states of Oregon, Idaho and Montana (BPA, 1985, Executive Summary, page 1, paragraph 1). The report represents a comprehensive, state-of-the-art evaluation of geothermal-economic data (BPA, 1985, Executive Summary, page 1, paragraph 4) and focuses on a broad spectrum of geothermal applications rather than on a single application (space heating) such as was referenced (Stoffel and Korosec, 1984) in the final EA. The report ranked the numerous (1,265) potential sites based upon an estimate of development potential and cost (BPA, 1985, Executive Summary, page 1, paragraph 4). Of the highest ranked direct utilization sites (BPA, 1985, Volume 1, page 315, Table 10.2), many are in proximity (as close as Othello at 25 miles to the northwest, Richland at 27 miles to the southeast, Pasco at 35 miles to the southeast, and Yakima at 45 miles to the west) to the reference repository location (RRL). The report ranked Yakima third in the four state area, Richland eighteenth, Pasco twentieth and Othello fifty-third (BPA, 1985, Volume 1, page 315, Table 10.2). Other highly-ranked sites are located within 45 miles of the RRL.

Comment 2

Potential Fault Activity - (Draft EA Major Comment 4)

Guidelines on Tectonics 10 CFR 960.4-2-7 (a), (b), (c)(2), (c)(6), (d); 960.5-2-11 (a), (b), (d) and Rock Characteristics 960.4-2-3 (a)

In NRC major comment no. 4 on the draft EA for the Hanford site, the concern was raised that existing evidence suggesting recent fault activity at or near the reference repository location (RRL) had not been adequately considered in evaluations related to the tectonic suitability of the site. Specifically, the NRC staff considered that evaluations of existing data indicating the presence of tectonic breccia, geophysical anomalies and microseismic activity in proximity to the RRL should have been incorporated into the draft EA evaluation of tectonic stability. The final EA includes an evaluation of these factors but concludes that the presence of these features does not indicate that potentially adverse structures exist within the RRL. The NRC staff considers that the existing limited data could also support the alternative interpretation that faulting may exist at or near the RRL.

Interpretations presented in the final EA (Section C.5.7, pages C.5-127 to 155) suggest that: (1) tectonic breccias observed in boreholes in the Cold Creek syncline do not indicate the presence of a significant fault zone because they are relatively thin (page C.5-129, 1st paragraph); (2) geophysical anomalies are subtle and cannot be reliably delineated (page C.5-135, 6th paragraph); and (3) extending major structural features into the RRL is conjecture and speculative (page C.5-155, cont. paragraph). The final EA interpretations outlined above are used to support the statement, originally made in the draft EA and repeated in the final EA (final EA, Section 3.2.3.3, page 3-58), that "...the reference repository location appears to be relatively free of potentially adverse structures." The NRC staff, however, remains concerned that the features listed above may indeed indicate the presence of relevant tectonic features within the Cold Creek syncline, and examination of the final EA indicates that this potential has not been factored into evaluations regarding tectonic stability of the RRL. For example, tectonic breccia zones within basalts near Hanford are known to be associated with major geologic structures (final EA, page C.5-127). However, the significance of breccia zones in the Cold Creek syncline is unknown. As stated in the final EA, the breccias suggest that structures of unknown extent, geometry, and dimensions may be present (page C.5-155). Tectonic breccias occur within all deep boreholes and appear to be concentrated in the Grande Ronde and Wanapum basalts possibly suggesting that they may be part of a significant structural feature or features. The fact that breccia zones in the boreholes within the Cold Creek syncline are thinner than they are in anticlines (C.5-129) may not be an indication of the lessening of fault significance away from the anticlines, but rather that the fault is rotating into the plane of bedding and not crossing major bedding surfaces. The characteristics, spatial orientation, and distribution of tectonic breccias are not completely known, thereby increasing the difficulty of assessing the tectonic suitability of the RRL at this time.

The final EA states that active faults do not appear to be present in the reference repository location (final EA, Section 6.3.3.4.1, page 6-248). However, exceptionally great horizontal stresses and related microseismicity (Rockwell, 1985) in the RRL area may indicate that rupture and (or) slip is occurring along either "very small faults or very limited parts of larger faults" (final EA, page C.5-156, paragraph 3). This information indicates that while there may be no surface expression of historical faulting in the Cold Creek syncline, faulting may be occurring in the subsurface. The NRC is concerned that there may be a cause and effect relationship between the tectonic breccias and the microseismicity.

Additional evidence supporting an alternative interpretation that faulting may exist within the RRL are seismic and aeromagnetic surveys that have delineated anomalies within the RRL which have been interpreted as faults (Holmes and Mitchell, 1981). While the nature of these geophysically identified features may not be completely understood, they suggest that structural features (i.e., faults and (or) folds) important to repository design may be present within the RRL.

The NRC staff is also concerned that the final EA has not considered the potential for structures extending to or through the RRL. For example, if extended to the southeast, faults exposed on Umtanum Ridge would pass beneath or through the RRL. The presence of tectonic breccias in drill holes within the RRL and also in association with known faults on Umtanum Ridge provide support to the interpretation that low-angle thrust faults could extend into the RRL (NUREG-0960, page 4-6). The NRC staff considers that combining the evidence for faulting in the Umtanum Ridge and RRL areas is a conservative hypothesis in an area where surface exposures are limited.

Comment 3

Rate and Style of Deformation

Guideline for Tectonics 10 CFR 960.4-2-7 (a)(1), (b)(1), (c)(2), (c)(6), (d)(1) and 960.5-2-11 (a)(i), (b)(1), (d)(1)

The NRC staff review of the draft EA for the Hanford site raised concern that existing geologic information indicates that Quaternary deformation of the Pasco Basin and Columbia Plateau may have occurred at higher rates than was reported in the draft EA. Examination of the final EA indicates that, although the limited existing data base and the need for additional study have been recognized, the final EA has not taken these recognized uncertainties into consideration when evaluating tectonic deformation. The NRC staff considers that the existing limited data could also support an alternative interpretation that deformation has occurred over a much shorter time period and at considerably higher rates than was concluded in the final EA evaluation.

The NRC staff is concerned that the concept of average rate of deformation as used in the final EA may not accurately predict the amount of deformation that has occurred in the Quaternary Period. The final EA indicates that deformation rates for the period 14.5 to 10.5 million years ago (m.y.a.) were between 40 and 80 meters per million years (0.04-0.08 mm/year). These rates of deformation are then projected to the present to give a uniform deformation rate and are used as the primary support for conclusions made in the final EA regarding tectonic suitability of the site. Specific NRC staff concerns related to the use of the average rate of deformation are as follows:

1) The final EA states that deformation in the area of the reference repository location (RRL) has followed an average rate of nearly north-south compression for the past 14 m.y. resulting in east-west trending folds. However, Barresh and others (1983) indicate that while there is evidence of compressive deformation in the Yakima fold subprovince in the period from 16 to 10 m.y.a., compression is believed to have resulted in only mild warping, with most deformation occurring after 10 m.y.a. The mild warping prior to 10 m.y.a. is evidenced by the lack of clear definition of structures on isopach maps of the RRL (LLNL draft letter report dated 9/26/85) which show little evidence of east-west oriented folds until Elephant Mountain member time (approximately 10.5 m.y.a.). Additionally, investigations in the Yakima fold subprovince (Beeson and Moran, 1979; Rockwell, 1979) suggest that northeast and northwest trending structures were formed during this time instead of east-west trending structures now apparent near the RRL. The NRC staff therefore considers that the deformational history observed in the RRL area is more complex than presented in the final EA, and the deformation responsible for structures now present near the RRL may have occurred over a substantially shorter time period (i.e., 10 m.y. to present vs. 14.5 m.y. to present).

2) Deformation rates of 0.1 to 0.14 mm/yr for the period of 10.5 to 4.0 m.y.a. presented by Barresh and others (1983) for the Saddle Mountains are 2.5 to 3.5 times greater than the rate presented in the final EA. Estimates of deformation rates presented by Kienle and others (1978) for the Yakima Ridge give values of 6.5 to 21 times as high as those presented in the final EA for the period between 8 and 4 m.y.a. The NRC staff is therefore concerned that the uniform deformation rate of 0.04 to 0.08 mm/yr. used in the final EA may significantly underestimate the actual deformation rate of the area.

3) The final EA indicates that deformation occurred at a constant rate and orientation over the period of 14.5 m.y. to the present. Although the final EA notes that deformation can be episodic and recognizes that "episodic movements may be significant to repository operations and to waste isolation" (final EA, page C.5-167), conclusions reached about preclosure and postclosure tectonics are based on the concept of uniform deformation over an extended period of time. The NRC staff is concerned that the uniform rate of deformation as used in the final EA does not take

into consideration that the orientation, style, and intensity of deformation in the Columbia Plateau may have changed significantly in the Late Miocene to Early Pliocene (approximately 5-10 m.y.a.) because of a major clockwise rotation in the regional stress field in the western United States (Eaton, 1984; Zoback and others, 1981). The timing of the stress field rotation roughly coincides with lessening of volcanism following deposition of the Saddle Mountains Basalt (approximately 10-8 m.y.a.) and also with the onset of a major episode of deformation (10-8 m.y.a.) in the Columbia Plateau (Barresh, et al., 1983). The NRC staff is concerned that rather than factoring into the tectonic evaluation the potential for episodic structural events, the final EA assumes that the deformation rate, orientation, and style did not change substantially across a rather dramatic change in the regional stress field. NRC staff considers that without further substantiation, this assumption and the concept of a uniform rate of deformation remain extremely tenuous.

The NRC staff is also concerned that the final EA has not thoroughly considered a substantial body of evidence supporting a "thin-skinned" or regional detachment style of deformation in the area of the RRL. Of particular concern to the NRC staff is the potential for detachment faults or imbricate zones splaying off of detachments (i.e., "thin-skinned" deformation) extending beneath, above, and/or through the repository level.

The final EA states that major faults result from folding and are, therefore, limited to anticlinal features. The final EA further proposed that the mechanism for the development of these folds is the presence of localized detachments beneath anticlines (Price, 1982). This hypothesis is used as the basis for the statement in the final EA that the Cold Creek syncline contains a basically undisturbed sequence of basalt (final EA, page 3-58) because deformation in synclines is not required to accommodate strain. The NRC staff is concerned that sufficient information may not be available to support the localized detachment hypothesis and that other mechanisms of deformation should be considered in a conservative approach to assessing preclosure and postclosure tectonics. Specifically, the NRC staff is concerned (draft EA detailed comment 3-8) about the consequences of "thin-skinned" or regional detachment type (decollement) faulting within the RRL. The NRC staff considers that existing evidence suggests that a regional detachment type fault system may be present at or near the RRL. For example, Laubscher (1981) initially proposed detachment type faulting in this area placing the master detachment near the base of the crust, a second detachment at the base of the basalt column and localized detachments at a depth of 1-3km in the basalt section. The NRC staff has also recognized the possiblity of detachment zones in the vicinity of the RRL. The WNP-2 Safety Evaluation Report states that reverse faults associated with overturned folds on Umtanum Ridge may be part of an imbricate thrust zone partially detached from basement (NRC, 1982). The report further states that the Frenchman Hills and Saddle Mountains are part of this imbricate thrust zone and that at least some of the faults are primary and not related to the effects of folding. In addition, Bentley (1982) indicates that "thin-skinned" tectonics is responsible for overthickening of basalt stratigraphy in deep test wells. He proposes the existence of decollements in sub-basalt and inter-basalt sedimentary layers.

Comment 4

Seismicity of the Reference Repository Location - (Major Comment 4)

Guidelines on Tectonics 10 CFR 960.4-2-7 (b) and (c)(2)

NRC staff comments on the draft EA raised concerns that while microearthquakes were recognized as the primary mode of seismic activity in the region, the potential for such activity to present a near-field seismic hazard was not evaluated. Examination of the final EA (Section C.5.7.3 and Section 6.3.1.7.3) indicates that although the need for additional study has been recognized, the seismic evaluation as presented in the final EA did not take into consideration the potential impact of microearthquake swarms on the tectonic suitability of the reference repository location (RRL). For example, most of the microearthquake swarms reported near the Hanford site have occurred from near surface to 2 kilometers (km) in depth which approximates the depth of the proposed underground facility of the geologic repository. The NRC staff is concerned that the lack of consideration in the final EA for the potential of microearthquake-induced fracturing within the repository horizon may have resulted in overly optimistic conclusions concerning the effects of seismic events on radionuclide release rates.

The final EA concludes that although microearthquakes are expected to occur in the immediate vicinity of the geologic repository during the postclosure period, they are not likely to affect releases of radionuclides to the accessible environment during the first 10,000 years after closure (final EA, Section 6.3.1.7.3). The NRC staff is concerned that, based on available data, many of the hypotheses presented in the final EA to support this conclusion are overly optimistic. For example, the hypothetical model of a microearthquake rupture surface as presented in the final EA (Section 6.3.1.7.3) indicates a relatively shallow dipping single surface involving a rupture of limited extent and a displacement of a few centimeters. A rupture of this type would not increase the permeability of the flow interior to more than the typical Grande Ronde flow top. The NRC staff considers that by using scaling relationships of Brune (1967) and Bonilla et al. (1984), the data could also support a model indicating a typical rupture surface of a microearthquake to be a circular area of approximately 10 to 200 meters radius with an average displacement of approximately ¼ to 11 millimeters for microearthquakes of magnitudes 0 to 3 respectively. Available data indicates that the Cohassett flow ranges in thickness from 73 to 81 meters including a flow top of from 5 to 10 meters in thickness. Assuming the underground facility were situated in the flow interior midway between the Cohassett flow top and the underlying flow top, and assuming a typical microearthquake rupture surface dip of 45 degrees (Malone, et al., 1975), a rupture of approximately 45 meters in length would extend from the underground facility to the flow top. A rupture of at least this length is considered typical for microearthquakes of magnitude 1 or greater. If a microearthquake swarm were to occur in the vicinity of the underground facility, it is possible that several tectonic fractures could be activated since it appears that multiple rupture surfaces have been involved in previous swarms. Thus there is a potential for several paths with permeabilities possibly equivalent to those of flow tops to be opened between the underground facility and the flow tops during a microearthquake swarm.

The occurrence of a microearthquake swarm in the vicinity of the underground facility during preclosure could disrupt operations. If the swarm was in the immediate vicinity of the facility, it could possibly trigger rock bursts, cause damage at sites of high stress, and affect the ground water flow. Microearthquake swarms in the vicinity of the underground facility during postclosure may significantly shorten the travel time for radionuclides to reach the accessible environment by opening paths between the flow interior and the flow tops. Waste canister emplacement space could also be affected by the number and spacing of fractures encountered within the repository. Active tectonic fractures are rarely single fractures but more often are a zone of fractures.

Comment 5

Groundwater Travel Time - (Draft EA Major Comment 1)

Guidelines on Geohydrology 10 CFR 960.4-2-1(b)(1) and 960.4-2-1(d)

The NRC staff's major comment no. 1 on the draft EA for the Hanford site identified five sources of concern regarding the assessment of groundwater travel times: 1) the applicability of previously published travel time estimates; 2) the reliability and representativeness of the data base for transmissivity, hydraulic gradient, and effective thickness; 3) the treatment of these data in deterministic and stochastic models; 4) the treatment of numerical model geometry; and 5) the definition of the orientations and lengths of flow paths (i.e., conceptual groundwater flow models) from the disturbed zone to the accessible environment. Only the first item on this list has been resolved in the final EA by stating that no reliance was placed on the previously published travel time estimates. The NRC staff considers that items numbered 2-5 above remain unresolved.

The NRC staff considers that the hydrogeologic conceptual model of the Hanford site as presented in the final EA is based on a data base that differs little from that used in the draft EA. Application of porous media concepts to describe flow in basalt flow tops and interiors continues to be an inadequately supported assumption in the final EA. The characteristics of hydrogeologic boundaries as well as the directions and magnitudes of both horizontal and vertical groundwater flow in the basalt aquifer system are still not well understood. The final EA did not consider hydraulic responses caused by construction of borehole DC-23. These responses suggest that large scale heterogeneities involving varying degrees of aquifer interconnection may be present in the vicinity of the RRL. There are also concerns about the limited extent to which existing hydrochemical data at Hanford (in particular, long-lived radionuclide data) have been used to assess and corroborate conceptual models of groundwater flow. For example, current conceptual models of groundwater flow in confined aquifers at Hanford are not fully consistent with available hydrochemical data, which can be interpreted to show varying degrees of aquifer interconnection. Of particular importance in such evaluations of conceptual models is the occurrence and distribution of long-lived radionuclides such as I-129, Cl-36, and Tc-99. These radionuclides can also be useful in evaluating groundwater recharge and discharge and migration paths of future and existing contaminants at the Hanford site.

In addition, new information presented in the final EA raises additional concerns about the overall groundwater travel time methodology. The staff considers that neither the final EA nor its supporting document (Clifton, 1986) provide sufficient supporting information with respect to the formulation of the five basic models used to predict groundwater travel times, thereby reducing the level of confidence placed on the travel times presented in the final EA. From the information provided, it can only be assumed that the methodologies used to calculate groundwater travel time in the draft and final EA's are similar (Clifton, 1984; Clifton et al., 1984). Specifically, information has not been provided with respect to boundary conditions, the number and size of model elements, number of calculated realizations, and modeling procedures and logic. Additionally, there is no indication that the model results were checked for sensitivity to the number of realizations. The absence of this supporting information raises questions with respect to utilization of model output distributions of groundwater travel time. By comparison, significantly more information on computational procedures was presented in the draft EA and its supporting documents (Clifton et al., 1984).

The NRC staff review of the draft EA raised concerns regarding the reliability of the preliminary geohydrologic data base. On page C.5-60 of the final EA it is stated that "... the available hydrologic data base is good." On page C.5-180, under discussion of the transmissivity data base, it is stated that the ensemble of Grande Ronde flow-top transmissivities is used (in the absence of specific data) to generate a representation of the flow top overlying the repository, and that "[T]he practice of using surrogate data sets to make initial predictions of performance for design purposes is common in the disciplines of engineering and hydrology." Although this situation is unavoidable at this early stage of site investigations, it is premature to refer to the overall data base as being "good" with respect to calculating groundwater travel times.

The NRC staff has previously questioned the adequacy and reliability of all of the data sets (transmissivity, hydraulic gradient, and effective thickness) on which the simulated travel times are based. In particular, the staff has questioned, based on existing data, the parameter ranges selected for use in the simulation calculations. For example, the final EA utilized a uniform distribution for effective porosity (derived from effective thickness) that is biased toward high values. The NRC staff considers the use of a log-uniform distribution with a median value centered about a value of effective porosity derived from the field test of effective thickness to be a more realistic and conservative approach. Similarly, problems exist with the selection of parameter ranges for transmissivity, vertical hydraulic conductivity, and hydraulic gradient.

In addition, it is noted that conclusions presented in the final EA based on the groundwater travel time analyses are primarily discussed in terms of the "median" travel times. The NRC staff considers this approach to be nonconservative because the median provides no information regarding uncertainties associated with estimates of groundwater travel times, and does not adequately address scenarios involving faster paths of likely radionuclide travel. In addition, the median travel time percentile is less sensitive to the variance of the travel time distribution than are lower or higher cumulative percentiles in the "tails" of the groundwater travel time distribution. Conclusions based on median values are less sensitive to the uncertainty implicit in hypotheses of groundwater flow system behavior. Use of a percentile smaller than the median would be more appropriate, because corresponding travel times are more sensitive to the spatial variability of field parameters, reliability of conceptual models, adequacy of hydrologic field testing, and measurement error.

The final EA concludes that groundwater travel time at the Hanford site "... has a high likelihood of exceeding 1000 years" (Volume 2, page 6-100). As discussed above, the NRC staff considers that such high levels of confidence cannot be assigned to any estimates of groundwater travel time at Hanford because of the limited hydrogeologic data base and of concerns regarding analyses and interpretations presented in the final EA. In addition, the staff considers that NRC's major comment no. 1 on the draft Hanford EA remains applicable to the groundwater travel time analyses in the final EA, with the exception of the concern about the reliability of previous groundwater models. Therefore, based on the existing limited data base and concerns expressed above, the staff considers that groundwater travel time estimates presented in the Hanford EA are overly optimistic and that travel times based on available data may be significantly closer to 1000 years than stated in the final EA.

Comment 6

Redox Conditions (Draft EA Major Comment 3)

General Geochemical Guideline 10 CFR 960.4-2-2

In NRC staff major comment no. 3 on the draft EA for the Hanford site, the concern was raised that the conclusions that site redox conditions are not "... chemically oxidizing" and that the reference repository has chemically reducing conditions that will maintain radionuclides in their least mobile state are based on insufficient data. Examination of the final EA (Volume 2, Section 6.3.1.2.2, page 6-109; Volume 2, Section 6.3.1.2.10, pages 6-123 and 6-124; Volume 3, Section C.5.2.1, pages C.5-81 through C.5-88; among others) indicates that although the draft EA concerns have been acknowledged, the evaluation in the final EA of pre- and post-waste emplacement geochemical characteristics of the Hanford site and the significance of these characteristics on radionuclide retardation is still optimistic. Therefore, the NRC staff considers that draft EA major comment no. 3 remains appropriate for the final EA. Draft EA comment no. 3 expressed the NRC staff concern that the effects of reaction kinetics may prevent the establishment of redox equilibria, and may inhibit either the transformation or the maintenance of radionuclides as reduced species. This concern is supported by Lindberg and Runnells (1984) who state (1) "... that equilibrium modeling of the redox chemistry of natural aqueous systems is not realistic as computed from Eh or pE as a 'master' redox variable," (2) "Equilibrium modeling should therefore be restricted to non-redox systems," and (3) "If redox chemistry is to be considered, investigations must analyze the waters for the specific valence states of the elements of interest...." Further, according to Hostettler (1984), predicting the valence states of multivalent radionuclides (and thus the mobility of radionuclides) requires analysis and knowledge of the kinetics of all relevant reactions. The NRC staff therefore considers that prediction of the valence states of radionuclide species should be made only to the extent that the behavior of the constituents can be shown to mimic the behavior of the couples measured. Accordingly, a realistic but conservative alternative assumption for those radionuclides for which this information has not been collected, or where the information is ambiguous, is that they will be released and move through the system as oxidized species.

In addition to the draft EA concerns being appropriate to the final EA, the NRC staff is also concerned with the final EA statement that there are "... strong indications that the reference repository location has chemically reducing conditions that will promote precipitation and will maintain radionuclides in their least mobile state ..." (See final EA, Volume 1, Section 6.2, page 16). Although the NRC agrees that available information indicates that ambient redox conditions are likely to be reducing (i.e., Eh less than 0.0 volts) in deep basalt groundwater systems, evidence presented in the final EA, such as equilibrium calculations of non-equilibrium redox couples involving either sulfate or methane (see final EA Comment 7), does not necessarily indicate that the Eh will either be reducing or as low as -0.4 volts as is suggested in the final EA (Baas-Becking et al., 1960; Thorstenson, 1970; Berner, 1971; Langmuir, 1971). Also, as previously stated, the likelihood that reducing conditions are present does not support equilibrium modeling of redox sensitive radionuclides as reduced species because what may be reducing for one redox couple could be oxidizing for another. Also, an additional source of concern is the incomplete discussion in the final EA of the impact of atmospheric oxygen introduced into the repository during construction and waste emplacement. For example, laboratory tests conducted by Apted and Myers (1982); Lane et al. (1983a and 1983b); Jantzen (1983); Grandstaff et al. (1984) and Moore et al. (1985) using crushed rock, and in some cases distilled water, are cited as support for the conclusion in the final EA that basalt can rapidly re-establish reducing conditions in the repository subsequent to closure. However, these references also support an alternative and more conservative conclusion that the re-establishment of ambient reducing conditions may be slow since the massive basalt host rock will not react as fast upon contact with the groundwater as does crushed rock. While it is acknowledged in the final EA that the experimental work cited had been completed with crushed basalt, the alternative interpretation of the experimental data was not identified in the final EA. Based on the above discussion, it is not clear that a conservative approach was taken as stated in the final EA (Volume 3, Section C.2.7.4, page C-2-78; and Volume 2, Section 6.1.2, page 6-4) in evaluating site redox conditions and their effect on the performance of the repository.

Comment 7

Microbial/Organic Complexes and Radionuclide Retardation (Draft EA Major Comment 3)

General Geochemical Guideline 10 CFR 960.4-2-2

In NRC staff major comment no. 3 on the draft EA for the Hanford site, reference was made to detailed comment 6-33 where the concern was raised that equilibrium between the redox couples sulfate/sulfide and methane/carbon dioxide, used to suggest non-oxidizing conditions, is unusual because such reactions require biological mediation and are not generally found to be electrochemically active. The final EA suggests that "(t)he presence of...certain bacteria..." in the Hanford site basalt environment may, in fact, help catalyze these redox couples (Volume 3, Section C.5.2.1, page C.5-82). However, the NRC staff considers that while the presence of bacteria in the geochemical system at Hanford may help resolve the redox concern, they could also result in a significant new concern by increasing the mobility of some radionuclide species. This possibility has not been recognized or factored into evaluations of radionuclide mobility in the final EA.

According to West et al. (1984), radionuclide microbial/organic complexes have different migration characteristics than inorganic complexes. For example, such material may form complexes with radionuclides, resulting in higher apparent solubilities, lower effective sorption and hence, higher release rates. The ultimate effect of microbes/bacteria/organics could therefore be an enhancement of radionuclide mobility thereby impacting the anticipated performance of the site (NRC, 1984).

Comment 8

Waste Package Lifetime - (Draft EA Major Comment 8)

In the NRC staff's major comment no. 8 on the draft EA for the Hanford site, concerns were raised on the draft EA's estimation of a 6,000 year waste package lifetime. Specifically, four areas of concern regarding the estimate of container lifetime were identified: 1) the oxidizing environment during repository operation and after closure; 2) localized corrosion as a waste package failure mode; 3) the effect of packing on corrosion of the overpack material; and 4) the effect which instability of packing may have on ingress of water as well as on the migration of radionuclides through the packing material. Examination of the final EA (Sections 6.4.2.1, 6.4.2.3, and 6.4.2.4) indicates that items 1 and 3 above have not been addressed, while items 2 and 4 have only been partially addressed. The NRC staff therefore considers that draft EA comment no. 8 applies equally well to the final EA. For example, while the final EA states that localized corrosion failure modes such as stress corrosion cracking (SCC) and pitting will be incorporated into future corrosion models (page 6-283), the document concludes on page 6-121 that "pitting and stress corrosion cracking will not be active corrosion modes." The NRC staff has identified major sources of uncertainty not recognized in the three references provided in the final EA as support for this statement (Lumsden, 1985; Pitman, 1985; and James, 1985). Major concerns identified in Lumsden, 1985 by the NRC staff include: (1) Lumsden's data was not measured in the presence of a radiation field which will be present in a repository environment; (2) the pitting potentials given in the paper may be uncertain*; (3) additional measurements (e.g. cyclic polarization) are needed to better determine pitting potentials and pit incubation times; and (4) alternate wetting and drying data at increased temperatures and times are also needed for projecting corrosion rates. In contradiction to the conclusion drawn in the final EA, one of the conclusions of the James paper referenced above states, "the tentative conclusion is that limited crack extension may have occurred." In other words, stress corrosion cracking (SCC) may have occurred for the A387-9 steel at 250°C after 2000 hours. Additionally, the Pitman paper stated,

*The pitting potentials given were determined only from the breakdown potentials of anodic polarization curves. Cyclic polarization data are needed in order to determine whether hysteresis is present. If hysteresis is present there will exist a protection potential which is different from Lumsden's pitting potential. In order for pitting not to occur under repository conditions, the potential must be less than the protection potential. Since the cyclic polarization data was not measured by Lumsden, it is not obvious what the protection potential is for these materials. Consequently, in this case it cannot be stated that pitting will not occur under repository conditions. It should also be noted that if pitting does occur, both the protection potential and the pitting potential (as measured by Lumsden) for the material would shift toward the corrosion potential.

"In summary, both 9% Cr, 1% Mo steel and A27 steel were found to be susceptable to decreasing ductility in 150°C basalt groundwater at low strain rates." Pitman further concludes that SCC exists in the low alloy A387 steel. For the A27 steel, even though Pitman concludes that there was no SCC observed, the reduced ductility implies a high probability that SCC may occur over a longer time period.

With reference to the NRC staff's draft EA concern related to packing instability (item 4 above), page 6-120 of the final EA comments on the bentonite instability results of Haire and Beall (1979), the NRC staff notes that a change in crystal structure of the bentonite is not necessarily a function of only the radiation dose rate, but also of the total dosage. The final EA states that the dose rate (3×10^9 rad/hr.) for the Haire and Beall (1979) work was 10^5 times what is expected in the repository. Therefore, using a dose rate of 3×10^4 rad/hr., the total dosage expected in one year is 3×10^9 rads. After only 1000 years, the total dosage would be 3×10^{11} rads which is about what Haire et al. used. Therefore, the statement in the final EA that the negative results of this study are "not considered applicable" due to the high dose rate is considered inappropriate by the NRC staff.

In addition to the above, the final EA also presented a revised waste package conceptual design which incorporates an outer carbon steel shell surrounding the overpack and preformed annular sections of packing material (see Figures 5-7, page 5-36; and 5-9, page 5-38). As discussed in §5.1.5.3 of the final EA, "The function of the shell is to facilitate handling and emplacement of the waste package components. The shell also has the potential to facilitate retrieval of the waste container by preserving the packaging in a dry state and by providing additional structural strength."

It is the NRC staff's opinion that this design change may improve the performance of the waste package in terms of waste package lifetime and controlled radionuclide release should the waste packages fail. However, the waste package performance analysis does not reflect this design change. Additionally, new potential failure modes for this design were not addressed in the final EA. For example, the temperature of the waste container is estimated to have a maximum value of 300°C, but more likely about 220°C (NUREG/CR-2482). If the waste package is a sealed system, water present in the packing will change to steam, increasing the pressure in the new outer metal shell. This could result in distortion of the shell making retrieval more difficult. Alternatively, in an unsealed waste package system, contact of the packing with groundwater may cause significant swelling presenting retrieval problems as well as potential vessel rupturing.

REFERENCES

Apted, M.J., and J. Myers, 1982. Comparison of the Hydrothermal Stability of Simulated Spent Fuel and Borosilicate Glass in a Basaltic Environment, RHO-BW-ST-38P, Rockwell Hanford Operations, Richland, Washington.

Baas - Becking, L.G.M., I.R. Kaplan, and D. Moore, "Limits of the Natural Environment in Terms of pH and Oxidation Reduction Potentials," Journal of Geology, Vol. 68, pp. 243-284, 1960.

Barresh, W., Bond, J., and Venkatakrishnan, R., 1983, Structural evolution of the Columbia Plateau in Washington and Oregon: American Journal of Science, v. 283, p. 897-935.

Beeson, M.H., and Moran, M.R., 1979, Columbia River Basalt Group stratigraphy in western Oregon: Oregon Department of Geology and Mineral Industries: Oregon Geology, v. 41, no. 1, p. 11-14.

Bentley, R.D., 1982, Late Tertiary thin skin deformation of the Columbia River Basalt in the Western Columbia Plateau, Washington-Oregon: EOS, v. 63, no. 8, p. 173.

Berner, R.A., Principles of Chemical Sedimentology: New York, McGraw-Hill, 240 p., 1971.

Bonilla, M.G., R.K. Mark, and J.J. Lienkaemper, 1984, "Statistical Relations among Earthquake Magnitude, Surface Rupture Length, and Surface Fault Displacement," Bulletin of the Seismological Society of America, vol. 74, pp. 2379-2411.

BPA (Bonneville Power Administration, U.S. Department of Energy), "Evaluation and Ranking of Geothermal Resources for Electrical Generation or Electrical Offset in Idaho, Montana, Oregon and Washington," WAOENG-85-02c, DOE/BP-13609-3, 3 Vols., Portland, Oregon, June, 1985.

Brune, J.N., 1967, "A Low Stress-Drop, Low-Magnitude Earthquake with Surface Faulting: The Imperial, California, Earthquake of March 4, 1966," Bulletin of the Seismological Society of America, vol. 57, pp. 501-542.

Clifton, P.M., 1984. Groundwater Travel Time Uncertainty Analysis - Sensitivity of Results to Model Geometry, and Correlations and Cross Correlations Among Input Parameters: Rockwell Hanford Operations, SD-BW-TI-256.

Clifton, P.M., 1986. Groundwater Travel Time Analysis for the Reference Repository Location at the Hanford Site: Rockwell Hanford Operations, SD-BWI-TI-303.

Clifton, P.M., R.C. Arnett, and N.W. Kline, 1984. Preliminary Uncertainty Analysis of Pre-Waste-Emplacement Groundwater Travel Times for a Proposed Repository in Basalt: Rockwell Hanford Operations, SD-BWI-TA-013.

Eaton, G.P., 1984, The Miocene Great Basin of western North America as an extending back-arc region: Tectonophysics, v. 102, p. 275-295.

Grandstaff, D.E., G.L. McKeon, E.L. Moore, and G.C. Ulmer, 1984. "Reactions in the System Basalt/Simulated Spent Fuel/Water," Scientific Basis for Nuclear Waste Management VII, G.L. McVay (ed.), Proceedings of the Material Research Society Symposium, Vol. 26.

Holmes, G.E., and Mitchell, T.H., 1981, Seismic reflection and multilevel aeromagnetic surveys in the Cold Creek syncline area; Appendix B, in Subsurface geology of the Cold Creek syncline: RHO-BWI-ST-14, p. B-1 to B-56.

Hostettler, J.D., "Electrode Electrons, Aqueous Electrons, and Redox Potentials in Natural Waters," American Journal of Science, Vol. 284, pp. 734-759, June, 1984.

James, L.A., 1985. Short-Term Stress Corrosion Cracking Tests for A36 and A387-9 Steels in Simulated Hanford Groundwater, SD-BWI-TS-012, Richland, Washington.

Jantzen, C.M., 1983. Methods of Simulating Low-Redox Potential (Eh) for a Basalt Repository, DP-MS-83-59X, E. I. DuPont de Nemours & Co., Savannah River Laboratory, Aiken, South Carolina.

Kienle, C.F., Jr., Bentley, R.D., Farooqui, S.M., Anderson, J.L., Thoms, R.E., and Couch, R.C., 1978, The Yakima Ridges--An indication of anomalous Plio-Pleistocene stress field, Geological Society of America Abstracts with Programs, v. 10, no. 3, p. 111.

Lane, D.L., M.J. Apted, C.C. Allen, and J. Myers, 1983a. The Basalt/Water System: Considerations for a Nuclear Waste Repository, RHO-BW-SA-320, Rockwell Hanford Operations, Richland, Washington.

Lane, D.L., T.E. Jones, and M.H. West, 1983b. "Preliminary Assessment of Oxygen Consumption and Redox Conditions in a Nuclear Waste Repository in Basalt," Geochemical Behavior of Disposed Radioactive Waste, G.S. Barney, J.D. Navratil, and W.W. Schulz (eds.), ACS Symposium Series 246, 1984, American Chemical Society, Washington, D.C.; also RHO-BW-SA-283 P, Rockwell Hanford Operations, Richland, Washington.

Langmuir, D., "Eh-pH Determinations," in Procedures in Sedimentary Petrology (Carver Edition), pp. 597-635, 1971.

Laubscher, H.P., 1981, Models of the development of Yakima deformation, in Final Safety Analysis Report WNP-2, Amendment no. 18, Appendix 2.5-O, Washington Public Power Supply System, Richland, Washington.

Lindberg, R.D., and D.D. Runnells, 1984, "Ground Water Reactions: An Analysis of Equilibrium State Applied to Eh Measurements and Geochemical Modeling," Science, Vol. 225, pp. 925-927.

LLNL, 1985, Transmittal of report entitled "Preliminary data and report on the timing and style of deformation since the Miocene Epoch in the Yakima fold belt": Lawrence Livermore National Laboratory letter dated September 26, 1985.

Lumsden, J.B., 1985. Pitting Behavior of Low-Carbon Steel, SD-BWI-TS-014, Rockwell Hanford Operations, Richland, Washington.

Malone, S.D., G.H. Rothe, and S.W. Smith, 1975, "Details of Microearthquake Swarms in the Columbia Basin, Washington," Bulletin of the Seismological Society of America, vol. 65, pp. 855-864.

Moore, E.I., G.C. Ulmer, and D.E. Grandstaff, 1985, "Hydrothermal Interaction of Columbia Plateau Basalt from the Umtanum Flow (Washington, U.S.A.) with Its Coexisting Groundwater," Chemical Geology, Vol. 49, pp. 53-71 (Also RHO-SD-BWI-TI-228).

NRC (U.S. Nuclear Regulatory Commission) 1982, Safety Evaluation Report (related to construction of Skagit/Hanford Nuclear Project, Units 1 and 2): NUREG-0309, Supplement No. 3.

NRC, 1983, Draft site characterization analysis of the site characterization report for the Basalt Waste Isolation Project: NUREG-0960.

NRC, 1984, "Draft Issue-Oriented Site Technical Position (ISTP) For Basalt Waste Isolation Project (BWIP)."

NUREG/CR-2482 Vol. 3. Review of DOE Waste Package Program, Brookhaven National Laboratory, March 1983 p. 14.

Pitman, S.G., 1985. Slow-Strain-Rate Testing of 9%Cr - 1%Mo Wrought Steel and ASTM A27 Cast Steel in Hanford Grande Ronde Groundwater, SD-BWI-TS-008, Rockwell Hanford Operations, Richland, Washington.

Price, E.H., 1982, Structural geometry, strain distribution, and tectonic evolution of Umtanum Ridge at Priest Rapids, and a comparison with other selected localities within Yakima fold structures, south-central Washington, RHO-BWI-SA-138, Rockwell Hanford Operations, Richland, Washington.

Rockwell, 1979, Geologic studies of the Columbia Plateau, a status report: Rockwell Hanford Operations, Richland, Washington, Report RHO-BWI-ST-4.

Rockwell, 1985, Geoengineering design parameters workshop: Proceedings of a workshop held in Rapid City, South Dakota: BWI-TI-299, Rockwell Hanford Operations, Richland, Washington.

Stoffel, K.L., and M.A. Korosec, "Low Temperature Geothermal Resources of the Columbia Basin, Eastern Washington," Washington Geologic Newsletter, Vol. 12, No. 4, pp. 5-11, October, 1984.

Thorstenson, D.C., Equilibrium Distribution of Small Organic Molecules In Natural Waters," Geochem. et Cosmochim. Acta, Vol. 34, pp. 745-770, 1970.

West, J.M., P.J. Hooker and I.G. McKinley, "Geochemical Constrants On the Microbial Contamination of A Hypothetical UK Deep Geological Repository," Fluid Processes Research Group (FLPU), FLPU 84-8, British Geological Surrey - Natural Environment Research Council, 1984.

Zoback, M.L., Anderson, R.E., and Thompson, G.A., 1981, Cainozoic evolution of the state of stress and style of tectonism of the Basin and Range Prcvince of the Western United States: Philosopical Transaction of the Royal Society of London, v. 300, p. 407-434.

MAJOR COMMENTS

ON

YUCCA MOUNTAIN SITE

Comment 1

Fault Activity (Draft EA Major Comment 1)

Guidelines on Tectonics 10 CFR 960.4-2-7 (d); and 960.5-2-11 (a),(c)(3)

In NRC staff major comment 1 on the draft EA for Yucca Mountain the concern was raised that despite indications elsewhere in the draft EA that the faults in the vicinity of Yucca Mountain are considered as potentially active, they are considered to be not active in the assessment of the expected nature and rates of fault movement at the Yucca Mountain site. Preliminary seismic assessments in the final EA are still based on the assumption--supported by some justification (final EA, Section C.4.1.1, page C.4-5)--that the faults at Yucca Mountain are not active (final EA, Section 6.3.1.7.5, page 6-275, last paragraph). However, elsewhere in the final EA (Section 6.3.1.7.4, pages 6-267 and 6-268) the faults are considered as potentially active; in light of the evidence supporting that position--in the final EA and in this comment--the NRC considers that the concerns expressed in the original comment remain relevant to the discussions in the final EA.

Justification for the assumption in the final EA that the faults at Yucca Mountain are not active is identified as being obtained from U.S.G.S. Open File Report 84-792 (final EA, page C.4-5, last paragraph). However, the interpretation presented in U.S.G.S. (1984) is at least in part based on the assumption that maximum and intermediate principal stresses are essentially equal (U.S.G.S., 1984, page 76), an interpretation that has recently been disputed (Healy and others, 1984; Stock and others, 1985). In addition, there is a growing body of evidence that supports an interpretation that at least some of the north-trending normal faults in the vicinity of Yucca Mountain have had movement in the last 40,000 years. The primary evidence for Holocene faulting at Yucca Mountain is a thermoluminescence age of approximately 6000 years for latest movement on a fault in the eastern part of Crater Flat (final EA, page 3-20, 1st paragraph). Isotopic evidence from other parts of the NTS supports ages of less than 40,000 years for latest movement along favorably oriented faults. This evidence includes ages of approximately 35,000 years and 37-97,000 years for the last natural movement on the Yucca and Carpetbag faults respectively (Knauss, 1981). At least portions of the Yucca fault may have had natural movement as recent as 1000 years ago (Knauss, 1981).

Both the Carpetbag and Yucca faults and similarly oriented faults in Pahute Mesa have been reactivated by nuclear weapons tests suggesting that stress magnitudes in the vicinity of the faults are at or close to values at which failure would occur along favorably oriented structures (final EA, page 6-268). At Yucca Mountain, hydrofrac tests in holes USW G-1 and G-2 by Stock and others (1985, page 8705) indicate that stress magnitudes at Yucca Mountain have measured values "close to values at which slip would occur on favorably oriented faults" (also see Healy and others, 1984). The fact that slip is occurring along favorably oriented structures is supported by seismic evidence that indicates that north trending faults are active on the NTS. For example, earthquakes associated with northeast-trending faults are believed to be associated with "shorter intervening fault segments with a north strike" (final EA, page 3-20, 3rd paragraph).

Comment 2

Northeast-Trending Faults-(Draft EA Detailed Comments 3-2, 3-3, 3-4, 3-5, 3-8)

Guidelines on Tectonics 10 CFR 960.4-2-7 (c)(5), (c)(6), (d) and 960.5-2-11 (c)(3), (d)

In several comments on the draft EA (detailed comments 3-2, 3-3, 3-4, 3-5, 3-8) the NRC staff indicated that the limited recognition and discussion of northeast-trending strike-slip faults near Yucca Mountain contributed to an inadequate assessment of the nature and rate of fault movement at the Yucca Mountain site. Examination of the final EA shows that consideration of those faults is still limited. In fact, the importance of the northeast-trending structures was de-emphasized by the omission of the northeast-trending Mine Mountain fault from figure 3-4 (final EA, page 3-14, map portraying major Basin-Range faults) and by the lack of discussion of Maldonado's (1985) map of the Jackass Flats area on which he extends the Mine Mountain fault zone across Jackass Flats east of Yucca Mountain. The NRC staff considers that the original comments remain relevant to the final EA and that the omission of the northeast-trending strike-slip faults reflects inadequate recognition of current uncertainties regarding the nature and rates of fault movement.

The bases for the concerns raised by the NRC staff relate to the aforementioned Mine Mountain fault in particular and to five features of northeast-trending faults in the Yucca Mountain area in general (detailed below). These six factors strongly suggest that northeast-trending faults are an important tectonic element in the seismotectonic evaluation of the Yucca Mountain site.

1) Historical seismicity is associated with the northeast-trending Mine Mountain, Rock Valley, and Cane Spring strike-slip faults (20, 26, and 28 kilometers from the site respectively) (U.S.G.S., 1984). Northeast-trending strike-slip faults are considered to be the most seismically active faults on the NTS (McKague and Orkild, 1984; U.S.G.S., 1984).

2) The southeastern corner of Yucca Mountain lies along the western margin of the Spotted Range-Mine Mountain structural zone, a major northeast-trending structural belt (Carr, 1984). The Mine Mountain fault, a major northeast-trending seismically active fault within the Spotted Range-Mine Mountain structural zone, trends southwestward into Jackass Flats (U.S.G.S., 1984, Figure 3) and may extend across Jackass Flats (Maldonado, 1985). Extension of the Mine Mountain fault southward through Jackass Flats brings the fault closer to Yucca Mountain than the 14 km which separates the Bare Mountain fault from the repository site. The Bare Mountain fault is used as the baseline for seismic risk (final EA, Section 6.3.1.7.5, page 6-276).

3) Scott and Bonk (1984) mapped an area of very closely spaced, northeast-trending faults in the southern part of the site (final EA, page 3-15, first paragraph). The significance of these northeast-trending faults at Yucca Mountain and their potential for movement in the present stress field is unknown.

4) A northeast-trending aeromagnetic lineament that passes through the center of Lathrop Wells basalt center is located just to the south of the site and east of Busted Butte (Carr, 1984, Figure 28). Maldonado (1985) places a northeast-trending fault along the trend of this aeromagnetic lineament (approximately 8 km from the repository site) extending the fault northeastward into the Shoshone Mountain area. Northeast-trending faults are known to be present on Yucca Mountain and Busted Butte; the relation of these faults to the aeromagnetic lineament (fault?) and to seismicity in the Spotted Range-Mine Mountain structural zone is unknown.

5) Volcanism, particularly younger basaltic activity, is oriented along a fairly consistent northeast trend (Carr, 1984). This northeast-trending belt of basaltic volcanism near Yucca Mountain is termed the Death Valley-Pancake Range belt by Carr (1984) and is known for its relative youthfulness and association with a higher than regional tectonic flux. Of concern to the NRC staff is the relationship of volcanism to the northeast-trending faults near Yucca Mountain as possibly demonstrated by the association of Lathrop Wells basalt center to the northeast-trending aeromagnetic lineament passing just to the east of Busted Butte (Carr, 1984).

The NRC staff considers that the lack of a comprehensive evaluation of northeast-trending structural features could result in underestimated values for magnitudes of vibratory ground motion and the potential for volcanism at the repository. In the final EA, the Bare Mountain fault is used for the determination of seismic risk. The U.S.G.S. (1984) states that if faults nearer to Yucca Mountain than the Bare Mountain fault are found to be active, then acceleration estimates determined for Yucca Mountain could be much higher. The Mine Mountain fault and its possible extension through Jackass Flats, the closely spaced faults of Scott and Bonk (1984), and the northeast-trending aeromagnetic lineament (Carr, 1984) are all important tectonic elements in the determination of seismic risk at Yucca Mountain.

Comment 3

Detachment Faulting

<u>Guidelines on Tectonics 10 CFR 960.4-2-7 (c)(5), (c)(6), (d); and 960.5-2-11 (c)(3), (d)</u>

The final EA states that low-angle detachment faults may be present below Yucca Mountain and that the possibility that they do exist will be explored during site characterization (final EA, Section C.4.1.1, page C.4-4, 4th paragraph). Based on documented evidence of the development of detachments in the Basin and Range Province during the mid-Miocene, it is reasonable to suggest the possible presence of detachments beneath Yucca Mountain. The NRC staff is concerned because recent publications (Scott, 1986; Scott and Rosenbaum, 1986) have suggested that detachment faulting may be a much more important element in the tectonic setting of Yucca Mountain than previously believed and because the implications of these features with respect to associated normal faults which intersect and bound the repository site have not been adequately addressed in the final EA. The NRC staff considers that omission from the final EA of the possible implications of detachment faulting and related listric normal faulting at Yucca Mountain reflects inadequate recognition of current uncertainties regarding the nature and rates of faulting during the Quaternary.

Scott (1986) implies that normal faults present at Yucca Mountain are connected to and are imbricates from a detachment surface at the Tertiary-Paleozoic boundary (depth of approximately 2 km). Moreover, to the northwest of Yucca Mountain, Hardyman (1984) has observed detachment surfaces at the Tertiary-pre-Tertiary contact and at most contacts throughout the Tertiary section. He also notes that high-angle shear planes can become quite common (several per meter) above detachment surfaces (Hardyman, 1984, page 196). The NRC staff is concerned that if detachment-type faulting is present at Yucca Mountain as has been reported by Scott (1986), then many unrecognized detachment surfaces may be present within the Tertiary section and there is potential for shattering of the units above the detachments. In addition, based on hydrofrac stress tests (Stock and others, 1985) normal faults on Yucca Mountain are at or close to a state of failure. If normal faults on Yucca are functionally associated with detachment surfaces, then the detachment along which they are connected may also be at or close to failure. Slip along a normal fault could then occur along a much more areally significant structure (i.e., the detachment) than previously believed. A discussion of the implications of this style of fault movement at Yucca Mountain is lacking in the final EA.

Comment 4

<u>Hydrothermal Activity - (Draft EA Major Comment 2)</u>

<u>Guideline on Tectonics (10 CFR 960.4-2-7) (b). (C)(1)</u>

NRC major comment 2 on the draft EA for Yucca Mountain raised the concern that the mean probability estimate for disruption of the repository by igneous or tectonic activity was not supported by the information provided in the draft EA. That probability formed much of the basis in the draft EA for the conclusion that there is less than one chance in 10,000 over the next 10,000 years of igneous activity or tectonic processes leading to release of radionuclides to the accessible environment. In addition, NRC major comment 2 raised the concern that the potential for hydrothermal activity, which is often associated with volcanic activity, was not considered in the draft EA. Examination of the final EA indicates recognition of current information which suggests that the probability of occurrence of a volcanic event at Yucca Mountain in the next 10,000 years could conservatively be estimated as exceeding one chance in 10,000 (final EA, Section 6.3.1.7.3, pages 6-262 and 6-263). However, the potential for associated hydrothermal activity and hence the potential for such activity to create new flow paths and adversely affect waste package corrosion and waste form dissolution is not addressed in final EA Volumes I and II and is inadequately addressed in final EA Volume III, Section C.5.7, pages C.5-41 and C.5-42.

Final EA Volume III, Section C.5.7 states that hydrothermal activity is thought to be an "unimportant contributor" to recent volcanic events near and at Yucca Mountain and further states that "should studies conducted during site characterization alter this perception, these processes will be considered." These comments indicate that hydrothermal activity is not recognized as a phenomenon needing study early in site characterization and overlook several lines of evidence suggesting that hydrothermal activity may have been present in the vicinity of Yucca Mountain during the Quaternary (Swadley et al., 1984) and may still be a factor in the area. Evidence suggesting hydrothermal activity includes: elevated water temperatures in drill holes near Yucca Mountain (draft EA, page 3-22; final EA, Section 3.2.4.1, page 3-23; Sass et al., 1980; Szabo and Kyser, 1985; Carr, 1982); hydrothermal alteration in rocks underlying the Paintbrush Tuff (draft EA, pages 6-216 and 6-217; final EA, Section 6.3.1.6.2, page 6-254 and Section 6.3.1.6.4, page 6-256); and calcite-silica vein deposits exposed in trenches CF1 (Swadley and Hoover, 1983) and 14 (DOE, 1986). If the latter are shown to be hydrothermal, they may indicate relatively recent upward movement of hydrothermal solutions. In addition, in the Wahmonie area, approximately 25 km east of Yucca Mountain, a subsurface granite mass was eliminated as a potential repository based, in part, on the presence of hydrothermal alteration and a spring deposit at that site (draft EA, page 2-14; final EA, page 2-14; Twenhofel, 1979).

Hydrothermal activity at the proposed Yucca Mountain repository site and the accompanying upward movement of heated waters could adversely affect waste isolation capabilities of the repository by opening new pathways for groundwater and the accompanying radionuclides to reach the accessible environment. The effects of the heated waters or vapors could also adversely affect performance of the waste package by significantly increasing corrosion rates of the waste package and dissolution rates of the waste form, resulting in more rapid waste package failure and in release of large amounts of radionuclides to the accessible environment earlier than calculated in the final EA.

Comment 5

Natural Resources Data Relevant to the Evaluation - (Draft EA Detailed Comment 6-94)

Guidelines on Human Interference 10 CFR 960.4-2-8 and Natural Resources 10 CFR 960.4-2-8-1(b)(1), (c)(1), (c)(4), (d)(2)

NRC staff detailed comment 6-94 on the draft EA for Yucca Mountain raised concerns that the analysis of historical mining and prospecting in the area of Yucca Mountain is not sufficient to assess economic potential inasmuch as natural resource exploration has been banned within the Nevada Test Site for over 30 years. Examination of the final EA indicates that several references have been added (Section 6.3.1.8.2, page 6-281, first paragraph; page 6-285, first paragraph; page 6-287, second paragraph) to show what work has been conducted at the Nevada Test Site in the past 30 years; however, arguments in support of the conclusion that "Yucca Mountain has no energy or mineral resources for which economic extraction is potentially feasible in the foreseeable future" (final EA, Section 6.3.1.8.4, page 6-288) do not recognize the direct knowledge currently available about natural resources at Yucca Mountain and overlook various indirect lines of evidence suggesting that there may be significant economic natural resource potential there. The NRC staff is concerned that the final EA does not recognize that the limited data base currently available permits alternate interpretations of the possibility of economically motivated postclosure human-interference activities that could adversely affect the isolation capabilities of the Yucca Mountain site.

None of the new references presented in the final EA support the conclusions cited in the preceding paragraph, although final EA Volume III, Section C.4.1.1, page C.4-7 and Section C.5.8, page C5-49 state that for natural resources "cores and cuttings... are routinely analyzed by geochemical methods...; no mineralization has been found of economic importance;" and that "field exploration and geologic mapping were conducted." To the NRC staff's knowledge no geochemical or geophysical data sufficient to delineate anomalies have been presented in reports on Yucca Mountain and vicinity. Conclusions related to mineral potential at the Yucca Mountain site are based on the studies of Bell and Larson (1982) and analyses of drill hole data presented in Maldonado and Koether (1983) and Spengler and others (1981) (final EA, Section 3.2.4, page 3-23). The contents of the reports by Maldonado and Koether (1983) and Spengler and others (1981) suggest those studies were conducted to determine the structure, stratigraphy, and petrographic features of local Tertiary volcanics and not necessarily for the purpose of resource assessment. Studies to assess natural resources should include assays, trace element analysis, and geophysical exploration methods. Surficial mapping, while of primary importance, is not sufficient to delineate "hidden" mineral deposits and must be combined with detailed geochemistry and geophysics.

Volume III, Section C.5.8, page C.5-50 of the final EA cites McKee (1979) as indicating that "of 98 mining districts in Nevada with $1 million or more production of gold, silver, copper, lead, zinc, mercury, antimony and iron, only 2 are within calderas, and only 5 are in silicic tuffs related to calderas" and that "93 percent of all the major metal-mining districts in the state are in rocks other than silicic tuff." These statements were used in the final EA (page C.5-50) to justify a negative correlation between calderas and ore deposits in Nevada. Of the five districts in tuffs identified by McKee (1979) it is important to note that three of the five (Divide, Goldfield, and Bullfrog) are within approximately 90 miles of Yucca Mountain and at one (Bullfrog, approximately 22 miles from the site) ores are associated with two lithologic units which are also present at the Yucca Mountain site, namely the Paintbrush and Timber Mountain Tuffs (Christiansen and others, 1977; McKee, 1979). Many ore deposits in Nevada in addition to those cited by McKee (1979) are associated with andesitic and rhyolitic tuffs. These include the Santa Fe, Rawhide, Borealis, Ivanhoe, Sixteen-to-One (Lowe and others, 1985) and two recent discoveries, Hog Ranch and Paradise Peak (Robert Schafer, Billiton Exploration, Pers. Comm.; Thomason, 1986). Therefore, although a significant correlation between mining districts and calderas cannot yet be demonstrated, a correlation can be shown between volcanic rocks, specifically silicic tuffs including units present at Yucca Mountain, and ore deposits in Nevada.

Yucca Mountain, due to its proximity to known mining districts (Bullfrog, 22 miles west; Bare Mountain, 10 miles northwest; Lee, 9 miles southwest; Amargosa, 6 miles southwest; Wahmonie, 12 miles east; and Mine Mountain, 15 miles northeast, (page 6-286, final EA)) could be interpreted as a possible exploration target. Of these mining districts, the Bare Mountain and Amargosa are still active and the Wahmonie and Mine Mountain are located within the Nevada Test Site. Reports on the Wahmonie area suggest that site may still be an "attractive" exploration target (Smith and others, 1983; Ponce, 1981; Hoover and others, 1982). Smith and others (1983) suggest that areas within the Bullfrog district may have bulk mineable gold potential. The Sterling Mine, in the Bare Mountain district and approximately 9 miles from Yucca Mountain, is currently in production with calculated gold reserves totaling $12 millon dollars ($350.00 oz. gold) (Smith and others, 1983; Lowe and others, 1985). Carr and Parrish (1985) suggest that Crater Flat may represent a caldera. If Crater Flat is a caldera, the Sterling Mine on the west side of Crater Flat may be located along a caldera rim suggesting that the potential for exploitable resources may also exist along the western flank of Yucca Mountain along what would be the eastern rim of the suggested Crater Flat caldera. Perceived potential, as well as known resources, should be assessed to determine the probability of post-closure human interference on or near the proposed Yucca Mountain site.

New techniques, models and methods for exploration and mining have evolved in the past 30 years since natural resource exploration was banned at the Nevada Test Site. For instance, the concept of bulk mineable gold deposits only began in the early 1960's with the discovery of the Carlin Mine. Also, the suggestion that an area has no economic potential if there exists no previous history of successful mining can be shown to be without merit. The recent large gold discovery at Hog Ranch in northwestern Nevada is located in an area with no nearby precious metal occurrences. In order to establish or conclude calderas" and that "93 percent of all the major metal-mining districts in the state are in rocks other than silicic tuff." These statements were used in the final EA (page C.5-50) to justify a negative correlation between calderas and ore deposits in Nevada. Of the five districts in tuffs identified by McKee (1979) it is important to note that three of the five (Divide, Goldfield, and Bullfrog) are within approximately 90 miles of Yucca Mountain and at one (Bullfrog, approximately 22 miles from the site) ores are associated with two lithologic units which are also present at the Yucca Mountain site, namely the Paintbrush and Timber Mountain Tuffs (Christiansen and others, 1977; McKee, 1979). Many ore deposits in Nevada in addition to those cited by McKee (1979) are associated with andesitic and rhyolitic tuffs. These include the Santa Fe, Rawhide, Borealis, Ivanhoe, Sixteen-to-One (Lowe and others, 1985) and two recent discoveries, Hog Ranch and Paradise Peak (Robert Schafer, Billiton Exploration, Pers. Comm.; Thomason, 1986). Therefore, although a significant correlation between mining districts and calderas cannot yet be demonstrated, a correlation can be shown between volcanic rocks, specifically silicic tuffs including units present at Yucca Mountain, and ore deposits in Nevada.

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Many economic mineral deposits in Nevada are hydrothermal in origin with ore placement controlled by fault zones (Lowe and others, 1985). Possible hydrothermal deposits (NRC, 1984; DOE, 1986) have been recognized in fault zones at or near Yucca Mountain. Additionally, the proposed site is bounded on the west by the large Solitario Canyon fault which is characterized by a wide zone of highly brecciated rock. The ore at the Sterling Mine (east side of Bare Mountain) is located in breccia zones along a thrust fault and rocks which underlie the ore zone are silicified from hydrothermal fluids (Smith and others, 1983). Breccia zones within faults provide excellent conduits for ore placement by hydrothermal processes suggesting that the Solitario Canyon fault and other faults at or near the Yucca Mountain site should be thoroughly explored. The potential for undiscovered resources exists in these fault and possible hydrothermal zones. These geologic characteristics of the area at Yucca Mountain (Tertiary volcanics, possible hydrothermal, faults), taken in combination with the previously mentioned proximity to areas of economic resoures and the aforementioned lithologic and structural similarities of the Yucca Mountain area to areas hosting known mineral deposits, indicate a potential for undiscovered natural resources.

Comment 6

Radionuclide Transport Increase Due to Changes in Geohydrologic and Climatic Conditions - (Draft EA Major Comment 8)

Guidelines on Geohydrology 10 CFR 960.4-2-1(c)(1) and Climate Changes 10 CFR 940.4-2-4(c)(2)

In the NRC staff major comments on the draft EA for Yucca Mountain it was noted that although groundwater velocities may be substantially increased as a result of plausible future changes in geohydrology and climate, the significance of these changes relative to increased radionuclide transport was dismissed because of the implied ability of geochemical retardation to limit radionuclide transport to the accessible environment. The concern was raised that because the ability of the geochemical system to effect sufficient retardation is highly uncertain, it is not reasonable to assume significant increases in radionuclide transport to the accessible environment due to changes in climate or geohydrologic conditions will not occur at Yucca Mountain solely as a result of retardation. Examination of the final EA indicates that while increased flux and recharge during pluvial conditions is acknowledged and discussed thoroughly (Section 6.3.1.1.4, pages 6-141 to 142; Section 6.3.1.4.3, pages 6-233 to 6-239), the conclusion that geochemical retardation will limit radionuclide transport to the accessible environment to an extent that there would be no significant increase in transport of radionuclides to the accessible environment is maintained (Section 6.3.1.4.4, page 6-242) without indication that there has been a re-evaluation in light of that discussion.

Neither the guidelines nor the final EA presents a quantitative definition for the term "significant." However, a change in flux of less than one order of magnitude--plausible based upon final EA estimates that recharge rate at Yucca Mountain could increase by a factor of 15 over modern rates (final EA, Section 6.3.1.1.4, page 6-142)--can affect calculated velocity by more than one order of magnitude. Therefore, the NRC staff considers plausible future changes in climate and geohydrology as significant. This, coupled with existing and unresolved uncertainty in retardation (particularly the contribution of matrix diffusion: refer to Comment 8) leads the NRC staff to conclude that the concern expressed in the original major comment is still valid.

Comment 7

Groundwater Travel Time - (Draft EA Major Comment 3)

Guidelines on Geohydrology 10 CFR 960.4-2-1(d), (b)(1) and (b)(5)(iii)

In the NRC staff major comments on the draft EA for Yucca Mountain it was noted that because of a series of technical concerns identified during the review, DOE's confidence in calculated groundwater travel time, which was used with regard to findings concerning the disqualifying condition of 1000 years groundwater travel time and the favorable condition of greater than 10,000 years groundwater travel time, was questioned. Many assumptions, hypotheses, and approaches used in the analysis did not incorporate uncertainties associated with available data. For example, the possibility of fracture flow was not factored into the calculations; plausible alternative conceptual models of water migration through the unsaturated zone were not included in the analysis; and single values for key hydrologic parameters in the calculations were used rather than a range of values. In addition, it was noted that the conclusion that a geologic unit which would divert downward infiltration of water beyond the limits of emplaced waste is present was not supported adequately by information presented. Therefore, it was recommended that existing field and laboratory data and experiments, including those concerned with spatial and temporal variability of the hydrologic system at Yucca Mountain, as well as other sources of uncertainty, be considered in revised. assessments of the groundwater travel time.

Examination of the final EA indicates that the original conclusion concerning diversion of downward infiltration away from the buried waste is no longer maintained (final EA, page 6-138, 3rd paragraph), because of a current lack of conclusively supporting information.

Further review of the final EA indicates that the analysis for groundwater travel time has been revised significantly in an attempt to incorporate uncertainties identified in the NRC staff major comment on the draft EA (NRC major comment 3 in Hydrogeology). For example, ranges in values for some hydrogeologic parameters are considered (final EA, Table 6-18) as well as the possibility of fracture flow. However, the NRC staff has concerns with the revised assessment for groundwater travel time in the areas of input data to the model and the subsequent statistical analyses. A brief description of specific problems that bear upon the findings in the final EA is given below.

1. <u>Uncertainties affecting groundwater travel times--general</u>: The computational procedures used in the final EA to generate a frequency distribution for predicted groundwater travel times can incorporate only the estimated uncertainties in those parameters input to the model as random variables. Uncertainties in those parameters treated as constants, uncertainty about the defensibility of the conceptual model, uncertainty about the validity of the boundary conditions, and uncertainty about some of the assumptions used in the mathematical flow model are not accommodated in the analysis which generated the frequency distribution for predicted groundwater travel times.

2. <u>Uncertainties with parameters input to model as random variables</u>: Probability distributions were estimated for hydrogeologic parameters treated as random variables (saturated matrix conductivity, porosity) by using subjective judgment and the results of tests on core specimens. However, the specific types of input distributions used to characterize the random variables are not listed in the final EA. This information may be contained in a supporting document cited in the final EA as Sinnock and others (1986), which was not available to NRC staff during review of the final EA. The NRC assumes, based on the range of data presented in Table 6-18, that the saturated hydraulic conductivity of the rock matrix was considered in the analysis to be lognormally distributed and that the porosity of the matrix was considered to be distributed in some type of symmetrical fashion (probably as a normal or uniform distribution). The NRC cannot evaluate these assumptions or considerations without listings of testing results and written documentation to support the parameter means and standard deviations reported in Table 6-18. There is also some confusion with the use or presentation of median and mean values of hydraulic conductivity in Table 6-18 (the given equation calculates median saturated hydraulic conductivity, but the results are given as <u>mean</u> saturated hydraulic conductivities), which may adversely affect use of data or interpretation of results for groundwater travel time.

3. <u>Uncertainties Regarding Vertical Movement of Groundwater</u>: Groundwater travel time values are critically dependent on whether matrix flow or fracture flow will dominate from the repository to the water table; that in turn depends primarily on three factors: (1) the vertical flux of water infiltrating from the repository to the water table, including the possibility of concentration of the flow along certain pathways; (2) the saturated hydraulic conductivity of the rock; and (3) the fraction of saturation at which flow changes from matrix to fracture flow. These three factors are elaborated upon below.

Flux

In the draft EA, the geometric mean saturated hydraulic conductivity of 1 mm/yr was used as the upper bound for flux for groundwater travel time calculations through the unsaturated zone. In NRC comments on the draft EA the choice of this value as an upper bound was considered to be inadequately supported and the suggestion was made that higher values be considered. In the final EA this value has been reduced to a constant value of 0.5 mm/yr (final EA, pages 6-150 to 6-153), a value supported by Wilson (1985), who uses two sources of information to arrive at this number: 1) data from in situ level of saturation values combined with capillary pressure-saturation data from Peters (1984); and 2) data from an empirical method of determining the ratio between recharge and precipitation rates in arid regimes.

The first of these methods appears to be reasonable, but the NRC is not able to verify independently the 0.5 mm/yr as a "conservative" upper bound because no other data are available. The second method, which also seems reasonable, suggests a wide range of possible recharge values at the Yucca Mountain site of between 0.45 and 1.5 mm/yr, which does not appear to support robustly the estimate of 0.5 mm/yr presented in the final EA. The NRC staff concludes that the uncertainty in the values of flux has not been adequately considered in the analysis of groundwater travel time.

The importance of taking into account uncertainties in flux values is emphasized by considering how a small change in flux affects groundwater travel times at Yucca Mountain. If the value of flux is less than the matrix saturated conductivity in the Topopah Spring unit, it is assumed that flow does not occur in the fractures, thereby resulting in a large (greater than 40,000 year) groundwater travel time. Conversely, if flux exceeds the saturated matrix conductivity in all rock units between the repository and the water table, fracture flow may result in relatively short groundwater travel times (less than 1000 years). As a specific example, if the flux is assumed to be 0.67 mm/yr rather than 0.5 mm/yr, then more than half of the model elements in the Topopah Spring welded unit would be expected to experience fracture flow, and the overall predicted groundwater travel times would be decreased considerably by this very slight increase in flux.

Another point related to uncertainties in flux values is that calculated groundwater travel time distributions are based on a one-dimensional model, restricted to the vertical dimension. All infiltration is assumed to occur uniformly across the vertical column. This does not allow for the possibility that there are preferential paths along which flow could concentrate. Phenomena such as "fingering" have been observed to occur in unsaturated porous media, leading to much faster movement of water in the vertical direction than would be indicated by uniform infiltration. Even a slight concentration of infiltration could significantly reduce groundwater travel time, because of its great sensitivity to flux. In this case, spatial uniformity in the lateral direction is the most optimistic assumption.

Saturated Hydraulic Conductivity

The NRC agrees in principle with the analysis of saturated hydraulic conductivity for matrix and fracture flow (final EA, pages 6-153 to 6-162). However, it must be recognized that the wide variation in saturated hydraulic conductivity values (0.03 to 14.2 mm/yr) reported by Peters et al., (1984) indicates that there may be significant zones in the Topopah Spring unit where the matrix saturated hydraulic conductivity is less than 0.5 mm/year. If such values occur throughout the entire depth of the unit, fracture flow could occur at flux values less than 0.5 mm/year thereby producing groundwater travel times of substantially less than 1000 years in certain areas of the Topopah Spring unit. Therefore, the possible spatial variability of saturated hydraulic conductivity must be adequately considered in combination with the uncertainty in the assumed value of flux in the analysis.

Transition between Matrix and Fracture Flow

The analysis in the final EA assumes that fracture flow is initiated when flux exceeds 95 percent of the saturated hydraulic conductivity of the rock matrix (final EA, page 6-153, last paragraph), but no rationale for this assumption is provided. The NRC is concerned about the justification for the use of this 95 percent value; furthermore, it is even more concerned that no sensitivity calculations were conducted (or at least none were reported) that would reveal the extent of the influence of choosing this percentage on the distribution of predicted groundwater travel times. Conceivably, this percentage could have been treated as a random variable in order to provide an analysis of uncertainty in the identification of the transition point from matrix flow to fracture flow.

4. Uncertainties related to intercorrelation of hydrogeologic properties: Hydrogeologic properties such as hydraulic conductivity and porosity are expected to be correlated; e.g., if porosity is larger, hydraulic conductivity is likely to be larger, all other things being equal. In addition, hydrogeologic properties are expected to be correlated spatially; e.g., measurements taken in close proximity are likely to be more similar than measurements separated by a large distance. Intercorrelations between hydrogeologic properties were not studied, evaluated, or used in the analysis of predicted groundwater travel time. Data sufficient for these more complicated studies may not exist; however, an effort to describe, at least subjectively, the probable intercorrelations and spatial correlations among the hydrogeologic parameters could have been made. By so doing, the potential effects of these correlations and intercorrelations on groundwater travel time predictions could have been evaluated. This might be especially important in the case of the vertical spatial correlation of saturated hydraulic conductivity, discussed further in the following section (#5).

5. <u>Uncertainties in methods of analyzing groundwater travel times:</u> The analysis of groundwater travel time in the final EA relied on a model, Method 1, in which the vertical layer spacing was 10 ft (final EA, page 6-153, third paragraph). The final EA also presents a second analysis for groundwater travel time, Method 2, (final EA, page 6-160, last paragraph) in which each hydrogeologic unit (some of which are hundreds of feet thick) represents one layer. The claim is made that Method 2 is more conservative than Method 1 because "as more physical realism is introduced into the travel time model, the range of travel times is likely to be compressed. Moving from Method 2 to Method 1 clearly has the effect of removing the low probability, extreme values in the tails of the frequency distribution of travel times from the disturbed zone to the water table" (final EA, page 6-162, third paragraph). The final EA concludes that Method 2 gives a more conservative groundwater travel time for small percentiles of the cumulative distribution function (CDF). On the other hand, Method 1, which is supposedly more realistic, suggests that there is only a low probability that the groundwater travel time is less than 10,000 years.

   These conclusions reached on the comparison of the results of Methods 1 and 2 in the final EA (Figure 6-9, page 163) are questionable. The stated increase in realism of Method 1 over Method 2 is probably a mathematical artifact. It can be demonstrated that as the layer thickness is diminished (as it is in Method 1 vis-a-vis Method 2), and if the properties of the layers remain spatially uncorrelated (as they are in Method 1), the groundwater travel time would approach a constant for each vertical column. Given this artificially-induced compressive effect, Method 2 is in fact more likely to encompass the correct distribution than Method 1.

6. <u>Uncertainties in use of simulated groundwater travel time distributions:</u> The NRC staff is concerned with how the distribution of groundwater travel time was used to evaluate the conclusions regarding travel times in the final EA. The conclusions were based on central tendencies (mean and median) of the simulated groundwater travel time distribution. Analyses using percentile criteria smaller than the mean or median would more properly reflect the high degree of uncertainty present in the groundwater travel time distribution.

   In support of the analyses leading to groundwater travel times in excess of 10,000 years, the final EA states (page 6-131, second paragraph) that "the extreme upper and lower portions of the travel time distribution are characteristic of travel times along unlikely paths of radionuclide travel, and therefore, inappropriate for evaluating this favorable condition (10,000 year groundwater travel time). The DOE considers this judgment to be consistent with the NRC staff position regarding the groundwater travel time requirement in 10 CFR Part 60 (Browning, 1985)." Although the NRC does anticipate excluding the extremes of the distribution of possible groundwater travel times in determining whether the performance objective has been met, excluding the tails (extremes) of a distribution is not equivalent to a choice of the mean or median as the measure of the groundwater travel time. This is particularly so for initial screening prior to site characterization, where attempting to reach conclusions about "likely" and "unlikely" flow paths is speculation at best. Indeed, eliminating the tails of the groundwater travel time distribution virtually requires ignoring the uncertainty that the analyses were intended to incorporate. In addition, the mean or median may be particularly poor choices of a criterion for the groundwater travel time distribution because of their relative insensitivity to modeling assumptions such as sampling methods and spatial correlations. The meaning of the NRC statement (Browning, 1985) that refers to excluding extremes is simply that the NRC might consider the performance objective to be met even if some small portion of the distribution was less than the time criterion (e.g., 1000 years), assuming the conceptual model and other determining factors behind the distribution itself are defensible.

Comment 8

Retardation of Radionuclides

Guideline on Geochemistry (10 CFR 960.4-2-2): (b) Favorable Conditions 2, 5

In the NRC staff major comment 6 on the draft EA for Yucca Mountain, the concern was raised that the retardation factors used in determining radionuclide releases were inappropriately large in assessing the effectiveness of geochemical processes affecting radionuclide retardation. In the final EA two mechanisms--matrix diffusion and sorption--are described which, if operative in the repository system, would diminish radionuclide releases to the accessible environment. In response to the NRC major comment on the draft EA, new evidence is presented in the final EA to support the position that matrix diffusion and sorption will play an important role in controlling radionuclide release. However, the NRC staff considers that the new evidence inadequately supports the conclusion that retardation of several key actinides by these mechanisms will occur.

Retardation of radionuclides by matrix diffusion in the fractured rock of Yucca Mountain is described in the final EA (Section 6.3.1.2.3.(2), page 6-177) and supported by the final EA reference (Travis et al., 1984). In this reference it is shown that in a fractured rock with low matrix permeability and interconnected pores, retardation factors can be as large as 400 for nonsorbing species and several thousand for sorbing species when these species are in solution. From the description in Travis et al. (1984) the fractured rock studied may be analogous to the reference repository host rock, the Topopah Spring Member. However, the scenario described in this reference does not consider how radionuclide release would be affected if the radionuclides were present as colloids or pseudocolloids rather than dissolved species. Based on the comparison of individual radionuclide inventories versus their EPA limits at 1000 years, the important radionuclides of nuclear waste are actinides (Kerrisk, 1985). The actinides, when leached from a glass waste form, are expected to occur as colloids (final EA, Section 6.3.1.2.3.(2), page 6-189); therefore, the effect of colloids on matrix diffusion in fractured rocks needs to be considered when evaluating how much credit can be taken for retardation by this mechanism.

The final EA does describe how radiocolloids can contribute to retardation in rocks in which porous flow will occur, such as the unsaturated tuffaceous beds of the Calico Hills unit, by being mechanically filtered from the flowing liquid (Section 6.3.1.2.3.(2), page 6-191). The final EA proposes that mechanical filtration will occur because some of the colloids will be bigger than some of the pores through which the fluid is flowing. However, if colloids are present in the fluids flowing through fractured rock, two scenarios are possible that could lessen the effectiveness of matrix diffusion for retarding radionuclide transport:

1. Colloids, which can range in size up to 10 µm (Stumm and Morgan, 1981), might be too large to pass into the pores of the matrix. In such cases, colloids would remain in the fluid flowing in the fractures and retardation would be decreased.

2. Colloids, partly because of their large size, can have diffusivities several orders of magnitude lower than those of dissolved ions in water (Weast, 1971). Therefore, compared to ions, large particles such as colloids will have much less tendency to diffuse into the matrix (Cathles et al., 1974).

In the final EA, sorption is the second mechanism given credit for retarding the release of radionuclides from the repository. In response to the NRC major draft EA comment regarding sorption, the final EA refers to new data from Rundberg (1985) which suggests that for simple cations (Sr, Cs, and Ba) sorption parameters determined from batch tests using crushed solids are in good agreement with sorption parameters obtained from corresponding tests with intact solids. The NRC staff finds this information unconvincing for the following reasons:

1. According to Kerrisk (1985), the important radionuclides in nuclear waste are not the simple cations listed above but instead are the actinides such as Am, Pu, U, and Np which can exist in more than one form (simple ions, complex ions, and colloids) in groundwater. Nyhan et al. (1985) present field evidence for multiple forms of actinides in groundwater below a liquid waste disposal site where significant quantities of Pu and Am were mobilized when water was allowed to flush through the system. Kelmers (1984) describes how sorption parameters from batch tests only average the sorption of the multiple species of a given radionuclide. The sorption parameter underestimates the amount of sorption for the strongly sorbed species but overestimates the amount of sorption for the weakly sorbed species.

2. Rundberg (1985) does not attempt to correlate between sorption parameters for actinides derived from tests using crushed and intact rock. In fact, he states that for americium and plutonium "the sorption mechanism is not known nor is the chemical form of plutonium and americium in neutral pH solutions known with any certainty" (Rundberg, 1985, page 19). This implies that at this time no meaningful correlation between the batch experiments on crushed tuff in the laboratory and the field situation with the intact tuff would be possible.

3. No correlation is apparent in Rundberg's experiments between the amount of actinide sorbed and the proportion of sorbents (zeolites and clays) in the solids. Therefore, zeolites and clays have not been shown to be effective sorbers of Pu and Am.

4. Rundberg (1985) states that precipitation, which would yield an apparent sorption ratio, cannot be ruled out in the batch measurements. If precipitation instead of sorption has occurred in the batch test, retardation is not proven. In such a case, concentration of a radionuclide species in the solution would be limited by the solubility of the radionuclide-bearing solid and insensitive to the presence of the other solids in the substrate. For example, if precipitation occurred in a batch test using a nonsorptive solid and a radionuclide-bearing solution, an "apparent sorption ratio" could be determined. This "apparent sorption ratio" could be erroneously inserted into the equation for calculating the retardation factor. However, if the liquid from the batch test was then decanted into a column containing the same nonsorptive solid, the concentration would be below the solubility limit (i.e., no additional precipitation would occur) and the radionuclide would travel down the column as fast as the liquid (no retardation). Thus, if precipitation is not disproved in a sorption test, credit cannot be taken for retardation of the radionuclide.

Given these concerns with the new information introduced in the final EA to support the assessments of geochemical factors affecting radionuclide transport, the NRC staff is concerned that those assessments do not fully recognize the uncertainties in the data currently available.

Comment 9

Waste Package Post-Closure Performance - (Draft EA Major Comment)

Guidelines on Post-Closure 10 CFR 960.4-1, 960.4-2-1(a) and 960.4-2-2(a)

In the NRC major comment 10 on the draft EA for the Yucca Mountain site the concern was raised that the performance analysis of the engineered barrier system was based on insufficiently supported assumptions concerning waste package failure modes and radionuclide release rates and that the uncertainties associated with the assumptions were not adequately conveyed. The comment suggested that the final EA consider more realistic assumptions in the reference case preliminary performance analysis and provide an estimate of the impact of uncertainties on the result of the analysis or reconsider the summary statements made in the draft EA. Examination of the final EA (Executive Summary, Section 6.2, page 18, third paragraph; Section 6.4.2, pages 6-364 to 6-388) indicates that some revisions have been made to identify areas of uncertainty which are to be addressed during site characterization (Sections 6.4.2.1.1, page 6-367, paragraph 3, and 6.4.2.2.2, page 6-374, first paragraph); however, the consequences of the current uncertainties on the analyses of waste package lifetime and radionuclide release rate have not been addressed and hence there is limited recognition that the current data base permits alternative analyses.

Although the final EA may imply that the assumptions used to make evaluations regarding the engineered barrier system are the best estimate of realistic conditions based on the current DOE data (Sections 6.4.2.2.1, page 6-372, first full paragraph, and 6.4.2.2.2, page 6-373, first paragraph), many of the assumptions are currently unsubstantiated and the range of uncertainties not considered when making the evaluations. For example, while it may be true that corrosion testing performed for the last couple of years in a Yucca Mountain simulated environment has not yet identified an operable corrosion mechanism other than uniform attack (Section 6.4.2.1.1, page 6-369, continuing paragraph), the historical susceptibility of the austenitic stainless steels to stress-assisted cracking in chloride/oxygen/water (steam) environments raises significant questions as to their long-term performance. Furthermore, based on the recent test results contained in NUREG/CR-4619, which indicate evidence of crack initiation for a range of simulated Yucca Mountain environments, the NRC staff cannot at this time accept a 3000 year container life as a realistic or conservative value. Until the prediction of the waste package lifetime is justified and the effects of input parameter and model uncertainties are accounted for, the possibility exists that the current analysis in the final EA may greatly overestimate the waste package lifetime.

The NRC staff is also concerned that the efforts made in the text of the final EA to more fully acknowledge the uncertainties in the analyses were not reflected in the discussion contained in the Executive Summary. In fact, the parenthetical sentence contained in the draft EA Executive Summary (op. cit.):

> "There is an issue as to the rate of corrosion in the unsaturated zone; it will be addressed further during site characterization;"

was deleted in the final EA, thereby strengthening the implication that a 3000 year containment lifetime is both realistic and conservative.

NRC staff concerns regarding waste package performance modeling and the effects of input parameters and model uncertainties on the waste package lifetime predictions have not been alleviated in the revision of the draft EA. The NRC staff considers that major comment 10 applies to the final EA.

REFERENCES

Abraham, T., H.Jain, P. Soo, Brookhaven National Laboratory, "Stress Corrosion Cracking Tests on High-Level-Waste Container Materials in Simulated Tuff Repository Environments," USNRC Report NUREG/CR-4619, June 1986.

Bell, E. J., and L. T. Larson, 1982. Overview of Energy and Mineral Resources for the Nevada Test Site, Nye County, Nevada, NVO-250, Nevada Operations Office, U.S. Department of Energy, Las Vegas, 67 p.

Browning, R.E., 1985, letter to R. Stein (DOE), June 12, 1985, regarding NRC position on groundwater travel time.

Carr, W.J., 1982. Volcano - Tectonic History of Crater Flat, Southwestern Nevada, as Suggested by New Evidence From Drill Hole USW-VH-1 and Vicinity, USGS-OFR 82-457, Open File Report, U.S. Geological Survey, Denver, CO, 23 p.

Carr, W.J., 1984. Regional Structural Setting of Yucca Mountain, Southwestern Nevada, and Late Cenzoic Rates of Tectonic Activity in part of the Southwestern Great Basin, Nevada and California, USGS-OFR 84-854, 109 p.

Carr, W. J., and L. D. Parrish, 1985. Geology of Drill Hole USW VH-2, and Structure of Crater Flat, Southwestern Nevada, USGS-OFR 85-475, 41 p.

Cathles, L. M., H. R. Spedden, and E. E. Malouf, 1974, "A Tracer Technique to Measure the Diffusional Accessibility of Matrix Block Mineralization," in Solution Mining Symposium 1974, Editors F. F. Aplan, Society of Mining Engineers, American Institute of Mining, Metallurgical and Petroleum Engineers, New York.

Christiansen, R. L., P. W. Lipman, W. J. Carr, F. M. Byers, Jr., P. P. Orkild, and K. A. Sargent, 1977. "Timber Mountain - Oasis Valley Caldera Complex of Southern Nevada," Geological Society of America Bulletin, V. 88, p. 943-959.

DOE (U.S. Department of Energy), 1986. Final Summary of Workshop on Fault-Related Calcite - Silica Deposits Near Yucca Mountain, April 28, 1986.

Hardyman, R.F., 1984, Strike-slip, normal and detachment faults in the northern Gillis Range, Walker Lane of West-Central Nevada; in Hardyman, R.F., Ekren, E.B., and Proffett, J., 1984, Tertiary tectonics of west-central Nevada: Yerington to Gabbs Valley: Western Geological Excursions, v. 4, p. 184-199.

Healy, J.H., S.H. Hickman, M.D. Zoback, and W.L. Ellis, 1984. Report on Televiewer Log and Stress Measurements in Core Hole USW-G-1, Nevada Test Site December 13-22, 1981, USGS-OFR 84-15, 47 p.

Hoover, D. B., M. P. Chornack, K. H. Nervick, and M. M. Broker, 1982. Electrical Studies at the Proposed Wahmonie and Calico Hills Nuclear Waste Site, Nevada Test Site, Nye Co., Nevada, USGS-OFR 82-466, 45 p.

Kelmers, A. D., 1984, Draft Analysis of Conservatism of Radionuclide Information Measured by Batch Contact Sorption/Apparent Concentration Limit Isotherms, Letter Report L-290-3 to the NRC.

Kerrisk, J. F., 1985, "An Assessment of the Important Radionuclides in Nuclear Waste," LA 10414 MS.

Knauss, K. G., 1981. Dating Fault Associated Quaternary Material from the Nevada Test Site Using Uranium-Series Methods, Lawrence Livermore Laboratory, UCRL-53231, 51 p.

Lowe, N. T., R. G. Raney, and J. R. Norberg, 1985. Principal Deposits of Strategic and Critical Minerals in Nevada, U.S. Bureau of Mines Information Circular 9035, 201 p.

Maldonado, F., 1985. "Geologic map of the Jackass Flats area, Nye County, Nevada," U.S.G.S. Miscellaneous Investigations Map I-1519.

Maldonado, F., and S.L. Koether, 1983. Stratigraphy, Structure, and Some Petrographic Features of Tertiary Volcanic Rock at the USW G-2 Drill Hole, Yucca Mountain, Nye County, Nevada, USGS-OFR 83-732, 83 p.

McKague, H.L., and P.P. Orkild, 1984. "Geologic Framework of Nevada Test Site," Geological Society of America Abstracts with Programs, v. 16, no. 6, p. 589.

McKee, E.H., 1979. "Ash Flow Sheets and Calderas: Their Genetic Relationship to Ore Deposits in Nevada," Geological Society of America Special Paper 180, p. 205-211.

NRC, Trip Report, December 1984, Comments on Data Review, B. Rice and J. Cutler.

Nyhan, J. W., B. J. Drennon, W. V. Abeele, M. L. Wheeler, W. D. Purtymun, G. Trujillo, W. J. Herrera, and J. W. Booth, 1985, "Distribution of Plutonium and Americium Beneath a 33-year-old Liquid Waste Disposal Site," Journal of Environmental Quality, vol. 14, 501-509.

Peters, R.R., Klavetter, E.A., Hall, I.J., Blair, S.C., Heller, P.R., and Gee, G.W., 1984, "Fracture and matrix hydrologic characteristics of tuffaceous materials from Yucca Mountain, Nye County, Nevada," Sandia National Laboratories, Albuquerque, NM, SAND84-1471.

Ponce, D.A., 1981. Preliminary Gravity Investigations of the Wahmonie Site, Nevada Test Site, Nye County, Nevada, USGS-OFR 81-522, 63 p.

Rundberg, R. S., 1985, "Assessment Report on the Kinetics of Radionuclide Adsorption on Yucca Mountain Tuff," Los Alamos National Laboratory, Los Alamos, NM.

Sass, J.H., A.H Lachenbruch, and C.W. Mase, 1980. Analysis of Thermal Data From Drill Holes UE 25a-3 and UE 25a-1, Calico Hills and Yucca Mountain, Nevada Test Site, USGS-OFR 80-826, Open File Report, U.S. Geological Survey, Menlo Park, CA., 25 p.

Scott, R.B., 1986. "Extensional Tectonics at Yucca Mountain, Southern Nevada," Geological Society of America Abstracts with Programs, v. 18, no. 5, p. 411.

Scott, R.B., and J. Bonk, 1984. Preliminary Geologic Map of Yucca Mountain, Nye County, Nevada with Geologic Sections, USGS-OFR 84-494, Scale 1:12,000.

Scott, R.B., and J.G. Rosenbaum, 1986. "Evidence of Rotation About a Vertical Axis During Extension at Yucca Mountain, Nevada," EOS, v. 67, no. 16, p. 358.

Sinnock, S., Lin, Y.T., and Tierney, M.S., 1986, Preliminary Estimates of Groundwater Travel Time and Radionuclide Transport at the Yucca Mountain Repository Site," Sandia National Laboratories, Albuquerque, NM, SAND85-2701.

Smith, P.L., J.V. Tingley, J.L. Bentz. L.J. Garside, K.G. Papke, and J. Quade, 1983. A Mineral Inventory of the Esmeralda - Stateline Resource Area, Las Vegas District, Nevada, Nevada Bureau of Mines and Geology, OFR 83-11.

Spengler, R.W., F.M., Byers, Jr., and J.B. Warner 1981. Stratigraphy and Structure of Volcanic Rocks in Drill Hole USW-G1, Yucca Mountain, Nye County, Nevada, USGS-OFR 81-1349, 50 p.

Stock, J.M., J.H. Healy, S.H. Hickman, and M.D. Zoback, 1985. "Hydraulic Fracturing Stress Measurements at Yucca Mountain, Nevada and Relationship to the Regional Stress Field," Journal of Geophysical Research v. 90, no. 10, p. 8691-8706.

Stumm, W. and J. J. Morgan, 1981, Aquatic Chemistry: An Introduction Emphasizing Chemical Equilibria in Natural Waters, 2nd Ed., John Wiley, p 647.

Swadley, W.C. and D.L. Hoover, 1983. Geology of Faults Exposed in Trenches in Crater Flat, Nye County, NV, USGS-OFR 83-608, U.S. Geological Survey, Denver, CO, 15 p.

Swadley, W.C., D.L. Hoover, and J.N. Rosholt, 1984. Preliminary Report on Late Cenozoic Faulting and Stratigraphy in the Vicinity of Yucca Mountain, Nye County, NV, USGS-OFR 84-788, U.S. Geological Survey, Denver, CO, 42 p.

Szabo, B.J., and T.K. Kyser, 1985. Uranium, Thorium Isotopic Analyses and Uranium - Series Ages of Calcite and Opal, and Stable Isotopic Compositions of Calcite From Drill Cores UE 25a#1, USW G-2, and G-3/GU-3, Yucca Mountain, NV, USGS OFR 85-224, U.S. Geological Survey, Denver CO, 25 p.

Thomason, R.E., 1986. "Geology of the Paradise Peak Ore Deposit," Geological Society of Nevada, May, 1986, Meeting Announcement.

Travis, B.J., S.W. Hodson, H.E. Nuttall, T.L. Cook and R.S. Rundberg, 1984. Preliminary Estimates of Water Flow and Radionuclide Transport in Yucca Mountain, LA-UR-84-40 (Rev.), Los Alamos National Laboratory, Los Alamos, NM

Twenhofel, W.S., 1979. Letter from W.S. Twenhofel (USGS) to R.M. Nelson (DOE/NVO), April 24, 1979; regarding technical findings on southwest quadrangle, 5 p.

U.S.G.S., 1984. A Summary of Geologic Studies Through January 1, 1983, of a Potential High-Level Radioactive Waste Repository Site at Yucca Mountain, Southern Nye County, Nevada, USGS-OFR 84-792, 103 p.

Weast, R. C., 1971, Handbook of Chemistry and Physics, 51st Ed., The Chemical Rubber Company, F-47 and F-199.

Wilson, W.W., 1985, letter to D.L. Vieth (DOE/NVO), December 24, 1985, regarding flux in the unsaturated zone.

MAJOR COMMENTS

ON

DAVIS CANYON SITE

Comment 1

Structure and Tectonics - (Draft EA Major Comment 1)

Guideline on Tectonics 10 CFR 960.4-2-7 (a),(b),(c)(4), and 10 CFR 960.5-2-11 (c)(3)

In major comment 1 of the NRC review of the draft EA for Davis Canyon, concerns were raised regarding incomplete evaluations of information and uncertainties with respect to the (1) tectonic regime in the site region, (2) subsurface structures (i.e., joints, fractures) and (3) major structural features in the site vicinity (e.g., Imperial fault, Chesler Canyon). Examination of the final EA indicates that these concerns have not been adequately addressed for the reasons discussed below.

With respect to the NRC concern that the site is in a region of active tectonism (item 1), the final EA presents a discussion of seismicity in an area along the Colorado lineament and in the vicinity of Shay Graben in Section 3.2.5.2 and in Section 6.3.1.7.1. The final EA states that "Concentrated microearthquake activity extending approximately 50km along the (Colorado) river southwest from Moab appears to reflect reactivation of a fault or faults within the lineament" (page 3-62). The final EA acknowledges that "microearthquakes have been observed in the vicinity of the Shay Graben faults," but qualifies this by stating that "the uncertainty of their locations precludes correlating these events definitely with the Shay Graben faults" (page 3-63). The final EA does not discuss the possibility that the Sweet Alice graben and the Dark Canyon fault are part of a southwestern extension of the Shay/Bridger Jack/Salt Creek graben system and that, if so, a more significant, active seismotectonic zone may be present in the site area. This could lead to a higher value for the maximum credible earthquake for this zone than is given in the final EA.

An additional concern emerges from new data presented in Figure 3-30 of the final EA which indicate a swarm of microearthquakes to the southwest of the site in the vicinity of the Imperial Fault zone that are not discussed in the evaluation of tectonics. Such activity is a source of uncertainty not incorporated into the evaluation of active tectonism.

Finally, also in regard to item 1 of the NRC concerns, an apparent discrepancy was noted regarding the relationship of the main basin-bounding fault in the Lockhart basin and Quaternary alluvial deposits adjacent to it. On page 3-58 of the final EA, it is stated that alluvial deposits overlie the fault without displacement suggesting a lack of fault movement during Quaternary time. However, on page 3-71 it is stated that Quaternary alluvial deposits are ponded on the southeast side of the fault. This raises the possibility of fault movements during Quaternary sedimentation.

Item 2 of the NRC concerns on the draft EA involves the incomplete information presented in the draft EA regarding subsurface structures in the site vicinity. The final EA contains an expanded discussion of subsurface structures in the vicinity of Shay graben and the Lockhart basin in Section 3.2.5.1. The final EA also contains a new discussion on jointing (Section 3.2.5.7). The data presented are based largely on air photo analysis and, as the final EA states, "air photo analysis does not provide adequate information to evaluate the age of jointing, its sequence, or its vertical continuity" (page 3-79). Given these limitations, the NRC staff considers that reliance on air photo analysis as partial support for the observation that "there is no evidence at the surface or in well logs of two boreholes located at the crest of the (Gibson) dome that joints have acted as conduits for groundwater to reach the salt, causing dissolution" (page 3-73) does not reflect the uncertainty or the data base.

The third concern expressed by NRC involved the apparent lack of recognition of the Imperial fault zone and northwest-trending structures in the area of Chesler Canyon, and the lack of an evaluation of these features with respect to the tectonic regime. As suggested in the NRC comment 1 on the draft EA, the final EA addressed the following structural features: the Meander anticline (Section 3.2.5.5), the Needles fault zone (Section 3.2.5.1), the north-northwest-trending salt anticlines and smaller parallel structures including Gibson dome, Rustler dome, and the Indian Creek syncline (Section 3.2.5.5), the valley anticlines (Section 3.2.5.4), the northwest-trending faults that run parallel to or within the core of salt anticlines (Section 3.2.5.1) and the northeast-trending faults (Section 3.2.5.1). Regarding the Imperial Fault zone and Chesler Canyon, however, the NRC staff was not able to locate any discussion of these features in the final EA. The Imperial Fault zone may be of special significance because the swarm of microearthquakes recently observed southwest of the site, and referred to above, is located at the eastern extension of this zone, thus suggesting the possibility of recent fault movement in this zone.

Comment 2

<u>Dissolution - (Draft EA Major Comment 2)</u>

<u>Guideline on Dissolution 10CFR960.4-2-6 (a) and (b)</u>

In the NRC staff major comments on the draft EA for Davis Canyon, NRC raised the following concerns related to dissolution:

1) limited seismic reflection coverage coupled with discontinuous salt reflector data in the site vicinity;
2) possibility that faulting has disrupted the evaporite sequence bringing the water-bearing Mississippian strata in contact with the salt sequence;
3) aeromagnetic anomalies coincident with anomalous areas on orthophotos and Landsat imagery near fault R and near Lavender Canyon;
4) data not presented on joints and fractures which could provide

NRC STAFF COMMENTS

ON THE

DOE FINAL ENVIRONMENTAL ASSESSMENTS

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DIVISION OF WASTE MANAGEMENT

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pathways for fluid migration;

5) possibility that limestone units could contain cavities, fractures or collapse features that would allow groundwater to contact salt;
6) small, active dissolution features that may have gone unnoticed in examination of well logs;
7) Leadville Formation water chemistry at GD-1 indicating salt dissolution which may be local; and
8) use of non-site-specific rates of dissolution.

Examination of the final EA has led NRC staff to consider that there no longer exist major concerns regarding the treatment in the final EA of items 6 and 8, but the staff continues to have major concerns with the remaining items as discussed below.

NRC's first concern, limited seismic reflection coverage, is acknowledged in Section 3.2.5.1, page 3-56 and Section 6.3.1.6, pages 6-157 and 6-158 and discontinuous reflector data between surface faults and Mississippian strata is mentioned on page 6-157. On page 6-157 of the final EA for Davis Canyon, it is stated that the resolution of the gravity surveys made for the EA's is 3.2 km (2 mi), and that even major features such as Shay Graben cannot be resolved given the regional gravity survey station coverage. Therefore, the possibility of dissolution along a feature such as fault R cannot be conclusively determined by available gravity data. The limitations in both the seismic reflection and gravity data make determinations of the continuity of subsurface features difficult or impossible to achieve at this time. For this reason, the NRC staff considers the statement on page 6-159 of the final EA "Within the limitations of the data...there is no evidence of Quaternary or earlier dissolution within the site" (emphasis added) does not sufficiently reflect the possible significance of the discontinuous salt reflectors and the severe inadequacy of existing seismic reflection coverage.

The second NRC concern, contact between Mississippian strata and salt units, was discussed with respect to fault R in Section 6.3.1.6, page 6-157. The final EA concluded that because the combined thickness of the Molas and Pinkerton Trail formations is 110 meters and the interpreted maximum displacement along Fault R is 80 meters, there is no juxtaposition of the limestone units and the Paradox salts along Fault R. However, because of the proximity of Fault R to the site and because of uncertainties regarding the thicknesses of the Molas and Pinkerton Trail and the maximum amount of offset along Fault R, the NRC staff continues to be concerned that faulting may have resulted in exposure of salt units to unsaturated groundwater, resulting in dissolution. Furthermore, interpretations of geophysical data in Kitcho et al. (1984) by the State of Utah High Level Nuclear Waste Office (1986) suggest that the number of faults identified in the site area appears to be proportional to the seismic coverage, and that on the basis of their interpretation of seismic reflection and aeromagnetic surveys, at least two additional faults may be present at the site. If additional faults are present at the site, there is the possibility of groundwater movement along these zones that could lead to dissolution of the salt.

The third NRC concern is related to coincidence of aeromagnetic anomalies and orthophoto anomalies noted during the NRC geophysics data review with DOE on October 18, 1984. Other geophysical data are discussed on pages 6-156 and 6-157 where the final EA cites Kitcho et al., 1984 in stating that "in the vicinity of Davis Canyon, no gravity anomalies were observed that would indicate significant subsurface geologic structures." However, the final EA does not discuss the NRC concerns with aeromagnetic anomalies and the possibility that they may represent previously unrecognized subsurface structures. Furthermore, in the recent report from the State of Utah High Level Nuclear Waste Office (1986), it is stated that "aeromagnetic surveys indicated that faults are present in Davis Canyon." Therefore, the possible significance of the aeromagnetic anomalies with respect to both subsurface structures and dissolution continues to be a concern to the NRC.

The NRC's fourth comment regarding pathways for fluid migration along joints and fractures is addressed in Sections 3.2.5.7, page 3-73 and 3.3.2.1, pages 200, 202, and 204 of the final EA. It is stated on page 3-73 that "There is no evidence at the surface or in well logs of two boreholes located at the crest of the (Gibson) dome that joints have acted as conduits for groundwater to reach the salt, causing dissolution." While we agree that there is no conclusive evidence of large-scale deep dissolution in the Paradox in the Davis Canyon area, geochemical and hydrologic head data suggest the potential for deep dissolution within this area. Figure 3-57 (page 3-198) indicates that Leadville Formation waters are undersaturated and Figure 3-60 (page 3-203) indicates that head potentials in the Leadville Formation are significantly higher than those measured in the Paradox. Therefore, it is possible that water from the Leadville could move upward through any fracture systems in the Molas and Pinkerton Trail formations and come into contact with Paradox Formation salts. Such deep dissolution could be well advanced and result in significant disruption of the Paradox Formation before surface effects such as the Lockhart Basin would appear.

NRC's fifth comment regarding cavities in the limestone units is addressed in Section 3.2.5.7, pages 3-72 and 3-73. The final EA states that the probability of occurrence of cavities allowing connection between limestone and salt is low "since there is no known evidence for such an occurrence in the geologic setting" (page 3-73). However, the final EA acknowledges that geophysical data are very limited and dissolution features smaller than 31 meters of vertical dissolution over an area of 2.6 square km. probably would go undetected with present surface mapping techniques. The NRC staff considers that, given the limitations in the geophysical data and the fact that a karst cavity was encountered in the Leadville limestone in a petroleum exploration borehole, it is possible that additional cavities probably exist, some of which may allow hydrologic interconnection between the Leadville and the overlying Paradox Formation salts.

The NRC's seventh concern regarding high total dissolved solids (TDS) in the Leadville Formation in GD-1 is discussed in Section 6.3.1.6.1, page 6-158. The final EA indicates that the high TDS may not result from local dissolution by modern, meteoric waters but rather the source of the high TDS may be the dissolution in the Lockhart Basin. The NRC, however, considers that the limited data available on the source of the high TDS does not preclude the possibility of active, localized dissolution.

Comment 3

Groundwater Travel Time - (Draft EA Major Comment 3)

Guideline on Geohydrology 10 CFR Part 960.4-2-1(b)(1)

The NRC staff major comment on the draft EA for the Davis Canyon site stated a general concern that many of the assumptions and approaches used in the groundwater travel time analysis were not conservative and did not incorporate appropriate uncertainties. In support of the major comment, the NRC staff cited several detailed comments describing specific concerns with respect to the conceptual model, flow path, vertical and horizontal hydraulic gradients, and porosity as follows. Potentially faster flow paths, such as through interbeds and along structural discontinuities, may exist as compared with the single pathway used in the evaluation. The occurrence of fracture flow was recognized but not used to bound the travel time estimate. The lateral gradient provided in the draft EA for the Leadville Limestone was not conservative based on available potentiometric head data. The presence of a downward gradient in the host rock and immediately surrounding units was not adequately demonstrated by the available data. Porosity data used in the evaluation were not conservative with respect to the available data. Conceptual and numerical models used to support the travel time estimates contained uncertainties that were not carried through to bound the travel time estimate. The travel time calculation did not consider that the size of the disturbed zone and size of the controlled area determine distance to the accessible environment. In addition, flow rates calculated for the Leadville Limestone as used in the travel time calculation contained an arithmetic error.

Examination of the Davis Canyon final EA indicates that the analysis for groundwater travel time has been revised significantly in attempting to incorporate uncertainties identified in the NRC staff major comment on the draft EA. A substantial degree of uncertainty and conservative assumptions are incorporated quantitatively into the new groundwater travel time calculations. Ranges of values for some hydrogeologic parameters are considered, as well as groundwater flow through permeable interbeds or along fracture zones. Environmental heads are used to calculate vertical hydraulic gradients and upward as well as downward hydraulic gradients across the host salt are also considered. In portraying uncertainty related to present knowledge of the Davis Canyon site groundwater flow system, the final EA presents simulated groundwater travel time distributions for both porous media and fracture flow (Section 6.4.2.3.5, pages 6-268 and 6-273), developed through a combined deterministic and stochastic approach. Each simulation uses a hypothesized hydrogeologic framework (deterministic model) to generate 1,000 realizations (runs) of groundwater travel times. For each run, certain system parameter values are chosen randomly from parameter distributions of test data or from assumed parameter ranges where no test data are available. The groundwater travel time distribution for porous media flow has a median value of 240,000 years and shows a 95.5 and 99.7 percent probability of travel times equaling or exceeding 10,000 and 1,000 year respectively. The fracture flow distribution has a median value of 120,000 years and shows a 78.6 and 92.6 percent probability of travel times equaling or exceeding 10,000 and 1,000 years.

In spite of the conclusions above, the NRC staff has significant concerns with the new analysis and how the analysis results are used in arriving at the conclusions for groundwater travel time. Because of limitations in the approach toward modeling groundwater travel times in the final EA, the frequency distributions for predicted groundwater travel times incorporate only some of the estimated uncertainties in those parameters input to the model as random variables. Uncertainties in those parameters treated as constants, uncertainty about the nature of the parameter distributions, uncertainty about the conceptual model, uncertainty about the boundary conditions and uncertainty about some of the assumptions used in the mathematical flow model are not accommodated in the uncertainty analysis. Given below is a brief description of specific problems with the new groundwater travel time methods of analysis and the use of the analysis results.

1. The fundamental limitation of the numerical model (PTRACK model (Andrews, et al., 1985 and Thompson, et al., 1985)) is that mass is not conserved when approximating conceptual hydrogeologic flow models. Models of steady state flow systems such as PTRACK should include a balance between inflow and outflow, or between sources of recharge and discharge to guarantee that in a given realization the mass balance condition is satisfied. Furthermore, in PTRACK hydrogeologic boundaries are not based on physical properties of the real system but are located at a prescribed distance from the edge of the repository to the accessible environment. Therefore, some combinations of hydrogeologic parameters are not realistic. Whether any groundwater travel time prediction from a realization in PTRACK happens to fall within the range of possible travel paths expected in a physically-based conceptual model cannot be determined, and effects associated with real or perceived boundary conditions cannot be simulated.

PTRACK is designed to evaluate the impact of parameter uncertainties rather than conceptual model uncertainties. However, it is not clear how parameter uncertainties can be separated from conceptual model uncertainties and it has not be demonstrated that the impact of data uncertainties can be evaluated without using a physically-based conceptual hydrogeologic flow model.

2. Uncertainty about the nature of most of the variable parameter input distributions are not accommodated in the uncertainty analysis. Because of insufficient data, parameter statistical moments and probability distributions for many of the hydrogeologic parameters are assumed based on expert judgment or engineering estimates of measurement accuracy. For example, the method of

analysis (PTRACK) requires mean values of pressure head and variance. However, the mean pressure head values are based on single measurements from one well (GD-1) rather than a statistic compiled from many measurements in more than one well. Likewise, the variance, which is based on estimates of measurement accuracy of a single measurement, has no statistical meaning. Studies on the sensitivity of the analysis to estimate parameter statistical properties (characteristics of the distribution) were not performed.

3. Uncertainty in the way anisotropy and fracture porosity are treated as constants is not accommodated in the analysis. Permeability in non-salt layers is assumed to be anisotropic with the anisotropy ratio fixed at 10 in all cases. Although this appears to be a reasonable value, and possibly conservative in most cases, it is more reasonable to allow the anisotropy ratio to be characterized with uncertainty. In vertical fracture zones it is possible that anisotropy may even be less than one. No justification is given for assuming that fractures can be modeled simply by decreasing matrix porosity 100 fold. This is important because fracture zones in brittle rocks, such as dolomites, may have porosities exceeding matrix porosity. To account for the effect of fractures on groundwater travel time, it may be more appropriate to adjust permeability.

4. The groundwater travel time analysis does not accommodate uncertainty related to the significant difference in scale between the hydrostratigraphic units (layers) represented in the model and the data, which are primarily from single-hole field tests or laboratory tests on small samples. In the analysis, the hydraulic response over the test zone of influence of a single well or sample is integrated over the much larger space of the model to represent the bulk response of an entire unit. This is particularly significant to analyzing groundwater flow in fractured rock when, as in PTRACK, it is modeled as equivalent porous media.

5. The groundwater travel time analysis presented in the final EA may be inconsistent with those portions of NRC regulations and DOE guidelines requiring travel times to be evaluated explicitly in terms of the "fastest path of likely radionuclide travel" (10 CFR Part 60.113(a)(2) and 60.112(b)(7)), and "any path of likely significant radionuclide travel" (10 CFR Part 960.4-2-1(d)) and "any path of likely radionuclide travel" (960.4-2-1(b)(1)). The regulations and guidelines suggest that uncertainty in groundwater travel time should be evaluated in terms of individual paths of likely groundwater flow. However, because of the uncertainty in the hydrologic properties in the vicinity of the site, the expected flow path as well as groundwater travel times to the accessible environment are presently uncertain. Due to this current level of uncertainty, PTRACK was developed to calculate travel times from the edge of the disturbed zone to the accessible environment along all possible particle trajectories within the constraints of the model (final EA, Section 6.5.2.3.5, page 6-261, paragraph 1). Although more particles enter the accessible environment through either salt cycle 5 or salt cycle 6 interbeds than through any other layer in the system, defining the likely flow path is not possible because in PTRACK all particle trajectories have an equal

probability of occurrence (1 in 1000) (Andrews, et al., 1985). Andrews and others (1985) recognize the difference between PTRACK and the regulations and guidelines when they state that, while PTRACK may not be equivalent in a strict sense, it does provide the statistical distributions required to quantify the work "likely." The NRC staff disagrees, in that a distribution of "likely" groundwater travel times for 1000 equally probable particle trajectories may be significantly different than the distribution of groundwater travel times along an individual likely pathway. However, because of uncertainty in current data, the staff considers use of the PTRACK analysis to be technically supportable at this time, although its future use, when site data exists, would be significantly inconsistent with NRC regulations and DOE guidelines as noted above.

6. The NRC staff is concerned with how the analysis results are used to make conclusions on groundwater travel time. The entire porous media and fracture flow travel time distributions are not used in the evaluations. Instead, only mean and median values (central values) are used. Some portion of the distributions based on a percentile criteria smaller than the mean or median would more properly reflect current uncertainty. In evaluating groundwater travel time, the distribution for fracture flow is not considered. This is not a conservative assumption given current data on fractures.

In addition, the final EA states (Section 6.3.1.1.2, page 6-100, paragraph 3) that "the extreme upper and lower portions of the travel time distribution are characteristic of travel times along unlikely paths of radionuclide travel, and therefore, inappropriate for evaluating this favorable condition (10,000 year groundwater travel time). The DOE considers this judgment to be consistent with the NRC staff position regarding the groundwater travel time requirement in 10 CFR Part 60 (Browning, 1985)."

For the eventual application of its regulation, the NRC is considering excluding the extremes of the distribution of possible groundwater travel times for the fastest path of radionuclide travel in determining whether the performance objective has been met. However, excluding the tails (extremes) of a distribution is not equivalent to choosing the mean or median as the measure of groundwater travel time. This is particularly so for initial screening prior to site characterization, where attempting to reach conclusions about "likely" and "unlikely" flow paths is speculation at best. Indeed, prematurely and arbitrarily eliminating the tails of the groundwater travel time distribution at this time virtually ignores the uncertainty that the current analyses were intended to incorporate. The meaning of the NRC statement referring to excluding extremes is simply that the NRC might consider the performance objective to be met even if some small portion of the distribution was less than the time criterion (e.g., 1000 years), assuming the conceputal model and other determining factors behind the distribution itself are defensible.

Finally, it should be noted that since all particle trajectories are equally probable in the PTRACK model, extremely long or short travel times are the result of the probabilistic combination hydrogeologic parameters and are not related to the unlikeliness of individual radionuclide pathways.

Comment 4

Decomposition of Carnallite

Guideline on Geochemistry 10 CFR 960.4-2-2 (c) Potentially Adverse Condition (2)

In the NRC major comment 5 of the draft EA for Davis Canyon, the concern was raised that the amount of carnallite near the waste packages and the potential thermal alteration of the hydrated phases were not considered in determining rock strength and water content of the host rock. No new information or revised assumptions regarding the amount of hydrated phases or the water content present in the host rock is included in the final EA. Thus, the NRC considers that its original comment concerning the amount of carnallite is appropriate to the final EA. While discussions have been added to the final EA regarding the carnallite dehydration process, the possible effects of the process on rock strength have not been evaluated. The following paragraph further explains the NRC concerns.

The final EA cites the study of Conner (1983) in describing the thermal stability of carnallite. In that study carnallite was subjected to differential thermal analysis (DTA). It was found that carnallite ($KMgCl_3 \cdot 6H_2O$) begins to dehydrate between 85 and 90°C and loses four of its six molecules of water. The last two molecules of water, which may be more tightly bound in the crystalline structure, are lost starting at 150°C with complete dehydration at 185°C. For every mole of carnallite that decomposes, 6 moles of H_2O, one mole of KCl, and one mole of $MgCl_2$ are produced. The resulting solid products are KCl and $MgCl_2$, two phases with relatively high melting points. Although this study accurately describes the decomposition of carnallite when water does not remain in the carnallite bed, it does not adequately describe the situation when the water of carnallite decomposition remains in place. The statement is made in the final EA that water from carnallite decomposition is not expected to move from the carnallite beds (Section 3.2.6.1, page 3-95 and Section 3.2.7.1, page 3-101). The final EA does not consider that some quantity of the anhydrous components produced in the dehydration reaction will be dissolved in the water of dehydration at temperatures below the melting point of carnallite. Thus, the relative proportions of liquid to solid produced in this dehydration reaction are underestimated in the final EA. The minimum liquid/solid volume ratio is 0.58 assuming none of the anhydrous solids produced in the dehydration reaction dissolves in the H_2O. Depending on the distribution of carnallite in the host rock relative to the waste packages, rock strength could be reduced. Thin laminae containing a large percentage of carnallite in the vicinity of the waste packages could result in planes of weakness. The final EA has not recognized or evaluated this effect and has concluded that rock strength will not be affected.

Comment 5

Redox Conditions - (Draft EA Major Comment 6)

Guidelines on Geochemistry 10 CFR 960.4-2-2(b)(2),(c)(3)

In the NRC staff major comment 6 of the draft EA for the Davis Canyon site, concerns were raised that the limitations in current evidence regarding processes that affect radionuclide migration, such as precipitation, sorption, radiocolloid formation, and organo-radionuclide complexation, were not factored into estimates of the above parameters which may lead to underestimations of radionuclide mobility. Examination of the final EA indicates that discussions of sorption, radiocolloid formation, and organo-radionuclide complexation have been adequately revised to include discussions of uncertainties in the data (Section 6.3.1.2.2, pages 6-125, items 3 through 6); however, concerns with redox conditions have not been factored into discussions and evaluations presented in the final EA regarding the mobility of redox-sensitive radionuclides (Section 6.3.1.2.2, pages 6-124 to 6-125, items 1 and 2; Section 6.3.1.2.3, page 6-133, last paragraph).

The NRC staff is concerned that evidence presented in the final EA does not support the conclusion that the groundwater is chemically reducing. The final EA states that the presence of reducing mineral assemblages, dissolved gases, and organics is qualitative evidence of chemically reducing conditions in both the Paradox Formation and in deeper groundwaters (Section 6.3.1.2.2, pages 6-124 to 6-125, items 1 and 2; Section 6.3.1.2.3, page 6-133, last paragraph). In addition, Eh values measured in deep basin brines are reported to be less than -80 mV (Section 6.3.1.2.3, page 6-134, continuing paragraph). The NRC staff is concerned that the presence of reducing mineral assemblages, dissolved gases, and organics, although indirect evidence of reducing conditions, is not conclusive because these components can exist metastably under oxidizing conditions. This possibility is not discussed in the final EA. Also, there is great difficulty in obtaining reliable Eh measurements, and these measurements may not represent actual conditions (e.g., see Lindberg and Runnells, 1984). Due to the uncertainties of the evidence presented, the existence of reducing or oxidizing conditions cannot be stated unequivocally in the absence of analyses which establish a consistency between various types of quantitative data.

Even assuming that reducing conditions are present, no evidence is presented in the final EA to show that redox-sensitive radionuclides released from the waste form will be reduced. If redox-sensitive actinide elements are dissolved from the waste form in the oxidized state, kinetic effects may prevent the establishment of redox equilibria and inhibit the transformation of oxidized actinide species to reduced species, which tend to be less mobile. This is of major concern regarding long-term release to the accessible environment because redox-sensitive radionuclides such as plutonium, uranium, neptunium and technetium have long half-lives. No evidence is presented to suggest how kinetic constraints will be overcome. Furthermore, contradictory statements regarding redox conditions are made. It is stated in the final EA that the oxidized species $UO_2(CO_3)_3^{4-}$ "can be thermodynamically stable under reducing conditions" (Section 6.3.1.2.2, page 6-125, item 5); elsewhere, however, it is stated that reducing conditions expected in the host salt and deep basin aquifers "will promote the precipitation of many redox sensitive radionuclides" (Section 6.3.1.2.2, page 6-124, paragraph 3) and "redox-sensitive radionuclides are expected to be stable in their lower oxidation states" (Section 6.3.1.2.2, page 6-125, paragraph 1). The NRC staff considers that the conclusion that redox-sensitive radionuclides will be in reduced states is premature because the field data on redox conditions are limited and highly uncertain and there is a lack of experimental studies investigating redox equilibria under chemical conditions expected in a repository.

Precipitation of radionuclides in the host salt and in the deep basin aquifers is an important process affecting radionuclide migration (Section 6.3.1.2.2, pages 6-124, paragraph 3, to 6-125, paragraph 1). Effective precipitation of redox-sensitive radionuclides is dependent on their being in a reduced state. The NRC staff believes that factoring uncertainties regarding redox conditions into the analysis can also support an alternative assumption that redox-sensitive radionuclides might remain in the more mobile oxidized state during the isolation time period.

Comment 6

Effects of Host Rock Mass Heterogeneity - (Draft EA Major Comment 7)

Guidelines on Rock Characteristics 10 CFR 960.4-2-3(b)(1), (b)(2), (c)(1), (c)(3), and 960.5-2-9(b)(1), (c)(2)

The Davis Canyon draft EA major comment 7 raised concerns that the existence of heterogeneities within the repository site and their possible effects on waste isolation were not adequately considered in the evaluations of rock characteristics related to the availability of a suitable host rock and the level of complexity of technology needed for the construction, operation and closure of the repository. Although the final EA recognizes that heterogeneities may exist within the Davis Canyon site (Section 3.2.6), the NRC staff continues to question whether the possible thermal and mechanical effects of heterogeneities have been conservatively factored into the evaluation of repository construction, operation, and maintenance.

The final EA states that "Paradox Salt is relatively pure" (Section 3.2.6.1, page 3-79) and "... the salt fabric in the repository host rock is expected to be relatively competent and homogeneous over the total area to be mined" (Section 6.3.1.3.2, page 6-137). Estimated values of physical, thermal, and geomechanical properties of the host rock reported in Tables 3-5 and 3-6 are determined from limited laboratory testing of core samples taken from the GD-1 borehole located approximately 5 miles from the site (Section 6.3.1.3.1, page 6-135). The evaluations presented in the final EA consider these estimates representative of the in-situ host rock mass. However, the effects of host rock heterogeneities on rock mass properties are unknown. Therefore, the representativeness of these estimates of in-situ rock mass properties is uncertain.

With respect to conclusions based on the thermal and ductility properties of the host rock, the uncertainties due to a lack of data associated with the effects of heterogeneities and impurities on fracture healing, and the response of carnallite/anhydrite to high temperatures were not considered in the analysis. Since uncertainties in the accuracy of the data have not been considered, the evaluation may not be conservative. Furthermore, the evaluations in the final EA do not reflect consideration of the effects of heterogeneities on strength, creep behavior, thermal conductivity, dehydration, and porosity of the host rock mass. These effects may limit design flexibility, roof and opening stability, and the requirements for rock support and reinforcement. Mining experience (such as at the Waste Isolation Pilot Plant (WIPP)) indicates that the effects of unforeseen heterogeneities should not be discounted since the engineering behavior of a salt rock mass can be dominated by heterogeneities, particularly when under the influence of waste-induced thermomechanical loadings. The NRC staff considers that substantial uncertainties remain that were not factored into the final EA evaluations of 1) rock mass physical, thermal, and engineering properties, 2) opening stability, 3) the extent of the disturbed zone, 4) rock support requirements, and 5) flexibility in locating the underground facility.

The evaluation which deals with the requirement for engineering measures that are beyond reasonably available technology for the construction of the shafts and underground facilities, does not reflect the requirement for special engineering measures that may result from rock mass heterogeneities when constructing adjacent to areas of emplaced waste. Opening stability may be adversely affected and may require complex rock support systems and reinforcement. The presence of heterogeneities may increase the extent of the disturbed zone beyond the 15 meters which has been estimated in Appendix 6A of the final EA (page 6A-7).

The evaluation which deals with rock conditions requiring engineering measures beyond reasonably available technology for construction, operation, and closure if such measures are necessary for waste containment and isolation does not include an analysis of (a) the engineering behavior of heterogeneous salt under anticipated repository environmental conditions, (b) the relationship of the cited excavation technology applied to ambient conditions to the excavation technology that will be required for the expected repository host rock thermomechanical behavior conditions, and (c) requirements for a retrieval system.

The evaluation of the existence of geologic structure, material properties, and hydrologic conditions such that heat generated by emplacement waste could reduce isolation does not show that the effects of heterogeneities on the thermal and mechanical properties of the host rock and on porosity increases, or on ground movements due to emplaced waste heat would necessarily be localized or negligible. The effects of these heterogeneities on characterizing evaporite response to thermal loading, the reaction of overlying stratigraphic units to waste heat, and the potential translation of stresses and strains to repository excavations outside the expected thermal pulse have not been addressed.

Finally, the evaluations which address host rock thickness and lateral extent to allow sufficient flexibility in selecting depth, configuration, and location of the underground facility do not reflect consideration of the effects of heterogeneities that may limit the available lateral extent of host rock needed for locating the underground facility. The lateral extent may be particularly limited due to both the potentially adverse stresses created by the mesas in the area if the two phase repository design is used, and to the proximity of the repository to Canyonlands National Park. Since the existence of heterogeneous features can affect creep and associated maintenance excavation requirements, it may be necessary to increase the size of the repository by reducing the design areal thermal loading. By doing so, the impact of heterogeneities on maintenance excavation requirements in a heated environment would be reduced. It may also be necessary to adjust the emplacement design due to the presence of heterogeneities into a larger repository area. Therefore, the NRC staff considers that the potential effects of heterogeneities in limiting the lateral flexibility of the repository location have not been considered.

Comment 7

<u>Shaft Sealing - (Draft EA Major Comment 9)</u>

<u>Guidelines on Rock Characteristics 10 CFR 960.4-2-3(c)(1), (c)(3), and 10 CFR 960.5-2-9(c)(2)</u>

The draft EA major comment 9 for Davis Canyon raised concerns that uncertainties and available evidence associated with constructing, sealing, and decommissioning shaft systems to assure containment and isolation of the waste were not adequately addressed. Review of the final EA indicates that, although the discussions on shaft construction were expanded (Section 4.1.2, pages 4-23 to 4-43), the information presented did not identify specific uncertainties described below related to the effectiveness of existing ground freezing and sealing technology and factor them into performance assessment of shaft seals.

The evaluation of in-situ characteristics and conditions which would require engineering measures beyond reasonably available technology in the construction of shafts does not address many of the sources of uncertainties associated with constructing shafts using reasonably available technology. The shaft construction concept presented in the final EA incorporates ground freezing technology to control rock movements and water flow. In the final EA (Section 6.3.3.2.3 (2), page 6-191), it is stated that "The freezing method, which if required at the Davis Canyon site, appears to have minimal impact on mechanical properties, although clay partings may deform when frozen." The discussion does not present an evaluation of the mechanisms which could cause permeability increases for the site soil and rock materials when subjected to freeze-thaw cycles. It is the opinion of the NRC staff that the heterogeneous physical nature of the ground to be frozen, the unavoidable deviations in freeze holes alignment, variations in the zone disturbed by shaft excavation, and liner placement all suggest that both freezing and thawing will be non-uniform. Non-uniform freezing and thawing would result in uncertain reliability of freezewall performance and variability in parameter values required for engineering. Increased permeability associated with shaft freezing and thawing could progressively reduce shaft integrity by introducing difficulties in achieving effective grouting and deleterious initial and long-term flow paths in penetrated strata. The final EA also proposes using grouting to control water flows in shafts (page 4-39, paragraph 3). It should be noted that in evaporite mines, it was reported that recurrent grouting to maintain seal performance is common and should be expected (ONWI-255, 1981, page 84). Furthermore, grouting processes are difficult to control, particularly in deviatoric in-situ stress fields where grouting can cause permeability to increase rather than decrease permeability (Houlsby, 1982, page 29). Therefore, based on the limited information available and the reasons given above, the NRC staff considers that over the pre-closure period there may be an increasing probability of progressive seal and liner deterioration that could lead to groundwater inflow and possibly shaft failure.

The evaluation of rock conditions that could require engineering measures beyond reasonably available technology for the closure of a repository if such measures are necessary to ensure waste isolation did not recognize or factor in the following sources of uncertainty. Changes to the shaft system, which can be expected to occur during the pre-closure period (i.e., seal deterioration, leakage damage, liner deterioration, etc.) due to the groundwater flow, might adversely affect the performance of the decommissioning seal system. Sealing materials, which are not yet designed or developed for long term compatibility with engineering and chemical properties of disturbed shaft wall rock and grout materials, may prove ineffective due to uncertainties in the effects of aging on shaft system components. The response of shaft seals/walls to potential dynamic earthquake motions and the likelihood for damage to seals during both pre- and post-closure periods is also at present not clearly understood. Furthermore, decommissioning sealing of the repository with crushed salt backfill and bulkheads may, in some shafts/drifts, not effectively prevent shaft water from reaching the waste storage area. This is because consolidation of the backfill due to creep of the salt rock may not be sufficient to reduce permeability to desired levels as this is dependent on both placing the backfill at the correct density, and predicting the creep/closure of the drift walls, roof, and floor. Therefore, limited flow through decommissioned passages may be possible.

The NRC staff also considers that Sections 5.1.1.3, 5.1.4.2.2, and 6.3.1.3.3 in the final EA do not adequately address sources of uncertainty such as potential thermally-induced ground movements that could result in deleterious strains in shaft linings and seals. Although surface uplifts predicted by thermoelastic analyses (Section 6.3.1.3.3, page 6-140) could be conservative, such analyses, when carried out for subsurface strata, may result in a non-conservative estimate of their thermomechanical response. For example, the potential for differential movement within the subsurface strata due to the effects of joint, fissures and discontinuities has not been evaluated. Such an analysis of the thermomechanical interaction of site stratigraphy, backfill, and shaft seal, including the nonlinear material behavior and properties of these system components, may well reveal deformation modes and differential movements which could affect shaft seal behavior. Furthermore, by omitting the effects of fractures, the analysis presented in Section 6.3.1.3.3, page 6-140 neither conservatively accounts for creation and dilation of fractures in shaft wall rock nor for distress of seals and linings. These omissions underestimate the potential for water migration through the shaft seal system. The NRC staff considers that an expected surface uplift above the shaft pillar centerline due to a 25 W/M^2 areal loading (as estimated in Wagner, et al., 1984, ONWI-512) may result in differential strains affecting post-closure shaft seal system performance. Differential displacement within the decommissioned shaft pillar region could result from small temperature changes due to the high coefficient of thermal expansion of salt.

Comment 8

Waste Package Performance Predictions - (Draft EA Comment 10)

Guidelines 10 CFR 960.4-2-2(b)(4), 960.4-2-2(c)(1) and 960.4-2-3(c)(1)

NRC staff concerns expressed in major comment 10 on the draft EA for the Davis Canyon site that the performance of the engineered barrier system was based on a number of inadequately supported assumptions and that the uncertainties associated with these assumptions have not been adequately addressed. The NRC staff recognizes that the response in the final EA indicates that some specific areas of uncertainty in the analysis such as temperature profiles, radiation effects, solubilities, brine quantities, corrosion modes and performance models that were discussed in the draft EA comment will be addressed during site characterization (Sections 6.4.2.3.3, page 6-247, third paragraph, and 6.4.2.7, page 6-287, last paragraph). However, examination of the final EA (Section 6.4.2, pages 6-213 to 6-287) indicates that the consequences of these assumptions and uncertainties on the analyses of waste package lifetime and radionuclide release rate have not been adequately addressed and, in large measure, the major comment on the draft EA continues to apply to the final EA.

The final EA recognizes that waste package design changes will be needed (Section 6.4.2.2.1, page 6-221) if the assumptions used in drawing conclusions regarding the post-closure guidelines (Sections 6.4.2.3.3, pages 6-235 to 6-250, and 6.4.2.3.4, pages 6-250 to 6-257) are not validated during site characterization activities (Appendix C, page C.5-47). However, the NRC staff continues to hold that the assumptions are not yet substantiated and the current range of uncertainties are not reflected in the conclusions. For example, the final EA continues to use the code BRINEMIG to model brine migration despite the fact that the code was developed using "assumptions... which do not realistically describe the movement of brine in salt" (Section C.5.11, page C.5-53). The model gave results for brine flow rates that were consistently less than observed results in in-situ heater experiments at the Waste Isolation Pilot Plant (WIPP) facility (Nowak, 1986). The use of BRINEMIG to conservatively predict brine migration rates is clearly questionable. In another example, the final EA continues to assume that brine entering a borehole will distribute itself uniformly over the overpack and that the overpack will corrode uniformly (Section 6.4.2.3.3, page 6-247). During the period the backfill remains as crushed salt, it is more likely that brine will collect at the bottom of each borehole and lead to corrosion over a limited portion of the overpack. As to the mode of corrosion, while uniform corrosion of overpack materials has been observed under some conditions (Kreiter, 1983; Westerman et al., 1983), the susceptibility of carbon steels to pitting corrosion, crevice corrosion, and stress-assisted cracking has been historically observed (Turnbull, 1983; Strutt et al., 1985; Ito et al., 1984; and Kruger, 1959) under other conditions. This observation raises significant questions regarding the long-term performance of the overpack. The final EA indicates that parametric studies have been performed (Section 6.4.2.3.3, page 6-247, paragraph 3) which use pitting ratios to account for the uncertainties in the uniform corrosion assumption. Neither the assumed pitting ratios nor the relationship between uniform and pitting or other localized corrosion process has yet been substantiated by data and analysis, but the final EA indicates (Section 6.4.2.3.3, page 6-247, paragraph 5) a high sensitivity of the computational results to non-uniform corrosion. Without adequate consideration of these alternative failure mechanisms, the NRC staff does not consider that the predicted 10,000 year container lifetime (which assumes uniform corrosion) reflects the current uncertainties.

Comment 9

<u>Potential Field Studies in Canyonlands National Park
(Draft EA Major Comment 12)</u>

<u>Guidelines on Environmental Quality 10 CFR 960.5-2-5(a), (c)(3), (d)(2) and (d)(3)</u>

Examination of the final EA (Section 4.1.1.1, Geologic and Hydrologic Studies) indicates that the NRC staff concerns expressed in draft EA major comment 12 about the program of field investigations proposed in Chapter 4 of the draft EA and its apparent incompleteness with respect to the hydrologic and geologic features and conditions in and in close proximity to Canyonlands National Park, at Davis Canyon proposed repository have not been addressed.

For example, the final EA for the Davis Canyon site (Section 4.2.1.1.3, page 4-88, paragraph 8) states "Site characterization activities such as borehole drilling and trenching will not occur within the boundaries of the Canyonlands National Park." The NRC staff again considers that the lack of geologic and hydrologic studies in and close to the National Park, as proposed in the final EA, may result in an incomplete site characterization program insufficient to produce needed data critical to the understanding of the hydrology and the geology of the Davis Canyon site.

Based upon the above, the NRC staff considers that the technical concerns and associated bases in its draft EA comment (major comment 12) is appropriate to the final EA and has included it as an attachment (Attachment 1).

Attachment 1

Comment 12

Potential Field Studies in Canyonlands National Park

Guidelines on Environmental Quality 10 CFR 960.5-2-5(a), (c)(3), (d)(2), and (d)(3).

The program of field investigations proposed in Chapter 4 of the draft EA does not address many of the geologic and hydrologic features and conditions in and in close proximity to Canyonlands National Park which might be important to repository performance. Also, consideration has not been given to the possibility that a larger control area might be needed than is presented in the draft EA (see major comment 11). The apparent incompleteness of the field program outlined would result in an under-estimation of the environmental impacts the field program will have on Canyonlands National Park.

Tectonic features, such as the Imperial fault zone, and salt dissolution features, such as the Grabens and Needles fault zones are present in the park. The relationship of such features to subsurface stratigraphy, dissolutioning and ground water flow is presently not well understood. The draft EA does not present a program that would resolve the NRC's concerns regarding tectonic features and dissolution (see major comments 1 and 2).

The Shay Graben appears to be part of a tectonic system that also includes the Bridger Jack and Salt Creek grabens (see detailed comment 3-10). This system is a potential active fault zone, a potential source of earthquakes, and a potential area of dissolution. It does not appear that a sufficiently detailed field program has been planned to fully evaluate this complex structural zone. The need for more borings, seismic lines and trenches has not been considered in the draft EA. This system lies within and in close proximity to Canyonlands National Park.

The DOE has identified several geophysical anomalies which do not appear to have been sufficiently analyzed (see major comments 1 and 2). Until these anomalies are understood with respect to structure and dissolution, it is impossible to predict the effect they will have on waste isolation. These features appear to overlap the eastern boundary of the park; therefore, investigations of these anomalies may have an effect on the park. The proposed field program in the draft EA does not include evaluations of these features.

The hydrologic testing scheme proposed for site characterization in chapter 4 does not describe any data collection between approximately 2 km and 22 km down gradient from the edge of the Geologic Repository Operations Area. The draft EA includes no technical justification for limiting intensive characterization to within 2 km of this area. The testing scheme may appear to be defensible on the basis of the hydrogeologic setting description presented in the draft EA which indicates that all radionuclide transport requirements can be met within an area of limited horizontal extent. However, the NRC concludes that this testing scheme may not be consistent with the present level of uncertainty regarding the possibility of certain hydrogeologic conditions such as localized upward gradients, flow thru interbeds and vertical structurally controlled flow (see detailed comment 4-2).

If a larger controlled area is needed (see major comment 11) which might overlay the park boundary, then evaluations are needed in the final EA to determine if additional site characterization activities are needed in this area.

The field program proposed in the draft EA does not appear sufficient in scope to resolve many of the potential technical concerns. The NRC, therefore, considers the above concern has not been adequately factored into the analysis in support of the Environmental Quality Guidelines 960.5-2-5(a), 960.5-2-5(c)(3), 960.5-2-5(d)(2) and 960.5-2-5(d)(3).

In revising the draft EA, the DOE should consider re-evaluating the field investigation program to determine if it will provide the information necessary to address the concerns raised above. The DOE should also consider revising those portions of the draft EA dealing with effects on Canyonlands National Park to reflect any revisions to the field program.

REFERENCES

Andrews, R.W., Kelley, V.A., McNeish, J.A., LaVenue, A.M., and Campbell, J.E., 1985. Travel Path/Time Uncertainties at Salt Sites Proposed for High Level Waste Repositories: Prepared by Intera Technologies, Inc. for Office of Nuclear Waste Isolation, ONWI/E512-02900/TR-36.

Browning, R.E., 1985. Letter to R. Stein (DOE), June 12, 1985, regarding NRC position on groundwater travel time.

Conner, Trent Gregory, 1983, "The Mineralogy and Water Content of Paradox Basin Evaporite Deposits," M.S. thesis, Georgia Institute of Technology, Atlanta, GA.

D'Appolonia Consulting Engineers, 1981. "Sealing Considerations for Repository Shafts in Bedded and Dome Salt," ONWI-255, Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH, p. 84.

Houlsby, A.C. "Cement Grouting for Dams," in ASCE "Proceedings of the Conference on Grouting in Geotechnical Engineering," 1982, New Orleans, LA, p. 29.

Ito, S., T. Murata and H. Okada, 1984. "A Statistical Approach to Corrosion of Marine Steel Structures," International Congress on Metallic Corrosion, Toronto, June 3-7.

Kreiter, M.R., 1983, "Waste Package Program," Section 3.1.1 in J.L. McElroy and J.A. Powell, compilers, Nuclear Waste Management Semiannual Progress Report, April 1983 through September 1983, PNL-4250-4, prepared for U.S. Department of Energy by Pacific Northwest Laboratory, Battelle Memorial Institute, Richland, WA, pp. 3.1-3.29.

Kruger, J., 1959. "Influence of Crystallographic Orientation on the Pitting of Iron in Distilled Water," Journal of the Electrochemical Society, Vol. 106, No. 8, p. 736.

Lindberg, R.D., and D.D. Runnells, 1984, "Ground Water Redox Reactions: An Analysis of Equilibrium State Applied to Eh Measurements and Geochemical Modeling," Science, v. 225, p. 925-927.

Nowak, E.J., 1986. Preliminary Results of Brine Migration Studies in the Waste Isolation Pilot Plant (WIPP), Sandia National Laboratories Report SAND86-0720, Albuquerque, NM.

State of Utah High Level Nuclear Waste Office, 1986, Davis Canyon Data Review and Comments.

Strutt, J.E., J.R. Nicholls and B. Barbier, 1985. "The Prediction of Corrosion by Statistical Analysis of Corrosion Profiles," Corrosion Science, Vol. 25, No. 5, pp. 305-315.

Thompson, B.M., Campbell, J.E., and Lognsine, D.E., 1985. PTRACK; A Particle Tracking Program for Evaluating Travel Path/Time Uncertainties: Prepared by Intera Technologies, Inc. for Office of Nuclear Waste Isolation, ONWI/E512-02900/CD-27.

Turnbull, A., 1983. "The Solution Composition and Electrode Potential in Pits, Crevices and Cracks," Corrosion Science, Vol. 23, No. 8, pp. 833-870.

U.S. Department of Energy, 1984. "Nuclear Waste Policy Act of 1982; General Guidelines for the Recommendation of Sites for the Nuclear Waste Repositories; Final Siting Guidelines," (10 CFR Part 960), Federal Register, Vol. 49, pp. 47714-47770, Washington, DC, December 6.

U.S. Department of Energy, 1984. Draft Environmental Assessment, Davis Canyon Site, Utah, Office of Civilian Radioactive Waste Management, Washington, DC.

U.S. Department of Energy, 1986. Final Environmental Assessment, Davis Canyon Site, Utah, Office of Civilian Radioactive Waste Management, Washington, DC.

U.S. Nuclear Regulatory Commission, 1985. NRC Staff Comments on the DEA for Davis Canyon Site, Utah, Office of Nuclear Material Safety and Safeguards, Washington, DC.

U.S. Nuclear Regulatory Commission, 1986. "Disposal of High-Level Radioactive Wastes in Geologic Repositories," 10 CFR Part 60, Subpart E, Technical Criteria. Code of Federal Regulations - Energy. Office of the Federal Register, Washington, DC.

U.S. Nuclear Regulatory Commission, 1986. "Draft Generic Technical Position on Groundwater Travel Time (GWTT)," Office of Nuclear Material Safety and Safeguards, Washington, DC, July 1986.

Wagner, R.A., M.C. Loken and H.Y. Tammemagi, 1984. "Preliminary Thermomechanical Analyses of a Conceptual Nuclear Waste Repository at Four Salt Sites," ONWI-512, Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH, 228 p.

Westerman, R.E., J.L. Nelson, S.G. Pitman, W.L. Kuhn, S.J. Basham and D.P. Novak, 1983. Evaluation of Iron Base Materials for Waste Package Containers in a Salt Repository, PNL-SA-11713, Paper D5.10, by Pacific Northwest Laboratory and Nuclear Waste Isolation, Battelle Memorial Institute, presented at Materials Research Society Annual Meeting, Boston, MA, November 14-17.

MAJOR COMMENTS

ON

DEAF SMITH SITE

Comment 1

Dissolution (Draft EA Major Comments 1 and 2)
Guidelines on Dissolution 10 CFR 960.4-2-6(a), (b), and
Geochemistry 10 CFR 960.4-2-2 (b)(1)

In the NRC staff major comments on the draft EA for Deaf Smith, the following concerns were raised with respect to dissolution:

1) uncertainty of projected rates of peripheral dissolution;
2) evidence of present and Pleistocene dissolution in the geologic setting;
3) effect of structural control on the dissolution process; and
4) possibility that thinning of host rock in vicinity of site may be related to deep interior dissolution.

Examination of the final EA indicates that the above four concerns have been addressed to varying degrees in the final EA as discussed below.

The analysis of the uncertainty of projected rates of peripheral dissolution (item 1) in the final EA appears to have responded to NRC concerns by reflecting the wide range of rates estimated from stream solute analyses along the northern and eastern dissolution fronts (Sections 3.2.3.3.1 and 6.3.1.6.1) and acknowledges that future pluvial conditions may increase dissolution at salt margins (Section 6.3.1.4). However, the analysis in the final EA (qualifying condition 10 CFR 960.4-2-6(a), pages 6-124 and 6-125) continues to treat the Permian salts as an isotropic, homogeneous medium in which dissolution rates are relatively uniform. This assumption does not consider the possibility that structural discontinuities such as through-going joints, fractures or faults may enhance dissolution along structural trends resulting in local dissolution front(s) closer to the site.

In response to item 2 of the NRC concerns, evidence of Pleistocene dissolution within the Southern High Plains is discussed in Sections 3.2.3.3.2 and 6.3.1.6.2 of the final EA. In Section 3.2.3.3.2, Interior Dissolution, the final EA states "the Southern High Plains lack most of the easily identified surface expressions of on-going or recent dissolution, such as collapse sinkholes, closed depressions, linear drainage elements and fractures (Gustavson et al., 1981; Gustavson and Finley, 1984)." Notably missing from this statement is any reference to the concern over playas raised in the NRC comment on the draft EA. There is no mention of playas which are present at the site as shown in Figure 4-2 or the possibility that they may be related to dissolution. However, in another section of the final EA (Section 3.2.3.3, page 3-48, paragraph 4) it is stated that some playas in the Palo Duro Basin may be related to dissolution. This omission results in an incomplete recognition and evaluation of features that might be evidence for Pleistocene dissolution at or near the site.

A second point to raise with respect to item 2, evidence of present or Pleistocene dissolution within the geologic setting, is that in the final EA (Section 6.3.1.6.2, page 6-125) it is stated that "no evidence has been found for Quaternary dissolution of the host rock at or near the site." Yet there is evidence of Pleistocene dissolution within the Southern High Plains. This evidence consists of lake basins containing Pleistocene sediments which occur "over areas of thin salt, structural lows on the Alibates Formation, and paleotopographic lows in the middle Tertiary erosional surface" which are interpreted to have formed as a result of dissolution during the Late Pliocene/Early Pleistocene (Gustavson and Finley, 1984, page 16). As noted in the NRC comments on the draft EA, deformation of the Pleistocene Tule Formation lacustrine sediments in northeast Swisher County, if caused by dissolution as Gustavson and Budnik (1984) suggest, provides the strongest evidence to-date for Pleistocene or younger dissolution in the Southern High Plains. None of this evidence was identified or evaluated in the final EA with respect to Quaternary dissolution near the site.

The final point to be made with respect to item 2 is that the discussion in the final EA of regional stratigraphy (Section 3.2.3.1) and site stratigraphy (Section 3.2.3.2) does not reflect new information which could affect the evaluation of Pleistocene dissolution. Table 3.3 of the final EA indicates that the Tertiary Ogallala Formation is present at the surface at the site. This is inconsistent with the representation of surface geology in Figure 3-18 which indicates that Quaternary loess and playa deposits are the surficial deposits at the site. Furthermore, according to Gustavson and Holliday (1985), the Quaternary Blackwater Draw Formation is present at the Deaf Smith site. This formation is known to be 10m thick at the type locality in northern Lubbock Co. and ranges in thickness to at least 25m locally. As stated in the NRC observations during the August 5-9, 1985 NRC/DOE Permian Core examination meeting (NRC and DOE, 1985), "The extent and characteristics of (the Blackwater Draw Formation) are important to the resolution of issues such as Quaternary dissolution and warping and ages of latest movements on faults."

The NRC staff concern regarding structural control on the dissolution process (item 3) was addressed in Section 3.2.3.3.2 of the final EA where it was stated that Gustavson and Budnik's (1985) "interpretation of (relatively open) northeast basement faults is possible because of the sparseness and limitations of the data." It appears that in the final EA this interpretation is rejected by presenting evidence to the contrary and by concluding that "the northeast trend may not be stratigraphically pervasive." This means that salt units would not be intersected by permeable features along which groundwater could flow and dissolve salt locally. However, there is no evidence in the discussion that this interpretation has considered the following items which lend support to the Gustavson and Budnik interpretation of the possibility of structurally controlled dissolution:

1) northeast-trending basement fault alongside the Arney Block in southeast Deaf Smith county (Budnik, 1984, Figure 12; Johns, 1985,

Figure 40) which is not apparent in Figure 3 of Regan and Murphy (1984);

2) thinning (approximately 30 meters) of Seven Rivers Formation salt and total loss of Salado salt (approximately 30 meters) above northeast-trending basement structural elements in southeast Deaf Smith County (Gustavson and Budnik, 1985);
3) northeast-trending system of paleotopographic lows and series of closed basins within the mid-Tertiary erosional surface in eastern Deaf Smith county (Gustavson and Budnik, 1984); and
4) northeast-trending lineaments (based on Landsat imagery) parallel to Frio Draw, Tierra Blanca Creek, and the western segment of Palo Duro Creek (Finley and Gustavson, 1981).

In the NRC staff comments on the draft EA, coincidence of structural discontinuities (e.g., joints, fractures, northwest-trending faults and lineaments) and northwest-trending differential thinning of the San Andres Unit-4 in northern Deaf Smith county was cited as possible evidence of deep interior dissolution (item 4). The discussion in the final EA cites data published subsequent to the draft EA comments which indicate that the thinning of the San Andres Unit-4 in northeast Deaf Smith county resulted not from structurally controlled dissolution but from the transgression which initiated the deposition of Unit 5 (Hovorka et al., 1985). While the NRC staff considers this as one plausible interpretation, the sparsity of the data within the site as compared with the conclusion stated above indicates uncertainty in knowledge of the dissolution process. As stated in the NRC staff comments on the draft EA, there is no direct evidence of dissolution of the San Andres Unit-4, yet as Gustavson and Budnik (1985, page 176) state "there is a persistent pattern of structural and geomorphic features that can be best explained by dissolution of Seven Rivers and Salado salts during the late Tertiary and perhaps as late as the Quaternary." Given the current limitations in data and understanding of the dissolution process, the NRC staff considers that neither of the above interpretations for the differential thinning of the San Andres Unit 4 in northern Deaf Smith County can be ruled out at this time.

(The NRC staff considers the concerns expressed in major comment 1 (Structural Discontinuities) of the review of the draft EA for Deaf Smith are closely related to structural control on dissolution. For this reason, these concerns have been factored into the above discussion.)

Comment 2

Groundwater Travel Time - (Draft EA Major Comment 3)

Guideline on Geohydrology 10 CFR Part 960.4-2-1(b)(1)

The NRC staff major comment on the draft EA for the Deaf Smith site stated a general concern that many of the assumptions and approaches used in the groundwater travel time analysis were not conservative and did not incorporate appropriate uncertainties. In support of the major comment, the NRC staff cited several detailed comments describing specific concerns with respect to flow path, vertical hydraulic gradient, permeability, and porosity as follows. The draft EA used mean values for hydrogeologic parameters (permeability and porosity) for estimating travel times. Mean values as used in the draft EA analysis did not reflect spatial variation or heterogeneity relative to the distribution of hydrogeologic data within hydrostratigraphic units. The draft EA considered a single conceptual groundwater flow model and did not factor into the analysis the possibility of flow through permeable interbeds, or flow through fractures or along structural discontinuities. The vertical hydraulic gradient across hydrostratigraphic unit B was underestimated because underlying Wolfcamp potentiometric head data were not converted to environmental heads.

Examination of the Deaf Smith final EA indicates that the analysis for groundwater travel time has been revised significantly in attempting to incorporate uncertainties identified in the NRC staff major comment on the draft EA. A substantial degree of uncertainty and conservative assumptions are incorporated quantitatively into the new groundwater travel time calculations. Ranges of values for some hydrogeologic parameters are considered, as well as groundwater flow through permeable interbeds or along fracture zones. Environmental heads also are used to calculate vertical hydraulic gradients. In portraying uncertainty related to present knowledge of the Deaf Smith site groundwater flow system, the final EA presents simulated groundwater travel time distributions for both porous media and fracture flow (Section 6.4.2.3.5, pages 6-252 and 6-236), developed through a combined deterministic and stochastic approach. Each simulation uses a hypothesized hydrogeologic framework (deterministic model) to generate 1,000 realizations (runs) of groundwater travel times. For each run, certain system parameter values are chosen randomly from parameter distributions of test data or from assumed parameter ranges where no test data are available. The groundwater travel time distribution for porous media flow has a median value of 87,000 years and shows a 89.3 and 99.5 percent probability of travel times equaling or exceeding 10,000 and 1,000 year respectively. The fracture flow distribution has a median value of 25,000 years and shows a 61.9 and 81.4 percent probability of travel times equaling or exceeding 10,000 and 1,000 years.

In spite of the conclusions above, the NRC staff has significant concerns with the new analysis and how the analysis results are used in arriving at the conclusions for groundwater travel time. Because of limitations in the approach toward modeling groundwater travel times in the final EA, the frequency distributions for predicted groundwater travel times incorporate only some of the estimated uncertainties in those parameters input to the model as random variables. Uncertainties in those parameters treated as constants, uncertainty about the nature of the parameter distributions, uncertainty about the conceptual model, uncertainty about the boundary conditions and uncertainty about some of the assumptions used in the mathematical flow model are not accommodated in the uncertainty analysis. Given below is a brief description of specific problems with the new groundwater travel time methods of analysis and the use of the analysis results.

1. The fundamental limitation of the numerical model (PTRACK model (Andrews, et al., 1985 and Thompson, et al., 1985)) is that mass is not conserved when approximating conceptual hydrogeologic flow models. Models of steady state flow systems such as PTRACK should include a balance between inflow and outflow, or between sources of recharge and discharge to guarantee that in a given realization the mass balance condition is satisfied. Furthermore, in PTRACK hydrogeologic boundaries are not based on physical properties of the real system but are located at a prescribed distance from the edge of the repository to the accessible environment. Therefore, some combinations of hydrogeologic parameters are not realistic. Whether any groundwater travel time prediction from a realization in PTRACK happens to fall within the range of possible travel paths expected in a physically-based conceptual model cannot be determined, and effects associated with real or perceived boundary conditions cannot be simulated.

PTRACK is designed to evaluate the impact of parameter uncertainties rather than conceptual model uncertainties. However, it is not clear how parameter uncertainties can be separated from conceptual model uncertainties and it has not be demonstrated that the impact of data uncertainties can be evaluated without using a physically-based conceptual hydrogeologic flow model.

2. Uncertainty about the nature of most of the variable parameter input distributions are not accommodated in the uncertainty analysis. Because of insufficient data, parameter statistical moments and probability distributions for many of the hydrogeologic parameters are assumed based on expert judgment or engineering estimates of measurement accuracy. For example, the method of analysis (PTRACK) requires mean values of pressure head and variance. However, the mean pressure head values are based on single measurements from one well (J. Friemel No. 1) rather than a statistic compiled from many measurements in more than one well. Likewise, the variance, which is based on estimates of measurement accuracy of a single measurement, has no statistical meaning. Studies on the sensitivity of the analysis to estimate parameter statistical properties (characteristics of the distribution) were not performed.

3. Uncertainty in the way anisotropy and fracture porosity are treated as constants is not accommodated in the analysis. Permeability in non-salt layers is assumed to be anisotropic with the anisotropy ratio fixed at 10 in all cases. Although this appears to be a reasonable value, and possibly conservative in most cases, it is more reasonable to allow the anisotropy ratio to be characterized with uncertainty. In vertical fracture zones it is possible that anisotropy may even be less than one. No justification is given for assuming that fractures can be modeled simply by decreasing matrix porosity 100 fold. This is important because fracture zones in brittle rocks, such as dolomites, may have porosities exceeding matrix porosity. To account for the effect of fractures on groundwater travel time, it may be more appropriate to adjust permeability.

4. The groundwater travel time analysis does not accommodate uncertainty related to the significant difference in scale between the hydrostratigraphic

units (layers) represented in the model and the data, which are primarily from single-hole field tests or laboratory tests on small samples. In the analysis, the hydraulic response over the test zone of influence of a single well or sample is integrated over the much larger space of the model to represent the bulk response of an entire unit. This is particularly significant to analyzing groundwater flow in fractured rock when, as in PTRACK, it is modeled as equivalent porous media.

5. The groundwater travel time analysis presented in the final EA may be inconsistent with those portions of NRC regulations and DOE guidelines requiring travel times to be evaluated explicitly in terms of the "fastest path of likely radionuclide travel" (10 CFR Part 60.113(a)(2) and 60.112(b)(7)), and "any path of likely significant radionuclide travel" (10 CFR Part 960.4-2-1(d) and "any path of likely radionuclide travel" (960.4-2-1(b)(1)). The regulations and guidelines suggest that uncertainty in groundwater travel time should be evaluated in terms of individual paths of likely groundwater flow. However, because of the uncertainty in the hydrologic properties in the vicinity of the site, the expected flow path as well as groundwater travel times to the accessible environment are presently uncertain. Due to this current level of uncertainty, PTRACK was developed to calculate travel times from the edge of the disturbed zone to the accessible environment along all possible particle trajectories within the constraints of the model (final EA, Section 6.5.2.3.5, page 6-247, paragraph 3). Although more particles enter the accessible environment through the LSA Unit 4 interbed than through any other layer in the system, defining the likely flow path is not possible because in PTRACK all particle trajectories have an equal probability of occurrence (1 in 1000) (Andrews, et al., 1985). Andrews and others (1985) recognize the difference between PTRACK and the regulations and guidelines when they state that, while PTRACK may not be equivalent in a strict sense, it does provide the statistical distributions required to quantify the word "likely." The NRC staff disagrees, in that a distribution of "likely" groundwater travel times for 1000 equally probable particle trajectories may be significantly different than the distribution of groundwater travel times along an individual likely pathway. However, because of uncertainty in current data, the staff considers use of the PTRACK analysis to be technically supportable at this time, although its future use, when site data exists, would be significantly inconsistent with NRC regulations and DOE guidelines as noted above.

6. The NRC staff is concerned with how the analysis results are used to make conclusions on groundwater travel time. The entire porous media and fracture flow travel time distributions are not used in the evaluations. Instead, only mean and median va ues (central values) are used. Some portion of the distributions based on a percentile criteria smaller than the mean or median would more properly reflect current uncertainty. In evaluating groundwater travel time, the distribution for fracture flow is not considered. This is not a conservative assumption given current data on fractures.

In addition, the final EA states (Section 6.3.1.1.2, page 6-93, paragraph 3) that "the extreme upper and lower portions of the travel time distribution are characteristic of travel times along unlikely paths of radionuclide travel, and therefore, inappropriate for evaluating this favorable condition (10,000 year groundwater travel time). The DOE considers this judgment to be consistent with the NRC staff position regarding the groundwater travel time requirement in 10 CFR Part 60 (Browning, 1985)."

For the eventual application of its regulation, the NRC is considering excluding the extremes of the distribution of possible groundwater travel times for the fastest path of likely radionuclide travel in determining whether the performance objective has been met. However, excluding the tails (extremes) of a distribution is not equivalent to choosing the mean or median as the measure of groundwater travel time. This is particularly so for initial screening prior to site characterization, where attempting to reach conclusions about "likely" and "unlikely" flow paths is speculation at best. Indeed, prematurely and arbitrarily eliminating the tails of the groundwater travel time distribution at this time virtually ignores the uncertainty that the current analyses were intended to incorporate. The meaning of the NRC statement referring to excluding extremes is simply that the NRC might consider the performance objective to be met even if some small portion of the distribution was less than the time criterion (e.g., 1000 years), assuming the conceptual model and other determining factors behind the distribution itself are defensible.

Finally, it should be noted that since all particle trajectories are equally probable in the PTRACK model, extremely long or short travel times are the result of the probabilistic combination of hydrogeologic parameters and are not related to the unlikeliness of individual radionuclide pathways.

Comment 3

Redox Conditions - (Draft EA Major Comment 5)

Guidelines on Geochemistry 10 CFR 960.4-2-2(b)(2),(c)(3)

In the NRC staff major comment 5 of the draft EA for Deaf Smith Site, concerns were raised that the limitations in current evidence regarding processes that affect radionuclide migration, such as precipitation, sorption, radiocolloid formation, and organo-radionuclide complexation, were not factored into estimates of the above parameters which may lead to underestimations of radionuclide mobility. Examination of the final EA indicates that discussions of sorption, radiocolloid formation, and organo-radionuclide complexation have been adequately revised to include discussions of uncertainties in the data (Section 6.3.1.2.2, pages 6-100 to 6-102, items 3 through 6); however, concerns with redox conditions have not been factored into discussions and evaluations presented in the final EA regarding the mobility of redox-sensitive radionuclides (Section 6.3.1.2.2, pages 6-100 to 6-101, items 1 and 2; Section 6.3.1.2.3, page 6-105, paragraph 4).

The NRC staff is concerned that evidence presented in the final EA does not support the conclusion that the groundwater is chemically reducing. The final EA states that the presence of reducing mineral assemblages, dissolved gases, and organics is qualitative evidence of chemically reducing conditions in both the San Andres Unit and in deeper groundwaters (Section 6.3.1.2.2, pages 6-100 to 6-101, items 1 and 2; Section 6.3.1.2.3, page 6-105, paragraph 4). The NRC staff is concerned that the presence of reducing mineral assemblages, dissolved gases, and organics, although indirect evidence of reducing conditions, is not conclusive because these components can exist metastably under oxidizing conditions. This possibility is not discussed in the final EA. Due to the uncertainties of the evidence presented, the existence of reducing or oxidizing conditions cannot be stated unequivocally in the absence of analyses which establish a consistency between various types of quantitative data.

Even assuming that reducing conditions are present, no evidence is presented in the final EA to show that redox-sensitive radionuclides released from the waste form will be reduced. If redox-sensitive actinide elements are dissolved from the waste form in the oxidized state, kinetic effects may prevent the establishment of redox equilibria and inhibit the transformation of oxidized actinide species to reduced species, which tend to be less mobile. This is of major concern regarding long-term release to the accessible environment because redox-sensitive radionuclides such as plutonium, uranium, neptunium, and technetium have long half-lives. No evidence is presented to suggest how kinetic constraints will be overcome. Furthermore, contradictory statements regarding redox conditions are made. It is stated in the final EA that the oxidized species $UO_2(CO_3)_3^{4-}$ "can be thermodynamically stable under reducing conditions" (Section 6.3.1.2.2, page 6-101, item 5); elsewhere, however, it is stated that reducing conditions expected in the host salt and deep basin aquifers "will promote the precipitation of many redox sensitive radionuclides" (Section 6.3.1.2.2, page 6-100, item 1) and "redox-sensitive radionuclides are expected to be present in their lower oxidation states" (Section 6.3.1.2.2, page 6-101, item 2). The NRC staff considers that the conclusion that redox-sensitive radionuclides will be in reduced states is premature because the field data on redox conditions are limited and highly uncertain and there is a lack of experimental studies investigating redox equilibria under chemical conditions expected in a repository.

Precipitation of radionuclides in the host salt and in the deep basin aquifers is an important process affecting radionuclide migration (Section 6.3.1.2.2, pages 6-100 to 6-101, items 1 and 2). Effective precipitation of redox-sensitive radionuclides is dependent on their being in a reduced state. The NRC staff believes that factoring uncertainties regarding redox conditions into the analysis can also support an alternative assumption that redox-sensitive radionuclides mignt remain in the more mobile oxidized state during the isolation time period.

Comment 4

Effects of Host Rock Mass Heterogeneity - (Draft EA Major Comment 6)

Guidelines on Rock Characteristics 10 CFR 960.4-2-3(b)(1), (b)(2), (c)(1), (c)(3) and 10 CFR 960.5-2-9(b)(1), (c)(2)

In the Deaf Smith draft EA major comment 6, concerns were raised that the existence of heterogeneities within the site and their possible effects were not adequately considered in the evaluation of rock characteristics related to availability of suitable host rock and the level of complexity of technology needed for construction, operation, and closure of the repository. Review of the final EA indicates that the likelihood of heterogeneities within the host rock (Unit 4 of the lower San Andres formation) occurring as discrete mudstone or anhydrite interbeds or as irregular masses of chaotic mudstone/salt mixtures or anhydrite within the halite has been acknowledged (Section 3.2.3.2, page 3-40, paragraphs 1 to 6; Section 3.2.6, page 3-83, last paragraph; and Section 3.2.6.1, page 3-100, last full paragraph). Review also indicates that evaluations have been expanded to recognize the uncertainties regarding the site-specific host rock stratigraphy and the potential effect of discontinuities on the construction and operation of the repository at higher than ambient temperature. However, the NRC staff continues to question whether the possible thermal and mechanical effects of heterogeneities have been conservatively factored into the evaluation of repository construction, operation and maintenance.

With respect to conclusions based on the thermal and ductility properties of the host rock mass, the final EA presents estimates of physical, mechanical, and thermal properties of the salt at the Deaf Smith site as representing the host rock mass characteristics (Section 3.2.6, page 3-83). These estimates are drawn from limited laboratory testing of small samples of intact salt rock cores taken from four boreholes located several miles away (distance range from 4 to 22 miles) and therefore these cores may not adequately represent the clastic interbeds and chaotic mudstone/salt mixture heterogeneities that may be present at the site. As indicated in the final EA (Section 3.2.6, page 3-84) the effects of the existing interbeds on rock mass properties are unknown and their presence introduces uncertainties into any estimate of in-situ rock mass properties. The engineering behavior of the in-situ rock mass, especially under waste-induced thermo-mechanical loading, can be dominated by heterogeneities. Because of the present lack of site specific data related to the potential location and characteristics of heterogeneities at the Deaf Smith site and the resulting uncertainties associated with the analyses performed to evaluate the impact of those heterogeneities on the performance of the geologic repository, the NRC staff consider that substantial uncertainties remain that were not factored into the final EA evaluations of (1) rock mass physical, thermal, and engineering properties, (2) opening stability, (3) the extent of the disturbed zone, (4) rock support requirements, and (5) flexibility in locating the underground facility.

The evaluation of in-situ characteristics or conditions that could require engineering measures beyond reasonably available technology in the construction of the shafts and underground facilities, does not reflect requisite consideration of the special demands that probable rock mass heterogeneities may make on the requirement for engineering measures when constructing adjacent to areas of emplaced waste. Opening stability may be adversely affected and may necessitate increased requirements for complex rock support and reinforcement. The potential adverse effects of heterogeneities might also extend the disturbed zone beyond the 15 meters estimated in Appendix 6A of the final EA (page 6A-6).

The evaluation of conditions requiring engineering measures beyond reasonably available technology for construction, operation, and closure if such measures are necessary for waste containment and isolation presented on pages 6-111 and 6-112 does not include an analysis of the influence of heterogeneities on the requirements for engineering measures beyond reasonably available technology. Areas of particular concern include: (a) the lack of an analysis of the engineering behavior of heterogeneous salt under anticipated repository environmental conditions; (b) the lack of an analysis of the relevance of the cited extensive excavation technology experience under ambient conditions, to the full range of repository host rock thermomechanical behavior conditions to be expected at the Deaf Smith site; and (c) lack of analysis of requirements for a retrieval system.

The evaluation of the existence of geologic structure, material properties, and hydrologic conditions such that heat generated by emplaced waste could reduce isolation does not show that the effects of heterogeneities on the thermal and mechanical properties of the host rock, and on porosity increases, or on ground movements due to emplaced waste heat would necessarily be localized or negligible. The effects of heterogeneities on characterization of the salt rock response to thermal loading, the potential for non-uniform reaction of the overlying rock units to thermal loading, and the potential for differential transfer of stresses and strains both within and outside the thermal pulse have all not been addressed. If experienced, these effects might decrease the isolation provided by the host rock as compared with pre-waste-emplacement conditions.

Finally, the evaluations of host rock thickness and lateral extent to allow sufficient flexibility in selecting depth, configuration, and location of the underground facility do not reflect consideration of the occurrence of such heterogeneous features as irregular masses of chaotic mudstone/salt mixtures and large discrete mudstone beds (as identified in Section 3, page 3-40, fourth paragraph) and of the potential existence of pockets of gases or brine (as postulated in Section 6, page 161, third paragraph). The existence of heterogeneous features such as those described above can affect creep and therefore affect maintenance excavation requirements. Therefore, it may be necessary to reduce the design areal thermal loading to reduce the impact of heterogeneities on maintenance excavation requirements in a heated environment. This in turn increases the size of the underground facility. It may also be necessary to adjust the waste package emplacement configuration due to the presence of heterogeneities, which may also increase the size of the underground facility. The final EA recognizes that the amount of remedial excavation that is required during repository operations could be controlled by changing the design extraction ratio or gross thermal loading (Section 6.3.3.2.3, page 6-164, paragraph 9). However, the evaluations do not address the effects of heterogeneities on either creep, maintenance excavation requirements, waste package emplacement configuration, the design extraction ratio, and gross thermal loading on lateral extent. The NRC staff recognizes that there has been appropriate consideration of the lack of significant flexibility in selecting the depth of the underground openings. However, the NRC staff considers that the potential effect of heterogeneities in limiting the lateral flexibility of repository siting has not been considered.

Comment 5

Shaft Sealing - (Draft EA Major Comment 8)

Guidelines on Rock Characteristics 10 CFR 960.4-2-3(c)(1), (c)(3), and 10 CFR 960.5-2-9(c)(2)

In the NRC staff major comment 8 on the draft EA for Deaf Smith, concerns were raised that uncertainties and available evidence associated with constructing, sealing, and decommissioning shaft systems to assure containment and isolation of the waste were not adequately addressed. Review of the final EA indicates that, although the discussions on shaft construction were expanded (Section 4.1.2, pages 4-16 to 4-42), the information presented did not identify specific uncertainties described below related to effectiveness of existing ground freezing and sealing technology and factor them into the performance assessment of shaft seals.

The evaluation of in-situ characteristics and conditions which would require engineering measures beyond reasonably available technology in the construction of shafts does not address many of the sources of uncertainties associated with constructing shafts using reasonably available technology. The shaft construction concept presented in the final EA incorporates ground freezing technology to control rock movements and water flow. In the final EA (Section C.4.2.2, pages C.4-54 and 55), it is stated that vertical permeability changes during the thawing process are expected to be minimal due to the expected physical properties of the Ogallala and Dockum formations; however, no evaluation is presented of mechanisms of permeability increase for the site soil and rock materials experienced during freeze-thaw cycles. The final EA further states, in Section C.4.2.2, page C.4-55, that uniform thawing can be achieved. However, it is the opinion of the NRC staff that the heterogeneous physical nature of the ground to be frozen over a depth of 1000 feet, the unavoidable deviations in freeze holes alignment, variations in the zone disturbed by shaft excavation, and liner placement all suggest that both freezing and thawing will be non-uniform when shafts are constructed using currently available technology. Non-uniform freezing and thawing would result in uncertain reliability of freezewall performance and variability in parameter values required for engineering. Furthermore, no discussion is presented to show that the activities described in Section C.4.2.2, page C.4-55, and on page 6-164, intended to confine the zone disturbed by the freezing process, may be completed successfully using present state-of-the-art techniques. Likely increased permeability, associated with shaft freezing and thawing, could progressively reduce shaft integrity by introducing difficulties in achieving effective grouting and deleterious initial and long-term flow paths in penetrated strata. The final EA proposes the use of grouting to control water flows in shafts (Section 4.1.2.2.2, page 4-35, paragraph 4). It should be noted that in evaporite mines, it was reported that a need for recurrent grouting to maintain seal performance can be expected (ONWI-255, 1981, page 84). Furthermore, grouting processes are difficult to control particularly in deviatoric in-situ stress fields, where grouting can increase rather than decrease permeability (Houlsby, 1982, page 29). Also, it should be noted that in the final EA available evidence of shaft failures causing flooding (NRC major comment 8 on the draft EA) is dismissed as irrelevant to waste isolation in salt (Section C.5.11, page C.5-59), yet some completed shafts contemporary to the failures are cited (Section 4.1.2.2.2, Table 4-9, pages 4-37 through 4-39) as relevant to the state-of-the-art in shaft construction. Therefore, based on the limited information available and the reasons given above, the NRC staff considers that over the pre-closure period there may be an increasing probability of progressive seal and liner deterioration that could lead to groundwater inflow and possibly shaft failure.

The evaluation of rock conditions that could require engineering measures beyond reasonably available technology for the closure of a repository if such measures are necessary to ensure waste isolation did not recognize or factor in the following sources of uncertainty. Changes to the shaft system, which can be expected to occur during the pre-closure period (i.e., seal deterioration, leakage damage, liner deterioration, etc.) due to the groundwater flow, might adversely affect the performance of the decommissioning seal system. Sealing materials, which are not yet designed or developed for long term compatibility with engineering and chemical properties of disturbed shaft wall rock and grout materials, may prove ineffective due to uncertainties in the effects of aging on shaft system components. The response of shaft seals/walls to potential dynamic earthquake motions and the likelihood for damage to seals during both pre- and post-closure periods is also at present not clearly understood. Furthermore, decommissioning sealing of the repository with crushed salt backfill and bulkheads may, in some shafts/drifts, not effectively prevent shaft water from reaching the waste storage area. This is because consolidation of the backfill due to creep of the salt rock may not be sufficient to reduce permeability to desired levels as this is dependent on both placing the backfill at the correct density, and predicting the creep/closure of the drift walls, roof, and floor. Therefore, limited flow through decommissioned passages may be possible.

The NRC staff also considers that Sections 5.1.1.3, 5.1.4.2.2, and 6.3.1.3.3 in the final EA do not adequately address sources of uncertainty such as the potential thermally-induced ground movements that could result in deleterious strains in shaft linings and seals. Although surface uplifts predicted by thermoelastic analyses (Section 6.3.1.3.3, page 6-113) could be conservative, such analyses, when carried out for subsurface strata, may result in a non-conservative estimate of their thermomechanical response. For example, the potential for differential movement within the subsurface strata due to the effects of interbeds and discontinuities has not been evaluated. . Such an analysis of the thermomechanical interaction of site stratigraphy, backfill, and shaft seal, including the nonlinear material behavior and properties of these system components, may well reveal deformation modes and differential movements which could affect shaft seal behavior. Furthermore, by omitting the effects of fractures, the analysis presented in Section 6.3.1.3.3, page 6-113 neither conservatively accounts for creation and dilation of fractures in shaft wall rock nor for distress of seals and linings. These omissions underestimate the potential for water migration through the shaft seal system. The NRC staff considers that an expected surface uplift above the shaft pillar centerline due to a 25 W/M^2 areal loading (as estimated in Wagner, et al., 1984, ONWI-512) may result in differential strains affecting post-closure shaft seal system performance. Differential displacement within the decommissioned shaft pillar region could result from small temperature changes due to the high coefficient of thermal expansion of salt.

Comment 6

Waste Package Performance Predictions - (Draft EA Comment 9)

Guidelines 10 CFR 960.4-2-2(b)(4), 960.4-2-2(c)(1) and 960.4-2-3(c)(1)

NRC staff concerns expressed in major comment 9 on the draft EA for the Deaf Smith County site that the performance of the engineered barrier system was based on a number of inadequately supported assumptions and that the uncertainties associated with these assumptions have not been adequately addressed. The NRC staff recognizes that the response in the final EA indicates that some specific areas of uncertainty in the analysis such as temperature profiles, radiation effects, solubilities, brine quantities, corrosion modes and performance models that were discussed in the draft EA comment will be addressed during site characterization (Sections 6.4.2.3.3, page 6-227, last paragraph, and 6.4.2.7, page 6-271, paragraph 2). However, examination of the final EA (Section 6.4.2, pages 6-193 to 6-243) indicates that the consequences of these assumptions and uncertainties on the analyses of waste package lifetime and radionuclide release rate have not been adequately addressed and, in large measure, the major comment on the draft EA continues to apply to the final EA.

The final EA recognizes that waste package design changes will be needed (Section 6.4.2.2.1, page 6-199) if the assumptions used in drawing conclusions regarding the post-closure guidelines (Sections 6.4.2.3.3, pages 6-217 to 6-232, and 6.4.2.3.4, pages 6-232 to 6-243) are not validated during site characterization activities (Appendix C, page C.5-44). However, the NRC staff continues to hold that the assumptions are not yet substantiated and the current range of uncertainties are not reflected in the conclusions. For example, the final EA continues to use the code BRINEMIG to model brine migration despite the fact that the code was developed using "assumptions... which do not realistically describe the movement of brine in salt" (Section C.5.11, page C.5-49). The model gave results for brine flow rates that were consistently less than observed results in in-situ heater experiments at the Waste Isolation Pilot Plant (WIPP) facility (Nowak, 1986). The use of BRINEMIG to conservatively predict brine migration rates is clearly questionable. In another example, the final EA continues to assume that brine entering a borehole will distribute itself uniformly over the overpack and that the overpack will corrode uniformly (Section 6.4.2.3.3, page 6-227). During the period the backfill remains as crushed salt, it is more likely that brine will collect at the bottom of each borehole and lead to corrosion over a limited portion of the overpack. As to the mode of corrosion, while uniform corrosion of overpack materials has been observed under some conditions (Kreiter, 1983; Westerman et al., 1983), the susceptibility of carbon steels to pitting corrosion, crevice corrosion, and stress-assisted cracking has been historically observed (Turnbull, 1983; Strutt et al., 1985; Ito et al., 1984; and Kruger, 1959) under other conditions. This observation raises significant questions regarding the long-term performance of the overpack. The final EA indicates that parametric studies have been performed (Section 6.4.2.3.3, page 6-232, paragraph 2) which use pitting ratios to account for the uncertainties in the uniform corrosion assumption. Neither the assumed pitting ratios nor the relationship between uniform and pitting or other localized corrosion process has yet been substantiated by data and analysis, but the final EA indicates (Section 6.4.2.3.3, page 6-232, paragraph 3) a high sensitivity of the computational results to non-uniform corrosion. Without adequate consideration of these alternative failure mechanisms, the NRC staff does not consider that the predicted 10,000 year container lifetime (which assumes uniform corrosion) reflects the current uncertainties.

REFERENCES

Andrews, R.W., Kelley, V.A., McNeish, J.A., LaVenue, A.M., and Campbell, J.E., 1985. Travel Path/Time Uncertainties at Salt Sites Proposed for High Level Waste Repositories: Prepared by Intera Technologies, Inc. for Office of Nuclear Waste Isolation, ONWI/E512-02900/TR-36.

Browning, R.E., 1985. Letter to R. Stein (DOE), June 12, 1985, regarding NRC position on groundwater travel time.

Budnik, Roy T., 1984. Structural Geology and Tectonic History of the Palo Duro Basin, Texas Panhandle, Bureau of Economic Geology OF-WTWI-1984-55, prepared for U.S. Department of Energy by The University of Texas at Austin, Austin, TX.

D'Appolonia Consulting Engineers, 1981. "Sealing Considerations for Repository Shafts in Bedded and Dome Salt," ONWI-255, Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH, p. 84.

Finley, Robert J., and Thomas C. Gustavson, 1981. Lineament Analysis Based on LANDSAT Imagery, Texas Panhandle, Geological Circular 81-5, prepared for U.S. Department of Energy by Bureau of Economic Geology, The University of Texas at Austin, Austin, TX.

Gustavson, Thomas C., Robert J. Finley, and Robert W. Baumgardner, Jr., 1981. "Retreat of the Caprock Escarpment and Denudation of the Rolling Plains in the Texas Panhandle," Bulletin of the Association of Engineering Geologists, Vol. 18, No. 4, pp. 413-422.

Gustavson, Thomas C., and Roy J. Finley, 1984. Late Cenozoic Geomorphic Evolution of the Texas Panhandle and Northeastern New Mexico - Case Studies of Structural Controls and Regional Drainage Development, Bureau of Economic Geology OF-WTWI-1984-39, prepared for U.S. Department of Energy by The University of Texas at Austin, Austin, TX.

Gustavson, Thomas C., and Roy T. Budnik, 1984. Salt Dissolution: Examples from Beneath the Southern High Plains, OF-WTWI-1984-3, prepared for U.S. Department of Energy by Bureau of Economic Geology, The University of Texas at Austin, Austin, TX.

Gustavson, Thomas C., and Roy T. Budnik, 1985. "Structural Influences on Geomorphic Processes and Physiographic Features, Texas Panhandle: Technical Issues in Siting a Nuclear Waste Repository," Geology, Vol. 13, pp. 173-176.

Gustavson, Thomas C., and Vance T. Holliday, 1985. Depositional Architecture of the Quaternary Blackwater Draw and Tertiary Ogallala Formations, Texas Panhandle and Eastern New Mexico, OF-WTWI-1985-23, prepared for U.S. Department of Energy by Bureau of Economic Geology, The University of Texas at Austin, Austin, TX.

Houlsby, A.C. "Cement Grouting for Dams," in ASCE "Proceedings of the Conference on Grouting in Geotechnical Engineering," 1982, New Orleans, LA, p. 29.

Hovorka, Susan D., B.A. Luneau, and S. Thomas, 1985. Stratigraphy of Bedded Halite in the Permian San Andres Formation, Units 4 and 5, Palo Duro Basin, Texas (draft), OF-WTWI-1985-9, prepared for the U.S. Department of Energy by Bureau of Economic Geology, The University of Texas at Austin, Austin, TX, Plates 2 and 10.

Ito, S., T. Murata and H. Okada, 1984. "A Statistical Approach to Corrosion of Marine Steel Structures," International Congress on Metallic Corrosion, Toronto, June 3-7.

Johns, Davis A., 1985. Sandstone Distribution and Lithofacies of the Triassic Dockum Group, Palo Duro Basin, Texas (draft), OF-WTWI-1985-25, prepared for U.S. Department of Energy by Bureau of Economic Geology, The University of Texas at Austin, Austin, TX.

Kreiter, M.R., 1983, "Waste Package Program," Section 3.1.1 in J.L. McElroy and J.A. Powell, compilers, Nuclear Waste Management Semiannual Progress Report, April 1983 through September 1983, PNL-4250-4, prepared for U.S. Department of Energy by Pacific Northwest Laboratory, Battelle Memorial Institute, Richland, WA, pp. 3.1-3.29.

Kruger, J., 1959. "Influence of Crystallographic Orientation on the Pitting of Iron in Distilled Water," Journal of the Electrochemical Society, Vol. 106, No. 8, p. 736.

Nowak, E.J., 1986. Preliminary Results of Brine Migration Studies in the Waste Isolation Pilot Plant (WIPP), Sandia National Laboratories Report SAND86-0720, Albuquerque, NM.

Regan, Terence R., and Philip J. Murphy, 1984. Structural Analysis of the Northern Palo Duro Basin, prepared by Stone & Webster Corporation for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH, Figure 3, in preparation.

Strutt, J.E., J.R. Nicholls and B. Barbier, 1985. "The Prediction of Corrosion by Statistical Analysis of Corrosion Profiles," Corrosion Science, Vol. 25, No. 5, pp. 305-315.

Thompson, B.M., Campbell, J.E., and Lognsine, D.E., 1985. PTRACK; A Particle Tracking Program for Evaluating Travel Path/Time Uncertainties: Prepared by Intera Technologies, Inc. for Office of Nuclear Waste Isolation, ONWI/E512-02900/CD-27.

Turnbull, A., 1983. "The Solution Composition and Electrode Potential in Pits, Crevices and Cracks," Corrosion Science, Vol. 23, No. 8, pp. 833-870.

U.S. Department of Energy, 1984. "Nuclear Waste Policy Act of 1982; General Guidelines for the Recommendation of Sites for the Nuclear Waste Repositories; Final Siting Guidelines," (10 CFR Part 960), Federal Register, Vol. 49, pp. 47714-47770, Washington, DC, December 6.

U.S. Department of Energy, 1984. Draft Environmental Assessment, Deaf Smith County Site, Texas, Office of Civilian Radioactive Waste Management, Washington, DC.

U.S. Department of Energy, 1986. Final Environmental Assessment, Deaf Smith County Site, Texas, Office of Civilian Radioactive Waste Management, Washington, DC.

U.S. Nuclear Regulatory Commission, 1985. NRC Staff Comments on the DEA for Deaf Smith County Site, Texas, Office of Nuclear Material Safety and Safeguards, Washington, DC.

U.S. Nuclear Regulatory Commission, 1986. "Disposal of High-Level Radioactive Wastes in Geologic Repositories," 10 CFR Part 60, Subpart E, Technical Criteria. Code of Federal Regulations - Energy. Office of the Federal Register, Washington, DC.

U.S. Nuclear Regulatory Commission, 1986. "Draft Generic Technical Position on Groundwater Travel Time (GWTT)," Office of Nuclear Material Safety and Safeguards, Washington, DC, July 1986.

U.S. Nuclear Regulatory Commission and U.S. Department of Energy, Permian Basin Core Examination Summary, August 5-9, 1985, Texas Bureau of Economic Geology Offices, Austin, TX.

Wagner, R.A., M.C. Loken and H.Y. Tammemagi, 1984. "Preliminary Thermomechanical Analyses of a Conceptual Nuclear Waste Repository at Four Salt Sites," ONWI-512, Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH, 228 p.

Westerman, R.E., J.L. Nelson, S.G. Pitman, W.L. Kuhn, S.J. Basham and D.P. Novak, 1983. Evaluation of Iron Base Materials for Waste Package Containers in a Salt Repository, PNL-SA-11713, Paper D5.10, by Pacific Northwest Laboratory and Nuclear Waste Isolation, Battelle Memorial Institute, presented at Materials Research Society Annual Meeting, Boston, MA, November 14-17.

MAJOR COMMENTS

ON

RICHTON DOME SITE

Comment 1

Redox Conditions - (Draft EA Major Comment 4)

Guidelines on Geochemistry 10 CFR 960.4-2-2(b)(2),(c)(3)

In the NRC staff major comment 4 on the draft EA for Richton Dome, concerns were raised that the limitations in current evidence regarding processes that affect radionuclide migration, such as precipitation, sorption, radiocolloid formation, and organo-radionuclide complexation were not factored into estimates of the above parameters which may lead to underestimations of radionuclide mobility. Examination of the final EA indicates that discussions of sorption, radiocolloid formation, and organo-radionuclide complexation have been adequately revised to include discussions of uncertainties in the data (Section 6.3.1.2.2, pages 6-95 to 6-96, items 3 through 6); however, concerns with redox conditions have not been factored into discussions and evaluations presented in the final EA regarding the mobility of redox-sensitive radionuclides (Section 6.3.1.2.2, pages 6-94 to 6-95, items 1 and 2; Section 6.3.1.2.3, page 6-99, paragraph 3).

The NRC staff is concerned that evidence presented in the final EA does not support the conclusion that the groundwater adjacent to the Richton Dome is chemically reducing. The final EA presents Eh values of -50 to -100 millivolts for the groundwater in the Upper Aquifer if suspect higher values are discarded (Section 6.3.1.2.2, page 6-95, item 2). Difficulties in obtaining reliable Eh measurements have been identified by Lindberg and Runnells (1984) which result in significant uncertainty in any Eh measurement. Such uncertainty of Eh measurements of the groundwater is recognized in the final EA where it is stated "reliable Eh measurements of groundwater is problematic" (Section 6.3.1.2.2, page 6-95, item 2). The final EA also states that the presence of reducing mineral assemblages, dissolved gases, and organics is qualitative evidence of chemically reducing conditions in both the Richton Dome salt and in groundwaters adjacent to the dome (Section 6.3.1.2.2, pages 6-94 to 6-95, items 1 and 2; Section 6.3.1.2.3, page 6-99, paragraph 3). The NRC staff is concerned that the presence of reducing mineral assemblages, dissolved gases, and organics, although indirect evidence of reducing conditions, is not conclusive because these components can exist metastably under oxidizing conditions. This possibility is not discussed in the final EA. Due to the uncertainties of the evidence presented, the existence of reducing or oxidizing conditions cannot be stated unequivocally in the absence of analyses which establish a consistency between various types of quantitative data.

Even assuming that reducing conditions are present, no evidence is presented in the final EA to show that redox-sensitive radionuclides released from the waste form will be reduced. If redox-sensitive actinide elements are dissolved from the waste form in the oxidized state, kinetic effects may prevent the establishment of redox equilibria and inhibit the transformation of oxidized actinide species to reduced species, which tend to be less mobile. This is of major concern regarding long-term release to the accessible environment because redox-sensitive radionuclides such as plutonium, uranium, neptunium, and technetium have long half-lives. No evidence is presented to suggest how kinetic constraints will be overcome. Furthermore, contradictory statements regarding redox conditions are made. It is stated in the final EA that the oxidized species $UO_2(CO_3)_3^{4-}$ "can be thermodynamically stable under reducing conditions" (Section 6.3.1.2.2, page 6-96, item 5); elsewhere, however, it is stated that reducing conditions expected in the host salt "will promote the precipitation of many redox-sensitive radionuclides" (Section 6.3.1.2.2, page 6-94, item 1) and "redox-sensitive radionuclides are expected to be stable in their lower oxidation states" (Section 6.3.1.2.2, page 6-95, item 2). The NRC staff considers that the conclusion that redox-sensitive radionuclides will be in reduced states is premature because the field data on redox conditions are limited and highly uncertain and there is a lack of experimental studies investigating redox equilibria under chemical conditions expected in a repository.

Precipitation of radionuclides in the host salt and outside the host salt is an important process affecting radionuclide migration (Section 6.3.1.2.2, pages 6-94 to 6-95, items 1 and 2). Effective precipitation of redox-sensitive radionuclides is dependent on their being in a reduced state. The NRC staff believes that factoring uncertainties regarding redox conditions into the analysis can also support an alternative assumption that redox-sensitive radionuclides might remain in the more mobile oxidized state during the isolation time period.

Comment 2

Effects of Host Rock Mass Heterogeneity - (Draft EA Major Comment 5)

Guidelines on Rock Characteristics 10 CFR 960.4-2-3(b)(1), (b)(2), (c)(1), (c)(3) and 10 CFR 960.5-2-9(b)(1), (c)(2)

In the NRC staff major comment 5 on the draft EA for Richton Dome, concerns were raised that the existence of heterogeneities and large anomalies within the Richton Dome were not acknowledged and the possible effects of such heterogeneities were not adequately considered in the evaluation of rock characteristics related to availability of suitable host rock and the level of complexity of technology needed for construction, operation, and closure of the repository. Review of the final EA indicates that the likelihood of heterogeneities and anomalies within the Richton Dome has been acknowledged (Section 3.2.3.2.4, page 3-30, third paragraph; Section 3.2.6.1.2, page 3-54, paragraphs 4 through 6; Section 6.3.1.3, page 6-102, paragraphs 1 and 5; Section 6.3.3.2.4, page 6-167, fourth paragraph). Review also indicates that the assessment of geomechanical properties of cap rock and salt (Section 3.2.6.1.2) has been expanded to consider the possible influence of discontinuities on mining operations (page 3-60). However, the NRC staff continues to question whether the possible thermal and geomechanical effects of heterogeneities have been conservatively factored into evaluations of repository construction, operation, and maintenance.

With respect to conclusions based on the thermal and ductility properties of the host rock mass, the final EA presents estimates of physical, thermal, and mechanical properties of the Richton Dome salt (Sections in 3.2.6.1.2 and 3.2.6.2, Tables 3-7, 3-8, and 3-10, pages 3-55 to 3-64) as representative of the host rock mass. These estimates draw upon limited laboratory testing of salt rock cores taken from a single borehole (MRIG-9). It also appears that the data used (Tables 3-7, 3-8, and 3-10) in rock characteristic evaluations was for essentially pure salt rock. Therefore, these samples may not fully represent in situ host rock mass at the site and have resulted in an implicit assumption of homogeneity. While the final EA correctly identified that the dome's internal structure is typically steeply dipping and that data from a single borehole cannot be considered representative of the entire salt stock (page 6-102, top of page), the uncertainties related to the adverse effects of heterogeneities were not factored into the evaluations. The engineering behavior of the in-situ rock mass, especially under waste-induced thermomechanical loading, can be dominated by heterogeneities. Because of the present lack of location and parametric data on heterogeneities and anomalies at the Richton Dome site and the resulting uncertainties associated with the analyses performed to evaluate the impact of those heterogeneities and anomalies on the performance of the geologic repository, the NRC staff considers that substantial uncertainties remain that were not factored into the final EA evaluations of (1) rock mass physical, thermal, and engineering properties, (2) the extent of the disturbed zone, (3) opening stability, (4) rock support requirements and (5) flexibility in locating the underground facility.

The evaluation of in-situ characteristics or conditions that could require engineering measures beyond reasonably available technology in the construction of the shafts and underground facilities does not reflect requisite consideration of the special demands that probable rock mass heterogeneities and large anomalies may make on the requirement for engineering measures when constructing adjacent to areas of emplaced waste. Opening stability may be adversely affected and may necessitate increased requirements for complex roof support and reinforcement. The potential adverse effects of heterogeneities and anomalies might also extend the disturbed zone beyond the 15 meters estimated in Appendix 6A of the final EA (page 6A-7).

The evaluation of conditions requiring engineering measures beyond reasonably available technology for construction, operation, and closure if such measures are necessary for waste containment and isolation presented on pages 6-103 and 6-104 does not include an analysis of the influence of heterogeneities on the requirements for engineering measures beyond reasonably available technology. Areas of particular concern include: (a) lack of analysis of the engineering behavior of heterogeneous salt and large anomalous zones under anticipated repository environmental conditions; (b) the lack of an analysis of the relevance of cited excavation technology and experience which is limited to the ambient conditions to the full range of expected repository host rock thermomechanical behavior conditions; and (c) lack of analysis of requirements for a retrieval system.

The evaluation of the existence of geologic structure, material properties, and hydrologic conditions such that the heat generated by emplaced waste could reduce isolation does not show that the effects of heterogeneities and large anomalies on the thermal and mechanical properties of the host rock and on porosity increases, or on ground movements due to emplaced waste heat would necessarily be localized or negligible. The effects of heterogeneities and large anomalies on characterization of the salt rock response to thermal loading, the potential for non-uniform response of cap rock and overlying strata to thermal loading, and the potential for differential transfer of stresses and strains in the cap rock and overlying materials, both within and outside the thermal pulse, have all not been addressed. If experienced, these effects might decrease the isolation provided by the host rock as compared with pre-waste-emplacement conditions.

Finally, the evaluations of host rock thickness and lateral extent to allow sufficient flexibility in selecting depth, configuration, and location of the underground facility do not reflect consideration of some of the potential effects of heterogeneities and anomalous zones in the host rock which would limit the available lateral extent of host rock needed for locating the underground facility and providing an adequate buffer zone beyond the limits of the underground facility. Heterogeneity effects that may impact lateral flexibility are: (1) gassy mine conditions, (2) anomalous zone(s) larger than that assumed in the final EA (page 6-102), and (3) reduced thermal loading. It may be necessary to reduce areal thermal loading to account for uncertainties in thermal conductivity (either due to heterogeneities or conservative application of laboratory values) as suggested in the final EA (page C.5-43). This would result in an increase of areal requirement of the underground facility. In addition, the two-phase repository concept would increase the total area required by 34 percent (Table 5-1, page 5-7, final EA). The NRC staff considers that, because significant potential effects of heterogeneities and anomalous zones that could limit the lateral flexibility of repository siting have not been considered, the evaluations do not reflect an appropriate conservative approach.

Comment 3

Shaft Sealing - (Draft EA Major Comment 7)

Guidelines on Rock Characteristics 10 CFR 960.4-2-3(c)(1), (c)(3), and 10 CFR 960.5-2-9(c)(2)

In the NRC staff major comment 7 on the draft EA for Richton Dome, concerns were raised that uncertainties and available evidence associated with constructing, sealing, and decommissioning shaft systems to assure containment and isolation of the waste were not adequately addressed. Review of the final EA indicates that, although the discussions on shaft construction were expanded (Section 4.1.2, pages 4-17 to 4-42), the information presented did not identify specific uncertainties described below related to effectiveness of existing ground freezing and sealing technology and factor them into the performance assessment of shaft seals.

The evaluation of in-situ characteristics and conditions which would require engineering measures beyond reasonably available technology in the construction of shafts does not address many of the sources of uncertainties associated with constructing shafts using readily available technology. The shaft construction concept presented in the final EA incorporates ground freezing technology to control rock movements and water flow. In the final EA (Section 4.1.2.2.2, page 4-37 and Section C.8.3, page C.8-10), it is stated that soils could experience vertical permeability increases during thawing, and that the effect has been shown to be highest in fine-grained, plastic clays. The final EA presents no thorough evaluation of mechanisms of permeability increase for the site soil and rock materials which may experience freeze-thaw cycles. The final EA further states, on page 4-37, that uniform thawing can be achieved. However, it is the opinion of the NRC staff that the heterogeneous physical nature of the ground to be frozen, the unavoidable deviations in freeze hole alignment, and variations in the zone disturbed by shaft excavation and liner placement all suggest that both freezing and thawing will be non-uniform when shafts are constructed using currently available technology. Non-uniform freezing and thawing would result in uncertain reliability of freezewall performance and variability in parameter values required for engineering. Furthermore, no discussion is presented to show that the activities described on page 4-37, and on page 6-164, intended to confine the zone disturbed by the freezing process, may be completed successfully using present state-of-the-art techniques. Likely increased permeability, associated with shaft freezing and thawing, could progressively reduce shaft integrity by introducing difficulties in achieving effective grouting and deleterious initial and long-term flow paths in penetrated strata. The final EA proposes the use of grouting to control water flows in shafts (page 4-37, paragraph 2). It should be noted that in evaporite mines, it was reported that a need for recurrent grouting to maintain seal performance can be expected (ONWI-255, 1981, page 84). Furthermore, grouting processes are difficult to control particularly in deviatoric in-situ stress fields, where grouting can increase rather than decrease permeability (Houlsby, 1982). Also, it should be noted that in the final EA available evidence of shaft failures causing flooding (NRC major comment 7 on the draft EA) is dismissed as irrelevant to waste isolation in salt (Section C.5.11, page C.5-50), yet some completed shafts contemporary to the failures are cited (Section 4.1.2.2.2, Table 4-9, pages 4-39 through 4-41) as relevant to the state-of-the-art in shaft construction. Therefore, based on the limited information available and the reasons given above, the NRC staff considers that over the pre-closure period there may be an increasing probability of progressive seal and lining deterioration that could lead to groundwater inflow and possibly shaft failure.

The evaluation of rock conditions that could require engineering measures beyond reasonably available technology for the closure of a repository if such measures are necessary to ensure waste isolation did not recognize or factor in the following sources of uncertainty. Changes to the shaft system, which can be expected to occur during the pre-closure period (i.e., seal deterioration, leakage damage, liner deterioration, etc.) due to the groundwater flow, might adversely affect the performance of the decommissioning seal system. Sealing materials, which are not yet designed or developed for long-term compatibility with engineering and chemical properties of disturbed shaft wall rock and grout materials, may prove ineffective due to uncertainties in the effects of aging of shaft components. The response of shaft seals/walls to potential dynamic earthquake motions and the likelihood for damage to seals during both pre- and post-closure periods is also at present not clearly understood. Furthermore, decommissioning sealing of the repository with crushed salt backfill and bulkheads may in some shafts/drifts not effectively prevent water in the shaft from reaching the waste storage area. This is because creep consolidation of the backfill may not be sufficient to reduce permeability to desired levels as this is dependent on both placing the backfill at the correct density and predicting the creep/closure of the drift walls, roof, and floor. Therefore, limited flow through decommissioned passages may be possible.

The NRC staff also considers that Sections 5.1.1.3, 5.1.4.2.2, and 6.3.1.3.3 in the final EA do not adequately address sources of uncertainty such as the potential thermally-induced ground movements that could result in deleterious strains in shaft linings and seals. Although surface uplifts predicted by thermoelastic analyses (page 6-105) could be conservative, such analyses, when carried out for cap rock and subsurface strata above it, may result in a non-conservative estimate of their thermomechanical response. For example, the potential for differential movement within the subsurface strata due to the effects of discontinuities has not been evaluated. Such an analysis of the thermomechanical interaction of site stratigraphy, backfill, and shaft seal, including the non-linear material behavior and properties of these system components, may well reveal deformation modes and differential movements which could affect shaft seal behavior. Furthermore, by omitting the effects of fractures, the analysis presented in Section 6.3.1.3.3 (page 6-105) neither conservatively account for creation and dilation of fractures in shaft wall rock nor evaluate the potential for distress of seals and linings. These omissions underestimate the potential for water migration through the shaft seal system. The NRC staff considers that an expected surface uplift above the shaft pillar centerline due to a 25 W/M^2 areal loading (as estimated in Wagner, et al., 1984, ONWI-512) may result in differential strains affecting post-closure shaft seal system performance. Even small temperature changes combined with the high coefficient of thermal expansion of salt could result in differential displacement within the decommissioned shaft pillar region.

Comment 4

Waste Package Performance Predictions - (Draft EA Comment 9)

Guidelines 10 CFR 960.4-2-2(b)(4), 960.4-2-2(c)(1) and 960.4-2-3(c)(1)

NRC staff concerns expressed in major comment 9 on the draft EA for the Richton Dome site that the performance of the engineered barrier system was based on a number of inadequately supported assumptions and that the uncertainties associated with these assumptions have not been adequately addressed. The NRC staff recognizes that the response in the final EA indicates that some specific areas of uncertainty in the analysis such as temperature profiles, radiation effects, solubilities, brine quantities, corrosion modes and performance models that were discussed in the draft EA comment will be addressed during site characterization (Sections 6.4.2.3.3, page 6-230, second paragraph, and 6.4.2.7, page 6-260, paragraph 2). However, examination of the final EA (Section 6.4.2, pages 6-193 to 6-260) indicates that the consequences of these assumptions and uncertainties on the analyses of waste package lifetime and radionuclide release rate have not been adequately addressed and, in large measure, the major comment on the draft EA continues to apply to the final EA.

The final EA recognizes that waste package design changes will be needed (Section 6.4.2.2.1, page 6-199) if the assumptions used in drawing conclusions regarding the post-closure guidelines (Sections 6.4.2.3.3, pages 6-212 to 6-230, and 6.4.2.3.4, pages 6-230 to 6-241) are not validated during site characterization activities (Appendix C, page C.5-36). However, the NRC staff continues to hold that the assumptions are not yet substantiated and the current range of uncertainties are not reflected in the conclusions. For example, the final EA continues to use the code BRINEMIG to model brine migration despite the fact that the code was developed using "assumptions... which do not realistically describe the movement of brine in salt" (Section C.5.11, page C.5-41). The model gave results for brine flow rates that were consistently less than observed results in in-situ heater experiments at the Waste Isolation Pilot Plant (WIPP) facility (Nowak, 1986). The use of BRINEMIG to conservatively predict brine migration rates is clearly questionable. In another example, the final EA continues to assume that brine entering a borehole will distribute itself uniformly over the overpack and that the overpack will corrode uniformly (Section 6.4.2.3.3, page 6-230). During the period the backfill remains as crushed salt, it is more likely that brine will collect at the bottom of each borehole and lead to corrosion over a limited portion of the overpack. As to the mode of corrosion, while uniform corrosion of overpack materials has been observed under some conditions (Kreiter, 1983; Westerman et al., 1983), the susceptibility of carbon steels to pitting corrosion, crevice corrosion, and stress-assisted cracking has been historically observed (Turnbull, 1983; Strutt et al., 1985; Ito et al., 1984; and Kruger, 1959) under other conditions. This observation raises significant questions regarding the long-term performance of the overpack. The final EA indicates that parametric studies have been performed (Section 6.4.2.3.3, page 6-230, paragraph 2) which use pitting ratios to account for the uncertainties in the uniform corrosion assumption. Neither the assumed pitting ratios nor the relationship between uniform and pitting or other localized corrosion process has yet been substantiated by data and analysis. Without adequate consideration of these alternative failure mechanisms, the NRC staff does not consider that the predicted 10,000 year container lifetime (which assumes uniform corrosion) reflects the current uncertainties.

REFERENCES

D'Appolonia Consulting Engineers, 1981. "Sealing Considerations for Repository Shafts in Bedded and Dome Salt," ONWI-255, Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH, p. 84.

Houlsby, A.C. "Cement Grouting for Dams," in ASCE "Proceedings of the Conference on Grouting in Geotechnical Engineering," 1982, New Orleans, LA, p. 29.

Ito, S., T. Murata and H. Okada, 1984. "A Statistical Approach to Corrosion of Marine Steel Structures," International Congress on Metallic Corrosion, Toronto, June 3-7.

Kreiter, M.R., 1983, "Waste Package Program," Section 3.1.1 in J.L. McElroy and J.A. Powell, compilers, Nuclear Waste Management Semiannual Progress Report, April 1983 through September 1983, PNL-4250-4, prepared for U.S. Department of Energy by Pacific Northwest Laboratory, Battelle Memorial Institute, Richland, WA, pp. 3.1-3.29.

Kruger, J., 1959. "Influence of Crystallographic Orientation on the Pitting of Iron in Distilled Water," Journal of the Electrochemical Society, Vol. 106, No. 8, p. 736.

Lindberg, R.D., and D.D. Runnells, 1984, "Ground Water Redox Reactions: An Analysis of Equilibrium State Applied to Eh Measurements and Geochemical Modeling," Science, v. 225, p. 925-927.

Nowak, E.J., 1986. Preliminary Results of Brine Migration Studies in the Waste Isolation Pilot Plant (WIPP), Sandia National Laboratories Report SAND86-0720, Albuquerque, NM.

Strutt, J.E., J.R. Nicholls and B. Barbier, 1985. "The Prediction of Corrosion by Statistical Analysis of Corrosion Profiles," Corrosion Science, Vol. 25, No. 5, pp. 305-315.

Turnbull, A., 1983. "The Solution Composition and Electrode Potential in Pits, Crevices and Cracks," Corrosion Science, Vol. 23, No. 8, pp. 833-870.

Wagner, R.A., M.C. Loken and H.Y. Tammemagi, 1984. "Preliminary Thermomechanical Analyses of a Conceptual Nuclear Waste Repository at Four Salt Sites," ONWI-512, Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH, 228 p.

Westerman, R.E., J.L. Nelson, S.G. Pitman, W.L. Kuhn, S.J. Basham and D.P. Novak, 1983. Evaluation of Iron Base Materials for Waste Package Containers in a Salt Repository, PNL-SA-11713, Paper D5.10, by Pacific Northwest Laboratory and Nuclear Waste Isolation, Battelle Memorial Institute, presented at Materials Research Society Annual Meeting, Boston, MA, November 14-17.