Department of Energy
Office of Civilian Radioactive Waste Management
Yucca Mountain Site Characterization Office
P.O. Box 30307
North Las Vegas, NV 89036-0307

QA: N/A

OVERNIGHT MAIL

MAR 2 2 2000

C. William Reamer, Chief
High-Level Waste and Performance
Assessment Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards
U.S. Nuclear Regulatory Commission
Two White Flint North
Rockville, MD 20852

U.S. DEPARTMENT OF ENERGY (DOE) REVIEW OF U.S. NUCLEAR REGULATORY COMMISSION'S (NRC) STRUCTURAL DEFORMATION AND SEISMICITY ISSUE RESOLUTION STATUS REPORT, REVISION 2

The DOE has reviewed Revision 2 of the Issue Resolution Status Report (IRSR) on the Key Technical Issue of Structural Deformation and Seismicity. The enclosed comments are directed primarily at the acceptance criteria for the subissues associated with structural deformation and seismicity and related discussions of the technical bases supporting those criteria.

In general, DOE agrees with the risk-informed performance-based approach that the NRC staff has adopted in its development of the proposed 10 CFR Part 63. However, we are concerned that some of the discussions in the subject IRSR contain explicit or implicit requirements beyond those in the acceptance criteria. A number of these requirements and some of the acceptance criteria themselves appear to be more prescriptive than is the intent of the performance-based proposed 10 CFR Part 63. They appear to remove some of the flexibility contained in the proposed regulation and are not linked clearly to repository performance. These concerns are discussed in our comments.

DOE appreciates the opportunity to review the IRSRs and provide comments. The enclosure contains both general and specific comments. We request that our comments be considered in the preparation of the next revision of the IRSR.

If you or your staff have any questions regarding our comments, please contact Tim Sullivan at (702) 794-5589 or Carol Hanlon at (702) 794-1324.

Stephan Brocoum
Assistant Manager, Office of
Licensing and Regulatory Compliance

OL&RC:DWK-0809

Enclosure:
Comments on Issue Resolution Status Report,
Revision 2, Key Technical Issue: Structural
Deformation and Seismicity

YMP-5

WM5507
WM-11
Reid from
DWST 1/23/02

MAR 2 2 2000

cc w/encl:
Ivan Itkin, DOE/HQ (RW-1) FORS
L. H. Barrett, DOE/HQ (RW-2) FORS
S. H. Hanauer, DOE/HQ (RW-2) FORS
R. A. Milner, DOE/HQ (RW-2) FORS
A. B. Brownstein, DOE/HQ (RW-52) FORS
C. E. Einberg, DOE/HQ (RW-52) FORS
N. H. Slater, DOE/HQ (RW-52) FORS
Richard Major, ACNW, Washington, DC
B. J. Garrick, ACNW, Washington, DC
J. H. Kessler, EPRI, Palo Alto, CA
Steve Kraft, NEI, Washington, DC
W. D. Barnard, NWTRB, Arlington, VA
R. R. Loux, State of Nevada, Carson City, NV
John Meder, State of Nevada, Carson City, NV
Alan Kalt, Churchill County, Fallon, NV
D. A. Bechtel, Clark County, Las Vegas, NV
Harriet Ealey, Esmeralda County, Goldfield, NV
Leonard Fiorenzi, Eureka County, Eureka, NV
Andrew Remus, Inyo County, Independence, CA
Michael King, Inyo County, Edmonds, WA
Tammy Manzini, Lander County, Austin, NV
Jason Pitts, Lincoln County, Caliente, NV
Jackie Wallis, Mineral County, Hawthorne, NV
L. W. Bradshaw, Nye County, Pahrump, NV
Jerry McKnight, Nye County, Tonopah, NV
Bill Ott, White Pine County, Ely, NV
R. I. Holden, National Congress of American Indians, Washington, DC
Allen Ambler, Nevada Indian Environmental Coalition, Fallon, NV
J. J. Curtiss, Winston & Strawn, Las Vegas, NV
F. S. Echols, Winston & Strawn, Washington, DC
K. L. Ashe, M&O, Las Vegas, NV
J. N. Bailey, M&O, Las Vegas, NV
D. R. Beckman, M&O, las Vegas, NV
M. A. Lugo, M&O, Las Vegas, NV
E. F. O'Neill, M&O, Las Vegas, NV
M. L. Scott, M&O, Las Vegas, NV
J. H. Smyder, Naval Reactors, Las Vegas, NV
J. T. Sullivan, DOE/YMSCO, Las Vegas, NV
Deborah Barr, DOE/YMSCO, Las Vegas, NV
R. L. Patterson, DOE/YMSCO, Las Vegas, NV
P. G. Harrington, DOE/YMSCO, Las Vegas, NV
D. W. Kane, DOE/YMSCO, Las Vegas, NV
M. C. Tynan, DOE/YMSCO, Las Vegas, NV
P. R. Russell, DOE/YMSCO, Las Vegas, NV
S. A. Morris, DOE/YMSCO, Las Vegas, NV

cc w/encl (continued)
Robin Sweeney, DOE/YMSCO, Las Vegas, NV
T. C. Gunter, DOE/YMSCO, Las Vegas, NV
C. L. Hanlon, DOE/YMSCO, Las Vegas, NV
C. M. Newbury, DOE/YMSCO, Las Vegas, NV
B. M. Terrell, DOE/YMSCO, Las Vegas, NV
OL&RC Library
Records Processing Center =

COMMENTS ON ISSUE RESOLUTION STATUS REPORT, REVISION 2, KEY TECHNICAL ISSUE: STRUCTURAL DEFORMATION AND SEISMICITY

General Comments

1. A very important outcome of Revision 2 of the Issue Resolution Status Report (IRSR) is the general acceptance of the Probabilistic Seismic Hazard Assessment (PSHA) (CRWMS M&O 1998a) as a basis for resolving the tectonic and geologic issues related to faulting, seismicity, and tectonic framework of the geologic setting. However, the specific comments that follow indicate differing NRC and DOE status on a number of aspects of these issues. DOE anticipates that these additional issues will be resolved once the NRC has reviewed Seismic Topical Report III.

2. DOE appreciates the NRC staff's acceptance of GFM3.1 for analyses of stratigraphy, faults, and fault blocks. The staff's acceptance of a common framework for the analyses represents a significant advance in issue resolution.

3. Revision 2 of the IRSR contains many suggestions for additional work with little if any explanation of the need for the additional work in terms of its importance to the evaluation of performance. In a number of cases (discussed in specific comments that follow), DOE does not believe the additional work is needed. We believe that prescriptive requirements for additional work, not clearly linked to repository performance runs counter to the performance-based approach discussed throughout the proposed 10 CFR Part 63. Therefore, performing such work would be inappropriate. DOE suggests that the NRC re-evaluate these suggestions as discussed below.

Specific Comments

1. Section 3.3.2, pages 11-12: The IRSR states that seismically-induced rockfall has the potential to directly breach waste packages. This statement does not include consideration of drip shields that are likely to be an element of the DOE repository design. Also, recent preliminary DOE analysis of rockfall parameters have provided information about key block sizes and frequencies of occurrence (Mackenzie 2000) that are discussed below. Results of other ongoing studies are expected to show that key blocks in about 85 percent of the repository would be too small and occurrences (number of key blocks per kilometer of drift length) too few to have major effects on the integrity of the drip shields or waste packages.

   Review of the information in the tables in (Mackenzie 2000) indicated that the majority of the rockfalls are small and rockfalls are expected to be infrequent. The method that was used to produce the block size information is based on 200 simulations along .024 km lengths of tunnel.

For the middle nonlithophysal zone of the Topopah Spring Tuff that contains about 7 percent of the repository, the results indicated that under static conditions, the expected number of blocks per km is 28 (increasing to 32 for maximum dynamic conditions analyzed), and the maximum block size for static conditions is about 12 metric tons for static conditions (versus about 33 metric tons for maximum dynamic conditions). However, the results indicated that about 95 percent of the blocks are less than 3 metric tons for static conditions and bout 4.3 metric tons for maximum dynamic conditions. Medium key block sizes are less that 375 pounds for static and dynamic conditions. So the information supports the interpretation that most keyblocks would be small and infrequent in terms of keyblocks per km of drift length.

For the lower lithophysal zone of the Topopah Spring Tuff that contains about 78 percent of the repository, preliminary information indicates that the maximum size of the key block is about 3 metric tons with no distinction between static and dynamic conditions. The median key block size is less than 220 pounds for static and dynamic conditions.

For the lower nonlithopysal zone to the Topopah Spring Tuff that contains the remaining 15 percent of the repository, the maximum block size of about 25 metric tons for static conditions and about 37 tons for dynamic conditions. the preliminary results indicate that about 95 percent of the blocks are less than about 13 metric tons for static and dynamic conditions, and the median sizes are about 530 pounds for static conditions and about 970 pounds for dynamic conditions.

DOE recognizes that the design available to the NRC at the time Revision 2 of the IRSR was developed did not include drip shields, and that the key block analyses discussed in the comment were not available. However, DOE suggests that the description in this section be modified to consider any intervening materials between the rock and waste package and that it recognize results of recent key block studies.

2. Section 3.3.4, page 14: The IRSR states "Tectonic framework information needs to be considered because it could provide geological and geophysical limits on, and alternative scenarios for, post-closure tectonic hazards and risks and preclosure design alternatives." DOE has considered the tectonic framework of Yucca Mountain. Given the rates of geologic processes, it appears unlikely that additional consideration of information about the tectonic framework will have any significant impact on selection of preclosure design alternatives. Similarly, unless the postclosure performance period is significantly extended, it is also unlikely that additional information about the tectonic framework will further influence the definition of postclosure tectonic hazards and associated risks. However, DOE will continue to evaluate new information and assess its significance for TSPA.

3. Section 3.4, page 14: The IRSR notes that the planned completion date for the Seismic Topical Report III is late 1999, and that ground motion and fault displacement descriptions in STR III will be used to design facilities at Yucca Mountain. These descriptions are incorrect.

   DOE is considering deferring Seismic Topical Report III to ensure that sufficient information is available to support the license application.

4. Section 4.1.1.2, page 29, last paragraph: The fault displacement hazard is expressed in terms probability of annual exceedance frequency. Since no time period is specified in the PSHA, it is misleading to state that "none of the hazard results predict more than 10 cm displacement for the next 10^8 yr." The PSHA results are applicable to any time period. Moreover the statement is incorrect. All sites except 7b, 7c, 7d, 8b, 8c, and 8d predict a mean hazard of greater than 10 cm at 10^8 yr mean annual frequency.

   DOE suggests that the IRSR be revised to clarify the statement "none of the hazard results predict more than 10 cm displacement for the next 10^8 yr."

5. Section 4.3.1.2, page 57, Origin of Fractures: The IRSR advises that the DOE should attempt "an adequate investigation and explanation of the mechanisms for fracture generation...." As described in the Site Description, Revision 0, Section 3.6 (CRWMS M&O 1998b), sufficient information about fracture characteristics, including origin, has been collected and documented. Therefore, no additional information about mechanisms of fracture generation is needed. The fracture characteristics information will be updated in Revision 1 of the Site Description in the summer of 2000. In addition, in comments on Revision 1 of the IRSR, DOE pointed out to the NRC that definition of the origin of fractures is not needed for TSPA because properties of fractures that may affect performance are not necessarily related to the origin of the fractures, and recommended that the NRC delete the item (DOE 1999).

   DOE reiterates our view that explanations of origins of fractures are not necessary to evaluate the potential impacts of fractures on design and performance assessment. Therefore we do not see this call for additional work as clearly linked to repository performance, and we recommend the discussion be revised accordingly.

6. Section 4.3.1.2, pages 59-62, Sampling Biases: The discussion of sampling biases in fracture data is generally no longer applicable. The work to produce a fracture orientation database derived from fracture strike and dip measurements mapped on the USGS/USBR Full Periphery Geotechnical Mapping (FPGMs) of the Exploratory Studies Facility (ESF) and registered to the 3-dimensional Nevada State plane coordinate system has been completed. Since the FPGMs, and thus the derived database, represent sampling of a three-dimensional volume, the question of directional bias associated with a 2-dimensional detail line survey is by definition not applicable. The final database for this work consists of 30,559 individual records (*Full Periphery Geotechnical Mapping, Strike and Dip Data Entry Correction Analysis*, CRWMS M&O 1999, p. 7 and Section 7.5). A planned Analysis and Model Report (Fracture Geometry Analysis for the Stratigraphic Units of the Repository Host Horizon [ANL-EBS-GE-00006]) will describe joint set orientations based on this database for the lithostratigraphic units associated with the Repository Host Horizon. This AMR will include an expanded fracture database with fracture strike and dip measurements from the Enhanced Characterization of the Repository Block (ECRB) Cross-Drift FPGMs. In addition, the information from the two reports will be used as input for an Analysis and Modeling Report that describes drift degradation (ANL-EBS-MD-000027).

   The volume-based fracture data is, by definition, unbiased. Hence, the discussions of sampling bias in and corrections to fracture data are no longer relevant. DOE suggests that the discussions of sampling biases be revised to show that DOE has adequately addressed the issue of sampling bias. DOE also requests that the issue be shown as resolved.

7. Section 4.3.1.2, page 79, Past Modifications of Fractures: The discussion emphasizes "an adequate investigation and explanation of modifications to fractures at YM that may affect characteristics of fractures that is consistent with field and laboratory observations and analog studies should be attempted by the DOE to help constrain the interpolation between and extrapolation beyond locally exposed fractures and faults that are abstracted into process level and PA models (ENFE, RDTME, and RT IRSRs)." The benefits of implementing the investigation(s) suggested are not clear.

   DOE does not believe that an explanation of the development history of fracture characteristics is necessary to include fracture characteristics in process models or TSPA abstractions. DOE believes it has adequately characterized fractures to support the development of process models and abstractions needed for TSPA (see for example, the UZ Flow and Transport PMR). DOE does not view the work described in the discussion of Past Modifications of Fractures as necessary, or clearly linked to repository performance.

8. Section 4.3.1.2, page 79, Current and Future Modifications of Fractures: The description indicates that DOE should attempt modeling of future fracture characteristics to help constrain parameter, assumed ranges, probability distributions, and bounding assumptions about perturbed conditions that are abstracted into process and TSPA models. Future fracture conditions will result from unknown future stress field conditions and resulting stress accumulations that cannot be accurately predicted. Therefore, there is little apparent benefit to implementing the work suggested.

   DOE does not believe that detailed explanations of the future development of fracture characteristics are necessary to include fracture characteristics in process models or TSPA abstractions. As discussed in the previous comment, DOE believes it has adequately characterized fractures to support the development of process models and abstractions needed for TSPA. DOE does not view the work described in the discussion of Current and Future Modifications of Fractures as necessary to support the evaluation of performance.

9. Section 4.4.1.2, page 86, paragraph 4: The last sentence in the paragraph states that the Staff does not consider the treatment of regional tectonic models in the DOE's Yucca Mountain Site Description (U.S. Geological Survey, 1998) to be complete or adequate. The Site Description is a CRWMS M&O document. The reference to U.S. Geological Survey 1998 is for the PSHA. However, the PSHA is also a CRWMS M&O document.

   DOE intends to provide an adequate discussion of tectonic models in the Site Description. DOE suggests that the references for the Site Description and the PSHA be corrected throughout the IRSR.

10. Section 4.4.1.2, pages 91-93, The Role of Faults in the Distribution of Dikes and Volcanoes: This discussion seems out of place in the Structural Deformation and Seismicity IRSR. The features and processes of primary interest should be the igneous processes that lead to the development of dikes and volcanoes along faults rather than the structural deformation that leads to the development of faults, which may eventually host a dike or act as a magma conduit supplying a volcano. Also, the discussion in the summary of this section (p. 94, item 3) notes that moderate to low angle faults may be able to capture dikes within 1 km of the earth's surface. The relevance of this statement to a discussion of regional tectonic models is not clear

because most tectonic models scarcely acknowledge the upper kilometer of the earth's crust and are not capable of depicting details of features and processes in that horizon.

DOE acknowledges the validity of the topic of structural control on volcanic features, but we suggest that the topic be deleted from the Structural Deformation and Seismicity IRSR and addressed only in the Igneous Activity IRSR. Because regional tectonic models are not capable of portraying fault capture of dikes in the upper kilometer of the earth's crust, DOE suggests that the discussion of low angle faults in the upper kilometer of the earth's crust capturing dikes be deleted.

11. Section 5.2.1, page 109, middle of paragraph: The statement, "Other models, however, were explicitly developed for the PSHA..." appears to refer to earthquake recurrence models; but this is not clear. If it does refer to earthquake recurrence models, it is not clear which models are included. Also, attenuation models were developed for defined rock conditions only – not soil.

    DOE suggests that the NRC staff provide clarification of whether the description refers to earthquake models and, if so, which models are included. DOE also requests the description be revised to specify that attenuation models were developed only for defined rock conditions.

12. Section 5.2.1, page 109, Path To Resolution Item 1: The description of Item 1 is not correct. As described in the AMR Preliminary *Seismic Design Ground Motion Inputs for a Geologic Repository at Yucca Mountain* (CRWMS M&O in prep.), design ground motions have been developed for a surface site above the repository for annual exceedance frequencies of 10^{-3} and 10^{-4} using site response analysis (not soil amplification). Preliminary ground motions have also been calculated for the site of the proposed waste handling building (WHB) for 10^{-3} and 10^{-4} annual exceedance frequencies. Contrary to the IRSR discussion, hazard curves have not been calculated for the WHB.

    DOE is defining the scope of the work planned to finalize seismic design ground motion inputs. DOE suggests the IRSR be revised to address the points made in this comment.

13. Section 5.2.1, page 110, Path To Resolution for Criterion 3, Item 2: The description of Item 2 is not correct. The ground motion experts addressed near-source directivity effects in their interpretations by considering the results of numerical modeling performed as part of the Scenario Earthquake Modeling Project (Schneider *et al.*, 1996) and modeling performed as part of the expert elicitation (CRWMS M&O, 1998a, Section 5 and Ground Motion Data Package Vols. 1, 1B and 2).

    Because near-source directivity effects have already been considered in the PSHA expert elicitations, DOE has adequately considered near-source directivity. Therefore, we believe that further work on this topic is unnecessary.

14. Section 5.2.1, page 110, Path To Resolution Item 3: The need for this item is not clear. Inconsistencies in the treatment of aleatory and epistemic uncertainties were identified in interviews with the ground motion experts (CRWMS M&O, 1998). These inconsistencies were not the result of differences in scientific judgment but from misconceptions or other inconsistencies. Removal of these unintended differences was one of the main goals of the

expert elicitation process. The treatment of uncertainty was thoroughly reviewed for each expert and each expert subsequently worked out how it should be applied in the context of his estimates. The sensitivity of the total hazard to the expert interpretations is discussed in Section 7.4.3 of the PSHA (CRWMS M&O 1998a). The mean plus and minus σ curves shown in Section 7 of the PSHA reflect the effect of σ_σ (each experts' assessment of epistemic uncertainty in σ) on the uncertainty in the calculated hazard. σ_σ also affects the mean hazard since the calculated hazard is a nonlinear function of σ (CRWMS M&O, 1998a). σ_σ is highest for expert John Anderson and to a lesser extent for expert David Boore than for the other experts. The importance of σ_σ does increase as frequency decreases.

DOE believes that sufficient understanding of the importance of uncertainty has been demonstrated and that uncertainty has been adequately considered in the PSHA expert elicitation. DOE views any further work on this topic as unnecessary.

15. Section 5.2.1, page 110, Path to Resolution Item 4: The meaning of the term "binning" is not clear. The term could be a reference to the deaggregation of M, R, and epsilon.

    DOE suggests that the meaning of the term "binning" be clarified.

16. Section 5.2.1, page 111, Path to Resolution: The discussion in this section indicates that resolution of seismicity issues is being linked to review of AMRs and to review and acceptance of the TSPA. Seismicity issues are properly resolved by the PSHA, and DOE believes it is unnecessary and confusing to link resolution to AMRs or the TSPA. The discussion also seems to suggest that the NRC is expecting the AMRs to be discussed in Seismic Topical Report III.

    DOE believes that the planned content for Seismic Topical Report III (as discussed with the NRC staff) will provide an adequate basis to close remaining open seismic issues. However, discussion of postclosure consequence analysis and its treatment in TSPA will be provided in AMRs, the Disruptive Events Report, and TSPA-SR.

    DOE recommends that the IRSR text be revised to address this comment.

17. Section 5.4.1, page 122, Analysis of Subissue Resolution, last sentence: "The use of tectonic models ...." The PSHA shows that only the planar fault tectonic model is given enough weight by the expert teams to warrant further consideration with respect to fracture evaluation. The alternative models can be ruled out on the basis of low weighting by the experts during the expert elicitation. Moreover, only the upper kilometer or so is being modeled in the scope of the work planned to determine seismic design ground motion inputs. This being the case, tectonic models, which have influence principally at depths greater than at least 5 km, should have no influence on fracture formation at the shallow depths being modeled in the transport model. Rather, the geometry and dimensions of the planer faults and other processes, (e.g., cooling of the volcanic flows, and similar processes) are important for fracture evaluation at this shallow depth.

This same comment applies to page 124, partial paragraph at the top of the page, last sentence, and to the discussion at the bottom of page 124 and top of page 125.

DOE suggests that the descriptions identified be revised to reflect the information contained in this comment.

18. Enclosure 2, page 4, DOE Comment 6, Tectonic Models Used for Evaluation of Volcanic Hazard: The NRC response asserts that models used in the PVHA and TSPA-VA are not consistent with models of tectonic features or models used in the PSHA.

    Tectonic information, data, models, and processes were used in both PSHA and PVHA. This tectonic information was evaluated by the PSHA and PVHA experts to identify and characterize seismic sources, volcanic sources, and so on. Although volcanic and seismic sources differ, this difference does not imply that volcanic source-zone models in PVHA are inconsistent with tectonic features or with models used in PSHA.

    Tectonic models of volcanic activity were considered in defining volcanic sources as well as in calculating recurrence and spatial distribution of volcanic events. The experts were asked to evaluate the relevance of fault control for the occurrence of volcanism in the Yucca Mountain region. The summary remarks are excerpted from the *Probabilistic Volcanic Hazard Analysis for Yucca Mountain Nevada* (CRWMS M&O 1996, Appendix E).

    The PVHA experts considered tectonic-structural control of magma ascent and formed two alternative interpretations: 1. Location and timing of intrusion is a function of mantle petrogenesis (Carlson, Walker), or 2. Location and timing of intrusion is controlled by crustal tectonics (Hackett, Kuntz, McBirney, Thompson, Sheridan). Most of the experts considered that magma ascent is related to extension (Crowe, Fisher, Hackett, Sheridan, McBirney, Thompson) but only McBirney, Thompson and Sheridan offered explicit statements local structural control. These experts gave weight to a pull-apart basin controlled by local but deep-seated normal faults. Strike-slip faulting related to Walker Lane deformation was interpreted as a possible structural control (Crowe, McBirney), but strike-slip alone was not considered to be a control on magma ascent. No expert gave weight to detachment faulting as a control for magma ascent.

    The PSHA instructions required explicit consideration of tectonic models, and each of the six expert teams followed these instructions with care. The teams evaluated known tectonic models and they were allowed to modify or to combine the models in any way that addressed the issue of fault geometry and fault plane interrelations. The teams were required to rank models according to the likelihood that these models accounted for faulting at Yucca Mountain.

    Reviews of the PVHA and PSHA documents show that the tectonic model given the highest weight by most experts is the planar fault model. According to this model, Crater Flat basin is a graben-like structure bounded by planar normal faults that descend to the base of the brittle crust. Yucca Mountain is a part of the basin and is cut by block-bounding faults that are also planar to seismogenic depths. Most experts believe that the basin has been modified by dextral shear but that it is not cut by a jog within a transcurrent strike-slip fault. The detachment model is given very low weight by most experts, and the caldera model is given none.

Based on the above information, DOE disagrees with the NRC staff's assertion that volcanic source-zone models used in the PVHA and TSPA-VA are not consistent with observed tectonic features or tectonic models used in the PSHA. Hence, DOE maintains that volcanic source zone models used in PVHA and TSPA-VA are consistent with observed tectonic features and also with tectonic models used in the PSHA.

DOE suggests that the assertion be deleted.

19. Section 5.4.2, page 125: Contradictory information is provided in section 5.4.2 and Appendix D of the IRSR regarding the resolution status of Site Characterization Analysis (SCA) comments 8, 47, 68, and 98. Section 5.4.2 lists the SCA comments as open, but Appendix D indicates that they are resolved.

    DOE suggests that the resolution status of several items be corrected in Section 5 of the next revision of the IRSR to show that these comments have been resolved.

20. Section 4.1.1, page 18, paragraph 3: The relevance of the reference to Youngs and Coppersmith, 1985 is not clear. The paper discusses earthquake recurrence models, not hazards.

    DOE suggests the reference be deleted.

21. Section 4.3.1.2, page 66, top of the page: The description of the Prow Pass and Bullfrog members of the Crater Flat Group is incorrect. The Prow Pass Tuff and Bullfrog Tuff have been formally designated as formations. (See Sawyer et al. 1994, page 1305 and Table 1.)

    DOE suggests that the description be revised to reflect the stratigraphy of Sawyer et al. (1994), especially since this reference is cited in the description as the source of the most recent regional stratigraphy.

22. Section 4.4.1.1, page 82, Criterion 4: The statement of this criterion is missing some words.

    DOE suggests that the criterion be revised as appropriate.

23. Section 4.4.1.1, page 86, paragraph 3: The text "latter five are dominantly..." is incorrect.

    DOE suggests the text be corrected to read "latter two are" or preferably "last two are"

24. Section 4.4.1.1, page 88, last paragraph: Figure 3.3-1 is not in USGS (1998) or in CRWMS M&O (1998).

    DOE suggests that the figure source be identified and the reference corrected.

25. Appendix C-1, page C-3: The Wong et al (1995) reference is not in the reference list. The correct reference is probably CRWMS M&O (1998).

    DOE suggests that the reference citation be corrected.

References

CRWMS M&O 1996. *Probabilistic Volcanic Hazard Analysis for Yucca Mountain, Nevada.* BA0000000-01717-2200-00082 REV 0. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971201.0221.

CRWMS M&O 1998a. *Probabilistic Seismic Hazards Analyses for Fault Displacement and Vibratory Ground Motion at Yucca Mountain Nevada Final Report.* Milestone Report SP321M3. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981207.0393.

CRWMS M&O 1998b. "Geology." Book 1 - Section 3 of *Yucca Mountain Site Description.* B00000000-01717-5700-00019 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980729.0049.

CRWMS M&O 1999. *Full Periphery Geotechnical Mapping, Strike and Dip Data Entry Correction Analysis.* BCAA00000-01717-0200-00016 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990326.0347.

DOE (U.S. Department of Energy) 1999. U. S. Department of Energy (DOE) Review of U.S. Nuclear Regulatory Commission's (NRC) Structural Deformation and Seismicity Issue Resolution Status Report (IRSR), Revision 1: Letter S. J. Brocoum to C. W. Reamer, dated May 11, 1999, Las Vegas, Nevada, Yucca Mountain Site Characterization Project Office, 3 pages with enclosure. Letter MOL.19990615.0068; Enclosure MOL.19990615.0069.

McKenzie, D.G., 2000. Input Transmittal for Possible Rock Block Geometry, Dimension, Orientation, Probability and Masses, Document number WP-SSR-00027.T, February 2, 2000 ACC:MOL. 20000208.0344.

NRC (U.S. Nuclear Regulatory Commission) 1999. Issue Resolution Status Report Key Technical Issue: Structural Deformation and Seismicity, Revision 2, September 1999. Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC: MOL.19991214.0623.

Sawyer, D.A.; Fleck, R.J.; Lanphere, M.A.; Warren, R.G.; Broxton, D.E.; and Hudson, M.R. 1994. "Episodic Caldera Volcanism in the Miocene Southwestern Nevada Volcanic Field: Revised Stratigraphic Framework, 40Ar/39Ar Geochronology, and Implications for Magmatism and Extension." *Geological Society of America Bulletin, 106* (10), 1304-1318. Boulder, Colorado: Geological Society of America. TIC: 222523.

Schneider, J.F.; Abrahamson, N.A.; and Hanks, T.C. 1996. *Ground Motion Modeling of Scenario Earthquakes at Yucca Mountain, Final Report for Activity 8.3.1.17.3.3.* Volume 1. Denver, Colorado: U.S. Geological Survey. ACC: MOL.19980617.0477.