REVIEW OF DOE STUDY PLAN 8.3.1.4.2.2

CHARACTERIZATION OF STRUCTURAL FEATURES IN THE SITE AREA (REV 2)

Prepared for

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1 GENERAL CONCERNS

Content of study plan is acceptable with respect to requirements specified in the 1993 DOE/NRC Level of Detail Agreement relative to (1) Purpose and Objectives, (2) Scope of Work, (3) Application of Results, and (4) Schedule.

The terms "fracture" and "fault" are used in the discussion to refer to breaks in the rock mass resulting from brittle mechanical failure. In fact, as defined in the American Geological Institute (AGI) Glossary of Geology (1987), "fracture" is a general term which includes both faults (fractures with displacement) and joints (fractures without displacement). In various parts of the study plan, "fracture" may refer to both faults and joints; while in other parts of the study plan, it appears to refer only to joints. Care should be taken in the text to use the term correctly, so that there is no confusion on the part of the reader regarding which type of brittle failure feature is being discussed. In this discussion of review comments, "fracture" is properly used to indicate both faults and joints. "Joint" and "fault" are used when it is important to make the distinction.

This study plan does not discuss a number of key issues for geophysical testing which may affect the success of the various tests. These factors include, but are not limited to, seismic wave propagation characteristics including attenuation, dispersion, and anisotropy; seismic source tool characteristics, including output strength and useful frequency content; resolution and detection threshold; and borehole spacing. It is not clear whether discussion of such issues will be done in technical procedures, since none are referenced.

The method or methods by which interpretation and integration of collected data will be accomplished are not addressed in sufficient detail.

The potential for using laboratory studies on core samples to help quantify geophysical properties, improve survey designs, and enhance the potential for success of the geophysical activities is not considered.

2 SPECIFIC CONCERNS

QUESTION 1 (Editorial) — Should "controlled area" be labeled on Figure 1-1 or defined in the text of the study plan?

Statement of Concern

Page 1-1, Section 1.1, 2nd paragraph, lines 1-2: The sentence refers to characterization of "fracture and fault systems" (see 2nd paragraph, General Concerns) inside the controlled area, with reference to Figure 1-1 for (implied) location of the controlled area. However, the "controlled area" is neither labeled on Figure 1-1 nor defined in the text.

Basis

Notwithstanding the sentence referenced above, the controlled area is not specifically labeled on Figure 1-1 or defined in the text.

Recommendation

Even though the informed reader may be aware, from definitions in 10 CFR 60.2, that the controlled area is the area included within the boundary of the accessible environment (which is labeled on Figure 1-1), to avoid possible confusion consider labeling the controlled area on the figure or defining "controlled area" in the text.

References

10 CFR Part 60

QUESTION 2 — Should physical properties of faults be included under more of the parameter listings in Table 1-2?

Statement of Concern

Page 1-2, Section 1.2, 1st paragraph, lines 2-4: Table 1-2 is referenced as showing information needs to be satisfied. Although "fault location and geometry" and "fracture geometry and properties" are commonly covered, physical properties of faults (e.g., slip amount, slip direction, type of slip, age of slip, nature of fillings, etc.) are generally not mentioned. (Physical properties of faults are listed under parameters only under Issue 4.4, page T-7 of Table 1-2.) There is also no mention of collection of *in situ* stress data.

NOTE: Clarification of the point raised in 2nd paragraph, General Concerns, about correct use of the term "fracture" may help resolve this concern. "Fracture" is clearly defined in the AGI Glossary of Geology (1987) as follows: "A general term for any break in a rock, whether or not it causes displacement, due to mechanical failure by stress. Fracture includes cracks, joints, and faults."

Basis

Inclusion of collection of "fault properties" data appears to be consistently omitted from this table, even though the reader is certain such information is planned for collection by the DOE. Both physical and hydrologic characteristics of faults and joints will be important information to acquire.

Recommendation

Consider including fault properties more universally in pertinent parts of Table 1-2 to indicate these data will also be collected, and clearly specify faults and joints where both are meant to be treated. Also consider whether *in situ* stress data should be included under information needs.

References

Bates, R.L. and J.A. Jackson, eds. 1987. *Glossary of Geology (3rd edition)*. Alexandria, Virginia: American Geological Institute.

QUESTION 3 — Can the statement that no regulations call for assessment of structural features be clarified?

Statement of Concern

Page 1-3, 1st paragraph, lines 1 and 3: The statements, "Although no regulations explicitly call for this study, ..." and "Briefly, those regulatory requirements . . . are . . . ." appear to present conflicting statements about whether the regulations call for assessment of structural features.

Basis

Siting criteria of 10 CFR 60.122 are referenced in the study plan, suggesting the first sentence doesn't reflect the same idea as the third sentence. Specifically, potentially adverse conditions under 60.122(c)(4) and 60.122(c)(11) relate directly to structural deformation. Deformation and regional groundwater flow are covered under (c)(4); deformation during the Quaternary, under (c)(11).

Recommendation

Consider clarifying the statement that no regulations call for assessment of structural features in the site area.

References

10 CFR Part 60

QUESTION 4 — In addition to mechanically cleared pavement surfaces, can natural exposures be used to determine abutting relationships, connectivity, and relative ages of fractures?

Statement of Concern

Page 2.2-1, Section 2.2, all paragraphs: It does not appear that Table 2.2-1 (Tests for surface fracture studies) is referenced in this discussion. The table indicates abutting relationships are normally done on pavement studies only.

Basis

Natural exposures may also be used for determining abutting relationships (connectivity) and consequent relative ages of fractures, however, this is not mentioned.

Recommendation

Consider that some natural exposures also may be used to determine abutting relationships and relative ages of fractures. Also, add reference to Table 2.2-1 in the text where appropriate.

References

None

QUESTION 5 — Can early reference be made to the need for obtaining cross-cutting relationships of fractures and the importance of comparing surface and subsurface fracture data?

Statement of Concern

Page 2.2-1, Section 2.2.1, 2nd paragraph, lines 3-7: Fracture network properties are mentioned for analysis of pavements and outcrops, but there is no statement in this list of properties about cross-cutting relationships and relative ages of faults and joints. (However, relative ages of fractures are mentioned on page 2.2-1, Section 2.2.2.1, last paragraph, last sentence.) Collection of the listed data on surface fractures will be important data for comparing with subsurface information when that phase of data collection begins.

Basis

Ascertaining cross-cutting relationships and relative ages may be important for separating faults and joints into distinct sets with a specific genesis. All information from surface fracture studies is potentially important for comparing surface data with subsurface information on fractures.

Recommendation

Consider early reference to the need for obtaining cross-cutting relationships of fractures as a part of data collection, and recognition of the importance of comparing surface and subsurface fracture data.

References

None

QUESTION 6 — Can early reference be made to the need for investigating both lateral and vertical variability in fractures?

Statement of Concern

Page 2.2-2, Section 2.2.2.1, 3rd paragraph, lines 2-3: Reference is made to obtaining sampling of lateral variability in fractures in the volcanic units, but not to investigation of vertical variability. (However, reference is made to lateral and vertical coverage on page 2.2-3, Section 2.2.2.2, 1st paragraph, line 1.)

Basis

If the relief is adequate, investigation of vertical variability in fractures both in and between units may provide useful data for comparison with subsurface information on fractures.

Recommendation

Consider adding an early statement regarding investigation of vertical variability in fractures.

References

None

QUESTION 7 — Will the area north of Yucca Wash (outside the "controlled area") be investigated to understand the importance of the difference in structural styles between that area and Yucca Mountain?

Statement of Concern

Page 2.2-3, Section 2.2.2.2, 2nd paragraph: Discussion of the number of sites is undertaken, but it is not clear if any study of structures outside the controlled area will include looking north of Yucca Wash where the structural style appears to change (as indicated on page 2.1-3, 1st paragraph, lines 1-2).

Basis

It is uncertain whether this noted change in structural style north of Yucca Wash is important for understanding the structural picture of Yucca Mountain.

Recommendation

If another study plan is meant to address structures north of Yucca Wash, consider providing a cross-reference to that study plan. If this work is not planned, consider discussing why it is not deemed to be important for understanding structures at and around Yucca Mountain.

References

None

QUESTION 8 — Will new, non-standard, or untested techniques be employed for field mapping and analysis of fractures at the surface?

Statement of Concern

Page 2.2-5, Section 2.2.3.4, last sentence of paragraph and Section 2.2.3.6, last sentence of paragraph: Reference is made to "validation of field methods" and "techniques developed in this activity" without any detailed discussion of new, non-standard, or untested techniques which may be employed.

Basis

It is not clear whether new, non-standard, or untested techniques will be developed and used for field mapping and analysis of surface fractures.

Recommendation

If new techniques for mapping surface fractures in the field are to be developed, consider providing more information on what is anticipated for these new techniques.

References

None

QUESTION 9 — Should it be stated that integration of surface and subsurface data is necessary for characterization of fractures in three dimensions?

Statement of Concern

Page 2.3-1, Section 2.3.1, 3rd paragraph, line 1: The statement is made that, "Core fracture logging provides all . . . required activity parameters (Table 2.3-1) . . . ." While core fracture logging may provide information on all parameters listed in Table 2.3-1, this list of parameters is not sufficient to characterize fractures in three dimensions. Surface and subsurface fracture data must be integrated.

Basis

Clearly, parameters in addition to those listed in this table are required to characterize faults and joints in three dimensions through integration of surface and subsurface data. Other parameters important for three-dimensional characterization of fractures include: trace length of fractures, physical properties of fault zones (e.g., width, amount, and type of slip, physical nature of fault zone). These parameters should be determined from surface studies, and the information integrated with information from core fracture logging. From efforts on underground mapping at the Underground Research Laboratory (URL) in the Canadian crystalline rock program, Everitt and others (1990) have clearly specified the importance of developing maps showing combined results from wall mapping, core logging, and borehole logging.

Recommendation

In order to indicate these are not the only parameters needed to characterize fractures in three dimensions, consider mentioning the importance of the integration of surface and borehole data.

References

Everitt, R.A., A.E. Chapman, A.V. Grogan, D. Laderoute, and A. Brown. 1990. *Geological Characterization for the URL Shaft Extension*. Atomic Energy Canada Limited (AECL) Technical Report 508. AECL.

QUESTION 10 — Will optimum borehole separation distances for transmissivity of energy be considered in location of boreholes?

Statement of Concern

Page 2.3-3, Section 2.3.2.1, 2nd paragraph, lines 1-4: The statement is made that, "Number and location of boreholes . . . are chosen to characterize spatial variability of rock characteristics . . . and to provide sufficient area coverage of the site . . . ." However, no discussion is provided about separation distances of boreholes and energy attenuation effects.

Basis

Borehole separation distances and transmissivity of energy between boreholes is not discussed. If holes are too far apart energy will be attenuated, possibly hindering acquisition of useful data.

Recommendation

Consider energy attenuation as an added factor in determining the separation distance of boreholes. Preliminary calculations could be done to make reasonable guesses about attenuation parameters. In addition, preliminary tests to quantify attenuation using core samples could be done before the drilling program is started.

References

None

QUESTION 11 — Will features mapped photogrammetrically be adequately field checked to assess their geological significance?

Statement of Concern

Page 2.4-5, 1st paragraph, lines 3-5 and 3rd paragraph, lines 1-4: On this page and others, there is an impression given to the reader that some features mapped photogrammetrically will not be carefully and systematically related to structures in the field or field checked.

Basis

Notwithstanding the advantage of photogrammetry in generating extensive detailed records (Hagen, 1980), field observation of structures may be considered one of the best ways of assessing data shown on a map. From the information presented in this study plan, it is not clear that pertinent features determined from the photogrammetric approach will be checked against what occurs in the field. As pointed out by Hardin (1992), detailed geologic inspection is needed to support photogrammetric mapping for recording lithology, collecting samples, observing and recording fracture surfaces and fracture fillings, describing key geologic and structural features and performing scanline mapping for quality control. Hardin (1992) also indicates the results from photogrammetric mapping have not been thoroughly compared for accuracy with products of conventional mapping.

Recommendation

Consider clarifying early in this discussion how structures mapped photogrammetrically will be proven to be structural features of importance by the process of field checking. Consider adding more descriptive explanation of the photogrammetric method, or cross-referencing a technical procedure if the information is to be presented therein.

References

Hagen, T.O. 1980. A case for terrestrial photogrammetry in deep-mine rock structure studies. *International Journal of Rock Mechanics, Mining Sciences and Geomechanics Abstract*. 17:191-198.

Hardin, E. 1992. *Survey of in situ Testing at Underground Laboratories*. Statens Kärnbränsle Nämnd (SKN) Report 59. Goteborg, Sweden: SKN (Swedish National Board for Spent Nuclear Fuel).

QUESTION 12 — Have photographic base maps been considered for mapping of underground surfaces to assure no pertinent data are lost?

Statement of Concern

Page 2.4-4, bullet 2, lines 1-2: " . . . critical data . . . lost by conventional mapping." On this page and others, the idea is presented that conventional mapping is an inferior way of recording structural data compared to photogrammetric mapping.

Basis

Critical data need not be lost by conventional mapping. A possible option is to use a photograph of the surface being mapped as the base map, enabling the mapper to carefully locate all pertinent structures on an overlay atop the photograph during the mapping process.

Recommendation

Consider using photographic base maps for surfaces being mapped, possibly as was done in photomosaic mapping at the URL in the Canadian crystalline rock program (see Everitt and others, 1990 and Hardin, 1992). More thoroughly address the concerns about careful field checking of data shown on the photogrammetric base as discussed under Question 11.

References

Everitt, R.A., A.E. Chapman, A.V. Grogan, D. Laderoute, and A. Brown. 1990. *Geological Characterization for the URL Shaft Extension*. Atomic Energy Canada Limited (AECL) Technical Report 508. AECL.

Hardin, E. 1992. *Survey of in situ Testing at Underground Laboratories*. Statens Kärnbränsle Nämnd (SKN) Report 59. Goteborg, Sweden: SKN (Swedish National Board for Spent Nuclear Fuel).

QUESTION 13 — Will there be a trace-length limit imposed for fractures being mapped?

Statement of Concern

Page 2.4-3, 2nd paragraph, lines 5-6: The statement is made that, "If time is short, fewer planar features may be measured . . . ." without any indication of whether there will be a trace-length limit imposed for fractures being mapped.

Basis

The above statement is made without any indication of whether all fractures are planned for mapping, or whether there will be a trace-length limit imposed for what is mapped.

Recommendation

Consider qualifying the trace length limit of structures planned for the geological mapping.

References

None

QUESTION 14 — Will geology of the features play a role in determining the interval and scale at which features will be mapped?

Statement of Concern

Page 2.4-4, 5th paragraph, lines 1-3: The statement is made that, ". . . data redundancy . . . kept within . . . limit by adopting a system of selected-interval mapping." There is no discussion of how the existing geology (e.g., spacing and complexity of structures) should play a key role in defining the mapping interval.

Basis

The geology of the features should dictate the mapping interval to some degree, since important structures or structural zones may require a more careful look than other areas. Careful appraisal of the faces is important to determine if they should be mapped in detail, rather than imposing a standard spacing for underground mapping. The concern again is related to a possible lack of field checking of features which will be mapped photogrammetrically, as discussed under Question 11.

Recommendation

Consider discussing how geology will play the key role in what features will be mapped, and at what interval and scale.

References

None

QUESTION 15 — Is it recognized that a prime reason for the ESF is collection of subsurface geological data?

Statement of Concern

Page 2.4-6, Section 2.4.2.2, 1st paragraph, lines 4-5: "To minimize interference with mining . . . ." Page 2.4-9, Section 2.4.3.6, line 1: ". . . mapping will be driven by the rate of excavation progress." Other references are also made elsewhere to concerns about the time required to record underground data. These statements do not appear to place emphasis on collection of geological data in the ESF, a main reason for this facility.

Basis

While it is understood that excavation time is important, emphasis should be placed on collection of important geological data in the ESF because this is a prime reason for this facility. Information to be acquired is very important site characterization data.

Recommendation

Consider stressing the concept that a most important reason for the mapping program in the ESF is to acquire important and much-needed subsurface data on faults and joints.

References

None

QUESTION 16 — Why is there no discussion on resolution and detection thresholds of the seismic methods being proposed?

Statement of Concern

Page 2.5-1, Section 2.5.1, paragraph, lines 7-9: The statement is made that, "Variations in lithology and fractures . . . can be detected, located, and characterized by seismic methods, because they represent mechanical anomalies . . . ." There is no discussion of the factors which influence what can be detected using these methods.

Basis

This is a blanket statement. Resolution, detection threshold, wavelength, and open versus closed versus filled fractures all influence what can be detected. The seismic methods proposed determine variations in seismic impedance, which seismologists usually reduce to seismic velocity contrasts. These data are then interpreted to give information on lithology and fractures when possible. Detecting fractures by seismic methods is an active area of research, and concise detection is not a certainty. The plan is written as if fracture detection is assured by using these methods.

Recommendation

Resolution and detection thresholds should be discussed, especially concerning the threshold size of detectable fractures, as part of the rationale statement.

References

None

QUESTION 17 — Is it possible to further qualify why seismic reflection will not be used and to address whether information from other studies which will use this method may provide helpful information for fracture characterization?

Statement of Concern

Page 2.5-1, Section 2.5.1, lines 9-13: The statement is made that seismic reflection, ". . . was not selected because . . . it is very difficult to obtain reflection data . . . to define either near-vertical features or small-scale features . . . ." There is little qualification why seismic reflection will not be used. And, there is no reference to other studies which will apply this method.

Basis

It is not clear exactly what is meant by "difficult." The proposed cross borehole studies are also "difficult," especially if the goal is determination of fracture characteristics.

While seismic reflection may not reveal small-scale structures at Yucca Mountain, whether such studies would reveal useful information about faults and fault zones (e.g., subsurface fault geometry) is another matter. It appears that other DOE study plans may use seismic reflection to investigate stratigraphic variations and structures in the region, but these study plans are not cross-referenced in this study plan. Seismic reflection has been successfully used to investigate geometry of faulting at depth in the Amargosa Desert (Brocher and others, 1993).

It is not obvious that an integration of borehole logging, cross borehole, and surface seismics (specifically shallow 3-D seismic) would not be better than only borehole logging and cross borehole investigations.

Recommendation

Consider qualifying the plan to not use seismic reflection, and addressing whether information may be gained from other studies which will use seismic reflection.

References

Brocher, T.M., M.D. Carr, K.F. Fox, Jr., and P.E. Hart. 1993. Seismic reflection profiling across Tertiary extensional structures in the eastern Amargosa Desert, southern Nevada, Basin and Range Province. *Geological Society of America Bulletin* 105:30-46.

QUESTION 18 — At this stage, is it possible to provide information on borehole separation distance for the C-holes?

Statement of Concern

Page 2.5-1, Section 2.5.2.1, paragraph, lines 3-4: It is specified that crosshole work in the C-holes will occur over an interval of approximately 150m, with measurements every 1m. However, the issue of borehole separation distance is not addressed.

Basis

One important factor in the success or failure of crosshole work is borehole separation since signal attenuation can lead to poor data if boreholes are spaced too widely. No information is given concerning well separation distance.

Recommendation

Address the issue of borehole separation distance or cross-reference a technical procedure if the information is to be presented there.

References

None

QUESTION 19 (Editorial) — Can references be provided to specify the studies to date which have been conducted for seismic tomography?

Statement of Concern

Page 2.5-1, Section 2.5.2.1. paragraph, lines 7-8: The statement about, "Studies to date have used . . . ." is not supported by any specific references for these studies.

Basis

Statement needs references to support the information given.

Recommendation

Add supporting references.

References

None

QUESTION 20 — What specific fracture characteristics are expected to be determined from seismic tomography? What potential difficulties exist for determining fracture characteristics using seismic tomography?

Statement of Concern

Page 2.5-3, Section 2.5.3.4, paragraph, lines 3-5: It is stated that, "Analytical methods used to analyze the data must be able to produce plots and maps of fracture characteristics." However, specific fracture characteristics to be determined are not defined. And, potential difficulties in determining fracture characteristics with this method are not discussed.

Basis

It is not clear what "fracture characteristics" the test planners expect to derive from the seismic methods, since this is not summarized in the text nor presented in a referenced table. (Table 2.5-1 shows only seismic parameters and does not equate them with fracture characteristics.) The wavelength needed to record data (i.e., ~ 10 feet or greater) may be too long to resolve anything but fracture location, and even that can be accurately done only under optimal conditions.

In addition, under optimal conditions, seismic methods can determine impedance contrasts, attenuation, anisotropy, and dispersion. These data must be interpreted to give the desired information, and that interpretation is not necessarily unique.

Recommendation

State the specific fracture characteristics expected to be determined. Consider discussing the potential difficulties in determining fracture characteristics with this method.

References

None

QUESTION 21 — If tectonic fractures exist and can be reorganized, why should preferred orientations not show up for fractures rather than orientations spanning the entire range? What is meant by "entire range" orientation?

Statement of Concern

Page 3.2-4, Section 3.2.5, 1st line of listing beneath paragraph: It is indicated that fracture orientation (azimuth of strike) will span the "entire range." There is no suggestion that preferred orientations are expected.

Basis

It is not clear why statistical fracture sets are not expected to show up if tectonic faults and joints exist at the site. The referenced statement suggests azimuths may show no preferred orientations. If fractures are analyzed to assure those of tectonic origin are distinguished from those of other origins (e.g., cooling fractures), preferred orientations should show up in a stereonet plot of poles to fractures.

Recommendation

Consider qualifying why azimuths will span the "entire range" and not show preferred orientations if tectonic fractures exist and can be recognized.

References

None

QUESTION 22 — Why is there no indication that integration of borehole and surface data on fractures is necessary to characterize fractures in three dimensions?

Statement of Concern

Page 3.3-1, Section 3.3.1, listing under 4th paragraph: In connection with the listing of fracture parameters to be measured in boreholes, there is no recognition that borehole data should be integrated with surface information on fractures to characterize the fracture pattern. All parameters necessary for characterizing fractures in three dimensions do not come from boreholes above (see Question 9).

Basis

"Observed length" of fractures in the borehole is not equivalent to fracture trace length. This list does not present all necessary parameters for quantifying faulting and jointing of the rock mass, so it may be useful to suggest borehole and surface data will be integrated as necessary to make it possible to characterize the fracture pattern at Yucca Mountain in three dimensions.

Recommendation

Consider stating that borehole data must be integrated with surface information on fractures to characterize the fracture pattern, since all parameters necessary for characterizing fractures do not come from boreholes alone.

References

None

QUESTION 23 — Why is there no discussion of determination of *in situ* stress?

Statement of Concern

Page 3.3-2, Section 3.3.2, Reference to Table 3.3-1: *In-situ* stress is shown in Table 3.3-1, but there is no discussion of this topic in the text of the study plan.

Basis

Measurement of *in situ* stress may provide useful information, but there is no discussion of this topic although it is included in Table 3.3-1. Apparently no hydrofrac studies are planned for investigation of *in-situ* stress, and the acoustic televiewer will be used. The televiewer can be used to analyze borehole "breakouts" for establishing a possible relationship of the "breakouts" to *in-situ* stress.

Recommendation

Consider adding a brief discussion on *in-situ* stress determinations using the acoustic televiewer or cross-referencing a technical procedure if the information will be presented there.

References

None

QUESTION 24 — What details of rock structure are expected to be determined from crosshole seismic studies?

Statement of Concern

Page 3.5-1, Section 3.5.1, 2nd paragraph, lines 3-5: It is indicated that crosshole work in C-holes will be done to determine details on rock structure. However, no information is provided on exactly what details are to be determined.

Basis

Considering potential difficulties with detection of fractures using this method, it is not clear what details of rock structure are expected to be determined.

Recommendation

Consider clarifying what details are expected from application of the method.

References

None

QUESTION 25 — What is the basis for the number of traces chosen for the VSP work?

Statement of Concern

Page 3.5-3, Section 3.5.1, 1st paragraph, lines 1-3: For the statement about 9 traces per offset for the VSP work, there is no basis given to support the selection of this number of traces.

Basis

The basis for the estimation of the number of traces is not clear.

Recommendation

Consider adding information to provide the basis for the number of traces anticipated.

References

None