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STATE OF NEVADA

AGENCY FOR NUCLEAR PROJECTS/ NUCLEAR WASTE PROJECT OFFICE

STATE OF NEVADA COMMENTS

ON THE

U.S. DEPARTMENT OF ENERGY

SITE CHARACTERIZATION PLAN

YUCCA MOUNTAIN SITE

NEVADA

VOLUME I

THE GREAT SEAL OF THE STATE OF NEVADA

ALL FOR OUR COUNTRY

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Part 1

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STATE OF NEVADA COMMENTS

ON THE

U.S. DEPARTMENT OF ENERGY

SITE CHARACTERIZATION PLAN

YUCCA MOUNTAIN SITE

NEVADA

VOLUME I

PREPARED BY

NEVADA AGENCY FOR NUCLEAR PROJECTS/
NUCLEAR WASTE PROJECT OFFICE

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INTRODUCTION

In December 1988, the U.S. Department of Energy issued a Site Characterization Plan (SCP) for the Yucca Mountain site, as required by Section 113 of the Nuclear Waste Policy Act of 1982 (NWPA). The purpose of site characterization is to develop sufficient information to support a determination of the suitability, or lack of suitability of the site to safely isolate high-level radioactive waste with reasonable certainty for thousands of years. The purpose of the Site Characterization Plan is to describe plans for obtaining sufficient information about the site, plans for mitigation of any adverse impacts occurring from site characterization activities, and plans for decontamination and decommissioning of the site if it is determined not to be suitable for a repository.

In September 1988 the State of Nevada provided comments to the Department on its Consultation Draft Site Characterization Plan (CD-SCP)for Yucca Mountain. The purpose of issuing the consultation draft was to obtain early feedback on the approach, adequacy, and completeness of plans to characterize the Yucca Mountain Site. There comments were neither acknowledged nor considered in the development of the SCP. On June 1, 1989 the State issued preliminary comments on the exploratory shaft facility (ESF) portion of the SCP. These has been no response by the Department to these preliminary comments.

The SCP remains an incomplete plan for study of the Yucca Mountain site. For example, it provides little in the way of required technical study activities and plans for decontamination and decommissioning of the site. Therefore, these comments may be revised when more complete plans for the project become available. The comments presented here represent a review by the Nevada Agency for Nuclear Projects and its technical support contractors and advisors.

Part I presents an overview of the State's comments. The overview takes the form of general concerns and comments organized by specific areas of concern. The overview does not follow the format of the SCP.

Part II contains specific comments of the Nevada Agency for Nuclear Projects. These comments respond to specifics of the SCP and do so in relation to the organizational format employed in the SCP. Because of the way it is organized, the SCP encouraged a certain degree of redundancy in our response.

Part III of this document contains the comments of the Agency's technical contractors and advisors. These comments address additional issues and contain some detailed information not contained in Parts I and II. As such, these comments are incorporated as part of the State of Nevada comments and should not be viewed as appendices to the State's comment document.

PART I

OVERVIEW

PART I

OVERVIEW

THE BASIC APPROACH OF THE SCP DOES NOT COMPLY WITH NWPA DIRECTIVE AND INTENT

In the State's comments on the CD-SCP, it was pointed out that the consultation draft was basically a licensing plan, rather than a plan for characterizing the site and determining its suitability as a location for a repository. It appears the State's comments in this regard have not been heeded. The Department's site characterization program as described in the SCP still consists of a strategy to uncover the information necessary to license, design and operate a repository at Yucca Mountain, rather than to determine whether the natural geology and hydrology of the site and its immediate environs will provide the necessary waste isolation. While the plan is replete with statements which appear to suggest that the purpose of site characterization is to determine suitability, most of the technical activities are designed to confirm previously optimistic views of site suitability.

Furthermore, the SCP again ignores what should be a fundamental aspect of any objective, well conceived and well managed site characterization program: to structure the program to determine as early as possible whether any conditions which would disqualify the site from further consideration exist. While the SCP discusses the need to determine if such condition exists, an evaluation of such findings will apparently be made only at the conclusion of the entire program. No mechanism exists, no key decision points are set out, to uncover the data necessary to make such decisions early in the program, before substantial, and perhaps unnecessary, resources are committed. The responsibility for these key decisions unquestionably lies with the Department and cannot be abrogated. In order to develop confidence in the technical programs, their progress and results, there needs to be a clear and concise understanding of the DOE decision process.

The SCP still does not comply with all of the requirements of 113(b)(1)(A) of the NWPA. Provisions of 113(b)(1)(A)(iii) require:

> " Plans for the decontamination and decommissioning of such candidate site, and for the mitigation of any significant adverse environmental impacts caused by site characterization activities if it is determined unsuitable for application for a construction authorization for a repository."

The Department, in Section 8.7, attempts to comply with this requirement by addressing those issues in "supporting documents", such as the Environmental Monitoring and Mitigation Plan. The level of specificity in Section 8.7 is certainly not equal to the other sections of the SCP or the State's view of what is contemplated by the NWPA. Since the supporting documents were not appended to the SCP, the stature of review and comment on these documents by the State and the NRC is significantly different than required for the SCP.

In the State's CD-SCP comments, it was recommended that the site characterization plan should not be finalized, and that site characterization should not begin, until final comprehensive EPA standards were in place. It appears from the SCP that the Department has ignored this recommendation and has finalized a plan whose foundation assumption is that the site already meets EPA standards and only documentation is required once the standards are promulgated. This type of pre-judged decision-making without supporting data or regulatory requirements is a further example of the lack of credible scientific methodology in the Yucca Mountain program.

<u>DOE's "REASONABLY AVAILABLE TECHNOLOGY" CONSTRAINTS HAVE NOT BEEN MET</u>

The SCP describes in general terms a large number of activities which will require the use of testing and analytical equipment and methods in order to collect the requisite data, yet there is no substantive review of the availability of state-of-the-art technology to perform the tests in a valid and verifiable manner. The Site Characterization Program is constrained to the use of "reasonably available technology", which is defined in DOE's Final Siting Guidelines (10 CFR Part 960) as "technology which exists and has been demonstrated or for which the results of any requisite development, demonstration, or confirmatory testing efforts before application will be available within the required time period." In addition to site characterization and exploratory shaft facility construction activities being constrained to the use of "reasonably available technology", repository construction, operation and closure are similarly constrained in the application of certain engineered barriers potentially necessary to enhance the natural geologic barrier system (eg. Rock Characteristics, 960.5-2-9(d); Hydrology, 960.5-2-10(d); Tectonics, 960.5-2-9(d).

The State's comments on the CD-SCP delineated specific examples (geophysical exploration, borehole logging, and unsaturated zone fluid extraction) where state-of-the-art technology are not presently capable of achieving the results anticipated in the plan. These comments still appear to be valid. The State's SCP comments identify other areas where the reasonably available technology constraint has not been met.

LACK OF ALTERNATIVE CONCEPTUAL MODELS CONSIDERATION INVALIDATES THE CD-SCP

A notable difference between the CD-SCP and the SCP is the inclusion of alternative conceptual models (ACM) tables, which are more confusing than enlightening. The ACM tables have had no impact on the development of site characterization activities themselves, which are biased to confirm the "current view" and dismiss the alternatives. Site characterization activities are designed to study the preferred model, and will not test alternative models. This biased view is especially clear in the eighth column of each ACM table which represents a judgement on the need to reduce uncertainty in the selection of hypotheses. The SCP states: "This judgement is based on the uncertainty in the current representation, the sensitivity of the performance parameters to alternative hypotheses, the significance and needed confidence of affected performance parameters, and the <u>likelihood that feasible data gathering activities could significantly reduce uncertainty</u>." (Emphasis Supplied). The need to reduce any uncertainty in the selection of hypotheses should be completely independent of this so called feasibility factor. If it is not feasible to reduce an unacceptably high level of uncertainty in the selection of any hypothesis, particularly one that effects suitability, then the hypothesis has licensing implications, and the Department should recognize that perhaps high uncertainty levels could be a disqualifying condition.

SYNOPSIS OF SPECIFIC COMMENTS

LICENSING

The SCP illustrates that either the DOE does not understand the present NRC licensing requirements or that somehow they are above the NRC licensing requirements. Particularly troublesome is the apparent DOE position that 10 CFR 100, Appendix A does not apply in any sense and therefore any guidance or precedent set by past use of 10 CFR 100, Appendix A is inappropriate to the evaluation of Yucca Mountain regarding its suitability site for a high level waste repository. This apparent DOE position directly contradicts the expressed NRC position that use of 10 CFR 100, Appendix A is conservative and appropriate for the period through permanent closure (Trapp and Coplan, 1986).

Site specific issues and their relative importance to waste isolation, are not clearly addressed. The NRC Regulatory guide 4.17 (Rev. 1, March 1987) clearly states: "the basic purpose of the SCP is simple: to provide a mechanism for identifying and delimiting the specific issues at a proposed repository site and to identify the plans for resolving those issues at an early time in order to avoid delays in the process." The SCP provides for neither of these requirements.

The SCP represents a primarily generic and generalized approach that does not recognize a full range of issues specific to the Yucca Mountain site that must be resolved. The SCP also does not recognize the need to address site suitability issues early in the site characterization program and prioritize programs to resolve these issues. Furthermore the SCP does not recognize that "surprises" or new issues may emerge during site characterization or that conflicts may occur from ambiguous data or different interpretations of physical processes from diverse lines of inquiry.

The schedule remains ambitious and vague. Much of the critical information necessary to resolving issues and determining site suitability (e.g. design earthquake, matrix vs fracture flow beneath the repository, amount of displacement to be expected on faults in the repository, natural resource potential, etc.) will not be available until the License Application is almost completed. The entire time-frame scheduled for completion, integration, and analysis of the myriad of tests and activities planned is overly optimistic. The proposed studies and activities outlined in the SCP requires a substantial commitment of earth science resources for an extended period of time, at least five-to-ten years. It is questionable whether all the work contemplated in the SCP can be accomplished at the necessary level of quality and completeness within the schedule described in the DOE Mission Plan (site characterization completed and license application submitted by 1995).

EXPLORATORY SHAFT FACILITY

The approach to seismic design for the Exploratory Shaft Facility (ESF), as presented in the SCP, is inadequate for a number of reasons. According to the schedule proposed in the SCP, the design and construction of the ESF will proceed in parallel with all of the other studies. Many of these studies have as their main objective the development of input data for the ESF design. A major concern is the establishment of an acceptable design-basis earthquake prior to proceeding with any ESF construction. DOE plans call for using a 0.4g earthquake for design purposes based on a probability approach (URS/Blume, 1986). The SCP implies that the design-basis earthquake could be substantially higher (0.6g) if a deterministic approach is used, depending upon the size of the earthquake used and the distance from the source. A deterministic approach appears to be more reasonable and conservative especially given that the ESF is planned to be integrated in the repository, and the approach is more scientifically acceptable. In addition, the present ESF design makes no allowance for displacement on active faults that may be penetrated within the repository block. It is inappropriate for ESF construction to proceed until these major design issues are resolved and enough information from surface-based testing becomes available to provide reasonable assurance that repository integrity will not be compromised by an inadequate seismic design.

At the Yucca Mountain site, it has been assumed that seismic motion decreases with depth. Hence, a general approach to reconciling underground seismic design with that of surface design would be arrived at by reducing the surface response spectra correspondingly, given that the depth reduction for the appropriate frequencies and that the geologic conditions of the site can be accurately determined (which is speculative). Therefore, the applicability and usefulness of a response spectra in the evaluation of mined underground openings, such as drifts and shafts, is questionable at this stage because the openings cannot vibrate independently, but move with the host rock. It is important to note that a primary mode of failure in underground design may prove to be differential displacement. Given the heterogeneous environment at the Yucca Mountain site, this failure mode may be a controlling parameter.

The frequencies most likely to cause damage to the exploratory shaft subsurface facilities are significantly higher than the frequencies that cause damage to surface structures. Given this situation, the design basis and corresponding response spectra (when applied) for the underground openings could be assessed using band widths which may not encompass higher frequencies. Such higher frequencies can be developed by near field displacements from nearby fault movement or volcanic activity. If the stability of the openings is assessed using lower frequencies than actually occur, failure of the excavations could occur.

Many of the site characterization activities will revolve around the Exploratory Shaft Facility which, according to the SCP, is the chief mechanism by which in-situ site-specific data will be obtained relating to the geologic conditions of the proposed repository horizon and the overlying formations. Of primary concern is that the proposed time frame or schedule for the testing activities is far too short to adequately assess many of the basic site characteristics. Many of the tests proposed will require an extremely long period of time to achieve accurate, reliable, and representative results.

GEOLOGY

Chapter 1, which is to summarize what is known about the site from DOE exploration activities completed to date, is invalid and out-of-date and does not represent a data base often referred to in Chapter 8.

The regional study of active faults is inadequate. There appears to be a general reluctance to incorporate information from a regional base unless it can be shown that something (be it a fault or volcanic feature) may have a direct consequence on the repository or on surface facilities. There is no attempt to understand the regional setting and how the conditions and processes in that setting might influence the site. For example, active faults within 100 km, but not within the site, are planned to be studied only if a cursory examination shows that they could sustain an earthquake event large enough to cause significant ground acceleration. This approach will not yield a true picture of the temporal and spatial history and, thus, potential of seismicity and faulting.

The concept and use of the 10,000 year cumulative slip earthquake (CSE) is unacceptable. This type of seismic source characterization is unconventional, unrealistic, misleading, and non-conservative. The 10,000 year cumulative slip earthquake is considered to be an attempt to combine deterministic and probabilistic hazard analyses. It is stated to be a deterministic method, because it provides an estimate of a specified magnitude for a specified seismic source. However, it incorporates a probabilistic aspect in that it downgrades the expected event size in consideration of the (perceived) infrequency of event occurrence. Prorating slip over a 10,000 year period creates artificial, inappropriate earthquake size estimates. This is an attempt to incorporate a risk factor into estimates of seismic sources, which is considered an inappropriate approach. The CSE is applied to only one fault at a time at Yucca Mountain, rather than to the collective suite of faults, which may be more appropriate. For the Yucca Mountain site, the widely used and accepted maximum or maximum credible earthquake methodology such as described in 10 CFR 100 Appendix A is more appropriate. Based on existing information, the most likely "anticipated event" during the post-closure period is a large magnitude earthquake, with complex distributed rupture, similar to the 1932 Cedar Mountain earthquake (Ms = 7.2).

The SCP gives the incorrect impression that the framework for volcanism and volcanic stratigraphy for the basalt volcanos (<8 Ma) of the southern Great Basin is well known. No defensible arguments are presented that justify the application of Poisson statistics to the evaluation of risk related to volcanic eruption.

A primary flaw of the SCP is the failure to adequately incorporate coupled-process considerations. For example, all disruptive scenarios involving faulting consider the possibility of rupture along only a single fault. The possibility of complex event with distributed rupture on multiple faults is not considered, even though existing evidence indicates this may have occurred in the past. Evidence from Yucca Mountain (basaltic ash in fault fractures and close spacing [< 2 km] of surface faults) suggests an intimate interrelationship between the surface faults and emplacement structures of the Crater Flat basalts/Lathrop Wells Cone. Faulting at Yucca Mountain might involve rifting and dike intrusion in the lower- to mid-crust, with extrusion of basalt and/or distributed rupture across several faults in the upper-crust and at the surface. A second example is the inadequate application of standard hydrologic models. Little is known about the boundary conditions of the zone of saturated flow, and no studies have been planned to address this problem. This deficiency has already been noted by Szymanski in his study of the ground water system of the Death Valley region. Earth scientists are accustomed to the idea that any set of rocks is an integrated result of physical, chemical, and biological interactions during and after the original formation of the rocks. For practical reasons, a simplified approach must be used initially in the study of such complex system, but it must always be kept in mind that the applications of simplified models to concrete crustal problems may or may not be reasonable, and that more sophisticated interpretations generally are developed as data bases become more complete and comprehensive.

NATURAL RESOURCES

The "evaluation" of mineral and hydrocarbon resource potential given in section 1.7 and 1.8 is built on incomplete, outdated, often inaccurate and misleading information and remains largely inadequate. The SCP omits a variety of important data on mineral deposits and mining that have become available since 1984, and that contradicts the statement given in Section 1.8.1.7.1 that the site represents an unattractive locality for mineral exploration because of the relative lack of alteration exposed at the surface and the lack of past mining activity. The present level of mining activity and probable future mineral interest in southwestern Nevada is markedly under-represented.

The proposed characterization program, in particular the proposed borehole drilling program, is inadequate to evaluate the resource base in and near Yucca Mountain and thus will not provide data which will assure a minimum likelihood of future human interference or intrusion. Future studies must include several boreholes within the site boundary and adjacent to it, and these must not only penetrate the Tertiary section, but also provide samples from a representative section of the underlying Paleozoic rocks. Several boreholes must also directly test faults, intersections of faults, breccia zones and highly fractured zones for evidence of hydrothermal mineralization.

The thermal regimes in the region are poorly understood. Unambiguous data are not available to rule out the existence of a moderate-to high-temperature geothermal resource in the vicinity of the site. None of the existing and planned drill holes are or will be completed in a manner suitable for high quality temperature measurements which might resolve the geothermal potential issue. Only deep drill holes (10,000 - 20,000 feet) would be appropriate to gather such temperature data.

The discussion on hydrocarbon resource potential demonstrates little or no understanding of the regional context of hydrocarbon assessment and the physical processes involved in creating hydrocarbon reservoirs. The SCP is devoid of discussions of basin analysis, particularly for potential source and reservoir units for liquid hydrocarbons; Mesozoic thrust structures critical for creating hydrocarbon traps and defining thermal and pressure histories; and structural and thermal evolution of southern Nevada stratigraphy. The hydrocarbon potential will remain untested without deep exploration drilling on Yucca Mountain.

ROCK MECHANICS

The investigation to establish the lithology, geologic structure, and geomechanical properties of the repository horizon rock mass depends totally on a) the locations of the experimental shaft facility (ESF), and b) the number and location of boreholes. The rock of the waste emplacement area will be investigated only using a few core samples, which brings into question the representativeness of these few samples to establish rock properties for the complete repository block.

The rock mass characterization plan is based on measurements made on small samples, both in the lab and in-situ, and the use of these measurements to extrapolate to the larger scale, using numerical programs. These extrapolations include the use of estimates of joint and fault behavior. This technique has not been validated for the large type of structure being studied. The approach to determining the effect of larger fractures, joints, and especially faults, both in and near the repository on the overall behavior of the repository is not adequately described.

GEOCHEMISTRY

The present data set is insufficient for developing appropriate and adequate plans for investigations, studies, and activities. As a result, the designers of the geochemistry program have relied on the following assumptions: a) matrix flow is dominant over fracture flow as transport mechanism in the vadose zone; b) vadose-zone water chemistry is similar to that in saturated zone; c) flow paths to the accessible environment are hypothetical; d) use of crushed tuff in sorption experiments is sufficient to simulate in-situ conditions; and e) J-13 well water is an acceptable reference water. The validity of these assumptions to design a geochemistry investigation plan is questioned.

There appears to be no comprehensive synthesis of the information available on the ground-water chemistry. The chemical analyses are not integrated with the hydrologic and geologic information. Synthesis of all such data is necessary to make the greatest use of hydrochemical information for planning and evaluation purposes.

There is a lack of detail about the needed collection of representative water samples from different tuff strata. For the saturated zone, most of the samples will be simply pumped from wells and will be considered to be composite samples. However, the water sampled will probably be from the most permeable zone nearest the pump intake so will not even represent composite samples from all the strata. Presently, there is no indication that waters from low permeability zones in the tuff will be sampled. More detail is necessary on the applicability of the data. Many of the tests appear to be prototypes and do not directly address site-specific data needs.

Undue emphasis is placed on modeling before, and occasionally in place of, collection and analysis of laboratory and field data. In the sorption studies, models are sometimes used to support other models, which only compounds errors or uncertainties which may exist in the models. Without data to validate the models, this layered use of models is unjustified and greatly increases the uncertainty of any results reported.

Most of the credit taken by the DOE for ground-water travel time derives from the vadose zone and therefore assumes most of the retardation would also occur in the vadose zone. Obtaining chemical analyses of a vadose-zone water should be of the highest priority and the range of vadose-water composition should be determined and be well known and understood before many performance assessment studies begin.

Not enough importance is being attached to determining the validity of extrapolating from laboratory sorption data to actual field conditions. It is extremely difficult to envision how data from experiments employing crushed tuff could be correlated to the field with any confidence in their scientific validity. Highest priority should be assigned to validating the proposed experimental approach through field tests of sorption or retardation before additional resources are expended in this extensively practiced but totally unproven methodology.

As in the case of geology and hydrology, the evaluation of individual geochemical scenarios for the purpose of eliminating those with insignificant consequences may overlook the coupling that can occur between two or more processes/events producing significant consequences for predicting release of radionuclides to the accessible environment. A good example is Szymanski's proposal (J. Szymanski, 1989, "Conceptual considerations of the Death Valley Groundwater system with Special Emphasis on the Adequacy of the System to Accommodate the High-Level Nuclear Waste Repository.") that kinetic and heat energy propagate upward, affect water chemistry, and horizontal-vertical movement of groundwater. Another example is the omission of the most obvious scenario of water vapor driven from the thermal envelope condensing in the cooler fractures that surround the repository horizon and returning to the boiling zone by gravitational forces.

HYDROLOGY

The conceptual model is based more on non-conservative assumptions than on data. It incorrectly emphasizes vertical recharge through the top of Yucca Mountain. Recharge is incorrectly assumed to be uniformly distributed throughout the proposed boundary area of the repository. Also, recharge is incorrectly assumed to be uniform in time. As a result, there are no plans directly related to assessing the recharge potential of the many ephemeral streams which drain to the east and north off of the site. In desert terrain such as the Yucca Mountain site, the recharge may be considered low yet it may also be highly variable in the amount and rate. Furthermore much of the recharge is certainly concentrated and focused beneath washes, in and through open and exposed fractures, and through faults in the rock matrix of the repository block.

The factors which control ground-water levels near Yucca Mountain are not well known. North and west of the repository area, hydraulic gradients are uncharacteristically high. South and east of the repository area the hydraulic gradient is relatively low. The reasons for the high gradient are unknown. One study is planned for the Solitario Canyon Fault which may contribute to the high gradient to the west. No studies of faults or other geologic features are planned to explain the gradient in the north, which is even greater than the unexplained high gradient to the west.

To investigate in detail the water table configuration and its fluctuations over time will require a number of changes to existing studies. Designing and drilling a number of "true" water table wells, with sets of closely-spaced wells near potential recharge area is needed. In addition the existing water table wells need to be modified so that they penetrate only a few meters beneath the water table.

The conceptual model for flow of water through the unsaturated zone is not based on nor supported by available data. The model assumes that matrix flow is dominant over fracture flow and that the matrix must be saturated for fracture flow to occur. No data exist to support these assumptions for any formation and especially for the Calico Hills formation which in the DOE's conceptual model is the most important barriers to the release of radionuclides to the environment. Furthermore, based on the very limited and questionable suction-head data available from well UZ-1 for the various rock units, the tuff units of the Calico Hills are most likely effectively saturated. Therefore, using DOE's reasoning, fracture flow should be dominant. Alternative and conservative conceptual models that fit the limited site-specific data have not been given serious consideration.

There are no activities which address the effects of fracture coatings and entrapped air, both of which can effectively isolate the fracture from the matrix, resulting in significant fracture flow.

The methodologies proposed for obtaining in-situ data on moisture conditions in the unsaturated zone are based on porous media models which are inappropriate for fractured tuff. The methodologies are highly experimental, and have questionable probability of success. No provision is made to address the possible occurrence of perched water throughout the unsaturated zone of the repository away from the exploratory shaft.

Simultaneous movement under thermal gradient conditions, of air, water vapor, and liquid water in the unsaturated zone is not adequately addressed. These processes may lead to the discharge of radionuclide to the immediate surface environment. The upward migration of air from the repository may represent the fastest pathway to the assessable environment and thus the site may not meet the EPA Standard (40 Part 191) for gaseous radionuclide releases.

The process of dispersion in partially-saturated, fractured tuff has not been addressed in the scientific literature beyond the theoretical stage. The dispersion process, while reducing maximum concentration will also decrease the time of first arrival at the accessible environment. The impact of dispersion will therefore result in reducing the travel time when compared with bulk ground-water travel-times.

The SCP places emphasis on the disturbed zone as that zone where intrinsic permeability and effective porosity are altered. For an unsaturated-zone repository such factors are not relevant. Disturbed-zone criteria should be based upon alteration of the relative permeability curves (analogous to intrinsic permeability) and water retention (analogous to effective porosity). These parameters will control fluid, air and radionuclide transport near the repository and will contribute more directly to a coherent picture of the effects of disturbance than will the parameters adopted in the SCP.

The studies of the saturated zone rely too heavily on previous, and questionable, aquifer tests which were analyzed using a porous media model that assumes homogeneity, isotropy, and radial flow. The model is inappropriate for use in interpreting most of the tests because steeply dipping fractures control the movement of water into and out of the boreholes. The inappropriateness of the model is demonstrated further by poor agreement between the type curves and the current data set. No attempt has been made in the SCP to develop or apply models that produce good agreement between the aquifer test data and the type curve.

The two dimensional, plan view conceptual model is inadequate to explain the flow system in the saturated zone. The areal pattern of hydraulic heads suggests the existence of narrow ground-water barriers across which large potential gradients occur, combined with larger regions of very small gradients. Additionally, areal variation of the location of the water table within each of these zones probably depends on relationships with deeper aquifers as well as on horizontal flow. A three dimensional model is essential.

Heavy reliance on computer codes to characterize the water vapor, liquid, and heat movement through the vadose zone has been used and is planned to be continued. The assumptions of the codes are not based on reliable laboratory or field data. The validation of the codes is questionable, and the DOE's schedules indicate that validation will not occur prior to license application.

SEAL PROGRAM

There is no precedent or experience supporting the application of concrete design and mixes that are proposed within the ESF and the repository. It is questionable whether the behavior characteristics of the rock mass, of the hydrological field, of the water chemistry, and of the thermal condition in relation to an established seal mix design will be soundly ascertained.

The seal program proposed in the SCP is mostly based on the report of Fernandez et. al. (1987) which fails to include a cumulative release formula in the analysis of radionuclide releases from failed canisters. The failure to consider cumulative releases can only result in an incomplete and inadequate performance assessment.

PERFORMANCE ASSESSMENT

The three sections on higher level findings, 8.3.5.6 -preclosure radiological safety, 8.3.5.7 - ease and cost of construction, and 8.3.5.18 - postclosure system and technical guidelines, lack schedules that indicate decision points which would allow reevaluation of the site characterization process and possible redirection or termination of research.

Circular logic is used in section 8.3.5.13 - total system performance, to justify the replacement of the cumulative complementary distribution function (CCDF) by the expected partial performance measures (EPPM) in the screening and elimination of scenarios. The EPPM is calculated by deterministic modeling, which is contrary to the statistical modeling called for in the EPA standard. As an example, the use of EPPM as a replacement for CCDF invites the application of the parametric volcanic modeling approach described in Link et. al. (1982) to dismiss the volcanic hazard at Yucca Mountain without further field data or analysis.

The discussion of water-pathway releases is based on two computer codes, GWTT and TOSPAC, without demonstration that the two codes complement and do not contradict each other. GWTT models a vertically constrained stochastic water flow problem, while TOSPAC models a boundary value problem. Without detailed evaluation, it appears that the codes are not complimentary. As an aside, the assumptions used to design the GWTT appear to assure that the ground-water travel time to the accessible environment will exceed 1,000 years even at a flux of 5 mm/yr.

The SCP offers no useful plan to determine the flow-system relationship and boundary conditions between the three aquifers known to exist in the vicinity of the site, which does not allow the resolution of the ground-water protection "special source" issues.

The economic cost of retrievability, which is also classified as a performance issue in section 8.3.5.2, is not addressed in any of the SCP studies.

PART II

SPECIFIC COMMENTS

PART II

SPECIFIC COMMENTS

INTRODUCTION

Specific comments

Page I-13

Supporting documents discussion of Volume I, Part A, begins with the following sentence:

"Numerous separate documents support the SCP by providing additional details concerning site data, design information, and plans for site characterization activities."

To the extent that these documents contain information called for by §113 of the Act they should be considered part of the SCP, and characterization should not begin until the State and the NRC have commented upon each of those documents, and the DOE has responded to those comments.

CHAPTER 3. HYDROLOGY

Specific comments

Page 3-6. 4th paragraph

Statement: "Uncertainty associated with the data presented in Chapter 3 is primarily related to the lack of a sufficient number of samples or tests for statistical reliability and also to measurement errors that are inherent in the investigations."

There should also be an emphasis as to whether the data summarized in Chapter 3 may or may not meet the QA standards required by the licensing process and whether it may be required to qualify the data by peer review.

Page 3-7. 2nd paragraph

Statement: "In very general terms, the regional hydrology and hydrogeology are fairly well understood and their levels of uncertainty are relatively low. However, the unsaturated zone at the site has only recently come under investigation and, therefore has produced a relatively meager data base."

It should also be pointed out, as is done in section 8.3.1, that hydrology of the unsaturated zone is poorly understood everywhere, not merely at the Yucca Mountain site. Furthermore, it is only DOE's opinion that the regional hydrology and hydrogeology are fairly well understood, scientists knowledgeable in the Great Basin believe that the hydrogeology is poorly known.

Page 3-25. 1st paragraph

Statement: "Surface-water use by man in the study area would probably increase only in the event of a change in climate to a wetter regime. Studies done to date indicate that such an event is possible, but not in the period of repository construction, operation, closure, and decommissioning (DOE, 1986)."

The period of construction, operation, closure, and decommissioning could be as long as 84 years, a very long period for socioeconomic processes. Surface-water use by man could easily increase because of an increased demand for agriculture and because of increased population. Las Vegas expects to become an urban area with a population in excess of one million before the turn of the century, which is before the repository is expected to be operational. If such a trend continues, Amargosa Valley's population could increase and might become a suburb of Las Vegas.

Page 3-98. 5th paragraph

Statement: "Several hypotheses have been advanced concerning the absence of older water (of middle Wisconsin age)."

The emphasis in the ensuing lines is on the hypothesis advanced by Claassen while the other hypotheses seemed to be ignored. Why are not the other hypotheses discussed?

Page 3-130. 3rd paragraph

It is emphasized, as is in all DOE reports that mention the subject, that the continuous pumping of well J-13 from 1962 to 1969 caused only a slight decline in the water level.

The quality of the data and the tests on which the statement is based may be questionable. The tests may have several systematic errors that could mask a greater drop than one foot in the altitude of the water level. Furthermore, Well J-13 is located in Forty Mile Wash which has been indicated as a potentially important recharge area.

Page 3-133. 3rd paragraph

Statement: "Water temperatures measured in test holes in the vicinity of Yucca Mountain are in the range of 50 to 60 ^{o}C at depths to 1,800 m (5,906 ft) (Craig and Robison, 1984)."

The statement does not appear to be in agreement with Figure 1-80, page 1-281, which indicates temperatures ranging from about 120 to almost 300 °C at depths of 5,000 to 6,000 ft.

Page 3-140. 3rd paragraph

Statement: "The term moisture is introduced here in a generic sense to include both liquid water and water vapor."

In the performance analysis sections of 8.3.5.12 and 8.3.5.13 the term is exclusively used for liquid water moving downward. There should be more consistency between performance analysis and Chapter 3.

Page 3-164. 3rd paragraph

Statement: "However, it is not known whether the southward slope toward drillhole USW H-1 is uniform, or if there are abrupt flections."

The uncertainty over the southward slope of the water-level altitude should be indicated in Figure 3-28. A possible method would be to dash potentiometric contours in areas of uncertainty in slope.

Page 3-212. 1st paragraph

Statement: "Both sets of model calculations, however, predicted that steady net infiltration rates (or percolation fluxes) exceeding values in the range from 0.5 to 1.0 mm/yr would produce complete matrix saturation in the TSw and TCw units after the mountain equilibrates to the change in flux."

The statement is not supported by the report of Sinnock et al., (SAND85-2701), which is summarized in section 3.9.4.1, and which appears to be the basis of section 8.3.5.12 and of future performance assessment studies of the ground-water travel time (GWTT). That study presents calculated GWTTs for fluxes of 0.5 and 1.0 mm/yr, which do not indicate any significant decrease in GWTT attributable to an increase in fracture flow, which should occur with the onset of complete matrix saturation.

Pages 3-216 to 219. Ground-water travel time in the unsaturated zone

The results of the modeling study of Lin, Y. T., M. S. Tierney, and S. Sinnock, 1986. Preliminary Estimates of Groundwater Travel Time and Radionuclide Transport at the Yucca Mountain Repository site, SAND85-2701, are summarized. The study is also the basis of section 8.3.5.12.

The model is very preliminary and appears to have been published hurriedly in support of the Environmental Assessment and the consultation draft SCP. The model allows for fracture flow if the flux is greater than the matrix hydraulic conductivity. The model is labeled as stochastic since the thicknesses of the formations between the repository horizon and the water table are sliced into layers, the porosity and hydraulic conductivity of which are sampled randomly from a normal and a log-normal distribution. The study contains travel time calculations for the two flux values of 0.5 and 1.0 mm/yr only.

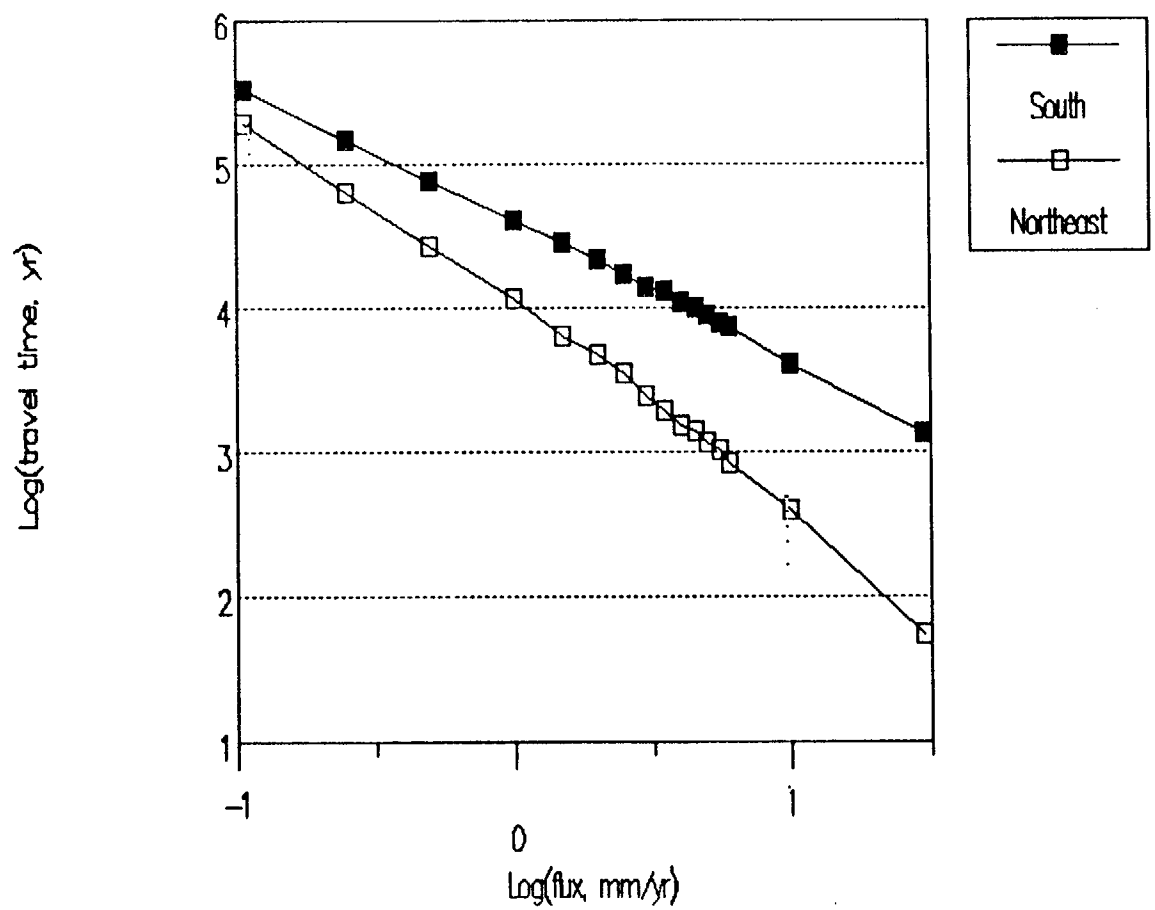
The model uses average hydraulic conductivity values of 0.722, 107.2, 0.535, 87.7, 21.6, 118.4, and 21.6 mm/yr for the TSw, CHnv, CHnz, PPw, PPn, BFw, and BFn formations respectively. Since fracture flow can occur only if the flux is greater than the matrix hydraulic conductivity, the model allows effectively for fracture flow in the TSw and CHnz formations only. But even in the TSw and CHnz formations, because the hydraulic conductivity is sampled from a log-normal distribution, there will always be layers that favor matrix flow over fracture flow even at flux values of 5 mm/yr. The ground-water travel time (GWTT) through a 10 m layer favoring matrix flow is always several hundred years and sometimes even closer to 1,000 yr. It only takes one or two 10 m layers favoring matrix flow to have a GWTT of over 1,000 yr even for a flux value of 5 mm/yr.

The above arguments are illustrated in the following two examples. The equations for the ground-water travel time of SAND85-2701 were programmed in a macro language for the spreadsheet Quattro. GWTT sample calculations were performed for a formation consisting of 45 m of TSw, and 115 m of CHnz, a thickness which is present in the north-eastern corner of the site, and for a formation consisting of 130 m of CHnv, 15 m of CHnz, 105 m of PPw, and 80 m of PPn, a thickness which is present at the southern tip of the site. The layer thicknesses were kept close to 10 m. The results are summarized in the attached figure. Each calculated datum is the average of 50 GWTTs. For the southern location, the GWTT varies as 1/flux indicating no fracture flow even at flux values of 30 mm/yr. For the northeastern location, the GWTT varies 1/flux for flux values of 1 mm/yr or less and as $1/(\text{flux})^2$ for the high flux values. However, even at flux values of 5 mm/yr, the GWTT is still in excess of 1,000 yr. The model cannot viewed as conservative because, if a layer favoring matrix at high fluxes is encountered, water is more likely to travel through fractures horizontally until vertical fracture flow is again preferred. The GWTT for such a tortuous motion would still be shorter than for straight vertical motion that allows for matrix flow.

As a further argument of weakness of the model, it should be noticed that as the flux increases the rock becomes more saturated and that the GWTT to the uncontrolled boundary in the

Average log of ground-water

travel time versus log of flux



tuff of the saturated zone, which is 5,000 m away, is estimated at a few hundred years.

Finally, the model is in contradiction to the earlier modeling study of Sinnock, S., Y. T. Lin, and J. P. Brannen, 1984, Preliminary Bounds on the expected Postclosure Performance of the Yucca Mountain Repository Site, Southern Nevada, SAND94-1492, since it fails to indicate any significant onset of fracture flow at a flux of 1.0 mm/yr and an abrupt decrease in GWTT.

Page 3-225. 2nd paragraph

Statement: "This section identifies all production wells that are located near the Yucca Mountain site."

The section actually discusses the usage of water from wells J-12 and J-13 for the years 1983, 1984 and 1985. The section fails to discuss the pumping of water from well VH-2, located in Crater Flat, which is almost as proximal to the site as wells J-12 and J-13, and which is used extensively by a local gold mining company. The withdrawal of water from well VH-2 may be increased substantially with increased gold mining activities. Also, the DOE should have included electrical consumption data of the pumps, which are available, and which allow an estimate of the total amount of water pumped from wells J-12 and J-13 since their activation in the early 1960s.

CHAPTER 6. CONCEPTUAL DESIGN OF A REPOSITORY

Specific comments

Page 6-2. 4th paragraph

Statement: "To inhibit subsidence, a low extraction ratio (ratio of the excavated area to the total underground area) has been maintained."

For vertical emplacement, the extraction ratio approaches 30 percent, a value that may not be considered as low. At the WIPP site, an extraction ratio of about 25 percent has also been considered as low, but the room closure has been greater than three times the expected value, and despite a large pillar, interaction effects due adjacent rooms on room closure are noticeable. There should be some elaboration on what criteria define a low extraction ratio.

Page 6-29. 4th paragraph

Statement: "To receive spent fuel by 1998 as required by the Nuclear Waste Policy Act of 1982, the DOE has elected to construct and operate the repository in two stages (SNL, 1987)."

It is not clear why Chapter 6 of the SCP is still based on the Mission Plan and not on the Amendment to the Mission Plan which calls for the start of operation in 2003.

<u>Page 6-33. 2nd paragraph</u>

Statement: "The time required for the removal of a waste package will not exceed twice the amount of time required for emplacement of the waste package."

The study SAND87-7076C, <u>An Analysis of Air Cooling Prior to Re-Entering a Drift Containing Emplaced Commercial Nuclear Waste</u>, suggests that the cooling of the drifts will take a long time, which may not make it possible to keep the above quoted commitment.

<u>Page 6-110. 2nd paragraph</u>

Statement: "This section describes the current concepts for the retrieval operations at the repository."

The section fails to emphasize the operations necessary to cool down the access and emplacement drifts, which are summarized on page 6-285. The cost of these operations may be prohibitive.

<u>Page 6-193. 4th paragraph</u>

Statement: "The entire ventilation is planned to be maintained in fully operational condition throughout the caretaker period; hence the system will be available for use if retrieval operations are necessary."

Because of the need to remove large amounts of heat before accessing the emplacement drifts, retrievability should require a much more powerful ventilation system than the one used for normal operation. Also, the normal ventilation system does appear to have been designed for reverse operations.

<u>Page 6-285. 5th paragraph</u>

Future analytical studies to further demonstrate the retrievability compliance of the ventilation system are enumerated.

The list should include a cost analysis. The system appears to be very energy consuming which may be contradictory to the concept of retrievability for the recovery of valuable resources. Additionally, the list should include an analysis of the total time required to empty fully loaded horizontal and vertical emplacement drifts.

CHAPTER 7. WASTE PACKAGE

Specific comments

General comment

Chapter 7 is very confusing because it attempts to do two tasks: summarize what has been done and discuss what should be or will be done. The second task should be reserved for Chapter 8.

Page 7-8. 6th paragraph

Statement: "The packages would not bear lithostatic load because the host rock is not expected to creep under the post-emplacement thermal regime (section 2.5). The load-bearing requirements for the waste packages are limited to pressures caused by sloughing of rock from emplacement boreholes."

Eventually, the sloughing of rock from emplacement boreholes will lead to lithostatic loads. The estimated time for the build up to lithostatic loads should be indicated. The combination of heat and rock sloughing may also influence the load-bearing requirements for the waste package.

Page 7-9. 3rd paragraph

Statement: "Aqueous corrosion of waste packages by liquid water and its dissolved constituents would only commence after the temperature of the container drops to the point where a liquid film could form on the container surface."

Corrosion of the waste package due to the flow of steam through the rock during the period of elevated temperature cannot be ruled out without some confirmation program.

Page 7-19. 1st paragraph

Statement: "The waste package as an entity will be designed to control the internal temperatures to less than the limits under anticipated postemplacement conditions."

Up to now, it appears that there are only two reports by O'Neal and O'Neal et al. which support this commitment. Both reports are calculations. Perhaps, reference should be made to Chapter 8 and to the experiments that will be done to justify this commitment. Clearly, the waste package cannot be designed without an adequate data base on the subject.

Page 7-207. 6th paragraph

Statement: "Oversby and Wilson (1985) have calculated the bounding flux to be 40 L/package-year for spent fuel packages assuming a recharge flux of 1 mm/yr."

A flux of 1 mm/yr may be adequate for preclosure GWTT calculations. Postclosure performance assessment may require the assumption of a flux of 5 mm/yr because of anticipated climate changes over the next 10,000 years.

Page 7-224. 5th paragraph

Statement: "One of the candidate sites for disposal of HLW is in the Topopah Spring Member of the Paintbrush Tuff."

The statement is ambiguous. Chapter 6 and section 8.4 state that the repository horizon has been set in the Topopah Spring Member of the Paintbrush Tuff and that there is no alternative.

Page 7-231. 7th paragraph

Statement: "The Yucca Mountain Project has completed a 2-yr feasibility study on the three copper-base materials."

The SCP should provide a reference that documents the 2-yr effort on the copper-based materials.

CHAPTER 8. SITE CHARACTERIZATION PROGRAM

SECTION 8.0. INTRODUCTION

Specific comments

Page 8.0-9. 4th paragraph

Statement: "The top level strategy focuses strongly on the investigations of the characteristics of the flow in the unsaturated zone, relying heavily upon on the current view that the percolation flux is low and that the water in the unsaturated zone is tightly confined within the rock matrix....As part of these investigations, the program will address alternative concepts including flow and fractures, lateral movement of water at rock interfaces in the unsaturated zone, and the effect on the flow of structural features such as faults." (Emphasis supplied)

What does "relying heavily upon" imply? This seems to be further evidence that DOE intends to give only passing treatment to alternative concepts, and devote most of its site characterization program to confirming (and conducting tests and studies with that in mind) the "current view". The program should be entirely reversed, with the emphasis placed upon tests and studies which are designed to ferret out whether or not the alternatives prevail at the site. This is particularly true since even some individuals in the Department (Blanchard to NRC Atomic Safety and Licensing Board, December, 1988) concede that if fracture flow predominates the site is probably unsuitable. Determining if fracture flow exists, as well as testing for other "alternatives", should be promoted to highest priority on which the top level strategy focuses since their existence may be a site disqualifier.

Page 8.0-10. 3rd paragraph

Statement: "The following is a general list of the disruptive processes and events that present data suggest are sufficiently credible to warrant consideration:"

The list of thirteen potential disruptive processes does not appear to be complete. The list does not appear to encompass, for example, the kind of coupled effects, including the introduction of corrosive water into the repository, posed in Jerry Szymanski's report.

SECTION 8.1. RATIONALE

Pages 8.1-2. 4th paragraph

Statement: "..they [key issues] are based specifically on the standards promulgated by the Environmental Protection Agency (EPA) in Subpart B of 40 CFR Part 191, and adopted by the Nuclear Regulatory Commission (NRC) of 10 CFR Part 60."

The State of Nevada has commented in the past that this process should await the final promulgation of new EPA standards.

Page 8.1-9. 2nd paragraph

Statement: "Moreover, failure to meet the goal (tentative goals to be assigned to each parameter) would not be reason to suspect that the license application will be unsuccessful because the goals are not values that, by themselves, are essential to the performance of a disposal system."

This is obviously not true in the case of a "goal" which involves a qualifying factor, or absence of a disqualifying factor. The Plan should clearly state that failure to meet a goal which implicates qualifying or disqualifying factors, and thus site suitability, will raise questions with respect to the success of the license application.

Page 8.1-11. Data collection and analysis

The Plan discloses that it is not likely that all of the hypotheses will be confirmed by the testing program, and that some of the conceptual models will be modified as a result of site characterization. It goes on to say (5th paragraph): "Accordingly, analysis of the results of the testing will be conducted as the testing proceeds to determine if the investigations set forth in the SCP need to be completed or if the testing strategies need to be modified." The results of the testing should obviously also be analyzed to determine whether or not the site characterization program should continue, or whether or not the site should be discarded. The SCP fails to describe the DOE decision-making process involved in determining modification or cessation of site characterization activities.

Page 8.1-13. 2nd paragraph

The Plan indicates that the current confidence in the parameter goals will be compared with the needed confidences expressed in the SCP in the semiannual progress reports. Because these needed confidences are qualitative and subjective, the comparison will require judgement and "technical review". What will be the process of technical review?

Page 8.1-14. 5th paragraph

Statement: "The DOE expects to interact with independent reviewers, including the NRC, regarding some of these questioned items before formal licensing activities."

Will the independent reviewers include the State?

Page 8.1-16. 4th paragraph

Statement: "The next step (10e) is to decide if the current level of confidence that the technical criteria are met is adequate or not. This determination will be a judgement based upon the information available and not upon pre-set criteria;..."

It is hard to believe that the DOE will not have any pre-set criteria upon which to base these kind of judgments. It is obvious from the statement the judgement process will not be a quality-level activity. Nuclear-level quality assurance programs require that plans and criteria be in place to making judgments or decisions.

Page 8.2-2. Table 8.2-1

Key Issue 3 is stated thus: "Can the mined geologic disposal system at Yucca Mountain be sited, constructed, operated, closed and decommissioned, and can the associated transportation system be sited, constructed and operated so that the quality of the environment will be protected and waste transportation operations can be conducted without causing unacceptable risks to public health and safety?" (emphasis supplied).

This issue clearly encompasses the system licensing concept which the State has been espousing to the NRC.

In Volume VIII, Part B, at pages 8.4.1-1 and 2, under the heading Phased Approach to Implementing Site Characterization Activities, the Plan discusses phases 1, 2 and 3 of their analyses, and the use of semiannual progress report to provide information to the NRC, State and other interested parties. It indicates that information from periodic evaluations will be used to "modify or refine the construction and testing activities associated with the ESF." The collection of data during site characterization activities "will strengthen the statistical basis for data sets as well as fill in gaps and sparse or limited data sets." Such data will be reported in semiannual progress reports to inform the NRC and the State of the results of characterization activities. All of this will "provide the means" to reevaluate the conclusions contained in the SCP. These reevaluations, according to the plan, will include determining if the activities will provide representative data of the site as a whole, if there is a potential for interference between or among construction and testing activities, and if the activities have a potential impact on the ability of the site to meet the postclosure performance objective.

The State questions how the DOE can meet this lofty goal for content of the semiannual progress reports and still characterize the site. It seems from the statement that the progress reports will either be so scant as to be meaningless or so late as to be virtually useless for their stated purpose.

Beginning on page 8.4.1-3 and continuing on 8.4.1-6 "three important concepts that form the basis for the descriptions and evaluations presented in Section 8.4" are set out. Are these concepts stated in any order of priority? Why is there not included in these "important concepts" the need to phase the site characterization program so as to ferret out any disqualifying factors or information as early in the program as possible?

Page 8.2-5. Table 8.2-2

Under Issue 1.7 (will the performance-confirmation program meet the requirements of 10 CFR 60.137?) the SCP states: "Information needs to be determined". If the information needed to resolve that issue has not yet even been determined, then the plan is, almost by definition, incomplete.

SECTION 8.3.1.2. GEOHYDROLOGY

Specific comments

Page 8.3.1.2-50. 4th paragraph

The paragraph indicates that the models will be evaluated through a combination of peer review and comparison of model predictions with laboratory experiments, field experiments and natural analogs, etc. Does this peer review include the State's experts?

Page 8.3.1.2-51. 9th paragraph

The SCP explains the eighth column entry found in Tables 8.3.1.2-2a and 2b, which represents a judgement on the need to reduce uncertainty in the selection of hypotheses. It says: "This judgement is based on the uncertainty in the current representation, the sensitivity of the performance parameters to alternative hypotheses, the significance and needed confidence of affected performance parameters, the likelihood that feasible data gathering activities could significantly reduce uncertainty." (Emphasis Supplied) The need to reduce any uncertainty in the selection of hypotheses should be completely independent of this so called feasibility factor. If it is not feasible to reduce an unacceptably high level of uncertainty in the selection of any hypotheses, particularly one that effects suitability, then the hypotheses have licensing implications, and the Department should recognize that perhaps this is not the right site.

Pages 8.3.1.2-54. Column 2

The second current representation is: "Hydrologically interconnected fracture systems and rock matrix defining macroscopic composite or equivalent porous medium." The level of uncertainty assigned to this representation is high, and the rational is given as "hydrologic interaction between matrix and fractures remain poorly known and unquantified."

Is not this statement inconsistent with hypothesis No. 3 found on page 8.4.1-14, which the Plan claims to have been extracted from those hypotheses presented in Section 8.3.1.2? The sensitivity of the parameter or performance measure to this hypothesis is given as medium, with the statement made that "if the hypothesis is invalid, GWTT calculations will be more difficult."

Page 8.3.1.2-54. Table 8.3.1.2-2a

"Model element eastward dipping fault." The Department assigns a high level of needed confidence to this parameter, but a medium level of need to reduce uncertainty. Are these inconsistent?

Page 8.3.1.2-55. Table 8.3.1.2-2a

"Model element lower boundary condition." The Department assigns a medium level to the need to reduce uncertainty to this element, rationalizing that level by stating that the water table configuration is unlikely to change significantly over the next 10,000 years. That statement is entirely conclusory. It could be the crux of a significant licensing problem, and should be assigned a high level of need to reduce any uncertainty, even if that uncertainty is presently low. Any uncertainty with respect to this element whatsoever could significantly impact licensing.

Page 8.3.1.2-62. Table 8.3.1.2-2a

"Model element system dynamic/response." A low level of need to reduce uncertainty is assigned to this model element, represented as "volcanism is unlikely to affect the UZ hydrogeologic system during the next 10,000 yr." The explanation for a low level of need to reduce uncertainty is that the "event is unlikely to occur during next 10,000 yr." Again, the Department will be required to prove unlikeliness of recurring volcanism during the life of the repository in order to obtain a license, and consequently a level of high should be assigned to reduce uncertainty.

Page 8.3.1.2-65. Table 8.3.1.2-2a

"Model element data-reduction." The SCP assigns a low level to the need to reduce uncertainty in the current representation that matrix potential is definable and measurable in terms of capillarity/absorption theory (Kelvin equation). Is not this element significant enough that there is a high need to reduce any level of uncertainty, even though the DOE expresses the belief that the current level of uncertainty is low?

Page 8.3.1.2-66. Table 8.3.1.2-2a

"Model element system dynamic/response." The SCP assigns a level medium to the sensitivity of this parameter or performance measure to the hypothesis that liquid-water flow in the Topopah Spring is restricted to the rock matrix. The statement is pure conjecture and without basis in fact. The assigned level should be high. If flow occurs in the fractures it will have a potentially higher impact on the sensitivity of the parameter or performance measure.

Page 8.3.1.2-71. Table 8.3.1.2-2b

"Model element faults." No current representation for this model element has been selected in Table 8.3.1.2-2b, which refers to representations and alternative hypotheses for the saturated-zone hydrologic system conceptual models. An alternative hypothesis is set out, however. How can there be an alternative to nothing? Is DOE really saying that a preferred model has not been selected from one of the two sub-hypotheses internally expressed within the alternative; that is that faults are either barriers or conduit to groundwater flow? If this is the case, then the SCP should discuss the attributes and adverse characteristics of each alternative hypothesis.

Page 8.3.1.2-71. Table 8.3.1.2-2b

"Model element lineaments." No current representation for this model element has been selected in Table 8.3.1.2-2b, which refers to representations and alternative hypotheses for the saturated-zone hydrologic system conceptual models. An alternative hypothesis is set out, however. Again, is DOE really saying that no preferred model has been selected from the two sub-hypotheses expressed in the alternative; that is that lineaments may act as either conduits or barrier to ground water flow?

Page 8.3.1.2-72. Table 8.3.1.2-2b

"Model element upper boundary." The statement of the rationale for the representation that the water table is the upper boundary of the saturated zone ground-water flow system, which ends with the words "as if it had", appear to be incomplete.

Page 8.3.1.2-74. Table 8.3.1.2-2b

"Model element upper boundary." The SCP assigns medium levels to the uncertainty with respect to the current rationale that water-table mounds and perched-water bodies originate primarily from water infiltration from above, as well as medium levels to sensitivity and the need to reduce uncertainty. High levels of uncertainty, sensitivity, and need to reduce uncertainty should be assigned.

Page 8.3.1.2-75. Table 8.3.1.2-2b

"Model element lower boundary." The SCP assigns a level of medium to the sensitivity for the representation of this model element, stating that "position of boundary and amount and direction of flux across it significantly effects GWTT, transport through the SZ to the accessible environment, and the response of the water-table elevation to temporal changes." (Emphasis Supplied). The level of sensitivity should be high since it directly implicates factors which might be dispositive in licensing.

Page 8.3.1.2-77. Table 8.3.1.2-2b

"Model element lateral boundary-site." Levels of low, high, and low are assigned to needed confidence, sensitivity, and need to reduce uncertainty, respectively, for this current representation. Needed confidence and need to reduce uncertainty should both be raised to at least medium, if not high. This is particularly so since the sensitivity level assigned is high because "estimates of GWTT and water-table altitude will depend in large part on model results."

Page 8.3.1.2-78. Table 8.3.1.2-2b

"Model element lateral boundaries-temporal." A level of medium is assigned to the uncertainty of the representation that material properties are assumed to be invariant with time, because the effect of climatic and tectonic changes "are expected to be small," but existing modeling and analyses to demonstrate this are inadequate. A level of medium is also assigned to the need to reduce uncertainty, based on that level of uncertainty. Both levels should be raised to high. Expectations should not suffice, where it is admitted that existing modeling and analyses are inadequate.

Page 8.3.1.2-79. Table 8.3.1.2-2b

"Model element equation of motion." Levels of low are assigned to both needed confidence and need to reduce uncertainty for the representation that Darcy's Law is applicable to describing ground-water flow throughout the regional and site flow systems. A level of high, however, is assigned to the sensitivity factor, because "estimates of SZ GWTT and transport characteristics are largely dependent on applicability of Darcy's Law". In light of this it seems that assigning a level of low to both needed confidence and need to reduce uncertainty is absurd.

Page 8.3.1.2-80. Table 8.3.1.2-2b

"Model element strain energy." The medium level assigned to the need to reduce uncertainty should be raised to high based on the sensitivity level, the rationale for which is given as "estimates of GWTT, water-table altitude, and transport characteristics are largely dependent on understanding the coupled effect of strain energy and fluid flow."

Page 8.3.1.2-81. Table 8.3.1.2-2b

"Model element thermal effect." A level of medium is assigned to the need to reduce uncertainty with respect to the representation that the coupled effect of heat convection in ground-water flow is likely to be minimal during the 10,000 year isolation period. In view of the high levels assigned to needed confidence and sensitivity, and the statement that "thermally driven convection could significantly effect transport of radionuclides", this level should obviously be raised to high.

Page 8.3.1.2-82. Table 8.3.1.2-2b

"Model element volcanism effects." The State disagrees with the assigning of low levels to both uncertainty and need to reduce uncertainty with respect to this element.

Page 8.3.1.2-87. Table 8.3.1.2-2b

"Model element coupled-effects modeling." Levels of high are assigned to needed confidence and sensitivity with respect to this element, yet levels of medium are assigned to uncertainty and the need to reduce uncertainty. The statement is made that the uncertainty level is medium because "insufficient data exists to determine if effects will be significant." If this is so, how is the uncertainty, and the need to reduce that uncertainty, anything less than high, particularly in view of that level having already been assigned to needed confidence and sensitivity?

Page 8.3.1.2-221. Bottom of page

The objectives of the Solitario Canyon horizontal borehole study are described. The horizontal borehole to explore the Solitario Canyon fault should be replaced by extending the drift to the Ghost Dance fault past the Solitario Canyon fault. Horizontal drilling is difficult and is unlikely to provide the desired information. Horizontal well logging is full of uncertainties. A horizontal drift to the Solitario Canyon fault would make it possible to characterize the western boundary of the site as well as the eastern boundary which will be characterized by a drift to the Imbricate faults.

Page 8.3.1.2-300. 2nd paragraph

The objectives of the experimental program for perched-water in the exploratory shaft facility are stated. As presently designed, the program will be meaningful only if perched-water is encountered during the excavation of the ESF. If no perched-water is encountered, The experiments will not be useful in explaining the water encountered during the drilling of USW UZ-1. The experiments are not designed to determine the conditions necessary for the development of perched-water. The experiments will not determine whether perched-water can develop at Yucca Mountain should there be a change in climate and an increase in the percolation flux.

Page 8.3.1.2-322. Bottom of page

The objectives of the gaseous-phase movement in the unsaturated zone are described. The studies appear to be designed to study the flow of air in the unsaturated zone. The studies do not emphasize the flow of carbon-14 dioxide in the unsaturated zone, which could be released from the repository in amounts violating the EPA standard. The studies, summarized in table 8.3.1.2-9 will not provide data on the effect of increased rock temperature on the flow of air and carbon-14 dioxide.

Page 8.3.1.2-367. 6th paragraph

Statement: "Beneath the repository block and downgradient from it, the water table is so flat that periodic water-level measurements (every several weeks), even when made with very high accuracy and precision, cannot be used to determine average water-level differences and gradients among wells."

The flatness of the water table or the absence of gradients might be the result of a hydrologic barrier further away to the south of the site. Alternatively, the apparent flatness may be a figment of well placement or extended period between measurements. No high quality continuous measurements of water levels are available or planned. The cause for the flatness of the water table should be thoroughly investigated. Experiments in wells outside of the NTS may be required.

SECTION 8.3.1.5. CLIMATE

Specific comments

Page 8.3.1.5-84. 2nd paragraph

Statement: "If the feasibility study does not produce encouraging results in terms of the resolution desired and computational efficiency regarding regional numerical modeling, as determined from criteria established by an expert panel, then the characterization of future regional climate and environments will be based essentially on the empirical modeling approach."

The time schedule does not contain any events that would indicate approximatly when the above identified commitments on regional climate modeling would take place. The subject is of importance to performance assessment and the timing should be identified.

Page 8.3.1.5-85. 3rd paragraph

Statement: "Following the testing period for the regional climate model, it will be decided if such a modeling approach is within the time and cost constraints of the Yucca Mountain Project. In addition, the defensibility of the model on its own will be analyzed as well as its ability to link with the global climate model."

Again, the time schedule does not contain any events that would indicate approximately when the commitments on linked global-regional climate modeling would occur. The subject is relevant to performance assessment. Furthermore, "time and cost constraints" place an unreasonable burden on resolving this issue with respect to licensing and regulatory requirements.

SECTION 8.3.1.8. POSTCLOSURE TECTONICS

Specific comments

Page 8.3.1.8-55. 4th paragraph

Statement: "Magma bodies of this type, if present, are likely to occur at depths of 5 to 15 km. As noted in Chapter 1 (Section 1.5.1.1) an absence of shallow silicic magma bodies beneath the Yucca Mountain area is suggested by the low heat flow and absence of high temperature springs."

There is no data supporting the notion that there exists a low heat flow beneath the Yucca Mountain area. Only one borehole, UE-25p#1, has been drilled to a depth of 6,000 ft or about 1,800 m. All other boreholes are substantially shallower. One of the two explanations for the Eureka low that are advanced in Section 1.7.1.5.2 (page 1-308) suggests that the Eureka low is the result of a complex inter-basin water flow with an appreciable downward flow of relatively cold water to a depth of approximately 3 km. The groundwater could be carrying off much of the earth's heat in the upper 3 km of the Yucca Mountain site and delivering it elsewhere. Below depths of 3 km, the heat flow could be relatively high and indicate the presence of a body of magma.

Page 8.3.1.8-56. 2nd paragraph

Statement: "The $^{3}He/^{4}He$ ratios in ground water adjacent to and surrounding Yucca Mountain will be measured to search for evidence of the presence or absence of subsurface magma bodies."

Again, with the exceptions of UE-25p#1, there are no deep boreholes beneath the Yucca Mountain site. It is possible to sample only ground water from the tuff aquifer, which must be considered as shallow and which acts as an open aquifer. Helium is likely to be lost rapidly by diffusion from an open aquifer and it is not likely that meaningful data will be obtained. Meaningful data is more likely to be obtained from confined aquifers deep beneath the Yucca Mountain site. The experiment requires several boreholes to depth greater than 3 km.

Page 8.3.1.8-61. 2nd paragraph

Statement: "Eruption parameters will be defined for an eruption scenario involving an initial hydrovolcanic eruption changing in time to Strombolian eruption. Parameters for a Strombolian eruption without a hydrovolcanic component have been completed (Link et al., 1982)."

There is no indication that parameters for a Strombolian eruption without a hydrovolcanic component have been completed. The study of Link et al., 1982, is outdated and based on assumptions, not data. This is acknowledged in the section on total system performance (Section 8.3.5.13, pages 8.3.5.13-80 and 8.3.5.13-132).

Page 8.3.1.8-66. Bottom of page

Statement: "The objective of this activity is to review and organize supporting field data collected by other activities, and to use this data to calculate the probability of an igneous intrusion penetrating the repository and the number of waste packages that would be affected by such an event."

The study should also consider that an igneous intrusion would add substantial amounts of heat to the rock around the repository causing thermal failure of many canisters and the release of a large amount of the Carbon-14 inventory.

Page 8.3.1.8-82. 5th paragraph

Statement: "This activity will take the data developed in Activity 8.3.1.8.1.1.4 on the probability of volcanic and igneous events penetrating the repository and expand that analysis to calculate probabilities for the area within 0.5 km of the controlled area boundary."

Such an analysis already exists and it is summarized on page 8.3.1.8-58. There should be a discussion indicating how the additional new data on heat flow, $^3He/^4He$, K/Ar dating, and the additional volcanic boreholes will improve the confidence to a value of high for the existing probability values.

Page 8.3.1.8-134. Table 8.3.1.8-9

The table indicates that most of the important reports on an igneous intrusion will not be available before 1994, which is just before the license application date.

It must be concluded from the time schedule that a meaningful performance assessment study on the volcanic intrusion scenario will not be available before license application. The State finds this schedule to be unacceptable given that the risk of volcanic activity may be a site disqualifying condition.

SECTION 8.3.1.9. HUMAN INTRUSION

Specific comments

Page 8.3.1.9-21. 4th paragraph

Statement: "The relative value of the ground-water resources that are located proximal to the site is known to be low at the present time. The depth to these resources, and the distance over which transport would be required, currently preclude economic exploitation (Sinnock and Fernandez, 1982)."

The statement is incorrect. According to Chapter 3, Section 8.3.1,the three water sub-basins of Oasis Valley, Alkali Flat -Furnace Creek Ranch, and Ash Meadows are over appropriated and the aquifers are over drafted. Section 8.3.2 describes the regional ground-water plan which indicates that it is almost impossible to get a new water permit. The report of Sinnock and Fernandez, which was written before 1982 is obviously out of date and an inappropriate reference on the subject. Furthermore, Chapter 3 neglects the potential of the regional carbonate aquifer as a future water resource.

Page 8.3.1.9-23. 3rd paragraph

Statement: "The scarcity of vegetation, wildlife, and water has historically precluded using the land within the controlled area for recreational purposes."

The statement is not supported by the archeological evidence. Numerous Indian artifacts have been found on the NTS indicating that it once supported a population of nomadic hunters. Furthermore, the statement is incorrect because the primary restriction on the use of Yucca Mountain for recreational purposes or resource exploration has been the proximity to the Test Site.

SECTION 8.3.1.15. THERMAL AND MECHANICAL PROPERTIES

Specific comments

Page 8.3.1.15-55. 1st paragraph

Statement: "A canister-scale heater will be emplaced in unit TSw, and temperatures, deformations, and changes in moisture content and changes in stresses will be monitored."

DOE, according to the SCP, has not made a decision relative to horizontal versus vertical canister emplacement, therefore it would appear that two experiments, one for horizontal emplacement and one for vertical emplacement, will be needed.

Page 8.3.1.15-62. 4nd paragraph

The heated room experiment is described. The heated room experiment should also include monitoring for radon gas.

SECTION 8.3.1.16 PRECLOSURE HYDROLOGY

Specific comments

Page 8.3.1.16-21. 4th paragraph

Statement: "The first part of this activity will focus on identifying the amount of unappropriated water available from sources other than wells J-12 and J-13."

The discussions of sections 3.8.1 and 3.8.2 indicate the water rights in areas near Yucca Mountain are over appropriated. The title of the section is "Location of alternative water supplies for a mined geologic disposal system at Yucca Mountain Nevada." Paragraph 4 indicates that the intention to locate alternative water sources is to redefine the ground-water yield potential and to drill a new well. That approach would only be viable with the advanced agreement of the State Water Engineer.

SECTION 8.3.1.17. PRECLOSURE TECTONICS

General comment

The section contains the following studies which involve new research techniques or have at best potential application for the generation of geological data: 8.3.1.17.4.7.1, Evaluate intermediate depth (2 to 3 km) reflection and refraction methods and plan potential application of these methods within the site area; 8.3.1.17.4.5, Evaluate surface geoelectric methods and plan potential applications of these methods within the site area; 8.3.1.17.4.7.6, Evaluate methods to detect buried faults using gamma-ray measurements, and plan potential application of these methods within the site; 8.3.1.17.4.7.7, Evaluate thermal infrared methods and plan potential applications of these methods within the site area; 8.3.1.17.4.7.8, Evaluate shallow seismic reflection (mini-sosie) methods and, if appropriate, conduct surveys of selected structures at and proximal to the site area; 8.3.1.17.4.8.2, Evaluate and test shallow borehole hydrofrac and triaxial strain recovery methods for the determination of in situ stress, and if appropriate, plan potential application of these methods within and proximal to the site; 8.3.1.17.4.9.1, Evaluate age and extent of tectonically stable areas at and near Yucca Mountain. There should be a discussion indicating the importance of the data these studies will generate with regards to site characterization and licensing, and there should be an indication of the backup studies available to produce similar data should the studies yield inconclusive data.

SECTION 8.3.3. SEAL PROGRAM

Specific comments

Page 8.3.3.1-1. 2nd paragraph

Statement: "Because of the timing activities from other activities, the seal program is somewhat different from other design-related activities. The repository surface facilities, the accesses, and portion of the underground facilities will be constructed shortly after construction is authorized; the remainder of the underground facilities will be constructed and waste packages emplaced during the repository operations. The seals, on the other hand, will not generally be installed until the repository is decommissioned."

The statement is certainly true for the ramps, shafts, and underground facilities. It is not correct for the numerous exploratory boreholes that will be drilled into Yucca Mountain to collect data for the construction of a three dimensional stratigraphy map. These boreholes will be sealed well before decommissioning. The statement also does not acknowledge that sealing will be required in the event the site is found not suitable.

SECTION 8.3.4. WASTE PACKAGE

Specific comments

Page 8.3.4-2. Figure 8.3.4-1

The figure shows a flow diagram that illustrates the waste package postclosure compliance strategy. The figure does not indicate at what step the cost effectiveness will be evaluated. Such a step is emphasized in section 7.2.1.3.2. A preliminary cost estimate of the waste package is contained in Appendix D of SAND85-1964. That estimate is the basis for estimating the total waste package cost at 600 million (1985 dollars). Since the evaluation of that analysis, the cost of steel and copper have risen significantly and the waste package cost is likely to rise because the important factor is the selection of the container material.

Page 8.3.4.2-27. 1st paragraph

Statement: "Second, for a vertical borehole, a liner with an unperforated bottom plate would totally block drainage. For a horizontal emplacement hole, a liner placed in a hole that was not sufficiently inclined to promote drainage might lead to local accumulation of standing water."

This statement is only correct for liners that have not failed. With time, all liner can be expected to fail, a process that may take only a few years. The conclusion that the accumulation of standing water in boreholes would lead to deleterious effects on the waste package performance has no real basis.

<u>Page 8.3.4.2-27. 3rd paragraph</u>

Two design goals for drainage of emplacement boreholes are discussed.

1. The boreholes will not fill with standing water under anticipated conditions at any time up to 10,000 yr following repository closure.

2. For the first 1,000 yr following repository closure, no more than 5 liters of standing water per waste package will accumulate in emplacement boreholes.

It is not clear how such performance allocation can be verified for these two goals.

<u>Page 8.3.4.2-32. 3rd paragraph</u>

The paragraph discusses the limits to alteration of water chemistry. The numerical values under test basis are not the same as those in table 8.3.2.4.2-4 (page 2 of 12).

<u>Page 8.3.4.2-53. 2nd paragraph</u>

Reference is made in the paragraph to computed impedance tomography. The subject is new and, therefore, appropriate references on the subject should be identified. The method is not mentioned in the ensuing section, Methods and Technical Procedures.

<u>Page 8.3.4.2-56. 4th paragraph</u>

Statement: "The extent to which waste containers can be loaded by rock-induced stresses will be evaluated. One of the potential mechanisms for such loading is slip of discrete blocks of rock along preexisting fractures."

It is not clear whether the study will evaluate the extent to which new or corroded waste containers can be loaded by rock-induced stresses. The loading of corroded containers is more important to performance assessment than the loading of new containers.

Page 8.3.4.4-2. Figure 8.3.4.4-1

The flow diagram does not indicate a step that would perform a cost analysis. A preliminary cost analysis is contained in Gruer E. R., et al, 1987, Cost Estimate of the Yucca Mountain Repository Based on the Site Characterization Plan Conceptual Design, SAND85-1964. According to that document, the cost of operation of the repository will be 4.4 and 4.8 billion dollars (1986) for horizontal and vertical emplacement, respectively. Included in these figures are 0.6 billion dollars for the waste packages, assuming that the package will be made of 304L stainless steel. The waste package represents 14 and 13 percent of the operating cost of the repository, respectively. The cost of steel and copper have increased significantly since 1986 and it is very likely that the waste package cost will be in excess of 1 billion dollars. Therefore, cost of manufacturing the waste package is becoming the most important parameter in waste package technology.

SECTION 8.3.5. PERFORMANCE ASSESSMENT PROGRAM

Specific comments

Page 8.3.5-1. 2nd paragraph

Statement: "Section 8.3.5.6 and 8.3.5.7 (Issues 2.5 and 4.1) differ from the previous sections, in that they address the site data requirements for supporting higher level findings on the DOE general siting guidelines (10 CFR 960). These findings are required at the time of selection of the first repository site".

The first site to be characterized for a repository has been selected. The purpose of DOE's higher level findings needs to be redirected and restated.

Page 8.3.5.1-4. 3rd paragraph

Statement: "The PRAM program will develop detailed analytical approaches for addressing each risk category. In developing the analytical approaches, the major considerations will be addressed collectively to reflect their interdependence."

Appendices F and L of the Conceptual Design/Site Characterization Plan contains much of what is promised in the PRAM program. It is not clear why section 8.3.5.1 contains numerous paragraphs, like the one quoted above, which convey the impression that the PRAM program has barely begun.

Page 8.3.5.2-22. 1st paragraph

The six information needs important to waste retrievability are enumerated in this paragraph. All these information needs are cost dependent. Yet a cost analysis of retrievability is avoided. Take for example Information Need 2.4.3 which requires the determination that access to the waste packages can be provided throughout the period of retrievability and the actual retrieval period for normal and credible abnormal conditions. Such an analysis has already been carried out in part and can be found in the report of Wallace, K. J. Jr., and D. P. Zerga, 1988. An Analysis of Air Cooling Prior to Re-Entering a Drift containing Emplaced commercial Nuclear Waste, SAND87-7076C. The report indicates that, for the vertical emplacement layout, it will take more than 360 days to cool down an emplacement drift if the inlet air is not cooled. If the inlet air is cooled, then it will take 50 days. Since the design includes over 600 emplacement drifts, about 20 drifts will have to be cooled each year for the retrievability operation to be successful over a period of 30 years. Clearly the cost of retrievability may turn out to be several times the cost of emplacement. Whenever addressing the subject of retrievability, a discussion of the economics of the issue must be included.

Page 8.3.5.2-46. 4th paragraph

Activity 8.3.5.2.6. Information Need 2.4.6: Determination that the retrieval requirements set forth in 10 CFR 60.111(b) are met using reasonably available technology. The discussion that follows seems to indicate that cost of retrievability is not included in the definition of reasonably available technology.

Page 8.3.5.3-5. 1st paragraph

Statement: "(Transportation of HLW to the repository is excluded from the definition of site characterization by the Nuclear Waste Policy Act) Transportation of this HLW within the repository boundaries will be considered part of the repository program."

The evaluation of radiation exposures due to transportation should be extended to the unrestricted area under consideration and should include Las Vegas and the roads leading into the city. The radiation monitoring program should not be limited by the boundaries of the repository. Table 8.3.5.3-1 should include performance measures for radiation exposure due to transportation.

Page 8.3.5.3-14. Table 8.3.5.3-2, Column 6

The expected parameter value for radon emanation rate from tuff is given as 0.48 pCi/m^2-s. It is not clear whether this emanation rate is from the underground facility or from the pile of mined tuff at the surface. The emanation rate from an underground facility will be dependent on the rock temperature and should increase with time as the repository is loaded with spent fuel elements. The emanation rate from the surface pile of mined tuff will be weather dependent.

Page 8.3.5.4-19. 3rd paragraph

Statement: "There is only one piece of site data needed to satisfy this information need: the radon emanation rate of the mined tuff."

The Information Need referred to is 2.2.1: determination for radiation environment in surface and subsurface facilities due to natural and man-made radioactivity. The statement needs elaboration. There are at least two sources of mined tuff, the underground facility and the large pile of mined tuff at the surface. The radon emanation in the underground facilities will vary in time and it is doubtful that the radon emanation rate during operation can be assessed adequately during site characterization. As the repository will be loaded with spent fuel, the rock will be heated and dried. The radon emanation rate into the drifts will vary with the rock temperature and effective porosity. Unventilated rooms are very likely to attain very high levels of radon, a not uncommon phenomena observed in unventilated mines. Radon gas will also emanate from the large pile of mined rock at the surface, and this emanation rate will be weather dependent. The mined tuff piled up during site characterization will be small compared to the pile that will accumulate during construction of the repository. There is no discussion in the Radiological Monitoring Plan that indicates an elaborate radon monitoring program that will make it possible to extrapolate from the site characterization period to the construction and operation period.

Page 8.3.5.6-1. Footnote

The footnote indicates that the passage of the Nuclear Waste Policy Amendments Act of 1987 (NWPAA, 1987) may have impact on the manner in which the site selection process is carried out. The passage of the NWPAA may require the amending of 10 CFR 960.

There should be an indication how the issue must be resolved and when there will be an attempt to resolve the issue. Revising 10 CFR 960 may be a time consuming process and may impact the characterization schedule.

Page 8.3.5.8-5. Figure 8.3.5.8-2

The figure illustrates the steps in performance assessment for post-closure performance issues. The figure seems to indicate that all issues will be resolved by an iterative acquisition process of additional data until no more data is necessary. The strategy needs elaboration. It is possible that the experiments will yield only ambiguous data, and it may happen that some important computer codes, such as TOSPAC, cannot be validated. The flow diagram addresses the evaluation of scenarios but it does not address the two most important licensing criteria, namely, the calculation of the ground water travel time (GWTT) to the uncontrolled boundary and the evaluation of the complementary cumulative distribution function (CCDF). The dislike for an early evaluation of the CCDF is also demonstrated in section 8.3.5.13, total system performance, in which it is indicated that the screening of scenarios will be done by evaluating the expected partial performance measure (EPPM). The flow diagram also fails to address how the probability of occurrence of a scenario will be obtained and verified.

Page 8.3.5.9-12. 3rd paragraph

Statement: "As discussed in Section 8.4.1.1, the unsaturated zone environment is naturally dry, and is likely to remain that way for 10,000 yr and more."

The statement is ambiguous and in contradiction with other sections of the SCP. The unsaturated zone is about 60% saturated and contains large amount of water. Furthermore, the dryness will change significantly over the next 10,000 years. Following emplacement of the spent fuel elements, the heating of the rock surrounding the repository horizon will cause water to be vaporized and expelled. Later, as the rock cools down, water will migrate back towards the repository horizon. Finally, a climate change, which could bring greater precipitation in the Yucca Mountain area, is possible over the next 10,000 years.

Page 8.3.5.9-19. 3rd paragraph

Statement: "Thus, to guide the testing program, the DOE has established the tentative criterion that release of these isotopes from the waste packages will be controlled such that their annual rates of release are each less than 1 part in 1,000,000 for those isotopes present in sufficient quantity in the 1,000-yr inventory."

The criterion is much too complicated and too confusing and additionally it is not probabilistic as called for by the NRC, who is quoted on page 8.3.4.9-4 as follows: "It is realized that a small fraction of the approximately 100,000 packages will be breached before 1,000 years due to variations in materials manufacturing processes, etc., that can only be estimated using statistical procedures and the NRC numerical criterion for releases following the end of the containment period." As stated in its present form, the criterion will require a myriad of scenario calculations. The DOE should develop criteria that states that the probability of a container failing will be less than a numerical value to be evaluated by risk analysis.

Page 8.3.5.9-23. 2nd paragraph

Statement: "The container will be designed with a design life goal that is consistent with the duration of the containment period."

The statement is too vague and ambiguous. There is a need for more conciseness and more elaboration.

Page 8.3.5.9-25. 2nd paragraph

The meaning of the "maximum failure in any given year", an important phrase in the caption of Figure 8.3.5.9-4, is discussed.

If a probabilistic approach is used to describe the performance of the waste package, then it is not correct to emphasize the upper limit of the failure rate. An appropriate discussion would indicate the statistic that will be used (Chapter 8 indicates that the Poisson process will be important in demonstrating the total system performance). The discussion should emphasize the statistical distribution that will be used to characterize the failure rate of the waste package.

Page 8.3.5.9-32. 3rd and 4th paragraph

Performance measures for the cladding are discussed in these paragraphs.

The discussion should indicate why the performance measures are not burnup dependent. More cladding failures should be expected from high burnup spent fuel elements which are expected to be generated in large quantities in the years ahead.

Page 8.3.5.9-35. 5th paragraph

Performance goals for the container are discussed in this paragraph.

Again, it is more meaningful to present the statistics that will govern the performance measure and the parameters necessary to describe statistics.

Page 8.3.5.10-14. 4th paragraph

Statement: "The second alternative would be to remove carbon-14 from the exterior of the cladding and assembly components by heating (and oxidizing the carbon to carbon dioxide) before emplacement."

The alternative requires a statement indicating the location of the carbon removal facility. Will the carbon-14 removal be performed in the Yucca Mountain surface facility, or at an MRS facility, or at the reactor? If the DOE expects the removal of carbon-14 to be done at Yucca Mountain, then the current CD/SCP is totally inadequate and the cost estimate of the facility of Gruer et al., SAND85-1964, should be redone. Also, the PRAM analysis discussed in section 8.3.5.1 would have to be restructured significantly.

Page 8.3.5.10-16. 1st paragraph

Statement: "Another alternative (which applies to both waste forms) would be to include a portion of the host rock as part of the engineered barrier system. This rock is expected to significantly limit the release rate."

The paragraph needs elaboration. It is not clear what portion and what thickness of host rock should be used. Also, there is a need to discuss the effect of the heat on the rock. Currently it is questionable whether the host rock will "significantly limit the release rate."

Also, the alternative of considering host rock as an engineered barrier is in contradiction to Section 6.1.5 which contains the following definitions: "Barriers important to waste isolation are defined by the DOE (DOE 1987c) as the barriers, structures, systems, and components that are relied on to achieve the postclosure performance objectives in 10 CFR 60, subpart E. The engineered barriers that meet this definition are placed on the Q-list." The natural barriers that meet this definition are not placed on the Q-list because they cannot be designed.

Page 8.3.5.10-17. Table 8.3.5.10-2

Tentative goals are given in the Table for the amount of water contacting the waste packages each year. The goals are given in the form of a simple distribution.

The discussion does not appear to be consistent with Section 8.3.5.9 which discusses also waste package failure rates, but which does not provides similar data, i.e. a distribution of the failure rate of waste packages. Section 8.3.5.9 provides instead a discussion of the maximum failure rate of waste packages with restriction. It is not clear how all these different mathematical expressions for the failure rate will be combined in evaluating the total system performance.

Page 8.3.5.10-74. 2nd paragraph

Statement: "The uncertainty methodology will be part of the waste package performance assessment model. Therefore, verification and validation of the methodology will be required. After development, verification exercises will be conducted to ensure the mathematical accuracy of the methods. Validation of the model will be accomplished by validation of the system model and through other means as available. As for the system model, the final validation of the uncertainty model will be performed through peer review."

The discussion indicates the assumption that validation of the methodology will be successful. What will be done if a convincing validation, i.e., a nearly unanimous peer review, is not possible?

Section 8.3.5.11. General comment

Section 8.3.5.11 appears to be preliminary when compared to the other sections of Chapter 8. The section gives the impression that the seal system performance assessment has not been given any consideration. The activities mentioned at the bottom of page 4 and the top of page 5 are not as detailed as are the activities in other sections of 8.3.5 and do not provide any insight in the work that is planned.

Page 8.3.5.12-9. Table 8.3.5.12-1, 5th and 6th column

The fifth column shows the performance goal in years while the sixth column shows the needed confidence which measured in units of standard deviation below the mean.

Column six cannot be understood because the origin and calculation of the standard deviation is not explained. An explanation using the results of Figure 8.3.5.12-5 or the numbers for mean and standard deviation of the Sinnock et al. study as an example should be included.

Page 8.3.5.12-12. Figure 8.3.5.12-4. Isopach contour maps of hydrogeologic units

The figure appears to be poorly constructed. Take for example the point in the upper right hand corner where the two dashed grid lines intersect. Figure B indicates a TSw thickness of 45 m and Figure D indicates a CHnz thickness of 115 m. The thicknesses of all other formations are zero. The thicknesses of Figures B and D add up to 160 m which is not in good agreement with the value of 140 m from Figure A. Similarly for the intersection of the two dashed lines in the lower left hand corner, Figures B, C, D, E, F, G, and H indicate thicknesses of 21 m for TSw, 92 m for CHnv, 32 m CHnz, 20 m for PPw, 86 m for PPn, and 0 m for BFw and BFn The total of 251 m is not in good agreement with the value of 300 m shown in Figure A.

Page 8.3.5.12-18. Figure 8.3.5.12-4. Examples of ground-water travel-time distributions

Two figures, created from data generated by the GWTT code for an input flux of 0.5 mm/yr, are presented to demonstrate that the GWTT code is capable of providing a statistical distribution of the ground-water travel time.

The figures show the thickness of the various hydrological units between the repository horizon and the water table. This is best illustrated by comparing the bottom picture of Figure 8.3.5.12-5 and (A) of Figure 8.3.5.12-4.

In the GWTT code, the area enclosed by the perimeter drift is divided into 963 columns. It would be useful to present the thickness histogram of the 963 columns next to ground-water travel time distribution.

Page 8.3.5.12-21. Table 8.3.5.12-2

The table presents the performance parameters for resolving Issue 1.6. The parameters are important in calculating the ground-water travel time (GWTT). Figure 8.3.5.12-9, page 8.3.5.12-64, indicates two GWTT calculations: a) the pre-waste emplacement GWTT, and b) the GWTT after repository construction and waste emplacement. Therefore, the table should contain two sets of parameters, one for each type of calculation.

Page 8.3.5.12-36. 5th paragraph

Statement: "These confidence levels are based on professional judgement about the relative importance of the various parameters and are not meant to imply any quantitative definition. The confidence levels indicate the desired confidence for the location-dependent mean, standard deviation and spatial correlation. For example, if the "true" standard deviation is large and the desired confidence in the standard deviation is high, sufficient samples must be measured to show high confidence that the standard deviation of the sample population is a good approximation of the real variance of the parameter of interest."

The paragraph is very confusing. A numerical example should be included in the explanation. First it is emphasized that there is no quantitative definition for confidence levels. Then it is emphasized that sufficient samples must be measured to show the desired level of confidence. Finally, Figure 8.3.5.12-9 indicates two GWTT calculations with completed updated calculations not available before 9/93 and 2/92. Since the DEIS is scheduled to be released by the end of 1993, there appears to be no time available for a reevaluation of the sufficiency of the number of samples considered sufficient.

Page 8.3.5.12-46. 2nd paragraph

Statement: "The numerical accuracy of the calculational models used in analysis of flow will be verified by tests including comparison to analytical solutions and benchmarking against other codes. Currently, the Yucca Mountain Project is participating in HYDROCOIN, an international effort to verify and support validation of computer codes to be used in assessment of environments related to nuclear waste disposal."

The reference to HYDROCOIN efforts is misleading. The DOE has published several reports on ground water movement in unsaturated rock that include computer calculations and none discusses analytical solutions. The report of Sinnock et al. which describes the GWTT code does not include a verification against analytical solutions. The United States is the only country attempting to build a repository in the unsaturated zone in tuff. Most other countries are looking at sites in granite which is very different from tuff and usually treated as saturated rock. Therefore, the HYDROCOIN effort deals mostly with hydrology in saturated rock.

Page 8.3.5.13-3 to 25. Methods for constructing a complementary cumulative distribution function (CCDF)

The proper title for this section should be "justification for replacing the CCDF by the expected partial performance measure (EPPM)."

The section is not a discussion of the development of the CCDF for the scenarios that are considered possible at Yucca Mountain. Rather, the section is a tutorial intended to show that the calculation of a few EEPMs is a "surrogate" for the calculation of the CCDF. The section, as well as ensuing sections, clearly indicate that the EEPMs for scenarios important to the licensing of Yucca Mountain will be calculated first using deterministic models. The CCDF will be constructed after it has been determined that the site can be licensed. The calculation of the EPPM before a knowledge of the probability distribution function or the CCDF is mathematically incorrect and an attempt to obfuscate the issue by the use of circular logic; as indicated by equations (8.3.5.13-6) and (8.3.5.13-8). The correct calculation of the EPPM requires a knowledge of the probability distribution function or its equivalent the CCDF.

Page 8.3.5.13-3. 1st paragraph

Statement: "The remainder of this section discusses a methodology for the performance assessments and for defining suitable information needs for the resolution of this issue. The methodology that will actually be used in preparing the license application may differ from the methodology proposed here."

Throughout the SCP, the position is taken that site characterization and license application are synonymous. The third step in Issue Hierarchy For A Mined Geologic Disposal System, DOE/RW-0101 (Figure 5), which is the basis for the planned activities in the Site Characterization Plan, is "set licensing strategy." Thus, it is unclear why suddenly a licensing methodology is not the basis for the assessment of the total system performance. In the pages that follow, it is apparent that the expected partial performance measures (EPPMs), which at first will be obtained using deterministic models and which is not called for in the license application, will be the basis of the process of screening and discarding scenarios. The complementary cumulative distribution function (CCDF), which is called for in license application, will be constructed only after the screening has been completed.

Page 8.3.5.13-7. 3rd paragraph

Statement: "An idealized geologic repository system must be described ultimately by a finite number of dependent variables (here called performance measures). In turn, the performance measures are functionally dependent upon a finite number of independent variables, which are called state variables."

The statement gives the indication that there are several performance measures. The performance measure M is described on page 4. If there are other important performance measures for the evaluation of the repository, they should also be described in the early pages of section 8.3.5.13.

Page 8.3.5.13-7. 4th paragraph

Seven examples of independent state variables are presented in the fourth paragraph.

Examples 2, 3, and 6 may not be independent as is emphasized in the discussion of the previous paragraph.

Page 8.3.5.13-9. 2nd paragraph

Statement: "The CCDF for the performance measure can be formally represented by

$$G(m) = E[u(M-m)] \qquad (8.3.5.13\text{-}4)$$

where u(x) is the unit step function ($u(x) = 0$ if $X < 0$ and $u(x) = 1$ if $X > 0$)."

The introduction of equation (8.3.5.13-4) is a good illustration of the circular logic used throughout the discussion on methods for constructing a complementary cumulative distribution function. In equation (8.3.5.13-3) the integration is over n variables denoted by $v_1, v_2, \ldots v_n$. In equation (8.3.5.13-4), the integration is over one variable denoted by M. In order to make the two equations consistent, relationships between the vector $(v_1, v_2, \ldots v_n)$ and M should be provided or discussed. There may be several vectors $(v_1, v_2, \ldots v_n)$ that correspond to a single value of M. It appears that the sole reason for equation (8.3.5.13-4) is to prepare the way for equation (8.3.5.13-8), which is in turn the justification for using the EPPM as a surrogate for the CCDF. The evaluation of F(dV) or of the CCDF is the task of the total system performance assessment. For the scenarios that are of importance over the next 10,000 years, this can be done only by enumerating geological events over a sufficiently large area surrounding the site and the probability of occurrence.

Page 8.5.3.13-10. 2nd paragraph

Statement: "The condition follows from Markov's Inequality (Loeve, 1960), which states that, for any non-negative random variable X and any positive number x,

$$\Pr\{X \geq x\} \leq E[X]/x$$

In other words, a CCDF must be bounded above by the positive branch of the hyperbola defined by $y = E[X]/x$."

The condition is of academic importance since the evaluation of E[X] requires a knowledge of F(dV) which is equivalent to a knowledge of the CCDF. The authors could have also made a similar statement using Chebyshev's inequality.

Page 8.5.3.13-12. 5th paragraph

Statement: "Although this procedure might be justified on the pragmatic grounds that all $P(S_j)$ are very small numbers whose assignments are ultimately based on subjective judgement, it nevertheless violates the logic of probability theory and provides no definite logical pathway for inferring the $P(S_j)$ from the more-fundamental probabilities of the occurrence of events and processes."

The logic of probability theory requires some normalization because, if the S_j scenarios are mutually exclusive and form the complete set of events, then $\mathrm{sum}(P(S_j)) = 1$. A credible evaluation of $P(S_j)$ is the important task of performance assessment.

Page 8.3.5.13-18. 1st paragraph

Statement: "Taking the formal derivative of Equation 8.3.5.13-6, to obtain a probability density function by m, multiplying that probability density function by m, and applying the expectation operator ((Equation 8.3.5.13-3) to the resulting product gives

$$E[M] = \text{sum}(E[M|S_j]P[S_j]) \qquad (8.3.5.13\text{-}3)"$$

Equation (8.3.5.13-8) is not consistent with equation (8.3.5.13-3). A link between the vector $(v_1, v_2, ..v_n)$ and M must be established first. Equation (8.3.5.13-8) has been introduced solely to justify the following statement of paragraph 3 on the same page: "It follows that the EPPMs for scenario classes involving the kth disruptive agent are bounded above by $p_k B_j$ (or B_j when p_k is unknown), and that the latter quantities can be used as surrogates of the EPPMs in a preliminary screening of potentially disruptive agents." This is a very good example of circular logic.

Page 8.3.5.13-19 & 20. 2nd and 3rd paragraph

In mentioning the Poisson and non-homogeneous Poisson process, reference is made to (Ross, 1985). Further, the reference is incomplete in the reference section accompanying the chapter.

The DOE did forward to the State a xerox print of chapter 1, pages 1 through 20 of Sheldom M. Ross, Introduction to Probability Models, Academic Press, Inc., Orlando, FL, 1985. The chapter is entitled Introduction to Probability Theory, and deals mostly with classical problems involving the throwing of dices and the drawing of cards. The chapter has no discussion of the Poisson process.

Page 8.3.5.13-26. 1st and 2nd paragraph

The scenarios of the decision-aiding methodology are summarized in these paragraphs.

The decision-aiding methodology used for the Environmental Assessment was a flawed study; the probabilities of the scenarios were obtained by sampling the opinion of high ranking DOE officials at DOE Headquarters only. The probability for the occurrence of a volcanic event at Yucca Mountain was different from the one reported in the Environmental Assessment.

Page 8.3.5.13-28. 2nd paragraph

Statement: "The sequence associated with climate change dismissed by Ross (1987) and the pages in his report giving the reasons for exclusion are as follow: increased recharge due to "greenhouse effect" warming that exceeds 50 percent (p. 16), recharge exceeding maximum level attained during the past 100,000 years (p. 16)..."

All scenarios involving the greenhouse effect should be subjected to the process of screening since the President of the United States has acknowledged that the greenhouse effect is an important environmental issue. It will be extremely difficult to accurately portray the greenhouse effect and its impact on the climate over the next 10,000 years. At best, the climate program outlined in section 8.3.1.5 may provide data that will emphasize the past 50,000 and 100,000 yr in great and moderate detail respectively. It is doubtful that an accurate value of the maximum recharge level during the past 100,000 yr will be available.

Page 8.3.5.13-32. 2nd paragraph

Only one scenario is developed for extrusive magmatic activity. A second credible scenario would include the failure of numerous canisters away from the dike because of the heating of the rock, adverse hydrologic changes and the release of all stored carbon-14.

Page 8.3.5.13-54. 2nd paragraph

Statement: "Then, scenario categories are defined in which the barriers important to waste isolation are significantly disturbed from the conditions defined in the nominal scenario. These scenario categories are shown in Table 8.3.5.13-3."

The scenario categorization of Table 8.3.5.13-3 may not be suitable for the construction of mutually exclusive scenarios and thus may be unsuitable for the construction of the CCDF. In paring down the number of scenario classes presented in Table 8.3.5.13-2, the most important criterion should be the evaluation of equations (8.3.5.13-1) and (8.3.5.13-6), the second of which implies mutually exclusivity of the scenarios.

Pages 8.3.5.13-56 to 75. Models for water-pathway releases

The discussion is a mixture of the equations used in the TOSPAC (Dudley, A. L., R. R. Peters, J. H. Gauthier, M. L. Wilson, M. S. Tierney, and E. A. Klavetter, 1988. Total system Performance assessment Code (TOSPAC) Volume 1: Physical and Mathematical Bases, SAND85-0002) and in the GWTT (Lin Y. T., M. S. Tierney, and S. Sinnock, Editor, 1986, Preliminary Estimates of Groundwater Travel Time and Radionuclide Transport at the Yucca Mountain Repository Site, SAND85-2701) codes.

The discussion does not indicate how the two codes complement each other. The TOSPAC code solves a boundary value problem which does not allow for fluctuation in density and hydraulic conductivity. The GWTT is a Monte Carlo method that assumes vertical steady state-flow at all times. The discussion further gives the impression that the DOE will rely on the GWTT for the estimation of radionuclide releases to the uncontrolled boundary. This is in contradiction to table 8.3.5.19-1 which indicates that the total integrated system will be evaluated using the TOSPAC, the NWFT, and the SPARTAN codes.

<u>Pages 8.3.5.13-75 through 80, Models for gas-phase releases</u>

Models to be used in the analysis of radioactive gases are outlined.

The discussion fails to address the scenario of increased release of natural radioactivity due to heating and dehydration of the rock surrounding the repository horizon. Because the repository is in the unsaturated zone and dehydration of a large volume of rock is expected, the heating of the rock will increase the radon emanation rate in the underground facilities as well as at the surface of the mountain. Significant excess releases of radon gas, which could elevate the background radiation level in a large area surrounding Yucca Mountain, are a possibility.

<u>Page 8.3.5.13-75. 1st paragraph</u>

Statement: "Using these values, one finds that at $q_U = 5$ mm/yr, the mean UZ transport time for nonsorbing species (where $R^i{}_m = 1$) is just about 10,000 yr, and much longer for sorbing species (e.g., uranium's mean transport time through the UZ would be 270,000 to 450,000 yr)."

The estimates are not conservative since they do not assume a rise in the elevation of the water table. With a flux of 5 mm/yr, an elevation of the water table can be expected.

<u>Page 8.5.3.13-80. 4th paragraph</u>

The report of Link et al. (1982) is used as a reference for a discussion of the geology of volcanism at the Yucca Mountain site.

The report of Link et al. is a modeling study on volcanism. It is not a proper reference for discussing the volcanic geology of the Yucca Mountain site. A reference to reports written by geologists should be used for the geological description of the Yucca Mountain site.

<u>Page 8.3.5.13-81. 3rd paragraph</u>

An estimate of the performance measure M for direct release assuming basaltic volcanism is presented. The calculation assumes that 11 waste packages are intercepted.

The calculation is not conservative. The magmatic intrusion could add large amounts of heat to the rock surrounding the repository, which could cause many waste package to fail as a result of thermal stress and thereby cause the release of a large fraction of the ^{14}C inventory. Also, the calculation is based on the report of Link et al. which used a deterministic model for the evaluation of the EPPM, not a probabilistic model. In fact, the report of Link et al. never had as its aim the evaluation of equations (8.3.5.13-1) and (8.3.5.13-6).

Page 8.3.5.13-82. 3rd paragraph

Statement: "Given the long transport times through the unsaturated zone that are predicted for the nominal case (less than 1 percent of calculated ground-water travel times are less than 10,000 yr (Sinnock et al., 1986), the consequences for direct release through ground-water withdrawal appear to be minuscule and probably can be ignored."

The report of Sinnock et al. is preliminary and contains two ground-water travel time calculations for fluxes of 0.5 and 1.0 mm/yr. Postclosure scenario modeling should be done for the maximum flux predicted over the next 10,000 years. In the climate section, the DOE has set itself the goal to demonstrate that the flux change will be less than 5 mm/yr. Therefore, the bounding values for ground-water travel time in section 8.3.5.13 should be a flux of 5 mm/yr, and it should also include a change in the elevation of the water table. Also, predictions of transport times for the nominal case only is not a conservative approach.

Page 8.3.5.13-83. 3rd paragraph

Statement: "Given that the entire thickness of the TS unit under the surface projection of the perimeter drift and extensions is vertically penetrated by the drill-bit, the probability that a waste package is at least grazed by any one drill-bit is

$$p = \begin{cases} 0.0125 & \text{(horizontal emplacement)} \\ 0.00152 & \text{(vertical emplacement)"} \end{cases}$$

In order to conform with equation (8.3.5.13-6), the probability p should be replaced by the conditional probability $P(E|S)$ where S is the event of human intrusion and E is the event of grazing the canister by the drill-bit. This notation would have prevented the error discussed in the following comment.

Page 8.3.5.13-84. Equation 8.3.5.13-35

The calculation of the performance measure M also includes the probability p of intercepting the canister.

The CCDF is a plot of the performance measure M, which is calculated using a deterministic model, versus the sum of the probabilities of event as given by equation (8.3.5.13-6). For the scenario of direct release via human intrusion, the product G(m|S)P(S) is estimated using socioeconomic data and expert judgement. Equation (8.3.5.13-35) is in error because the calculation of M should not involve G(m|S), the conditional probability of grazing the canister with the drill-bit.

Also, the calculation of M should involve more than 1 drilling. The proposed EPA draft standard allows for 3 boreholes per square kilometer per 10,000 years. The Yucca Mountain site has an area of about 6 square kilometers, which allows for 18 boreholes. Yet, for a typical resources exploration program, drillholes on 100-foot centers is appropriate.

Page 8.3.5.13-89. 4th paragraph

Statement: "Column 6 shows the performance measure for each scenario class, the expected partial performance measure (EPPM). The EPPM is defined earlier in this section, in the discussion entitled "Screening for significant events, processes, and features"; it appears formally in Equation 8.3.5.13-8. Ideally, the value of the entire CCDF could be used as the performance measure. To obtain such a value would, however, require that information for all the scenario classes be available at the same time;..."

The table should contain preliminary values on P(Si), the probability of the occurrence of scenario class i, and M_i, the performance measure for release. Tentative goals should then be assigned on these parameters that show that an acceptable CCDF can be achieved.

Page 8.3.5.13-93. Table 8.3.5.13-9, Column 3

The table indicates a tentative parameter value of < 0.5 mm/yr for q_u, the average flux through the R-area UZ, for scenario class E, the nominal case.

This tentative goal is inconsistent with the discussions on climate, Chapter 3, and Section 8.3.1.5. The future climate discussions clearly indicate that a change of climate will occur during the next 10,000 years. Section 8.3.1.5 includes an activity that will attempt to demonstrate that the change in flux will be less than 5 mm/yr. Therefore a flux value of 5 mm/yr should be used in class E scenario.

Page 8.3.5.13-98. Table 8.3.5.13-12, Column 5

The table indicates a tentative parameter goal of < 0.5 mm/yr with 67% confidence or more for changes in flux of class C-1 scenario or more.

The selection of this tentative parameter is inconsistent with Table 8.3.1.5-1, page 8.3.1.5-4, which indicates an expected flux change of < 5 mm/yr as a result of climate changes over the next 10,000 years.

Page 8.3.5.14-5. 4th paragraph

Statement: "For the resolution of Issue 1.2, however, a bounding-value calculation will be used. The inventory of carbon-14 available for rapid release, a total of 200 Ci for 1,000 yr, is small compared with (1) an average release of 5 to 10 Ci for each operating nuclear power plant (boiling water and pressurized water reactors) into the atmosphere every year and (2) the design basis release of approximately 800 Ci/yr from a 1,500-MTHM/yr fuel-reprocessing plant."

A release of 200 Ci of carbon-14 in Nevada should be considered as large since the state does not have any nuclear power plants, does not have a fuel-reprocessing plant, and is remote from both nuclear power plants and fuel-reprocessing plants.

Page 8.3.5.15-6. 5th paragraph

Statement: "In addition to its protection by the thick unsaturated zone, the lower carbonate aquifer has a higher potentiometric head than does the tuff aquifer in the vicinity of the site, according to data obtained from drillhole UE-25p#1 Craig and Robison, 1984)."

The statement is based on one measurement of the potentiometric head in a borehole that penetrates merely the upper part of the carbonate aquifer. Several additional measurements in more than one borehole and for several depths will be necessary to validate the statement.

Page 8.3.5.16-7. Table 8.3.5.16-1

The table does not indicate any performance confirmation program for volcanic activity. It must be assumed that volcanic activity will be studied only during site characterization.

Page 8.3.5.17-20. Potential adverse condition 2

The discussion of the strategy for the resolution of potential adverse condition (PAC) 2 fails to mention whether the condition is present at Yucca Mountain. The water usage discussion of

Chapter 3, especially Figure 3-24 on page 3-132, indicates that PAC 2 is present near Yucca Mountain, therefore, a strategy for resolution of PAC 2 should be presented.

<u>Page 8.3.5.17-36 to 49. Tables 8.3.5.17-6 & 7, Column 3</u>

The tables indicates an expected flux change due to climatic changes over the next 10,000 yr will be < 0.5 mm/yr.

A flux change of < 0.5 mm/yr over the next 10,000 yr would not be in agreement with the flux change of < 5 mm indicated in Table 8.3.1.5-1 on page 8.3.1.5-4.

<u>Page 8.3.5.18-24. 5th paragraph</u>

Statements: "The steps of this resolution strategy have been completed through the identification and information needs." and "Over the 10,000-yr period, the DOE has determined that disruptive climatic changes have a probability of occurring of less than 0.1 and are, therefore, considered in the disturbed-performance scenario classes. However, over the 100,000-yr period these changes are expected to have a probability of occurring of greater than 0.1, and, therefore, need to be included in the 100,000-yr nominal-performance scenario class."

The statements need to be referenced, or at the very least it should be indicated that the analyses have not been published or released for public information. To date, no report that addresses the resolution of issue 1.9(b) of 10 CFR 960.3-1-5 has come to the attention of the State.

<u>Page 8.3.5.18-24. 5th paragraph</u>

Statement: "The tectonic events and processes that were determined to have a probability of realization of less than 0.1 during the next 10,000 yr (and are, therefore, included in the disturbed-performance scenario classes of Issue 1.1) are expected to also have a probability of realization of less than 0.1 for the 100,000-yr period and hence need not be considered in the 100,000-yr assessments since they are not natural events or processes."

Again, a report detailing the analyses in support of this statement should be made available. The recent age analyses of the Lathrop Wells cone would suggest that volcanic activity cannot be ruled-out over the 100,000-yr period. Volcanic activity should be included in the resolution of 10 CFR 960.3-1-5 until it is conclusively proven that volcanic activity near the Yucca Mountain site has become benign.

Page 8.4.3-58. 3rd paragraph

Statement: "Climate change consists of a global warming due to increased atmospheric carbon dioxide, accompanied by an increase in summer precipitation of probably less than 50 percent. Subsequently, the onset of a cooler and wetter pluvial period is expected. Thus, climate change could increase flux, which could reasonably be expected to increase the volume of water moving from saturated fractures or perched-water zones into the site characterization penetrations."

The statement should be amplified or clarified to show that it is not in contradiction with the following statement of page 8.3.5.18-24 of the SCP: "Over the 10,000-yr period, the DOE has determined that disruptive climatic changes have a probability of occurring of less than 0.1 and are, therefore, considered in the disturbed-performance scenario classes."

SECTION 8.7. DECONTAMINATION AND DECOMMISSIONING

General comment

The section is entirely inadequate. It is devoid of the detailed discussion found in other sections of the SCP. Only one paragraph (8.7.3, 18 lines and 6 sentences long) attempts to address the plans for mitigation of significant adverse environmental impacts. It merely cites the findings of the environmental assessment and "standard operating procedures and good engineering practices", as their mitigation plans. There seems to be only an oblique reference to the EMMP and none to the SMMP. There is no intent apparent to even incorporate those documents by reference into the SCP. The discussion of decontamination and decommissioning is not a "plan", but merely various statements of DOE's intentions.

PART III

COMMENTS OF TECHNICAL CONTRACTORS AND ADVISORS

COMMENTS OF

DAVID TILLSON

COMMENTS ON THE SITE CHARACTERIZATION PLAN (SCP)
FOR THE YUCCA MOUNTAIN SITE
NEVADA RESEARCH & DEVELOPMENT AREA, NEVADA

by

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Engineering Geologist

June 30, 1989

General Comments

The following presents a summary of my observations and comments on the Site Characterization Plan for Yucca Mountain. The focus of my review has been Chapters 1, 8.3.1.4; 8.3.1.8; and 8.3.1.17 along with appropriate parts of Chapters 2, 3, 6, and 7. I found no substantive changes from the CD/SCP with the exception of minor cosmetic changes in Chapter 8. All of the comments on the CD/SCP provided previously to the State of Nevada (Sept. 1988) are still very much applicable. The text (including figures and tables) remains extremely variable with a considerable amount of unnecessary and distracting detail that in many places could have been treated more succintly and a general lack of detail in those places that obviously need greater exposition. The SCP seems to be a classic document that doesn't describe the forest but provides an excruciating detailed description of most but not all of the trees. Chapter 8.3, in particular, suffers severely from a lack of any clear, concise road map for the major plan elements. All of the tasks have been compartmentalized down to the smallest level possible with no indication of how any of the unpredictable results will effectively be brought back together.

The plan is so generic that it is bound to encompass any issue that could ever be raised. However, it is exceedingly difficult to determine what the site specific issues are, their relative importance to early determination of site suitability, or how they will effectively be addressed in an open public forum before another five-ten years and several more billions of dollars have been needlessly expended. Some of this type of information may be included in forthcoming study plans although there is no obvious mechanism to assure this happening. If more of the promised study plans had been available for this SCP review it is possible that one would arrive at a different conclusion. However, based upon a review of the five study plans that were made available, arriving at a different conclusion seems to be unlikely.

The SCP appears to have no focus nor do the predicted results indicate the participation of any cohesive scientific leadership. It appears to be a case of bureaucratic anarchy. The SCP appears to reflect an attitude of certainty concerning available information and prospective characterization findings that is unwarranted with respect to its information content.

In addition, despite State, NRC, and USGS comments on the draft and final Environmental Assessment and on the CD/SCP, the statutory SCP remains highly insensitive to uncertainties, to alternative interpretations and assumptions, and to the rigorous demands for positive substantiation that will be required throughout the licensing process. Pervasive throughout the SCP are the unanswered questions as to who and where are the scientists that will be making the decisions that a given program or test has provided the necessary and sufficient data to satisfy the very arbitrary qualitative goals that have been set by some third party? Any earth scientist knows how difficult it is to arrive at an inter-disciplinary consensus particularly when it regards limited data on a problem that is ill-defined and may be part of someone else's hidden agenda. By what method and by whom will the intra-disciplinary decisions be made? The SCP itself appears to be strong evidence that these intra-disciplinary decisions are now effectively being made by some unknown and continually changing combination of DOE and support contractor management, few of whom have the relevant technical background or appropriate experience.

The SCP appears to be a classic example of a parallel research approach that assumes all of the necessary questions are known before starting and what all the answers will be after finishing. The parallel research approach proposed by the DOE is fundamentally wrong and has a very low probability of being successful. This SCP outlines an engineering type approach to a geological research problem; a very complex geologic research problem which at this point has not been well defined. The approach proposed by DOE will almost assuredly make the problem even more complex than it needs to be. A simple analogy made by an ACNW consultant is that it is like trying to force nine women to produce one baby in one month and then if by some miracle it happens, expect to be able to explain the results.

Even if the parallel research approach could be made to work the DOE's site characterization plan still needs a lot of work to smooth out the unevenness. Many test plans propose to examine relative small parts of the system in excruciating detail and then try to extend the results to the remainder of the repository using unproven geophysical and geostatistical methods that have significantly less resolution. There are other test planned (e.g. radiometric dating of detachment faults) that appear to be very expensive to conduct, time-consuming, probably irrelevant, that will do very little to reduce the uncertainties, but on the contrary, add considerably to the uncertainties that already exist.

Inherent in the parallel research approach that is outlined in the SCP is the strong implication that <u>all</u> of the information can be integrated and understood (e.g. fluid flow related to insitu stresses and faulting); subsequently withstand outside critical review and still allow for an objective scientific decision to be made concerning the site viability. It is very naive to assume that the whole of the geophysical data that will be obtained can be understood to the depth implied by the SCP. The results will likely be a never-ending controversy in the licensing process because the DOE will not be able to adequately explain what has been learned from their characterization program to the depth implied by the SCP.

For example, Section 8.3.1.2 describes numerous tests and discusses models to define both matrix and fracture flow. Section 8.3.1.4 describes development of a 3-dimensional rock characteristics model in which "an important function of the computer-based model will be to provide input for numerical computer analysis that involve hydrologic, thermal, thermal-mechanical, and geochemical processes. Section 8.3.1.8.3.1.4 has as its objective to "estimate the effects that the creation of scarps, the diversion of drainage, the change in the depths of beds, or juxtaposition of beds due to fault offset would have on the average percolation flux at the top of the Topopah Springs welded unit". These statement imply a 3-dimensional coupled hydrologic/mechanical model that could be used to evaluate flows to significant times into the future. Yucca Mountain would literally have to be taken apart and even then you would have to be lucky to obtain the necessary data on which to effectively base a model which would describe the existing hydrology and how it is currently influenced by the rock characteristics. Furthermore, the resultant size of any meaningful 3-dimensional numerical would be absolutely prohibitive. The process appears to be analogous to feeding a cow a food mixture; watching very closely with the latest high resolution scientific instruments how the mixture goes down only the first 10 cm of the cow's throat; and then expect to predict exactly the quantities and qualities of milk, urine, and manure that will come out the other end.

If there is to be any hope of success the SCP must be able to establish that the DOE has a reasonable understanding of the total geologic system within which the repository must operate in a predictable fashion for the next 10,100 years and what the most important technical questions are that need to be answered. The next step should be a program plan to decide whether the geologic system which you are dealing with is amenable to providing sufficient unambiguous data that can then be used to favorably resolve all of the critical regulatory issues within some reasonable time frame. If the site you're working with is Yucca Mountain where the obvious site suitability issues cover a majority of the Potentially Adverse Conditions (60.122(c)) i.e. active faulting in the repository block; high seismic potential; near field igneous activity; high mineral resource potential; saturated ground water travel times that are substantially less than 1,000 years; and potential for rapid gaseous radionuclide transport; and where the ability to positively demonstrate the extent that such adverse conditions are present and that the site performance will not be compromised (60.122(a)); is limited by a lack of suitable geology to work with, a prudent course of action might be to look for another site in a more favorable geologic setting. First however, a logical approach would be to estimate as objectively and as conservatively as possible the extent to which the adverse conditions may be present and whether the licensing issues inherent with addressing these adverse conditions can reasonably be resolved given the type of geology available to work with. Unfortunately this is not the approach laid out by the SCP. The starting point for this more logical sequential approach would be a good set of regional geological maps, geophysical maps, and remote sensing imagery covering a large enough area to understand and defend the choice of geologic setting that is made. Another set of maps and integrated imagery should then be developed at a smaller scale for the subregional geologic setting that includes the site. Once the size of the ballpark (geologic setting) is reasonably established then the rules that the site characterization program must follow (e.g. 10 CFR 60; 10 CFR 100, Appendix A; 10 CFR 960; and 40 CFR 191) can be interpreted within the context of that geologic setting. If such a set of maps had been available as an integral part of the SCP either directly as figures or as readily available references, instead of the cartoons, fragmented figures, and non-published references that are used, DOE's proposed program would likely be more understandable. In particular, the SCP definition of the geologic domain which they propose to investigate as being limited to 100 km radius of the site might have been easier to comprehend. Since all of the kinds of information necessary for these maps was available prior to 1983, it is difficult to understand why the maps were not included in the SCP published in late 1988. Considering the extensive amount of new data that could become available during the site characterization program, the inability of DOE to produce a simple set of basic maps in five years with all of the data available is one example of why the public should not be optimistic that the DOE will be able to produce an integrated and credible 3-dimensional model of the Yucca Mountain geological setting in another five-ten years that will get them successfully through the licensing process on schedule. A schedule that in an of itself is so vague and ambiguous as to be meaningless. The SCP calls for extensive data collection and design efforts to begin almost simultaneously on all tasks with the results coming together on the major licensing issues in about five-seven years if all goes well. In the interim there appears to be no effective way that any adverse information developed during characterization will be fed back into the system or released for public consideration.

Comments on Insufficient Information Content

A brief summary of some of the areas in the SCP that are either insufficiently covered or lacking are the following:

NRC Regulations - The SCP illustrates that either the DOE does not understand the present NRC licensing requirements or that somehow they are above the NRC licensing requirements. Particularly troublesome is the apparent DOE position that 10 CFR 100, Appendix A does not apply in any sense and therefore any guidance or precedence set by past use of 10 CFR 100, Appendix A is inappropriate to the evaluation of Yucca Mountain as a suitable site for a high level waste repository. This apparent DOE position directly contradicts the expressed NRC position that use of 10 CFR 100, Appendix A is conservative and appropriate for the period through permanent closure (Trapp and Coplan, 1986). In addition, more recently it is known that the NRC is in the process of preparing a more specific comparative analysis of 10 CFR 100, Appendix A in regards to 10 CFR 60 requirements. Based upon limited informal discussions with NRC staff it appears to be almost a certainty that the siting guidance found in 10 CFR 100, Appendix A will be applicable to 10 CFR 60 siting requirements unless the DOE can provide a good case to the contrary. Whether 10 CFR 100, Appendix A is ultimately applied or not is somewhat irrelevant at this stage in the site characterization process at Yucca Mountain. Although it is possible that some of the investigation requirements found in 10 CFR 100, Appendix A could be relaxed it is very unlikely that any of the requirements would be made more stringent. Based upon these thoughts it is difficult to understand why the DOE has chosen to unilaterally establish their own less conservative criteria for the area and scope required for investigating geologic phenomena. The SCP lacks any coherent discussion of this matter. This would appear to be a very risky and ultimately expensive course of action if the NRC fails to acquiesce to the DOE criteria some five-ten years down the road at the time of formal license application. Given that the DOE will probably not be receptive to a suggestion for a major change in the overall program direction from the present parallel approach to a more logical and less costly sequential approach, it is strongly urged that the DOE revise the necessary plans for studies and activities to comply with 10 CRF 100, Appendix A requirements. Although proof of compliance with 10 CFR 100, Appendix A requirements will not assure the issuance of a license it would substantially increase the probability. On the other hand, failure to demonstrate compliance with 10 CFR 100, Appendix A requirements will not in and of itself prohibit the issuance of a license but would substantially increase the probability.

Prioritization - NRC Regulatory Guide 4.17 (Rev. 1, March 1987) "Standard Format and Content of Site Characterization Plans for a High Level Waste Repository" clearly states that "the basic purpose of the SCP is simple; to provide a mechanism for identifying and delimiting the specific issues at a proposed repository site and to identify the plans for resolving those issues at an early time in order to avoid delays in the process". The SCP effectively provides for neither of these requirements. The SCP lays out an elaborate and very complicated program of parallel studies that is intended to provide all the data that could possibly be required to resolve all the issues relevant or not that could possibly arise without any apparent recognition of what the critical issues are going to be. Although it might be argued that the SCP shotgun approach meets the first NRC requirement of Reg. Guide 4.17 for identifying specific issues (albeit not very succintly) it most certainly can't be argued that there is any semblance of prioritization to resolve those most critical issues that bear on the immediate question of site suitability for characterization. It should be obvious to the DOE that such issues as active faults transecting the repository; ground water travel times to the accessible environment that are less than 1,000 years; high potential for rapid gaseous radionuclide release to the accessible environment; probable active Holocene igneous activity in the immediate site vicinity; etc. and whether these issues can be satisfactorily resolved given the type of geology available to work with needs to be enjoined before significant underground construction such as the ESF is initiated. Since it is obvious to all parties except the DOE that their proposed SCP schedule can never be met, a delay of two to three years to conduct an early site review on critical issues should ultimately save time in the schedule and significant cost if the results are as DOE predicts in the SCP.

Integrated Geologic Model - The SCP contains many discussions and tables throughout regarding "models" and alternative hypothesis for "models". Some of the discussions are coherent; most are not. Upon close examination it appears that the DOE has laid out a wide variety of "models", in fact, one to fit almost every possible aspect of the site and the region of the site. In addition, many of the "models" are broken down into even smaller elements that implicitly are themselves considered models (e.g. see Table 8.3.1.4-2). There is a rock characteristic model; there is a structural model; there is a tectonic model; there is an unsaturated zone hydrologic model; there is a saturated zone hydrologic model; there is a volcanic model; there is a thermal model; there is a mechanical model; etc. ad infinitum. Three major omissions are (1) a clear and concise representation of what DOE thinks the present integrated model is for the site; (2) how the DOE will effectively test the validity of their preferred integrated model as the characterization program proceeds; and (3) how the DOE plans to effectively handle couple processes between more than a few elements at a time given that the resultant size of the proposed 3-dimensional numerical model will be absolutely prohibitive.

Decision Mechanisms - Throughout Chapter 8 and particularly in Chapter 8.3 the SCP states explicitly and implicitly that decisions will be continually made regarding such matters as the adequacy of data from a given activity; whether additional studies are required; whether and to what extent any adverse data that is developed disqualifies the site; etc. The responsibility for these types of decisions unquestionably lies with the DOE and cannot be abrogated. However, what is missing from the SCP is any explanation as to how these types of critical decisions have been made in the past and more importantly, how these critical decisions will be made in the future and by whom. In order to develop confidence in the technical results of the site characterization program there needs to be a clear and concise understanding of the DOE decision process. A commitment by DOE to seek the advice and consent of NRC and State before making any substantive change in any activity would also be helpful.

Staffing and Cost Estimates - The very nature of the proposed studies and activities outlined in the SCP implies that a substantial commitment of earth scientists will be required for an extended period of time; at least five-ten years. There are many outside of DOE who feel there aren't enough qualified earth scientists available to do the work proposed by the SCP. In order to make any kind of an informed judgment as to whether the proposed studies and activities can reasonably be accomplished within the schedule laid out in the SCP requires some idea of the numbers and types of scientists (including their level of experience) and non-scientists that will be necessary. In the case of a discipline that is in short supply and in heavy demand (e.g. experienced geohydrologists a.k.a. experienced hydrogeologists) some indication as to where the necessary staffing will come from and how the DOE intends to maintain that staff level throughout the life of the characterization program would also be helpful in making a judgment as to the likelihood of success. In addition to staffing estimates, some idea of the non-personnel expenditures that the DOE feels are appropriate for each study and activity should be provided. While it is recognized that cost estimates beyond two years are nebulous at best, such estimates would provide an idea of how well DOE understands their own requirements for each study and activity. In addition, non-personnel costs would provide a way of judging whether the DOE is just paying lip-service or whether they are really serious about each study and activity. The SCP is presently silent in each of these areas.

Identification and Qualification of Technical Personnel - The success or failure of any program no matter how well conceived ultimately depends upon the commitment and qualification of those actually doing the work. While it is recognized that substantial personnel changes may occur as the site characterization program matures, a knowledge of the qualification and experience of those key technical staff presently involved with the program and the role they are expected to play in getting each study and activity started would be helpful in judging the likelihood of success and the probable quality of product that may be produced.

Comments on Objections and Concerns

A brief summary of some specific objections and concerns are the following:

Chapter 1 - The so-called "data" Chapters 1 through 5 are extremely important in that they should objectively and succintly present any hard data that is available about the site and environs along with all of the interpretations and inferences that have been made; good, bad, or indifferent. This is certainly not the case for Chapter 1 and probably is not the case for Chapters 2 - 5. Considering that approximately 95% of the proposed geologic repository already exists and that only approximately 5% will be engineered gives one some idea as to the importance of Chapter 1, "Geology". The geology chapter provides the fundamental foundation upon which the site characterization program must rest. The DOE basis for that foundation still appears to be very shakey. Inspite of the many comments on the CD/SCP received by the DOE from the NRC, USGS, and State regarding Chapter 1's shortcomings and assuming that the DOE had themselves re-evaluated Chapter 1 for completeness and accuracy the changes made were disappointing. There were a total of 54 references and less than four pages of text added. Of the 54 references added, 18 were related to Mineral Resources and 7 related to Geothermal; which indicates that the DOE was at least aware of the State's concern even though their comments may not have been formally available. An additional observation is that there were only 4 references added to the Volcanology discussion (no text changes); 4 mystery references that were by various authors and "et. al."; and only 20 of the 54 references that were post-1987 (the approximate time that the original CD/SCP was assembled). Of the approximately 4 pages of text added, all related to Mineral Resources and Geothermal. This discovery made the SCP review easier in one regard, in that all of the comments made by the State on the CD/SCP still apply. The bottom line is that Chapter 1 is still an incomplete, inaccurate, and misleading presentation that is totally inadequate to make an intelligent informed decision in regards to suitability of the Yucca Mountain site for characterization or whether the Yucca Mountain site can ever be characterized to the depth that will be required by the NRC licensing process that requires reasonable assurance of site safety.

Maps Available for SCP Review - The maps available for the SCP review are totally inadequate. It is inconceivable that the

SCP does not contain any integrated maps that can effectively be used to follow the discussions of the geologic system throughout the region, the site vicinity, and the site. What maps that are included are invariably 8-1/2" x 11" modifications of other generally unavailable maps that often fail to include enough detail or are of an insufficient scale to evaluate the DOE position or fail to cover the full area that is under discussion. This same problem extends to the principal reference geological maps; USGS (1984); Swadley, et.al. (1984); and Scott & Bonk (1984) from which most of the SCP figures were derived. There appears to be no plans to remedy this situation. A significant amount of 1:24,000 and 1:12,000 scale mapping covering the site region was reported to have been completed in the 1981-1983 period. Except for the 1/4 portion covering the site area (USGS, 1984) and Scott & Bonk (1984) the remaining 3/4 of the mapped area is yet to be published. DOE Study Plan 8.3.1.4.2 "Characterization of Structural Features in the Site Area", dated February 1989, states that "mapping began in FY-1982 and continued intermittently into FY-1986; transfer of field data to a topographic base was finished in FY-1987; and compilations of geologic maps will be finished by FY-1988" (September, 1988). These maps should have been available for inclusion with the SCP which was published in December 1988. Although it is possible that these maps are being delayed because of the stop-work orders associated with quality assurance consideration, they were obviously used by those preparing the SCP. It is unacceptable that copies of these same maps with suitable disclaimers attached were not provided to the principal technical reviewers for the State.

Mapping Scales and Areas of Coverage - The three principal reference geological maps are a 1:62,500 scale map by Swadley et al, (1984) that covers an area of roughly ten miles in radius from the Yucca Mountain site; a 1:48,000 scale map by USGS (1984) that essentially covers the same geographical area as Swadley et al; and a 1:12,000 by Scott & Bonk (1984) that covers only the northeast portion of the immediate Yucca Mountain site. According to Study Plan 8.3.1.4.2 (Feb 1989) all mapping has been completed. The areas of coverage and the map scales available will likely be found inadequate to serve as a basis for the studies DOE has proposed in 8.3.1.4, 8.3.1.8, and 8.3.1.17. The areas of coverage and map scales available are clearly inadequate for use in demonstrating compliance with NRC siting requirements (60.122(i)). Demonstration of compliance with applicable parts of 10 CFR 100, Appendix A will likely require compilations of larger scale maps over an area of up to 320 km in radius that includes at a minimum all of the seismo-tectonic province within which the site lies. At a local level, the scales of 1:12,000; 1:24,000; and 1:48,000 will probably be inadequate to effectively compile and represent the data that is proposed for collection. For example, the maximum resolution expected from VSP and tomography is approximately 60 feet which would plot out as 0.0656 inches on a 1:12,000 scale map or cross-section.

At a minimum the DOE should use 1:5,000 scale maps (Wu, 1985) for compiling all data within the boundary of the accessible environment. Appropriate smaller scale maps should be used to compile and represent critical areas of detailed studies, e.g. pavement mapping; FITS; ESF surface site; etc.

Repository Block - The way that the repository block is represented on the various maps and cross-sections is misleading. With the exception of the Ghost Dance fault the repository block is invariably shown to be essentially void of other faults, joints, and fractures that appear to be pervasive to the east, south, and north. Although this may turn out to be the case, the DOE does not present data in the SCP to justify this representation. In addition a very honest and conservative interpretation of Scott & Bonk's 1984 map just does not support the DOE position.

Surface Facility Site - The DOE representation of the site area east of Exile Hill in Midway Valley chosen for the surface facilities is very misleading. Neal (1986) presents clear evidence to support his interpretation of a fault zone that is at least 1 km wide with a cumulative offset of several hundred meters that appears to cover the entire area beneath the proposed surface facilities site. DOE repeatedly tries to minimize the significance of these data. For example, DOE makes the statement (Page 8.3.1.17-93 and 94) attributed to Neal (1986) that "indicates that closely spaced faults (less than 50 meters) occur beneath the surficial deposits". Neal (1986) makes no statement regarding specific fault spacing but instead interprets a zone of faulting over 1 km wide. Another example can be found on Page 8.3.1.17-61 where DOE states that "surface facilities (FITS) will be cited where there is no evidence of Quaternary faulting". On Page 8.3.1.17-60/61 the DOE implies that it is acceptable to site FITS over Quaternary faults as long as the slip rate is less than 0.001 mm/yr or the faults don't measurably offset materials less than 100,000 years old. Since the DOE will probably not be able to demonstrate either of these conditions at the Midway Valley site unless they are willing to dig a 1 - 2 km long trench to a depth of 60 - 90 meters, they should give serious consideration to finding an alternate site for FITS. In the interim a candid representation of the existing geological data coupled with an honest statement of the difficulties that will be faced in demonstrating site suitability would be a welcome change from the present SCP descriptions.

Geophysics - The SCP discussion of geophysical activities is ambiguous and misleading throughout. The erroneous impression is continually given that useful geophysical techniques are available that will work at Yucca Mountain and have sufficient resolution such that the data can be used in supporting performance assessment and design. The implication is that geophysics will somehow be able to provide considerable information between, beneath, and/or outside of the limited number of boreholes. This is contrary to the findings of NUREG/CR-4957 (1987), "Survey of Geophysical Techniques for Site Characterization". Because of the geophysical homogeniety of the upper 6,000 foot tuff section at Yucca Mountain the seismic reflection technique has been found to be of limited use and other geophysical techniques, such as refraction, electrical, gravity, and magnetic methods were found to be suited primarily for near-surface investigations. The best of the down-hole geophysical techniques appears to be VSP and tomography which has the potential to provide a resolution of 60 feet when conditions are optimum. All of the other down-hole geophysical techniques can at best provide substantial detailed data on the rock properties within a few borehole radii. Reliable interpretation of the lateral variability between boreholes spaced 3,000 feet apart does not appear to be possible.

Geostatistics - Apparently geostatistics will be extensively used as a substitute when other forms of empirical data cannot be obtained. Reliance on this approach is particularly troublesome when applied to the vadose zone between the repository and the past, present and possible future saturated ground water system. Given that the present saturated ground water travel time is considerably less than a 1,000 years from any point immediately beneath the repository to the accessible environment, the margin for error in calculating travel time in the vadose wouldn't seem to be large enough to convincingly argue from a strictly geostatistical standpoint that the site would always meet the less than 1,000 year criteria.

The proposed test and demonstration of geostatistical techniques is also troublesome because of the area that has been chosen. Boreholes SD-8 through SD-12 and UZ-7 and UZ-8 and UZ-9 complex (see Figure 8.3.1.4-12A) encompass an area where the imbricate faulting appears to be at a maximum and which is also traversed by the Ghost Dance fault and the Abandoned Wash fault (Scott & Bonk, 1984). The aperture of this array is less than 1,000 feet. The credibility of extending the results by geostatistics to single boreholes located at least 3,000 feet distance will certainly be questioned unless some alternative geophysical data is available to support the degree of lateral variability of the parameter being estimated. Whatever the results of this evaluation are, it hopefully will not be representative of the main part of the repository.

Fractals - The SCP indicates that fractual analysis will be used as a primary method for quantifying the spatial distributions of fracture traces and fracture trace intersections. Use of fractals to describe geologic parameters has some intriguing possibilities. However, this approach is still a long way from being accepted as a standard geologic tool. The three references all by the same principal author, used in support of the fractual analysis, offer little help in this regard since two of the references are abstracts and one reference is an unrefereed paper that was given at an obscure international proceeding in Lapland, Sweden. It doesn't seem prudent to base such an important study on an unproven technique. If fractual analysis works it still only describes the surface characteristics of the Tiva Canyon tuff. According to Study 8.3.1.4.2, Figure 2.2-1, the surface area for these fracture studies will be limited to the northeast corner of the repository block in the vicinity of ES-1 and ES-2. Any interpretation of subsurface fracture distribution, particularly in the vadose zone between the repository and saturated ground water system will still have to be based upon a geostatistical interpretation between the limited number of boreholes. It is unlikely that the results will be sufficient to resolve the critical licensing issues involved.

10,000-Year Cumulative Slip Earthquake - The DOE defines a 10,000-yr cumulative slip earthquake to be one that, occurring every 10,000 years, would produce the observed or estimated average Quaternary slip rate on a fault. As pointed by J. Bell in his CD/SCP comments, the 10,000 year cumulative slip earthquake has no precedents in practice or in the professional literature and is non-conservative. M. Savage points out in her CD/SCP comments that if a cumulative slip earthquake is to be used then it should be at least a 100,000 year event. It appears that the DOE has contrived this approach to meet their preconceived ideas of the geologic system at Yucca Mountain. The issue of a 10,000 year or 100,000 year cumulative slip earthquake may be moot however since present NRC practice does not readily allow for such an approach nor is the geology at Yucca Mountain particularly favorable for providing the data necessary to confidently establish what the recurrence intervals are.

ESF Design and Construction - According to the schedule proposed in the SCP, the design and construction of the ESF will proceed in parallel with all of the other studies. Many of these studies have as their main objective the development of input data for the ESF design. A major concern is the establishment of an acceptable design-basis earthquake prior to proceeding with any ESF construction. DOE plans call for using a 0.4g earthquake for design purposes based on a probability approach (URS/Blume, 1986). The SCP implies that the design-basis earthquake could be substantially higher if a deterministic approach is used (g.t. 0.6g) depending upon the size of the earthquake used and the distance from the source. In addition, the present ESF design makes no allowance for displacement on active faults that may be penetrated within the repository block. It is unacceptable for ESF construction to be allowed to proceed until these major design issues are resolved and enough information from surface-based testing becomes available to provide reasonable assurance that repository integrity will not be compromised.

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TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 1 pg. 1 of 1	CHAPTER NO.: 8
SEC. NO. 8.3.1.4 PAGE NO. 8.3.1.4-2 DRWG. NO.	

It is stated that the geologic complexity of the Yucca Mountain site may cause large amounts of uncertainty associated with the variability of properties between sample locations and therefore the physical property data will be correlated with the geologic and geophysical data to reduce uncertainty. This is wishful thinking, apparently written by a non-geologist or someone who has never worked with field geologic data. If there are large amounts of uncertainty between sample locations, correlations by DOE using geologic interpretations that are even more uncertain (since they are based on the same samples) and geophysical techniques that have very little resolution (NUREG/CR-4957, 1987) is likely to make the uncertainty even higher.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 2 pg. 1 of 1 | CHAPTER NO.: 8

SEC. NO. 8.3.1.4
PAGE NO. 8.3.1.4-2
DRWG. NO.

The first paragraph states that the nature and number of site characterization studies to be conducted will be determined by the current understanding of the site.......and the numerical models in which they are being input. DOE's less than objective position on current understanding of the site is considerably different than the understanding of the NRC and State. Unless and until some consensus is reached on key parameters the risk to the DOE of jeopardizing the integrity of the Yucca Mountain site by proceeding with the ESF is very high.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 3 pg. 1 of 1 | CHAPTER NO.: 8

SEC. NO. 8.3.1.4
PAGE NO. 8.3.1.4-2
DRWG. NO.

In the third paragraph that discusses characterization parameters, it is not obvious how the statistical distribution of activity parameters will be used in the geologic model.

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COMMENT NO.: 4 pg. 1 of 1 | CHAPTER NO.: 8

SEC. NO. 8.3.1.4
PAGE NO. 8.3.1.4-2
DRWG. NO.

The third paragraph appears to be a good example of how a non-objective goal-oriented program might work. By using arbitrary goals to establish the data needs rather than basing the goals on the existing data should make it much easier to handle any adverse data as it arises. One simply changes the goals.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 5 pg. 1 of 1 | CHAPTER NO.: 8

SEC. NO. 8.3.1.4
PAGE NO. 8.3.1.4-4
DRWG. NO. Table No. 8.3.1.4-1

Table 8.3.1.4-1 provides a very complete list of rock unit geometry and properties. It is hard to imagine any factor relevant or not that has been overlooked. If all of the parameters are determined as proposed the results should produce a geologic model that is unsurpassed. However the complexity will also be unsurpassed. Experience with siting critical facilities over the last 20 years has demonstrated that site investigation programs that are conducted in parallel invariably diverge rather than converge.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 6 pg. 1 of 1 | CHAPTER NO.: 8

SEC. NO. 8.3.1.4
PAGE NO. 8.3.1.4-17
DRWG. NO.

The third paragraph states that the 3-dimensional model could be developed based only on physical property data from core samples. The fact of the matter is that the 3-dimensional model will be developed only from core samples. Estimates of the variation between samples is just that - an estimate. Interpretation or interpolation is more of an art than a science. By this it is meant that the results are not unique. If interpretation was more of a science there wouldn't be so many dry holes drilled. Geologic studies are by definition interpretative. Good geophysical data when available goes a long ways towards reducing uncertainties in the geologic interpretations. Unfortunately the applicability of geophysical techniques with anything but the grossest resolution is yet to be demonstrated in the Yucca Mountain area.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 7 pg. 1 of 1 | CHAPTER NO.: 8

SEC. NO. 8.3.1.4.
PAGE NO. 8.3.1.4-17 & 18
DRWG. NO.

Under the discussion of alternative conceptual models the SCP states that integration of information from different disciplines increases confidence in the data and is often necessary to comprehensively evaluate alternative hypotheses. Almost all of the studies proposed in the SCP will be done in parallel. Any integrated models necessary to realistically assess alternative concepts won't be developed until the fourth or fifth year of the program. The parallel approach also assumes that there will be no major surprises in the geologic system. This is an unlikely result.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 8 pg. 1 of 1 | CHAPTER NO.: 8

SEC. NO. 8.3.1.4
PAGE NO. 8.3.1.4-18
DRWG. NO.

The discussion of the 7th column of Table 8.3.1.4-2 implies that a judgment of the sensitivity of the performance parameters to the selection of alternative hypotheses has been made. These judgments may be based on entirely erroneous assumptions regarding the geologic system. Until a more complete and factual data set has been developed there appears to be no way of determining the validity or possible success of the proposed program.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 9 pg. 1 of 1 | CHAPTER NO.: 8

SEC. NO. 8.3.1.4
PAGE NO. 8.3.1.4-19
DRWG. NO. Table 8.3.1.4-2

The definition of geologic domain is not compatible with the NRC definition. The NRC definition indicates a much wider area needs to be covered. DOE's current representation is arbitrary. The boundaries cannot be defined with any degree of certainty until considerable additional knowledge of the system has been assembled.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 10 pg. 1 of 1 | CHAPTER NO.: 8

SEC. NO. 8.3.1.4
PAGE NO. 8.3.1.4-19
DRWG. NO. Table 8.3.1.4-2

The table states that the uncertainty for the geologic domain is low and that properties and processes outside the model domain are unlikely to affect rock properties within the controlled area. DOE has presented insufficient data to support this kind of a judgment.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 11 pg. 1 of 1 | CHAPTER NO.: 8

SEC. NO. 8.3.1.4
PAGE NO. 8.3.1.4-19
DRWG. NO. Table 8.3.1.4-2

The alternative hypothesis for the geologic domain is shown as none. The table goes on however, with a number of entries to indicate the significance of the alternative hypothesis. Under performance measures it is stated that ground-water travel time (GWTT); radionuclide release to accessible environment which implies that the only concern is for the unsaturated zone between the repository and the ground-water system. The table fails to address the critical unsaturated zone area between the repository and the surface that will possibly provide direct pathways for gaseous radionuclide release.

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DRWG. NO. Table 8.3.1.4-2

The table indicates the need to reduce uncertainty on the geologic domain model is low because existing data indicate that geologic domain is not likely to change. This position is undefensible. Activity of any kind on the faults going through the repository is likely to change the fracture permeability. Renewed volcanic activity is another obvious possibility.

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DRWG. NO. Table 8.3.1.4-2

The table states that the vertical extent of the geologic domain includes only the Tertiary section and that the alternative hypothesis includes the Tertiary section plus the upper part of the underlying Paleozoic section. The table goes on to state that the need to reduce uncertainty is low. This position seems to be premature when the only knowledge about the pre-Tertiary comes from one borehole, UE25P-1 that is outside of the proposed repository. It would seem that since the major aquifers are all in the Paleozoic section it should be included in the current representation of the geologic domain and that the Tertiary section should be considered as the alternative model.

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DRWG. NO. Table 8.3.1.4-2

Under stratigraphic geometry it is stated that the uncertainty is medium. The table goes on to state that the vertical variation within units are less well defined and may be as important. The table fails to address the horizontal variability. DOE's present knowledge of horizontal variability is limited to the Tiva Canyon because of its exposure at the surface. Any horizontal variability is an interpretation based on the limited borehole data.

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DRWG. NO. Table 8.3.1.4-2

Under stratigraphic geometry, it is stated that the second order vertical variability in rock properties is imparted by mineralogical alteration in distinct quasi-horizontal zones transecting primary unit contacts. The table goes on to indicate that the need to reduce uncertainty is high and that more adequate characteristics of the upper boundary of mineralogical alteration is very important. This conclusion is correct insofar as it addresses the unsaturated zone above the repository. If radionuclides are released and transported by water the most important section will be the unsaturated zone beneath the repository. The proposed program studies fail to adequately address this concern.

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DRWG. NO. Table 8.3.1.4-2

For the first-order lateral variability the table indicates that the sensitivity is medium and that lateral variability has less effect on GWTT than radionuclide migration. This statement is true only in the most general sense. There appears to be a need to consider a combination of vertical fractures and lateral high permeability zones, particularly in regard to gaseous radionuclide transport from the repository to the surface.

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DRWG. NO. Table 8.3.1.4-2

Under alternative hypothesis for the lateral and vertical variability of rock properties it is stated that other Markovian processes can be used to characterize heterogeneity. There is a need to also consider non-parametric and chaotic processes in which case the system may be generally describable but completely non-predictable. The table goes on to indicate that the need to reduce uncertainty is low because modeling scale will be set conservatively as equal to or larger than the variogram range. The DOE has yet to establish the applicability of geostatistics in the subsurface nor have they presented any data on the variogram range.

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PAGE NO. 8.3.1.4-21
DRWG. NO. Table 8.3.1.4-2

For the structure model element the current representation states that the first-order lateral anisotropy imparted to rock mass will be by tectonic faults and fractures that increase in abundance to the south. The SCP does not present enough data to demonstrate what happens to the east, west, or in the unsaturated zone below the repository. The table goes on to state that uncertainty is low because available data indicate faults and fractures are zonally distributed. Available data represented by Scott and Bonk, 1984; Swadley, et al, 1984; and USGS, 1984 have been shown to be incomplete and in error for the surrounding area. Significant geologic maps are still unpublished. The table goes on to indicate that the alternative hypothesis is for faults and fractures to be uniformly distributed. There can be lateral and vertical heterogenieties in the structural model just as easily as in the stratigraphic model. The table goes on to indicate that the need to reduce uncertainty is medium due to the effects of structural anisotropy on performance. The extent structural anisotropy exist needs to be established first.

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DRWG. NO. Table 8.3.1.4-2

It is stated that the structural model includes intact blocks inclined and rectangular in cross-section that are bounded by imbricate normal faults that continue at depth as parallel faults. This is all two-dimensional thinking based on cross-sections only and is not supported by the surface maps (Scott and Bonk, 1984).

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DRWG. NO. Table 8.3.1.4-2

The current representation of the structure model states that fractures along some interconnected pathways are open. It seems that this position contradicts other statements by DOE that matrix flow would predominate. The table goes on to state that the sensitivity is high for open fractures that would significantly effect ground-water travel time, especially in the saturated zone. This statement conflicts with other DOE plans that indicate the saturated zone won't be studied because it is considered unimportant in the geologic domain. The table goes on to indicate that the need to reduce uncertainty is medium and that the unsaturated zone GWTT depends on matric potential more than aperture. This will be the case only if matrix flow predominates over fracture flow in the unsaturated zone below the repository. An added dilemma will be for the DOE to adequately characterize the fracture distribution in the unsaturated zone below the repository without drilling an extensive number of boreholes.

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DRWG. NO. Table 8.3.1.4-2

It is stated that the open fractures are coated with secondary minerals. This would imply that fracture flow has predominated in the past. This also implies that the same situation could be expected for the unsaturated zone below the repository. Again there is a dilemma as to how this will be demonstrated without drilling an extensive number of boreholes beneath the repository.

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DRWG. NO. Table 8.3.1.4-2

It is stated that variation in tectonic stress is not likely in 10,000 years and that the probability of changes in stress and significant hydraulic loading is low. This representation is very misleading. There may be little variation, however, the stress will remain relatively high. The data provided so far by the DOE suggests that fault movement within the repository is likely with continued opening of the fractures.

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DRWG. NO. Table 8.3.1.4-2

Current representation for rock characteristics states that the repository block does not contain a large number of faults that will result in localized failures when subjected to expected conditions. This position is not supported by the limited amount of data that the DOE has presented. It doesn't matter how a fault fails if failure causes changes in the flow system either in the unsaturated zone or in the saturated zone. The current representation also does not consider repeated fault movement. The table goes on to state that the uncertainty is medium based on the rational that the properties of faults precludes inducing movement along a majority of the faults when excavation and thermally induced stresses are introduced. The DOE fails to recognize that movement is not precluded due to local or regional earthquakes or UNE's.

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DRWG. NO.

The SCP discussion of integration of geophysical activities is ambiguous and misleading. The implication is that geophysics will be able to provide considerable information about the rock structure between, beneath, and/or outside of the drill hole when in fact the geophysics is almost exclusively down hole and provides very little detailed data outside of several borehole radii.

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DRWG. NO.

The second objective for the integrated drilling program activity states that DOE will integrate and prioritize surface-based activities to produce a schedule that best addresses representativeness and efficacy concerns, given budgetary constraints. This appears to be one more example of the characterization program being driven by schedule and money rather than being an honest and objective scientific characterization of the geologic system. It would be more appropriate to use the data results sequentially to determine what the additional data needs are.

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The description of the integration of geophysical activities states that performance assessment and design will be supported by geophysical information to insure that the range of variability of site characteristics considered in calculations is representative of actual site conditions. This implies that there are useful geophysical techniques that have the required resolution. This is contrary to the conclusions reached by Jones, et al, NUREG/CR-4957, 1987.

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DRWG. NO.

The description goes on to state that geophysical applications such as fault detection are a form of non-probabilistic support for the representativeness of site data. This statement is misleading. There are few geophysical techniques that provide unambiguous and unique solutions. Invariably interpretation is required which implicitly is a form of subjective probability.

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DRWG. NO.

It is stated that information needs identified through the performance allocation process for technical areas, such as tectonics, mineral resources, rock characteristics, and hydrology, will be further defined and assessed for common objectives. This statement appears to be in conflict with Table 8.3.1.4-2 in that it implies a much larger geologic domain both horizontally and vertically needs to be investigated.

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Under the technical rational for the geologic framework investigation it is stated that the model will provide the geologic constraints for developing quantitative 3-dimensional models of rock properties. The program that is proposed does very little for understanding the most critical unsaturated zone beneath the repository.

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It is stated that the proposed perimeter drift defines an area where a significantly lower concentration of faults has been mapped relative to surrounding areas. With the exception of Scott & Bonk, 1984, DOE has not published the geologic maps of the site area or of the remainder of the controlled area. Given that there appears to be errors and omissions in Scott & Bonk, 1984, and the fact that the map was not prepared under a qualified QA program, it is not possible at this point to determine if the surface faults mapped represent the expected subsurface conditions.

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It is stated that the area of investigation will include a larger area than the site as the understanding of the characteristics of each lithostratigraphic unit on a regional scale will allow a higher level of confidence when using deterministic information.....site area. Regional scale is being used improperly in this sense since all the studies proposed are confined to a much smaller area as defined on Figure 8.3.1.4-2.

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It is stated that geophysical surveys may play a major role in providing information on the gross spatial distribution of bulk properties. NUREG/CR-4957, 1987 concludes that the use of geophysics at Yucca Mountain will provide gross spatial distribution at best. The alternative to geophysics can only be provided by considerable additional boreholes with implicit risk to the integrity of the repository. It would be prudent for the DOE to develop the necessary geophysical tools prior to developing the ESF.

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It is stated that with the incorporation of additional stratigraphic data collected from surface field studies, a more complete stratigraphic database will be used to map the distribution of intrinsic lithologic characteristics within Yucca Mountain. The paragraph goes on to state that surface and subsurface mapping of lithologic characteristics within stratigraphic units aids in interpreting the transportation, implacement, cooling, and alteration histories of major ash-flow tuff sheets. The proposed mapping will be almost exclusively in the Tiva Canyon and will provide very little information about the Topopah Springs. The text goes on to state that recognition of small scale structure within and near the site area is achieved through detailed mapping of zonal features of exposed ash-flow stuffs (sp) and interpretation of detailed surface and subsurface geophysical surveys. With the exception of the immediate boreholes there are no geophysical techniques available that can provide required resolution over the 3,000 foot spacing between the planned boreholes.

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It is stated that lateral components of the system (structural setting) are studied principally by mapping and analyzing surface exposures. The SCP appears to have no program for doing this kind of mapping for the Topopah Springs, Calico Hills, or the underlying tuffs.

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It is stated that in addition to the vertical component of the fracture system, borehole geophysics particularly surface-to-borehole seismic profiling, cross-hole seismic surveys, and borehole-to-surface electrical resistivity methods may provide information regarding bulk distribution of fractures. The best resolution that these geophysical techniques can obtain is approximately 20 meters. It would appear that this kind of resolution would be inadequate to effectively describe the detailed fracture distribution.

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This study indicates that the vertical and lateral variability and implacement history of the stratigraphic units will be determined. Surface-based mapping and borehole activities will be complimented by geologic mapping and testing in the exploratory shaft and drifts. Because surface-based mapping will be limited to the upper part of the Tiva Canyon and immediate site area, and because the two proposed shafts are little more than two 14 foot diameter boreholes spaced 300 feet apart, very little new data will be provided on the characteristics of the Topopah Springs.

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The number of new boreholes proposed for the surface and subsurface stratigraphic studies of the host rock is unlikely to add significant information to the existing database. The SCP is silent on what course of action the DOE would take if the results of this limited drilling aren't as predicted.

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In the description of the activity it is stated that studies of the hydrology of the unsaturated and saturated zone will be conducted. These plans call for two boreholes, UZ-2 and UZ-3 to be drilled next to each other and in close proximity to UZ-6 in the southwest end of the repository block. UZ-10 which is also part of this study is considerably south of the repository block. No information will be developed on the Calico Hills and the rest of the unsaturated zone between the repository and the ground-water. With the addition of boreholes SD-2 through 6 there will be a total of seven boreholes on approximately 3,000 foot center that will be used to describe the repository block. Without the availability of a high resolution geophysical technique to provide information between these boreholes the data will clearly be inadequate.

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The proposed study of outcrops in highlands surrounding the study area in order to improve the ability to predict lateral variability of the Paintbrush Tuff, Calico Hills tuffaceous beds, and Crater Flat Tuff is very appropriate. Strong consideration should be given to doing this part of the study first before risking the viability of the repository by inappropriate placement of any boreholes.

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SEC. NO. 8.3.1.4.2.1.2
PAGE NO. 8.3.1.4-41
DRWG. NO.

It is stated that surface-based geophysical surveys will be used to help define the lateral and vertical distribution of the stratigraphic units. Only the seismic refraction survey has any reasonable chance of providing lateral information and that type of survey has many limitations. The other geophysical techniques proposed will provide significantly more detailed vertical information on the same seven boreholes within the repository block at 3,000 foot spacing. Unless the new boreholes show a great deal more homogeneity than the existing boreholes it will be difficult to provide convincing arguments regarding the lateral variation of the intervening rock units.

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SEC. NO. 8.3.1.4.2.1.2
PAGE NO. 8.3.1.4-41 & 52
DRWG. NO.

The proposed intermediate depth seismic refraction survey may pick up the water table but is unlikely to provide any definitive stratigraphic data (NUREG/CR-4957, 1987).

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SEC. NO. 8.3.1.4.2.2
PAGE NO. 8.3.1.4-65
DRWG. NO.

It is stated that surface and subsurface structural studies will be performed to identify and characterize fracture-fault systems within the site area. These studies will, for the most part, deal only with the Tiva Canyon member of the Paintbrush Tuff. The program as described will provide very little information about the underlying section except in the immediate vicinity of the seven boreholes on 3,000 foot spacing that are proposed for drilling within the repository block. There will be little, if any, information developed from this program on the unsaturated zone section between the repository and the ground-water system.

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SEC. NO. 8.3.1.4.2.2.1
PAGE NO. 8.3.1.4-66
DRWG. NO.

Most of the 1981 to 1983 geologic mapping that has been reported to be complete has not yet been released. This makes any constructive comment on the adequacy of this activity difficult. However, since the only map released (Scott & Bonk, 1984) is known to be in error and has not been qualified under an acceptable QA program, it would be reasonable to conclude that a significant amount of new mapping will be required. The one existing map (Scott & Bonk, 1984) at a scale 1:12,000 will probably not be adequate to resolve the many geologic issues that are posed by 10CFR100, Appendix A.

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SEC. NO. 8.3.1.4.2.2.1
PAGE NO. 8.3.1.4-66
DRWG. NO.

It is stated that the northeastern and eastern limits of the map area will not be extended because rock units of interest are poorly exposed in those areas. It would appear to be premature to decide what rock units of interest are available until suitable mapping has been done.

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SEC. NO. 8.3.1.4.2.2.2
PAGE NO. 8.3.1.4-68
DRWG. NO.

A discussion of the surface-fracture network studies is misleading. The surface-fracture studies are only applicable to the Tiva Canyon. No evidence has been provided that the results can be extended to the underlying Topopah Springs. There also appears to be no plans to provide supporting analysis.

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SEC. NO. 8.3.1.4.2.2.2 PAGE NO. 8.3.1.4-69 DRWG. NO.	

It is stated that since no detailed surface-fracture network study of this scope involving comparable rocks has been attempted, extensive innovation in measurement and analytical procedures will be required. Study Plan 8.3.1.4.2.2, "Characterization of Structural Features in the Site Area" indicates that up to 27 sites will be mapped at an average of 8 weeks per site. If all 27 sites are mapped this implies that over four years may be required. Consideration for demonstrating the use of fractals and developing the necessary measurement and analytical procedures before proceeding with the study would seem to be a more prudent course of action.

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PAGE NO. 8.3.1.4-70
DRWG. NO.

It is stated that fractual analysis of each pavement will quantify the spatial distribution of fracture traces and fracture trace intersections. Use of fractals to describe geologic parameters has some intriguing possibilities, however, this approach is still a long way from being an accepted standard. The three references all by the same principal author used in support of the fractual analysis offer little help in this regard since two of the references are abstracts and one reference is an unrefereed paper that was given at an obscure international proceeding in Lapland, Sweden. It doesn't seem prudent to base such an important study on an unproven technique. If fractual analysis works it still only describes the surface characteristics of the Tiva Canyon. Subsurface lithology, particularly the unsaturated zone between the repository and ground-water system will still be based upon an interpretation between a limited number of boreholes.

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SEC. NO. 8.3.1.4.2.2.3
PAGE NO. 8.3.1.4-71
DRWG. NO.

It is stated that fracture and fault studies in continuous core will help determine the relative spatial relationships of these features. It needs to be added that this is only in the vertical dimension and includes only the unsaturated zone above the repository. For the unsaturated zone above the repository the lateral spatial relationships will be based upon interpretation between boreholes spaced 3000 feet apart. In the unsaturated zone below the repository the spatial relationships of all rock properties both vertical and horizontal will have to be based on speculation unless considerably more boreholes are drilled or some type of geophysical technique with the necessary resolution can be developed.

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SEC. NO. 8.3.1.4.2.2.4
PAGE NO. 8.3.1.4-74 thru 79
DRWG. NO.

The activity for geologic mapping of the exploratory shaft and drifts appears to be reasonable if in the unlikely event the results of all other surface-based testing is as expected. To proceed with the ESF and most particularly with the perimeter drifts before some of the major design parameters (e.g. design earthquake; fault rupture within the proposed repository block; etc.) are agreed to by all parties is high-risk venture with little room for error. Without the perimeter drift most of the data that would come from the two shafts, ES-1 and ES-2 could be obtained from the two multi-purpose boreholes. It is suggested that the DOE consider a re-evaluation of the need to proceed with the ESF pending results of the multi-purpose borehole evaluation and completion of the surface-based testing programs.

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SEC. NO. 8.3.1.4.2.2.5
PAGE NO. 8.3.1.4-79 and 80
DRWG. NO.

It is stated that the resolution of vertical seismic profile (VSP) could be as small as 20 meters. 20 meters resolution is about four to five times larger than the diameter of the planned shafts, ES-1 and ES-2. If 20 meters is the best that can be done with geophysics, it is difficult to understand the need for all the detailed mapping that is proposed for the engineered shafts and drifts.

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SEC. NO. 8.3.1.4.2.3.1
PAGE NO. 8.3.1.4-81 and 82
DRWG. NO.

The compilation scales of 1:48,000, 1:24,000, and 1:12,000 appears to be inadequate. Much of the data that is proposed for collection can't be effectively compiled or represented at these scales. For example, a pixel of 20 meters on a side (the maximum expected resolution of VSP and tomography) would plot out as 0.0656 inches on a 1:12,000 scale map or cross-section. At a minimum, consideration should be given to utilizing the 1:5,000 scale topographic maps (Wu, 1985) available for the site as the principal maps for compilation of all critical data.

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SEC. NO. 8.3.1.4.3
PAGE NO. 8.3.1.4-84 and 86
DRWG. NO.

It is stated that the principal result of this investigation will be the development of computer-based representations of the 3-dimensional distribution of physical property data. The concept of a 3-dimensional computer-based model for representing the spatial distribution of physical property data is overwhelming. If the immediate repository block (approximately 2,000 acres x 500 meters deep) is modeled on 20 meter spacing, approximately 500,000 pixels would be required for each physical property parameter. If a 2 meter spacing is used, 500,000,000 pixels would be required for each characterization parameter. Exercising the model to investigate coupled processes and analyzing the results will be a formidable task.

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SEC. NO. 8.3.1.4.3.1.1
PAGE NO. 8.3.1.4-87 and 88
DRWG. NO.

It is stated that one of the principal objectives of this activity is to provide information for the evaluation of the geostatistical approach for characterizing spatial variability and obtaining representative data. It is surprising that such an evaluation has not already been completed. It would seem more prudent to first evaluate the geostatistical approach on the shallow part of the Paintbrush Tuff before taking a substantial risk in destroying the integrity of the repository. In addition, more liberal use of surface-based geophysics (e.g. high-resolution reflection, refraction, resistivity, etc.) is commonly completed first and used as a guide in determining borehole locations. This approach would help to mitigate the impact on the program schedule that will result from the discovery of adverse conditions that commonly occurs when critical sample locations are chosen for nontechnical reasons.

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SEC. NO. 8.3.1.4.3.1.1
PAGE NO. 8.3.1.4-89
DRWG. NO.

It is stated that each borehole will be drilled to a depth of approximately 100 meters below the water table; the unsaturated zone will be protected by casing or other means from water produced while drilling below the water table. Unless provisions are made for sampling and geophysical surveying in the unsaturated zone before proceeding into the saturated zone, considerable damage to the borehole is likely to result from the installation of casing.

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SEC. NO. 8.3.1.4.3.1.1
PAGE NO. 8.3.1.4-89
DRWG. NO.

It is stated that the seven boreholes, USW SD-1 through USW SD-7, are to be located within or just outside of the conceptual perimeter drift boundary (CPDB) at an effective borehole spacing of roughly 3,000 feet. It is difficult to evaluate how effective or ineffective a 3,000 foot spacing will be based on a reference study (Rautman, et al, 1988) that is still in preparation. Considering the spatial variability that is evidenced in the Tiva Canyon on Scott & Bonk's 1984 map certainly raises questions as to the adequacy of a 3,000 foot spacing for determining the spatial distribution of the critical Calico Hills tuffaceous beds.

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SEC. NO. 8.3.1.4.3.1.1 PAGE NO. 8.3.1.4-93 DRWG. NO.	

It is stated that boreholes SD-8 through SD-12 and UZ-7 and UZ-8 along with the UZ-9 complex will be the principal boreholes for the geostatistical evaluation. It is not obvious why the DOE would choose an area of known significant faulting (Ghost Dance and Abandoned Wash) and where the imbricate faulting appears to be at a maximum to evaluate the application of the geostatistical technique. Whatever the results, it would hopefully not be representative of the main part of the repository.

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SEC. NO. 8.3.1.4.3.2
PAGE NO. 8.3.1.4-100 through 102
DRWG. NO.

In terms of development of 3-dimensional models of rock characteristics at the repository site it does not appear that the overall schedule allows enough time to effectively analyze the data as proposed, based upon the probable complexity that will result from the geostatistical evaluation. Covariance analysis and kriging of multiple 5×10^5 to 5×10^8 matrices is very likely to require substantial time beyond what is presently scheduled.

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SEC. NO. 8.3.1.4.4
PAGE NO. 8.3.1.4-103 through 108
DRWG. NO.

The proposed schedule is unrealistic. Beyond the starting point continual adjustments will have to be made in the schedule for each activity as unexpected results arise. It is extremely difficult to reliably estimate the time required to investigate geologic phenomenon on even the grossest scale and under the best of conditions. In addition, because the activities are all being conducted in parallel, the number of geologists involved will likely be substantial. The probability of several geologists arriving at a consensus interpretation on any one activity in a timely manner according to schedule is extremely low. The probability of a much larger group of geologists arriving at a consensus interpretation on multiple inter-related activities in a timely manner according to schedule is even lower. Even without the above caveat it is not clear where the DOE will obtain the large number of qualified geologists required to effectively carry out the proposed studies.

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SEC. NO. 8.3.1.17
PAGE NO. 8.3.1.17-27
DRWG. NO.

It is stated that the deterministic approach will be used to establish ground-motion conditions to be considered in the advanced conceptual design, and if appropriate, in the final design. The design earthquake is a key parameter that must be established with a high degree of confidence very early in the program if the ESF is to be included as part of the final repository. The proposed schedule essentially does not provide for enough appropriate data to be available to make an acceptable deterministic assessment of the design earthquake for about four to five years into the program. In the interim, proceeding with design and construction of the ESF, based upon a non-conservative probabilistic approach could jeopardize the ultimate acceptability of the system.

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SEC. NO. 8.3.1.17
PAGE NO. 8.3.1.17-27
DRWG. NO.

It is stated that in addition to the deterministic approach for establishing ground-motion conditions from earthquakes, underground nuclear explosions (UNEs) will also be considered. The proposed program appears to ignore the possible cumulative effect of UNEs on the stress state of faults within or in the immediate vicinity of the site. Of particular concern should be the Stagecoach Road, the Mine Mountain Fault, and the Rock Creek Fault System.

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SEC. NO. 8.3.1.17
PAGE NO. 8.3.1.17-28
DRWG. NO.

It is stated that the Paintbrush Canyon, Bow Ridge, Solitario Canyon, and Windy Wash Faults show evidence of normal dip-slip movement along surfaces that dip steeply to the west. The text fails to mention the Midway Valley Fault System between the Paintbrush Canyon and Bow Ridge Faults which also underlies the proposed surface facilities. This fault zone is estimated to be over 1 km wide with several hundreds of meters offset. The fault zone is also reported to dip to the east rather than to the west (Neal, 1986). The Midway Valley Fault is estimated to be as long or longer than the Bow Ridge Fault (USGS, 1984). A conservative position required by present NRC practice is to assume that the entire fault length could be active if any one segment is active. The question then becomes one of the size of earthquake that such a fault could sustain and not which segment is active.

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PAGE NO. 8.3.1.17-29
DRWG. NO. Figure 8.3.1.17-2

The inferred fault zone that connects the Stage Coach Road Fault with the Paintbrush Canyon Fault and Mine Mountain Fault is considerably different from the interpretation shown on the maps from the principal references (USGS, 1984 and Swadley et al, 1984). If this interpretation is correct it implies that a major fault system extends to Yucca Flats and could therefore be activated by UNEs as has happened in the past. This figure also presents conflicts with the values shown in Table 1-11, Page 1-173, which shows 10 km length and 20 km distance for the Mine Mountain Fault. Figure 8.3.1.17-2 would indicate a length g.t. 28 km and a distance that could be as close as 8 km. Using Schnabel & Seed, 1973, and Mark & Bonilla, 1977, would result in a deterministically computed mean peak acceleration that is in excess of 0.6 g. The present seismic design value of 0.4 g proposed for the ESF would appear to be seriously underestimated.

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PAGE NO. 8.3.1.17-30
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The recurrence interval on the Paintbrush Fault is irrelevant at this stage in the process in terms of deterministically establishing the design basis earthquake under NRC regulations. A 6.5 magnitude earthquake on the Paintbrush Canyon Fault is likely to produce a mean peak acceleration that is well in excess of the 0.4 g presently proposed as the design value for the ESF.

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DRWG. NO.

In regards to detachment faults that dip gently to the west it is stated that until such uncertainties are resolved the evaluation and characterization of potential ground-motion and faulting at the site must allow for alternative interpretations of the local tectonics. The SCP appears to be silent on how the DOE proposes to resolve the uncertainties of a detachment fault. With the exception of an east-west refraction line north of Yucca Mountain there appears to be no investigations directed specifically at determining deep crustal structure on a regional scale.

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PAGE NO. 8.3.1.17-31
DRWG. NO.

In the discussion of consideration of fault displacement it is stated that significant displacement on a fault along a distributed zone of faulting immediately adjacent to repository facilities could disrupt operations and damage facilities. This seems to be an understatement. Displacement of any kind on fault zones in the repository area should be cause for concern because of the unpredictable effect such movement would have on the hydrologic system, both in the vadose zone and the saturated zone. Given the type of geology available to work with at Yucca Mountain, it is unlikely that positive demonstration can be affected that an active fault will not move at all, let alone more than 5 cm in the next 100 years. At the very least, discovery of active faults in the foundation of the proposed waste handling facilities will likely cause extended licensing delays.

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It is stated that the maximum allowable annual probability for exceeding 5 cm of fault displacement will be less than 10^{-4}/yr which appears to be consistent with safety considerations for this and other types of facilities. The text goes on to state that the risk resulting from a 5 cm fault displacement of 10^{-4}/yr is probably less than the risk resulting from vibratory ground motions that exceed the design basis for a nuclear power plant. The DOE has no basis for this statement. There are no waste handling facilities comparable to the ones being proposed at Yucca Mountain that have been evaluated for seismic risk and the approach proposed by the DOE is not consistent with the present NRC position regarding seismic risk assessment for nuclear power plants. The issue is not whether the risk is less for a waste handling facilities but whether the DOE can ever reasonably demonstrate what the actual risk is.

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SEC. NO. 8.3.1.17
PAGE NO. 8.3.1.17-32
DRWG. NO.

It is stated that extensive field investigations will be conducted in the immediate site vicinity of facilities important to safety (FITS). The design parameter being used gives preliminary guidance on the distance (100 meters) detailed studies (continuous trenching) should extend from the location of FITS. The 100 meter trench distance is unlikely to meet NRC requirements for investigations of possible surface fault rupture at the FITS site in Midway Valley. Present NRC regulation requires mapping over a distance of at least 10 miles (16 km) in both directions along the fault trace to establish the control width. Based upon the results of the mapping, the control width (zone requiring detail study) is then established. Based upon the maps presently available from the DOE (USGS, 1984 and Neal, 1986) it is estimated that the control width will be closer to 1 km rather than the proposed 100 meters.

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DRWG. NO.

DOE states that the goal of the deterministic approach is primary in establishing the design earthquake and that the probabilistic approach will be used to guide, test, and substantiate the deterministic analysis. In order to make an acceptable deterministic finding, the geology must be such that positive evidence can be provided that will allow the DOE to reach closure on all of the questions posed by the presence of active faults in and around Yucca Mountain. At Yucca Mountain there is a significant lack of late Quaternary and Holocene deposits that can be used to constrain the time of latest movement or establish reliable estimates of recurrence intervals. It would therefore appear that the DOE will be forced to rely on a probabilistic approach as the primary method to establish the design earthquake. Unless the NRC changes their present technical position, it would appear that extended licensing delays will result from this issue.

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DRWG. NO.

The DOE defines a 10,000-year cumulative slip earthquake to be one that, occurring every 10,000 years, would produce the observed or estimated average Quaternary slip rate on a fault. The 10,000-year cumulative slip earthquake has no precedence in practice or in the professional literature. It appears that the DOE has contrived this approach to meet their preconceived ideas of the geologic situation at Yucca Mountain. The issue of a 10,000-year cumulative slip earthquake may be moot however, since present NRC practice does not readily allow for such an approach nor is the geology at Yucca Mountain favorable for providing the data necessary to confidently establish what the recurrence intervals are. An additional factor that must be considered is that fault displacement of any kind during the life of the repository provides an unpredictable and unacceptable pathway to the accessible environment. If the DOE intends to use the 10,000-year cumulative slip earthquake as a primary design basis, then resolution with the NRC and State should be effected before proceeding with the ESF.

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DRWG. NO.

DOE indicates that a similar procedure to the one being proposed for the 10,000-year cumulative slip earthquake will be used to characterize potential ground-motions from UNEs. The proposed program does not appear to consider stress build-up and subsequent rupture of faults that extend from the area where UNEs are occurring into the immediate repository area. In addition, the proposed DOE analysis would not appear to cover the full range of past UNEs in establishing the maximum future UNE.

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SEC. NO. 8.3.1.17.2
PAGE NO. 8.3.1.17-56
DRWG. NO.

The study parameters to provide required information on fault displacement that could affect repository design or performance are probably inadequate to meet NRC requirements. Present NRC requirements call for investigations of all faults greater than (g.t.) 1.6 km long at a distance of 0 to 32 km from the site; g.t. 8 km long at a distance of 32-80 km from the site; g.t. 16 km long at a distance of 80-160 km from the site; g.t. than 32 km long at a distance of 160-230 km from the site; and g.t.ter than 64 km long at a distance of 230-320 km from the site. Until such investigations have been completed it is unlikely that the full suite of earthquakes that could affect repository design or performance will be identified. In addition, for any faults within 16 km (10 miles) of the site detailed fault investigations are required in order to establish the controlled width. Any suspected Quaternary displacement on faults beneath FITS would probably at the least be cause for extended delays in siting unless unequivocal data can be provided to the contrary.

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The characterization parameters related to the potential for underground fault displacement in areas of implaced waste are unacceptable. The logic of the approach taken by DOE is not obvious. There is no basis for considering one meter of Quaternary offset as the limit for surface fault displacement. There is very little, if any, Quaternary material on the surface of the repository block necessary to make this kind of determination. In addition, not to consider any Tertiary faults with displacements of less than 100 meters doesn't seem to be very practical when the proposed design of the air gap around the canisters is approximately 7 cm.

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DRWG. NO.

It is stated that because significant faulting is sometimes accompanied by sympathetic displacements in adjacent areas, information on fault-zone widths and recurrence of movement on Quaternary faults within 5 km of surface FITS will be analyzed. Present NRC practice is to require mapping to a minimum distance of 16 km in either direction before establishing the control width for surface investigations. In the case of the Midway Valley Fault underlying FITS, the zone is estimated to be at least 1 km wide. If present NRC guidance is followed the control width requiring detailed fault investigations would be approximately 2 to 3 km wide based on a 6.5 magnitude earthquake estimate for the Paintbrush Fault.

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It is stated that any site without faults having apparent Quaternary slip rates greater than 0.001 mm/yr and faults that measurably offset materials less than 100,000 year old is expected to meet the so-called conservative goal of less than 1% chance of exceeding 5 cm of net slip displacement in 100 years with high confidence. The criteria of less than 100,000 year old material being offset is misleading. According to Figure 1-24b the only material in the site area less than 160,000 years old are Holocene deposits of about 9,000 years old. What this implies is that any fault that is found to displace 160,000 year old material but does not displace Holocene material will not be considered significant. It is unlikely that this approach would meet NRC requirements. In addition, reliable estimates of slip rates for faults that show Quaternary offset will be extremely difficult to determine unless a substantial part of the Quaternary section is available for dating. This is not the case at Yucca Mountain where there is a significant hiatus in both the middle and late Pleistocene section.

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DRWG. NO.

It is stated that to meet the design-parameter goal of identifying and characterizing significant late Quaternary faults in the repository block, the location of faults with more than 1 meter offset of Quaternary materials or with more than 100 meter offset of Tertiary rocks (materials), will be determined. This goal is misleading. The reason that only the Bow Ridge and Solitario Canyon Faults have been identified as showing Quaternary displacement is because of an inherent lack of Quaternary material on the surface of the repository block. By establishing the Tertiary offset at g.t. 100 meters (328 feet) the DOE appears to conveniently eliminate all the other faults in the immediate area. Just because there are no Quaternary deposits to prove that displacement took place in the Pleistocene or Holocene does not eliminate such faults from serious consideration as possible pathways to the accessible environment.

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PAGE NO. 8.3.1.17-60 and 61
DRWG. NO.

The parameters required for the synthesis of data to assess the potential for surface faulting that FITS indicates that only faults within 100 meters of locations proposed for FITS that have apparent Quaternary slip rates g.t. 0.001 mm/yr or that measurably offset materials less than 100,000 year old will be investigated. It is reported (J. T. Neal, SAND85-0815, 1986) that the Midway VAlley Fault Zone is at least 1 km wide with a cumulative offset of "several hundred meters" beneath the site chosen for the surface facilities. If the proposed synthesis includes only data within 100 meters of FITS, it is quite probable in the case of Midway Valley that the NRC requirements for control width zone investigations will not be met.

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PAGE NO. 8.3.1.17-61
DRWG. NO.

It is stated under parameters that the fault-zone widths and recurrence of movement on potentially significant faults within 5 km of location proposed for FITS will be investigated. Present NRC requirements are for investigation of significant faults for evidence of surface rupture should be carried out over a distance of at least 16 km in both directions from the potential site for FITS.

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The SCP states that surface FITS will be sited where there is no evidence of Quaternary faulting. It is not obvious why the DOE is so vague on this most important criteria. At the present proposed site for FITS, east of Exile Hill in Midway Valley, several hundred meters of fault offset has been identified (SAND85-0815, 1986). Positive demonstration that there is no evidence of Quaternary faulting (it is assumed that "several hundred meters" qualifies as substantial) when the Quaternary-Tertiary contact is over 60 feet below the surface will be an expensive and time consuming task.

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The SCP states that since fault systems tend to have self-similar geometries (i.e., to have similar degrees of branching and complexity over a wide range of map scales) an analysis of the fractal characteristics of local fault systems may be useful for estimating the spatial density and lengths of subsidiary faults that may lie concealed in the vicinity of FITS. There is limited published data to support the statement that all fault systems have self-similar geometries over a wide range of map scales. Even if such data existed, the fractal nature of faults in the Yucca Mountain area would still need to be demonstrated. Available maps such as Scott & Bonk (1984) indicate that there are more concealed faults than faults that have surface expression. In the Midway Valley area where the FITS is proposed, the major faults are all concealed under the alluvium. A fractal description of the Paintbrush Fault or Bow Ridge Fault based upon existing data from the SCP would not have predicted the apparent width and complexity of the Midway Valley Fault Zone.

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It is stated that data will be required for locations of faults in the repository block that offset Quaternary materials by more than 1 meter or Tertiary rocks by more than 100 meters. Since there are limited Quaternary deposits on the surface and no Quaternary deposits in the subsurface the de facto criteria becomes 100 meters of Tertiary offset. Given that the air gap between the canisters and rock is supposed to be approximately 7 cm, it is not obvious why any fault with g.t. 7 cm displacement should not be considered important in the design of the repository.

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The second parameter states that surface and subsurface location of faults with Quaternary slip rates g.t. 0.005 mm/yr that intersect areas proposed for waste implacement will be identified. Due to the almost total lack of Quaternary material in the immediate area of the repository block and a lack of a continuous complete Quaternary section anywhere in the area that could be used for calibration, it is not obvious how the DOE will effectively develop this parameter.

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The third parameter states that approximate regional spacing and rate of Quaternary faults will be established. This parameter implies that a much larger area will need to be studied than is presently proposed in the SCP. If present NRC requirements are followed, an area of up to 320 km from the site may have to be investigated.

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For the fourth parameter it is implied that the tectonic interrelationships among local faults will be established. It is unlikely that the DOE will be able to understand the tectonic relationships among local faults until a much better understanding of the regional relationships among fault systems is developed. The DOE should consider developing a sound understanding of the regional relationships before proceeding too far with the study of the local fault relationships.

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It is stated that the inference of faulting potential will be based on the average spacing of Quaternary faults that is estimated within the structural domain that encompasses the site. A structural domain is defined in the SCP as a crustal block within which faulting of a given genetic type generally occurs with uniform characteristics. The concept of a structural domain is an interesting planning tool, but not very practical in application. The earth science community is a long way from understanding the near-surface structural domain on the local scale of Yucca Mountain let alone the more regional 3-dimensional scale of the southern Basin and Range. Preliminary information on the crustal structures is just now beginning to emerge. Many years will be required before the knowledge base is extensive enough to accurately define crustal blocks. The SCP does not appear to propose acquiring such data.

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It is stated that the results of the investigations on potential fault displacement will be used in the development and analysis of the repository design. Given the most optimistic and well managed program and with no surprises in the data that requires significant program modification (a very low probability event) it will most likely take four to five years before enough results are available to provide reasonable assurance that the repository design is adequate. It would seem to be more practical to do extensive parametric evaluations now using worse case scenarios based on existing data before proceeding with large commitments of funds.

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Parameter two states that identification of earthquake sources will be limited to 100 km radius of the site. Present NRC practice is to require investigation of all faults g.t. 1.6 km in length for a distance of 0-32 km from the site; 8 km in length for a distance of 32-80 km from the site; 16 km in length for a distance 80-160 km from the site; 32 km in length for a distance of 160-230 km from the site; and 64 km in length for a distance of 230-320 km from the site.

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Parameter six states that the closest distance between the site and potential future UNEs at NTS will be identified. A major parameter missing from this list is a study of the closest distance between the site and possible earthquake sources that could be activated by future UNEs. In addition, the stress build-up from past UNEs on fault systems in the immediate Yucca Mountain site area should be considered.

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It is stated that the main purposes of this investigation (8.3.1.17.3) are (1) develop a seismic-design basis for repository facilities that are important to safety and (2) provide other information that will facilitate the assessment of the adequacy of the seismic-design basis and the identification of credible accidents that might be initiated by seismic events and lead to release of radioactive materials. If the ESF is to be included in the repository it would seem to be a prudent course of action to resolve the issue of the seismic-design basis, including the need to consider design for surface faulting and fault displacement in the repository, before proceeding with significant construction activities. Failure to resolve these seismic-design issues could risk the viability of the site, particularly if the DOE proceeds with the perimeter drift.

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The SCP states that one of the parameters will be a map showing Quaternary faults with lengths greater than about 20 km within 100 km of the site and Quaternary faults with lengths greater than about 1 km within 10 km of the site. The NRC's present position appears to be that the methodology prescribed in 10CFR100, Appendix A, is applicable to the investigations for a high level waste repository as required by 10CFR60. To argue whether 10CFR100, Appendix A will be ultimately applied or not is somewhat irrelevant at this stage in the process. A prudent plan should certainly take 10CFR100, Appendix A and the licensing precedents that have been set over the last 16 years under 10CFR100, Appendix A into account. If the DOE develops their database on relevant earthquake sources using 10CFR100, Appendix A guidance and the site is found acceptable then the NRC, State, or any other entity would effectively have limited cause to deny a license for construction. On the other hand, if the DOE persists in their apparent cavalier approach to developing a data set that includes only the information the DOE thinks is relevant and supports their preconceived ideas of site suitability, the NRC, State, or any other entity should have little difficulty in finding issues that would likely be the cause of extensive delays in the program.

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The 10,000-yr cumulative slip earthquake appears to have been contrived to specifically fit the data available for the Paintbrush Fault, i.e., 0.1 meter per event per 10,000 years (see M. Somerville in SAND85-0815, 1986). Although the concept of a 10,000-yr cumulative slip earthquake could be valuable in establishing seismic risks in areas of low seismogenic potential it hardly seems appropriate for an area like the southern Basin and Range that has experienced six earthquakes g.t. magnitude 6.8 (all with surface rupture) during the last 127 years (see Table 1-10, Page 1-166). Disregarding the inherent controversial nature of the 10,000-yr cumulative slip earthquake and the fact that it may not be able to meet NRC requirements, there is a fundamental problem with data availability. Because of the limited amount of Holocene deposits and the shortage of late Quaternary deposits both spatially and temporaly, it is doubtful that an acceptable database can be developed.

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The SCP activity for determining the range of UNE sources appears to be limited to establishing possible sites for potential future UNEs. The plan does not appear to consider the effects of past and future UNEs on the state of stress for faults or fault systems that may be critical to repository seismic-design parameters.

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SEC. NO. 8.3.1.17.3.4
PAGE NO. 8.3.1.17-77
DRWG. NO.

The SCP calls for studying the effects of local site geology on surface and subsurface (ground) motions. In order for this type of study to be meaningful the DOE must first develop a sound basic model of the geologic system between the sources and the site. Present SCP plans for developing such a model are of questionable adequacy. However, if somehow the program does succeed in producing a usable model, the results are unlikely to be available for four to five years. Construction of any facility that may be important to safety (FITS) should be delayed until such time as the seimsic-design issues are well settled.

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SEC. NO. 8.3.1.17.3.4.1
PAGE NO. 8.3.1.17-78
DRWG. NO.

The activity to determine site effects from ground-motion recordings in general could provide important information and should be initiated at the earliest possible time. It is suggested that in addition to the planned instrumentation, additional instrument arrays be installed around several of the most likely sources (e.g. Bear Mountain; Cedar Mountain; Death Valley/Furnace Creek; etc.) for the purpose of studying the source parameters and determining near field effects.

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SEC. NO. 8.3.1.17.3.5.1
PAGE NO. 8.3.1.17-80
DRWG. NO.

In general the activity to identify controlling seismic events appears to be a state-of-the-art approach with the exception of the 10,000-yr cumulative slip earthquake. The area of consideration (100 km from the site) will likely need to be expanded to fit NRC requirements. A major question that needs to be asked regards the schedule which calls for most of the input to be available within 15 months from the time the ESF construction is initiated. Since the DOE has yet to produce a regional geologic map that will meet NRC requirements to establish the probable seismo-tectonic province of concern (which in itself requires considerable input from a number of other studies) it is unlikely that the 15 month schedule can be met.

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SEC. NO. 8.3.1.17.3.6
PAGE NO. 8.3.1.17-82
DRWG. NO.

The probablistic seismic hazards analysis study appears to be pretty much state-of-the-art. However, it suffers from the same basic schedule problem as Study 8.3.1.7.3.5, "Ground Motion From Controlling Seismic Events". It appears from the schedule as shown on pg. 8.3.1.17-208 and pg. 8.3.1.17-214 that the probablistic analysis will be the primary basis for establishing the seismic design in order to keep the ESF schedule on track. Any adverse deterministic data that comes to light and doesn't support the probablistic assessment will then need to be submerged in the existing probablistic model in order to not jeoprodize the ESF seismic design. It is also noted on the schedule that the probablistic seismic hazards analysis is apparently not tied into the study of surface faulting potential at the site.

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SEC. NO. 8.3.1.17.4.1.1 PAGE NO. 8.3.1.17-88 DRWG. NO.	

The activity to compile historical earthquake records is limited to a 100 km radius of Yucca Mountain. The 100 km radius proposed for the historical earthquake record compilation will probably be inadequate to develop and defend a seismo-tectonic province as presently required by the NRC regulations.

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SEC. NO. 8.3.1.17.4.1.2
PAGE NO. 8.3.1.17-90
DRWG. NO.

It is stated that for the larger (g.t. M=5.5) earthquakes available information will be compiled on 12 different characteristics. If the regional detection threshold is approximately M_L 1.0, a considerable amount of this type of information with the exception of epicentral intensity should also be available down to the M_L 2.5 - 3.0 range. Because of the limited amount of seismic activity expected in the immediate Yucca Mountain site area during the characterization period, efforts should be made to glean as much information as possible from the data without placing and artificial cap on the magnitude level.

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SEC. NO. 8.3.1.17.4.2.1.
PAGE NO. 8.3.1.17-93 and 94
DRWG. NO.

The statement attributed to Neal (1986) that "indicates that closely spaced faults (l.t. 50 meters) occur beneath the surficial deposits", is taken out of context and is misleading. Neal (1986) makes no statement regarding the specific spacing of the faults. The statement is "the individual offsets in the zone of close-spaced, normal faulting may be small and difficult to detect, but the zones may be as much as a kilometer in width with a cumulative vertical offset of several hundred meters." An additional important point raised by Neal (1986) is the existence of a down to the east high angle reverse fault between borehole RF-9 and RF-3. This interpretation is inconsistent with the structural profile proposed by Scott & Bonk (1984). It is possible that the Midway Valley Fault could represent the west side of a graben structure with the Paintbrush Fault representing the east side.

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SEC. NO. 8.3.1.17.4.2.1
PAGE NO. 8.3.1.17-94
DRWG. NO.

The statement is made that faults (Midway Valley) are not believed to penetrate alluvial units; surface expression is not evident. This statement is misleading and appears to be an attempt to minimize the significance of the data on faulting in the area of FITS. The seismic data and available borehole data show that the fault zone extends for a distance of at least 1 km to the east of Exile Hill. There is no evidence, pro or con, to support the statement that alluvial units are not offset. In addition, Figure 3 from Neal (1986) implies that the faulting must continue across the valley to the Paintbrush Canyon Fault where it has been recognized that alluvial units are offset.

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COMMENT NO.: 100 pg. 1 of 1	CHAPTER NO.: 8

SEC. NO. 8.3.1.17.4.2.2
PAGE NO. 8.3.1.17-95
DRWG. NO.

The impression is given in 8.3.1.17.4.2.1 and 8.3.1.17.4.2.2 that the surface fault investigations will be limited to the immediate vicinity of Midway Valley next to Exile Hill. Present NRC criteria for surface fault investigations requires that studies be conducted for 16 km (10 miles) in both directions along the fault trace and over a zone that is some multiplier times the control width. In the case of the Paintbrush Fault the multiplier would be 2 or 3 based on a magnitude 6.5 earthquake. Since the Midway Fault is known to be at least 1 km wide (Neal, 1986) the zone for requiring detailed fault investigation would be considerably wider than the proposed 100 meters on either side of FITS.

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COMMENT NO.: 101 pg. 1 of 1 | CHAPTER NO.: 8

SEC. NO. 8.3.1.17.4.3
PAGE NO. 8.3.1.17-97
DRWG. NO.

It is stated that the study of Quaternary faulting will be limited to a zone within 100 km of Yucca Mountain. The present NRC requirements for the study of "active" faults is a zone of 0-32 km for faults longer than 1.6 km; a zone of 32-80 km for faults longer than 8 km; a zone of 80-160 km for faults longer than 16 km; a zone of 160-230 km for faults longer than 32 km; and a zone 250-320 km for faults longer than 64 km.

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SEC. NO. 8.3.1.17.4.3
PAGE NO. 8.3.1.17-97
DRWG. NO.

Figure 8.3.1.17-7 shows and the text states that the areas to the north and east of Yucca Mountain are covered by modern geologic maps of bedrock at a scale of 1:24,000 or larger. Most of the so-called modern geologic mapping north and east of the site was completed 15 to 20 years ago and for entirely different purposes. Recent mapping was done in 1981 to 1983. A substantial part of this mapping has yet to be published. As shown on Figure 8.3.1.17-7, there are substantial areas in addition to the Amargosa Desert, Crater Flat, Bear Mountain, and the Beatty area that are within the arbitrary 100 km radius that have little to no mapping available of the quality needed to demonstrate compliance with NRC requirements. Although there are indications that mapping will be done for various purposes in most of these areas, there appears to be no early activity to compile a complete up-to-date geologic map that can be used to define the basic seismo-tectonic province.

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COMMENT NO.: 103 pg. 1 of 1 | CHAPTER NO.: 8

SEC. NO. 8.3.1.17.4.3
PAGE NO. 8.3.1.17-101
DRWG. NO.

It is stated that the Walker Lane is approximately 600 km long, shows substantial (25 to 30 km) post-Miocene right-lateral displacement, and is seismically active in its northern and central parts. Unless the DOE can demonstrate unequivically that the Walker Lane shows no Quaternary movement in the southern part or can provide strong evidence for segmentation there is a high probability that at least a 7.2 to 7.3 magnitude earthquake will have to be considered to occur in the immediate site vicinity.

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SEC. NO. 8.3.1.17.4.3.1
PAGE NO. 8.3.1.17-105
DRWG. NO.

The proposed list of deep geophysical surveys appears to be very comprehensive and the description of geophysical tests is considerably better than the description for most of the other activities described in the SCP. However, the proposed geophysical tests suffer from many of the same shortcomings that appear to be endemic throughout the SCP. First is the lack of suitable maps within the SCP to judge the adequacy and relevance to the problem being addressed. Second is an idea of how the data will be used in an integrated sense to help determine site viability. There is a strong implication that the geophysical surveys will somehow provide a clear and unambiguous picture of what the regional geologic system looks like in 3-dimensions, when in fact, the opposite is closer to reality. Based upon the SCP referenced results of past feasibility studies (e.g. USGS BULL. 1790, 1988) the picture will most likely become cloudier. Fourth, the proposed geophysical program needs to be prioritized and then conducted in a more logical sequence that generally flows from the regional to the site specific. Results from each step could then be used to guide the studies for the next step. A sequenced program, although taking longer to initially conduct, would probably result in considerable savings in the long run by eliminating a lot of unnecessary data collection.

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COMMENT NO.: 105 pg. 1 of 1 | CHAPTER NO.: 8

SEC. NO. 8.3.1.17.4.3.2
PAGE NO. 8.3.1.17-119
DRWG. NO.

The activity to evaluate Quaternary faults within 100 km of the site is very important and should proceed at the earliest possible time. However, without the availability of integrated geologic, geophysical, and seismic map that includes the latest available data, it is not obvious why the study should be limited to a 100 km radius of the site or why the focus in this stage in the program should be on the particular faults mentioned. A careful reading of Chapter 1 leaves the impression that a significant amount of work needs to be done first on integrating and trying to understand the geologic data that already exists before overwhelming the system with a considerable amount of new data, much of which may turn out to be irrelevant.

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COMMENT NO.: 106 pg. 1 of 1	CHAPTER NO.: 8

SEC. NO. 8.3.1.17.4.3.3
PAGE NO. 8.3.1.17-127
DRWG. NO.

Regarding the evaluation of the 1932 Cedar Mountain earthquake, a considerable amount of study has already been completed and published by the University of Nevada, Reno and Nevada Bureau of Mines and Geology. It would be wise to carefully consider this work before prematurely preceding with any additional studies that may not significantly increase the understanding of the geologic system. In addition, time and money with redundant studies of the 1932 Cedar Mountain earthquake might be essentially wasted if the NRC regulations end up requiring that a 7.2 to 7.3 magnitude earthquake be considered on the southern end of the Walker Lane in the immediate site vicinity.

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SEC. NO. 8.3.1.17.4.3.4.
PAGE NO. 8.3.1.17-128
DRWG. NO.

The activity to evaluate the Bear Mountain fault zone should be initiated at the earliest time in order that the results can be available and used as a guide to similar studies of other Quaternary faults in the region. The proximity to the site; the ongoing mining activities that can provide good exposures; the lack of logistical problems because the site is outside of NTS; and the possible availability of a relatively complete Quaternary section all support this suggestion.

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SEC. NO. 8.3.1.17.4.3.5
PAGE NO. 8.3.1.17-131
DRWG. NO.

There appears to be no technical justification at this point to limiting the studies of structural domains and regional patterns of faults and fractures to a radius of 100 km from the site. The regional data should be analyzed first and used to establish support for the geologic domain determination (seismo-tectonic province). This approach is much more logical and would likely produce results that could meet the present NRC requirements.

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SEC. NO. 8.3.1.17.4.4
PAGE NO. 8.3.1.17-132
DRWG. NO.

The study of Quaternary faulting proximal to the site within northeast-trending fault zones could be very important in determining the design earthquake for the ESF and should be initiated at the earliest possible time. The present data that already exists should first be integrated and used to optimize the locations for initial geophysical studies and to identify the best trenching locations.

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SEC. NO. 8.3.1.17.4.5
PAGE NO. 8.3.1.17-143
DRWG. NO.

The study of detachment faults at or proximal to Yucca Mountain appears to be very interesting from a scientific standpoint but appears to be about five years late and perhaps somewhat irrelevant. The time and money that will be allocated to this study could be better spent on determining the geometry of the detachment fault(s) beneath the Yucca Mountain site that have already been identified. Because a detachment fault has been identified in UE-25p#1 (Carr, et al, 1986) and has been interpreted from the gravity data (Snyder and Carr, 1984) and dips in the direction (N 60° W) of least horizontal stress (Stock, et al, 1985) there is a very high probability that detachment faults will need to be considered regardless of the outcome of the proposed studies.

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SEC. NO. 8.3.1.17.4.5.5
PAGE NO. 8.3.1.17-151
DRWG. NO.

The activity to evaluate the age of detachment faults using radiometric ages is academic for the most part and will probably have little effect upon the ultimate decision as to whether the detachment faults will be considered active. In addition, the time frame proposed to complete this activity is probably too long to have much effect on any results of detachment fault evaluation.

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DOCUMENT TITLE: Site Characterization Plan	
COMMENT NO.: 112 pg. 1 of 1	CHAPTER NO.: 8
SEC. NO. 8.3.1.17.4.6. PAGE NO. 8.3.1.17-154 DRWG. NO.	

The site area defined for the Quaternary faulting study seems to be based more on administrative direction and logistical convenience rather than sound geologic reasoning. Further, it is misleading to imply that all Quaternary faults are predominantly north-trending, west-dipping normal- or oblique-slip faults when the purpose of the study is to identify all the Quaternary faults. The available data does not support the DOE's position. Data from Midway Valley indicates there could be significant east-dipping faults and Yucca Wash is mapped as a right lateral strike-slip fault. If the Windy Wash Fault is a potentially significant example, then the site area should be expanded to the west to include as a minimum the Windy Wash Fault within the boundary area.

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COMMENT NO.: 113 pg. 1 of 1 | CHAPTER NO.: 8

SEC. NO. 8.3.1.17.4.6.1
PAGE NO. 8.3.1.17-156
DRWG. NO.

It is not obvious why the map scale is being expanded from 1:12,000 (Scott & Bonk, 1984) to 1:24,000 for this most critical activity of evaluating the Quaternary faults in the immediate site area. It would seem more logical to use a scale of 1:6,000 (Wu, 1982) that matches the low sun angle photographs. In addition, activity 8.3.1.5.1.4 which is suppose to support this study is not scheduled for completion for another four years which may be too late to effectively be useful. As a way for the public to monitor the progress of this most important activity it is suggested that any Quaternary fault maps that result should be published in draft form as part of the six month SCP progress reports as the data becomes available.

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SEC. NO. 8.3.1.17.4.6.2
PAGE NO. 8.3.1.17-159
DRWG. NO.

The discussion of volcanic ash that may possibly be used for dating implies that there are a number of volcanic ashes in the site area, at Busted Butte for example, that came from the Cascades and Yellowstone. This is preposterous. There is no published evidence of Cascade or Yellowstone ash ever being identified in the southern Basin and Range. Other than the Bishop tuff which came from the eastern Sierra Nevada area, ashes in the site area are most likely locally derived. Establishing the chronology, stratigraphy, and areal distribution of individual ash layers could be very useful in deciphering the Quaternary tectonic history, however it is not a trivial task as implied by the SCP discussion.

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COMMENT NO.: 115 pg. 1 of 1 | CHAPTER NO.: 8

SEC. NO. 8.3.1.17.5
PAGE NO. 8.3.1.17-207 to 226
DRWG. NO.

The proposed schedule for the preclosure tectonics program is illogical and appears to have been developed more to satisfy administrative requirements rather than as an honest estimate of how long the studies would effectively take considering the technical problems involved. The present proposed schedule for the preclosure tectonics program calls for all major studies and subordinate activities to essentially begin concurrently in late 1989. If DOE can find enough qualified scientists to perform all the proposed studies and activities simultaneously and there are no surprises along the way the results will be overwhelming. To further assume that the results can then somehow be brought together in three to five years in a giant 3-dimensional computer model to produce a meaningful geologic picture is very unrealistic. Almost all of the studies proposed are either feasibility studies or research programs that don't appear to have a clear concept of where to begin, let alone any idea of how or when the results will come out. The DOE should reconsider doing the site characterization program sequentially starting with an integration of existing data followed by appropriate studies based upon an objective evaluation of the results.

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DATE: June 30, 1989

COMMENTS OF

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AND TECTONIC STUDIES,

DEPARTMENT OF GEOSCIENCE,

UNIVERSITY OF NEVADA - LAS VEGAS

REVIEW OF THE SITE CHARACTERIZATION PLAN FOR THE PROPOSED NUCLEAR WASTE REPOSITORY AT YUCCA MOUNTAIN, NEVADA

BY

CENTER FOR VOLCANIC AND TECTONIC STUDIES
DEPARTMENT OF GEOSCIENCE
UNIVERSITY OF NEVADA
LAS VEGAS, NEVADA 89154

REPORT NO. 21

JULY 1, 1989

SPECIFIC COMMENTS

REVIEW OF THE SITE CHARACTERIZATION PLAN FOR THE PROPOSED NUCLEAR WASTE REPOSITORY AT YUCCA MOUNTAIN, NEVADA

BY THE CENTER FOR VOLCANIC AND TECTONIC STUDIES
DEPARTMENT OF GEOSCIENCE
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GENERAL COMMENTS

The staff of the Center for Volcanic and Tectonic Studies (CVTS) reviewed sections of the Site Characterization Plan (SCP) that dealt with basaltic volcanism. The following parts of the SCP were reviewed:

1.3.2.1 Volcanic history
1.5.1 Volcanism
8.3.1.8 Overview of the postclosure tectonics program
8.3.1.8.1 Direct releases from volcanic activity
8.3.1.8.5.1 Study: Characterization of volcanic features
8.3.1.17 Overview of preclosure tectonics (p. 30-31; p. 51-56)

CVTS staff activity involved in the reviewing process were:

Eugene Smith
Dan Feuerbach
Terry Naumann

The general comments regarding the SCP were organized to answer the following questions:

(1) Is the present data set sufficient and accurate enough to develop appropriate and adequate plans of investigations?

(2) Are the activities underlying assumptions defensible?

(3) Is the actual study of testing activities correctly designed to obtain the desired information?

(4) Are the proposed activities accomplishable within a reasonable time frame?

We first present general statements addressing each question and then present a score-sheet that evaluates each activity in the SCP related to basaltic volcanism in relationship to the questions above.

Statement: Question 1

The present data set is not sufficient and accurate enough to develop appropriate and adequate plans of investigation. The SCP gives the impression that the geologic framework for volcanism and volcanic stratigraphy for the basalt volcanoes (<8 Ma) of the southern Great Basin is well known. In fact, much of the mapping that provides the basis for the SCP is reconnaisance when dealing with the Pliocene or younger basalts. Therefore, the detailed volcanic stratigraphy required to collect samples for geochemical, paleomagnetic and geochronologic studies is presently not available for most areas.

Bedrock geology adjacent to basalt fields (Lunar Crater, Reveille Range) is at the 15 degree quadrangle scale (1" to the mile). Therefore, the details of the bedrock geology required to determine the structural control of volcanism is also not available.

Before geochemical cycles can be established and the age framework determined, a considerable amount of detailed mapping must be accomplished. The older and slightly larger volume fields (larger volume than volcanoes at Crater Flat or Lathrop Wells) provide the key to the understanding of the younger volcanoes. These older fields must be mapped in detail.

Statement: Question 2

In general, the assumptions for each activity are defensible. One important exception is activity 8.3.1.8.1.1.4 (Probability calculations and assessment). The SCP relies heavily on probability calculations that suggest that the risk related to volcanic eruption or dike emplacement is low. A medium level of confidence is placed on these results. The probability calculations assume a Poissonian model. Application of this model is based on certain critical assumptions. If the assumptions are not valid, the numerical probability values have a low reliability or are invalid. We question the validity of the assumptions and suggest that the reliability of these numbers is low to very low. They should not be used to estimate risk until probability models are developed that rely on valid assumptions. See comment 15 in the Detailed Comments section for more details.

Statement: Question 3

In general, not enough information is provided in the SCP to determine whether the testing activities are correctly designed. A work plan should contain details concerning how each individual activity will be completed, where mapping or collecting will take place and who will complete a particular activity. This information is rarely presented in the SCP.

Also, the SCP does not clearly state how the various studies will be integrated. Volcanic and structural studies are closely related, but are apparently being done by two or more contractors. Integration is a key to successfully solving problems such as structural control, the nature of geochemical-cycles, and changes in volume and eruption rate with time. A detailed section on "result integration" must be included.

Statement: Question 4

Activities such as the "Characterization of Volcanic Features" and "Determination of the probability of a volcanic eruption penetrating the repository" are planned to be completed by 9/94 and 10/94 respectively. These deadlines are quite ambitious, since they do not appear to include the time required to develop a geologic framework for collecting samples or the time involved in mapping each young (Pleistocene and Pliocene) basalt volcano in detail. To complete these studies by the target dates is unreasonable. Also, we feel that the 10/90 target date for completion of a draft report on He-3 and U-Th dating is unrealistic, since neither of these techniques have been calibrated for young basalts.

The SCP does not provide estimates of the number of geologists who will be actively working in the field or the amount of man-hours alloted for each study, therefore it is difficult to determine whether the activities related to basaltic volcanism can be completed by the scheduled dates.

Activity-by-Activity Analysis

Activities in section 8.3.1.8.1 (Studies to provide information required on direct releases resulting from volcanic activity), 8.3.1.8.1.2 (Effects of volcanic eruptions penetrating the repository), 8.3.1.8.5.1 (Characterization of volcanic features) and section 8.3.1.17.1.1 (Potential for ash fall at the site) are rated in four catagories. The catagories are directly derived from the four questions listed above. The catagory statements are:

(1) The present data set is sufficient and accurate enough to develop appropriate and adequate plans of investigations.

(2) The activities underlying assumptions are defensible.

(3) The actual study of testing activities is correctly designed to obtain the desired information.

(4) The proposed activities are accomplishable within a reasonable time frame.

Each catagory is rated as high, medium or low. High suggests that there is a high probability that the catagory statement is true for the appropriate activity. Low suggests that there is a low probability that the catagory statement is true. Medium suggests an intermediate level of confidence. For more detailed comments regarding each activity, see the individual comments in the next section.

8.3.1.8.1.1.1 Activity: Location and timing of volcanic events
(1) Medium
(2) Medium
(3) Low
(4) Low
Comment: Detailed mapping of each volcano must be completed before an estimate of the number of vents can be determined.

8.3.1.8.1.1.2 Activity: Evaluation of the structural controls of basaltic volcanism.
(1) Low
(2) Low
(3) Low
(4) Low

Comment: Detailed mapping of areas surrounding each young basalt field are required to locate regional structures. Also detailed mapping must be completed for the older fields (<8 Ma).

8.3.1.8.1.1.3 Activity: Presence of magma bodies in the vicinity of the site.
(1) Low
(2) Medium
(3) Medium
(4) Low
Comment: The techniques have not been tested or calibrated in the Yucca Mountain area.

8.3.1.8.1.1.4 Activity: Probability calculations and assessment.
(1) Low
(2) Low
(3) Low
(4) Low
Comment: The basic assumptions that probability calculations rely on are not valid.

8.3.1.8.1.2.1 Activity: Effects of Strombolian eruptions.
(1) High
(2) Medium
(3) Medium
(4) High
Comment:

8.3.1.8.1.2.2 Activity: Effects of hydrovolcanic eruptions.
(1) High
(2) Medium
(3) Medium
(4) High
Comment:

8.3.1.8.2.1.1 Activity: Assessement of waste package rupture due to igneous intrusion.
(1) Low
(2) Low
(3) Low
(4) Low
Comment: This activity relies heavily on probability calculations.

8.3.1.8.5.1.1 Activity: Volcanic drillholes
(1) Low
(2) Medium
(3) Medium
(4) Medium
Comment: More than one hole may be required to determine volumes of buried volcanic centers.

8.3.1.8.5.1.2 Activity: Geochronology Studies
(1) Low
(2) Medium
(3) Medium
(4) Low
Comment: Sample collecting for geochronologic studies is not based on a detailed knowledge of the volcanic stratigraphy.

8.3.1.8.5.1.3 Activity: Field Studies
(1) Low
(2) High
(3) Low
(4) Low
Comment: Mapping of older basaltic centers (>6 Ma) is not in sufficent detail to unravel stratigraphy or to characterize volcanic centers.

8.3.1.8.5.1.4 Activity: Geochemistry of Scoria Sequences
(1) Medium
(2) High
(3) High
(4) Medium
Comment:

8.3.1.8.5.1.5 Activity: Geochemical Cycles of Basaltic Volcanic Fields
(1) Low
(2) Medium
(3) Medium
(4) Medium
Comment: Sample collecting for geochemical studies is not based on a detailed knowledge of the volcanic stratigraphy.

8.3.1.17.1.1.1 Activity: Survey literature regarding Quaternary silicic volcanic centers in the western Great Basin
(1) High
(2) Medium
(3) Medium
(4) High
Comment: Additional field studies are necessary to locate silicic centers within basalt fields.

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COMMENT NO.: 1 pg. 1 of 1 | CHAPTER NO.: 1

SEC. NO PAGE NO. DRWG. NO.	COMMENT
1.1.3.1.1 pg. 1-28	In the eastern Reveille Range basalt flows as young as 3.4 Ma were uplifted and geomorphically modified. Therefore, in the Reveille Range conditions of geomorphic stability did not begin until the Pliocene (not the Miocene as stated in the SCP) (Center for Volcanic and Tectonic Studies-University of Nevada, Las Vegas (UNLV), unpublished mapping).

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COMMENT NO.: 2 pg. 1 of 1 | CHAPTER NO.: 1

SEC. NO PAGE NO. DRWG. NO.	COMMENT
1.2.1.2.2 pg.1-49	Local felsic volcanism did occur in the southern Great Basin in the last 6 million years. A trachyte dome with associated flows and pyroclastic units formed at 4.7 Ma in the northern Reveille Range. This felsic unit is interbedded with flows of alkali basalt (Center for Volcanic and Tectonic Studies-UNLV, unpublished mapping). Also, the Muddy Creek Formation (conglomerate, sandstone) in the southern Great Basin (10 to 5 Ma) contains localized beds of rhyolite ash (Metcalf, 1982). It is important to determine the source of these ash horizons. REFERENCE: Metcalf, L.A., 1982, Tephrostratigraphy and potassium-argon age determinations of seven volcanic ash layers in the Muddy Creek Formation of southern Nevada: M.S. Thesis, University of Nevada, Reno, 187p.

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COMMENT NO.: 3 **pg.** 1 of 1 | **CHAPTER NO.:** 1

SEC. NO PAGE NO. DRWG. NO.	COMMENT
1.3.2.1.1 pg. 1-93 Fig. 1-28d.	The map does not show the alkali basalts of the Fortification Hill field in northwestern Arizona. These basalts are dated at 4.7 to 5.8 Ma (Feuerbach et al., in review). REFERENCE: Feuerbach, D.L., Smith, E.I., Damon, P.E., and Shafiqullah, M., in review, Changes in volcanism during and following the waning stages of extension in the Lake Mead area of southern Nevada: Submitted to Geological Society of America Bulletin.

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COMMENT NO.: 4 pg. 1 of 1	CHAPTER NO.: 1
SEC. NO PAGE NO. DRWG. NO.	COMMENT
1.3.2.1.1 pg. 1-95	It is important to determine whether Crater Flat is the site of a caldera. Detailed mapping (structures and stratigraphy) about Crater Flat is required to locate faults or other features that may be associated with a caldera.
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COMMENT NO.: 5 pg. 1 of 1	CHAPTER NO.: 1

SEC. NO PAGE NO. DRWG. NO.	COMMENT
1.3.2.1.2 pg. 1-96	The bedrock geology in the Pancake and Reveille Ranges is not known well enough to state that "younger basalts show no relation to the silicic volcanic centers." for example there is controversy as to whether a caldera exists in the Reveille Range. Studies of the younger basalts must be integrated with detailed studies of the Miocene and older basement rock to establish a structural framework for their emplacement.

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COMMENT NO.: 6 pg. 1 of 1

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
1.3.2.1.2 pg. 1-96	Even though individual Strombolian eruptions last for a short period of time, the development of a young basaltic center (cinder cone) may occur over a period as long as 100,000 years (Crowe et al., 1988). The formation of a cinder cone may be a long-duration event. REFERENCE: Crowe, B.M., F.V. Perry, B.D. Turrin, S.G. Wells, and L.D. MacFadden, 1988, Volcanic hazard assessment for storage of high-level radioactive waste at Yucca Mountain, Nevada: Geological Society of America Abstracts with Programs, v. 20, no. 3, p. 153.

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COMMENT NO.: 7 Pg. 1 of 1 | CHAPTER NO.: 1

SEC. NO PAGE NO. DRWG. NO.	COMMENT
1.3.2.1.2 pg. 1-96 Table 1-6	The tectonic settings for the volcanic fields listed in the table is often based on an incomplete knowledge of basement geology. Detailed mapping of areas adjacent to each field is critical to determining their tectonic setting.

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COMMENT NO.: 8 pg. 1 of 1 | CHAPTER NO.: 1

SEC. NO PAGE NO. DRWG. NO.	COMMENT
1.3.2.1.2 pg. 1-96	Even though faults and fractures may serve as conduits for magma at depth, near the surface (upper 2000 feet) dikes commonly cut across structures, and may intrude areas that have not been previously faulted (Feuerbach et al., in review). REFERENCE: Feuerbach, D.L., Smith, E.I., Damon, P.E., and Shafiqullah, M., in review, Changes in volcanism during and following the waning stages of extension in the Lake Mead area of southern Nevada: Submitted to Geological Society of America Bulletin.

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
1.3.2.1.2 pg. 1-99	Rates of volcanic activity during the last 8 Ma should be based on the number of vents per given area, not the number of cones. Cones (such as the Black Cone and Red Cone in Crater Flat) are composed of numerous vents (Center for Volcanic and Tectonic Studies-UNLV, unpublished mapping). In fact, at Black Cone, little or no lava erupted from the main cone. Most of the lava vented from scoria mounds (adventive cones) adjacent to Black Cone (Center for Volcanic and Tectonic Studies-UNLV, unpublished mapping).

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
1.3.2.2.1 pg. 1-107 Figure 1-33.	The Saddle Island detachment fault in the Lake Mead area of Nevada (Choukroune and Smith, 1985; Weber and Smith, 1987) should be added to this map. REFERENCES: Choukroune, Pierre, and Smith, E.I., 1985, Detachment faulting and its relationship to older structural events on Saddle Island, River Mountains, Clark County, Nevada: Geology, v. 13, p. 421-424. Weber, M.E., and Smith, E.I. 1987, Structural and geochemical constraints on the reassembly mid-Tertiary volcanoes in the Lake Mead area of southern Nevada: Geology, v. 15, p. 553-556.
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COMMENT NO.: 11 pg. 1 of 1 | CHAPTER NO.: 1

SEC. NO PAGE NO. DRWG. NO.	COMMENT
1.5.1.1.2 pg. 1-202	Silicic volcanism (trachyte dome, flows and pyroclastic rocks) occurred in the Reveille Range 4.7 million years ago (Center for Volcanic and Tectonic Studies-UNLV, unpublished mapping). Therefore the statement that "no silicic volcanism has occurred in south-central Great Basin during the past 6 million years" is incorrect.

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COMMENT NO.: 12 pg. 1 of 1	CHAPTER NO.: 1

SEC. NO PAGE NO. DRWG. NO.	COMMENT
1.5.1.2.1 pg. 1-202	Note that hydrovolcanic eruptions preceded the formation of the Lathrop Wells cone (Crowe et al., 1983). Therefore, it is possible that this type of activity may occur at the site of a future eruption. Thus, the statement "hydromagmatic volcanic explosions are considered unlikely" is too strong.

REFERENCE:

Crowe, B.M., Self, S., Vaniman, D., Amos, R., Perry, F., 1983, Aspects of potential magmatic disruption of a high-level radioactive waste repository in southern Nevada: Journal of Geology, v. 91, p. 259-276.

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COMMENT NO.: 13 pg. 1 of 1 | CHAPTER NO.: 1

SEC. NO PAGE NO. DRWG. NO.	COMMENT
1.5.1.2.1 pg. 1-203	Basalt centers in the southern Great Basin may be complex and polycyclic. Eruptions may last for as long as 100,000 years (Crowe et al., 1988). Therefore the formation of a cinder cone may a long-duration event. REFERENCE: Crowe, B.M., F.V. Perry, B.D. Turrin, S.G. Wells, and L.D. MacFadden, 1988, Volcanic hazard assessment for storage of high-level radioactive waste at Yucca Mountain, Nevada: Geological Society of America Abstracts with Programs, v. 20, no. 3, p. 153.

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CHAPTER NO.: 1

SEC. NO PAGE NO. DRWG. NO.	COMMENT
1.5.1.2.1 pg. 1-203	Geologic and geochemical patterns are not known well enough to make the statement "No geologic or geochemical patterns indicate that the rate of volcanism in the southern Great Basin are increasing, that such rates might increase in the future, or that basaltic activity could evolve into more voluminous types of basalt fields." Only three volcanic fields in the Death Valley-Pancake Range zone were studied, and these studies were reconnaissance in nature. The statement in the SCP is premature. Considerable detailed geologic work must be done on the young basalts and associated bedrock before the nature of future activity can be predicted.

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COMMENT NO.: 15 pg. 1 of 2 | CHAPTER NO.: 1

SEC. NO PAGE NO. DRWG. NO.	COMMENT
1.5.1.2.3 p.204-205	The geologic assumptions incorporated in the probability model for the disruption of the repository at Yucca Mountain by basaltic volcanism are questionable. Crowe et al. (1982) calculated the probability of volcanic disruption of a repository located at Yucca Mountain by using a Poisson probability model. Poisson processes are used to describe phenomena that occur over a period of time in a random fashion. The Poisson probability model assumes: (1) the events occur independently and randomly (2) the probability than an event occurs does not change with time (3) the probability that an event will occur in an interval is proportional to the length of the interval (4) the probability of more than one event occurring at the same time is vanishingly small. Assumptions 1,2 and 4 are not suitable for probability modelling for volcanism near Yucca Mountain. Volcanic eruptions in a single field may not be independent events (assumption 1). Separate volcanoes may be intimately related by having common magma sources, high level chambers, and vent systems. The assumption that volcanism must be random is questioned because volcanoes are commonly aligned along structures (e.g., Crater Flat). Vaniman and Crowe (1981) suggest that magma production in the southern Great Basin has declined in the past 4 million years. Therefore, assumption 2 is not applicable. Volcanic eruptions in Crater Flat may have occurred simultaneously at two or more separate vents. The similar dates of Black Cone and Red Cone (1.1 Ma) also suggest that simultaneous eruption is possible. Therefore, assumption 4 does not appear to be applicable. The accuracy of the probability calculations are limited by the validity of the assumptions incorporated into the models. Since, three of the four basic assumptions

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COMMENT NO.: 15 pg. 2 of 2 | CHAPTER NO.: 1

SEC. NO PAGE NO. DRWG. NO.	COMMENT
1.5.1.2.3 pg. 204-205	for the Poissonian model are not satisfied, the reliability of the probability estimates is low to very low. These values should not by used to estimate risk until probability models are improved.

REFERENCES:

Crowe, B.M., Johnson, M.E., and Beckman, 1982, Calculation of the probability of volcanic disruption of a high-level radioactive waste repository within southern Nevada, USA: Radioactive Waste Management and the Nuclear Fuel Cycle, v.3, no. 2, p. 167-190.

Vaniman, D. and Crowe, B.M., 1981, Geology and petrology of the basalts of Crater Flat: applications to volcanic risk assessment for the Nevada Nuclear Waste Storage Investigations: LA-8845-MS, Los Alamos National Laboratory, Los Alamos, NM, 67p.

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
1.5.1.2.3 pg. 204	Ratios of area are used to calculate disruption of the depository by volcanism. However, the repository has a 3-dimensional geometry, therefore a more intuitive way to measure the probability that a repository would be disrupted during a given eruptive event is the ratio of the <u>volume</u> of the repository to minimal <u>volume</u> that encloses all the volcanic deposits used to define the rate of volcanic events.

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COMMENT NO.: 17 pg. 1 of 1	CHAPTER NO.: 1

SEC. NO PAGE NO. DRWG. NO.	COMMENT
1.8.1.5.1 p. 337	Silicic volcanism (trachyte dome, flows and pyroclastic rocks) occurred in the Reveille Range 4.7 million years ago (Center for Volcanic and Tectonic Studies-UNLV, unpublished mapping). Therefore the statement that "no silicic volcanism has occurred in south-central Great Basin during the past 6 million years" is incorrect.

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COMMENT NO.: 18 pg. 1 of 1	CHAPTER NO.: 1

SEC. NO PAGE NO. DRWG. NO.	COMMENT
1.8.1.5.1 pg. 337	The reliability of probability values for volcanic disruption of the Yucca Mountain site is low to very low (see comment 15). These values should not by used to estimate risk until probability models are improved.

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
1.8.3.3.2 pg. 1-348	It is not clear how the various projects will be integrated. The success of the site characterization depends of successful integration of the numerous studies. The integration process should be described in detail.

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8 pg. 8.3.1.8-4 Table 8.3.1.8-1b	The confidence level of the annual probability of volcanic eruption is listed as moderate. However, because assumptions are questionable (see comment 15), the reliability of these probability values is low to very low. These values should not by used to estimate risk until probability models are improved.

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8 pg. 8.3.1.8.11 Table 8.3.1.8-3b	The confidence level of the annual probability of volcanic eruption is listed as moderate. However, because assumptions are questionable (see comment 15), the reliability of these probability values is low to very low. These values should not by used to estimate risk until probability models are improved.

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8 pg. 8.3.1.8-15 Table 8.3.1.8-4b	The confidence level of the annual probability of dike emplacement is listed as moderate. However, because assumptions are questionable (see comment 15), the reliability of these probability values is low to very low. These values should not by used to estimate risk until probability models are improved.

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8 pg. 8.3.1.8-18 Table 8.3.1.8-18	The confidence level of the annual probability of igneous intrusion is listed as moderate. However, because assumptions are questionable (see comment 15), the reliability of these probability values is low to very low. These values should not by used to estimate risk until probability models are improved.

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8 pg. 8.3.1.8-20 Table 8.3.1.8-6b	The confidence level of the annual probability of igneous intrusion is listed as moderate. However, because assumptions are questionable (see comment 15), the reliability of these probability values is low to very low. These values should not by used to estimate risk until probability models are improved.

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8 pg. 8.3.1.8-26	A Poissonian recurrence model for volcanic eruption and dike emplacement may not be valid, because rates and volumes of eruption change with time (see comment 15). A Poisson model assumes that the probability of the occurrence of an event does not change with time. The performance goal that volcanic eruption will remain unanticipated with a high level of confidence can not be attained without using a different probability model. Probability values indicated in the SCP that use the Poisson model should not by used to estimate risk.

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8 pg. 8.3.1.8-27	The assumptions in the second paragraph that describe the performance parameter goal for igneous intrusion are unclear.

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<table>
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<tr><td colspan="2">COMMENT NO.: 27 pg. 1 of 1</td><td>CHAPTER NO.: 8</td></tr>
<tr><td>SEC. NO
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<tr><td>8.3.1.8
pg. 8.3.1.8-36
Table 8.3.1.8-7</td><td colspan="2">There is an alternative hypothesis that should be considered for the model element "Type of Volcanism." The alternative model is:
(1) volcanism related to felsic dome emplacement. This type of activity includes initial explosive eruptions (surge, low-volume pyroclastic flows, and air-fall) followed by dome extrusion. Extrusion may be accompanied by explosive disruption of the dome and low-volume pyroclastic flows (Fisher and Schmincke, 1984).

This model should be considered because of the presence of a trachyte dome interbedded with alkali basalt (4.7 Ma) in the Reveille Range (Center for Volcanic and Tectonic Studies-UNLV, unpublished mapping).

REFERENCE:

Fisher, R.V., Schmincke, H-U., 1984, Pyroclastic Rocks: Springer-Verlag, New York, 472 p.</td></tr>
<tr><td colspan="2">REVIEWER: Dr. E. I. Smith
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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8 pg. 8.3.1.8-37 Table 8.3.1.8-8	Volcanic activity may be localized at or near sites of previous activity as well as along geologic structures. Therefore, the occurrence of volcanism is probably not randomly distributed in the domain, and a Poissonian probability model is not appropriate to estimate volcanic risk (see comment 15).

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8 pg. 8.3.1.8-44 Table 8.3.1.8-8	The current representation for the nature of volcanism does not consider that dikes may be long-lived features. Because, volcanic eruptions may be localized at or near the sites of previous activity, magma may use the same conduit systems over long periods of time. A dike may represent a batch of magma related to the last eruption at a center, but many other pulses of magma may have passed through the same conduit over a period of time.

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8 pg. 8.3.1.8-45 Table 8.3.1.8-8	When constructing alternative hypotheses for the distribution of volcanism, it is important to realize that lineaments and patterns that connect volcanic fields must have some physical significance. Integration of volcanic and detailed structural studies is critical to providing a structural framework for the localization of the young alkali basalts.

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8.1 pg. 8.3.1.8-49	The statement "Basaltic volcanism is considered to be the only credible type of activity to have a possibility of occurrence in the next 10,000 yr." is too strong. Volcanism related to felsic dome emplacement should also be considered as a possibility. This type of activity includes initial explosive eruptions (surge, low-volume pyroclastic flows, and air-fall) followed by dome extrusion. Extrusion may be accompanied by explosive disruption of the dome and low-volume pyroclastic flows (Fisher and Schmincke, 1984). This possibility should be considered because of the presence of a trachyte dome interbedded with alkali basalt (4.7 Ma) in the Reveille Range (Center for Volcanic and Tectonic Studies-UNLV, unpublished mapping). REFERENCE: Fisher, R.V., Schmincke, H-U., 1984, Pyroclastic Rocks: Springer-Verlag, New York, 472 p.

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8.1 pg. 8.3.1.8-49	The assumption that the occurrence of basaltic volcanism in the region is independent of time and location is not reasonable (see comment 15).

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8.1 pg. 8.3.1.8-49	The determination of structural control of volcanism requires detailed studies of bedrock adjacent to the volcanic centers as well as detailed regional studies. Volcanic and structural studies must be closely integrated. The procedures for this integration should be clearly described in the SCP.

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8.1 pg. 8.1.3.8-51	The term "Volcanic vent" should be defined. If a vent is defined as an individual volcano, then vent counts may not be a reliable way of estimating rates of future eruptions. A single volcano (e.g., Black Cone in Crater Flat) may be contain more than one vent (scoria mounds) (Center for Volcanic and Tectonic Studies-UNLV, unpublished mapping). Therefore, it is critical to count the total number of vents associated with each volcano rather than the number of volcanoes.

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8.1.1.2 pg. 8.3.1.8-52	It is not clear who will do the tectonic map of the Yucca Mountain region and how it will be integrated with the volcanic studies.
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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8.1.1.2 pg. 8.3.1.8-52-53	The young volcanic centers (<4 Ma) that will be mapped should be identified. Also the "other basaltic volcanic fields" (<8 Ma) that will be used to develop "petrologic cycles" should be listed.

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8.1.1.2 pg. 8.3.1.8-53	Petrologic cycles must be developed in areas where the volcanic stratigraphy is well known. This requires detailed geologic mapping of a volcanic field before collecting samples for geochemical analysis.

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8.1.1.2 8.3.1.8-54	Methods of integration of aeromagnetic and field structural data are not indicated. It is critical to obtain ground-truth for any geophysical survey. The aeromagnetic survey should be supplemented by a detailed field structural analysis.
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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8.1.1.3 pg. 8.3.1.8-56	Detachment faults are unlikely pathways for rising magma. The concept of detachment tapping proposed by Guth (unpublished manuscript) has not been substantiated by either field or geophysical studies (with the possible exception of a basalt cone in the southern part of Death Valley).

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8.1.1.3 pg. 8.3.1.8-56	Methods for calculation of magma generation rates for older basalt fields are not stated. Older fields are eroded, structurally disrupted or covered by younger units. Only minimum volumes could be calculated for these fields.
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8.3.1.8.1.1.4 pg. 8.3.1.8-58	See comment 15 regarding probability calculations, and comment 34 regarding the importance of making vent counts rather than cone counts.

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8.1.1.4 pg. 8.3.1.8-58	The southwest migration of volcanism mentioned in this section is based on poor quality K-Ar dates and only reconnaissance mapping. A considerable amount of additional dating and mapping is required to substantiate this observation.

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8.5.1 pg. 8.3.1.8-107	Chapter 1 does not provide sufficient detail to evaluate the statement that "Much of the work for this study [Characterization of Volcanic Features] has been completed..." Tasks required for this study must include detailed investigations of volcanic stratigraphy before samples are collected for other studies.

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8.5.1.1 pg. 8.3.1.8-110	Drill core data and aeromagnetic anomaly geometry may not provide enough information to accurately calculate volumes of buried volcanic centers. Volume calculations depend on an accurate knowledge of the three-dimensional geometry of the buried center. The technique of volume calculation should be clearly stated.

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8.5.1.2 pg. 8.3.1.8-112	Geochronological studies of the older basalts must be based on a firm geologic framework of geologic mapping. It is not stated whether this geologic framework exists or whether samples were collected with a knowledge of the detailed volcanic stratigraphy.

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8,3.1.8.5.1.2 pg. 8.3.1.8-112	The youngest silicic activity in the area appears to be in the Reveille Range (Trachyte dome) (Center for Volcanic and Tectonic Studies-UNLV, unpublished mapping). This feature should also be considered in the activity, "Geochronologic Studies."

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SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8.5.1.2 pg. 8.3.1.8-114	The methods of calibration of the techniques used to date the Lathrop Wells cone are not clearly stated.

REVIEWER: Dr. E. I. Smith
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Center for Volcanic and Tectonic Studies-Department of Geoscience
University of Nevada, Las Vegas

DATE: July 1, 1989

STATE OF NEVADA
AGENCY FOR NUCLEAR PROJECTS
NUCLEAR WASTE PROJECTS OFFICE
QUALITY ASSURANCE PROCEDURE

QAP-3.4
REVISION 0
JANUARY 20, 1989

NEVADA NUCLEAR WASTE PROJECT OFFICE
TECHNICAL REVIEW COMMENT FORM

DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 48 PG. 1 of 1	CHAPTER NO.: 8

SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8.5.1.3 pg. 8.3.1.8-116	Detailed mapping of the older volcanic centers (<6 Ma) is required to establish the detailed volcanic stratigraphy needed to collect samples for other studies (geochronology, paleomagnetic studies, geochemistry). Reconnaissance mapping is not adequate to establish the stratigraphic framework required to adequately interpret results from other studies.

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 49 pg. 1 of 1	CHAPTER NO.: 8

SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8.5.1.3 pg. 8.3.1.8-116	The section on "Parameters" should specify which volcanic centers will be mapped, and should indicate the scale of mapping.

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COMMENT NO.: 50 pg. 1 of 1

CHAPTER NO.: 8

SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.8.5.1.5 pg. 8.3.1.8-121	The technique used to calculate the rock norm should be indicated. Also the procedure for determining the Fe(3)-Fe(2) ratio should be stated clearly. The amounts and/or the occurrence of normative minerals like hypersthene and nepheline are especially sensitive to the Fe(3)-Fe(2) ratio.

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COMMENT NO.: 51 pg. 1 of 1	CHAPTER NO.: 8

SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.17.1 pg. 8.3.1.17-51	The possibility of silicic volcanism should be re-evaluated in light of the discovery of a trachyte dome and related pyroclastic rocks in the Reveille Range (see comment 2).

REVIEWER: Dr. E. I. Smith (Print) E. I. Smith (Signature)	ORGANIZATION: Center for Volcanic and Tectonic Studies-Department of Geoscience University of Nevada, Las Vegas DATE: July 1, 1989

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DOCUMENT TITLE: Site Characterization Plan

COMMENT NO.: 52 pg. 1 of 1 | CHAPTER NO.: 8

SEC. NO PAGE NO. DRWG. NO.	COMMENT
8.3.1.17.1.1.1 pg. 8.3.1.17-54	A literature survey regarding silicic volcanism assumes that previous work is in sufficient detail to provide the stratigraphic and geochronologic information required to locate potential sources of air-fall units at the Yucca Mountain site. This assumption is not valid, because most mapping of volcanic centers in the vicinity of the site was not completed in sufficient detail to provide the required information.

REVIEWER: Dr. E. I. Smith
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University of Nevada, Las Vegas

DATE: July 1, 1989

COMMENTS OF

WATER RESOURCES CENTER

DESERT RESEARCH INSTITUTE

REVIEW COMMENTS ON HYDROLOGIC SECTIONS

SITE CHARACTERIZATION PLAN

(December 1988)

YUCCA MOUNTAIN SITE,
NEVADA RESEARCH & DEVELOPMENT AREA, NEVADA

By

Water Resources Center

Desert Research Institute

University of Nevada System

June 1989

CONTENTS

INTRODUCTION

The Yucca Mountain site has been preliminarily studied and is considered by DOE to have the potential of being a technically sound location for the long-term isolation of high-level nuclear waste. There are a number of potential, favorable hydrogeologic features associated with Yucca Mountain such as the following:

1) A relatively thick unsaturated zone;
2) Low precipitation and high potential evaporation;
3) The presence of zeolitic clays;
4) Long ground-water travel paths to discharge areas; and
5) Limited ground-water development.

Most of these features have been measured and quantified with a fair degree of accuracy.

However, there are a number of hydrogeologic features which have not been adequately quantified. One of the main reasons for this lack of quantification is the extreme complexity of the hydrologic system. Ironically, some of this complexity is due, in part, to hydrogeologic features listed above. The thick unsaturated zone makes it extremely difficult to collect hydrologic data with which to quantify the unsaturated and saturated zones. The low precipitation rate makes it difficult to quantify the recharge flux.

The SCP has identified a number of key issues that need to be addressed for characterization of the Yucca Mountain site. A variety of complex experiments have been proposed in an attempt to address these issues. Although considerable time, money, and effort has been spent on characterizing the Yucca Mountain area to date, there are still many unresolved technical issues.

Since many of the experiments proposed in the SCP have never been done in an unsaturated fractured medium, it is impossible to tell if they will be successful. Results of these experiments may indicate that new test designs or data collection procedures are needed to address the issues.

Our approach to reviewing the SCP has been to first identify key technical issues which have not be resolved and to make specific comments associated with the hydrologic experiments proposed.

The SCP does not provide enough detail on these experiments with which to evaluate the technical aspects of their design, data collection, and analyses procedures. A detailed evaluation of the experiments will be needed when the Work Plans are released.

Specific comments have been made on virtually all studies and activities we believe to be relevant from a hydrologic standpoint. For the most part, comments have been made on the general concepts and the design of experiments when adequate information was presented. In some cases, additional data collection or design changes have been proposed.

KEY TECHNICAL ISSUES

There are a number of key technical issues which have not been adequately addressed for the Yucca Mountain site, partly because of the difficulty involved in measuring the parameters needed to quantify the process. Theoretical and practical techniques with which to quantify flow and transport in an unsaturated fractured medium are only now being developed. The following key technical issues need to be resolved before travel times and concentration to the accessible environment can be evaluated:

1) Mechanisms and rates of water flow in the unsaturated zone;
2) Rates and locations of recharge at Yucca Mountain;
3) Rates of flow in the saturated zone;
4) The validity of models to be used in calculating repository performance; and
5) The geochemical environmental.

These key technical issues are further elaborated on in more detail in the following section.

CONCEPTUAL MODEL FOR UNSATURATED FLOW

The current conceptual model for unsaturated flow developed by the U.S. Geological Survey (Montazer and Wilson, 1985) assumes that no significant flux of moisture occurs within fractures. All moisture that enters a fracture is quickly sucked into the matrix due to the hypothesized high tensions in the matrix.

This conceptual model has never been tested in field or laboratory experiments. Tensions have not adequately been measured in fractures and matrix materials. There is only one unsaturated borehole near Yucca Mountain (USW UZ-1) in which an attempt has been made to measure tensions. Tension measurements in this borehole are continuing to decline as the borehole equilibrates to the natural conditions. Therefore, it is still questionable, based on this limited data, whether the proposed conceptual model is valid.

Only a limited number of measurements of moisture and even fewer of tension have been made to date in the tuffs. The reliability of these limited data is open to question. Even when no water is used, drilling may affect the moisture characteristics of rock through heating and contact with air at a different humidity than the pore air. There is, for example, a large apparent discrepancy between tension and moisture content measurements in the Topopah Springs Member in well H-1, which was drilled with mist, and in well UZ-1, which was dry-drilled. With the observed air movement occurring in the mountain, it may also be difficult to obtain reliable measurements in the shaft. There is concern that no reliable determination is yet possible of the extent to which samples have been disturbed by drilling. This concern is particularly serious for tension measurements, because the addition or subtraction of a small amount of water in the most permeable pores or fractures could greatly change tensions while having very little effect on the total water content of a sample. The plan to observe moisture potential over long periods in packed-off intervals has promise for overcoming these difficulties, but its success is not certain and will require careful verification.

Other features which have not been addressed concerning this conceptual model are the potential effects of fracture coatings and entrapped air. Fracture coatings and entrapped air can effectively isolate the fracture from the matrix resulting in significant fracture flow. Fracture mapping in the exploratory shaft will help to define the extent of fracture coatings. The potential impacts of entrapped air limiting imbibition into the matrix need to be evaluated experimentally. There are no experiments currently planned to address the problem of entrapped air.

The anisotropy of both fracture and matrix material needs to be addressed. At present no one has attempted to define anisotropy in three dimensions. Flow directions and paths can be significantly influenced by the anisotropy of the fractures and matrix materials. It is not clear in the SCP how the anisotropy of the system will be determined.

Another key parameter that needs to be addressed is the effective porosity of the fractures and matrix. The effective porosity in the unsaturated zone is a function of the moisture content and will have to be defined for both gas and water. A few of the planned activities indicate that this issue will be addressed; however, there are some serious concerns about how successful this testing will be.

There is a need to define the preferred flow paths in the unsaturated zone. At present, the conceptual model predicts the flow paths to be within matrix material, which has not been experimentally demonstrated. In addition, there is a need to evaluate the potential impacts of faults on flow paths. Tests are planned for both the Solitario and the Ghost Dance Faults. The ultimate success of these experiments is unknown, since not enough details are provided for the experiments. The SCP does not present a specific test plan for Ghost Dance Fault.

The potential impacts that the natural flow of air through Yucca Mountain will have on experiments planned for the exploratory shaft will have to be evaluated. Tests are planned to quantify the potential impacts air flow has had on drying the rock surrounding USW UZ-6 and USW UZ-6s boreholes. These tests should be evaluated prior to shaft excavation, in order that the drying effect can be minimized and accounted for in the exploratory shaft.

The spatial variability of hydrologic properties has not been adequately addressed. Spatial variability needs to be addressed in order to accurately assess the potential recharge flux through the repository. The planned installation and testing of additional unsaturated boreholes will help to quantify the degree of spatial variability; however, it cannot be determined at this time whether the number of boreholes and tests planned will be sufficient.

The presence or absence of perched water needs to be evaluated for Yucca Mountain. The only tests planned to look for perched water are in the exploratory shaft and the two mutli-purpose boreholes. The first will consist of a visual inspection of the rocks after each mining shift. A careful evaluation of neutron hole logs can be used to help identify perched water, but because water saturation in the tuffs is high, very sensitive logging is required.

The potential success of the tests planned for the unsaturated zone is still unknown. Numerical models have been proposed to help in the design and analysis of tests planned for the unsaturated zone. However, many of the numerical models have not been identified or developed yet. Therefore, there is a serious concern that the data from the tests can be analyzed.

The conceptual model for the ground-water flow system underlying Yucca Mountain is discussed in Section 3.9.3. On p. 3-208 of that section, the following is stated:

> "...hydrologic data from the unsaturated zone at Yucca Mountain are to be obtained directly only from the exploratory shaft test facility and from a relatively small number of surface-based boreholes. Consequently, it will be necessary to rely on indirect methods, such as numerical flow and solute-transport modeling and geostatistical techniques, to infer the state of the presently existing natural hydrologic system by interpolating within and extrapolating from a somewhat incomplete set of field data."

Yet, later on p. 3-212, a somewhat contradictory statement is made:

> "One of the major tasks to be accomplished through the data-acquisition program at the site...is to collect sufficiently large sample sets to delimit the uncertainties associated with the quantitative predictions of the numerical models."

There are two issues that derive from the above statements: (1) will sufficient and representative data be collected to validate the conceptual model of ground-water flow within Yucca Mountain; and (2) will the models be appropriate and sufficient to analyze and interpret the data?

It is difficult to answer both questions, given the information in the SCP. The latter question concerning models applies to both models for site-scale conceptualization, as well as models used to interpret various tests (e.g., pressure or tracer tests). The models discussed in Section 3.9.3.4 (Unsaturated-zone relationships) were simplified and did not consider all of the processes that are occurring at Yucca Mountain. The models discussed in Section 8.3.1.2.2.9 (Site unsaturated-zone modeling and synthesis) are all TBD (to be determined). Therefore, how the data will be interpreted and what models will be used to test conceptualizations of Yucca Mountain are issues that are not clarified in the SCP.

RECHARGE ESTIMATES

One of the key technical issues that has not been adequately addressed is the estimation of past, present, and future recharge flux for the Yucca Mountain site. A number of investigators have developed empirical formulas and estimates of recharge and have been referenced in the SCP; however, no hard data have been collected to date to substantiate these estimates. The recharge flux for Yucca Mountain has been estimated by various investigators to range from 0.2 to 10 mm/yr (SCP, p. 3-201 to 3-205). This relatively large range of present day recharge estimates can significantly impact the performance of the repository and resultant travel time to the accessible environment. Current conceptual models proposed for Yucca Mountain assume that significant fracture flow will not occur (Montazer and Wilson, 1985). This is based, in part, on the assumption that the recharge flux for the site is less than 0.5 mm/yr and that tensions in the rock matrix are large. A preliminary analysis of travel times to the accessible environment by Sinnock and others (1987) indicates that significant fracture flow can occur if the recharge flux exceeds the saturated hydraulic conductivity of the rock matrix times the hydraulic gradient. Recharge fluxes larger than 1 mm/yr can result in significant fracture flow. Therefore, the potential exists with the current range of recharge fluxes (0.2 to 10 mm/yr) for much higher travel times through fractures than have previously been calculated based on matrix flow. Depending on the actual recharge flux rate, the 1,000 yr travel-time requirement may not be met for this site. Therefore, a refinement of the recharge estimates are needed in order to more accurately evaluate the Yucca Mountain site.

The conceptual models presented by the DOE have been evolving away from steady uniform infiltration toward areal inhomogeneity and intermittence of recharge. Now it appears (p. 3-195) that "steady-state moisture flow is presumed to be established in all but a thin, near-surface interval of the unsaturated zone". It has not been established whether the system is in a steady state. Transient behavior might be due to major recharge events occurring as infrequently as once every 100 or 500 years. The few interpretations to date of tension vs. depth profiles have been based on steady-state concepts. If transient phenomena must be considered, interpretation of such profiles is more complex and very different conclusions may be reached.

It is generally agreed that estimation of past recharge rates from paleoclimate reconstructions remains a problem. The water-balance modeling approach does not provide a credible way of making such estimates in the absence of directly applicable data. Measurement of present-day recharge in the areas with climate and vegetation similar to past conditions at Yucca Mountain would be more convincing.

Plans to model ground-water regimes under paleoclimatic conditions have focused on the question of whether the repository will flood. This certainly may be important with respect to waste package performance. However, a water table rise that comes no where near the repository could still adversely affect repository performance. In particular, if the water table below the repository were to rise into the densely welded Topopah Springs zone, a lateral pathway could be created for more rapid transport of radionuclides to the accessible environment. It appears likely that most of the ground water at Yucca Mountain represents underflow from recharge areas further north. Consequently, the position of the water table may depend more on recharge conditions to the north than on the amount of local recharge. If direct evidence cannot exclude a water table rise large enough to be of concern, then modeling studies would be needed to estimate pluvial water tables. These studies would require estimates of pluvial recharge in the recharge areas at Timber Mountain and further north.

Flow of perched water to local discharge areas might also drastically shorten migration path lengths. There is some evidence of ancient springs on Yucca Mountain. More attention to perched water is needed in the paleohydrology program.

SATURATED FLOW SYSTEM

Several important, unresolved issues that pertain to the saturated zone near Yucca Mountain exist:

1. Rates of flow in the saturated zone can be estimated several different ways. One approach is to estimate an average hydraulic conductivity, an average hydraulic gradient, and an average effective porosity, and calculate a velocity using Darcy's Law. The drawback to this approach is that the hydraulic conductivity varies greatly. Therefore, many measurements are needed before a reliable average can be calculated. Because most of the water will travel along the most permeable pathways, the average flow velocity will be faster than calculated using this approach. A second approach is to use computer models to calculate average flow rates. In the models that have been developed in the past, the boundary conditions (which of necessity have been estimated) drive the model. Aquifer parameters are backed out of the model as the model is calibrated. The values of the aquifer parameters should be reasonable, reliable estimates, but are directly influenced by the boundary fluxes (recharge and discharge) used during development of the model. Unfortunately, recharge measurements are difficult to make, except perhaps in eastern Jackass Flats. The recharge estimates used in the models are based on empirical procedures that do not consider many of the factors that affect recharge, and on estimates or measurements of discharge. In the Amargosa Desert, discharge is primarily by evaporation and transpiration rather than from springs and, therefore, the discharge estimates need to be significantly refined.

The repository block is generally bound by known and suspected faults or fracture zones. The relationship between faults and the observed discontinuities in hydraulic head is not known. It may be possible that on a repository-to-accessible-environment scale the effect of fractures on ground-water flow can be evaluated by applying "bulk properties" to the medium (which means that at a certain scale the medium will respond like a porous medium). But the distribution of head data suggests that at least some of the faults are affecting the flow field by acting as independent hydraulic features whose properties cannot be averaged out in a larger-scale conceptual model. The testing program should determine the hydraulic characteristics of all faults near the repository block. In order to adequately assess ground-water flow from the repository to the accessible environment, a testing program by which the hydraulic character and importance of these faults can be determined is necessary. Such a testing program needs to include sufficient measurements to delineate three-dimensional variations in hydraulic properties and/or parameters.

The areal pattern of hydraulic head measurements suggests the existence of narrow ground-water barriers across which large potential gradients occur, combined with larger regions of very small gradients. However, the complex pattern of vertical gradients indicates that a two-dimensional, plan-view conceptual model would not fully explain the flow system. In particular, variations from point to point in the location of the water table within each of the zones listed above probably depend on relationships with deeper aquifers as well as on horizontal flow. Consequently, additional water-table holes, by themselves, will add little to the understanding of the flow system. A better understanding of the flow regime will be aided only by more three-dimensional potentiometric information. Such information, along with additional chemical and heat-flow data, is essential to calibrate a model.

Closely associated with the problem of areal variation is the issue of scale dependence and definition of a representative elementary volume (REV). Any geologic medium is extremely variable on a very small scale; hydrogeologists define an REV as a volume over which small-scale random variation can be averaged. Ground-water systems are understood in terms of bulk properties, averaged over an REV, and large-scale variations which can be observed directly and treated as known trends or discrete features. The difficulty in a fracture-dominated environment like Yucca Mountain is finding a scale at which to define an REV so that bulk properties can be measured and used to interpret the flow system. One or two experiments with 300-ft spacings may not be adequate to establish an REV.

2. Controls on water levels near Yucca Mountain are not well known. North and west of the proposed repository, hydraulic gradients are uncharacteristically high. Beneath and east of the proposed repository, the gradient is very low. The causes of the high gradient are not known.

The new water-table wells have helped to clarify the potentiometric surface (and perhaps probable flow paths) within and surrounding the repository block. Preliminary analysis of new head data indicates that if wells penetrating beneath the Tuffs of Lithic Ridge are excluded, then the potentiometric levels fall into three closely grouped categories: (a) The two wells north of Drillhole Wash have heads of 1,020 m and 1,029 m, (b) Wells in Crater Flat and some wells on the crest of Yucca Mountain have heads between 769 m and 780 m, and (c) The remaining wells, within most of the repository block and to the east and south, have heads between 724 m and 732 m. The deeper wells H-1, P-1, and (perhaps) G-1, all located in area (c), show heads in the "older tuffs" and Paleozoic carbonates to be 20 to 50 m higher in the younger tuffs.

3. Almost all the measurements of head made in the deeper parts of the saturated zone (below the upper 200 feet) are either short-term measurements made in packed-off intervals, or are long-term measurements made over long intervals of open hole. Therefore, the hydraulic head in low-permeability parts of the boreholes (where a long period of time is required for water levels to equilibrate) is not known. Most of the measurements made in packed-off intervals were made in conjunction with hydrologic testing shortly after the well was drilled. The drilling subjected the rock to higher water pressures than to which it was naturally subjected, which would tend to increase the pore pressure in the rock. However, pumping tests were generally performed after the hole was drilled but before the packer tests were performed. Therefore, the water levels measured during the packer tests could be either higher or lower than would occur naturally, especially in the lower permeability rocks; therefore, true vertical gradients are not well known.

4. The hydrologic testing that has been performed clearly demonstrates the importance of fractures in the transmission of water in the saturated zone. Mapping of fracture orientations both on the surface and in drillholes indicates that there is a greater number of fractures with an approximate north-south orientation than with other orientations. The vast majority of the faults also strike approximately north-south. Therefore, the rock is not isotropic with respect to permeability. This fact has not been considered in the modeling that has been performed to date, or in estimations of flow directions. No aquifer tests have been analyzed to determine the effects of the fracturing on anisotropy, and few have been performed. The effect of the anisotropy will be to make the dominant flow direction much more to the south than has been previously assumed.

Permeable zones in different boreholes occur at different stratigraphic locations. These zones have not been successfully correlated areally. The degree of correlation between permeable zones can yield useful inferences about the nature and degree of large-scale permeability of the rocks; such interferences are of particular value when, as in this case, little information on the extent of and the hydraulic connection between permeable zones is available.

5. Another factor that might affect direction of flow is the presence of the tuffaceous beds of Calico Hills between the repository area and Fortymile Wash. Because of its zeolitized nature, the Calico Hills beds have been assumed to have a low permeability. Its permeability has only been tested in situ at UE-25b#1, where it was fairly permeable. However, it may be cut by faults in that drill hole. At the C-hole complex, the Calico Hills beds were not very permeable, and tests were not performed because water did not flow from the unit. If the Calico Hills unit is generally of low permeability, then it would tend to hinder the movement of water from Yucca Mountain toward the Fortymile Wash area or from Fortymile Wash toward Yucca Mountain.

6. The effective porosity is an important parameter in the calculation of flow velocities. This parameter is also difficult to measure and, to date, has not been. Estimates can be made based on the number of fractures contained in a certain volume of rock and their estimated apertures. Fracture network models of flow in fractures indicate that the details of the network are important in determining flow velocities, and that calculating flow estimates ignoring the network can be misleading. At present, there are no firm plans to measure the effective porosity except at the C-hole complex, the location of which was to be near a minor fault, and which may not be characteristic of either the majority of the saturated zone, or of rock near the larger faults.

The overall modeling strategy appears to be one of first modeling the regional flow and then modeling the subregional flow system as a segment of the regional system. This, in turn, would lead to modeling the repository block and environs to assess a repository's isolation capability. Insufficient data are available concerning Timber Mountain, northern Yucca Mountain, northern Crater Flat, and the boundary region between Crater Flat and the Amargosa Desert. Further refinement of the model seems unlikely to be useful without a large amount of new data from test wells throughout the extent of the subregional model area.

The regional model alone, for which transmissivities and fluid potentials are generalized, usually from sparse data, may not provide a sound basis on which to establish boundary conditions for the subregional or repository flow models. The boundaries of the current subregional model are mostly in areas for which little or no hydrogeologic data has been collected and in which the zonation of the regional model ignores geologic complexities. Although current data are insufficient to calibrate a three-dimensional flow model, existing data do indicate a three-dimensional nature to the flow system. Therefore, we believe a three-dimensional model is necessary and activities should be implemented to obtain adequate vertical gradient data to model the three-dimensional nature of the system.

AQUIFER TESTS

Numerous aquifer tests were performed in the past in the saturated zone. With few exceptions, these have been analyzed using a porous media approach assuming homogeneity, isotropy, and radial flow. The data do not agree well with these assumptions. First, it is well known that the fractures control movement of water into and out of the boreholes. These fractures are steeply dipping, so that the radial flow assumptions may be inappropriate. Second, high flow rates in the fractures close to the well bore may result in non-Darcian flow, and errors may also result from ignoring the kinetic term in the calculation of hydraulic head. Third, because the fractures are steeply dipping, leakage around packers during the injection tests is more likely to occur than in layered, sedimentary rocks. If leakage occurs, then the well bores above and below the test interval may behave as constant-head boundaries, a condition not considered in the mathematical models used to interpret the test results. Fourth, the high pressures used in the injection testing may have increased fracture apertures, changing the hydraulic properties during the test.

Careful analysis of the testing results has not been performed. Even though poor matches to type curves have consistently been observed, there has been little effort to determine the causes, or to find other approaches to correctly interpret the data. The published interpretations of the tests should be viewed with skepticism.

An exception to the statement in the previous paragraph is the interpretive work performed at the C-hole complex. Research has been performed in the past, and additional work is planned to understand the characteristics of the fractured tuffs and correctly interpret the test results. When this work has successfully developed approaches to interpreting the testing data, these approaches should be used to re-interpret the testing data collected at other sites around Yucca Mountain. Until the re-interpretation is performed, the published results should be used as indicators, but not measures, of hydraulic properties.

GEOCHEMISTRY

Insufficient effort has been spent on interpreting the chemical analyses and integrating them with flow analyses. The recent water analyses have been very extensive - including a large number of trace elements and isotopes in addition to major element chemistry. Yet there appears to be no comprehensive synthesis of the information already available on ground-water chemistry. Further, the chemical analyses are reported virtually independently of the hydrologic and geologic information. Synthesis of all such data is necessary to make the greatest use of hydrochemical information. Just as rock properties are now being evaluated in their stratigraphic and structural framework, ground-water geochemistry must be considered in light of the geologic, lithologic, and hydrologic setting.

Most of the samples are simply pumped from wells and are considered to be composite samples. However, the water sampled is probably from the most permeable zone nearest the pump intake so they are not really composite samples from all the strata that the well penetrates. Even when samples are taken from intervals, often these intervals are very large (for example, a 1,142 m interval in USW H-1). But even more problematic, it is still not clear how these intervals are related to hydrology or lithology. One of the most difficult and necessary tasks is to truly sample water from different tuff strata. Ideally, each individual stratum that may ultimately be part of the repository or part of the flow path should be sampled. Presently, there is no indication that waters from low permeability zones in the tuff have been sampled. This identification of individual water chemistries is necessary if they are to be subsequently used in hydrologic modeling of flow paths, mixing, etc. The possibility exists that the major element chemistry of individual waters may not be significantly different from each other. Trace element or isotopic signatures may still be useful in hydrologic modeling. Current information is inadequate to address the question of the distinction of individual water chemistries.

Some samples have been taken from different depths in water standing in the well bore by lowering remotely-opened bottles. These samples will not be any more specifically tied to the geologic setting than the composite samples will be. Further, standing water is much less representative of formation water than those samples obtained at the conclusion of pumping tests or from production wells. Chemical and biological reactions are likely to occur in the standing water which would alter its chemical characteristics. In laboratory studies on geochemical retardation, LANL (1982) has been using an "average" J-13 sample as a reference standard water. In experiments contacting this J-13 water for three weeks at ambient temperature with individual tuff samples, the resultant water chemistry was observed to change. Most elements changed somewhat compared to the starting composition. In contact with tuff from the J-13 well, the Mg content of the water decreased noticeably. With tuffs from another hole (USW G-1), the solution had especially increased Na and decreased Mg and Ca concentrations.

These results should be considered in light of the hydrochemistry of individual tuff layers. It may be that the J-13 composition chosen does not represent formation water of any one of the tuffs chosen for reaction. Then the subsequent chemical reactions are to be expected. However, it is possible that the water is not in chemical equilibrium with its host tuff. This condition would make reaction path modeling extremely complex. Simple mixing or mass balance models (for example, BALANCE) could not be readily used for help with hydrologic modeling. Temporal chemical variability of water from one tuff unit does not necessarily imply that kinetically-controlled reactions dominate water chemistry; it may, in fact, reflect flow-path conditions.

COMMENTS

The Site Characterization Plan for Yucca Mountain is an extensive document providing a glimpse of investigations planned at Yucca Mountain. The hydrologic parts of the SCP were reviewed, and both general and specific comments are provided.

GENERAL COMMENTS

1. Insufficient information is provided to allow appropriate comments to be developed on many activities. Many of the tests are experimental, and may or may not be successful. Both test procedures and interpretive methods have yet to be developed.

2. The studies proposed for unsaturated zone characterization may be inadequate. It appears that insufficient effort is to be spent developing an adequate understanding of flow and transport properties in the fractured tuffs. The movement of waters in the fractures will largely be determined by the amount of water available, and the rate at which water will move from the fractures into the matrix. Too little effort is being directed toward this last question. Proper understanding of this process is critical for predicting travel time through the unsaturated zone.

3. There is a very strong reliance on the use of unvalidated models for the design of experiments in the exploratory shaft and the interpretation of the resulting data. The assumptions of these models should be thoroughly investigated.

4. The construction of the exploratory shaft and test facilities will alter the hydrologic environment, by drying the rock, unless the humidity of the ventilation air is carefully controlled. The drying process will bias the results of the experiments toward meeting the regulatory criteria for acceptance of the repository and may invalidate the characterization process.

5. Collection of water samples and characterization of water encountered in fractures in the unsaturated zone should receive high priority. This is a critical point. Adequate characterization will probably require temporary cessation of mining and other activities. These delays should be planned for, and technical personnel need to have the authority to immediately stop other activities in the instance water is encountered.

6. There is too great a reliance on previous studies of the saturated zone. The models used for analysis of the hydrologic tests are not appropriate for use in interpreting most of the testing; there is poor agreement between the type curves and the data. These tests should be re-evaluated in view of knowledge to be gained from the C-hole complex.

7. The SCP shows little directly related to assessing the recharge potential of the many ephemeral streams which drain to the east off of Yucca Mountain (other than Fortymile and Pagany Washes). It is our opinion that these areas have significant potential to

produce localized pulses of recharge into the subsurface. Such phenomena suggest that local fracture flow may dominate in these areas which must be addressed in the travel time and radionuclide migration analysis. The SCP indicates only extended studies of Fortymile Wash will be conducted. Although this feature is important to the overall ground-water hydrology of the site, it will not influence the recharge rate estimates through the entire repository environment.

Our recommendation is that detailed studies be conducted in several additional wash environments on Yucca Mountain to quantify this important recharge component.

8. The process of dispersion in partially-saturated, fractured tuff has not yet been addressed in the scientific literature beyond the theoretical phase. The dispersion process, while reducing the maximum concentration will also decrease the time of first arrival at the accessible environment.

The impacts of dispersion will therefore reduce the travel time when compared with the bulk ground-water travel-time expressions suggested by the NRC. Studies should be conducted to study the dispersion process in the unsaturated fractured tuffs of Yucca Mountain to determine if theoretical studies completed to date agree with field results. Additional work will also be needed in code development of model transport in both saturated and partially-saturated, fractured tuff.

9. At this time, the study of water and solute movement in fractured rock is in its infancy and it therefore does not appear scientifically valid to choose one media approximation over another until further studies have been completed. An EPM approach may be valid for bulk fluid transport, however, discrete fracture models may be necessary to handle the transport processes of radionuclides. This discrete approach is being taken by many other countries (Canada, Switzerland, etc.) and there is no data to suggest that Yucca Mountain will behave in an equivalent porous-media manner.

10. There appears to be little attention paid to the SCP to the study of fracture/matrix interactions, specifically, studies aimed at understanding the hydraulic properties at the fracture/matric interface. There appears to be a feeling within the SCP that fluid will move into the matrices in response to capillary gradients and governed by matrix permeability. Yet we know from other field sites and core data that many of the fractures are lined with chemical precipitates or may have radically differing properties than the interstices of the matrix blocks. It is quite reasonable to assume that these fracture skins will significantly retard the uptake of fluid from the fractures into the matrices. Such behavior will tend to channelize fluid flow and will significantly alter any travel-time calculations.

11. The use of traditional soil-physics mass balance equations (Richard's equation) for high-tension fractured tuff simulation appears tenuous at this time due to lack of validation. The conceptual model inherent in Richard's equation has only been validated in the true

sense of the term by 50 years of soil physics for shallow-soil studies in humid areas. It has not been applied, however, to the scenarios of Yucca Mountain tuff, nor was it ever intended to be used for such conditions. As a result, the inherent assumption that the Richard's conceptual model of flow can be applied is invalid. Data must be collected to show that all of the processes of fluids moving in fractured rocks are inherent within Richard's model before it can be used indiscriminately.

Several factors, such as wetting front instability, potential non-wetting or hydrophobic surfaces, and vapor transport, are likely to be occurring at Yucca Mountain, however, Richard's equation does not have such processes as its basis. It is clear that much more basic research is needed in the study of partially-saturated fluid flow in fractured rocks before we can apply our traditional models.

12. The SCP states that the model-calibration phase will use either tension or water content as the calibration criteria. There is no problem with the use of tension (other than the data are hard to come by), however, the calibration by water content (or saturation) is erroneous due to the hysterisis problem. At this time, no data has been presented on the hysteritic behavior of the tuff-retention characteristics. Based upon traditional soil-physics data, we would expect to see significant hysterisis in the tuff. Such hysterisis leads to multi-valued water content and therefore multi-valued permeability data. Such behavior will significantly alter travel-time estimates.

13. The SCP (as well as the NRC) places emphasis on the disturbed zone as that zone where intrinsic permeability and effective porosity are altered. For an unsaturated-zone repository such factors are not relevant. Disturbed-zone criteria should be based upon alteration of the relative permeability curves (analogous to intrinsic permeability) and water retention (analogous to effective porosity). These data will control fluid, air, and radionuclide transport near the repository and will provide a much more coherent picture of the affects of disturbance.

The SCP also states that fluid flow and, therefore, performance will be within the matrix within the disturbed zone. There is no data to suggest that the non-isothermal conditions near the repository will lead to only matrix flow. On the contrary, we expect (but do not know) that fluid flow will be locally fracture-controlled due to the non-isothermal conditions. Until data is collected, it is imperative that both fracture and matrix flow be considered within the disturbed zone.

The fact that the SCP calls for ignorance of this condition appears to be a serious flaw in the planned analysis.

14. The entire time frame scheduled for completion, integration, and analysis of the myriad of tests planned is overly optimistic. It is our impression that the five- to seven-year period will perhaps be adequate to actually carry out many of the tests as described, provided

there are no major disruptions. However, the amount of time required to properly analyze these data and to then integrate them into "models" of the system which can be used for performance evaluation may be well beyond that allocated in the plan. One aspect of this concern which is not apparently addressed in the SCP is how DOE plans to resolve conflicting data or interpretations of physical processes from the different lines of inquiry.

Most of the rather ambitious modeling exercises assume that these various tests and experiments will all support one concept of flow.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.2.1.3 pgs. 8.3.1.2-174	Subject: Double ring infiltrometry measurements and ponding tests. Specific Information: "Ponding tests that measure infiltration rates over approximately the upper 15 ft of unconsolidated surficial materials will be conducted at the same locations as double-ring infiltrometry measurements." Discussion: The use of these methods to establish maximum infiltration rates in surficial materials is appropriate, as long as air entrapment is accounted for; however, these tests will not address infiltration in areas with limited surficial material. Precipitation directly on fractured rocks can result in rapid infiltration. Another objective of the ponding tests is to ascertain the relative importance of fracture versus matrix flow. The use of neutron access holes to track moisture fronts in the fractured bedrock will be doubtful for reasons discussed previously (Chapter 8.3.1.2.2.1.2). Hence, the potential for successfully tracking moisture fronts through the fractured bedrock is doubtful. A dye will be added to the ponded water, such that preferential flow paths can be visually identified at the completion of the study. The mining of the fractures rock below the ponding sites may provide the data to quantify the accuracy with which moisture fronts were actually identified through the neutron holes.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.2.3.1 pgs. 8.3.1.2-183	Subject: Matrix hydrologic properties testing. Specific Information: "Matrix hydrologic property measurements will be conducted on consolidated geologic rock samples only." Discussion: The laboratory hydrologic property measurement activity has been designed to collect unsaturated and saturated hydrologic property data on the porous matrix material, while no attempt has been made to collect unsaturated hydrologic property data on fractures. Determination of unsaturated hydrologic properties for fractures has been ignored, in part, because of the difficulty in making these measurements and in obtaining good fracture samples. There is a proposed activity in the exploratory shaft study to collect fracture samples for hydrologic and solute transport property analyses. The collection of fracture property data from the shaft is important; however, fracture property measurements are needed prior to the collection of fracture samples from the exploratory shaft, in order to test the USGS/DOE proposed conceptual model for flow in the unsaturated zone. Most of the activities planned for the exploratory shaft are designed based on the USGS/DOE conceptual model. Prototype testing of this conceptual model prior to the mining of the shaft may identify the need for additional studies and data collection in the shaft. Therefore, samples of fractures should be collected from either shallow excavations or rock outcrops for prototype hydrologic testing. Fracture samples from core will tend to be unsuitable for hydrologic testing because of their limited size. Data from these fracture samples should then be used to evaluate the USGS/DOE conceptual model fro the unsaturated zone and hydrologic tests planned for the exploratory shaft.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.2.3.2 pgs. 8.3.1.2-200	Subject: Site vertical borehole studies. Specific Information: Approximately 17 additional boreholes are planned for unsaturated testing in this activity. Tests planned for this activity include: 1. single-hole gas permeability tests; 2. cross-hole pneumatic tests; 3. gas-tracer diffusion tests; 4. long-term monitoring, similar to UZ-1; 5. vertical seismic profiling (VSP); and 6. fluid-injection tests. Discussion: Unsaturated zone testing and data collection, such as proposed in this activity, are needed near the proposed repository location. However, a major concern for hydrologic testing in this area is the in-situ condition of the fracture and matrix material as a result of gas and moisture discharges from UZ-6 and UZ-6S. Work and Weeks (1987) indicate that a significant drying out of the rock around UZ-6 and UZ-6S has occurred since they were drilled in September 1984. An evaluation should be made concerning the potential impacts this drying will have on the proposed hydrologic tests. In addition, the potential for open boreholes to at as pathways for gas and moisture flow needs to be minimized in the design and implementation of these proposed tests. The gas tracer diffusion tests will be influenced by the flow of air and moisture to open boreholes. Therefore, test intervals will have to be isolated from barometric and elevation effects to deduce the potential for air flow.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.2.3.3 pgs. 8.3.1.2-223	Subject: Solitario Canyon horizontal borehole study. Specific Information: "It is recognized that the hydraulic properties of the fault zone may vary from unit to unit, but the principal investigation effort will be focused on the Topopah Spring unit because it s the proposed repository host rock". Discussion: It is difficult to evaluate the specific test and analyses to be performed on this fault zone, because of the limited information provided. The difficulty of drilling and instrumenting a 300 m horizontal borehole will be much greater than previously encountered at the site. Therefore, new techniques may have to be developed for instrumenting and testing this hole from those previously used. We question the feasibility of installing a horizontal borehole across the Solitario Fault zone. It may be better to install vertical boreholes on both sides of the fault to perform crosshole testing.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.2.4.1 pgs. 8.3.1.2-238	Subject: Intact-fracture tests in the exploratory shaft facility. Specific Information: The first activity proposed under the exploratory shaft program is the collection and hydrologic testing of fractured rock samples. This will be the first attempt at measuring fracture flow properties for the tuffs. Laboratory tests planned for the intact-fracture samples include standard unsaturated property measurements for the matrix material; the fractures will have injection tests fro two-phase flow properties, tracer column tests, flow channelization tests and stress permeability measurements. Discussion: "The design of the ESP hydrologic tests is principally based on the initial conceptual unsaturated-zone hydrologic model for the site..." (SCP, p. 8.3.1.2-232). A quantification of fracture hydrologic properties is an integral part of characterizing unsaturated and saturated flow for Yucca Mountain. A conceptual model has been proposed by the USGS (Montazer and Wilson, 1984) for unsaturated flow; however, this conceptual model has never been verified. Yet, the design of tests proposed for the exploratory shaft are based on this conceptual model. Hence, there is a need to collect fractured tuff samples and obtain data on hydrologic properties of the fractures to test this conceptual model prior to the tests proposed for the shaft. Depending on the results of these tests, there may be a need to modify the test design or add new tests to the exploratory shaft program. Limited information is provided on the actual tests planned for the fractured tuff samples. Therefore, we are unable to comment on this aspect of the activity.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.2.4.1 pgs. 8.3.1.2-238 through 242	<u>Subject</u>: Intact-fracture test in the exploratory shaft facility. <u>Specific Information</u>: Amount of time required to complete tests. <u>Discussion</u>: The amount of time required to perform the myriad of laboratory tests indicated in this section may be considerable. Given the experience at the University of Arizona using reasonable-sized fractured blocks, it may require a much larger number of samples to complete the variety of tests contemplated if the results are to be timely and of value to those who are evaluating and modeling various flow processes.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.2.4.2 pgs. 8.3.1.2-255	Subject: Percolation tests in the exploratory shaft. Specific Information: Time required to complete the test. Discussion: As in the previous comment, some past experiments with larger fractured cores have taken considerable time to either achieve breakthrough of flow through fractures or to reach a saturated condition. Since the proposed 2 m cube is considerably larger than previously tested core samples, the time required to reach saturation (steady-state conditions) could be quite long and push results from the varied percolation rate experiments well into the future. The results of all three related ES tests 8.3.1.2.2.4.1, 8.3.1.2.2.4.2, and 8.3.1.2.2.4.3 must be available prior to finalizing the UZ conceptual model and analyzing the performance of the site under study 8.3.1.2.2.9.
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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.2.4.3 pgs. 8.3.1.2-274	Subject: Bulk-permeability test in the exploratory shaft facility. Specific Information: "A gaseous tracer will be injected into several test intervals, and its arrival time will be measured at the outflow point to determine the effective porosity of the system." Discussion: The proposal to use a gas tracer in conjunction with the bulk-permeability tests to determine the effective porosity of the system is good in concept; however, the collection and analysis of data from this test will be extremely difficult and may be of little practical use. First, it will be necessary to identify all potential discharge points for the tracer in order to measure a concentration breakthrough curve. Second, if the data could be collected and analyzed, the effective porosity value would only be applicable to gas and will be highly dependent upon the moisture contents of the matrix and fracture material. Small changes in moisture content can result in large changes in effective porosity. Hence, the applicability of a gas effective porosity value for unknown moisture conditions is questionable.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.2.4.4 pgs. 8.3.1.2-285	Subject: Radial borehole tests in the exploratory shaft facility. Specific Information: There are two primary objectives for this activity. "1) To detect vertical movement of water in both the vapor and liquid forms and to evaluate the potential for lateral movement of water along the hydrogeologic contacts." "2) To evaluate the radial extent of shaft excavation effects on the hydrologic properties of unsaturated hydrogeologic units." Discussion: It is highly questionable if the second objective stated for this activity can be accomplished. It will be difficult to analyze the tests to determine changes in permeability and moisture content as a result of mining. First, the air-injection tests will tend to dry the rock units, increasing the permeability as a result of changes in moisture content. Second, the presence of the shaft will affect the boundary conditions associated with the air injection tests. Sections of the shaft that are grouted will tend to act as a no-flow boundary while the ungrouted portion will act as a time-dependent constant head. Hence, the permeability of the fractured rock will change as new fractures are exposed to the shaft and others are sealed. Therefore, changes in the permeability of the rock units as a result of mining have the potential of being overwhelmed by changes in moisture and boundary conditions. It will be very difficult to separate the changes in permeability as a result of mining from changes in the test conditions. Not enough information is provided to evaluate the first objective. It is not clear how the potential for the lateral movement of air and water along hydrologic contacts will be detected in the cross-hole tests. The SCP (p. 8.3.1.2-285) indicates that these tests will be conducted after long-term monitoring is completed. Data from

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.2.4.4 pgs. 8.3.1.2-285	USW UZ-1 indicates that years may be required for the hydrologic system to equilibrate. Perhaps it might be better to conduct the cross-hole tests before long-term monitoring.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.2.4.5 pgs. 8.3.1.2-293	Subject: Excavation effects test in the exploratory shaft facility. Specific Information: The objective of this activity is to measure stress and permeability changes as a result of excavation and lining of the shaft. Discussion: As was stated in the radial borehole test activity, it may be difficult to detect changes in permeability of the rock adjacent to the shaft because of changes in moisture contact and boundary conditions.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.2.4.7 pgs. 8.3.1.2-300	Subject: Perched water tests in the exploratory shaft facility. Specific Information: "Aquifer tests will be conducted from the exploratory shaft to determine the extent, yield and hydraulic coefficients of the perched water zone." Discussion: The most important data to collect if perched water is encountered is a water sample for chemical analysis and age dating. Performing an aquifer test by inserting a small diameter screen into the shaft wall will provide little useful data if the test could be performed. The most likely scenario is that perched water will be flowing into the shaft from a number of intersecting fractures planes, such that the insertion of a well screen will do little to concentrate the flow. It will be important to isolate the zones of discharge, such that changes in water pressure and water quality can be monitored with time (several years). If longer term monitoring indicates the perched zone is extensive, specific aquifer tests might be designed to investigate the zone. However, drying up the zone by draining or pumping it may decrease the moisture content as greater depths, which would bias the investigations toward acceptance of the site.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.2.4.8 pgs. 8.3.1.2-304	Subject: Hydrochemistry tests in the exploratory shaft facility. Specific Information: One objective of this activity is to "determine the flow direction, flux and travel time of water in the unsaturated zone by isotope geochemistry techniques". Discussion: In the objectives of this activity it is stated that the flow direction will be determined from isotope geochemistry techniques. The description of the activity (SCP, p. 8.3.1.2-305) goes even farther and states that flow paths can be determined from isotope ratios. Because of the complex nature of ground-water flow in unsaturated, fractured rock, it will be difficult to interpret the data (assuming the data can be collected). The use of isotope data to determine the age of recharge water will have to account for the potential for isotope exchange as a result of natural air flow through the mountain (Weeks, 1987). In addition, it is not clear how the data will be corrected for contamination resulting from the shaft ventilation. All drilling phases will have a SF6 tracer added to it; however, it does not appear that the shaft ventilation will have a tracer gas added to it. Variable flow rates (fracture vs. matrix, different fracture apertures, etc.) may make interpretation difficult.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.2.5.1 pgs. 8.3.1.2-320	Subject: Diffusion tests in the exploratory shaft facility. Specific Information: "The objective of this activity is to determine in situ the extent to which nonsorbing tracers diffuse into the water-filled pores of the tuffs of the Topopah Spring welded unit that the exploratory shaft will penetrate." Discussion: The diffusion test proposed under this activity has both theoretical and practical problems associated with it. The Topopah Spring tuffs are unsaturated in the exploratory shaft; this is contrary to the stated objective of testing water-filled pores. As a result of the pores being unsaturated, there will be two forces acting on the aqueous tracer solution: 1) a gravity head which will drive the aqueous tracer solution vertically; and 2) a suction head present in the unsaturated matrix. The combined effect of these two forces will overwhelm the diffusivity coefficient that they are attempting to measure. A second theoretical problem with the test is that a diffusivity coefficient for the unsaturated zone cannot be measured by the introduction of an aqueous tracer. The diffusivity coefficient is a function of both the molecular diffusion of the solute and the tortuosity of the porous medium. In the unsaturated zone the tortuosity is a function of both matrix material and moisture content. Hence, the diffusivity coefficient in the unsaturated zone changes as the moisture content changes. In the saturated zone the diffusivity coefficient is a constant, since it is not a function of the moisture content. A practical problem associated with the test is the identification of nonfractured section of the borehole through the use of a television log. It will be difficult to identify micro-fractures with a television camera log. It would be better to obtain continuous core for visual inspection.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.2.6 pgs. 8.3.1.2-322	Subject: Characterization of gaseous-phase movement in the unsaturated zone. Specific Information: None Discussion: The gaseous-phase movement activity is one of the more important studies to be conducted. The study is ambitious with the type of experiments to be conducted. It is not clear how the analysis will be performed for some of the experiments. As is the case for most of the experiments in fractured rock, may be easier to conduct the experiment than it is to analyze the results. The SCP states that gas phase modeling will be used to help interpret the results. The use of the USG HST code to model the water vapor and gaseous radionuclide transport from Yucca Mountain is proposed. This code may be a good first approach at looking at the data: However, it has not been demonstrated that the fractured tuff can be represented as a porous media at this scale. One important assumption that needs to be evaluated in this work is whether a porous media model is appropriate at the Yucca Mountain scale. The SCP (p. 8.3.1.2-156) indicates that a three-dimensional, two-phase flow, heat and transport model will be developed for Yucca Mountain. However, it is not clear if this will be a fracture flow or porous media model. Other tests in the exploratory shaft will use a fracture flow model to analyze the results. Another concern with the development of a two-dimensional cross-sectional model is the design and parameter values that will ultimately be used in it. Kipp (1987) performed some preliminary modeling of gas flow through Yucca Mountain. The model design for this work was simplified and used unproven parameter values.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.2.6 pgs. 8.3.1.2-322	The complex stratigraphy of Yucca Mountain was represented by two hydrostratigraphic units: one for the fractured tuff and one for the soil. An accurate model of Yucca Mountain will have to incorporate the welded and nonwelded stratigraphy as well as zonations for highly fractured zones. An example of one questionable parameter value used in Kipp's model was a porosity of 10 percent for the fractured tuff. Work by Erickson and Waddell (1985) estimates the fracture porosity at 0.1 to 0.01 percent. The final porosity value used in the model will have a significant impact on calculated travel times for gas and moisture transport; travel times will decrease as the porosity values decrease. Therefore, the final design of the model for this study and other studies on Yucca Mountain will have major impacts on the data analysis and interpretation.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.2.6 pgs. 8.3.1.2-321 through 334	Subject: Characterization of gaseous - phase movement in the unsaturated zone. Specific Information: Study results. Discussion: Because of the nature of the SCP, it is difficult to determine the degree of thoroughness planned for each study. However, it seems all work is relevant and realistic, though the results may not be as conclusive as the document implies. The main limitation is that the theory of two-phase fracture flow is still in its infancy, and since one result of this study is three-dimensional gas flow and transport model, the equations solved by the model may not accurately represent the physical system. As an example, it is still unclear of the relationship between flow through fractures and flow through matrix, their corresponding thermodynamic state, and exchange of mass between the two. Stated on page 8.3.1.2-330 is that additional studies will be needed if it is indicated that moisture or gas movement through the mountain is significant. There is no elaboration of what is "significant". The studies proposed are important and realistic, however, incorporating the results from each study into one grand unifying theory of gas flow through Yucca Mountain will be extremely difficult to achieve because flow theory in this setting is still poorly understood. In addition, though there is mention that the models need to be validated and calibrated, there is no mention how this is to be done. Verifying and validating a three-dimensional flow code is non-trivial. Also, the model will have to be calibrated as steady-state, since there will be little time-series data.

REVIEWER: CLAY A. COOPER Print Clay A. Cooper Signature	ORGANIZATION: Desert Research Institute University of Nevada System DATE: June 21, 1989

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.2.7.1 pgs. 8.3.1.2-334 through 337	Subject: Gaseous-phase chemical investigations. Specific Information: Interpretation of information. Discussion: In order to interpret the isotopic information, either the isotopic composition of the water in the unsaturated zone, or the fractionation and exchange relationships between the water and the gas, should be known. The gas composition is proposed to be used to develop information about the water, so that the latter information on relationships will be required. Because of temperature changes with depth, the effects of temperature may be important, both in terms of the relationships in situ, and in terms of fractionation during sampling. As the water vapor cools as it is pumped to the surface, it may condense, changing the composition of the gas. Nonequilibrium effects may also be important. Details on how these effects will be considered should be presented. A typographical error exists in the text. "Oxygen-13" should be "oxygen-18".

REVIEWER: Scott Tyler Print [signature] Signature	ORGANIZATION: Desert Research Institute University of Nevada System DATE: 6/2/89

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.2.7.2 pgs. 8.3.1.2-337 through 341	Subject: Aqueous-phase chemical investigations. Specific Information: Sampling procedure, isotope and gas exchange, interpretation of ages. Discussion: Collection and preservation methods are not discussed. It will be important to prevent contamination by exchange with modern gases and liquids, especially with the radioactive isotopes. Extraction of the water should occur under an inert atmosphere. It may be possible to extract water using elevated gas pressures, rather than a triaxial press. This may reduce changes in water chemistry caused by breakage of grains exposing new surfaces for reaction, although the effect of the gas pressure increase should be investigated. If significant quantities of gas are moving through the unsaturated zone as suggested by Weeks (1987), the water samples may not be representative of recharge environments at all. Exchange of gases between the water and gas needs to be considered. Interpretation of radioactive "age" data will probably not be straight-forward because of the gaseous exchange, and because of the possibility of diffusion of dissolved gases and ions from fracture surfaces into the rock matrix. For example, in the saturated zone, diffusion of C-14 from the fracture into the matrix can make the flow rate in the fracture appear to be much slower than it actually is. Diffusion into the matrix makes the C-14 content of the water a function of the distance from the fracture. Interpretation of these data will be difficult.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.2.9.1 pgs. 8.3.1.2-351 through 353	<u>Subject</u>: Unsaturated-zone flow and transport modeling. <u>Specific Information</u>: Preliminary Numerical Modeling. <u>Discussion</u>: The former section "Preliminary Numerical Modeling" has now been split into Conceptualization and Computer Code Development. This is a healthy change, alternative models are now explicitly listed in Table 8.3.1.2-2a and b (pgs. 8.3.1.2-52 to 87). The tables list most of the alternatives that have been discussed to date. No plan is presented in section 8.3.1.2.2.9.1 for how alternative models might be proposed by DOE contractors, except through the forum of "peer review" (p. 8.3.1.2-353). As such, this section and Table 8.3.1.2-2 represent a response to outside critiques of DOE's conceptual models, rather than a clear plan of how alternative models might be developed internally.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.2.9.3 pgs. 8.3.1.2-356 through 358	Subject: Unsaturated-zone flow and transport modeling. Specific Information: Simulation of Natural Hydrogeologic System. Discussion: This final model has as one of its objectives to "predict probable future and past states of the system under changes in the environmental conditions" (p. 8.3.1.2-356). Like the saturated zone synthesis model, this model will be based on approximate models planned in earlier activities. Since the basis of this final model is a series of models that must be "...highly simplified version(s) of a complex three-dimensional system..." (p. 8.3.1.2-140), it is likely to contain significant uncertainties making results impossible to evaluate.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.2.9.3 pgs. 8.3.1.2-359 through 360	<u>Subject</u>: Unsaturated-zone flow and transport modeling. <u>Specific Information</u>: Stochastic Modeling and Uncertainty Analysis. <u>Discussion</u>: The intent of this activity is to quantify the uncertainty present in model results. The basic premise is that uncertainty distribution functions can and will be accurately known. This kind of characterization is nearly impossible to achieve, and therefore estimates of the degree of uncertainty will themselves be highly uncertain. One important source of uncertainty that cannot be tested in the proposed manner is conceptual model uncertainty. Processes ignored, or inadequately treated in the underlying model may contribute significant errors that do not appear in Monte Carlo simulations. As in the rest of the reviewed sections, this activity fails to take into account practical limitations, and is unlikely to deliver what is promised.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.3 pgs. 8.3.1.2-364 through 371	Subject: Investigation: Studies to provide a description of the saturated zone hydrologic system at the site. Specific Information: General comments. Discussion: Within the more permeable tuffs, hydraulic heads are likely to be similar. In order to obtain reliable data, the SCP indicates that very frequent measurements will probably be required. This statement is probably true for measuring both horizontal and vertical gradients. To date, relative few reliable measurements of vertical gradients have been obtained. More piezometer nests should be installed for long-term monitoring. The SCP indicates that comprehensive interpretation of data will be restricted to data from the C-hole complex. Unfortunately, a careful reinterpretation of previously collected data from other hydrologic test holes should also occur. In the majority of instances, the analytical models used to interpret the tests did not agree with the testing data. Before these data are used in the characterization of this site, careful re-evaluation is required. While the high gradient measured across Solitario Canyon suggests that the fault may act as a barrier to ground-water flow, the Solitario Canyon fault is only one of many faults at Yucca Mountain. Information on the hydrologic characteristics of other faults should also be collected. In addition, the gradient is much steeper between USW H-1 and USW G-2 than it is across Solitario Canyon. The cause of this steep gradient should be determined as well.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.3.1.1 pgs. 8.3.1.2-372 through 374	<u>Subject</u>: Solitario Canyon fault study in the saturated zone. <u>Specific Information</u>: Data collection, analysis of data. <u>Discussion</u>: According to figure 8.3.1.2-21, there is no evidence to suggest that the Solitario Canyon fault acts as a barrier to flow in the earea where the testing is proposed. The high gradient occurs between USW WT-7 and USW H-3, and further to the south. Head data are simply not available for much of the proposed repository area. For example, there is no evidence that the water table has an elevation of less than 740 meters in the central part of the block. Prior to drilling USW H-7 to peform a pumping test that may not be beneficial, the configuration of the water table should be better defined. Although there may be some questions about drilling through the unsaturated zone in the middle of the block, this is probably the best place to collect additional water-leel data. The proposed testing program will probably not provide information on all of the stated parameters. For example, there appears to be no intention of drilling through the fault zone, so that, geologically speaking, it will probalby not be any better characterized than has already been done by durface mapping. The nature and extent of the fault zone is already pretty well known. It has been known for a long time that the displacement decreases to the north. Whether a low-permeability fault gouge has developed along the faults will probably not be determined without collecting samples of the material along the fault. If the character of the fault is of prime interest, slant core holes through the fault might provide better data. If pumping tests are performed, analysis of the data may be diffi-

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.3.1.2 pg. 8.3.1.2-375	Subject: Site potentiometric-level evaluation. Specific Information: "2. Refine the potentiometric surface." Discussion: This section, like the regional section, ignores the possibility of differing potentiometric surfaces in differing hydrogeologic units. This work plan should acknowledge the possibility of vertical gradients and how to investigate them, or justify not examining them.

REVIEWER: Jenny Chapman
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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.3.1.2 pgs. 8.3.1.2-375 through 382	Subject: Site potentiometric-level evaluation. Specific Information: Drilling locations, calibration. Discussion: Most of the drilling into the saturated zone has been performed outside of the perimeter drift. USW G-4, the pilot hole for the exploratory shaft, is the lone exception, and it lies in the zone of higher fault density east of Ghost Dance fault. The location of the 740 meter potentiometric contour (Figure 8.3.1.2-21) is not well known; it may actually be in error by half a mile. Bending the contour toward the east would alter directions of flow, and may affect travel time calculations. The 30-day pumping test of one of the C-hole complex wells may not provide much additional data unless additional observation wells are drilled. These should be located in a manner to best measure effects of anisotropy, for comparison with the fracture network models to be developed. The existing holes are probably too far away to detect drawdown because of barometric, earth tide, and instrumental noise. The typical WT well which only penetrates one or two hundred feet into the water table may not be deep enough to be useful for this purpose. The water table wells to be drilled north of Drill Hole Wash should be drilled in manner to allow some testing, either in conjunction with sampling, or separate packer tests. Pressure data can be collected using downhole digital recorders. Fracture mapping in the drill hole through television or televiewer logs is useful, but does not provide permeability information. Many of the fractures identified in drill holes are not capable of providing appreciable water.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.3.1.2 pgs. 8.3.1.2-375 through 382	Proper calibration and maintenance of the monitoring network is essential. If pressure transducers are used for long-term monitoring, their calibration should be frequently confirmed. The small differences in head present in the wells east of Yucca Mountain will require accurate measurements to differentiate. Transducer or power supply drift can easily make the measurements virtually useless.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.3.1.3 pgs. 8.3.1.2-383 through 393	<u>Subject</u>: Analysis of single- and multiple-well hydraulic-stress tests. <u>Specific Information</u>: Re-analysis of tests performed in other holes. <u>Discussion</u>: A great number of hydrologic tests have been performed in holes at and near the site. The agreement between the testing data and the analytical models used to interpret the tests has been poor in many or most cases. These data should not be accepted until a re-analysis is performed, based on fracture flow models. The emphasis in the past has been on obtaining a value for transmissivity, rather than understanding the flow system in the vicinity of the well. It is essential that the flow system be better understood before aquifer parameter values are calculated. Careful work at the C-hole complex should be extended to other test wells. The methods used to collect the data, and instrument calibration procedures, need to be carefully documented, or the data and their interpretations may not be acceptable for licensing. The lack of vertical gradients is not an indicator that unconfined conditions exist, but only that vertical flow rates are low or that vertical permeabilities are high. Transient, fracture network flow models may eventually be required to interpret test results. These may need to be deterministic in the immediate vicinity of the well, but random away from the well.
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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.3.1.4 pgs. 8.3.1.2-393 through 397	Subject: Multiple-well interference testing. Specific Information: Adequacy of observation well network. Discussion: Prior to performance of the 30-day pumping test, calculations of expected results (based on previously collected data) should be performed. These calculations should incorporate possible effects of anisotropy caused by the dominant approximately N-S strike of the fractures in the area around the C-hole complex. Additional monitoring wells (probably deeper than the WT wells) may be needed, and should be drilled early enough to allow them to stabilize prior to the pumping test.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.3.1.5 pgs. 8.3.1.2-400	Subject: Testing of the C-hole sites with conservative tracers. Specific Information: Tracer selection, interpretation of data. Discussion: One tracer, 3-trifluoromethylbenzoate, is proposed for use in the three single well tests, and the two re-circulating tests. One of the big advantages of the benzoic acid tracers is their low detection limits, coupled with their anthropogenic origin. Use of the tracer will increase its ambient concentration at the site. It may be unwise to plan to use the same tracer for all tests. The drift-pumpback tests, especially the early part of the drift phase, will be most sensitive to the characteristics of fractures intercepted by the well. Because observations will only be available from the well, the drift test may not be an accurate measure of velocity outside the immediate vicinity of the well bore. Simulations should be performed testing the sensitivity of the experiment to transport properties several meters away from the well. How will information on the concentration of the tracer during the drift phase be obtained? There was no mention of use of radioactive tracers, so that downhole gamma counters will presumably not be used. Collection of samples may disrupt the experiment. A puff-drift-pump technique may be more informative. Interpretation of the tests will be a challenge. It may turn out that the porous media approach will be sufficient to explain the test data. The approach of Grove and Beetem was fairly successful at the Amargosa Tracer Site, but the geometry of the transmissive zone there was appropriate. If the approach works, the results should not be overextended. For example, the dispersivity that results should be considered to be a function of the experiment

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sec. 8.3.1.2.3.1.5 pgs. 8.3.1.2-400	(both scale and sampling approaches) rather than of the fractured medium. A re-circulating test may not be able to separate matrix diffusion effects from the tail caused by re-circulation. Because diffusion looks like kinetic, rather than equilibrium sorption, running multiple tests at different pumping rates may indicate whether diffusion is occurring. This would best be done in a laboratory, using natural fractures. The dual-porosity model of Huyakorn et al. is for the case of advective movement in the fractures (assuming porous medium equivalency), with diffusion into the matrix. Advective movement in the matrix is not considered. Prior to beginning any tests, simulations should be performed in order to estimate tracer concentrations needed for the tests. These concentrations should be high enough to overcome detection limit and analytical noise constraints. The work plans should include these calculations.
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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.3.1.6 pgs. 8.3.1.2-408 through 413	Subject: Well testing with conservative tracers throughout the site. Specific Information: Choice of wells. Discussion: Some of the proposed wells for additional testing may not be suitable. For example, UE-25a#1 was not constructed for hydrologic testing. It is a small diameter well containing s string of tubing which may not be removable without great effort. The tubing is not cemented. Similarly, USW G-3 may be too small for testing, although its tubing string is probably removable. USW H-3 is a well with a generally low permeability. It's head (approximately 730 m) suggests that it may, however, be near a high permeability area. Results from it may not be useful in terms of characterizing the area. It may be a good well to test for matrix diffusion, although the effects of fracture coatings will be absent. USW H-4 is a well that is not proposed for these tests, even though it is immediately downgradient from the proposed repository area, and has been generally well characterized, through previous static I-131 logging. It should be considered for further testing.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.3.2.1 pgs. 8.3.1.2-425	<u>Subject</u>: Assessment of site hydrochemical data availability and needs. <u>Specific Information</u>: Depth-integrated sampling. <u>Discussion</u>: The majority of water samples collected from the Yucca Mountain area have been collected without regard to the depth from which the sample is collected. For example, most of the samples were collected during pumping tests of the entire saturated thickness encountered by the hole, less 50 to 100 feet of cased-off rock at the top of the saturated zone. Hence, the resulting sample is a mixture of all water that was entering the hole at the time of sampling. The depths at which the water entered the hole was predominantly determined by the depth of permeable, connected fractures. Although data were collected on the distribution of these fractures, it will be quite difficult, if not impossible, to assemble a database that is meaningful and convincing. Exceptions to the above statements include samples collected from the WT holes, the long-term pumping of USW H-3 (where the depth of the few permeable fractures is known), samples taken from the piezometer tubes in USW H-1, and possibly samples taken during the month-long pumping of UE-25b#1, when a bridge plug was used in an attempt to isolate the pumped interval from the lower part of the hole. Interpretations of flow directions should incorporate the possible anisotropy of permeability.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.3.3 pg. 8.3.1.2-434	Subject: Saturated-zone modeling and synthesis. Specific Information: Conceptualization, Accessible Environment. Discussion: This section opens with the statement that "all reliable data and reasonable interpretations of it will be assimilated..." The SCP and the DOE program in general are not structured to support alternative concepts, and the above statement is meaningless in such an environment. The only way to carry out this assimilation is in settings such as specialized technical symposia, where free exchange of ideas is possible. This kind of exchange is not currently supported by DOE, but must be included if any of the planned conceptualization activities are to be carried out successfully.

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sec. 8.3.1.2.3.3.1 pg. 8.3.1.2-435	Subject: Conceptualization of saturated zone flow models within the boundaries of the accessible environment. Specific Information: None Discussion: Insufficient information for comment. How will conflicting interpretations be resolved? What are criteria for acceptance of previously collected data?

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.3.3.2 pg. 8.3.1.2-438	Subject: Saturated-zone modeling and synthesis. Specific Information: Activity: Fracture Network Model. Discussion: A fracture network model will be useful for studies of near-field effects. The more general applications alluded to in the plans, e.g., p. 340, "evaluate the general hydrologic behavior of the saturated zone", are probably not feasible. Fracture network models of relatively small volumes should be successful; for large volumes they may be impossible.
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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.2.3.3.3 pg. 8.3.1.2-441 through 443	<u>Subject</u>: Calculation of flow paths, fluxes, and velocities within the saturated zone to the accessible environment. <u>Specific Information</u>: Use of Winter et al., or Schwartz and Smith. <u>Discussion</u>: As theories and techniques for modeling dispersive processes and flow and transport in fractures are still developing, limiting approaches to the two listed is inappropriate at this time.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.5 pgs. 8.3.1.5-4 and 5	Subject: Table 8.3.1.5-1 "Climatic Program Goals". Specific Information: Table 8.3.1.5-1 lists as "tentative goals" for the climate program to: "Show expected flux change will be <5 mm/yr." Discussion: There is a philosophical problem here with the objectivity of a program of study whose goals are to develop a predetermined result. The uncertainty ranges of climate variability and hydrologic response result in nonunique solutions, some of which may satisfy the stated goals. The statement of goals provides the appearance that the program will seek out those particular solutions, at the expense of other reasonable solutions that do not satisfy the program goals.

REVIEWER: GILBERT F. COCHRAN
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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.5 pgs. 8.3.1.5-7 8.3.1.5-8 8.3.1.5-9 8.3.1.5-10 tbl. 8.3.1.5-2 pgs. 8.3.1.5-13 8.3.1.5-14	Subject: Paleoclimate Investigations Specific Information: Terminology Discussion: Under "Approach to satisfy performance and design requirements," last paragraph on the first page and the first two paragraphs on the second page and in Table 8.3.1.5-2. The distinction drawn between the activities included under "paleoclimate" and "paleoenvironment" is artificial and confusing. All the data included under these two terms in the text and in the table are paleoenvironmental data that can be used as paleoclimatic proxy data. The distinction drawn between the two kinds of data in the text is fallacious. The term "paleoclimate," in the contexts used on the cited pages and tables, probably should be changed to "biology" and the term "paleoenvironment" should be changed to "geology." For example, on pages 8.3.1.5-7 and 8.3.1.5-8 in Table 8.3.1.5-2 under the column "Parameter category" the phrase "Quaternary regional paleoclimate" should read "Quaternary regional biology" and the phrase "Quaternary regional paleoenvironment" should read "Quaternary regional geology." Terms that are in general usage and already having established meanings should not be redefined simply to satisfy the demands of a bureaucratic document.

REVIEWER: Peter Ernst Wigand
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sec. 8.3.1.5 pgs. 8.3.1.5-14	Subject: Overview of the climate program: description of future climates. Specific Information: General Concern Discussion: A confusing distinction appears to have been made between the terms paleoclimate and paleoenvironment. Climate is one component of the environment of a region. Inferences regarding the nature of past climates are derived from paleoenvironmental history, using various lines of evidence such as soils, surficial, eolian, and lacustrine deposits, geomorphology, palynology, pack-rat midden analysis, and tree rings. In the second paragraph on this page it is stated that the principal line of evidence for the 'synthesis' will be the paleoclimatic history, and that the paleoenvironmental history will serve to complement the paleoclimate chronology. This distinction is artificial and confusing, since paleoenvironmental data are used to infer changes in paleoclimate. In the third paragraph, discussing the plans for global climate modeling, it is stated that no input is required from any previously discussed site activities. Further, the regional numerical climate modeling schemes require information on present regional climate. I think there needs to be a much stronger consideration of paleoclimate change and variability in parameterizing the GCM's that will be used to determine the effects of future climate on geohydrological conditions. Additionally, there needs to be a strong focus on the particular aspects of paleoclimate that are actually being reconstructed using the various paleoenvironmental indicators. Specific questions need to be addressed regarding the temporal and spatial inferences that can be generated from any

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sec. 8.3.1.5 pgs. 8.3.1.5-14	particular reconstruction. This leads to a need for an objective conceptual framework that states how the different paleoenvironmental reconstructions will be integrated. For example, different paleoenvironmental reconstructions are dated with different degrees of accuracy and precision. This is primarily a function of the radiometric techniques employed. Different paleoenvironmental indicators may also exhibit different responses in the frequency and spatial domains to the same climatic forcing. Some may yield more accurate reconstructions of low frequency climatic variability while others may provide an excellent indication of high frequency changes. The responses also have the potential for being temporally and spatially out-of-phase with one another and with the climatic forcing event(s). An explanatory framework must be created that explicitly states how these factors will be taken into account in a fashion that is objective and that can be subjected to independent verification.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.5.1 pgs. 8.3.1.5-35	Subject: Models of future climate. Specific Information: Use of the term "forecast". Discussion: In the section on Purpose and Objectives of the Investigation, it mentions that recent meteorological data and Great Basin historical climate data will be used to calibrate and validate models of future climate. Someplace in this section there needs to be a consideration of no-modern-analog conditions. That is, are there conditions in the past that are simply not represented by the relatively short period of modern climatic observations. It states that the paleoclimate/environmental synthesis will provide time sequential reconstructions for modeling activities that will, in turn, be used to 'forecast' climatic variables for the next 100,000 years. In statistical climatology and time series analysis, forecast implies a statement of anticipated conditions for a specified place and period of time. If this is the meaning of forecast in this context, there need to be qualifications as to the spatial and temporal domain of the forecast and potential error that may be associated with it.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.5.1.1 pgs. 8.3.1.5-40 and 41	Subject: Synoptic characterization of regional climate. Specific Information: Adequacy and interpretation of existing climatic data. Discussion: The characterization of modern regional climate seems to address the necessary question of providing a baseline and a background for the interpretation of climatic variation. Synoptic characterization of regional climate will be used to provide the basis for various climate transfer function models, to provide an understanding of spatial and temporal variation in climate, and to determine the climate conditions under which recharge occurs. An interpretative explanatory framework is needed that will help to define the temporal and spatial representation that is offered by modern and historical climate from the southern Great Basin and surrounding region. This would not only indicate what data is available from what time periods and locations, but even more importantly, what is not available in terms of what areas and time periods are under-represented or possibly even not represented. Specifically, what climate data (what stations) are going to be used in the analysis and what time periods are represented? What elevational biases are present in the climate data and what areas are not represented? Even with reasonably lengthy climate records, consideration needs to be focused on the homogeneity of the data. Will the station history be analyzed to isolate changes in station relocation, instrumentation, or observational procedures that have the potential for introducing changes of mean and variability in meteorological parameters that can be mistaken for climate change or variability? Also, do the data contain a strong macroclimate signal, or are they providing a measure of conditions that are frequently

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sec. 8.3.1.5.1.1 pgs. 8.3.1.5-40 and 41	localized? These are especially important factors that must be considered prior to utilizing any of the climate data in transfer function analyses with paleoenvironmental indicators. Additionally, a network of weather stations will be set up in the region, in conjunction with the meteorology and geohydrology programs. The weather data represent atmospheric conditions at particular locations for time periods ranging from minutes and days to months. Several questions need to be addressed with respect to this information. 1 - How representative is the weather data over a larger spatial area? 2 - What is the variability in weather data over elevational gradients? 3 - What is the nature of the co-variation between the meteorological parameters observed in the Yucca Mountain network, spanning a relatively short period of time, with those from nearby stations in the region that have been in existence for many years? If consistent and significant statistical relationships can be established between stations operating for short time periods with those that have been recording observations since the early 20th century, the potential exists for creating lengthy series of high-frequency meteorological observations for the immediate test site area. 4 - Perhaps the most important feature that needs to be addressed with the short-term meteorological observations is whether they are even representative of high-frequency atmospheric conditions over longer time periods. What is their context within the regional climate of the past 100 years? Is the data in-

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sec. 8.3.1.5.1.1 pgs. 8.3.1.5-40 and 41	dicative of the meteorological situation during 'normal' conditions (as numerically defined with the available historic instrumental climatic data), or is it being obtained during a climatic period that is anomalously hot/dry or cool/moist? When evaluated within the context of available paleoclimatic reconstructions, we must also consider what meteorological conditions are not represented, or at best poorly represented, to insure that our comprehension of future climatic conditions is as scientifically unbiased as possible.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.5.1.3.1 pg. 8.3.1.5-55	Subject: Paleoclimate Investigations Specific Information: Woodrat Middens Discussion: Under "Description," paragraph 3, lines 5-7. The nature of woodrat midden data precludes the creation of a time series of vegetational change from given areas. The data are discontinuous in both time and space. Stratigraphic relationships between the individual strata within a woodrat midden cannot be used to verify the chronological position of any one strata. The law of superposition does not apply. In addition, in many cases size of radiocarbon age error does not allow resolution of these problems. In those few cases where these problems can be overcome the limited time span covered by any one midden (four or five thousand years) and the sporadic nature of this coverage at any one locality prevents the construction of a true time series. If, as we suspect, woodrat middens reflect primarily "favorable" time periods at any one locality then there is little or no record of the vegetation representing bad times. In addition, because the formation of a midden layer is dependent upon the presence of woodrats at the midden locality, it is possible that as a result of changing geographical distribution of woodrats through time there may be periods when there were no woodrats at the locality to produce a midden layer even though times were good. It is evident from the above discussion that woodrat midden data cannot be used for time series analyses.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.1.5.1.3.2 pg. 8.3.1.5-57	Subject: Paleoclimate Investigations Specific Information: Pollen Discussion: Under "Description," paragraph 2, lines 5-9. Although woodrat middens contain pollen from the regional pollen rain, they also contain copious pollen that has been brought in through the collecting activities of the woodrat. Statistical relationships between these samples and the regional pollen rain are almost impossible to establish. However, the pollen content of a woodrat nest can be used to provide additional information on plants that may have occurred in the area surrounding the fossil woodrat midden that may not be evidenced in the macrofossil record.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.5.12 pgs. 8.3.5.12-1 through 69	Subject: Issue Resolution Strategy for Issue 1.6: Will the site meet the performance objective for pre-waste-emplacement ground-water travel time as required by 10 CFR 60.113? Specific Information: The performance objective is stated in 10 CFR 60.113(a)(2) as "The geologic repository shall be located so that pre-waste-emplacement ground-water travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment shall be at least 1,000 years or such other time as may be approved or specified by the Commission". The disturbed zone has been defined qualitatively in 10 CFR 60.2 as "that portion of the controlled area the physical or chemical properties of which have changed as a result of underground facility construction or as result of heat generated by the emplaced radioactive wastes such that the resultant change of properties may have a significant effect on the performance of the geologic repository". The accessible environment has been defined in 10 CFR 60.2 to mean the atmosphere, the land surface, surfacewater, oceans, and the portion of the lithosphere that is outside the controlled area.The controlled area, defined in 40 CFR 191.12(g), means (1) A surface location, to be identified by passive institutional controls, that encompasses no more than 100 square kilometers and extends horizontally no more than five kilometers in any direction from the outer boundary of the original location of the radioactive wastes in a disposal system, and (2) the subsurface underlying such a surface location. In order to resolve this issue, DOE proposes to define, characterize, and assess the multiple barriers to ground-water flow. These are further defined in a five-part process as:

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sec. 8.3.5.12 pgs. 8.3.5.12-1 through 69	1. Identifying all hydrogeologic units along potential flow paths to the accessible environment and identifying all potentially operating processes within each of these units. 2. Classifying hydrogeologic units and flow processes as primary, secondary, and auxiliary "barriers" to establish a defense-in-depth basis for reasonable assurance that flow time to the accessible environment is at least 1,000 yr. 3. Establishing measures of performance (i.e., travel time) that allow comparisons of the flow behavior in each unit to the 1,000 yr flow time requirement. 4. Assigning goals and associated levels of confidence for each performance measure. 5. Identifying relevant parameters and associated levels of confidence that will be used to predict the travel time and associated uncertainty through each unit. With the next step to construct and apply numerical models to make travel-time predictions. The primary reliance in this process is noted in Table 8.3.5.12-1 as being the Calico Hills nonwelded vitric and zeolitic tuffs. Other components are characterized as being of either secondary or auxiliary importance." <u>Discussion</u>: In order to place primary importance on the two Calico Hills units and to have a high level of confidence on these predictions, it is required that the physical characteristics of these units be well-defined throughout the repository area in order that the "fastest path" be defined. Given the current confidence level and the desired confidence (high) as shown in Table 8.3.5.12-2 "Performance parameters for resolving Issue 1.6", there appears

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sec. 8.3.5.12 pgs. 8.3.5.12-1 through 69	to be the need for an intense program to obtain additional information concerning these units. The program outlined for the field efforts does not show that the level of information will be collected which will yield the desired level of confidence. Table 8.3.5.12-3 gives a thorough listing of each of the performance parameters needed and its level of confidence for each as well as for each of three statistical measures: the mean, standard deviation, and spatial correlation. The minimal new data to be collected are described under activity 8.3.1.2.2.3.2 "Site vertical borehole studies" and perhaps none under 8.3.1.2.2.4.6 "Calico Hills Test in the Exploratory Shaft Facilities." This first activity proposes to dry drill six new surface-based holes which will be completed in the Calico Hills units; however, only UZ-2 and UZ-3 will be within the repository boundary. The remaining holes will be either east of the UZ-9 complex or south of the repository UZ-10. The second activity is not really proposed at this time, however, alternatives are briefly mentioned. These activities if performed will provide some additional information about the Calico Hills units; however, it is difficult to have a great deal of confidence in the Calico Hills unit characterization based upon the two new holes primarily in the nonwelded vitric tuff at the southern end of the repository and the drift and 9-meter horizontal holes in the nonwelded zeolitic tuff at the northern end of the repository. These two activities will not provide satisfactory information to evaluate the spatial variability likely to be encountered beneath the repository. In order to have a high confidence in the understanding of these units, a much-enhanced drilling and testing program would be

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sec. 8.3.5.12 pgs. 8.3.5.12-1 through 69	necessary. However, as pointed out, exterior penetration or excavation of the unit for testing purposes within the repository block may jeopardize the integrity of the unit as a barrier. Given this concern, it is doubtful that it will be possible to characterize the Calico Hills unit to the extent necessary and therefore it is likely that great uncertainty will surround the resolution of Issue 1.6.

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sec. 8.3.5.13 pg. 8.3.5.13-55	Subject: Total system performance. Specific Information: Table 8.3.5.13-3, Table title page 8.3.5.13-55 Discussion: The failure modes delineated under (C) and (D) relate to ground-water travel and the performance of that barrier. Under (E), the undisturbed barrier will be evaluated with some indication of concern for gas/vapor flow, yet there should be concern related to possible disruption which would increase the likelihood of gaseous transport.
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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.5.13 pgs. 8.3.5.13-55 through 92	Subject: Total system performance. Specific Information: Technical Discussions of the Release Scenario Classes: Nominal case (E): Water-release pathways (pg. 8.3.5.13-55 through 8.3.5.13-92, as well as cases (C) and (D). Discussion: Key to being able to evaluate either the nominal case or the disruption scenarios and independent of the specific model to be used is the ability to determine the key characteristics of the unsaturated zone units beneath the repository level. It is not apparent that the limited amount of data collected from the surface-based drilling (new UZ holes) and the potential ES drift into the Calico Hills will provide an adequate data base upon which to base the models. The spatial variability cannot be determined from this limited amount of testing. In Table 8.3.5.13-8, the Calico Hills are the primary barrier which needs to be characterized to a level of confidence if it is to be treated as an equivalent porous media, flow-transport process. A second question arises when considering the magnitude of potential computational power required to analyze problems of this magnitude. Given the current "state-of-the-art" of being able to model unsaturated-zone flow, can DOE realistically expect to model these coupled processes or will the simplifications have to be such that these modeling efforts are essentially meaningless?

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.5.13 pg. 8.3.5.13-131	<u>Subject</u>: Water-pathway models. <u>Specific Information</u>: Given the experience of using the one-dimensional model TOSPAC as exercised by Sandia, the description on page 8.3.5.13-131 indicates that there is little concern in moving to a two-dimensional model which is stated as being necessary. <u>Discussion</u>: Recent reported modeling activities given at the "International Conference and Workshop on the Validation of Flow and Transport Models for the Unsaturated Zone" would bring this into question. A number of presentations expressed concern at being able to actually simulate flow in naturally-heterogeneous, porous media for any large-scale field problems. In order to handle realistic problems, tremendous computing power must be made available simply to obtain solutions. Validation of the more complex models brings in further complications. The entire discussion here and under the subactivities related to model development and use under 8.3.5.13.4 assumes that "simplified, computationally efficient" models can be constructed and exercised which represent the essential events and processes. These models are to be used to make predictions over very long time frames. The ability to make even short-term predictions based on the best data available, making as few simplifying assumptions as possible, has not yet been reliably demonstrated. Therefore, this entire concept is suspect.

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sec. 8.3.5.16 pgs. 8.3.5.16-1 and 2	Subject: Design of a long-term performance monitoring program . Specific Information: The specific area of concern is the lack of planning for long-term monitoring of containment of radionuclides within the proposed repository. Discussion: In light of recent political developments that have designated the Yucca Mountain site as the only location to be characterized for the proposed repository and the associated implication thatthis site will be the location for the repository, it is important that serious thought be given to the idea of long-term monitoring of site performance. Long-term monitoring will require development of pre-construction baseline data; this will be accomplished during the site characterization effort, if the described efforts are carefully planned and conducted (see SCP sections 8.3.5.16 and 8.2.2.1.1.7). The long-term monitoring effort will also require continuing observation of repository performance using observation systems intended to detect releases at various points within the multiple barrier containment system. Such detection systems are not discussed in the Site Characterization Plan.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.5.16 pgs. 8.3.5.16-1 through 10	Subject: Performance Confirmation Program Specific Information: Leak detection. Discussion: This chapter of the SCP has been lengthened considerably. The current text implies that the majority of the Performance Confirmation effort is intended to substantiate the accuracy and reliability of the characterization data collected for, and the numerical models utilized in, the site evaluation process. There continues to be no presentation of plans to conduct regular monitoring during the operations or post-closure phases of the repository that would detect leakage of materials past any of the several engineered or natural barriers being relied upon for waste containment.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.5.19 pg. 8.3.5.19-1	Subject: Substantially completed analytic techniques. Specific Information: The definition of these techniques is "those that already exist and could be used, with little additional work or only minor modifications, to conduct performance assessment analyses". It further lists these techniques in Table 8.3.5.19-1 and codes in Table 8.3.5.19-2, while stating that most have not been fully verified and validated for application to Yucca Mountain. Discussion: This section expresses little information concerning verification and validation of each proposed "substantially complete" code. It is our position that one should not consider these codes complete until they have been verified and validated, which is no trivial task. The amount of effort required to verify and then validate these codes could be quite substantial as indicated by the past activities of various DOE contractors.These codes, as listed, fall for the most part into the same category as those in Section 8.3.5.20, i.e., those requiring significant development. The descriptions of plans for verification and validation under 8.3.5.20.2 should apply to all codes for use in performance assessment. Each must be examined to determine the model needs for validation which may change or add substantially to the data gathering and testing program. Considering this last concept, it may be that the preferred conceptual models are still driving the site characterization and determining the data acquired to justify the modeling.

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SEC. NO. PAGE NO. DRWG. NO.	COMMENT
sec. 8.3.5.20 pg. 8.3.5.20-2	Subject: Analytical techniques requiring significant development. Specific Information: Validation of models for performance assessment. Discussion: The activities which are needed to test modeling assumptions, guide model development, and calibrate and validate the models is comprehensive; however, there are only minor citations relating back to the planned tests, analyses, and studies which provide the parameter estimations with which the models will be calibrated and against which they will be validated. There is no way to readily compare the goals of validation with the information gathering activities to determine whether there is any hope of validating the models.

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