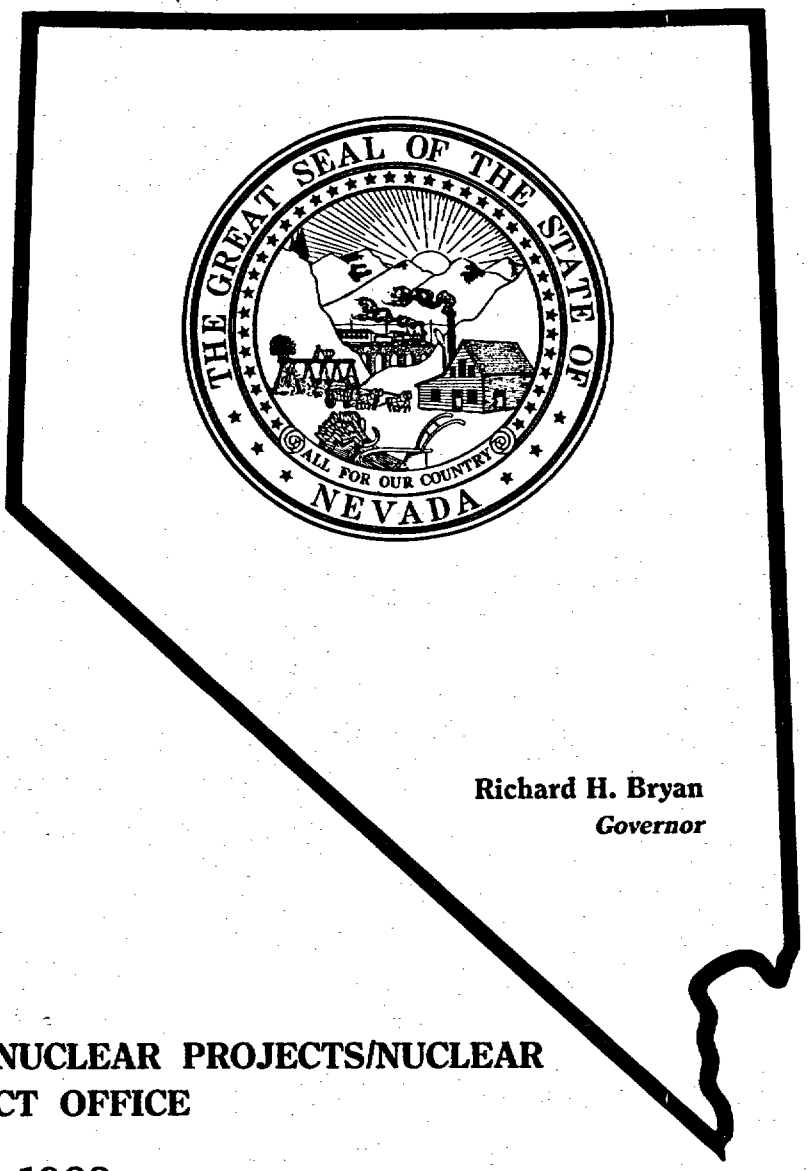
STATE OF NEVADA COMMENTS

ON THE

U.S. Department of Energy Consultation Draft Site Characterization Plan, Yucca Mountain Site, Nevada Research and Development Area, Nevada



Richard H. Bryan
Governor

COMPILED BY

AGENCY FOR NUCLEAR PROJECTS/NUCLEAR WASTE PROJECT OFFICE

SEPTEMBER, 1988

VOLUME I

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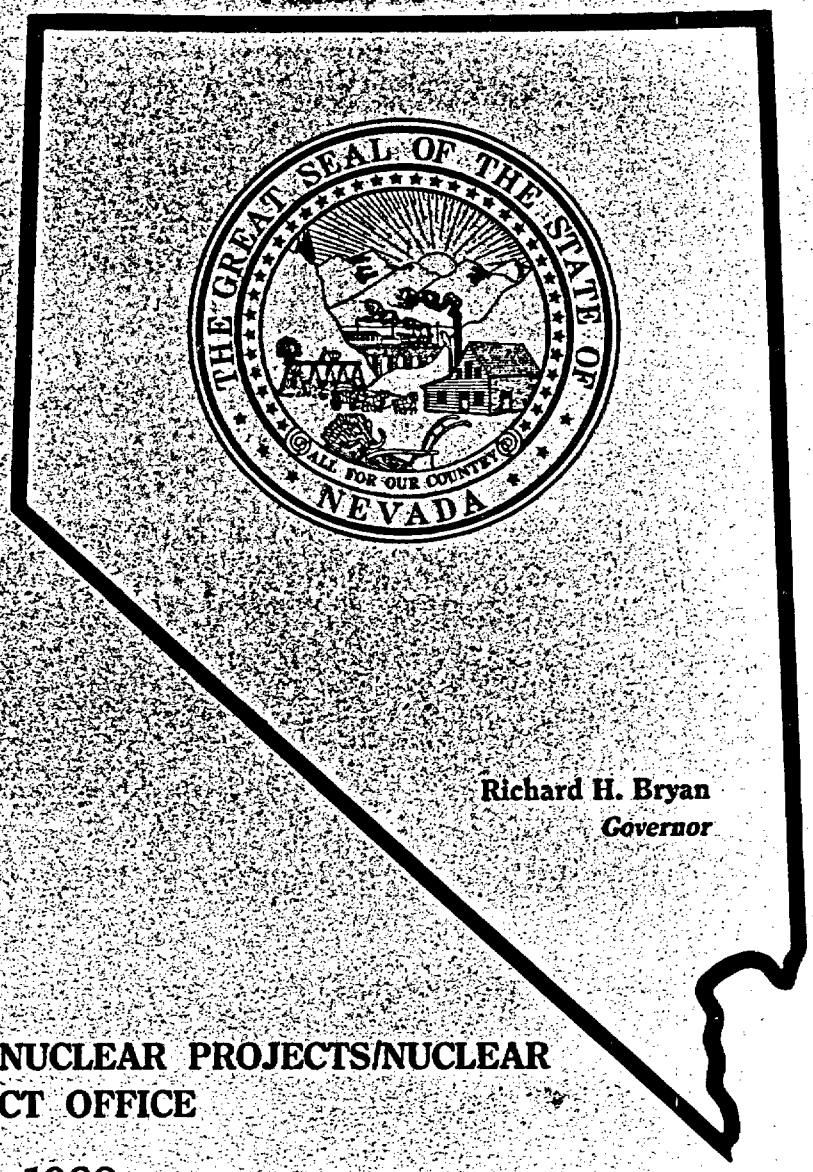

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VOLUME I

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Governor

STATE OF NEVADA

ROBERT R. LOUX
Executive Director

AGENCY FOR NUCLEAR PROJECTS
NUCLEAR WASTE PROJECT OFFICE
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September 6, 1988

C.E. Kay, Acting Director
Office of Civilian Radioactive
Waste Management
U.S. Department of Energy
1000 Independence Ave.
Washington, D.C. 20585

Dear Mr. Kay:

The State of Nevada has completed its review of the Consultation Draft - Site Characterization Plan (CD-SCP) for Yucca Mountain issued by the Office of Civilian Radioactive Waste Management (OCRWM) of the U.S. Department of Energy (DOE) in January. This document (Volumes 1 & 2) contains our comments for your review and consideration. We are pleased to have the opportunity to provide such comments on the CD-SCP and hope that you find them constructive and useful as you prepare the statutory Site Characterization Plan as required by Sec. 113 of the Nuclear Waste Policy Act (NWPA).

As you are aware, Sec. 113 (b)(1) of the NWPA requires the Secretary of Energy to submit to the Nuclear Regulatory Commission and the State of Nevada for review and comment:

A. a general plan for site characterization activities to be conducted at such candidate site, which plan shall include -

i) a description of such candidate site

ii) a description of such site characterization activities...

iii) plans for the decontamination and decommissioning of such candidate site...

iv) criteria to be used to determine the suitability of such candidate site...; and,

v) any other information required by the Commission

B. a description of the possible waste form or packaging for the high-level radioactive waste and spent nuclear fuel...; and,

C. a conceptual repository design that takes into account likely site specific requirements.

Considering the NWPA requirements for the content of a Site Characterization Plan, we find the CD-SCP to be statutorily deficient. In general, the description of site characterization activities is inadequate and incomplete, plans for decontamination and decommissioning absent, description of the possible waste form or package is nonexistent and the document does not contain a conceptual repository design.

The NWPA contains several other requirements regarding the issuance of the Site Characterization Plan and the initiation of site characterization activities. Sec 113(a) requires that the Secretary shall consider fully the comments received on the statutory SCP and shall conduct site characterization activities in a manner that minimizes any significant adverse environmental impacts identified in such comments. Sec. 113(b)(2) requires that before proceeding to sink shafts at any candidate site, the Secretary shall (A) make available to the public the statutory Site Characterization Plan, and (B) hold public hearings in the vicinity of such candidate site to inform the residents of the area, and to receive their comments.

The CD-SCP is not the statutory SCP required in Sec. 113 of the NWPA, and contains no discussion of environmental impacts. Further, the CD-SCP has not been released for public comment nor have public hearings been conducted.

Based upon the foregoing review of Sec. 113 regarding the Site Characterization Plan, it is clear that Congress intended that the Department of Energy not engage in any site characterization activities, including preparation to proceed to sink shafts until the statutory SCP has been released, public hearings conducted, and the public's and others' comments received and fully considered by the Secretary of Energy. Only then can DOE begin site characterization activities.

In August of 1987, when DOE initially announced plans for the release of a "consultive draft SCP for Yucca Mountain", the State of Nevada and the DOE reached agreement on several issues related to the State's review of the CD-SCP. First, Nevada initiated and requested a series of technical workshops on

issues. In addition, the State requested that the CD-SCP be a comprehensive, complete document containing study plans, the environmental program plan, environmental field activity plans, and environmental and socioeconomic monitoring and mitigation plans.

Despite a firm commitment from DOE that the CD-SCP would be a comprehensive document containing or accompanied by all of the aforementioned plans, DOE released the CD-SCP on January 8, 1988 without these plans, with the exception of the draft environmental and socioeconomic monitoring and mitigation plans. As of the writing of these comments, these plans have yet to be released. This makes a thorough review of the site characterization program impossible.

Without a reasonably complete set of detailed study plans and environmental program plans, it is impossible to adequately oversee and review DOE's proposed program for characterization of the Yucca Mountain Site. It is also impossible to adequately assess the complete impact of site characterization on the citizens and the environs of the State of Nevada. Therefore, the enclosed comments must be considered preliminary given the inadequacy of the current SCP document.

We believe the DOE's approach to site characterization should be reexamined and the SCP significantly revised before it can be viewed as a credible basis for evaluating the suitability of Yucca Mountain to host a repository. 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. It should come as no surprise that Nevada's expectations in this endeavor are that any repository site determined to be suitable must, first, be the best understood piece of geology on earth. To meet this requirement, nothing less than the most rigorous objective scientific research and investigation will be acceptable. If the site proves too complex to meet this goal, or if its natural waste isolation capabilities will be compromised by the techniques necessary for collection of subsurface information or the construction of underground facilities, this should be determined as rapidly and efficiently as possible in order to avoid wasting billions of dollars and a number of years in fruitless pursuit of a national nuclear waste repository at Yucca Mountain. The document as written fails to ask crucial site suitability questions, lacks the specificity required for an adequate and meaningful review, and, most importantly, attempts to cloud and obscure technical issues and divert attention from potentially disqualifying flaws.

Perhaps the most fundamental shortcoming of the CD-SCP is the implicit assumption that Yucca Mountain is, in fact, suitable for development as a repository. The CD-SCP reflects no focused, credible effort to examine, at any time during the site characterization program, potential disqualifying conditions which are well recognized to exist at the site. A major decision point must be established within the statutory SCP, to determine whether site characterization should continue or not. A "go no-go" determination should be made early in the site characterization program consistent with recommendations made to the DOE in 1979 about the Yucca Mountain site by the National Academy of Sciences.

In order to arrive at the expected and required level of knowledge and understanding of the site, the DOE's plan must take into account, in the most scientifically objective and rigorous manner, the complexity of the site and setting and the fact that the available data can lead to various interpretations of the geologic history and dynamics of the system of which Yucca Mountain is a part. It is only through a very carefully planned and comprehensive data collection effort, allowing for the emergence of a spectrum of alternative interpretations, that the future dynamics and effects of the system can be reasonably predicted and serve as the basis of a license application to the NRC. It is not the initial purpose of site characterization to simply seek to collect sufficient data to support a preconceived site suitability or repository design notion. The geologic barrier system and all geologic processes that affect it must be fully defined. If the competence of this primary barrier is judged suitable for long-term waste isolation, the design options and their effects on waste isolation can subsequently be evaluated. The enclosed comments demonstrate that serious flaws exist with the CD-SCP and with the DOE's entire approach to site characterization.

Our review of the CD-SCP suggests that (1) the Department of Energy has failed to recognize the complexity of the site; (2) the Department of Energy has made a determination that careful characterization is not necessary, nor perhaps desirable; and (3) the Department of Energy has failed to effectively develop and manage the required scientific program to confidently select and characterize the site. I urge you to re-examine the SCP and the Department's entire site characterization program.

Finally, the State of Nevada has reviewed the Nuclear Regulatory Commissions comments on the CD-SCP and find agreement with all of the issues which NRC has raised, including the need for DOE to have a fully qualified Quality Assurance Program in place prior to finalizing the design or initiation of the excavation of the exploratory shafts.

I trust that our comments will be taken in the constructive manner in which they are presented. My staff stands ready to meet with representatives of the Department of Energy to discuss our comments. I look forward to your response.

Sincerely,

Robert R. Loux
Executive Director

RRL:CAJ:ed

STATE OF NEVADA COMMENTS

ON THE

U.S. DEPARTMENT OF ENERGY CONSULTATION DRAFT

SITE CHARACTERIZATION PLAN

YUCCA MOUNTAIN SITE

NEVADA RESEARCH AND DEVELOPMENT AREA

NEVADA

PREPARED BY

NEVADA AGENCY FOR NUCLEAR PROJECTS/
NUCLEAR WASTE PROJECT OFFICE

SEPTEMBER 1988

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INTRODUCTION

In January 1988, the U.S. Department of Energy issued a consultation draft of the Site Characterization Plan (CD-SCP) for the Yucca Mountain Site. 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 present plans for decontamination and decommissioning of the site if it is determined not to be suitable for a repository. The consultation draft was issued by the Department of Energy to obtain early feedback on the approach, adequacy, and completeness of its plans to characterize the Yucca Mountain Site.

In January 1988 the State of Nevada informed the Department of Energy that a complete review of the CD-SCP could not be conducted because the CD-SCP as issued was not a complete document. The document did not contain study plans which describe in detail the individual technical study activities to be conducted, the environmental and socioeconomic program plans, and the plans for decontamination and decommissioning of the site. Therefore, the review comments contained in this document are restricted to the CD-SCP as issued. The comments are not based on a complete understanding of the project, and may be revised when a complete set of plans for the project is available. The comments presented here represent a review effort by the Nevada Agency for Nuclear Projects and its Technical Support Contractors and advisors.

Part I presents an overview of the comments contained in the document. 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 CD-SCP.

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

Part III of this document contains verbatim comments received from the Agency's Technical Contractors and advisors. These comments address issues and contain information not contained in Parts I and II. As such, these comments should be viewed as important in their own right -- not as appendices to the State's comment document.

PART I

OVERVIEW

PART I

OVERVIEW

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

In its fundamental approach, the CD-SCP can more accurately be described as a licensing document, rather than a plan for characterizing the site, for determining its suitability in the first instance as the location for a repository. The CD-SCP, and indeed the entire site characterization program, 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.

The Preface itself is enlightening in this respect. In discussing the process of consultation the draft says:

> "The DOE believes that the benefits of the consultation process would be maximized if the interactions focused on several key questions. For the NRC staff the key question is as follows: does the SCP-CD provide confidence that the DOE has adequately identified the issues and the kinds of information the NRC will need in its licensing decisions? The key question for the states and the affected indian tribes is how well the specific concerns have been identified and addressed." (Emphasis supplied) Vol. I, page clvi.

Nowhere does it say that a key issue for anybody is whether or not the Yucca Mountain site is suitable, or whether or not it is capable of isolating the nuclear waste. The Preface goes on to state, at page clvii:

> "The purpose of preparing such a comprehensive and detailed plan is to facilitate the review of the planned site characterization program by the states and affected indian tribes [and] (sic.) to obtain from the NRC staff input as to whether the program covered by the plan can be expected to be sufficient for eventual licensing." (Emphasis supplied).

Many of the detailed sections of the CD-SCP set out a program designed to gather the data necessary to design a repository that will attempt to comply with the applicable standards and regulations, not to determine whether one should be located at this site in the first place. This is evident from the outset. For example, in par. 1.0.3 the draft says:

"Tectonic data collected to date are insufficient for a full assessment of earthquake and volcanic hazards at Yucca Mountain. A key uncertainty is the location, length, and slip rates of Quaternary faults at and near Yucca Mountain. This uncertainty impedes reliable estimates of the magnitude, recurrence intervals, and ground motion from future earthquakes that are to be considered <u>in the design and performance of the repository</u>." (Emphasis supplied).

This is but one example of what seems to be a pervasive defect in the CD-SCP, and in the entire site characterization program.

Furthermore, the CD-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 CD-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 <u>early</u> in the program, before substantial, and perhaps unnecessary, resources are committed.

This is not a new concern. The State and the NRC have been consistent in making such a recommendation for some time. Those recommendations have, just as consistently, been ignored. In 1979 the Committee on Radioactive Waste Management of the National Academy of Sciences also urged the DOE to structure its program in this way. The Committee suggested "...that the explorations and investigations be conducted in a logical sequence so as to assure that certain fundamental questions be addressed first before major resources are committed."

Those fundamental questions remain unanswered. The State again urges the DOE to structure its entire site characterization program to diligently search for disqualifying information <u>first</u>, through an adequate surface-based testing program, before any further resources are committed to the exploratory shaft and, perhaps unneeded, underground testing program.

The DOE's fundamental approach is misguided for another reason as well. The SCP should not be finalized, and site characterization should not begin, until final comprehensive EPA standards are in place. Perhaps the best support for this position is the language of the CD-SCP itself.

In section 8.1.1.1 the draft sets out and discusses the issues hierarchy, saying:

"On the first, or highest tier there are four key issues, which embody the principal requirements established by the regulations governing geologic disposal. . . . The issues hierarchy, then, defines issues that must be resolved to demonstrate compliance with key regulatory requirements".

That section goes on to say:

"Key Issue 1 (post-closure performance) is derived directly from the post-closure system guideline (10 C.F.R. 960.1-4), which defines the general long-term performance requirements for the disposal system as a whole. These performance requirements reflect the general objectives of protecting the health and safety of the public and the quality of the environment; <u>they are based specifically on the standards promulgated by the Environmental Protection Agency (EPA) in subpart B of 40 C.F.R. Part 191 (EPA, 1985)</u>. . . .

Key Issue 2 (preclosure radiological safety) is derived from preclosure system guidelines (10 C.F.R. 960.1-5-1(a)(1)). <u>It requires compliance with the applicable requirements of the EPA standards in subpart A of 40 C.F.R. Part 191</u>. . . ." (Emphasis supplied).

In discussing the issues, within the issues hierarchy, the draft, on page 8.1-3, says:

"The issues are derived, in part, from the DOE citing guidelines in 10 C.F.R. part 960, from the NRC performance objectives and design criteria of 10 C.F.R. Part 60, and from the EPA requirements of 40 C.F.R. Part 191".

As is now known much, if not all, of the "existing data" which form Chapters 1 through 7 of the draft is unusable because it cannot be qualified under NRC quality assurance requirements. This is true of all the DOE generated "data" reported in Chapters 1 - 7, which form the foundation for the entire site characterization program outlined in Chapter 8. At a minimum a thorough, comprehensive and objective review of all of that information should be conducted. Any "existing data" which cannot clearly meet QA requirements should be discarded, Chapters 1 - 7 revised, and Chapter 8 rewritten to encompass studies designed to provide a comprehensive data base which meets all QA requirements.

The entire underlying framework for the CD-SCP which is hinged upon the presumption that indeed the Yucca Mountain site is suitable for development as a repository is not only wrong but demonstrates the lack of scientific process and methods which has permeated this program since 1979. Additionally, the CD-SCP does not comply with the intent of Sec. 112 and 113 of the Nuclear

Waste Policy Act. As has been well documented, the Department of Energy has in nearly every instance since the program began made concrete programmatic decisions without any scientific or technical data. Only after these decisions have been made, does the Department collect data, and then only data that support DOE's predetermined view of the site. The CD-SCP is a continuation of this process, where the assumption that Yucca Mountain is suitable has already been made in the absence of any credible scientific data. The site characterization program as laid out in the CD-SCP is an exercise to only collect data that support DOE's predetermined view of Yucca Mountain while a subsurface and surface facility is being designed.

This type of pre-judged decision making without supporting data has been the subject of criticism of the program since the beginning by all parties and suggests that very little, if any, portion of the program is based in credible science or technical merit. The fact that DOE has, in essence, determined that Yucca Mountain is suitable in the absence of the EPA standards, which the site must meet, is a further example of the lack of any meaningful scientific processes or method.

LACK OF ALTERNATIVE CONCEPTUAL MODELS CONSIDERATION INVALIDATES THE CD-SCP.

Since release of the CD-SCP, there has been considerable comment and discussion on the matter of the document failing to consider a range of alternative conceptual models (working hypotheses) of the Yucca Mountain site geology and geohydrologic setting. Furthermore, it does not establish a site testing program that would lead to an evaluation of alternative conceptual models that could be consistent with site data, were such an objective included in the CD-SCP.

The NRC, USGS (Headquarters), State of Nevada, and Nevada geotechnical contractors have reviewed, commented upon, and discussed this matter with the DOE, and appear to be in general agreement with the conclusion that the CD-SCP is deficient in that the plan does not provide a basis, from site testing, for predictive performance assessment where uncertainty exists, as required by the NRC's 10 CFR 60. The CD-SCP appears to have adopted, and seeks to defend a single, simplified model of the site that largely ignores the need for thorough investigation of a range of coupled geologic and hydrologic processes and events and their potential significance to waste isolation.

In order to resolve this major deficiency in the CD-SCP, extensive and integrated revision is necessary to incorporate an appropriate range and sequence of testing necessary for determining site suitability for waste isolation and support a license application.

DOE'S "REASONABLY AVAILABLE TECHNOLOGY" CONSTRAINTS HAVE NOT BEEN MET.

The CD-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, 960.5-2-11(d)).

A notable example of a general field of technology necessary for site characterization in which there is considerable concern about the ability of available technology to provide needed data from the Yucca Mountain site is geophysical exploration. Efforts to acquire certain necessary data from depth at Yucca Mountain, using available seismic reflection techniques, have provided no useful results, and it is likely that further, possibly extensive research and development in geophysical techniques will be necessary in order to resolve subsurface issues in the Yucca Mountain setting. This concern regarding geophysical techniques is further evaluated in NRC NUREG/CR-4957 (July 1987): Survey of Geophysical Techniques for Site Characterization in Basalt, Salt and Tuff.

The CD-SCP does not provide specific information on how this matter is to be resolved, nor does it acknowledge that 1.) new techniques that may be developed would likely require, for purposes of validation and verification, core and borehole data from the repository block, resulting in additional boreholes that may adversely affect waste isolation (a concern expressed in NRC's 10 CFR 60.15(d)); 2.) if it is determined that existing or newly developed geophysical techniques cannot provide valid data needed for licensing, an alternative might be to drill and core a large number of boreholes in and around the site to acquire the needed stratigraphic, structural and other data (although this, too, may be unacceptable in view of 10 CFR 60.15(d)).

Other examples of fields in which reasonably available technology likely will not provide the necessary valid data for a license application at the Yucca Mountain site are comprehensive borehole logging and collection of fluids from boreholes in the unsaturated zone. Again, a program of research and development, validation and verification will probably be necessary in advance of collection of valid data from the Yucca Mountain site, yet specific recognition of this need and plans for such activities are not included in the CD-SCP.

SYNOPSIS OF SPECIFIC COMMENTS

LICENSING

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 CD-SCP provides for neither of these requirements.

The CD-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 schedule is ambiguous and vague. Much of the critical information (e.g. design earthquake, matrix vs fracture flow beneath the repository, amount of offset to be expected in the repository, etc.) will not be available until the License Application Design (LAD) is almost completed (Fig. 8.5-3, p. 8.5-80A; Fig. 8.5-4, p. 8.5-86).

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. For example, active faults within 100 km, but not within the site, are only to be studied 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 of seismicity.

The concept and use of the 10,000 year cumulative slip earthquake is unacceptable. This type of seismic source characterization is unconventional, unrealistic, misleading, and non-conservative. First the CD-SCP states that the 10,000 year event "can be determined with greater confidence than a true maximum magnitude." This may be incorrect, because additional input parameters and uncertainties are involved in the estimation of the 10,000 year event as compared to the maximum earthquake estimate. Second, the CD-SCP argues that "low slip-rates suggest that the use of fault length or displacement to develop deterministic estimates of magnitude for a given fault are misleading." The analysis of faults with low slip rates (or longer recurrence intervals) may incur larger uncertainties but this does not render the analysis meaningless or "misleading". Third the CD-SCP states that, "Use of slip-rate data (to constrain recurrence times) in conjunction with more conventional fault data provides added assurance that adequately conservative assessment of the local seismogenic potential will be accomplished". This is a fuzzy statement which appears to imply, incorrectly, that the use of a maximum earthquakes is overly conservative in most local source scenarios since the duration of "cumulative slip" of these events would be longer than 10,000 years.

There are two additional reasons for not considering the 10,000 year event as conservative. First, the 10,000 year event estimation is completely dependent on long-term averages. Recent work, however, has shown that fault activity in the Basin and Range Province and other regions commonly exhibit spatial and temporal clustering events. Averages and recurrence intervals over short-term periods can be greatly different that those over the long term. Second, considering historical earthquakes in Nevada that have involved several faults rather than a single fault, a seismic source estimation of a single fault may actually underestimate potential seismic hazards.

A primary flaw of the CD-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 events, 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. 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 systems, 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 sections 1.7 and 1.8 is built on incomplete, outdated, often inaccurate and misleading information and is wholly inadequate.

The proposed characterization 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. 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 hydrocarbon and geothermal potential will also remain untested without deep drilling in the controlled area or the repository block.

ROCK MECHANICS

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 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

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 purposes.

The details of analytical methodologies and technical procedures is often inadequate. There is a lack of detail about the needed collection of representative water samples from different tuff strata. More detail is necessary on the effect of filter size, the redox potential, and analytical quality for proper assessment of 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 experimental methodologies are proven and meaningful field data are collected.

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 as quickly as possible.

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 scientifically valid confidence. 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 is the case for the topics 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. It appears that this has occurred, i.e. the DOE has omitted 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 DOE's conceptual model incorrectly emphasizes vertical recharge through the top of Yucca Mountain. Recharge is assumed to be uniformly distributed throughout the proposed boundary area of the repository. Also, recharge is 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 low and variable. However, 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. Beneath and east of the repository area the hydraulic gradient is very low. The reasons for the high gradients are unknown. One effort is planned that may provide an explanation of the gradient in the west. No testing is planned to study the gradient in the north, which is greater than the gradient in the west.

The current 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 predominates over fracture flow in the unsaturated zone 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 one of the most important barriers to the release of radionuclides to the environment. In fact, based on the very limited and questionable suction-head data available from well UZ-1 for the various rock units, these tuff units are most likely effectively saturated and therefore fracture flow should be predominant. The adopted estimate of the vertical ground-water flux for performance assessment studies is inconsistent with the recharge flux information available from published data.

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.

Air and water vapor migration in the unsaturated zone is not adequately addressed. These processes may lead to the discharge of radionuclides to the immediate surface environment. The CD-SCP deals entirely with travel time from the repository to the saturated ground-water system, and ignores this other likely process. The possibility of upward vapor migration has been suggested in Montazer and Wilson (1984), but no research is proposed to study the impacts of such processes on gaseous radionuclide migration.

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 reduce the travel time when compared with bulk

ground-water travel-times. 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 the field results. Additional work will also be needed in model development of transport in both saturated and partially-saturated, fractured tuff.

The CD-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 to a coherent picture of the affects of disturbance.

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 to develop or apply models that produce good agreement between the aquifer test data and the type curves.

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.

SEAL PROGRAM

The program 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.

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 time schedules that indicate decision points which would allow reevaluation of the site characterization process and possible redirection or termination of research.

At the beginning of Section 8.3.5.13 the assertion is made that a complementary cumulative distribution function (CCDF) will be evaluated, but in the ensuing analyses the emphasis is on the evaluation of the expected partial performance measure (EPPM). This section should be revised, and must conform with the NRC's outline for implementing performance assessment relative to total system performance.

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

CHAPTER 1. GEOLOGY

Specific comments

Page 1-252. 2nd paragraph

It is indicated that water produced from USW VH-2 has been used for nearby milling ponds for gold ore that was mined at Bare Mountain. This subject should be discussed in greater detail in chapter 3, Hydrology, because Crater Flat is part of the sub-basin that includes wells J-12 and J-13 and because gold mining at and nearby Bare Mountain will expand significantly in the coming years.

Page 1-253. 3rd paragraph

Statement: "Drillhole UE-25p#1 was drilled through the Tertiary volcanic rocks in the repository area to investigate the Paleozoic rocks beneath the repository site and to study the hydrologic flow characteristics of these rocks." Drillhole UE-25p#1 was drilled into the upper layer of the Paleozoic rock. There is no deep drillhole that investigated the entire thickness of Paleozoic rock and permitted a detail hydrology study of the formation. The DOE has no plans for drilling deep boreholes (down to pre-Cambrian rock) to investigate the Paleozoic formation.

Page 1-305. 4th paragraph

The geothermal system in the vicinity of Yucca Mountain is discussed. There is no mention of drillholes USW G-1 and USW G-2 which according to Figure 1-60 could have potential as geothermal resources.

Page 1-319. 2nd paragraph

Statement: "In summary, no Paleozoic rocks in the area or from drill core (UE-25p#1) have been reported to contain significant organic matter." Drillhole UE-25p#1 does not penetrate very deep into the Paleozoic formations and should not be used as a reference for such a broad statement.

CHAPTER 3. HYDROLOGY

Specific comments

Page 3-71. Paragraph 3

The need for additional work on recharge mechanisms and rates is emphasized. Forty Mile Wash is singled out as a possible recharge area during flooding events. Recharge in the Amargosa Valley during flooding events may be equally as important to the elevation of the water table as recharge through Fortymile Wash. Should the Fortymile Wash investigation indicate an important recharge mechanism through highly transmissive stream-channel sediments, then a similar investigation should be considered in the Amargosa Valley.

Page 3-130. 2nd paragraph

The preliminary estimates of the quantity of water needed to construct the exploratory shaft are discussed. There should be also a discussion of the water needs for dust control of roads and drilling pads as well as water needs for other field activities of site characterization.

Page 3-156. Table 3-24

The water table elevation measurements reported in the table were all made near the end of 1983. More recent data should be presented since such measurements are an on-going activity and the SCP is dated January 1988.

Page 3-157. Table 3-24

The altitude of the water table for well J-13 is given as 728.1 m while in Figure 3-28 the altitude is given as 728.3 m. Furthermore, well J-13 is a continuously producing well and therefore very questionable for measurements of the water table altitude.

Page 3-172. 2nd paragraph

The following statement is made: "One principal objective of the bulk-permeability test, which is to be performed within the exploratory shaft as described in Section 8.3.1.2.2.4, is to field test the REV hypothesis as it may apply to the fractured Topopah Spring welded unit at the potential repository horizon."

It must be emphasized that section 8.3.1.2.2.4 does not contain an activity that will analyze specifically all the data and verify or disprove the REV hypothesis. The testing of the REV hypothesis is mentioned as a part of activity 8.3.1.2.2.4.2 which describes infiltration tests in the exploratory shaft facility.

The following statement is made on page 8.3.1.2-197: "The exploratory shaft model will also be used in concert with simulations and data from other exploratory shaft tests (i.e., intact fracture and bulk permeability tests) to define the representative elementary volume (REV)." Activity 8.3.1.2.2.4.3 which describes bulk-permeability tests does not mention testing the REV hypothesis. The milestone table on page 8.3.1.2-288 does not single out the issuance of a report on the REV hypothesis. For the saturated zone, the REV hypothesis is mentioned in activity 8.3.1.2.3.3.2, which discusses the development of a fracture network model.

Also, should the REV hypothesis be proven to be valid, then measurements will be necessary at several locations since it is to be expected that the REV will vary laterally and vertically throughout Yucca Mountain.

Page 3-214. Section 3.9.4.1

The pre-waste emplacement ground-water travel times as calculated by Sinnock et al[1] are discussed. Unlike the first ground-water travel time study[2] by Sinnock et al, it is not a parametric study. Rather, it appears to be a test of a new, uncertified computer code. Ground-water travel times are calculated only for two values of the percolating flux, 0.5 and 1.0 mm/yr respectively. The distributions of ground-water travel times reflect primarily the distribution of rock thickness from the repository horizon to the water table. Variations due to fluctuations in porosity and hydraulic conductivity are masked by the distribution of rock thickness. The earlier study[2] had indicated that fracture flow would become important for a flux of about 1 mm/yr. The referenced study[1] does not indicate any significant effect attributable to fracture flow for a flux of 1.0 mm/yr. Another study by Sandia also has indicated that the ground-water travel time decreases markedly[3] when fracture flow becomes important. No attempts seem to have been made to determine the onset and the effect of fracture flow on the ground-water travel time. The code and its methodology may not be valid should the REV hypothesis turn out to be correct.

Page 3-226. 2nd paragraph

Statement: "Pumping tests performed after 1968 on well J-13 produced drawdowns of less than seven meters with pumping rates in excess of 3,500 m^3/d (Table 3-33)." It must be pointed out that the tests referenced were of short duration, 5 and 4 hours respectively. Longer pumping tests are necessary to provide more confidence in the data.

CHAPTER 4. GEOCHEMISTRY

Specific comments

Page 4-3. 2nd paragraph

Statement: "Natural systems and large-scale field tests (Section 4.3) are also being studied to provide information over longer times and larger distance than can be obtained in the laboratory."

Actually, field test and analogue studies are deferred to the distant future in chapter 8. The following statements are made: page 8.3.1.3-125, 4th paragraph, "Ultimately, field testing may be the only way to establish the applicability of laboratory data to repository transport calculations." Same page, 5th paragraph, "several field-scale studies are already described in Chapter 8. Section 8.3.1.2.1.5 through 8.3.1.2.1.8 describe testing of the C-wells with both conservative and reactive tracers. These tests are in the saturated zone and will be used to measure the physical and chemical properties of the geological media in the saturated zone that will affect retardation in the Yucca Mountain vicinity." These tests are meant to be hydrological studies and to provide data on travel time. The experiments may not provide useful geochemical data. Also, it may not be possible to extrapolate to transuranics which may travel primarily as colloids. Again page 8.3.1.3-123, 6th paragraph: "A field scale test outside of the exploratory shaft in an area where the potential host rock is near the surface, such as Fran Ridge, could provide useful information." Early monthly progress report of the Yucca Mountain project indicate that DOE intended at one time to perform field tests at Fran Ridge. Now the subject is discussed in the form of an "if" statement. Page 8.3.1.3-124, paragraph 2: "An alternate approach or concurrent approach to large scale field tests is to study natural analogs. The study of natural analogs to radionuclide migration has not been given attention in this program because these environments typically have chemistry and mineralogy radically different from the potential candidate site."

Page 4-36. 1st paragraph

Statement: "Mineral stability in Yucca Mountain must be considered in two ways. The first is to consider whether the present mineral assemblages in Yucca Mountain are stable under present conditions and, if they are not, what mineralogy changes are probable. The second consideration is what effect repository heating will have on mineral stability, due to both increased temperature and possible dehydration of the rock." The construction of the repository and the chemical leachant from the spent fuel may alter the chemistry of the water flux which may affect the mineral stability.

Pages 4-110 - 4-113. Figures 4-16 and 4-17

Reference is made on these figures to a report authored by Vaniman, dated 1987. The report has not been provided to the State with the issuance of the CD-SCP (no copy can be found among the references sent along with the SCP).

CHAPTER 5. CLIMATOLOGY AND METEOROLOGY

Specific comments

Page 5-45. Paragraph 1

It is pointed out that the data of Figure 5-10 can be subjected to spectral analysis which often provides better insight in cyclic parameters. Figure 5-10 provides water level data for the Great Salt Lake over the past 140 years. Spectral analysis cannot be applied to the data in Figures 5-16, 5-18, and 5-21 which portray relevant data for predicting the climate changes in great detail for the next 50,000 years. The DOE is overly optimistic in indicating that spectral analysis is an important tool in the prediction of future climate at Yucca Mountain.

CHAPTER 6. CONCEPTUAL DESIGN OF A REPOSITORY

Specific comments

Page 6-71. 6th paragraph

The need for dust characterization data is emphasized, but no activity for collecting the data is referenced. The need for dust data is also emphasized in section 8.3.2 but again no activity is referenced. Section 8.4, which summarizes the ES construction and experiment activities also fails to indicate the collection of dust data. The collection of data on dust generation rates is contained in activity 8.3.1.15.1.8.4, which emphasizes that the experiments have not been finalized and may change.

Page 6-73. 3rd paragraph

The PRSA method employed in Appendix F of the SCP-CDR is referenced and summarized in Section 6.1.4 of the CD-SCP. An analyses for the source term following an accident is contained in Section 5 of Appendix F of the SCP-CDR, which deals with dose consequence analyses. The emphasis is on developing a source term following the dropping of a loaded shipping cask from a height of about 40 feet. There is no attempt to develop a source term following a fire involving a spent fuel cask. The

analysis in Section 5 of Appendix F for the pulverization factor relies entirely on data of an R&D program at Argonne National Laboratory that appears to have been terminated prematurely and that may not be applicable to spent fuel elements. The following short-comings are noted in the pulverization factor analysis:

1. The experiments involved UO_2 pellets which were considerably smaller than spent fuel elements. Formula 5-1 is temperature independent. It is not clear whether the experiments were conducted with samples at room or at an elevated temperature. The UO_2 in the spent fuel element will be at an elevated temperature of a few hundred ^{o}C. The interior of the shipping cask will be at an elevated temperature. Higher releases should be expected at higher temperatures. There is at least one transportation accident in which the interior of a DOE spent fuel shipping cask was severely contaminated because of an error in the decay heat estimate. At the very least, the effect of temperature should be mentioned either in the form of data or in the form of an assumption.

2. In the discussion on the energy partition factor, it is pointed out at the bottom of page 5-24 that the UO2 tests and correlations at Argonne were established with small, bare specimens that had a uniform energy density and that large complex spent fuel assemblies or DHLW canisters will not have uniform energy densities from impacts. It should be pointed that non-uniform energy densities from impacts may bring about higher releases. In fact, part of the kinetic energy of the canister and the shipping cask may be transferred to pulverizing the spent fuel. The shipping cask is ten times as heavy as the spent fuel load and can provide very large amounts of energy for the break-up of the spent fuel. A good example is the 55-gallon drum which is certified as a type A package for the transportation of low level waste. Experiments have shown that the 55-gallon drum by itself will survive the tests required for certification of type B packages. However, 55-gallon drums arranged in 6-packs or inside a large container such as the TRUPACK will pop open when the entire package is subjected to a drop, puncture test, or fire test. The use of an energy partition factor in the SCP-CDR may not be conservative.

3. The analysis seems to be eager to reduce the source term because of gravitational settlement. The analysis ignores completely the effects of re-suspension which are significant in a well ventilated system. For respirable particulate (less than 10 μ aerodynamic diameter), re-suspension may cancel the gravitational settlement. The generic doses presented in Figures 5-9 through 5-11 may be underestimated.

Page 6-92. Figure 6-18

The steps in fuel consolidation are illustrated. Much emphasis is made in chapter 6 that waste handling building 2 will include fuel consolidation. Actually, some nuclear power plants will be forced in a few years to introduce fuel consolidation techniques in their storage facility. Therefore, some fuel rods can be expected to be shipped to Yucca Mountain in consolidated forms. Also if a Monitored Retrievable Storage (MRS) facility is constructed, fuel rod consolidation could be accomplished there.

Page 6-125. Figure 6-48

The central surface facilities area is illustrated. The illustration includes the performance confirmation building which is not described in chapter 6 of the SCP but in the SCP-CDR. It should be pointed out that the performance confirmation program is meaningful only for vertical emplacement where all the canisters can be retrieved. For horizontal emplacement, only the canister nearest the end-plug can be retrieved for confirmation inspection. The other canisters cannot be removed without removal of the preceding canisters closest to the end-plug.

Page 6-194. 5th paragraph

Statement: "If waste emplacement operations are in progress, the waste-handling building is expected to be in operable condition. However, the current planning basis is that the building will not be constructed for reverse operations for full retrieval, and, therefore, extensive modifications and additional construction would be necessary to accomplish full retrieval. In the current plan, the equipment located in the waste-handling building will not be maintained in an operational state during the caretaker period." The statement clearly indicates that the facility is not built for retrievability. This should be emphasized in sections that discuss retrievability. The construction period for modification of the waste-handling building should be shown in figures like figure 6-84. The cost of the modifications should be estimated to properly assess the feasibility of retrieving the waste.

Page 6-292. 3rd paragraph

The potential hazard to excavation workers is discussed. Emphasis is made that the NTS tunneling operations have a significantly better safety record that the industry average. Such a comparison is specious because the tunneling operations at Yucca Mountain will be different from those in the weapon testing areas. At Yucca Mountain, a commitment has been made to minimize the water usage. Hazard for the inhalation of dust may be significant and may force changes in the mining procedures. Horizontal boring for emplacement holes, an unproven technique, may be more hazardous than vertical boring because it can be expected to produce very large amounts of fine dust.

Page 6-342. 1st paragraph

The cost of the repository is briefly summarized with reference to table 6-38. It should be pointed out that such data for site characterization cannot be found in the SCP. Also, the SCP does not contain any cost data for retrievability.

CHAPTER 7. WASTE PACKAGE

General comment

The chapter fails to mention that the waste packages produced by the Savannah River and West Valley will be certified by the NRC before the waste package research program is completed. It may be necessary to use an overpack for these packages. Fractional releases from spent fuel, which include colloid particles, are discussed in section 7.4.3.1.1, but there is no effort to predict a colloid source term. Great emphasis is placed on the EQ3/6 code, which does not include colloids, in the modeling studies for the source term.

Specific comments

Page 7-16. 3rd paragraph

Statement: "Maximum temperature of the waste forms must be maintained below limits established for them. These limits are 500 °C for West Valley (WV) and Defense High-Level Waste (DHLW) glass and 350 °C for spent fuel cladding." No reference is made to experiments that will ensure that these limits can be achieved or maintained. The subject is again reemphasized at the top of page 7-19 as follows: "The waste package as an entity will be designed to control the internal temperature to less than the limits under anticipated post-emplacement conditions." Again, no reference is made to waste acceptance criteria that will ensure that the limits can be achieved.

Page 7-125. 3rd paragraph

The fractional release data of table 7-16 are discussed. It is mentioned that the releases also include suspended particles or colloids. The chapter does not make reference to modeling studies that will be able to predict the fractional releases, which probably represent the true source term. The SCP should include studies attempting to predict fractional releases.

Page 7-134. 2nd paragraph

Statement: "The link between the laboratory data and the expected repository performance comes through geochemical

modeling calculations. The EQ6/3 geochemical modeling code is being used for this purpose." The EQ6/3 code is capable only of modeling dissolution studies, it is not capable of modeling the release of colloids which is important in the source term for transuranics.

Page 7-140. 3rd paragraph

Statement: "The result of previous studies of spent fuel and UO_2 oxidation clearly indicated that there are substantial differences in the oxidation kinetics of various fuel types and especially between irradiated and nonirradiated fuel." This comment stimulates the following question: how will the DOE obtain data for the high burnup spent fuel which will be discharged by nuclear plants in the next two decades?

Page 7-208. 6th paragraph

Statement: "The waste form alteration model will calculate the annual quantity of each radionuclide converted into mobile form. The mobile forms are assumed to be solutes in water, carbon-14 in the form of carbon dioxide, and noble gas radioisotopes." It is inferred that the DOE does not consider colloids and suspended particles as mobile forms.

CHAPTER 8. SITE CHARACTERIZATION PROGRAM

SECTION 8.3.1.2. GEOHYDROLOGY

Specific comments

Page 8.3.1.2-58. 1st paragraph

Statement: "Partial validation of the models will be accomplished through a combination of peer review and comparison of model predictions with laboratory experiments, field experiments, and natural analogs." The phrase peer review should be further defined. Will it involve only DOE contractors or will independent outsiders also be included?

Page 8.3.1.2-86. 3rd paragraph

It is indicated that potentiometric level in the Amargosa Desert will be obtained in boreholes of a mining company. The paragraph should also make reference to the application of DOE QA procedures to boreholes not owned by the DOE. Also, Figure 3-1, which is referenced for the location of the boreholes, shows the entire hydrographic study area for the Yucca Mountain repository. The SCP should be more precise in indicating the location of these boreholes.

Page 8.3.1.2-96. 1st paragraph

Statement in reference to hydrochemical tests and analyses: "The usefulness and applicability of [sic.] uranium-series disequilibrium analyses will be evaluated; if determined to be appropriate, these analyses will be done." The activity under which analyses will be evaluated should be referenced. The schedule of the study should also be referenced. Uranium-series disequilibrium measurements will have to be carried out to support the water sampling of the environmental monitoring program.

Page 8.3.1.2-120. 5th paragraph

Preliminary studies on the selection of the most appropriate infiltration-related hydrologic measurements are briefly discussed. The activity under which the discussed preliminary studies will be carried should be referenced so that it is easier for the reader to follow the time schedule and the relationship to other experiments.

Page 8.3.1.2-124. 1st paragraph

Artificial infiltration tests that will include ponding tests are discussed. Ponding tests should be carried out also over fault areas such as Fortymile Wash.

Page 8.3.1.2-168. Activity 8.3.1.2.2.3.3

This activity discusses the Solitario Canyon horizontal borehole study. The boreholes will be located in an area indicated in Figure 6-88 as expansion area 2EA. The effect of the horizontal boreholes on the integrity of the expansion area should be discussed. The applicable section of the borehole sealing program for sealing these boreholes should be referenced.

Page 8.3.1.2-181. 2nd paragraph

It is indicated that neutron logging will be used to measure the moisture content in horizontal boreholes in the experimental shaft facility. This is a speculative activity because the table on page 8.3.1.2-200 indicates that the procedure manual as well as the calibration manual for measuring moisture content using a neutron moisture meter in horizontal holes have yet to be done. This appears to be a new logging technique that has to be demonstrated to be feasible and for which the tools have yet to be developed.

Page 8.3.1.2-227. 4th paragraph

It is emphasized that neutron surveys will be conducted in the radial boreholes during construction of the shaft to determine

whether excavation or shaft lining change the moisture content of the host rock. The possibility of horizontal neutron logging has already been questioned. Performing neutron surveys in the experimental shaft during excavation is also questionable since large quantities of water will have to be used for dust control. Perhaps a pilot program should be considered before making a commitment to such procedures.

Page 8.3.1.2-238, 2nd paragraph

Statement in reference to excavation tests in the exploratory shaft facility: "The model that gives the best match between the measured and computed stresses and permeabilities will be used to predict disturbances around other openings within the repository." The statement indicates a reliance on curve fitting procedures. It will be necessary to show that the curve fitting can be used for extrapolations.

Page 8.3.1.2-242, 3rd paragraph

The desire to construct a drift from the Calico breakout room to the Ghost Dance fault is indicated. There should be a statement regarding when such a decision will be made and what criteria will be used in making the decision.

Page 8.3.1.2-298, Activity 8.3.1.2.3.1.1

The activity that will determine the nature of the Solitario Canyon fault and whether it is a barrier to eastward movement of ground water through the repository block is discussed in detail. A similar activity is necessary to analyze and understand the hydraulic gradient to the north and north east as shown in Figure 8.3.1.2-23. The SCP appears to avoid such an activity.

Page 8.3.1.2-316, Activity 8.3.1.2.3.1.4

Multiple-well interference testing program to be conducted in the C-hole complex is discussed.

The two producing wells, J-12 and J-13, may influence the testing program. The method of dealing with this perturbation should also be discussed.

SECTION 8.3.1.3. GEOCHEMISTRY

General comment

Beginning on page 8.3.1.3-101, there are at least 8 activities for which the methods and technical procedures have to be developed. This adds a great deal of speculation to the SCP since many of the experiments may not yield data which allow

conclusive statements. There should be a qualitative statement on the alternatives should the activities fail to produce meaningful data.

Specific comments

Page 8.3.1.3-60. 1st paragraph

Statement: "Experiments that may be conducted at a later time if a strong technical need is recognized, are sorption experiments as a function of atmosphere (CO_2)." A recent draft generic technical position paper of the NRC[4] indicates that such experiments should be planned now. The following statement is contained in the draft GTP: "The scenarios for anticipated processes and events for the post-closure should conservatively reflect modifications to the projected climatic trend, resulting from such phenomena as the greenhouse effect, if the climatic model assumed in the analysis warrants consideration of such effect."

Page 8.3.1.3-103. 1st paragraph

An activity which studies the movement of tracers through naturally fractured Yucca Mountain cores is described. This activity can, at best, study the movement of tracers through small fractures with sizes smaller than the dimensions of the core. No activity is described that studies the movement of tracers through large fractures or faults.

Page 8.3.1.3-121. 2nd paragraph

The terms code verification and code validation are defined. On the following page, six codes that will be used to support transport models are presented. The status of the validation and verification of the codes should be mentioned.

8.3.1.4. ROCK CHARACTERISTICS

Specific comments

Page 8.3.1.4-19. Table 8.3.1.4-2

The table indicates that the deepest holes to be drilled will have a depth of 5,000 feet. The deepest existing hole has a depth of slightly more than 6,000 feet. The DOE does not indicate an intent to characterizing the carbonate aquifer and to test for natural resources in the older rocks beneath Yucca Mountain.

Page 8.3.1.4-60. 3rd paragraph

Statement: "A suite of commercially available geophysical logs will be obtained in future holes drilled in the vicinity of Yucca Mountain." How will the DOE make commercially available logs comply with its QA procedures? This should be indicated in the table on page 8.3.1.4-62.

Page 8.3.1.4-76. Figure 8.3.1.4-11

The proposed layout of the exploratory shaft and drifts differs significantly from the layout illustrated in figure 8.4-30. It is clear that the exploratory shaft facility had not been designed at the time of issuance of the CD-SCP.

SECTION 8.3.1.5. CLIMATE

Specific comments

Page 8.3.1.5-28. 2nd paragraph

One of the objectives of activity 8.3.1.5.1.2.1 is to reconstruct the past 50,000 years in great detail. The most extensive data for the last cycle are presented in Figures 5-16, 5-18, and 5-21 in the form of chronologies of the elevation of lake surfaces. The figures provide data for a time span of about 25,000 years. Furthermore, it is a matter of judgement whether the figures include much detail. It is doubtful that the DOE can extend the data for another 25,000 years and add more detail to them.

Page 8.3.1.5-72. 2nd paragraph

Statement at the end of the paragraph: "As a result, numerical approaches to the prediction of future climate may be required to supplement the empirical methods." The statement should be amplified by mentioning the parameters that will be important in the numerical approaches.

Page 8.3.1.5-80. 1st paragraph

Five factors are listed for the altitude of the water table beneath the repository block. The discussion fails to mention tectonic events which were recently emphasized in the J. Szymanski report. The effect of tectonic processes and events on changes in the water-table elevation is the subject of activity 8.3.1.8.3.2.

SECTION 8.3.1.8. POSTCLOSURE TECTONICS

General comments

The activities on volcanic intrusion often make reference to the dated study of Link et. al[5]. The study has many biased assumptions which suggest that it was an attempt to minimize the consequences of the volcanic intrusion scenario. The Link study assumes that the area of the repository is smaller than that of the present conceptual design. There should be an indication that the Link study is only of historic value and that the DOE will start anew with a more elaborate analysis.

Specific comments

Page 8.3.1.8-37. 2nd paragraph

It is pointed out that three factors enter into the estimation of the probability of volcanic activity in the Yucca Mountain area. It must be emphasized that there is no analytical formula for estimating volcanic activity. The probability value is estimated from empirical plots of magma volume/time, petrologic patterns through time, and decreased volume versus increased eruptive frequency.

Page 8.3.1.8-78. 3rd paragraph

Statement: "This activity will also review the available literature for evidence of water-table changes during volcanic events in other parts of the world that are analogous to the types of events that might occur in the vicinity of the site." The review of the available literature can at best produce a few theoretical concepts that can be applied to the Yucca Mountain site. In order to apply the data to the Yucca Mountain site the geology will have to be similar, which is unlikely.

Page 8.3.1.8-80. 1st paragraph

Statement: "Field evidence from the site will be reviewed to determine if there is any evidence of past water-table fluctuations that may be related to tectonic events." The techniques used to determined water-table fluctuations should be described. The techniques are not mentioned in the method and technical procedures table at the bottom of page 8.3.1.8-80.

Page 8.3.1.8-104. 2nd paragraph

Statement: "The anomaly sites will be drilled and continuous core recovered from the drillholes. Data from this work will be used to refine probability calculations, to evaluate the tectonic setting of volcanic centers, and to test concepts of the temporal geochemical patterns of basalts in the NTS."

The analytical methods that will be used to refine the probability calculations should be detailed or referenced. It is difficult to imagined how three cored drill holes will help reduce significantly the numerical value of the probability of a volcanic event at Yucca Mountain.

SECTION 8.3.1.9. HUMAN INTRUSION

Specific comments

Page 8.3.1.9-16. 4th paragraph

Reference is made to the probability of inadvertent human intrusion and interference.

For the Yucca Mountain site, the probability of destruction of site markers as a result of military exercises after the site is abandoned may not be insignificant. This scenario should at the very least be evaluated and shown to be not significant.

Page 8.3.1.9-24. 5th paragraph

Statement at the bottom of the page: "This probability will be evaluated by an expert panel and incorporated into a subjective probability that describes the likelihood of future exploratory drilling." Indicating that the panel will be made up of experts is not adequate to stimulate confidence in the project. In many fields of science, most of the experts receive some financial support, either research grants or consultantship, from the DOE. The independence of such a panel to make unbiased judgments about future resource potential is questioned.

SECTION 8.3.1.11. LAND OWNERSHIP AND MINERAL RIGHTS

Specific comments

Page 8.3.1.11-2. 6th paragraph

Statement: "If the Yucca Mountain site is recommended and approved for development as a repository following site characterization, it will be necessary, pursuant to 10 CFR 60.121, for the DOE to withdraw the land that would comprise the repository operations area and controlled area and reserve this land for its use." The statement needs to be changed because it was written before the enactment of the amendment of the nuclear waste policy act. However, since the Yucca Mountain has now been chosen as the first to be characterized site, the DOE should start the withdrawal of the repository operations area and controlled area to assure that such a withdrawal can be accomplished. This subject needs clarification.

SECTION 8.3.1.12. METEOROLOGY

Specific comment

Page 8.3.1.12-12. 2nd paragraph

It is pointed out that no single study encompasses all the meteorological monitoring needed to characterize the site and that data are needed by four different programs including the atmospheric dispersion, geohydrology, and climate. The meteorology program appears to be oriented to obtain data for atmospheric dispersion calculations and for the design specification of buildings. The emphasis is on obtaining wind data up to a few hundred feet above ground level. The climate program will require data on the pattern of high winds which can only be collected by large organizations such as the national weather agency. There is no indication that those responsible for the meteorology program will be involved in analyzing the data for the climate program.

SECTION 8.3.1.13. OFFSITE INSTALLATION

Specific comment

Page 8.3.1.13-3. 3rd paragraph

It is indicated that estimates of radiological releases from the operations of all nearby DOE, industrial, transportation, and military operations will be collected. Also, reference is made to the meteorological parameter program (8.3.1.12).
The estimates of radiological releases due to weapon testing operations will require a broader meteorological program then the one described in section 8.3.1.12, which is designed to obtain chi/Q data for the 50-mile radius surrounding the site.

SECTION 8.3.1.15. THERMAL AND MECHANICAL PROPERTIES

Specific comment

Page 8.3.1.15-71. 1st paragraph

The activity to supply the data for the air quality program is described. The activity includes the determination of dust generation rates for the different types and qualities of rock encountered throughout the ESF. It is emphasized that the experiments for the activity have not been finalized and may be changed.

The experiments should be finalized before the start of the exploratory shaft. This should be indicated in the time schedule on page 8.3.1.15-74 by indicating that milestones 17 and

18 should be completed before the start of the ESF. Also, the section should be referenced in other parts of the SCP that discuss the measurement of dust generation rates.

SECTION 8.3.1.16. PRECLOSURE HYDROLOGY

Specific comment

Page 8.3.1.16-19. 5th paragraph

The following statement is made: "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. Other sources may include other water wells located on the NTS, or other unappropriated ground water in basins adjacent to the site." The statement seems to ignore the discussions of sections 3.8.1.1 and 3.8.1.2 which indicate that there currently is an overdraft of 3,000 acre-feet per year in the Alkali Flat-Furnace Creek Ranch basin, and significant overdrafts for such areas as Yucca Flats and Frenchman Flat.

SECTION 8.3.1.17. PRECLOSURE TECTONICS

Specific comments

Page 8.3.1.17-3. Table 8.3.1.17-1(a)

The goal for the probability of a volcanic eruption that would disrupt surface facilities is set at 1 chance in 10,000 in 100 years. The current probability estimates indicate a value of less than this goal. The need for additional work should be detailed to indicate the weakness of current estimates.

Page 8.3.1.17-84. 2nd paragraph

It is stated that experience from coal mines in the eastern Wasatch Plateau are of particular relevance to the excavations at Yucca Mountain. This statement should be elaborated. The Yucca Mountain facility is a repository which must be stable for 84 years. This criterion may be accomplished by keeping the extraction ratio low. In coal mines, the goal is to maximize the extraction ratio, which is contrary to the goal of a repository. It is not clear why the experience of an extraction mine is applicable to a repository.

Page 8.3.1.17-84. 3rd paragraph

Statement: "Considerable mining experience exists at the NTS (e.g., Zimmerman and Finley, 1987) and no reports of mine-induced catastrophic failure are known." It should be pointed that a catastrophic failure has occurred following the Midas explosion, which may be relevant to the Yucca Mountain repository.

Page 8.3.1.17-158. 3rd paragraph

The possibility of detecting buried faults through measurement of gamma rays using portable gamma-ray spectrometers is mentioned. References of previous investigations should be added or it should be indicated that this is a totally new research tool.

SECTION 8.3.2. REPOSITORY PROGRAM

Specific comment

Page 8.3.2.1-7. First paragraph

The advanced conceptual design (ACD) phase is discussed. Yucca Mountain has been selected by Congress as the first site to be characterized. The general tone of chapter 8 of the SCP indicates that the DOE is actually working directly on the license application design yet no characterization work has begun. The meaning and time schedule of the ACD should be redefined.

SECTION 8.3.2.4. NONRADIOLOGICAL HEALTH AND SAFETY

Specific comment

Page 8.3.2.4-30. 2nd paragraph

Statement: "Studies are required to assess the impact of site characterization on the ventilation requirements necessary to provide a safe working environment. Site characteristics will determine dust quantities produced during construction, in situ gas types and quantities, and the wall roughness required for the ventilation flow calculation." The activities in which the data will be obtained should be referenced (see activity 8.3.1.15.1.8.4). The activities should also be discussed in section 8.4 so that it is possible to determine at what phase of the ES mining activities the data will be obtained.

SECTION 8.3.2.5. PRECLOSURE DESIGN AND TECHNICAL FEASIBILITY

General comment

The discussion of the preclosure design is very generic and ignores the conceptual design that has been issued and that is the basis of chapter 6. It seems logical that the feasibility of designing a facility for the preclosure period must be based on the existing conceptual design.

The discussions on technical feasibility do not include cost analyses. Cost analyses are ignored in subsections 8.3.2.5.8, and 8.3.2.5.9, which deal with identifying technologies for construction, operation, closure, and decommissioning of surface

and underground facilities. Given an unlimited amount of money, it can be stated without much hesitation that the technologies exist. The important issue is to demonstrate that the technologies will not bankrupt the nuclear waste fund or the federal budget.

SECTION 8.3.3.2. SEAL CHARACTERISTICS

Specific comment

Page 8.3.3.2-24. 2nd paragraph

Reference is made to the report of Fernandez et al[6] for the details of the performance and design goals.

The important performance parameter in the Fernandez report is the maximum allowable amount of water entering the waste disposal area, which is defined as the maximum amount of water that can contact the UO_2 matrix and not exceed the NRC criterion of 1 part in 100,000/year release for the inventory at 1000 years for a specific radionuclide (See 10 CFR 60.113a). The performance is calculated assuming congruent matrix dissolution, a hypothesized mechanism which limits the fractional release rate of the radionuclides to the fractional release rate of the matrix. The report has the following shortcomings:

1. The performance goals are always greater than 1.3×10^5 m^3 water/year which is a very large amount of water. The analysis does not include the EPA cumulative release formula for the first 10,000 years

$$(Q_a/RL_a)+(Q_b/RL_b)+(Q_c/RL_c)<1$$

which governs the simultaneous release of radionuclides a, b, and c in cumulative amounts of Q_a, Q_b, and Q_c. RL_a, RL_b, and RL_c are the EPA release limits. This formula takes precedence over the NRC criterion of 1 part in 100,000/year release for the inventory at 1000 years for a specific radionuclide. The incorporation of the EPA release limits and the cumulative release formula in the formula for Qmax would lead to a much smaller performance goal which would negate the authors claims that sealing is not needed and that their analysis is conservative.

2. The analysis does not allow for the release of radionuclides in the form of colloids. This is very important for transuranics such as the isotopes of plutonium. An analysis that includes the release of colloids would also make the performance parameter much smaller.

3. The parameter bn in the formulae on page 3-8 should also be defined in the form of an equation so that a reviewer can easily verify Figure 3-1 using a spreadsheet.

4. The rational for formula 3-6 on page 3-10 is not clear.

SECTION 8.3.4.2. WASTE PACKAGE CHARACTERISTICS (POSTCLOSURE)

General comment

The section lacks a sensitivity analysis for the chemistry of the water that can come in contact with the waste package.
The SCP fails to point out that many of the tests described in this section are preliminary and will be used to develop experiments for license application. According to a report by Glassley[7], most of the test described in the section are for the following three types of preliminary activities: 1) instances in which tests and analyses necessary to develop a license application cannot be designed or executed because the current scientific database is insufficient; 2) tests to provide data necessary for establishing protocols for use of the code at QA level I; 3) tests that explore analytical or laboratory techniques that have the potential to produce information necessary for license application, but for which insufficient information exists to establish the efficacy of the technique.

Specific comments

Page 8.3.4.2-23. 4th paragraph

Reference is made to table 8.3.4.2-4 for a description of the water chemistry parameters. If there is a climate change and the flux increases an order of magnitude, then it is likely that the increase in water content of the rock will affect the water chemistry parameters. This issue is important in postclosure performance assessment. A sensitivity analysis, which is not indicated in table 8.3.4.2-4, is therefore required.

Page 8.3.4.2-31. 4th paragraph

The limits to the alteration of water chemistry are presented. Actually these values are not too different from the characterization goals for water chemistry which are presented on page 8.3.4.2-23. There is no real attempt to achieve a sensitivity analysis.

SECTION 8.3.5.1. STRATEGY FOR PRECLOSURE PERFORMANCE ASSESSMENT

Specific comments

Page 8.3.5.1-1. 3rd paragraph

It is indicated that the economic cost of accidents is part of the scope of preclosure safety assessment. However, the thought of performing cost analyses of accidents is abandoned on the next page and the only risk categories considered are RAP, RAW, RRP, and RRW.

Page 8.3.5.1-5. 4th paragraph

Statement: "Accidents during construction of the mined portion of the repository should be typical of any large underground construction project and will primarily affect workers and have little or no public effect." The experience gained at WIPP indicates that accidents during construction of the mined portion of the repository received wide coverage from the news media and have an effect on the public.

SECTION 8.3.5.2. WASTE RETRIEVABILITY

General comment

The economic cost of retrievability, which is also classified as a performance issue on page 8.3.5.2-1, is not included in any of the SCP studies.

The end product of the efforts on waste retrievability will be six reports describing in detail the following items or activities of waste retrieval:

1. Summary of site and design data required to support retrieval analyses.

2. Provide access to the emplacement boreholes.

3. Provide access to the waste packages.

4. Remove waste package from the emplacement borehole.

5. Transport and deliver the waste packages to the surfaces.

6. Show that retrieval requirements set forth in 10 CFR 60.111(b) are met using reasonably available technology.

If retrievability is for economic reasons, than the efforts described in reports 2 through 5 and the transportation of the spent fuel to a reprocessing facility may turn out to be much more expensive than the value of the resources in the spent fuel elements. If these items are indeed more costly than the resources, then the criteria of report 6, which requires that retrievability be performed using reasonably available technology, cannot be met. An economic analysis is essential to resolve the subject covered in report 6.

Specific comment

Page 8.3.5.2-1. 2nd paragraph

Statement: "Finally, the decision to retrieve will be made as part of the performance confirmation program or by the DOE for

recovery of resources." The performance confirmation program will occur after site characterization is over. However, the contents of the program should be detailed because it would include an economic analysis of retrievability which the discussion in the SCP fails to mention.

SECTION 8.3.5.3. PUBLIC RADIOLOGICAL EXPOSURES - NORMAL CONDITIONS

General comment

The section is written as if the DOE will start from scratch in the estimation of radiation doses to the general public resulting from normal operating conditions of the repository. Procedures for such estimates have been outlined in great detail by the NRC for nuclear power installations and it is not clear why this subject is treated as if it needs further development.

Specific comments

Page 8.3.5.3-13. Bottom of table 8.3.5.3-2

The expected radon emanation referenced in Section 8.3.1.15 is 0.48 pCi/ml. Furthermore it is stated that the needed confidence is high while the current confidence is low. The radon emanation rate will vary with temperature and the transport of radon to the surface will depend on ventilation. The radon emanation rate will vary from drift to drift. It is not clear how a value with high confidence can be obtained.

Page 8.3.5.3-22. Data requirements

It is indicated that the radon emanation rate from the tuff is necessary information to evaluate public radiological exposures. The need for these data should be further detailed. It is not possible to calculate a radiation field from the knowledge of the radon emanation rate only. What is really needed is the average yearly background radiation as measured by pressurized ionization chambers and by TLD dosimeters.

SECTION 8.3.5.4. WORKER RADIOLOGICAL SAFETY - NORMAL CONDITION

General comments

See general comments for review of 8.3.5.3.

Specific comments

Page 8.3.5.4-4. Paragraph 4

Statement: "In addition to complying with 10 CFR Part 20, the DOE has voluntary agreed to comply with the radon monitoring and

control provisions established by the Mine Safety and Health Administration in 30 CFR Part 57. To ensure adequate protection of repository workers, the contribution of radon and its daughter products to occupational exposure will be considered in assessing compliance with the applicable standards of 10 CFR Part 20." It is difficult to imagine how the procedure outlined in the second sentence can be carried out. Radiation workers are generally monitored with TLD badges and it is not possible to separate the hard gamma exposure from by-product materials and radon daughters. The sentence implies that the DOE will come up with a new personnel monitoring system that can distinguish between radiations originating from the high level waste and from naturally occurring elements.

Page 8.3.5.4-19. 3rd Paragraph

The statement is made that the only piece of data needed to satisfy information need 2.2.1 is the radon emanation rate of the mined tuff. This statement is completely incorrect. The radiation environment in surface and subsurface facilities due to natural and man-made radioactivity cannot be calculated from a knowledge of the radon emanation rate. What is necessary is the measurement of the background radiation by pressurized ionization chambers and TLD dosimeter over a period of one or two years. The total body dose due to background radiation is an important parameter in assessing the radiological exposures at the site. The radon emanation rate is important in designing a ventilation system that is adequate.

Page 8.3.5.4-24. Data requirements

It is indicated that the dust particle size distribution is required to satisfy information need 2.2.2 - determination that the projected worker exposures and exposure conditions under normal conditions meet the applicable requirements. This should be detailed. In fact, it is not clear why meteorological data is necessary to estimate the radiation dose to workers who are indoors, in underground facilities, or in transit in busses or private cars.

SECTION 8.3.5.5. ACCIDENTAL RADIOLOGICAL RELEASES

Specific comments

Page 8.3.5.5-4. 2nd Paragraph

The following statement is made: "The definition of credible accidents is still being discussed within the DOE." It should be pointed out that in the SCP-CDR[8] no such doubt is expressed and an event tree method is used to select accidents for the PQ list.

Page 8.3.5.5-31. 1st Paragraph

Statement: "This activity consists of presenting the results of the accident risk assessment in a manner consistent with the needs of the NRC, the DOE, and the repository program in general." It can be expected that, before licensing, the NRC will produce a regulatory guide on the format of the safety analysis report for a geological repository. That regulatory guide should be the guideline for documentation.

SECTION 8.3.5.6. HIGHER LEVEL FINDINGS--PRECLOSURE RADIOLOGICAL SAFETY

Specific comment

Page 8.3.5.6-11. 1st paragraph

The resolution of the guidelines of site ownership and control is deferred to environmental program planning activities which are dismissed as not part of site characterization activities. Because of the amendment to the Nuclear Waste Policy Act, Yucca Mountain is the first chosen site. Therefore the DOE should resolve this issue before the start of site characterization.

SECTION 8.3.5.7. HIGHER LEVEL FINDINGS - EASE AND COST OF CONSTRUCTION

General comment

The section was written while three sites were still being considered for characterization. It calls for cost comparison of the three sites. With the amendment to the Nuclear Waste Policy Act there is only one site left and new standards for comparison will be necessary.

The section should include a time schedule that indicates decision points which would allow reevaluation of the site characterization process and possible redirection or cessation of research.

Specific comments

Page 8.3.5.7-4. First paragraph

Statement: "Each of the qualifying conditions references requirements for technical feasibility based on reasonably available technology and reasonable costs relative to other siting options." With the cancellation of site characterization at Hanford and Deaf-Smith the comparison to other sites will have to be changed.

Page 8.3.5.7-6. Bottom paragraph

Statement: "Repository siting, construction, operation, and closure shall be demonstrated to be technically feasible on the basis of reasonably available technology, and the associated costs shall be demonstrated to be reasonable relative to other available and comparable siting options." Again, the last sentence must be changed in view of the cancellation of Hanford and Deaf-Smith. Also, an explanation should be given for why retrievability, which could occur before closure, is not included in the opening sentence of the statement.

Page 8.3.5.7-8. 2nd paragraph

The following statement is made with regards to the requirements of 10 CFR 960.5-1(a)(3): "That subpart requires a comparative evaluation of the relative costs for each of the comparable siting options. To make this comparative evaluation, the DOE will develop a total-system life-cycle cost (TSLCC) estimate (1) for construction, operation (including maintenance of the retrieval option), closure, and decommissioning of a repository at each of the candidate sites that has been characterized and (2) for design and fabrication of the waste packages to be used at each site." With the cancellation of the site characterization at Hanford and Deaf-Smith, 10 CFR 960.5-1(a)(3) will have to be restated and the TSLCC analysis will have to be given a new purpose.

SECTION 8.3.5.10. ENGINEERED BARRIER SYSTEM RELEASE RATES

General comment

The section does not indicate that the DOE plans to study releases and release rates of colloids from spent fuel. The emphasis is toward studying the releases and release rates of dissolution and leaching. It is recognized that transuranics will be released in the colloidal form rather than dissolved in the water that comes in contact with the waste.

The DOE uses the term "near field" for the modified tuff adjacent to the borehole that contains waste canisters. The subject is treated vaguely and there are no indications of setting criteria for determining the radius or other dimensions of the near field. Activities associated with 8.3.5.10.5 indicate that the near field is considered as an engineered barrier.

Page 8.3.5.10-57. Description

The section indicates that there will be no attempt to modify the EQ3/6 code to model the release of colloids. The emphasis appears to be on discussions of dissolution and leaching.

Page 8.3.5.10. Schedule and milestone

The schedule should indicate when a decision will be made on horizontal versus vertical emplacement. In horizontal emplacement, backfilling with sorbing materials such as bentonite is not possible. The near field is the steel liner. In the vertical emplacement, surrounding the canister with sorbing materials is possible. The decision on the selection of an emplacement mode is very important if the discussion is to be specific.

SECTION 8.3.5.12. GROUND-WATER TRAVEL TIME

General comment

The section is based on Sinnock et. al. (1986)[1], which is primarily based on the results of an unvalidated computer code and which does not contain an adequate sensitivity analysis. Groundwater travel times (GWTT) were calculated for fluxes of 0.5 and 1.0 mm/yr in the unsaturated zone. The study claims that fracture flow is included in the model. The Sinnock et. al. (1984) study[2] had indicated that fracture flow would become dominant at a flux of 1mm/yr. Therefore, a proper sensitivity analysis would have included GWTT for fluxes above 1.0 mm/yr.

Specific comments

Page 8.3.5.12-11. 3rd paragraph

Statement: "Because radionuclide travel may occur by particles larger than inert tracers (such as colloids), characterization of colloid formation is also planned." The plans for the study of colloids should be referenced. There is no indication that such a study is planned in section 8.3.5.10, Engineered barrier system release rates.

Page 8.3.5.12-16. 4th paragraph

Statement at the end of the paragraph: "Standard hydrochemical data may also be used to help determine whether computed travel times are consistent with the isotopically determined ages (Section 8.3.1.2.2)". Dr. Yang of the USGS has developed a method for extracting water from rocks of the unsaturated zone of Yucca Mountain. Preliminary isotopic analyses of the waters, δD and $\delta^{18}O$, have also been performed. However, there is no theoretical justification for dating the waters by comparison with standard δD and $\delta^{18}O$ values, which vary widely for winter and summer precipitation. Also, it is believed that there is an upward vapor flux in the unsaturated zone at Yucca Mountain. The effect of the upward vapor flux on isotopic dating of the water is unknown.

Page 8.3.5.12-19. 2nd paragraph

The following definitions for performance goals are presented: "Very high indicates that the goal lies at least three standard deviations below the mean of the ground-water travel time distribution; high indicates that the goal lies at least two standard deviations below the mean; medium, at least one standard deviation below the mean; low, less than the mean; and very low, less than one standard deviation above the mean." The Sinnock[2] analysis indicates that this may not be possible for the CHnv and CHnz formations which have mean GWTT of 11,000 and 13,695 years respectively, and which have standard deviations of 7,760 and 8,145 years respectively. It is doubtful that site characterization will help reduce the standard deviation. The DOE should provide explanations on how to resolve this issue.

Page 8.3.5.12-55. 4th paragraph

Statement: "If spatially varying parameters (represented by a covariance matrix) can be estimated, then stochastic models or conditional simulation will be applied. This potential technical commitment should also be discussed and detailed in the section entitled "Technical basis for addressing the information need".

Page 8.3.5.12-56. 2nd paragraph

Statement: "Currently, travel-time distributions have been estimated only by simplified one-dimensional modeling (Sinnock et al, 1986). The simplifying one-dimensional assumptions will be modified to account for the dependence between outflow locations, travel times, and quantities." Again, this technical commitment should also be discussed and detailed in the section entitled "Technical basis for addressing the information need".

SECTION 8.3.5.13. TOTAL SYSTEM PERFORMANCE

General comment

The format of this section does not follow the NRC's outline for performance assessment[9] of the total system. At the beginning of the section the assertion is made that a CCDF will be evaluated, but in the ensuing analysis the emphasis is on the evaluation of the EPPM. The section should be rewritten. The format for the calculation of the CCDF in the example of NUREG/CR-4510[9], which like this section, was written by SANDIA, should be followed using currently available data.

Specific comments

Page 8.3.5.13-6. 1st paragraph

Equation 8.3.5.13-4 is incorrect because the following condition has been made implicit

$$p = \iiint f(V)dv_1dv_2...dv_n$$

where

f(V) = joint probability distribution of the component of V.
p = probability of the parameter [•] in equation 8.3.5.13-4

If the dimensions of p are (number of outcome)/(unit time) then the dimensions of [•] are (dimension of [•])/(unit time) which is not the same as (dimension of [•]).

Equation 8.3.5.14-4 should be written either as

$$E([\cdot]f) = \iiint [\cdot]f(V)dv_1dv_2...dv_n$$

or as

$$E[\cdot] = \frac{\iiint [\cdot]f(V)dv_1dv_2...dv_n}{\iiint f(V)dv_1dv_2...dv_n}$$

Page 8.3.5.13-8. 2nd paragraph

Statement: "The EPPMs do not account for uncertainties in the consequences of a given scenario class and, therefore, are not sufficient to establish the overall probability distribution in themselves. Nevertheless, they provide useful measures to focus the testing during site characterization on the information needed for this overall probability distribution and are therefore used here as simple surrogates for the full CDFs associated with the scenario." The statement indicates that the DOE plans to shift the emphasis towards obtaining EPPMs rather

than CDFs for the resolution of performance assessment issues. The entire section, which starts with a discussion of the CDF lacks an emphasis on performing an adequate sensitivity analysis which is essential in the determination of the CDF.

Page 8.3.5.13-15. Table 8.3.5.13-3

The table provides an overview of the super-categories of scenarios to be studied. The scenarios are treated in a generic way which conceals difficulties in providing a meaningful performance assessment. For example, the DOE plans to characterize the tuff aquifer only. It does not plan to characterize the carbonate aquifer, which lies below and, which is separated from the tuff aquifer by an impermeable zone. For a rise in the water table, the DOE relies on the analysis of Czarnecki[10] which postulates a change in climate that increases the flux in the unsaturated zone by a factor of sixteen. The carbonate aquifer has a higher hydraulic head than the tuff aquifer which could cause a significant rise in the elevation of the water table should the impermeable zone separating the two aquifers be fractured by tectonic events. A change in climate will also affect the carbonate aquifer which might also have a bearing on the elevation of the water table in the tuff aquifer. In the present site characterization plan these scenarios will not be addressed because of a failure to characterize the carbonate aquifer.

Page 8.3.5.13-42. 3rd paragraph

The equation at the bottom of the page for the EPPM is in error. See the comment with regards to equation 8.3.5.13-4.

SECTION 8.3.5.18. HIGHER LEVEL--FINDINGS POSTCLOSURE SYSTEM AND TECHNICAL GUIDELINES

General comment

The section should include a time schedule that indicates decision points which would allow reevaluation of the site characterization process and possible redirection or cessation of research.

Specific comment

Page 8.3.5.18-26. 3rd paragraph

Statement: "Over a 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." A reference should be given for the occurrence probability value of less than 0.1

because in section 8.3.5.13 and 8.3.5.20 the DOE emphasizes that the simplified physical models that will be used in the probabilistic analysis still require significant development.

SECTION 8.3.5.19. COMPLETED ANALYTICAL TECHNIQUE

General comment

Many developed codes to be used in preclosure and postclosure performance assessment are described. It would be useful if the DOE were to indicate the codes that are NRC certified or validated.

SECTION 8.3.5.20. ANALYTICAL TECHNIQUE REQUIRING DEVELOPMENT

Specific comment

Page 8.3.5.20-7, 1st paragraph

The following statement is made: "This expert judgement review will be provided through peer review groups developed within the NNWSI Project and OCRWM." It is difficult to see how internal DOE peer reviews could be in accordance with the definition presented in the NRC's generic technical position paper[11].

SECTION 8.4. PLANNED SITE PREPARATION ACTIVITIES

General comment

The section does not mention experiments to measure and characterize the particle size distribution of the dust that will result from the mining activities. The amount of dust and its particle size distribution will determine the amount of water to be used for dust control. It will also influence the design of the ventilation system. Dust control activities should be described in greater detail in this section. The section also fails to convey the message that the excavation of the shaft and the drifts will provide the economic data that will allow a true estimate of the cost of the repository and therefore its feasibility.

There is no discussion of the smoothing activities for the floor of the drifts and breakout rooms in the ES facility. The excavation of drifts by blasting an mining in a hard rock like tuff produces jagged floors that are difficult to walk on. Electric carts cannot move comfortably on a jagged floor. Smoothing the surface of the floor will require the use of much water. The subject should be discussed in the final version of the SCP.

Page 8.4-16. Figure 8.4.8

Part of the figure is reproduced on the following page. Clearly, the exploratory shaft (ES) facility covers only a small area to the north of the repository. At the WIPP site, the DOE excavated a north to south drift that went the entire length of the repository and experimental area. Later on, a long east to west drift was excavated in the north end of the facility. The ES facility in its present configuration is much inferior to the SPDV study at WIPP, which is only a test and experimental facility. The DOE should consider expanding the ES facility.

Page 8.4-50. 3rd paragraph

The experiment for the prototype boring machine is summarized. Has the DOE given proper consideration on moving the machine from the surface to the underground facility? Has there been adequate consideration of the electrical needs of the boring machine and the layout of the high voltage cable in ES1?

SECTION 8.5. MILESTONES, DECISION POINTS, AND SCHEDULE

General comment

Numerous timeline diagrams are presented. Some clarification on time zero should be presented, i.e., have the investigation activities already started or is time zero the date of the issuance of the final SCP.

GLOSSARY AND ACRONYMS

General comment

Many geological terms pertaining to seismic events are defined including the word "fault." The term "detachment fault" should also be included in this section.

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PART III

COMMENTS OF TECHNICAL CONTRACTORS AND ADVISORS

COMMENTS OF

CENTER FOR NEOTECTONIC STUDIES

MACKAY SCHOOL OF MINES

UNIVERSITY OF NEVADA - RENO

Center for Neotectonic Studies:

Review Summary of DOE's Consultation Draft of the Site Characerization Plan

June 30, 1988

Introduction

Relevant parts of the CDSCP have been critically reviewed by the principal or co-investigators of the seven tasks within the Yucca Mountain Project. It was suggested that each reviewer organize their critique as if it were a paper submitted for publication to an international journal.

This is a summary of these reviews, and serves also as a guide to them. The most significant general comments and recommendations made in the various reviews are presented in this summary, with some examples of specific concerns. General comments and objections are listed first, followed by specific concerns and questions, and ending with general conclusions and/or recommendations. It is not the intent of this general summary to repeat many specific examples justifying the criticisms; the specifics may be found in the individual reviews.

We are fully aware that the document under review is a *draft*, and anticipate that the final SCP will be substantially modified and improved upon. There are certainly good aspects of the CDSCP, most significant of which is the considerable improvement over the 1984 Draft Environmental Assessment and the 1986 Environmental Assessment documents (Task 1, Bell et al.). Nevertheless, the reviews are by their nature critical, but are intended to be constructive.

The listed personnel critically reviewed the following sections:

Task 1:	John W. Bell, Craig M. dePolo, and Alan R. Ramelli
Chapter 1	Geology
1.1	Geomorphology
1.2	Stratigraphy and lithology
1.3	Structural geology and tectonics
1.4.2	Seismology of Yucca Mountain
1.5	Long-term regional stability with respect to tectonic and geological processes
1.8.1	Summary of significant results
Chapter 8	Site characterization program
8.3.1.6	Erosion
8.3.1.8	Postclosure tectonics
8.3.1.17	Preclosure tectonics

Center for Neotectonic Studies:

Review Summary of DOE's Consultation Draft of the Site Characerization Plan

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Task 2: Frank W. Dickson

Chapter 4: Geochemistry

Chapter 8: Site characterization program

- 8.2.2.4.2 Geochemistry (Summary)
- 8.2.2.4.7 Postclosure tectonics (Summary)
- 8.3.1.3 Geochemistry (Overview)
- 8.3.1.7 Rock dissolution (Overview)
- 8.3.1.8.4.1 Study: Analysis of the effects of tectonic processes and events on rockgeochemical properties.

Task 3: L.T. Larson, Donald C. Noble, and Steven I. Weiss

Chapter 8 Site characterization plan

- 8.2.2.4.(7, 8, 16) Summaries of specific site characterization programs
- 8.3.1.3 (2) Geochemistry program
- 8.3.1.4 (2) Geologic framework of the Yucca Mountain site
- 8.3.1.5 (2) Future climatic conditions
- 8.3.1.8 (5) Future tectonic processes
- 8.3.1.9 (2,3) Human interference - natural resources
- 8.3.1.11 Land and mineral rights
- 8.3.1.14 (2) Surface characteristics
- 8.3.1.17 (4) Preclosure processes - tectonic and igneous events
- 8.3.4.1 Waste package programs

Task 4: James N. Brune, John G. Anderson, William Peppin, Keith Priestley, Martha Kane Savage, and Ute Vetter

Overview

Chapter 1: Geology

Chapter 2: Geoengineering (Summary)

Chapter 3: Hydrology (Summary)

Chapter 4: Geochemistry (Summary)

Chapter 5: Climatology and meteorolgy (Summary)

Chapter 6: Conceptual design of a repository (Summary)

Chapter 7: Waste package (Summary)

Chapter 8: Site characterization plan

- 8.1 Rational for the SCP
- 8.2 Issues to be resolved and information required during site characterization.
- 8.3.1.(4, 6, 8, 9, 17) Site program

8.3.2.1	Repository program (Overview)
8.6	QA program
8.7	Decontamination and decommissioning

Task 5:	Richard A. Schweickert, and Michael A. Ellis
Chapter 1:	Geology
Chapter 8:	Site characterization plan
8.0	Introduction
8.2.(1,2)	Issues to be resolved and information required during site characterization.
8.2.2.4	Summaries of specific site characterization programs
8.2.2.4.(7, 16)	Summaries of specific site characterization programs
8.3.1.4.2	Investigation: Geologic framework of the Yucca Mountain site
8.3.1.8	Postclosure tectonics
8.3.1.17	Preclosure tectonics

Task 7:	Robert J. Watters
Chapter 8:	Site characterization plan
8.0	Introduction
8.1	Rational for the SCP
8.2	Issues to be resolved and information required during site characterization.
8.3.1.(1,2)	Site program
8.3.1.4	Rock characteristics program (Overview)
8.3.1.15	Thermal and mechanical rock properties program (Overview)
8.3.1.17	Preclosure tectonics
8.4	Planned site preparation activities

There are two major criticisms that require early emphasis. The first is that the CDSCP appears implicitly to accept the Yucca Mountain site as *the* high-level nuclear waste repository, and possibly as a result, there do not appear to be decision points within the CDSCP where the characterization can be reevaluated, resulting in a possible redirection or cessation of research; there appear to be no means of recognizing a potentially disqualifying factor.

The second comment, and recommendation, is that the CDSCP is largely unsuccessful at addressing the scientific issues, and that the SCP be structured to adequately investigate the

problems at hand (Task 4, Anderson; Task 5, Ellis, and Schweickert).

In addition, almost all reviewers have made a point of stating that the CDSCP is poorly written, and poorly organized. The CDSCP is an overly complicated piece of bureaucratic writing in which the scientific issues are lost among a plethora of cross-references and "organizational" diagrams to the extent that "it contains countless internal inconsistencies and contradictions" (Task 5, Schweickert). Symptomatic of this is the apparent contradiction found in Chapters 1 and 8 concerning the adequacy of the tectonics data base in assessing the volcanic and earthquake hazard at Yucca Mountain. Various statements are found in the CDSCP, mainly in chapter 1, that suggest the data base to be inadequate, while the opposite is stated elsewhere in chapter 1 and in several places in chapter 8 (Task 1, Bell, dePolo, and Ramelli).

The CDSCP appears to have been written by a great number of people, and looks as though the authors themselves were not always aware of the nature of the Plans contents, or even of the problems involved. Several reviewers have stated that the scientific parts of the CDSCP would not be able to compete with normal scientific proposals if submitted to an independent funding agency such as the NSF.

The implication behind the poor organization of the CDSCP is more significant than the poor organization itself, and that is the implication of poorly understood problems. The reviews summarized here support this implication; the CDSCP does not appear to be written by people who have a thorough understanding of the problems at hand. "There is no demonstration that there is an understanding of the basic principles involved at a level necessary to give confidence that all important conceptual models, physical factors, and initiating events are being considered" (task 4, Brune). This is not supposed to be a slight against the qualifications or experience of the personnel involved in either the projected work or the writing of the CDSCP, but rather of the manner in which the information and projects have been amalgamated. The CDSCP appears to be "driven entirely from engineering considerations with little thought about the broader scientific questions which are raised by the proposed repository" (Schweickert). An important omission in the CDSCP is that there are no built-in decision points to evaluate where the investigations stand, or to assess whether there are fatal flaws and to decide whether major investigative changes are necessary. This omission is a critical deficiency of the present Plan.

Center for Neotectonic Studies:

Review Summary of DOE's Consultation Draft of the Site Characerization Plan

June 30, 1988

Major Critcisms

There are six classes of major criticism concerning scientific issues that are discussed below under the following headings:

1: Implicit acceptance of Yucca Mountain as the high-level nuclear waste repository, and the absence of periodic reevaluation plans;
2: Scientific problems improperly addressed, or appreciated, with particular reference to the 10,000 year cumulative slip earthquake.
3: Neglect of coupled-process studies.
4: Misuse of qualitative data or assumptions, and the over reliance on numerical and probabilistic studies.
5: Unrealistic time schedule.
6: Inadequate data base.
7: Inadequacy of regional studies.

1: Implicit acceptance of Yucca Mountain as the high-level nuclear waste repository, and the absence of periodic reevaluation points.

The CDSCP appears implicitly to accept the Yucca Mountain site as *the* high-level nuclear waste repository, and assumes that all investigations and studies will provide the data necessary for NRC licensing (Task 3: Larson; Task 4, Anderson; Task 5, Ellis, and Schweickert). Perhaps as a result of this implicit acceptance, there do not appear to be decision points within the CDSCP where the characterization can be reevaluated, resulting in a possible redirection or cessation of research. The ability to discover potentially disqualifying factors is not incorporated in the present plan.

2: Scientific problems improperly addressed, or appreciated, with particular reference to the 10,000 year cumulative slip earthquake.

There are numerous specific criticisms of this nature; the general consensus is that the scientific problems are addressed through a shotgun approach. There are a great number of studies proposed in the CDSCP, and a more limited number of basic problems to be solved. The connection between these two groups, however, is tenuous at best. Many of the studies

do not appear to be driven by the nature of the problems, but are instead a series of generic research projects standard to most geologic and seismologic investigations. This is not to say that the studies are intrinsically wrong, rather that they have not been designed to solve the basic scientific problems concerned with siting a high-level nuclear waste facility.

Examples:
- The drilling program is considered inadequate to properly investigate the geotechnical problems (Task 7, Watters), the mineral/energy potential at the site (Tasks 3, Larsen), and in providing sufficient data on the character of faults at Yucca Mountain (Task 1, Bell et al.).
- The regional study of active faults is considered inadequate in determining a temporal and spatial history of seismicity (Task 5, Ellis).
- The regional structural studies will not solve the problems of stratigraphic geometry or deep structure (Task 5, Schweickert).
- The rock mass characterization plan does not adequately describe how the existence of larger fractures, joints, and especially faults, both in and near the repository, will effect the overall behavior (Task 4, Brune).

The one significant exception to the point above (i.e., that studies are generic and not driven by specific problems) concerns the invention of the 10,000 year cumulative slip earthquake. This is a new concept, which appears to have been designed specifically for the Yucca Mountain project. This type of source characterization is unconventional, unrealistic, misleading, and nonconservative (Task 1, Bell et al., Task 4, Brune et al.). For example, the CDSCP states that the 10,000 year event "can be determined with greater confidence than a true maximum magnitude" (p. 8.3.1.17-36). This is incorrect. The input parameters required to estimate the magnitude of the 10,000 year event probably have greater uncertainties than those data and procedures associated with the usual deterministic analyses of maximum earthquakes (see Task 1 review, p. 1-9, and Task 4, Savage, p. 2, for more details).

3: Neglect of coupled-process studies.

A particular case of an improperly addressed scientific problem deserves separate mention, that of the neglect of coupled-process studies. This is clearly connected to the previous category, in particular to the shotgun approach of the Plan. The application of generic studies to the solution of inter-related and complex problems is clearly not

satisfactory (Task 2, Dickson).

We are not yet aware of the relation between many of the physical processes, particularly over a ten-thousand year period. Studies must be designed to solve the specific problems at hand, which may often mean carefully reevaluating the basic physics and chemistry of geologic processes.

Two examples are worth emphasizing. The first is suggested by the intimate association between basaltic ash and faults in the Yucca Mountain area (Task 1, Bell et al., and Task 5, Schweickert). A likely scenario based on this association involves simultaneous faulting of the upper crust with intrusion at depth and venting at the surface. The second example concerns the application of standard hydrologic models to various different problems (Task 5, Schweickert and Ellis). These standard hydrologic models may not properly describe the physical system, as suggested by Szymanski's report on the ground water system of the Death Valley region.

4: Misuse of qualitative data or assumptions, and the over reliance on numerical and probabilistic studies

Virtually all reviews returned the verdict that the CDSCP misuses or is over reliant on a set of qualitative data or assumptions (Task 1, Bell et al., Task 3, Larson et al., Task 4, Brune et al., Task 5, Schweickert and Ellis). There are several major examples of this. The DOE have given themselves the option to suspend some or all activities if they determine that, based on unspecified criteria, the activites will not reasonably increase the level of confidence in the descriptive parameters (Task 1, Bell et al., p. 1-2). Furthermore, these confidence estimates are qualitative and not subject to rigorous verification (see Table 8.3.1.17 (1-6)), and thus could instead be misused to imply that the DOE have improved on an earlier data base or basic understanding where no real improvement has occurred (Task 4, Anderson).

There is an over-reliance throughout the CDSCP on "rigorous numerical modeling" where it is based on a set of qualitative data or assumptions (Task 4, Peppin, Task 5, Ellis). The results of these studies are often very impressive in their apparent mathematical rigor, yet the confidence in the probability values so produced may belie the confidence in the original data by a considerable amount. The reviews do not criticise the intrinsic value of numerical

analysis. The concern here is that the input data is often poorly known, and thus the results of numerical analyses may be misleading, unless the uncertainties in the input data are made clear. It is critical that this type of scientific misrepresentation is removed from the CDSCP; the appearance of hard numbers where in many cases there should be none will be taken by the public and possibly the NRC as an indication of great science having been done, when quite the opposite will be true.

5: Time schedule problems

The CDSCP proposes to do numerous studies in order to obtain the necessary information for licensing. If all of these studies are performed, particularly by state-of-the art techniques (as proposed), it is likely that the characterization of the Yucca Mountain site will take several times longer than anticipated by the DOE (Task 1, Bell et al., Task 2, Dickson, Task 3, Larson, Task 4, Savage). The time frame of the DOE's plans is not realistic if valid results are to be obtained.

6: Inadequate data base

The data base for all CDSCP geologic studies is Chapter 1, which is out-of-date (Task 3, Weiss, and Task 5, Schweickert). The description of the tectonic framework of Yucca Mountain contains several *non sequiturs*, and gives the impression that it was written by someone unfamiliar with the modern plate tectonic setting. In addition, the CDSCP states that the historical seismic data base is essentially adequate, and requires very little further work. This is not correct by any means (Task 4, Anderson, Task 5, Ellis).

7: Inadequacy of regional studies

Studies of both regional active faulting and bedrock geology are poorly planned or are not planned at all in the CDSCP. Studies of regional active faults are to be conducted only if the fault can be shown to have a direct influence on the Yucca Mountain site. This approach will not yield a true picture of the temporal or spatial history of seismicity, which may be of considerable significance (Task 5, Ellis). In addition, regional studes of the bedrock geology may place tight constraints on the disposition of stratigraphic units at depth below Yucca Mountain, and enable the hydrologic flow system and mineral resource potential to be better characterized (Task 3, Noble and Larson; Task 5, Schweickert). An alternative point of view has been expressed by Task 1 (Bell et al.) who suggest that time and resource limitations placed on the DOE may cause studies of some regional Quaternary faults to be done at the expense of site-specific studies.

Recommendations

The general recommendations described by each Task review are outlined here, while recommendations specific to studies, activities, etc. can be found in the individual reviews.

The CDSCP generally does not incorporate the features listed below, and it is our recommendation that the SCP should clearly include these items.

1: A demonstration that our current knowledge of the geology and seismology of the Yucca Mountain is clearly understood (the data base should be up-to-date, and a realistic regional structural model must be developed);

2: The identification of major uncertainties in data which are unlikely to be eliminated by further study;

3: The SCP needs to allow for the reevaluation (and possible redirection, reprioritization or cessation) of the characterization, as well as incorporate the means to identify potentially disqulaifying factors;

4: A demonstration that the basic physical processes are understood, or that appropriate plans are made to study these processes and possible coupling of these processes;

5: The uncertainties in the results of numerical analyses and probablisitic studies should be clearly and unambiguously stated;

6: The studies need to be driven by the specific problems at hand, rather than represent a series of generic or standard geologic or geophysical studies;

7: The use of the 10,000 year earthquake should be abandoned, and should be replaced by the maximum or maximum credible earthquake as used in seismic hazard analyses.

REVIEW OF SITE CHARACTERIZATION PLAN-- CONSULTATION DRAFT YUCCA MOUNTAIN SITE

Task 1 Quaternary Tectonics Comments

Principal Investigator: John W. Bell
Co-investigators: Craig M. dePolo and Alan R. Ramelli

Introduction

The following comments are related to Quaternary tectonics issues contained in the January, 1988, Department of Energy Consultation Draft of the Site Characterization Plan (CDSCP) for the Yucca Mountain Site. The sections reviewed here include, but are not limited to:

Chapter 1 Geology
- 1.1 Geomorphology
- 1.2 Stratigraphy and Lithology
- 1.3 Structural Geology and Tectonics
- 1.4.2 Seismology of Yucca Mountain
- 1.5 Long-term Regional Stability with Respect to Tectonic and Geological Processes
- 1.8.1 Summary of Significant Results

Chapter 8 Site Characterization Program
- 8.3.1.6 Erosion
- 8.3.1.8 Post-closure Tectonics
- 8.3.1.17 Pre-closure Tectonics

Each section was reviewed by Task 1 for scientific credibility, applicability to the siting criteria for high-level nuclear waste repositories (10 CFR 60), and consistency with established and state-of-the-art knowledge in the area of Quaternary geology and active faulting. Unfortunately, it is difficult to completely evaluate the proposed characterization program in the absence of detailed study plans; most proposed studies listed in the CDSCP present only a summary of the activities.

Beginning first with an overview of both the positive and negative aspects of the local and regional Quaternary tectonics and stratigraphy, this review is then divided into segments which rank our comments on the basis of our level of concern: General Objections-- major disagreements or flaws; General Concerns-- Significant disagreements; and Specific Comments and Questions-- Remarks directed at specific statements in the CDSCP.

General Overview

On the positive side, the CDSCP outlines a very detailed scope of work for the site characterization phase which will address many Quaternary tectonics issues which were raised in earlier reviews of the 1984 Draft Environmental Assessment (Bell, 1985) and the 1986 Environmental Assessment (Bell, 1986). An obvious attempt has been made in the CDSCP to address topics which were regarded in these previous reviews as deficiencies in the study program; in fact, one is struck by the effort that has been made to include activities which are designed to satisfy our original concerns. For example, the activity and seismogenic potential of the Quaternary faults at Yucca Mountain are treated much more realistically than originally proposed by DOE, even though the published data base has not changed significantly since the DEA and EA were released. This suggests that the DOE has become more receptive to legitimate scientific concerns regarding the conceptualization of fault models for Yucca Mountain.

In addition, the list of proposed activities designed to assess pre- and post-closure tectonics issues is impressive. Although not completely addressing all of our present concerns, these proposed activities cover many of the major elements necessary for developing multiple tectonic models. The recognition of the need for modeling the linkage between the regional Walker Lane system, a possible detachment system, and the site-specific faulting, for example, indicates that consideration will probably be given to a range of models.

On the negative side, it is not clear that the proposed level of assessment will, or can, be carried out based either on unrealistic characterization schedules or on DOE methodology.

The CDSCP outlines an extremely ambitious scientific research program that will be difficult to accomplish in a realistic time frame. Although the January 1988 version of the CDSCP does not place constraints on the schedule (section 8.3.1.17.4.14), the earlier version (August, 1987) indicates that all of the Quaternary tectonics studies would be completed by early 1991. If this is indeed the anticipated time frame, the scientific goals presented in the CDSCP are probably unrealistic.

In addition, there appears to be a question as to how the DOE intends to pursue the characterization program. The CDSCP, for example, states (p. 8.3.1.8-24):

> " ... the feasibility of planned or potential activities will be evaluated to determine if the activities will reasonably increase the level of confidence in the parameters that describe the process or not. If it is not feasible to increase the level of

confidence, then no additional studies will be performed and the site performance will be evaluated on the basis of available data."

This caveat appears to suggest that DOE may suspend some or all activities if they determine that, based on unspecified criteria, the activities will not reasonably increase the level of confidence. If this is the approach to be used by DOE, it effectively renders the proposed studies and activities largely meaningless, and suggests that DOE may still only be superficially addressing the technical data base, as they did in the DEA and EA documents. Although this potential problem is difficult to completely assess, there are some indications that site characterization may not necessarily revolve around the detailed investigation program outlined in the CDSCP as much as it will be dependent upon the philosophies and methodologies adopted by the DOE. This is supported by the apparent conflict in scientific approach encountered in a number of places throughout the CDSCP.

Apparent Conflict in Approach

The CDSCP states in numerous places, in particular in Chapter 1, that the present tectonics data base is inadequate to fully assess the earthquake and volcanic hazards at Yucca Mountain (p. 1-5). This sort of disclaimer is consistently repeated:

" The present tectonic model is a preestablished fault system in which recurrent Quaternary and some Holocene movement has been demonstrated and which is favorably oriented in the existing stress field for future movement...The present data base allows some conclusions about locations and orientations, offsets, relative importance, and ages of movement of some of the faults at and near Yucca Mountain. However, it is insufficient to reliably gauge future tectonic effects on seismicity and on the hydrologic regime." (p. 1-334).

" In general, additional work is necessary to better document the recurrent nature of faults near the site" (p. 1-205).

" It is difficult to assess accurately the probability of faulting because little is known about expected earthquake magnitudes or the recurrence intervals and displacement for faults in the southern Great Basin, and at Yucca Mountain in particular...Slip rates on seismogenic faults in the Great Basin are considered to be nonuniform in both space and time (Wallace, 1985)"

(p. 1-206).

" In determining the probability of faulting at Yucca Mountain, once sufficient paleoseismic data are available, it may not be correct to assume a uniform stress release model as a basis for probability calculations..." (p. 1-207).

In contradiction to these disclaimers, there are numerous statements implying a low probability and rare occurrence of tectonic activity at Yucca Mountain throughout Chapters 1 and 8.

" An outline of our current perception of the effects from faulting is presented in DOE (1986) and summarized here. It appears unlikely that faulting would lead to radionuclide releases during the first 10,000 yr following closure of the repository" (p. 1-205).

" Even if new fractures formed, they are not expected to significantly alter ground water flow conditions because the area is already strongly fractured" (p. 1-206).

" Because these faults (such as the Windy Wash and Paintbrush Canyon) have very low slip rates, it is anticipated that the demonstration can be made that the occurrence of 5 cm of displacement is a very low probability event" (p. 8.3.1.8-27).

" During the Quaternary, tectonic and volcanic processes in the Yucca Mountain area have included...slow (less than 3 cm/1000 yr) relative vertical tectonic adjustment...The effect of these intermittent and localized constructional processes on the late Quaternary landscape of the Yucca Mountain area has been limited...Comparable tectonic and volcanic activity over the next 10,000 yr would likely induce a comparably limited effect on the (late Quaternary) landscape of the Yucca Mountain area" (p. 1-30).

" Quaternary deposits are offset or fractured by 32 faults in the 1,100 km^2 area...23 of them moved 1.2 to 2 million yr ago, four of them about 1 million yr ago, and five of them during the past 270,000 yr" (p. 1-127)

" If the average offset per event (on the Windy Wash fault) was about 10 cm, each event had a magnitude (Ms) of about 6 to 6 1/2...The rate of offset averaged over the past 270,000 yr has been about 0.0015 mm/yr which is "extremely low" in the classification scheme of

Slemmons and dePolo (1986)" (p. 1-132).

" The (Solitario Canyon) fault shows no evidence of movement during the past 270,000 yr but does show evidence of movement about 1.2 million yr ago" (p. 1-132).

" Considering the length and nature of this (Paintbrush Canyon) fault, it could have been the source of moderate earthquakes (M 6 1/2) in the past, although such events would appear to be rare based on the low rate of movement" (p. 8.3.1.17-31).

" ...the annual probability for the controlling earthquake is expected to be low (less than 10^{-4} for the Paintbrush Canyon fault)...(p. 8.3.1.17-37).

This conflict arises because the impression is given that the position has already been adopted that significant faulting has a low probability of occurrence, as it was in the EA. One could easily speculate that this dichotomy is one based on the different approaches taken by the U.S.G.S. and the DOE.

Local Quaternary Tectonic Studies

For the most part, the program outlined in the CDSCP for evaluation of local tectonics is quite extensive and describes lofty goals. This program calls for collection of an enormous amount of information. As outlined in sections 8.3.1.17.4.6.1 Activity: "Evaluate Quaternary geology and potential Quaternary faults at Yucca Mountain" and 8.3.1.17.4.6.2 Activity: "Evaluate age and recurrence of movement on suspected and known Quaternary faults", the "parameters" to be obtained in order to evaluate local tectonics include;

* Length, location, and spatial orientation of faults
* Segmentation within individual faults
* Width of faults
* Age and nature of Quaternary deposits and Quaternary surfaces displaced by or covering Quaternary faults within the site area
* Location, amount, and direction of displacement of Quaternary deposits and Quaternary surfaces
* Age, lateral extent, and height of fault scarps

* Lineaments with expression in surficial deposits

* Age of soils overlapping or displaced by faults

* Age of volcanic ashes intercalated in surficial deposits that overlap or are displaced by faults, or that have filled fissures within the fault zones

This information is to be obtained primarily through Quaternary mapping, exploratory trenching, and associated dating of Quaternary materials. We consider this to be an appropriate approach, but feel that it is not made clear that these goals can be reasonably achieved. Several of these issues involve data that are not easy to obtain and that usually have fair to high levels of uncertainty (e.g. age estimates, strike-slip displacements, locations and orientations of buried faults, ages of compound fault scarps). In particular, given the complex, anastomosing nature of the Yucca Mountain fault system, we do not believe it is possible to make a meaningful interpretation of fault segmentation, at least with regard to discrete rupture segments. It is not made clear in the CDSCP that these problems are appreciated, nor how uncertainties will be incorporated.

Regional Quaternary Tectonics Studies

The CDSCP correctly assesses the need for and relative importance of regional Quaternary tectonics studies:

> " The first important object of the tectonic studies is to describe the location, nature, amount, and probability of potential fault movement at the proposed Yucca Mountain repository. Accomplishing this requires integrating results from regional and site-specific studies. Among the required data will be 1) slip rates and recurrence rates of movements on Quaternary faults, 2) probability of future faulting on different styles of faults, 3) character of the regional stress field, and 4) probabilities from the tectonic scenarios" (p. 1-344).

The proposed regional tectonics data collection program is described in the pre-closure tectonics section 8.3.1.17.4. Geological and geophysical evidence of large-scale Quaternary faulting within 100 km of the site will be assessed in order to determine the potential for fault displacement that could affect repository design or performance. The activities planned for site characterization include:

* An evaluation of crustal structure and subsurface expression of Quaternary faults in an east-west

transect crossing the Furnace Creek fault zone, Yucca Mountain, and the Walker Lane

* An evaluation of surface expression of Quaternary faults within a 100 km radius of the site

* An evaluation of the Cedar Mountain earthquake of 1932 and its bearing on wrench tectonics of the Walker Lane

* An evaluation of the Bare Mountain fault

* An evaluation of structural domains and characterization of the Yucca Mountain region with respect to regional patterns of faults and fractures

* An evaluation of the Quaternary faulting proximal to the site within northeast-trending fault zones

* An evaluation of detachment faults at or proximal to Yucca Mountain

Based on the principle that the regional studies should be relevant to the design and performance of the repository, we endorse the activities listed above; we are, however, concerned with some of the planned sub-activities based either on relevance or on level of detail. Given the apparent schedule constraints and resource limitations, and the fact that some additional studies in the site area are lacking, we question whether the levels of detail proposed for all of these regional activities are necessary.

Quaternary Geology Studies

Quaternary stratigraphic and geomorphic studies are critical to constraining the recency and frequency of faulting at Yucca Mountain; discussions of the approach and planned activities are given in Chapter 1 and in section 8.3.1.17.4 of the pre-closure tectonics investigations in Chapter 8. Separate studies are planned for the surface facilities area in Midway Valley (section 8.3.1.17.4.2) and for the site area as a whole (section 8.3.1.17.4.6).

The activities outlined for Midway Valley appear consistent with the level of detail necessary for delineating fault activity critical to the surface handling facility. These activities include mapping surficial deposits at 1:5,000-scale, differentiating and trenching Quaternary faults, and identifying those faults that have Quaternary slip rates exceeding 0.001 mm/yr or that measurably offset materials less than 100,000 yr old.

The Quaternary geology studies for the site area are contained within the investigations designed to identify and characterize Quaternary faults that either intersect the repository or that have a potential for generating ground shaking that could impact design or performance of the repository. Planned activities include:

* Mapping surficial deposits of Yucca Mountain
* Compiling a Quaternary fault map of Yucca Mountain
* Mapping and analysis of offset of Quaternary datums in trenches and outcrop for the Paintbrush Canyon, Bow Ridge, Windy Wash, Ghost Dance, and Solitario Canyon faults
* Conducting uranium-trend and uranium-series dating of Quaternary deposits
* Analyzing Quaternary volcanic ash
* Conducting tectonic-geomorphology studies of the Yucca Mountain region, including the application of the rock varnish dating technique

Although the outlined study program is comprehensive in that it addresses all areas of major importance, we are concerned that the level of detail may not be adequate for the Quaternary stratigraphic framework or the scale of surficial and Quaternary fault maps.

Probabilistic Studies

Probabilistic analyses need to be used carefully and appropriately, and not be used to either mask a lack of data or in lieu of gathering additional data. We have serious concerns regarding the arbitrary use of data in probabilistic studies. In particular, we object to the use of the "10,000 year cumulative slip earthquake", a specially "designed" earthquake unique to the Yucca Mountain site investigation. This earthquake was originally referred to as the "exceptional earthquake" in the August, 1987, version of the CDSCP, but this term has been removed from most parts of the January, 1988, version.

The Quaternary tectonics portions of the CDSCP do not address the anticipated and unanticipated events. These events are required by 10 CFR 60 to be defined and utilized in modeling repository performance. The 10 CFR 60 definitions of these terms appear to be straight-forward, and the CDSCP appears to have avoided relating any proposed investigations to these events; in particular, there is no indication as to how the probabilistic assessments will contribute to identifying these events.

General Objection

Objection 10,000 Year Cumulative Slip Earthquake

The concept and use of the 10,000 year cumulative slip earthquake are unacceptable. This type of seismic source characterization is unconventional, unrealistic, misleading, and nonconservative.

As defined in the CDSCP, the 10,000 year cumulative slip earthquake is "an earthquake that, occurring every 10,000 years, would produce the observed or estimated average Quaternary slip rate on a fault." It is proposed to use this type of estimate in seismic design for the preclosure period. Although it is not explicitly stated as being used for the postclosure period, it is quite implicit (e.g. Table 8.3.1.8-2(b), p. 8.3.1.8-8, Tentative parameter goal - "Annual probability less than 10^{-4} of faulting with displacement over 5 cm" and Activity 8.3.1.8.3.1.3, p. 8.3.1.8-70, "...cumulative offset in 10,000 yr."

Prorating slip over a 10,000 year period creates artificial, watered-down earthquake size estimates. This is an attempt to incorporate a risk factor into estimates of seismic sources, which we consider an inappropriate approach.

For such a critical facility, the widely used and accepted maximum or maximum credible earthquake methodology should be used instead of the proposed 10,000 year cumulative slip earthquake.

The CDSCP presents three arguments in support of the 10,000 year cumulative earthquake which will be addressed here:

First, the CDSCP states that the 10,000 year event "can be determined with greater confidence than a true maximum magnitude" p. 8.3.1.17-36). This may be incorrect, because additional input parameters and uncertainties are involved in the estimation of the 10,000 year event as compared to the maximum earthquake estimate. There are considerable uncertainties associated with the estimation of ages, slip rates, recurrence intervals and b-value relationships, which are used to produce the 10,000 year cumulative slip earthquake. The 10,000 year event methodology does not include theoretical or practical concepts of charateristic earthquakes (i.e. events to occur in the future will be similar to those seen in the geologic record). We feel that these uncertainties are greater than the data and procedures used in conventional deterministic analyses of maximum earthquakes for known sources.

The CDSCP states (p. 8.3.1.17-36):

"Because large earthquakes occur infrequently, few

observational data are available for calibrating the maximum seismogenic potential of individual faults. This is particularly true for faults of the type found in the southwestern Great Basin, where recurrence intervals for large earthquakes appear to range from about 10,000 to 100,000 yr. Therefore, conventional methods for determining maximum earthquake magnitudes from the physical characteristics of local faults appear to be subject to larger uncertainties than the more active faults associated with plate motions".

Conventional methods may have larger uncertainties in analyzing faults with longer recurrence intervals relative to plate margin faults, but this has little bearing on what kind of seismic hazard analysis should be conducted for Yucca Mountain facilities.

Second, the CDSCP states, "low slip-rates suggest that the use of fault length or displacement to develop deterministic estimates of magnitude for a given fault are misleading" (p. 8.3.1.17-63). As discussed above, the analysis of faults with low slip rates (or longer recurrence intervals) may incur larger uncertainties, but this does not render the analysis meaningless or "misleading". In fact, recent studies suggest that faults with lower slip rates may be associated with earthquakes of higher stress drops and moments, (Kanamori and Allen, 1986; Cao and Aki, 1986). Thus, prudent and conservative deterministic and probabilistic analyses are even more appropriate for faults in the Yucca Mountain region.

Third, the CDSCP states that, "Use of slip-rate data (to constrain recurrence times) in conjunction with more conventional fault data provides added assurance that adequately conservative assessments of the local seismogenic potential will be accomplished" (p. 8.3.1.17-36). This is a somewhat fuzzy statement, but it is assumed in this review that "adequately conservative assessments" implies that the use of maximum earthquakes is overly conservative in most local source scenarios since the duration of "cumulative slip" of these events would be longer than 10,000 yrs.

For two additional reasons, it is considered that the 10,000 year event is nonconservative. First, the 10,000 year event estimation is completely dependent on long-term averages. Recent work, however, has shown that fault activity in the Basin and Range province and other regions commonly exhibit spatial and temporal clustering of events (Wallace, 1985; Pearthree and Wallace, 1988). Averages and recurrence intervals over short-term periods can be greatly different than those over the long term. Secondly, considering historical earthquakes in Nevada that have involved several faults, rather than a single, discrete fault, a seismic source estimation of a single fault, such as the

Paintbrush Canyon fault, may actually underestimate potential seismic hazards.

The artifical nature of the 10,000 year cumulative slip earthquake will make it impossible to accurately estimate the uncertainty or conservatism of the estimate. The use of a maximum earthquake analysis is a direct method, and uncertainties can be incorporated into the analysis. Considering different earthquake scenarios, the sensitivities of input parameters can be judged and more meaningful estimates of conservatism can be made.

In short, the 10,000 year cumulative slip earthquake is felt to be a nonconservative estimate for seismic hazard considerations of facilities important to safety.

A seismic source analysis of the site should include deterministic maximum or maximum credible earthquake estimates for the known and speculated sources and probabilistic maximum or maximum credible earthquake estimates to represent unknown and new faults. Multiple estimation methods and uncertainties should be utilized to understand the sensitivity and conservatism of the estimates. Nevada's historical earthquake record also needs to be considered in the analysis. For example, several similarities have been noted between the Yucca Mountain and the Cedar Mountain areas, suggesting a 1932 Cedar Mountain type of event should be considered in the seismic analysis (Bell, 1985; Bell and others, 1987). The 1932 Cedar Mountain earthquake was a complicated, multiple fault event, yielding an $M_s = 7.2$.

The NRC has expressed they believe the use of Appendix A of 10 CFR Part 100 for the period through permanent closure is conservative and appropriate (Trapp and Coplan, 1986). Trapp and Coplan comment that, "Appendix A of 10CFR100 has become a standard against which nuclear facilities other than power plants have been evaluated." Two of the projects reviewed by NRC are the Independent Spent Fuel Storage facilities and the proposed Monitored Retrievable Storage facility. These facilities are regulated by 10 CFR Part 72, which states "west of the Rocky Mountain front (west of approximately 104° west longtitude), and in other areas of known potential seismic activity, seismicity will be evaluated by the techniques of Appendix A of Part 100 of this chapter (10 CFR 100)." Appendix A calls for "determining the earthquakes of greatest magnitude related to the faults." This is also supportive of using maximum or maximum credible earthquakes in the seismic considerations for Yucca Mountain.

The Yucca Mountain site lies within a tectonically active area, with many potential seismogenic sources lying immediately adjacent to it. A consequence of this is that conventional maximum or maximum credible earthquake analyses would yield high seismic design values for this site. High design values are

viewed as appropriately characterizing the site, rather than being overly conservative. The seismic hazards of the site need to be characterized correctly, similar to other critical facilities, located in areas with numerous local, capable faults. The 10,000 year cumulative slip earthquake falls far short of that goal.

General Concerns

Concern Consideration of complex faulting events

All considerations of disruptive scenarios involving faulting consider the possibility of rupture along only a single fault. This applies to analyses of both ground motion and rupture of waste packages. The possibility of complex events, 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 Well Cone. Combined with observations of historical earthquakes in the Basin and Range, this indicates that complex events are quite possible. A reasonably likely faulting scenario at Yucca Mountain would be a large earthquake or earthquake sequence involving rifting and dike intrusion in the lower- to mid-crust and distributed rupture across several faults in the upper-crust and at the surface. Failure to allow for this could cause the effects of seismic events to be seriously underestimated.

Applicable sections:
8.3.1.8; p. 8.3.1.8-27; "...a throughgoing fault..."
8.3.1.8.2.1.2 Activity: ...packages intersected by a fault...
8.3.1.8.2.1.4 Activity: ...package rupture due to faulting...
8.3.5.13 Item 2) ...selection of release-scenario classes...
Applicable tables:
8.3.1.8-2(b); p. 8.3.1.8-7 Number of waste packages...
8.3.5.13-1. Potentially significant scenarios

Concern Study of the Fatigue Wash fault

In the CDSCP, both discussions and plans for study of north-south faults in the site vicinity usually refer to the Paintbrush Canyon, Bow Ridge, Solitario Canyon, and Windy Wash faults. Mention is rarely made of the Fatigue Wash fault. This fault has geomorphic expression similar to the others, and it is an integral part of the complex fault system at Yucca Mountain. Due to the anastomosing nature of this system, inferring extensions of individual faults can be very subjective. For example, the fault trace cut by trench CF-1 could just as easily be called the Fatigue Wash fault as the Windy Wash fault, as has been done. The Fatigue Wash fault is an integral part of this system, but it has not yet been studied. While this fault will probably not control design parameters for the initial waste emplacement area, it bounds one of the principal areas considered for expansion.

For example:
p. 8.3.1.17-29 Review of local tectonic environment
Section 8.3.1.17.4.6.2 Activity: Evaluate age and recurrence...

Concern Strike-slip displacements

Even though it is acknowledged in the CDSCP (p. 8.3.1.17-31, paragraph 1) that strike-slip displacements on some of the Quaternary faults can not yet be ruled out, all estimates of displacements and slip-rates are based solely on vertical displacements. In fact, strike-slip displacement is discounted as insignificant (p. 8.3.1.17-46; Technical rationale for investigation) even if it exists.

Although no direct evidence of strike-slip displacement has been recognized, at least some circumstantial evidence has been observed (e.g. patterns of faults exposed in trenches along the Windy Wash and the Bow Ridge faults). For any faults that have a significant amount of Quaternary strike-slip displacement, the observed vertical displacements could be considerably less than the net displacement. Since so much is being based on slip-rates, failing to account for strike-slip displacements could result in greatly underestimated magnitudes, displacements through waste packages, etc.

Concern Seismic hazard of the Paintbrush Canyon fault

The CDSCP states (p. 8.3.1.17-31) that the Paintbrush Canyon fault "may be capable of producing a moderate earthquake (M about 6.5) with a recurrence interval greater than ten thousand years."

Selecting a magnitude, "about 6.5", is premature and extremely nonconservative. This size earthquake is on the order of a random earthquake for the Basin and Range Province, and could occur nearly anywhere in this province, regardless of the specific tectonic setting. Based on what we know of the Yucca Mountain site faults, and the historical earthquake record of Nevada, larger earthquakes should be anticipated.

Several moderate-sized historical earthquakes in the Basin and Range Province have produced limited surface rupture and fracturing (e.g. 1934 Excelsior Mountains, 1935 Helena, 1948 Verdi, 1966 Boca Valley, 1980 Mammoth Lakes earthquakes). The 1986 Chalfant earthquake was an M_L=6.4 event and occurred on a secondary or splay fault that does not have a clear surface expression. Surface fracturing from this earthquake was scattered over a wide area, was on the order of a millimeter to a few centimeters, and is already poorly preserved. The historical

record suggests that a moderate earthquake should be considered as a floating or random earthquake, which can occur on secondary as well as main faults.

The second part of this statement regarding the recurrence interval of a moderate event, is misleading because the data are to incomplete to determine this.

Concern Uncertainties of values used in risk assessment

Throughout the CDSCP, there is considerable emphasis placed on the precise determination of various parameters that can not be estimated without considerable uncertainty. For example, it is intended to use slip-rate values to define earthquake hazards. Slip-rates normally have a great deal of inherent uncertainty, due to such factors as paucity of datable materials or geomorphic features, the combined uncertainties of age-estimates of Quaternary materials, age-bracketing as opposed to direct age-estimates, and amounts of displacement. It is not made clear that this problem is understood and how these uncertainties will be conservatively dealt with. Another example; it is stated that determining displacement on faults in the subsurface will be "nearly impossible" (Sec. 8.3.1.17.2.1.2), but plans call for identification of faults in the subsurface with a probability of greater than 10^{-4} for displacements greater than 7 cm (e.g. p. 8.3.1.17-34). In the "current estimates", it is evident that values will be assumed to meet the desired goals, unless demonstrated otherwise. It thus appears that when data are "nearly impossible" to obtain, values will be assumed to be favorable.

Levels of uncertainty should be clearly stated and carried through into estimates that rely on data with large uncertainties.

Concern Estimation of annual probabilities

The CDSCP estimates annual probabilities of seismic events on given faults by merely inverting the estimated recurrence intervals (p. 8.3.1.17-37). These probability estimations are misleading for several reasons: they do not account for the elapsed time since the last event; they do not consider uncertainties in the estimates; they do not include a sophisticated examination of the earthquake history of the source (e.g. if the most recent event on a fault was smaller than previous events, this event may have released only part of the stress); and they do not consider (add in) a random probability of earthquake clustering and contageous interactions with other faults.

The estimates and procedure of estimating annual probabilities used in the CDSCP are misleading and inappropriate for use in analyses or decisions.

Concern Probability "precedent" from nuclear power plants

The CDSCP states on p. 8.3.1.17-35 that:

> "An important precedent is provided by nuclear power plants where annual probabilities for exceeding the design-basis motions have been found to be on the order of 10^{-3}/yr to 10^{-4}/yr for several operating plants (Reiter and Jackson, 1983)".

It is important to place this "precedent" in context. The broad range of "on the order of 10-3/yr to 10-4/yr" corresponds to the estimated return periods of probabilistically derived spectra which are similar to spectra derived using Appendix A of 10 CFR Part 100 for several nuclear power plants (Reiter and Jackson, 1983; L. Reiter, 1988, pers. comm.). These plants are located in the central and eastern United States, were constructed before the implimentation of Appendix A, and were undergoing reanalysis for seismic hazards. Reiter and Jackson (1983) report these values as "implicitly accepted by NRC in recent licensing decisions", because these values correspond to the Appendix A type analysis for these facilities. The final review memorandum contained in Reiter and Jackson (1983) states, "Application of this study and its review recommendations to other sites or other programs should be examined on a case by case basis". Thus this report is not meant as an ubiquitous precedent for nuclear power plants and facilities.

Significant differences exist between these central and

eastern United States sites and the Yucca Mountain site. The Yucca Mountain site has several capable faults in the immediate area, and a similar analysis would probably yield greater corresponding return periods (lower corresponding annual probabilities).

The CDSCP also appears to misuse this broad range of annual probabilities in subsequent citations. The term "on the order of 10^{-3}/yr to 10^{-4}/yr" is a fuzzy range, and it means the actual values reviewed may have been a little higher or lower than the reported values (L. Reiter, 1988, pers. comm.). The CDSCP uses this range, however, rigidly defining goals, decisions, and estimations of conservatism.

Concern Quaternary stratigraphy

The stratigraphic scheme of Swadley and others (1984) will be used for mapping surficial deposits (section 1.2.2.3, and p. 8.3.1.17-85). As discussed in previous reviews of the DEA and EA, this scheme is not entirely adequate for delineating surficial deposits in the degree of detail necessary for constraining timing of fault activity. The results of the study by Whitney and others (1986) on the Windy Wash fault and our on-going soil-geomorphic studies in Crater Flat also support this conclusion; the stratigraphic sequence may be adequate for mapping on a regional scale, but the late Quaternary stratigraphic relationships of Yucca Mountain are sufficiently complex to warrant a more detailed scheme for site investigation purposes. A scheme should be used which subdivides the Swadley and others' units into finer divisions commensurate with the level of present knowledge.

Concern Scale of mapping

The scale of mapping proposed for the site area does not appear to be adequate for delineating and constraining Quaternary fault activity. Section 8.1.3.17.4.6.1 indicates that the surficial deposits and Quaternary faults will be mapped at a scale of 1:24,000 for the site area (91 mi^2). Our concern is that this scale is not adequate for a site investigation of this nature; a scale of 1:24,000 is considered to be a reconnaissance level. At a minimum, the scale for mapping in the site area should be 1:12,000. The original bedrock mapping of the site area by Scott and Bonk (1984) is 1:12,000, and there is now complete 1:12,000-scale aerial photography available for the site area. Consequently, the surficial and Quaternary fault mapping should be integrated with the mapping of Scott and Bonk (1984) so that a comprehensive, detailed geologic map of the site area can be

produced.

Similarly, the scale of the Quaternary fault map for the site area should be large scale so that subtle details of fault and related fracture patterns are displayed. The ability to analyze detailed fault patterns is particularly important in interpreting the evidence for strike-slip faulting.

Concern Cane Springs fault zone

Studies of northeast-trending fault zones proximal to the site are necessary for constraining the recency and recurrence of activity of these structures in as much as they are regarded as conjugate features within a northwest-trending Walker Lane system. In so far as they relate to characterizing the faults at the site, however, we regard the Rock Valley and Mine Mountain fault zones as most important and the Cane Springs fault zone as less important. The Rock Valley and Mine Mountain fault zones appear to be structurally linked to the Yucca Mountain fault system, whereas the Cane Springs fault zone is once-removed from this system. The detailed surficial geology studies planned for the Cane Springs fault zone could be substantially reduced, especially if they are at the expense of additional work needed on the local fault systems.

Concern Detachment faults

An evaluation of the presence of detachment faults at and proximal to Yucca Mountain is proposed because detachment faults could represent a significant seismogenic source or they could conceal a significant seismogenic source at depth (p. 8.1.3.17-131). We agree in general with the need for detachment fault studies, but are concerned somewhat with the level of detailed studies planned on a regional basis. The question of a detachment fault beneath Yucca Mountain may be mute as far as seismogenic sources are concerned. The presence of Quaternary basalts in Crater Flat and at Lathrop Wells indicates the existence of crustal-penetrating structures.

We are concerned somewhat with the level of detailed bedrock mapping planned for the Paleozoic and Tertiary rocks in the Beatty, Specter Range and Camp Desert Rock, and Sheep Range areas, and the extensive age dating planned for the Amargosa Desert core complex. The level of effort placed on these activities appears rather ambitious given the type of data necessary for delineating the presence of a regional detachment fault.

The presence or absence of a detachment fault beneath Yucca Mountain is important for modeling fault geometry and tectonic interrelationships, understanding seismic potential, and interpreting subsurface stratigraphy, and the studies should be directed primarily toward these purposes.

Concern Supporting bases for parameters

Supporting bases for various parameters are often not given. Examples include: "significantly large" offsets of 2 m during the postclosure period (p. 8.3.1.8-60 and 8.3.1.8-73); a 5 km radius to assess the possibility of sympathetic displacements (p. 8.3.1.17-46), even though sympathetic rupture is known to have occurred in response to events at much greater distances than this; and a cutoff of 1 m of Quaternary displacement or 100 m of Tertiary displacement (p. 8.3.1.17-50), potentially excluding Holocene/late Pleistocene displacements of less than a meter and excluding the Ghost Dance fault. Since DOE has established "goals" for themselves that they claim will provide an adequately conservative assessment of the site, they should provide clearly stated bases for goals and parameters to demonstrate that these are in fact appropriate numbers.

Concern Carry-through of studies into risk assessment

There is a lack of carry-through of planned studies or activities into disruption scenarios and risk assessment. For example, an assessment of tectonic interrelationships of Quaternary faults is stated as planned, but disruptive scenarios treat faults as acting independently and call for evaluation of the effects of rupture along only a single fault. This makes the CDSCP appear to be an unintegrated document and leads to the worry that studies, even if accomplished, will be lost and not incorporated into risk assessment.

Concern Ash-fall potential

The analysis of ash-fall potential (Section 8.3.1.17.1.1) considers only silicic volcanic sources in the western Great Basin, even though it is known (p. 8.3.1.17-146) that ash-fall from other sources (e.g. Cascades and eastern Snake River Plain/Yellowstone) have occurred at the site in the past. This could greatly affect the results of probability analyses, which are being used. It could also affect the potential particle density and size distribution at the site, since ash from more distant sources would probably have a finer average particle

size.

Also, the same logic as the 10,000 year earthquake (see above objection) is used in the form of a 1,000 year ash-fall. Such events, if they were to occur, would probably exceed these watered down values.

Concern Input of tectonics into the drilling program

The manner in which the systematic drilling program is outlined (Section 8.3.1.4.3.1) expresses a lack of concern for providing information on faults. Throughout sections on faulting in the CDSCP, it is stated that drill-hole data will provide the needed information on down-dip fault location and geometry. Description of this study, however, gives little indication that the drilling program will be tailored to provide such information (e.g. 8.3.1.4.3.1.1 Activity: Systematic drilling program; paragraph 2 states "Data from this study are used principally in ... geohydrology, ... geochemistry, ... three-dimensional models". No indication is made of input into post- or preclosure tectonics; or preclosure hydrology, for that matter.).

This problem is reflected in the proposed distribution of first phase core holes (Figure 8.3.1.4-12). No holes are located in order to intersect the Ghost Dance fault; the only one that would intersect the Solitario Canyon fault would do so at a depth of only a few hundred feet.

Also, no indication is given as to how conflicts will be resolved regarding reasoning for differing locations of drill-holes (e.g. it may be advantageous to move one hole for fault study, but not for groundwater study).

As the drilling program is outlined, it is quite difficult to evaluate whether it will be sufficient to fulfill the stated objectives.

Concern Waste package spacing

There seems to be a philosophy for waste package spacing that results in the hottest, most hazardous materials being placed in the most questionable areas. This concerns statements in the CDSCP that spacing of packages will be flexible enough to allow questionable areas (e.g. fracture zones or perched water) to be avoided and that spacing will vary, depending on heat output of individual packages, which will vary by up to an order-of-magnitude. The conclusion that can be reached out of this is that the hottest waste will be placed adjacent to questionable

areas, since these will have the lowest spacing. This also applies to the statement that one possibility for evenly distributing the heat is to have a closer packing of waste packages at the outer edges of the repository (in other words, next to the main fault zones).

Applicable sections

8.3.2.2.3 Design concepts...;
Product 1.11.3-2 Usable area and flexibility evaluation;
Product 1.11.3-5 Criteria for contingency plan;
Product 1.11.6-2 Borehole spacing;
Product 1.11.6-4 Stategy for containment enhancement.

8.3.2.2.6.2 Design Activity 1.11.6.2 ...spacing strategy

Applicable tables

8.3.2.2-7 Parameters ... to satisfy Info. Need 1.11.3;
Product 1.11.3-2 Usable area...

Specific Comments/Questions

Comment Age of basaltic volcanism

Section 1.2.1.2.2, paragraph 1, p. 1-49; This discussion states that the most recent period of basaltic volcanism "occurred from 3.7 to ... 0.1 million yr before present." This implies inactivity, which is obviously not the case, especially in light of the evidence that Lathrop Wells Cone is younger than 20,000 yr old (Wells et al, 1988). Even if the youngest eruptions were 0.1 million yr old, we would still probably be within this volcanic cycle, given the apparent recurrence rate of these eruptions.

Comment Age of calcite deposits

Section 1.2.2.2.10, p. 1-73; It is stated that "a correlation with even the younger ash is consistent with a relatively old age for the calcite deposits." This is not necessarily true, especially in light of recent evidence that Lathrop Wells Cone is younger than 20,000 yr old (Wells et al, 1988). Also, no evidence is presented that excludes the possibility of calcite formation postdating the ash.

Comment Stress rotations

Section 1.3.2.2.1, subsection Extensional tectonism, p. 1-102; A change in stress orientation is said to possibly correspond to a change in plate boundary conditions at about 10 to 12 million yr ago. This does not take into account published information that indicates that significant stress rotation may have occurred as recently as about 3 million yr ago (e.g. Ander, 1984).

Comment Fault lengths and earthquake magnitude

It is stated that "Because the entire mapped fault length is assumed to rupture, the estimate of maximum magnitude is conservative" (p. 1-191). In light of several historical earthquakes in the western Basin and Range province (e.g. 1915 Pleasant Valley, 1932 Cedar Mountain, and 1954 Fairview Peak-Dixie Valley earthquake sequences) and comments by Blume and Associates (1987, page 16), ruptures along individual traces often extend well beyond mapped lengths and overall rupture zones may have lengths several times that of individual traces. There

is considerable uncertainty in whether a seismic event will extend beyond the mapped trace of a single fault; therefore, assuming ruptures will be confined to mapped fault lengths is <u>not</u> conservative.

<u>Comment</u> <u>Effects of igneous intrusion</u>

In table 8.3.1.8-3(b), p. 8.3.1.8-11, a current estimate of the trend of source structures for basaltic intrusions is given as about N30E. This would be the trend of the Lathrop Wells Cone projected into the surface facilities area. An igneous intrusion immediately adjacent to the repository block could greatly affect percolation flux rates. Despite the importance of this, DOE feels their "confidence" in the current estimate matches their perceived "needed" confidence level (i.e. both are "moderate") and "no new activities are planned" with regard to this subject.

<u>Comment</u> <u>Localization of basaltic volcanism</u>

On p. 8.3.1.8-36, it is stated that;

> "Preliminary evidence suggests the Bare Mountain fault is no longer a structural boundary for the localization of sites of basaltic activity. This interpretation implies that future volcanic activity should occur southwest of the Crater Flat area, between the Bare Mountain and the Death Valley fault zones and that the peak of basaltic volcanic activity has passed from the Crater Flat area."

Considering the age of the Lathrop Wells Cone (possibly less than 20,000 years; Wells and others, 1988), and that the Lathrop Wells Cone is close enough to be considered to be in the Crater Flat area, this statement is in gross error.

<u>Comment</u> <u>Estimation of slip-rate values</u>

We are concerned that elementary level procedures are being used to determine the slip-rates of faults (p. 8.3.1.17-31). Estimating the slip-rate of a fault for seismogenic purposes is often one of the most difficult and uncertain tasks in neotectonics. Several problems often have to be addressed, such as: how much surface distortion has occurred? is the slip distributed? is this slip-rate estimation representative of the entire fault (a point problem)?, and how accurately can offset units be measured? What is the true sense of displacement of the

fault? These potential uncertainties, which are unknown if unaddressed, would be propagated into other estimates derived from slip-rates, such as estimates of recurrence intervals and magnitude.

Comment Use of time/magnitude/slip-rate graph

We are concerned that the time/magnitude/slip-rate graph presented in Slemmons and dePolo (1986) is being misused to estimate recurrence intervals (p. 8.3.1.17-31). The input information used is premature and not based on data. The magnitude of 6.5 is extremely nonconservative (see comment on seismic hazard of the Paintbrush Canyon fault) and the slip-rate used does not consider distributed slip and the percentage of strike-slip component, etc. (see comment on estimation of slip-rates).

The graph being used was developed from a data set of dominantly strike-slip faults from plate boundary settings. The recurrence behavior of earthquakes in the Basin and Range province is likely somewhat different than plate boundary settings. Perhaps specific relationships developed from the Basin and Range province would be more applicable for use at the Yucca Mountain site.

The value estimated-- "50,000"-- for these input parameters (M6.5, 0.01 mm/yr) is technically misestimated from the graph. The corresponding value to these input parameters from the graph is 40,000.

Question 1,000 year period in fault analysis

Where does the widespread use of a 1,000 yr period for faulting come from? Is there a basis specifically stated for deviating from the 10,000 year period? Might not the 1,000-10,000 year period be more critical, since the waste will have cooled, allowing more groundwater to reach the packages?

Question Air gap

What is the level of confidence that the air gap will be maintained, allowing 7 cm of slip to be accommodated before rupturing the packages? Significant spalling seems likely, given the high temperatures imposed by the waste and the vibratory ground motion that would accompany a near-field seismic event.

Question Folding or distributed shear

Why do all the discussions of "folding or deformation from distributed shear" drop consideration of the latter in current estimates (i.e. "folding has not occurred in the last 10 million years"), when we know that deformation from distributed shear has occurred? (For example; Table 8.3.1.8-2(b), p. 8.3.1.8-8)

Question "10,000" year period used in table 8.3.1.17-3(a)

In table 8.3.1.17-3(a) Design and performance parameters... (p. 8.3.1.17-7), is "[faults] that measurably offset materials less than 10,000 yr old" a misprint? This is usually talked about in terms of 100,000 yr.

Summary

The CDSCP outlines a very detailed scope of work which addresses most, but not all, important Quaternary tectonics issues relevant to the suitability of the Yucca Mountain site. On the positive side, the CDSCP covers nearly all of the deficiencies noted in the DEA and EA, and it proposes studies of critical elements necessary for developing multiple tectonic models. On the negative side, it is not clear whether the proposed level of investigation will, or can, be carried out. There is an apparent conflict in approach based primarily on the interpretation of the existing data base; on the one hand, the CDSCP indicates that much data needs to be collected before assessing fault hazards, while on the other hand it also indicates that anticipated hazard is expected to be low.

We seriously object to the concept and use of the "10,000 year cumulative-slip earthquake". This is a specially designed definition which incorrectly incorporates a predetermined level of risk into the earthquake hazard analysis. Instead, we recommend that a "maximum magnitude" or "maximum credible" earthquake be utilized. Based on existing data, the most likely "anticipated event" is a magnitude 7+ earthquake occurring on Yucca Mountain faults during the post-closure period.

The proposed studies of the local and regional Quaternary tectonics issues are fairly comprehensive, but there are several elements of these studies with which we have concerns.

Although the Quaternary stratigraphic and geomorphic investigations are relatively detailed, the scale of mapping to be done in the site area is inadequate for delineating surficial geologic and fault relationships. A scale of 1:24,000 is planned; for a site investigation of this nature, the scale should be at least 1:12,000.

The studies planned for the fault and tectonic relationships within the site area are extensive. However, some proposed goals appear to be unrealistic based on the level of uncertainty known to be associated with the collection of data of this nature. In addition, we are concerned that not enough emphasis has been placed on considering complex faulting (including volcanic) events, on young faulting along the Fatigue Wash fault, on strike-slip faulting, or on considering faulting and tectonics in the drilling program.

The regional Quaternary tectonic studies are also comprehensive, but we are concerned that a couple of the planned activities may be too detailed given the resource and time constraints of the characterization program. Based on the principle that the regional studies should be relevant to the design and performance of the repository, we question the need

for detailed study of the Cane Springs fault zone and the need for the ambitious program outlined for detachment faulting.

Principal Recommendations

* The use of the 10,000 year cumulative slip earthquake should be abandoned and maximum or maximum credible earthquakes used in the seismic hazard analysis. Based on existing information, we feel that a reasonably conservative seismic analysis will include a large magnitude earthquake, with complex, distributed rupture, similar to the 1932 Cedar Mountain earthquake (M_S=7.2), as an "anticipated event".

* A study of the Fatigue Wash fault should be initiated.

* Mapping of Quaternary deposits and faults in the site vicinity should be done at a scale of 1:12,000.

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ROUGH DRAFT

Site Characterization Plan Consultation Draft Review

Geochemistry Review, F. W. Dickson

Sections covered:

Chapter 4
Chapter 8, sections 8.2.2.4.2
8.2.2.4.7
8.3.1.3
8.3.1.7
8.3.1.8.4.1

Summary

DOE's Consultation Draft Site Characterization Plan in Geochemistry recognizes the mandate from NRC to: establish the existing geochemical setting of Yucca Mountain as characterized by natural solids, liquids and gases, as a baseline to detect changes caused by human activity; use in prediction efforts; anticipate reactions near and far from the canisters before and after closure; and understand the implications for past and possibly recurring processes by determining specialized mineralogical, petrological and compositional properties of materials in the system.

Need for Supervision and Coordination of the Research

Some gross difficulties in the Draft SCP stem from the absence of a coordinated plan, clearly conceived before the research began, aimed at ensuring in-context closely coordinated research by qualified persons, stepwise evaluation of results, systematic application to the problems, and arrival at consciously known check-points at which go-no go decisions are made. Chapter 8 makes an elaborate attempt to present the notion that these difficulties are being acknowledged and overcome but the absence of an agency to oversee, actively supervise and coordinate makes the elaborate planning more an exercise in form than a commitment to action.

The geochemical research is supported by DOE funds made available to research organizations on the basis of submitted proposals; these organizations are mainly the U.S. Geological Survey, Denver Office; Los Alamos National Laboratory; Sandia National Laboratories, Lawrence Livermore National Laboratory; and Argonne National Laboratory. Excellent researchers with modern facilities have studied various aspects of the needed work, with the relevancy of one project to the other and its place in the decision-making sequence being the responsibility of DOE. Unfortunately, DOE personnel lack the breadth of view and the operational insights to ensure sound progress.

The geochemical and related research that has been done, therefore, is a patchwork of projects organized without the guidance and evaluation of a central responsible group. It is a horizontal organization into which research funds have been dropped, to splatter and run to the edges of the agencies, much as mercury dropped on the laboratory floor runs to the corners of the room.

My opinion is that DOE will prove unsuccessful in meeting technical criteria required by NRC and requested by the State of Nevada, if they use the present organizational system.

Complexity and Size

The plans do not seem to recognize the extreme amount of work required to answer at a reasonable level of certainty even simple geochemical questions. The Draft SCP refers in almost an off-hand manner to various measurements they will make to answer some geochemical questions. As an example, an important question is whether the rocks contacted by groundwaters in a leaky repository will react and precipitate radionuclides from solution. To solve this question requires data on solution reactions over the temperatures, pressures, and concentrations at Yucca Mountain, solid phase physical and thermodynamic data, absorption isotherms, solubilities of solids and gases in groundwaters, the radiolysis effect, influence of microbial organization, and effects of canister and back fill materials. The data on these reactions are incomplete. Equilibrium data to be gathered in the laboratory on reactions is costly, time-consuming, and not possible in some instances. Disequilibrium data on reaction kinetics is even more difficult because the reactions of silicate-water systems below 300°C are unpredictable, difficult to establish empirically, and lacking in theoretical bases.

Interactive Systems

A surprising aspect of the Draft SCP is the low level of understanding of the importance of interactive effects. Geologists 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. The oceans and the atmosphere have compositions that are the result of integrated processes of many kinds. The continental crust is the result of long sustained cyclic processes that mixed and sorted inorganic and organic matter, which led to the low density, silica-rich rocks that float as a crust on top of denser mantle rocks. For practical reasons, to study such complex systems the approach used must be simplified, but it must always be kept in mind that the applications of such work to concrete crustal problems may or may not be reasonable. Nature follows interactive paths, over millions of years, in her own ways, not necessarily those deduced from

simplified studies.

For example, let us consider the interaction of a glass-crystal mixture of rhyolite with dilute groundwater. The crystals are mostly quartz and k-feldspar. One could measure the solubility of each phase in turn over the range of temperature, pressure and solution composition. The solubility of quartz is controlled by temperature and pressure:

$$SiO_2^{q} + H_2O \rightarrow Si(OH)_4 \text{ or } H_4SiO_4$$

The H_4SiO_4 molecule in solution ionizes:

$$H_4SiO_4 \Leftrightarrow H^+ + HSiO_4^-$$

thus making a weakly acidic solution.

Sanidine, the high-temperature form of K-feldspar, can react:

$$KAlSi_3O_8 \Leftrightarrow K^+ + Al^{+++} + 3\ Si(OH)_4$$

From the equilibrium point of view, the K-feldspar that can coexist with aqueous solutions at low temperatures is microcline, not sanidine. Microcline forms slowly in rocks, taking millions of years. The reaction is also pH or acidity dependent. Al^{+++} tends to react with H_2O:

$$Al^{+++} + 2H_2O \Leftrightarrow HAlO_2 + 3H^+$$

precipitating diaspore ($HAlO_2$) and liberating H^+.

Metastable reactions such as these are difficult to anticipate or characterize.

The SiO_2 content of solution will adjust to both quartz and K-feldspar. However, the back reaction of SiO_2 in solution to make quartz is slow, and the SiO_2 concentration can build up beyond the quartz solubility. This high SiO_2 then promotes the appearance commonly of SiO_2-rich metastable solid phases as opal or zeolites. Once formed, the metastable zeolite influences the concentration of dissolved substances. The kinetics of breakdown of zeolite to stable phases is not known and difficult to measure.

Meanwhile, the unstable volcanic glass makes step-wise reactions with solution, feeding it with a flood of released constituents, which then enter the solution reactions.

The point here is that Yucca Mountain reactions involve coupled step reactions of stable and metastable phases. Little is known from first principles. These interactions are entirely within the field of geochemistry, and are troublesome. The interactions with other subsystems in geology and geophysics pose

even greater problems, such as the effect on rock strength by solution interactions.

A good illustration of unanticipated coupled effects is Szymanski's proposal that kinetic and heat energy propagate upward, affect water chemistry,and horizontal-vertical movements of groundwater. DOE was caught by surprise by Szymanski, and it is probable that they will likewise be subjected to a series of such surprises as the work proceeds and further insights are developed.

Adsorption

The chemical behavior of natural solids and solutions are complex variables of many factors. Adsorption behavior of solution species is needed to judge retardation. Many experiments have been done on adsorption of individual solution species on solids analogous to minerals of high surface areas, generally at low temperatures and 1 bar pressure. One may use groundwater or simplified analogue solutions. Adsorption is only partly an equilibrium phenomenon; a given solution constituent reacts with the solid to form steady states achieved over the times of the experiment. The fine grained solid is highly reactive, and can coarsen or transform to another phase given enough time. The best that can be done is to empirically establish absorption ratios as a function of temperature, solution composition and time, for one solution species.

If enough is known about the nature and concentrations of solution species, the reaction can be treated according to principles of solution chemistry. For example, copper species formed when chloride dissolves in solution are Cu^{+}, Cu^{++} (depending on redox) or as complex ions, $CuCl^{+}$, $CuCl_2^{o}$, or $CuCl_3^{-}$ etc. The absorption behavior of a metallic ion or complex ion depends strongly on charge, and is quite different for a positive charge compared to a zero charge and/or a negative charge. The equilibrium ratios of the concentrations of dissolved species at a given temperature and pressure depends therefore on the stabilities of ions and is a function of total metallic and Cl^{-} concentrations, ionic strength, hydrogen ion concentration, and oxygen fugacity. To experimentally cover the range of conditions for one dissolved substance on a particular substrate is a great deal of work.

Suppose that the absorption behavior of copper species has been determined satisfactorily. Of course, many other species are in natural solutions that are capable of interacting with copper, but the chloride complexes are likely to be the most important. But let's look at another factor, the presence of other metallic substances, such as compounds of uranium and vanadium in which the valence can range from +6 to +1, and various oxy-compounds can form. Radioactive waste contains many compounds of different nuclides. Each with sufficient effort can be worked out. At some

stage, then, a large amount of empirical data on each solution component is on hand. How can this be used?

The need is to apply the data to transport rate problems in the worst case scenario of canister rupture at the thermal maximum in the presence of oxygenated flowing groundwater. The nature and levels of radionuclide compounds injected into solution, let's say, can be estimated. A problem immediately arises: to evaluate the sorption by materials in the site region, one must know the appropriate behavior of the individual radionuclide components in the presence of all the other dissolved species. That is, the various ions and complexes in solution will naturally interact with each other, with the solution, and with the solids. To deduce effects in a mixed system from data on individual solution species requires fundamental understanding of the reaction kinetics, which does not exist and which is not likely to be generated in any finite time.

If estimating performance of the site rests on such knowledge, the amount of time, energy and money needed to gather it would be so great to cast doubt on the suitability of the site. It would be far better to drop Yucca Mountain and search for a potential site about which fewer questions must be answered, where the natural conditions are more suitable for containment.

Maturation

The documents are mute on the identity of persons and institutions that have overall responsibility for the work. Presumably, the future efforts will be done in the same as in the past and as are going on now, that is, in bite-sized packages allocated to researchers on the basis of proposals, invited or uninvited. Will the overall assessment at the close of the program be done in a similar way? If so, strong objections should be lodged.

The difficulty is not whether or not the persons and institutions are capable of doing the research. Many high quality individuals are doing excellent work. The work is eventually published in internal documents, at which point the researchers go on to their next project, which may or may not be relatable to Yucca Mountain. This generates alternating intense focus and inattention, which results in a lack of maturation in the scientific work. Researchers who can stay with the research and who are responsible for interpretations and applications commonly go through stages of development of understanding and insights. Many leads have to be followed, some without positive results, but overall progress is made and insights are deepened. Connections with other research eventually can be perceived and applied.

The situation apparently stems from the belief held by DOE that geological research can be done in an engineering fashion.

Break it up into identifiable bits, make sure that capable people are assigned the correct tasks, and simply wait for results. Those that are not in agreement with this approach are written off as being merely partisan.

Specific Research Projects in Geochemistry

Geochemical sections in Chapters 4 and 8 have been organized to meet NRC and EPA criteria for performance. Discussions were made of areas in which substantial progress has been made, notably in the chemistry, mineralogy and petrology of Yucca Mountain, mostly by the U.S. Geological Survey,and Los Alamos National Laboratory. Three dimensional distributions have been worked on, but the lack of bore holes spaced to detect important structures that are deep enough to bottom in basement rocks has handicapped the researchers. The nature and distributions of pore fluids above and below the groundwater table have not been completely characterized, which is an important goal of the proposed research.

In general, the importance of geochemistry to site characterization was recognized. Research was planned to answer the various process questions by using a battery of field and laboratory studies. The studies were outlined to show sequential activities, uses in the program and relationships to other studies. The geochemical problem areas were discussed and the research formulations designed to solve these problems. So far as general approaches in geochemistry are concerned, the paper research plan was thorough and in general relevant.

A major problem I see is in implementing the research. The agencies and individuals to be involved are not specified. The time sequence of planned events were presented in linear fashion without a quantitative scale. Relationships, uses, and dependence on other research areas were mentioned. No clear statement was made as to how the objectives were to be achieved, who was in charge of what, and who, if anybody, was responsible for overviews and integration of all work. I draw the conclusion that future work will be done in a manner similar to the past work, by isolated individuals and agencies, without an overall plan. The Draft SCP likely represents the best planning that DOE is capable of, which is not good enough, in my view.

A second operational problem, developed in more detail in an addendum, is the apparent lack of appreciation of the overwhelming amount of work required to achieve research activities mentioned commonly in an off-hand manner in the Draft SCP. To actually do the work described would require many years of effort at a cost which would make the characterization not practical. Any experimenter who has worked with silicate-fluid systems at 300°C and below is aware of the painfully slow progress made if the work is to stand up to ordinary critical review by his peers. The DOE

work not only must meet standards of colleagues but also of NRC, EPA, interveners, and State agencies. See the section on enormity of experimental tasks appended.

Appendix

Enormity of Experimental Tasks

The appended figure, "The Experimental Stairs," shows a plot of the number of experiments required for different numbers of experimental variations. The figure shows the exponential increases in the number of experiments needed to cover step-wise addition of variations. Going from 4 variations to 5 increases the experiments needed from 24 to 120. Going to 8 would require 40,320 experiments.

The following list was developed to illustrate the large number of experiments implied in the Yucca Mountain SCP, drawn from my own experience in doing Rock-Solution reactions.

Experimental variables		Number of Variations
1.	Rock Types: Glass, Holocrystalline, Mixtures	3
2.	Minerals: Feldspar, Sphene, Allanite	3
3.	Solution Types: Natural, NaCl, $NaCl_2$, $NaCl_3$	4
4.	Rock-Solution Mass Ratios: 1/1, 1/10, 1/100	3
5.	Agitated, Non-Agitated	2
6.	Temperatures: 50, 100, 150, 200, 250, 300°C	6
7.	Pressure, Total: 100, 1000 bars	2
8.	Oxygen Fugacity: Natural, Hematite-Magnetite, Magnetite-Wustite	3
9.	Hydrogen Activity: pH5, pH7, pH9, Natural	4
	Total number of experiments	31,104

The total number of experiments, 31,104, required to investigate combinations of variables fully, as above, would be excessively expensive in time and money. One researcher has his hands full in running 2 sets of equipment simultaneously. About 30 days are needed for one experiment; therefore, one person doing 24 experiments a year would complete the sequence in 1,296 years. Ten persons doing 240 experiments a year would need 130 years. 100 could do the work in 13 years, if 200 sets of gear were on hand; the cost of the equipment would be 200 x $20,000 or $4,000,000; and the cost for salary of 100 employees for 13 years would be $26,000,000 or more. I doubt that there are more than 25 experimental geochemists who are acquainted with the specialized techniques involved, and a costly training program would be needed.

The above did not take into account: (1) replication and duplication for quality assurance; (2) the need to study the

influences of site components on solid and fluid reactions; or (3) the need to study vapor phases.

Enormous backup in support facilities also would be needed, for:

1. Characterizing changes in the chemical, physical and mineralogical properties of the solids produced during the reactions of 31,000 samples would require use of microscope, x-ray diffractometer and fluorescence, SEM, and microprobe.
2. Analyzing liquid solutions taken from the equipment at the rate of 10 per experiment, amounting to a total of 310,000 samples, for major elements, minor elements, trace elements and anions by all the different methods, is also a serious undertaking, costing time and money.

3. Machine shops, electronic shops, and computer facilities needed for maintaining the laboratory equipment and to help in data storage and processing.

Of course, normally an experimenter would drastically reduce the number of variations to those considered of greatest importance, cross-checking some of the others for unexpected results. But the scientist need only satisfy his knowledgeable colleagues as to the validity and meaning of the experiments for publication. DOE has to satisfy NRC's broad requirements. They also must be able to respond appropriately to interveners who will pounce upon any weak point in the chain of data and conclusions, on the advice of their technical people, and grimly hold their ground.

SCP Consultation Draft Review
Task 3
L. T. Larson, D. C. Noble and S. I. Weiss
May, 1988

Summary Comments

The assigned responsibilities of the Task 3 group have a focus on volcanic geology and associated mineral/energy resources relative to Yucca Mountain and most of our comments which follow, even if they are on tectonics or geophysics, geochemistry, volcanics, or other topics, are ultimately premised upon and directed toward this Task 3 charge. We have not read the entire SCP draft but those parts which we have reviewed strongly suggest to us that the following general comments are called for:

1. We consider that the activities proposed in the DOE draft SCP will not provide geologic, volcanological, geochemical, geochronological, tectonic, or geophysical information required to appropiately evaluate the mineral/energy potential of Yucca Mountain and the lands about the potential site. If only the presently planned activities are carried out we will have only a very marginally better idea of the size and value of resources at depth below Yucca Mountain in either the tuffs or the underlying Paleozoic strata. Further, the same comment applies to presently known mineralization in or near the site area such as that at Wahmonie, Calico Hills, etc. Sampling programs, drilling programs, geophysical studies (with respect to mineralization) and geochemical programs are simply inadequate. For example, has any thought been given to the possibility that mineralization at Yucca might have taken place before deposition of the Tertiary tuffs, or before deposition of the Tiva or Topopah Spring Members? If this occurred, how will surface or repository horizon geochemistry detect such? It could not! We believe that DOE continues not to take seriously concerns of resource potential.

2. We believe that DOE has an apparently very incomplete and compartmentalized concept as to volcanic/caldera geology and, in particular, to how hydrothermal activity and mineralization may relate to volcanism. None of the proposed activities we have reviewed are adequate or integrated in such a way that major improvments will result in our knowledge of potential mineralization in and about the Timber Mtn. caldera, the Crater Flat caldera, Yucca Mountain, etc. A serious omission is evident in their lack of recognition in sections 1.7, 1.8 and Chapter 8 of the world-wide importance of structural control on localization of ore mineralization in hydrothermal mineral deposits. Clearly, sufficient evidence currently exists for hydrothermal mineralization beneath Yucca Mountain, yet no mention is made of any plans to directly test the types of structures in Yucca Mountain that elsewhere localize economic mineralization.

The "evaluation" of mineral and hydrocarbon resource potential given in sections 1.7 and 1.8 is built on incomplete, outdated, often inaccurate and/or misleading information and is wholly inadequate. The assumptions, interpretation, discussion and analysis given in sections 1.7 and 1.8 do not constitute data (facts). All references in Chapter 8 and elsewhere in the SCP to sections 1.7, 1.8 and much of the rest of Chapter 1 as "data" constitute misrepresentation and should be removed.

3. The proposed borehole drilling program is totally inadequate to evaluate the resource base in and near Yucca Mtn. and thus completely inadequate to provide data which will keep the likelihood of future human interference at a minimum. Future drilling must include boreholes (several) in the site proper and about it, and these must penetrate completely the Tertiary section and 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 hydrocarbon potential will also remain untested without deep drilling (20,000 - 25,000 feet) in the controlled area or the repository block. Such a deep borehole would yield important geologic, geophysical and regional structural information.

4. This SCP draft has within it technical procedures and methods that make use of of almost every conceivable geologic, geochemical, geophysical tool known to man. One gets the distinct impression that the DOE attitude and thought process is one that given a problem they don't understand, their answer is to 'throw' technology at the problem and hope the answer will 'fall' out; a classic example of the 'shotgun' approach. Cost or likely time for completion appear to be of very little concern. What further concerns us in this regard is that we believe that some of the proposed methods are likely to be ill-used, misapplied or under-utilized. For example, proposed surface geophysics is not at all to be focussed on potential resources at depth and geochemistry sampling is only at surface or repository levels-- not in holes in rocks which underlie the proposed repository unit and would likely be the target of future exploration efforts.

5. This edition of the SCP makes frequent and continued use of terms such as near to, proximal to, adjacent to, at, in the vicinity of, and so on. Just what do these terms mean concerning the distance from the proposed site where it is essential to have complete knowledge of geologic framework, mineral/energy potential, or, for that matter, seismicity, etc.? Give us some definitions and the rationale behind them!!

6. The Draft refers to the need to map and interprete 'small scale' structures (etc.) and they propose that the largest scale of mapping to be used is 1:12,000(one inch = 1000 feet), or twice that of a of a 71/2 minute topographic quadrangle. This scale is

much too small for 'detail' unless DOE defines detail differently than do we. Certainly structures significant to the localization of ore in many mines throughout the World cannot be depicted on such a scale.

7. The draft SCP sections on mineral/energy resources and human intrusion fail to recognize and address the fact that water is currently being exploited immediately adjacent to the site. Such exploitation of water resources is likely to accelerate dramatically in the near future as gold mines in the Beatty-Bare Mountain area, currently in the development and permitting stages, commence production.

8. It is our opinion that this SCP draft exudes the feeling of 'fait accompli'. The draft reads as though the DOE has a predetermined opinion that Yucca is clearly an acceptable and desirable location for a repository and the activities proposed are 'going through the motions' to prove they are right. The draft simply does not to us read as a scientific/engineering effort to do a complete assessment and evaluation preceding a decision. We are convinced that in the area of our expertise, such is the case.

LIST OF SECTIONS REVIEWED BY TASK 3

Section # / Reviewer

8.2.2.4.7 Summary of the post-closure tectonics site program /LTL, SIW

8.2.2.4.8 Summary of the human interference program /LTL, SIW

8.2.2.4.16 Summary of preclosure tectonics program /SIW

8.3.1.3.2 Studies to provide information on mineralogy . . ./LTL

8.3.1.3.2.1 Mineralogy, petrology and chemistry of transport.../LTL

8.3.1.3.2.1.3 Fracture mineralogy /LTL

8.3.1.3.2.2 History of mineralogic and geochemical alteration.../LTL

8.3.1.3.2.2.1 as above- an activity /LTL

8.3.1.4.2 Investigation: Geologic framework of the Yucca Mountain site /DCN

8.3.1.4.2.1.1 Activity: Surface and subsurface stratigraphic studies of the host rock and surrounding units /DCN

8.3.1.4.2.1.2 Activity: Surface-based geophysical surveys /DCN, LTL

8.3.1.4.2.1.2 Surface based geophysical surveys /LTL

8.3.1.4.2.2 Characterization of structural features ..../LTL

8.3.1.4.2.2.1 Geologic mapping of zonal features . . . ./LTL

8.3.1.4.2.2.3 Borehole evaluation of faults and fractures.../LTL

8.3.1.4.2.2.4 Geologic mapping of shaft and drifts.../LTL

8.3.1.4.2.3 Three dimensional geologic model /LTL

8.3.1.4.2.3.1 Development of 3-D model /LTL

8.3.1.5.2.1.5 Activity: Studies of calcite and opaline silica vein deposits /DCN, LTL

8.3.1.8 Overview of the postclosure tectonics program: description of future tectonic processes and events required by the performance and design issues /LTL, SIW

8.3.1.8.5 Studies ... assessment of tectonics program ../LTL

8.3.1.8.5.1 Characterization of volcanic features /LTL, SIW

8.3.1.8.5.1.1 Activity: Volcanism drillholes /LTL, SIW

8.3.1.8.5.1.2 Activity: Geochronology studies /DCN, LTL

8.3.1.8.5.1.3 Activity: Field geologic studies /DCN, LTL

8.3.1.9 Overview of human interference program /LTL

8.3.1.9.2 Investigation: Studies to provide the information required on present and future value of energy, mineral, land, and groundwater resources /DCN, LTL, SIW

8.3.1.9.2.1 Study: Natural resource assessment of Yucca Mountain, Nye County, Nevada /DCN, LTL, SIW

8.3.1.9.2.1.1 Activity: Geochemical assessment of Yucca Mountain in relation to the potential for mineralization /DCN, LTL, SIW

8.3.1.9.2.1.2 Activity: Geophysical/geologic appraisal of the site relative to mineral resources /DCN, LTL, SIW

8.3.1.9.2.1.3 Assessment of potential for geothermal..../LTL

8.3.1.9.2.1.4 Assessment of hydrocarbon resources..../LTL, SIW

8.3.1.9.2.1.5 Activity: Mineral and energy assessment of the site, comparison to known mineralized areas, and the potential for undiscovered resources and future exploration /DCN, LTL, SIW

8.3.1.9.2.2 Study: Water resource assessment of Yucca Mountain, Nevada /SIW

8.3.1.9.3 ...information required on potential effects of exploiting natural resources ..../LTL, SIW

8.3.1.9.3.1 Data evaluation to support assessment of likelihood of future inadvertent human intrusion ...../LTL

8.3.1.9.3.1.1 Activity: Compilation of data to support the assessment calculation of the potential for inadvertent human intrusion at Yucca Mountain /SIW

8.3.1.11 Overview of land ownership and mineral rights..../LTL

8.3.1.14.2.3.3 Activity: Geophysical field measurements /LTL

8.3.1.17.1 Studies to provide info on volcanic activity.../LTL

8.3.1.17.4.5.1 Eval. significance of Miocene-Paleozoic contact in the Calico Hills...../LTL

8.3.1.17.4.5.2 As above for Bare Mtn-Beatty /LTL

8.3.1.17.4.5.3 Eval. potential relation of megabreccia...../LTL

8.3.1.9.3.3 Application of results /SIW

8.3.4.1 Dev. of an integrated drilling program /LTL

Also some pertinent comments by Alan Chamberlain on 1.7.2.2.1 Hydrocarbon potential....

SCP Consultation Draft Review
L. T. Larson
May, 1988

8.2.2.4.7 Summary of postclosure tectonics site program

General Comment: This still does not address (the pre-closure concern did not either) the intrusive/volcanic heat flux modeling that I think will be necessary.

8.2.2.4.8 Summary of human interference program

General Comment: This may discuss identification of resources at the site with current markets or those potentially... but the question remains just what does at the site mean? 0 km, 3 km 10 km, 20 km, of what?? Not clear! And then when they conclude that Ground Water is the only resource in the immediate vicinity (meaning???) I get the distinct impression that they are concluding things prior to doing the work. Not good science. Certainly with the DOE continued use of near, proximal, in the vicinity, etc. with no or very few numbers much of this SCP can't be considered good engineering either.

8.2.2.4.16 No comment.

8.3.1.3.2 Information on mineralogy, petrology, rock chemistry within the potential emplacement horizon and along potential flow paths

Specific comment: Parameters: 1. The coverage appears complete but methodology to obtain statistically meaningful mineral distribution in bulk rock and in the fractures in that rock are not laid out either here or in Section 4.1. . . . . as best as I can ascertain. How will sampling be done so as not to destroy site integrity? How will it be done given the very limited geologic borehole drilling proposed for the site proper? Further, geometry of flow paths-a parameter indicated as needed is, at best, very poorly known.

Specific Comment: Purpose and objectives of the investigation: They state that the first study will provide a 3-D distribution of mineral types, etc. and that this must be known for transport calculations. . .. BUT they do not say how they are going to go about the sampling.

General Comment: The outlined work is a major study and one requiring exhaustive sampling. Yet they do not indicate the capability of doing this or how they intend to proceed. Thus the entire section appears ill thought out and very poorly internally co-ordinated.

8.3.1.3.2.1 Activity: Petrologic Stratigraphy of the Topopah Springs Member

General Comment: In the last two paragraphs on page 8.3.1.3-33 it is evident that they presently have no reasonable, thorough and systematic sampling plan which will allow good statistics on chemistry, mineralogy, etc. variability in Topopah Spgs unit and certainly not for units below the Topopah Spgs-since apparently most of their proposed samples will be taken from the shaft and drifts in the Topopah Spgs unit. They have certainly not done so for potential flow paths which, since the T. S. is in the unsaturated zone, will in very large part be downwards.

8.3.1.3.2.1.3 Activity: Fracture Mineralogy

Specific Comment: Parameters. Model needed is a correct model and no evidence exists that such an agreed-upon model exists. Data should also include volume %'s of individual mineral species for any given fracture in any given area.

Specific Comment: Description. Re: Mn minerals. It is the oxides and only a few of them, that have sorptive capacities. Further, I suspect that in order to ascertain the very imperfectly known specific cation sorptive capacities for such as U, Th, Cs, etc. of the minerals, the quantitative abundance of individual MnOx's will have to be established at room temperature and at proposed repository operating temperatures. This will require experimental work to be done to determine their individual significancies. It will not be a trivial thing and it will be time intensive.

Re: Sample Collection. This program will result in a vast # of samples and will be very time intensive to study all of them. Also, they will be collected over time of repository preparation and will only give us hind-sight, not foresight. More importantly, however, they propose to sample cores from future boreholes and I can't find any of these proposed for the repository per se. Also, no indication is given that such fracture fillings will be collected and studied from units below the Topopah Spgs.

Specific Comment: Methods and Technical Procedures. Maybe its OK-with sampling exception given above but one gets the real feeling that DOE has opted for the shotgun approach of throwing every-thing at it and hoping for the best. Little thought has been given as to what each technique might provide and how they should be integrated.

8.3.1.3.2.2 - No comment.

8.3.1.3.2.2.1 Activity: History of mineralogic and geochemical alteration of Yucca Mountain

Specific Comment: Objectives. Para. 1 sentence 1, I can't figure out what this objective is.
Para. 2, sent. 1- makes an unevidenced and to my knowledge unknown statement.
Para. 2- entire paragraph. This whole paragraph is totally spectulative and what they have apparently done is take the shotgun approach of throwing everything at the problem in the fond hopes that something will work. They really have no idea.

Specific Comment: Parameters. 1. such as? what authigenic minerals and in what unit(s)? 4/5. Here again we pre-suppose the correct hydrologic flow models.

8.3.1.3.2.2.2 No comment.

8.3.1.4.1 NNSWI Project Drilling-inclusive of table 8.3.1.4-2 and Fig. 8.3.1.4-2 on page 8.3.12.4-23.

General Comments: I can see some major problems/paradoxes herein.

Specific Comments: 1. DOE is proposing and 'laying out' all this drilling prior to clarification of the permissibility of drilling within the repository boundary.
2. No rationale or reasoning is given for the proposed bore hole distribution plan shown in Fig. 8.3.1.4-2. Why are holes sited as shown? Better yet, why is there a 1/2 mile wide X 1 1/2 mile long "gap" in drill hole pattern and a much larger lack of geologic holes of which only three are in the 2 mile X 1 1/2 mile perimeter drift zone. I doubt if the data from this sparse drilling could ever be statistically meaningful in terms of data for structure or for mineralization.
3. No evidence is given that any of the holes will attempt to penetrate the Paleozoic. So, on the basis of proposed drilling direct information on the Paleozoic under Yucca is still totally absent. This is simply not acceptable.

8.3.1.4.2.1.2 Activity: Surface-based geophysical surveys.

General Comment: Objectives. The objectives are vastly incomplete. Given the limited drilling proposed to depths we must also have much more geophysical data in order to evaluate mineral potential at depth. Just to

improve the confidence in stratigraphic models is totally insufficient.

Specific Comment: Description. 1. Para. 3 Assumes there are marker horizons with 'sufficient' contrast . . .. Who says??
2. Para 4 DOE does not provide any reason for the proposed survey locations and they are not obvious.
3. Table 8.3.1.4-4 The techniques proposed are exhaustive but a) how will they 'combine' with existing surveys (not at all I think) and b) how many many years are we looking at. Also, here again is the shotgun approach. They don't know if any of them will work so they will try them all. And still we will have almost no information useful to evaluation of potential mineral resources.

General Comment: This comment is also appropiate to other sections of the SCP. No indication of man-year effort is given. Must this all be done in time for a proprosed 2000 AD (or whatever) opening of the repository? If so, it will never happen. The people who prepared this draft are not realists-they have simply taken the 'do everything' approach and have made little effort beyond logic diagrams to integrate work..

8.3.1.4.2.2 Characterization of the structural features within the site area.

General/specific comments: 1. p. 8.3.1.4-67, para. 2. Detailed geologic mapping of zonal features in ash-flow tuffs . . .. will provide necessary stratigraphic control for identifying 'small scale' faults. Comment: That depends entire on extent and consistency and presence of zonal features not presently known and also on what is meant by 'small scale'.
2. A mapping scale of 1"12,000 is not for detail. Small faults (widths of inches and lengths of meters or 10's of meters) and joint sets (widths of cm's) cannot be indicated on this proposed scale. Scale should be at least 10X larger and preferably even larger.

8.3.1.4.2.2.1 Surface mapping at 1:12,000

General Comment: SCP indicates that such mapping is complete. Are they referring to Scott's?? -but that it will be extended W and S as shown in Fig. 8.3.1.4-10 on page 8.3.1.4-69. They will then assess need for 1:2400 mapping. I can forsee absolute need right now!!-if, as they say, they want detail.

8.3.1.4.2.2.2 No comment.

8.3.1.4.2.2.3 Borehole evaluation of faults and fractures.

Specific comments: 1. The methods and approaches suggested on p. 8.3.1.4-73 for orienting segments of the core and the use of 'continuous core' are, to my mind, very suspect. The very existence of 'oriented' cores in past drilling is very doubtful.
2. A continuous visual television camera display of the hole is a nice idea-if it works. I don't think it will, however. If they have to use mud or foam to drill the hole and for any deep holes I think they will, nothing much will be seen by that wonderful camera. This is, I think, another example of the DOE 'shotgun' approach with very little thought attached.
3. Also - as they note, vertical fractures will not be seen very well in vertical coreholes, and, no angle holes have been proposed.
4. Also, large wide fracture zones can often not be seen in holes because of poor core recovery or because they are very wide with respect to the field of view at any one time in the hole.

8.3.1.4.2.2.4 Geologic mapping of shaft and drifts.

Specific comment: 1. Should remap selected areas after walls have been excavated 3 to 6 months to determine spalling characteristics which later may be important to:
a) waste package integrity, and
b) working accessibility and retrievability for 100 yrs.

8.3.1.4.2.2.5 Seismic tomography. No comment.

8.3.1.4.2.3 3-D geologic model.

Comment only that:
a) they apparently, on the basis of what is proposed, will have very little hard data on the depth dimension, and
b) compilation scales of 1:48,000 or even 1:12,000 appear to be much too small a scale to get any detail on.

General Comment: They repeatedly profess a desire to identify and characterize 'small scale' faults, etc. This is at odds with their chosen scale of 1:12,000 which should be at least 10X larger. The modeling dimensions also give a problem in that on a 1:48,000 scale map even big mines can not be plotted in the sense of giving their true significance.

8.3.1.5.2.1.5 Studies of calcite and opaline silica veins..

Specific Comment: It would appear that this is yet another of the 'shotgun' approaches that exist throughout this draft SCP. DOE proposes almost all possible techniques to answer the question are these veins formed by ground waters going down or hydrothermal waters going up? What they do not appear to have done is to consider these possibilities in any sort of broader context (regional geologic significance??). Do the veins presently exposed in Trench 14 presage a broad-scale, post volcanic, hydrothermal event at or near Yucca?? Such are known elsewhere-witness the Golconda, Nv. deposits of manganese-tungsten and silver hosted in Quaternary valley alluvium and the slightly older but clearly post-volcanic Sulfur, Nv. gold deposits. What possibilities do these sorts of considerations open?

8.3.1.8 Overview of postclosure tectonics program. Description of future tectonic processes and events required by the performance and design issues.

Specific Comments: Approach. - page 8.3.1.8-24. NNSWI will base its analysis of performance measures on a projection of Quaternary rates . . . at and proximal to the site. Here they are saying the lasat 2 million years where elsewhere they refer to the past 4 million years. Also, what is considered "proximal". Is Crater Flat proximal; is Timber Mtn., Bare Mtn? What?
- page 8.3.1.8-26, para. 3. More refined data is needed as stated but also beyond the immediate site area on basaltic volcanism and also on such volcanism not penetrating repository but otherwise affecting it-see later general comments.

General Comments: Summary. Overview covers most approaches and possibilities but leaves some serious gaps in thinking.

1. In their table on pages 8.3.1.8-3 thru -21 they select 'goals' and 'measurements' and 'needed confidence levels' etc.- Who makes these decisions and on what bases? It seems a circular path-one where the fox may well be deciding how many chickens are to be in the hen house.

2. None of the siting issues or probabilities refered to in the lengthy tables addresses what I consider two important igneous or volcanic aspects. To wit:
a) Basaltic volcanism is most likely, agreed, and I agree it is likely to be structurally controlled - but present basaltic volcanism in Crater Flats is along a structure leading into or very near to the repository. Reactivation of this structure and its attendant

volcanism is inadequately addressed.
b) Much thought is given to intrusive interrupting the repository but I think zero thought has been given to a total system whereby the waste is dissipating heat through the rock- creating heat flow outward from repository while at the same time an intrusive at depth or laterally (and present higher heat gradiant in G-3 near caldera edge evidences this possibility) is also giving off heat outwards-this time toward repository waste. Thus normal heat flow gradiant is disrupted and heat might 'pond'-thus elevating ambient heat to unacceptable levels in repository during post closure period. This in turn could cause a chain of undesireable events such as moisture drive off,mineralogic changes, etc.

3. Item 8.3.5.18 in table 8.3.1.8-2(a). Ground motion causes spalling and closes air gap around waste package. Fault to do this is not necessary because Topopah Spgs has an abrupt failure mode and character when unconfined and once this rock is open to air it will spall readily-thus, just by the nature of the rock, it will at least partially close the air gap about the waste packages. Needs consideration.

8.3.1.8.5 (including .1-.2) Studies to provide the information required by the analysis and assessment investigations of the tectonics program..

Specific comment: Parameters section.
1. Why is investigation restricted to younger than 4 million years. If they are restricting work to Quaternary then use 2 million, if not why pick 4 million, why not 10 or . . .. The same sort of criticism could be directed at restricting study to 70 km. What is rationale for these time/area restrictions??
2. On parameter #4. What changes and how many kinds of tuffs will be studied relative to how many kinds and sizes of dikes and then how hot?? So we could, putting all possibilities together, calculate n.n to the n-1 possilbilities plus . . ..

Specific comment: Technical Rationale section. 1. Para. 2. Clearly its more logical to assume that volcanism will be structurally controlled than vice versa-as they do herein.

Specific comment: 8.3.1.8.5.1.1 Volcanism Drillholes.
1. Holes only 1000 foot deep to test magma sources that are estimated to be present by aeromagnetics?? Nonsense!!-might as well not drill at all. And, what was rationale for picking 330 meters? Why not 500 or

1000 or ???
2. All the sophisticated things on p. 8.3.1.8-106 are completely irrelevant if they don't hit something and in 1000 feet it appears to me unlikely that they will!

General comment: 8.3.1.8.5.1.2 Geochronology. 1. Fascinating new methods proposed. Really state-of-the-art. Truely experimental. So I doubt if any two will agree and if this is so, which does one believe?? Also, how many years or decades do we have for the work?? Is this another example of the DOE shotgun approach??

8.3.1.9 Overview of human interference program

General Comments: 1. nowhere in this section does DOE address the very real (judging from present day human activities) problem of random vandalism and curiosity of humans about something that may have been 'locked' away 000's of years ago. 2. The entire effort seems to disregard NRC regulations that "require that resources at the site with current markets be identified and described in terms of net and gross values" and that it must "be demonstrated that the site is located in an area such that natural resources at or near the site are not likely to give rise to interference activities. On page 8.3.1.9-3 DOE goes on to say that intrusion by exploratory drilling for resources can be the most severe intrusion scenario . . .. Taking these items in keeping with what they propose to do to ascertain mineral resource potential in and near the site it is evident that the program they propose is totally inadequate in terms of geology, drilling, geophysics, etc. In particular, great gaps are present and apparently will remain present, in our knowledge of possible mineralization in the Paleozoics below Yucca tuffs. Also, just how near do you have to be to be revelant in terms of mineralization. Calico??, Wahmonie??, Mine Mtn??Bare Mtn? Camp Transvaal?? Where??? On page 8.3.1.9-3 the DOE says "current information and new data acquired from site activities will be employed to assess the natural resource potential of Yucca Mtn." They have laid out very little effort directed specifically toward mineral potential determinations. What they have done is ill-conceived and ill-integrated.

8.3.1.9.2 Studies to provide information required on present and future value of energy, mineral, land and groundwater resources.

This section refers to 1.7 and 1.8.1.7 (summary).
Purpose and Objectives. I agree with their stated

objectives i.e. . . . within or near the controlled area, and possible subsequent resource exploitation.

Specific comments: Technical Rationale. 1. Their statement that the scarcity of vegetation, wildlife and water has historically precluded using the land for recreational purposes - I take exception to. Look at Sand Mtn. Nv. and others. Much greater recreational use would have been made had not most of the land been withdrawn into NTS and Nellis.
2. Their statement that probability that natural resources occur at Yucca is a required input parameter for evaluating the probability that future exploratory drilling will occur is true. BUT, it is also true that it is required to define the presence or absence of resources which, if present, is an NRC disqualifier. They do not address this little item here. Also they say 'in the vicinity' of Yucca Mtn. Just what is vicinity?? They do not define.
3. A systematic and biased p. 8.3.1.9-26. Biased how?? In what way? It's important to know.

8.3.1.9.2.1.1 Geochemistry Assessment of Yucca

General Comment: a) This appears to be thought of as a separate item and it should not be- it should be a part of geologic assessment. b) No mention is made of depth dimension. You certainly will not be able to assess all potential mineralization from surface studies.

Specific Comment: Parameters. To list of elements given in silicic tuffs I think one could easily add Fl, Be, Al (alunite), Mo (Valles Caldera)... (others??).

Specific Comment: Page 8.3.1.9-27
1. They state that adjacent areas with surface and subsurface anomalies (e.g. Wahmonie, etc.) would prove more likely. Probably this is true but should one not consider these within the affected area??
2. Their statement that samples will also be collected and analyzed from N Yucca Mtn, Calico and Wahmonie. Should they also not include Camp Transvaal, and Mine Mtn.??]
3. They state that sample spacing in the controlled area will be between 250 and 750 feet for geochemistry. Specific spacing should be based upon sizes of analog systems - which I am sure will be at their narrowest much smaller than 250 feet. That is if they are talking about mineralization.
4.DOE says subsurface program will be carried out ina similar manner. A representative number of drillhole cores will be selected that uniformily.... Comments on

this are that this is not a sufficient statement. Specifically: a) no comment on depth feature. How deep the holes? To the Paleozoic? How many will do this?? Not clear. b) no uniformly spaced holes now exist and none are evidenced on their borehole program. c) core will be sampled at 50-300 foot intervals?? Really!! they should be sampled much closer and specific samples should be premised upon geology.
5. On p. 8.3.1.9-28 DOE indicates that specifically excluded elements are Cr, Co and Pt-group because they are known only to be associated with mafic and ultramafics. This is not in general true for cobalt and while generally true for Cr and Pt-group exceptions to exist-such as Goodsprings, Nv etc.
6. The DOE statement on p. 8.3.1.9-29 in the Table - that all geochemical sampling plan, analytical methods and field methods are "To Be Determined" leaves one with little basis for evaluation.

8.3.1.9.2.1.2. Geophysical/Geologic appraisal of the site relative to mineral resources.

Specific Comments: 1. The parameter section is a paragraph full of "may's" which will allow them to do or not do exactly what they wish. And just what is 'qualitative' evaluation?? Merely looking at? How does this fit their directive to define resources by tonnage and grade?? 2. They don't propose to do anything new at all. Merely look at existing data. This clearly indicates that they do not take their charge seriously as far as resources go.

8.3.1.9.2.1.3 Assessment of geothermal energy potential.

Specific comment: 1. They require only existing holes and data. I doubt if this is sufficient and new holes should be drilled -or, if drilled for some other reason-at least measured for resource potential.

8.3.1.9.2.1.4 Assessment of hydrocarbon resources.

Specific Comment: 1. Again at the site they intend to use only UE25p#1 since it was the only one to hit Paleozoics. This is clearly and obviously inadequate for appraisal of anything . Further, how far did it penetrate Paleozoics and what variety were encountered?? 2. Finallly, many more specifics on units and locations away from Yucca which are to be sampled is needed. 3. The table on page 8.3.1.9-34 is very difficult to evaluate since everything is TBD.

8.3.1.9.2.1.5 Mineral and energy assessemtn of site and comparison to known mineralized areas etc.

Specific comment: The analog selection parameters seem reasonable to me. Should , however, include the New Mexico Valles system, the San Juan system, the New Zealand systems, and probably Fiji and Peru???? I must ask, however, where they are going to get the data to make reasonable comparisons if they don't drill and explore in all ways the Yucca situation more thoroughly than they have proposed.

8.3.1.9.3 Studies to provide information required on potential effects of exploiting natural resources on hydrologic, geochemicals and rock characteristics.

General comment: 1. At this time this section pertains only to ground water. Why? It would appear to me more than appropiate-indeed essential to model effects of other possible occurrences based on analogs. 2. Fig. 8.3.1.9-4 logic diagram. This diagram, in common with essentially all of their logic diagrams tends to separate tasks into discrete activities which, at the level the work is to be done, are not mutually supporting and should be. For example, how can 8.3.1.9.2.1.5 -mineral and energy assessment-be done at all without 8.3.1.9.1.1.1 Geochemical, and 8.3.1.9.1.1.2 -Geophysical/geological assessment.

8.3.1.9.3.1 Evaluation of data need for assessment of likelihood of future inadvertant human intrusion at Yucca as a result of exploration and/or extraction of natural resources.

General Comment: Here, how can you evaluate data need and predict drilling intensity over the next 10K years unless you have a very good and documented idea of what is present - and not just at or near the surface. They simply do not have any such idea and they will not with what they propose to do in the mineral resource evaluation.

8.3.1.11 Overview of land ownership and mineral rights program

General Comment: 1. page 8.3.1.11-2. Their statement in paragraph 1 that "prior investigations have identified no mineral rights in the immediate vicinity of Yucca" is not true. There presently exist mineral claims on BLM land right up to the Nellis boundary. Unless, of course, this is not considered "immediate vicinity". Just what is immediate vicinity anyhow??

8.3.1.14.2.3.3 Geophysical field measurement.

General Comment: 1. Here once again zero consideration is given to the defining of mineral resource potential at depth. This section is representative of what I believe the attention DOE has placed on this requirement. They simply don't want to know and are not going to employ a program which will truely find out.

8.3.1.17.1 Studies to provide required information on volcanic activity that could affect repository design or performance.

General Comment: 1. All that is being done is a survey of existing literature-no new research indicated. They clearly either are uninformed or do not wish to really understand problem. 2. Thinking in this section is that such volcanic activity will not be a fatal flaw for the site but merely give data to change engineering design. It is typical of the "fait accompli" thinking and mentality which permeates this entire SCP.

8.3.1.17.4.5 Detachment faults-at or proximal to Yucca Mtn.

Specific Comments: 1. I must disagree with their statement as to the key questions given on page 8.3.1.17-131. Statement illustrates DOE compartmentalized thinking. Other key questions are the tectonic significance and the mineral potential significance, and are they there?

8.3.1.17.4.5.1 Calico Hills study.

Specific comment: 1. Geologic mapping at 1:12,000 and compliation at 1:24,000 may be insufficient in that not enough detail can be accurately recorded to clearly show possible detachment.

8.3.1.17.4.5.2 Evaluation of detachments in the Beatty-Bare Mtn area.

Specific Comment: 1. here as in Calico Hills above, a 3rd objective should be to see if such detachments are relevant in any way to mineralization control or displacement in the area. There is a reasonable body of opinion at present that recent Au discoveries at Ladd Mtn ,perhaps Gold Bar, and certainly the old Original Bullfrog are in structures relateable to detachments.

8.3.1.17.4.5.3 Megabreccia evaluation.

Specific Comment: 1. No real new work proposed. How do they propose to determine relevance of this to the tectonic development and volcanic activity and potential mineralization processes with the work they propose to do (or not to do??)?

Dr. Donald C. Noble, Co-Principal Investigator, TASK 3

Fundamental Objections and Concerns

8.3.1.4.2 Investigation: Geologic framework of the Yucca Mountain site

As written, the draft SCP tacitly assumes that the fundamental geologic framework of the region within which the Repository Site is situated is adequately known. This assumption is simply not correct. It is well known, for example, that there are important and fundamental questions concerning the presence or absence, age, etc., of detatchment faults. In addition, there are questions of equal or greater practical importance concerning a number of fundamental aspects of the Neogene (late Cenozoic) volcano-tectonic evolution repository region. These questions include, for example, aspects of volcanic stratigraphy, the location of calderas and relation to known ash-flow sheets, the relative and absolute age of various lava units and their relation to caldera systems, the timing of hydrothermal activity and mineralization and its relation to magmatic/caldera system(s), etc., etc., etc.

During their preliminary investigations, the Task 3 group has recognized a number of uncertainties in the basic volcano-tectonic framework of the southwestern Nevada volcanic field. These questions include the nature, age, and(or) ash-flow sheet assignments of a number of features of the Timber Mountain-Oasis Valley-Crater Flat caldera complex, the timing of initiation of magmatic activity of the southwestern Nevada volcanic field, and the probable identification of a new caldera of the southwestern Nevada volcanic field. Work carried out a few years ago (e.g., Noble et al., 1984, Jour. Geophys. Res., v. 89, p. 8593) showed that there were fundamental errors that had existed for decades concerning the stratigraphy and source assignments of ash-flow sheets of the youngest and best preserved caldera centers. Major revisions in basic geology have not been restricted to our group; for example, Warren et al. (1988, Geol. Soc. America Abs. with Programs, v. 20, p. 240) have made fundamental revisions in the stratigraphy, age and caldera assignment of a number of units of lava situated only a few miles north of the repository site. It is therefore highly unlikely that DOE's current understanding of the older, less well exposed or preserved volcanic geology is substantially complete and without similar errors.

Certain fundamental aspects of the volcanic/caldera geology have been essentially ignored for decades. Although Smith and Bailey, in their classic 1968 paper on resurgent cauldrons, explicitly recognized a late, post-collapse stage of hydrothermal activity, only very recently has work been begun on understanding the nature, timing, mineralogical, chemical, and metallization effects of hydrothermal activity and its relation to the various

caldera and other volcanic centers of the southwestern Nevada volcanic field (e.g., Aronson and Bish, 1987, abs. of presentation at Clay Minerals Society, Socorro, NM; Bish, LANL Rept. LA-10667-MS; Jackson et al., 1988, Geol. Soc. America Abs. with Programs, v. 20, p. 171). See also our discussion of 8.3.1.8.5.1.2 Activity: Geochronology studies.

Most of the basic geologic work - that is, stratigraphy, geologic mapping at various scales, caldera geology, geochronology, and related work - at the southwestern Nevada volcanic field has been done by the U.S. Geological Survey. Morover, work done at other organizations, for example Los Alamos, has been largely guided by former U.S.G.S. employees. This includes the recent detailed lithologic, stratigraphic identification, etc., work on cores from the various drill holes in the Yucca Mountain area, and the studies and interpretative models of possible detatchment faults, buried calderas, etc. The ongoing stop-work order for the U.S. Geological Survey clearly demonstrates that the D.O.E. lacks confidence in that organization and its geologists. Therefore, the geologic work must be held suspect by D.O.E.; and thus the basic geologic framework upon which the many very specific "speciality" studies outlined in the draft SCP must also be called into question. However, we would emphasize that although there are a number of aspects of the geologic framework of the southwestern Nevada volcanic field that require additional study, the U. S. Geological Survey has in aggregate carried out an excellent long-term study of the region.

8.3.1.9.2 <u>Investigation: Studies to provide the information required on present and future value of energy, mineral, land, and groundwater resources</u>

8.3.1.9.2.1 Study: Natural resource assessment of Yucca Mountain, Nye County, Nevada

1. The possibility of economic and(or) potentially economic mineral resources within and in the general vicinity of the Yucca Mountain Repository Site is a much more serious issue than has been considered by DOE as is presently represented in the draft SCP. The following examples provide clear evidence of the mineral potential of the region surrounding Yucca Mountain and of the rock units of the Repository Site.

   The Beatty-Bullfrog-Bare Mountain area, which based on certain structural interpretations may within the past 10 million years have been appreciably closer to Yucca Mountain, is presently extremely active with regard to mineral production, mine construction, and mineral exploration. At the Gold Bar mine gold is presently being produced from ore hosted by welded ash-flow tuff of the Paintbrush Tuff. At Ladd Mtn., about one mile south of

the Montgomery-Shoshone, mine reserves of 3.2 million ounces of gold have recently been announced by Dallhold, Inc., and a world-class mine is presently in the permitting stages. The host rocks for this mine are welded ash-flow tuffs of the Timber Mountain-Oasis Valley caldera complex. Reserves of 0.15 million ounces of gold have recently been announced by GEXA Gold at the Telluride district directly northeast of Bare Mountain, and active drilling continues. Radiometric dating by Task 3 has shown that hydrothermal activity is related to activity of the Timber Mountain-Oasis Valley caldera complex. The Transvall district, underlain by welded ash-flow tuff of the Timber Mountain-Oasis Valley caldera complex, is presently the subject of negotiation with a major mineral company with respect to options for mineral exploration. Other mines (e.g., Mayflower and Pioneer) and prospects are also hosted in volcanic rocks of the southwestern Nevada volcanic field.

The northern part of Yucca Mountain clearly would be explored/sampled/evaluated for precious-metal mineral deposits if it were open to the public. In view of these and other available information, particularly published information from drill holes at Yucca Mountain, a comprehensive study of the mineral resources of the region based on the acquisition of a wide range of geologic, mineralogic, geochemical, isotopic, geophysical data and other data through new field and laboratory work is essential.

2. The review of mineral deposits presented in Section 1 clearly demonstrates that the DOE lacks scientific personnel who are qualified to evaluate the mineral deposit geology and mineral resource potential of the Yucca Mountain Repository Site Area. The dicussion reads like a major term paper written by an industrious but inexperienced graduate student. A lack of knowledge of the most recent literature and cutting-edge thought as well as a lack of knowledge of and contact with the exploration and mining industry in the region is obvious.

3. The amount of work proposed to evaluate mineral resources is completely and utterly inadequate. At least an order of magnitude more work will be required to provide an adequate understanding of the probability of mineral resources at depth in the region of the Yucca Mountain Site. Based on the effort proposed in the consultation draft SCP for evaluating various tectonic, hydrologic, cultural, and other factors, the effort devoted to evaluting mineral resource potential should be <u>two orders of magnitude greater</u> than that outlined in the draft SCP.

4. The nature and balance of the work proposed by DOE in the draft SCP to evaluate mineral deposits potential is largely improper. Specificially, no systematic, comprehensive and detailed geologic investigations and ancillary support petrographic, geochemical, isotopic, radiometric dating, etc., studies are proposed of the many areas of hydrothermal alteration, known and potential mineralization, and other pertinent areas! The work of Task 3 to date has clearly demonstrated that the knowledge presently available is totally inadequate. To remedy this a Geologic Studies Program must be set up to evaluate mineral potential and related problems in volcanic stratigraphy, caldera geology, structural geology, etc.

5. The geochemical assessment of Yucca Mountain outlined in the SCP (activity 8.3.1.9.2.1.1) is improperly administratively structured; it is presently set up as effectively a separate activity independent of detailed geologic (and geophysical) work. Instead, it should be one portion of (and under the scientific and administrative control of) an intensive, and fundamentally geologic, program of evaluation of mineral potential as stated in section 3, above.

6. No new geophysical work is planned by DOE, although the geophysical data presently available is largely of a character inappropriate for evaluating mineral potential. A program of appropriate geophysical support should be set up within the geological program; it should not be administratively under a separate geophysical or seismological group.

Specific Comments, Concerns and Questions

8.3.1.4.2.1.1 Activity: Surface and subsurface stratigraphic studies of the host rock and surrounding units

The work proposed in this section appears reasonably comprehensive. The detailed studies of the Topopah Spring Member outlined on pages 8.3.1.4-39 -42 are desirable, but it should be emphasized that such work does not take the place of the fundamental studies of the Cenozoic geologic setting as outlined in the previous section.

8.3.1.4.2.1.2 Activity: Surface-based geophysical surveys

The program is nothing if not comprehensive. Certain of the studies appear desirable, for example the vertical seismic profiling, the paleomagnetic studies, and the commerically available logs. Certain other proposed work has the appearance to the geophysical layman of overkill.

8.3.1.5.2.1.5 Activity: Studies of calcite and opaline silica vein deposits

The SCP outlines methods and technical procedures that utilize almost every conceivable laboratory - petrographic, chemical, isotopic, etc., procedure to characterize the vein deposits. The principal weakness in their approach is geological, and reflects an inadequate consideration of the importance of a thorough and quantitative understanding of the late Cenozoic paleohydrothermal history of the region within which the southwestern Nevada volcanic field is situated.

Specifically, the veins would be of much greater significance to the potential for disruption or flooding of the Repository if it could be shown that important hydrothermal activity had taken place in the region in latest Neogene (late Pliocene and/or Quaternary) time, than if this period, during which their was very little or no silicic igneous activity, was a time when no major hydrothermal/geothermal systems had developed in the region. This is particularly true if, as we suspect, it will not be possible to accurately date the veins by radiometric or other methods.

A regional understanding of the space-time distribution of hydrothermal activity is thus required. Moreover, it should be noted that there are several localities in Nevada (e.g., Sulfur, McGinniss) where there has been important hydrothermal activity, which in one case deposited economic precious-metal mineralization and in the other deposited Au and Ag, but in subeconomic amounts, well after the cessation of known Cenozoic volcanic activity!

Task 3 of the Center for Neotectonic Studies' Yucca Mountain Project has begun investigations of paleohydrothermal systems in the region (e.g., Jackson et al., 1988), and has recently indentified several important systems that may be very young.

8.3.1.8.5.1.2 Activity: Geochronology studies

This section provides additional examples that the individuals who prepared the SCP do not possess thorough and current knowledge and understanding of the late Tertiary volcanic and tectonic evolution of the southwestern Nevada volcanic field.

For example, on page 8.3.1.8-108, the youngest K-Ar age for the Black Mountain volcanic center (caldera) is given as 6.5 Ma after Kistler. (Actually, Kistler's age is 6.2 Ma, which recalculates to 6.3 Ma using presently acceptable constants.) Noble et al. (1984, Jour. Geophys. Res, v. 89 p. 8593) show that the unit dated, the Spearhead Member of the Stonewall Flat Tuff (formerly termed the Labyrinth Canyon Member of the Thirsty Canyon Tuff), is from the Stonewall Mountain volcanic center to the northwest. Ages available for the Thirsty Canyon Tuff (Kistler,

1968; Weiss et al., in press, Jour. Geophys. Res.) are older, ranging from 7.5 to 7.8 Ma.

Furthermore, it is incorrect to state that K-Ar ages on Na-rich sanidines are suspect. A number of replicate ages, for example on the Stonewall Flat Tuff, show that ages obtained on such materials are both precise and accurate.

Rather, the radiometric ages on the basalts must be suspect, and are probably too old. Further work is required on dating the basalts that have yielded ages in the 8 to 9 Ma range. Any errors most probably do not lie in the analytical procedures applied but rather in the selection and/or preparation of materials for radiometric dating.

Finally, the focus of dating the youngest silicic volcanism in the region should not be on the Black Mountain. Rather, the most likely candidates for young silicic volcanism are various domes and flows of rhyolite exposed west and northwest of the Timber Mountain-Oasis Valley caldera complex. These domes are presently being investigated by personnel of Task 3 of the Center for Neotectonic Studies' Yucca Mountain Project.

8.3.1.8.5.1.3 Activity: Field geologic studies

This section provides further evidence that the individuals who prepared the SCP do not possess thorough and current knowledge and understanding of the late Tertiary volcanic and tectonic evolution of the southwestern Nevada volcanic field.

8.3.1.9.2.1.1 Activity: Geochemical assessment of Yucca Mountain in relation to the potential for mineralization

Note: This section provides a critical evaluation of specifics of the above activity.

The most important criticism of the activity is that, as outlined in the Fundamental Objections and Concerns, the proposed geochemical work is completely divorced from, and not under the guidance of, a geological study team.

Specific comments include the omission of Be as an element that occurs in a volcanic setting (e.g., Spor Mountain, Utah) and the omission of Tl, Te, NH_4^+ (ammonium), Mo and W as pathfinders. In particular, the omission of thallium shows that the individual(s) who prepared this section are unfamiliar with modern knowledge of the trace-element associations of epithermal precious-metal systems. A closer sampling grid than that proposed is probably desirable, although the major criticisms of the plan of investigation relate to the conceptual design of the study.

No discussion is given of several important geological features that bear directly on the use of geochemical data to evaluate the mineral potential of the Yucca Mountain area. Specifically, no mention is made of the definite possibility that mineralization occurred before the deposition of the Topopah Spring Member of the Paintbrush Tuff, and thus that a potential ore deposit could be very effectively shielded from surface detection by geochemical sampling methods. Secondly, no indication is given that in many epithermal Au-Ag systems both economic elements and pathfinders are largely - or completely - restricted to a rather limited vertical range, and that in some systems there is little or no chemical or mineralogical signature spatially above ore at depth.

Finally, and perhaps most important: Mineral systems - including areas of hydrothermal alteration and enrichment in pathfinder elements - commonly are appreciably smaller than the area of the Repository block. Without a systematic program of deep drilling within the actual Repository area it will be impossible to determine the possible presence of economic mineralization within and/or below the Repository. Evaluation of those portions of the draft SCP dealing with studies involving drilling, etc., (e.g., Figures 8.3.1.4-2, -14, -25, -26, -33) show that very few, if any drill holes are planned that will penetrate the repository horizon, not to mention rocks beneath the horizon.

8.3.1.9.2.1.2 Activity: Geophysical/geologic appraisal of the site relative to mineral resources

It is stated in the section Methods and technical procedures

"There are no procedures for Activity 8.3.1.9.1.2. Existing data will be used."

In a similar manner to our evaluation of section 8.3.1.4.2 Investigation: Geologic framework of the Yucca Mountain site, we believe that the present geologic and geophysical data base is insufficient to adequately evaluate the mineral resources potential of Yucca Mountain site and environs.

8.3.1.9.2.1.5 Activity: Mineral and energy assessment of the site, comparison to known mineralized areas, and the potential for undiscovered resources and future exploration

We reiterate that the D.O.E proposed Site Evaluation Procedures (Activities 8.3.1.9.2.1.1, -.2, etc.) do not provide adequate fundamental geologic and other data necessary to evaluate mineral, etc., potential of the Yucca Mountain Site.

In addition, we note that it will in all likelihood be impossible, or a best unfeasible, to calculate "tonage, or other

amount, grade, and quality". Rather, only a probabilistic estimate can be given as to the mineral, etc., potential of the Site and environs (see page 8.3.1.9-35).

We also note (see page 8.3.1.9-36) that the selected analogues do not, but should include important volcanic-hosted producing mineral deposits in the immediate region (e.g., Gold Bar mine, Bullfrog district) or deposits that will soon come on line, such as the world-class open-pit operation presently being developed by Dalhold Resources at Ladd Mtn. south of the Montgomery-Shoshone mine in the Bullfrog district.

Recommendations

The gravity investigations should clearly continue. In addition to the work proposed in the draft SCP, it would be very desirable to set up an Activity having the objective of providing detailed local gravity studies to support the fundamental geologic activities that we recommend below.

We recommend that geologic, and perhaps geophysical, activities be included in the Site Characterization Program aimed specificially at evaluating mineral potential. These activities should be closely coordinated with those proposed in our discussion of section 8.3.1.4.2, and perhaps should be intergrated therewith. Indeed, it may be desirable to have the activity(ies) carried out by the same group(s).

The D.O.E. Site Characterization Plan requires a major strengthening of section 8.3.1.4.2 - Investigation: Geologic framework of the Yucca Mountain site.

Specific fundamental geologic activities that must be added should include mapping, stratigraphic and correlation (petrographic, paleomagnetic, petrochemical, etc.) studies, and radiometric dating of volcanic units; various caldera studies; in-depth regional studies of hydrothermal alteration and mineralization during Neogene (late Cenozoic) time; and the study of the interrelation of magmatic activity (including volcanic eruptions and caldera formation) and local and regional tectonic events. Funding must be allocated for deep drilling to answer fundamental questions of caldera geology and stratigraphy; for example, to determine if thick sections of Crater Flat Tuff of probable intracaldera origin are present in the proposed Crater Flat-Prospector Pass caldera complex.

The most advantageous make-up and administration of the various groups constituted to carry out this work is unclear. However, the actively working groups should include senior volcanic geologists and volcanologists who possess major direct mapping experience at the southern Nevada volcanic field from the

U.S. Geological Survey, the University of Nevada, and Los Alamos National Laboratory.

It should be emphasized that such fundamental geologic study is highly cost-effective, even with the inclusion of the costs of necessary deep drilling.

Steven I. Weiss, Research Associate, Task 3

SUMMARY COMMENTS

References to Chapter 1 being "data", or to "data" of Chapter 1 are misleading and should be removed because most of Chapter 1 is obviously not data and should not be referenced as such. In my opinion, to refer to interpretations, assumptions and discussion as data (FACTS) is wholly incorrect; the authors and editors of this document lose credibility by such references.

Chapter 1 and Chapter 8 completely ignore the importance of structural control on localization of ore mineralization in hydrothermal mineral deposits. Evidence of economically important mineralization within hydrothermal mineral deposits is obvious throughout the region (e.g., Bullfrog Hills, Bare Mountain, Mine Mountain(?) Calico Hills(?) and numerous areas within Nellis AFB&GR to the north). In the Bullfrog Hills (e.g., Original Bullfrog, Gold Bar Mine, Dallhold's Ladd Mountain) ore-grade Au-Ag mineralization has been, is presently, and will in the near future be exploited where it is largely hosted by faults that are of probable extensional nature in rocks of the Timber Mountain-Oasis Valley caldera complex. Hydrothermal alteration associated with epithermal mineralization is clearly evident in the sparse published data from the subsurface of Yucca Mountain, yet virtually no mention is made of any plans or intent to identify and test the fault and fracture structures within and beneath the site for mineralization. This omission surely reflects either a lack of understanding and technical expertise concerning epithermal ore deposits, or a predetermined opinion on resource potential and site suitability more easily supported by absence of key information.

I found no mention of plans to directly test hydrocarbon potential of the Paleozoic section beneath the site. In the context of the proposed investigations, activities, studies etc., the issue will likely remain unresolved without a direct test with a deep drillhole (-20,000 ft ??) within the controlled area. Such a test would also provide important information on the deep structural geology. See attached comments by A. K. Chamberlain on the summary discussion of hydrocarbon potential given in Sections 1.7 and 1.8

Fundamental Objections and Concerns

8.2.2.4.7 Summary of the post-closure tectonics site program

<u>Objection</u>: References are made repeatedly to SCP Chapter 1 as a "data chapter"; it must be made very clear to the general readership that Chapter 1 is in many places quite interpretive, often incomplete and outdated, not uncommonly presented in

misleading or incorrect context and therefore not really data. The information given in Chapter 1 would be more appropriately referenced as "DOE interpretive presentation of selected technical information". Chapter 1 should not be cited as a technical reference; aside from problems of selective presentation of information, misleading manipulation of available data or interpretations, it has not been subjected to the type of peer review that generally qualifies bonafide research publications and data contained therein.

General Concern: Nowhere in this summary is any provision offered for any type of inadequacy in characterization, demonstration of ability to meet siting, performance or design requirements, etc. Somewhere in each major summary section should be an explicit statement to the effect that should a generally accepted charaterization or demonstration prove unattainable, the Site is disqualified and abandoned.

8.2.2.4.8 Summary of the human interference program

Objection: Deliberate human intrusion should be considered as a credible possibility. It is historically well documented (e.g., tombs of the Egyptian Pharaohs) that "unacceptable" risks are not sufficient deterents to intrusion.

8.2.2.4.16 Summary of preclosure tectonics program

General Concern: This section promises a great deal, yet the approach appears to be based on only current knowledge and uncertainties about the local tectonic environment. Certainly this is not an adequate level of understanding for design and performance requirements. A major contradiction is evident in DOE's thinking here because if the current understanding is sufficient, why bother with all of the investigations mentioned in the last two paragraphs and shown in Figure 8.2-17??

8.3.1.8 Overview of the postclosure tectonics program: description of future tectonic processes and events required by the performance and design issues

General Concern: the complexity of the language, sentence structure and nomenclature used throughout this section render an intelligent evaluation of the content almost impossible. One of the central problems is that references are repeatedly made to four of the 12 (and possibly 15?) "investigation"s shown in Figure 8.3.1.8.1, but exactly to which of these "investigations" are they referring? Several times the "investigation" is not specified and the reader is left guessing and unable to follow the argument(s).

Objection: As shown on pages 8.3.1.8-3 through 8.3.1.8-21, the levels of confidence needed, available in current estimates and

needed in final values appear totally unsupported. Is this section going to be referenced later as "data" ?--Nonsense.

8.3.1.8.5.1 Study: Characterization of volcanic features

Objection: If the relation of basaltic volcanism and intrusion to structural features is important, then much valuable information available by cost-effective mapping and radiometric dating is being ignored by not including the Quaternary mafic volcanism of the Sleeping Butte - northwest Oasis Valley - northern Bullfrog Hills(??) area in this study.

General Concern: Ignores need to test/resolve the questions of the volcanic and tectonic nature and significance of Crater Flat (c.f., Carr, 1988, GSA Abstr. v. 20, p. 148) Is Crater Flat a volcanic feature or tectonic feature, combination, what??

8.3.1.8.5.1.1 Activity: Volcanism drillholes

General Concern: Drilling the anomalies to test for subsurface volcanic features is a good idea. However, the choice of 330m depth for the holes seems arbitrary and probably insufficient to adequately test the anomalies. The drillhole depths should be more flexible if they are serious about a real test here. This is particulary important for testing the available geophysical data; we know from past experience (e.g., drillhole UE25a-3, Calico Hills) how valuable such drilling is for testing data on the location of even large subsurface plutons.

8.3.1.9.2 Investigation: Studies to provide the information required on present and future of energy, mineral, land and groundwater resources

Objection: The preliminary assessment presented in the environmental assessment (DOE, 1986b) was so inadequate that it should not be considered a credible reference. Sections 1.7 and 1.8 of the SCP do provide additional information, but in no way should these be considered a bonafide "evaluation" of anything.

8.3.1.9.2.1.2 Activity: Geophysical/geologic appraisal of the site relative to mineral resources

General Concern: As proposed, this activity is not integrated with the mineral resource testing program. Existing data is too regional in scope and scale and is unlikely to have resolution needed to detect mine-scale structures or mineralized zones. Remote sensing is not at all appropriate for the most important aspect of the activity: attempting to detect and map subsurface structures and hydrothermal alteration.

8.3.1.9.2.1.4 Assessment of hydrocarbon resources....

General Concerns: As written, this activity is unlikely to provide the required information. Unless the regional structural geometry becomes well known, it is unrealistic to assume that the planned tests will be of sufficient value to substantially improve our knowledge of the hydrocarbon potential beneath the Site. Specifically, without a deep drill-hole (-20,000 feet) through the Site, it is unlikely that the objectives of the activity will be acheived. Also, Section 1.7.2.2.1 is referenced as if it were a bonafide literature reference; indeed it is not and should not be presented as such.

8.3.1.9.2.1.5 Activity: Mineral and energy assessment of the site, comparison to known mineralized areas, and the potential for undiscovered resources and future exploration

General Concerns: The objectives of this activity are unlikely to be acheived without systematic drilling of mineralized structures. Such structures, if they exist, will need to be discovered accidentally by unrelated drilling or excavation because the proposed geological, chemical and geophysical studies are do not appear oriented towards identification of structures likely to host epithermal mineralization that may be present.

8.3.1.9.2.2 Study: Water resource assessment of Yucca Mountain, Nevada

General Concern: This study depends on obtaining proprietary information, that may or may not become available, from current and projected large water users (e.g., Saga, Dallhold).

8.3.1.9.3 Investigation:...information required on potential effects of exploiting natural resources ....

Objection: Again, The Environmental Assessment (DOE, 1986b) and Section 1.7 of the SCP should not be considered satisfactory evaluations or data sets. Estimates, assumptions and interpretations are referred to as data (e.g., p. 8.3.1.9-40), this is incorrect and misleading and should be removed so that it does not become accepted by less-informed readers.

General Concerns: The "panel of experts" is likely to be used as a public relations gimmic unless their authority and appointments to this panel come from outside of DOE. If they are to have no authority, why bother at all?

As written the investigation does not address the impact that perceived resources would have on exploration and attempts at extraction.

8.3.1.9.3.1.1 Activity: Compilation of data to support the assessment calculation of the potential for inadvertent human intrusion at Yucca Mountain

General Concerns: The 2 objectives seem unrealistically ambitious, particularly regarding expected drilling density, depth and frequency; how will the needed parameters be obtained or evaluated? What kind of data do they intend to compile that is likely to provide such information? The fact that methods and technical procedures are to be determined sometime in the future is not reassuring to the reader considering the importance and complexity of this activity.

Specific Comments, Concerns and Questions

8.2.2.4.7 Summary of the post-closure tectonics site program

p. 8.2-199: First, third and fifth paragraphs of this section implicitly assert that probability calculations will be meaningful; this is unlikely to be the case as the calculations will most likely rely considerably on interpretation of limited, possibly inaccurate information and all assumptions implicit in such interpretations.

Third paragraph-- approach is likely to be unrealistically ambitious by assuming that the effects of tectonic processes a) may all be identified and b) that the Quaternary rates may be accurately measured.

p. 8.2-201: Assumption (that site geologic data will be sufficient to characterize the probability and effects of tectonic initiating events) has at best a questionable basis. No evidence is given to support this major, underlying assumption. Furthermore, no provision is offered for the possible inability to develop such a characterization. I get the distinct impression that the proposed studies are to support many conclusions have already been drawn. Not good science.

8.2.2.4.8 Summary of the human interference program

p. 8.2-202: Table 8.2-40; under Major Parameters for 8.3.1.8.3 should not changes in direction of flux be addressed?

p. 8.2-202: second sentence ignores the resource potential beneath the Site!

p. 8.2-204: third paragraph: the uncertainties of the interpretations necessary for the assumptions needed for such probabilistic calculation are likely to be so large that the calculation is nearly or entirely meaningless. It is frightening to consider that the uncertainties may be

ignored or not understood by the politicians who will use the probability calculation as the basis for decision-making.

p. 8.2-204: last sentence and top of page 8.2-205: This sentence reflects a lack of knowledge of current water use in the immediate vicinity of the Site, where water is already being economically exploited at this moment (e.g., Sterlng Mine's use of water from Crater Flat), not somewhere off in the future.

8.2.2.4.16 Summary of preclosure tectonics program

p. 8.2-225: third paragraph: This important(?) summary paragraph is impossible for me to understand. It is entirely unclear what the "fourth investigation" of Figure 8.2-17 is that they refer to as containing the necessary geologic field data gathering activities. Is this 8.3.4.1 - Drilling Program?, 8.3.1.17.3 - Vibratory Ground Motion that Could Affect...?? or what??

8.3.1.8 <u>Overview of the postclosure tectonics program: description of future tectonic processes and events required by the performance and design issues</u>

p. 8.3.1.8-20: Nature and age of mineralogic changes on faults... age of changes may be impossible to determine unless dateable phases are present. Geologic mapping at 1:48,000 or 1:24,000 is going to be useless for the needed level of detail.

p. 8.3.1.8-22: fourth paragraph: How will the Quaternary rate of igneous activity be measured? by volume of intrusive rocks, extrusive rocks, surface area? weight? what??

p. 8.3.1.8-24: top paragraph: The discussions, interpretations and conclusions presented in Chapter 1 are not "data" and should not be referenced as such; this is misleading and certainly not good science. Furthermore, the statement may be incorrect-- for example why are geochemical changes considered non-credible as related to release calculations?? Who decides what is credible in these cases? Are we to believe that the chemistry and phase relations of the rock-water system of the Repository are so well known that additional data are not needed??

p. 8.3.1.8-24: last paragraph: WHICH ONES ARE THE FIRST FOUR INVESTIGATIONS?? The assupmtion that the effects and rates of tectonic processes operating at or near the site are all measureable is tenuous at best.

8.3.1.8.5 Investigation: Studies to provide the information required by the analysis and assessment investigations of the tectonics program

p. 8.3.1.8-101, 102: The SCP chapters referenced in the first paragraph are NOT DATA! These chapters contain much summary, discussion, and interpretation, some of which is accepted and much of which is unaccepted by the general research community. Much relavent information remains unavailable. Many, many unresolved questions and uncertainties remain concerning basic topics such as volcanic stratigraphic relations, vent areas, ages, even the existence, location and nature of the source calderas (e.g., Rainier Mesa Member of the Timber Mtn. Tuff, Crater Flat Tuff, etc. Why 4 m.y.?? Why 70 km?? How does one measure or calculate the "petrology and geochemistry of late Cenozoic rocks in the region"??- for all of the late Cenozoic volcanic rocks of the entire region?? Incredible, no, this is absurdly unrealistic nonsense.

p. 8.3.1.8-102: Technical rationale... if many of the intended techniques are previously unemployed, and thus untested, how will the data obtained by these techniques be considered sufficiently reliable to refine the existing data base??

p. 8.3.1.8-103: third paragraph: First sentence is redundant and reflects a frightening lack of understanding by the author(s) and editor(s) of basic structural geology. Are we and the uninformed public to believe "detachments" are something other than systems of faults??

8.3.1.8.5.1 Characterization of volcanic features

p. 8.3.1.8-103: First sentence--what exactly is young?? what is vicinity??

p. 8.3.1.8-103: Third sentence--statement that much of this work is completed is simply not correct. Recent information (e.g. Wells et al., 1988, GSA Abstr. v. 20, p. 242) shows important assumptions and interpretations contained in Chapter 1 to very likely be wrong, and at the very least requiring considerable further basic geologic study.

8.3.1.9.2 Investigation: Studies to provide the information required on present and future of energy, mineral, land and groundwater resources

p. 8.3.1.9-24: Second half of page: This whole line of reasoning based on historical use is suspicious at best. Historically there was no large, affluent population in nearby regions with recreational time and technology until

after WW II that was able to access the area; but by then most of the area was already withdrawn from public access.

p. 8.3.1.9-25: First sentence (continued from bottom of p. 8.3.1.9-24) refers to an "expert panel" who will evaluate the calculated probability of natural resources. Who will be on this panel? When will this evaluation occur? What type and how much authority, if any, will this panel have?

8.3.1.9.2.1 Study: Natural resource assessment of Yucca Mountain, Nye County, Nevada

p. 8.3.1.9-25: Third paragraph on this page (second paragraph of this Study) is internally inconsistent because it states that information in this Study will allow calculation of tonnage, grade, etc., of undiscovered resources that may have value in the future. Surely the information needed for such a calculation will require the actual discovery of any such undiscovered resources; a rather large undertaking if they are truly serious. This paragraph should be revised for clarity.

8.3.1.9.2.1.1 Activity: Geochemical assessment of Yucca Mountain....

p. 8.3.1.9-26: 5.: Just what "average elemental values found in silicic tuffs" are they refering to here? Name one reference in the professional literature that gives such values for precious metals and(or) pathfinder elements.

p. 8.3.1.9-26: Last paragraph: Drilling is a type of exploration and may be likely, but not necessarily, based on favorable surface chemistry. Certainly there are examples of drilling programs conducted without elevated values at the surface (e.g., Ladd Mtn., mineralized structures at depth at Creede, CO discovered by Homestake, etc.). As written, the next sentence implies that Sections 1.7 and 1.8 comprise the currently available data and regional comparisons. This is simply not correct; they are neither current nor complete.

p. 8.3.1.9-27: Top of page, continued from preceeding page: More likely, but will also attract attention to the general area, including Yucca, and eventually explorationists may wish to test nearby, less obvious sites such as Yucca. Should also include Mine Mountain.

p. 8.3.1.9-27: Last three paragraphs: Normally the biased sampling is done first, in order to better locate grid-based sampling. Grids are then used to define the spatial distribution of values after biased sampling has demonstrated the presence of elevated values. As written,

sampling on the grid system will be too widely spaced to be meaningful; spacing should be based on geological relations and an evaluation of the results of the biased sampling.

8.3.1.9.3.3 Application of results

First sentence: What panel of experts is referred to here? What authority, if any, will they have?

Third sentence: What if significant resources are found in Yucca Mountain? How can this be demonstrated if the information to be obtained does not support this predetermined idea? This is another example of drawing conclusions before doing the study. Why bother if only the desired information is to be collected and(or) considered?

Alan K. Chamberlain

Project: YUCCA MOUNTAIN: OIL AND GAS POTENTIAL
Of YUCCA MOUNTAIN AREA

Task 3 Job G Hydrocarbons

Comments on 1.7.2.2.1

First paragraph: It is true that there are no oil and gas fields and that several moderately deep boreholes have been drilled without success in the Las Vegas area. However, several of the boreholes had very good oil and gas shows and were relatively encouraging. Shell OIl Cos. Bowl of Fire Unit #1 drilled in T20S R66E S05 had very good shows in the Triassic, Pennsylvanian, Permian, and Mississippian. Commonwealth Oil Co R#54 #01 T21S R60E S31 had gas shows in the Permian and Pennsylvanian. Time Petroleum Corp. 148 Fed #31-1 T21S R60E S31 had good oil and gas shows in the Pennsylvanian. These are just some examples of 21 boreholes with oil shows in Clark County. Having such good oil shows suggests that there are hydrocarbons in the system. It may be interesting to remember that several hundred wells were drilled on the Utah/Wyoming Overthrust Belt with just shows of oil and gas before the discovery of Pineview and subsequent discoveries of several giant gas fields.

Second Paragraph: It may be true that there are no known oil shales known in southern Nevada. Neither are there any known oil shales in the prolific Utah/Wyoming Overthrust Belt. However, there are excellent source rocks in the region. The Mississippian sediments are believed to have generated the 20 million barrels of oil already produced in Nevada. These source rocks are thicker and richer northwest of the Las Vegas area where several tests have been made. The potential should only increase to the northwest, making the Nevada Test Site an attractive area for Mississippian source rocks.

Prolific oil fields 120 miles to the north of the Nevada Test Site show that some source rocks have been subjected to the appropriate thermal maturation, and suitable traps have formed in this complexly thrusted and faulted terrain that did not allow the release of the generated hydrocarbons. There is no reason to believe that such conditions do not exist in the Nevada Test Site area.

Third Paragraph: I agree with all the comments in this paragraph. I had the privilege of having a two day seminar in Reno by Dr. Waples who was cited in the paragraph. He instructed me on techniques of thermal modeling that may be very helpful to the Yucca Mountain project.

Fourth Paragraph: I strongly disagree with conclusions reached in this paragraph. The fact that large calderas and plutonic rock masses are in the area does not preclude hydrocarbon preservation. The Grant Canyon Field, Railroad Valley, Nevada which boasts of one of the most prolific flowing oil wells in North America is located adjacent to an intrusive. In fact, several of the offset wells have penetrated the pluton on several sides of the field. Also the Blackburn Field in Pine Valley, Nevada with its flowing wells has an intrusive adjacent to it. Furthermore, a major volcanic complex of several calderas, is located adjacent to the Trap Spring Field in Railroad Valley, Nevada.

Fifth Paragraph: Part of the paragraph is all right but the last sentence stating that there are no potential source rocks known to exist in the vicinity of Yucca Mountain is misleading. It is true that Yucca Mountain is composed of volcanic tuffs which are not potential source rocks. However, buried Mississippian source rocks and Devonian reservoir rocks probably underlie the volcanic rocks. The volcanic flow rocks probably have no effect on the deeper Paleozoic rocks. Only recently have the tremendous potential of Devonian reservoirs have begun to be realized. The prolific Grant Canyon field flows over 6000 barrels of oil a day from Devonian carbonates below volcanic flows. The Blackburn field flows over 1000 barrels of oil a day from Devonian carbonates buried below Tertiary volcanic rocks.

Sixth Paragraph: The thermal analysis mentioned in this paragraph fails to take into account the effect of Mesozoic thrusting. In a well northwest of Elko, Nevada, for example, the measured thermal values were beyond the oil and gas generating level yet the bottom hole temperatures were anomalously low. Waples, (personal communication, 1988) suggested that this situation would indicate thrusting in the region. The overmature upper plate probably has been thrust over mature lower plate sediments. There is a strong possibility that any overmature rocks in the Yucca Mountain area could have been thrust over source rocks that are at peak oil generating levels. Additional modeling calibrated with new data should help resolve some of this problem. Actually the most definitive way of accessing the hydrocarbon potential at Yucca Mountain is drilling a 35,000 foot bore hole.

Summary Paragraph: I am not familiar with the interval tested by drill hole UE-25p#1. If the well never penetrated Mississippian source rocks or if the core was not adequately tested, then the bore hole does not condemn potential source rocks of the region. If Silurian conodont alteration indices in drill hole UE-25#1 show that the sediments still have gas production potential then there's a good chance that Mississippian sediments are in the oil window. Furthermore, the drill hole may have penetrated only more mature upper plate rocks while more favorable lower plate rocks are yet untested.

The additional work being considered is what I am attempting to do in Task 3. I have yet to examine, sample, and analyze the organic content of Paleozoic rocks and especially Mississippian rocks from bore holes in the Nevada Test Site region. I am prepared to begin to make thermal maturation models using Lopatin time temperature indices. I would like to see reservoir analysis made on potential Devonian and Mississippian reservoir rocks in the Nevada Test Site region.

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Review of parts of the Consultation Draft
Site Characterization Program

Summary of contributions from members of the Seismological Laboratory by John G. Anderson

1. Introduction

The following scientists on the staff of the Seismological Laboratory at the University of Nevada - Reno have read parts of the SCP and written a review of the parts that they read:

Prof. James N. Brune, Director
Prof. John G. Anderson
Dr. William A. Peppin
Prof. Keith Priestley
Dr. Martha Kane Savage
Prof. Ute Vetter

Because of the scope of the SCP, it was not practical for each review to be organized by the same format, and thus each scientist has submitted his (or her) review in his own format. Another important reason for selecting this format is to allow for differences of opinion among the reviewers; an attempt to coalesce these reviews into a more coherent document would suppress these differences. Each review is appended after this introduction in the order (mostly alphabetical) listed above. Each scientist was free to review any part of the document he found interesting, as a minimum each reviewed sections closest to his own particular fields of expertise.

2. Sections reviewed

The following sections are identified as having been read, or at least skimmed for relevant sections, by at least one member of the Seismological Laboratory. Other sections may have been read, but not specifically commented upon.

Overview
Chapter 1.
Chapter 2
Chapter 3 (Summary)
Chapter 4 (Summary)
Chapter 5 (Summary)
Chapter 6 (Summary)
Chapter 7 (Summary)
Chapter 8.1
Chapter 8.2
Chapter 8.3.1.4
Chapter 8.3.1.6

Chapter 8.3.1.8
Chapter 8.3.1.17
Chapter 8.3.1.9
Chapter 8.3.2.1
Chapter 8.6
Chapter 8.7

3. General comments

Words of praise for the CDSCP are few and far between in the attached reviews, although it is recognized that many of the problems with the SCP are inherent in the difficulty of the scientific problem. Although not reflected in the reviews, there was a sense of many of the scientists of the Seismological Laboratory that the CDSCP is in fact a remarkable document for the scope and completeness of the research that is proposed. In fact our review suffers from several of the same faults as the SCP, particularly in being discontinuous and hard to follow, rather than being presented as a coherent document. The purpose of the review was not to praise the CDSCP, of course, but to identify weaknesses that are within the scope of our expertise. Everyone seems to find some ways that the SCP could be improved. This is not at all surprising, since this is a draft document; our expectation is that our comments will be used to improve upon this draft plan. There is little point in trying to repeat all of the comments here. It is better for the reader to read the reviews for himself.

4. Major omissions / inadequacies / specific comments

There are numerous specific comments throughout the attached reviews. Many of them point out fundamental issues that we believe need to be resolved for that section of the characterization to succeed.

5. Recommendations

One fraction of the Seismological Laboratory staff, but not all, believes that site characterization should wait until after the site characterization plan has been upgraded to a higher level of scholarship. The missing elements seem to be a demonstration that we (including the entire scientific community) have

1. A review and synthesis of the existing information about the Yucca Mountain region that would withstand academic scrutiny.
2. A clear and complete statement of relevant physical phenomena and how these are best modeled (current technology), and a corresponding identification of needed improvements and critical boundary conditions.
3. Based on the above two items, a clear, well focused concept of what critical scientific issues need to be resolved to

determine if the site is suitable (in contrast to determination of design parameters, which the SCP seems to address more directly).

This is not to imply that the authors of the CDSCP do not have these concepts in mind, but they are not demonstrated in the parts of the CDSCP that were reviewed within the Seismological Lab. We expect that when the final SCP is released it will take into account most of the concerns that have been expressed here.

SCP REVIEW

OVERVIEW

It is unclear how to approach review of the CDSCP. Although I have had considerable experience in reviewing a number of types of scientific projects in the earth sciences,including projects funded by NSF, NASA, USGS, DOE, private companies, and consulting firms, including projects in foreign countries, I have never encountered a scientific project justified by a document anything like the CDSCP. It is intricate and obscure. Various parts are hard to fit into any context. From a scientific point of view it is extremely nebulous since the fundamental background scientific context is almost totally missing, and there is no assurance the persons writing it have the required scientific understanding of the chemistry and physics involved. One never knows whether a confusing statement or part of a table is a result of ones own lack of knowledge or that of the persons writing it. Although most of this difficulty may be a result of the objectives of the document being more than scientific, an unfortunate result is that it is almost impossible to give an adequate scientific evaluation. This kind of support for a proposal to a funding agency would be totally unacceptable.

The biggest single problem I have with the CDSCP is that there is no demonstration that we (myself, the writers, or anyone in DOE, or its contractors or consultants) understand the basic scientific problems and principles involved at a level necessary to give confidence that all the important conceptual models, physical factors and initiating events are being considered. One can proceed with the faith that even though basic science may not be understood, it will become understood as the SCP progresses, or that any problems that turn up can be handled by clever enough engineering. However there are some dangers involved in this approach. Proceeding without a fundamental understanding of the physical processes involved runs the risk that at some point a fundamental flaw in the general concept will be found which will require a major restructuring of objectives, large cost overruns,or a compromise on safety for current or future generations. Obviously if we had the luxury of proceeding systematically we would start with extensive research programs aimed at understanding the fundamental physical processes involved, and require demonstration of this fundamental understanding before any SCP is accepted. This would require basic research programs similar to those funded by NSF and would certainly delay the time schedule by several years. However it might save money in the long run and provide an important reduction in risks to future generations. I believe the current

schedule to implement the SCP and begin repository operations runs the risk of late discovery of important flaws in the overall concept of a repository at Yucca flat.

This is not meant to be a criticism of persons involved preparing the SCP, --some of the difficulties involved are inherent in the difficulty of the problem being proposed, and many of the deficiencies can be remedied before the final SCP. Also our understanding of the problems will evolve in the process of the SCP review itself, and sufficient constraints on parameters of a particular problem to insure safety may be obtainable without thorough understanding of a particular problem. Nevertheless, I conclude that a serious deficiency in the CDSCP is the lack of a clear explanation of our current understanding of the basic physics and chemistry involved, and the lack of proposed basic research programs to remedy deficiencies, either initially, or concurrent with the SCP implementation.

Problems which need further basic research effort include most of the general topics in the CDSCP, ranging from understanding the regional geologic and tectonic setting of the southern Basin and Range(witness the wide range of tectonic models proposed by various investigators and the lack of data and analysis necessary to decide between them), the local geologic, structural, and tectonic setting in the immediate vicinity of the site and the wide range of poorly studied phenomena in partially saturated pourous media(chemical,mechanical, and thermal coupling).

CHARACTERIZATION OF ROCK MASS

The overall plan for rock mass characterization is based on measurements made on small samples, both in the lab and in-situ, and use of these measurements to extrapolate to larger scales, using numerical programs. These extrapolations include use of estimates of joint and fault behavior. This technique has not been validated by actual empirical studies for the type of structure being proposed. It is true that the structure qualifies as a mined structure of the type for which there is considerable experience. Nevertheless for such an important structure we should not rely on questionable extrapolations from mining experience in other types of rock, but should determined in detail for the mass properties of the actual in-situ rock. The detail provided in sections 8.3.1.4 and 8.3.1.17 are not sufficient to give confidence that the proposed plans for rock characterization and understanding of long term behavior will

work. The geophysical and geotechnical methods briefly mentioned in the SCP are not demonstrated to be effective. The SCP should either document the proposed studies better, or expand the SCP to include more extensive experiments to establish the rock behavior.

Similar comments apply to characterization of the structure after excavation and heating, and backfill. There is little justification that the proposed methods can be expected to work.

An important aspect of the rock mass characterization is the potential response to a stress field favorable to fault slippage(2.3.2.1 and 1.3.2.3). Given preliminary indications that such conditions may exist, and the seriousness of such a possibility, the SCP is totally deficient in outlining the type of extensive program that should be carried out to verify, eliminate, or mitigate against such a possibility. The frictional properties of faults in the rock mass should be thoroughly understood. If the rock mass is near failure, detailed determination of the effects of possible triggering mechanisms should be carried out(e.g. nuclear explosions, nearby earthquakes, atmospheric loading, and ground water loading).

In general the rock mass characterization plan does not adequately describe how the existence of larger fractures, joints, and especially faults, both in and near the repository, will effect the overall behavior. Some fundamental research ias probably required in estimating these effects.

The SCP generally lacks documentation of the extensive stress, strain, and seismic monitoring which should be carried out, both before, during and after construction, to verify that the rock mass is behaving as expected. The SCP should include a more extensive description of how the performance of the structure will be monitored in general.

LOCAL TECTONIC STRESS AND EARTHQUAKE MECHANISM

The CDSCP is lacking in plans for determining the true local tectonic stress system and the potential for local earthquake generation. Given the importance of the site and the indications that the local stress system may be favorable to initiation of normal faulting along certain fault planes, there should be a comprehensive study of the local stress system, and the failure characteristics of the local crustal formations. In addition there should be a well funded basic research program to determine the basic physics of failure in normal and oblique faulting environments. The program outlined in the SCP is based on outdated technology and does not aim for as comprehensive an

understanding as is possible with modern instrumentation and analysis.

The research program for Yucca mountain should include extensive effort in determining the true potential for earthquakes in the repository and the local region. This involves not only the traditional methods of seismic monitoring to determine epicenters and fault plane orientations, but also state-of-the-art digital instrumentation to determine rupture characteristics of local earthquakes (stress drop, direction of rupture propagation, source complexity, etc.), extensive studies of the absolute stress field locally and regionally with all modern techniques (overcoring, hydrofracture, etc.), monitoring of changes in the strain field (strainmeters, tiltmeters, gravity meters, and geodetic studies), determination of crustal as well as local geomechanical properties, the local and regional thermal structure which controls rock breaking strengths, stress relaxation, friction, and local strain energy density (using detailed mapping of heat flow and deep hole temperature gradients), detailed geophysical studies to determine local and regional crustal structure, especially the orientation of young folds and faults (using seismic reflection and refraction, and potential geophysics methods), and lastly detailed geologic structure mapping focussed on the recent stress field and tectonic movements).

Along with the extensive field programs carried out in the Yucca Mountain area, the SCP should include a basic research funding plan at Universities and laboratories to better understand the basic phenomena important to safety. A simple plan to make routine measurements in the local area is not adequate.

Review of parts of the Consultation Draft
Site Characterization Program
by John G. Anderson

GENERAL COMMENTS

This is a very complex and difficult document to review. Because of the size and scope, it is far beyond the capability of any one scientist to review more than a small part, just as it was beyond the capability of any one scientist to write it. Even figuring out how to approach the document is not trivial. Sometimes I had the feeling that one could nit-pick at the SCP for months, itemizing inadequacies in Chapters 1-7, and listing more research targets for Chapter 8. My hope is that the comments given here will be received in a spirit of cooperation, for that is how they are intended, and that they will be helpful for improving the standards of the coming revisions of the SCP and the research that will be carried out in accordance with the SCP.

The SCP takes the form of the scientific part of a proposal to solve a problem: first a description of what is known, followed by a description of what research is proposed. The problem has two parts: first, to determine if Yucca Mountain is a suitable location for a high-level nuclear waste repository and second, if it is, to learn enough about the site so that engineering designs will assure that less than a trivial amount of radioactive waste will escape to the accessible environment. My impression, and I think this is a fundamental flaw, is that the document assumes that Yucca Mountain is suitable, and the emphasis is on the second part of the problem.

I think another fundamental flaw is that the description of what is known (Chapters 1-7, particularly Chapter 1) fails to demonstrate that the investigators possess a clear and complete understanding of the existing information about the Yucca Mountain region and existing physical models of the pertinent geophysical phenomena. The word "demonstrate" is used carefully here; it is not meant to imply that the investigators lack the understanding, but only that the text does not demonstrate that understanding. More importantly, the CD SCP lacks a clear, well focused conception of what scientific issues need to be resolved to solve the first part of the problem. I thought the research proposal (Chapter 8) contains a shotgun approach in which nearly everything that one can think of is to be investigated; this approach will probably gather most of the needed information for the second part of the problem and much more irrelevant data besides. In many cases, the work plan is quite vague, and fails to demonstrate that the investigators know what they are doing. Unlike a research proposal, the authors are anonymous, and the document lacks any statement of who will do the work, how long it will take, or how much it will cost. As a research proposal, the SCP would thus be totally unacceptable. It would not stand any chance of being supported in a competition for NSF funds. This is not intended as a criticism of the scientists who prepared the SCP. It is a monumental document, and in a manuscript of this

size, multiple revisions are often necessary before it is able to withstand academic scrutiny.

It is obvious that a consortium of authors wrote the document, and that a consortium of people will be responsible for the research that is proposed. One interpretation is that the entire consortium is "out of control". This feeling can arise from the extensive duplication of material, said in slightly different ways, from one part of a chapter to another (obviously by different authors), and be reinforced by the lack of coordination between the "background" information (especially Chapter 1 in my review) and the related research (Chapter 8). Finally, the sheer quantity of research proposed, some of which is sure to be irrelevant to the suitability of the site, could be interpreted as evidence that some of the consultants to the DOE are interested in the most prompt and economical solution to the problems that are at hand. A more favorable interpretation of these same observations is that the consultants are intending to be as thorough and complete as is humanly possible, and that many of the flaws are the result of an attempt to complete the document under an excessively restrictive time schedule. My inclination is to favor this second viewpoint.

RECOMMENDATION

My concern is that the DOE will forge ahead with their research program without first completing an adequate SCP, and that in the long run this will result in possibly millions of dollars of poorly spent research monies. My recommendation is that site characterization should not begin until the flaws with this document, as described in the first two paragraphs above, are eliminated. This does not necessarily imply a lengthy delay, as the consultants to the DOE include capable scientists; some of the problems mentioned above can be explained by poor writing or overly-hasty preparation of the SCP.

Review of parts of the Consultation Draft
Site Characterization Program
by John G. Anderson

1. Sections reviewed
   Chapter 1. Geology

2. General comments

3. Major omissions / inadequacies

4. Specific comments

1.1 Geomorphology
This section pretends to demonstrate that present geomorphic characteristics are all favorable for a geological waste repository. To me, it seems that the critical geomorphic issues are:
   A. Quaternary volcanism
   B. Glacial conditions
   C. Incision rates
This chapter addresses all three of these.

A. Quaternary volcanism. There have been 5 volcanic vents in the past 1.2my, all within 15? km of the site. This comes to one chance in 24 of an eruption in 10,000 years if they are random in time. The questions this raises are:
   1. Could volcanism be triggered and localized by the change in stress or the change in the heat regieme generated by the presence of the repository? Does anybody know why the volcanism was localized where it was.
   2. Could volcanism change the drainage significantly, for example by damming the Fourtymile Creek drainage, and causing conditions favorable to lake formation if another glacial period were to begin?

Both of these ideas are rather "far out", almost science fiction. The report seems to be correct in characterizing the significance of possible future volcanism as small.

B. Glacial conditions. The report cites several lines of evidence that give an impression that things will not be very different there in a glacial period. The questions I see are:
   1. What happens to the water table during glacial conditions. The report argues that lake formation is not likely for various reasons. My experience is that I've seen lakes in the Mojave Desert nearby under current inter-glacial conditions. Is the climate that much different there?
   2. Even if conditions are not very different at Yucca Mountain, they will be very different everyplace else, and the Yucca Mountain region might be a much more attractive place to live. As glacial conditions make life impossible in northern cities like New York and Boston (which were covered with glaciers last time), the people will have to go someplace. This might be a great economic opportunity for Nevada!
   3. Glacial conditions will affect incision rates.
   4. Glacial conditions of increased water availability might affect earthquake occurence rates. Geologists should study whether occurence rates were greater during past glacial maxima.

C. Incision rates. The report presents data that average erosion

rates are low, and waves its arms at incision rates, even though these seem to me to be a more critical issue affecting the integrity of the repository and the tunnels connecting to it. The questions I see are:

1. The construction activities will significantly disturb the landscape and the stability of the existing surface, leading to expanded opportunity for incision to occur.
2. Under glacial conditions, incision will occur at an increased rate.
3. Under existing conditions, incision rates are apparently not adequately known.
4. Are there any areas where vigorous incision at rates far greater than present could compromise the integrity of the repository?

1.2 Stratigraphy & Lithology

This section discusses the rock & sediment deposits near Yucca Mountain. I only skimmed over considerable sections. I paid more attention to the tutorial on the regional geology, since I'm only learning that. I also was interested in the geological evidence for a shallower water table (p71-78), including calcite deposits, lacustrine deposits, and spring water deposits, and marsh deposits in the Amaragosa Desert (not discussed in detail here). The report cites a paper (p74) by Winograd and Szabo (1986) that suggests that the water table has declined by 10's to 100's of meters in response to tectonics and increased aridity. To me, perhaps because I lack a clear concept of the geometry, the evidence that suggests a shallow water table sounds contradictory to the Winograd and Szabo conclusion. The Winograd and Szabo study seems to receive a considerable amount of credibility, but is there any conflicting evidence or difference of interpretation? It is plausible at first reading, but it seems to be a such a critical result to support the viability of this site for the repository, but I think it ought to be examined very critically.

1.3 Structural Geology and Tectonics

This section discusses structural features, especially active and inactive faults, stress regeime, and heat flow. The section obscures on one of the most important points, namely active faults. Table 1-7, starting on p 123, summarizes Quaternary faulting, but it is not accompanied by a map to show the locations of the faults mentioned! A hostile opponent to the repository could consider this oversight (?) to be a form of whitewashing.

Important issues as I see them:

A. Detachment faulting: what is a realistic assessment of its probability and its resultant ground motions - not considered in the assessment here.

B. The claim is that the Las Vegas Shear Zone is seismically inactive. So are a lot of important fault zones with demonstrable Holocene activity - this one cannot be written off so easily. This shear zone is a good topic for research - why is the style apparently so different from the San Andreas - what mantle processes are involved and how do they differ?

C. Do ages of fracture filling tell us when the fractures formed, as claimed (p137), or do they tell us when the climate was different?

D. Research topic - why is the area undergoing an ongoing southward tilting? Is it relevant to the repository? (probably not).

E. State of stress and strain. The data in this section seemed to be not totally consistent. How well do we need to know this in order to estimate earthquake potentials and possible energy releases triggered by the activity at the repository or naturally?
F. The downward flow of water contaminating the heat flow measurements - does this make sense?
G. The low heat flow is a regional average. Is there high heat flow and a potential for geothermal energy at those volcanic centers in Crater Flat?

1.4 Seismicity
This long section talks about earthquake occurences. The current work probably includes all of the obvious things to do. My thoughts below have not tried to give a complete list of these obvious issues although some are included. The review of seismicity is a very standard presentation, boring to read!

A. The ability to induce seismicity at NTS & at Lake Mead should tell us something about the ability to induce earthquakes at Yucca Mtn. (159)
B. Completeness of record (p160). Can Rogers prove that the record is complete in Nevada for M=7 events since 1845? That sounds almost incredible to me considering the sparse population. In contrast, Topozada considers it likely that M7 events in California could have been missed even in the 1880's (My recollection is that is his conclusion but I did not check the reference).
C. If the record is complete the implications are remarkable - 1845 to 1931, no events over M 7 in Nevada (86 years) (should we count 1972 Owens Valley?) 1932-1954, 2 events with M>7, 5 with M>6.5. (22 years) This suggests that the seismicity is strongly episodic, and introduces an additional complication into the seismic hazard analysis.
D. Strike slip mechanisms - is it common for small shock mechanisms to differ from the largest events? I know that some of the largest events in Nevada also have strike slip mechanisms. But also consider that if we were to study the San Andreas stress province from the Coalinga sequence, our conclusions might be wrong.
E. Fig 1-57, text p172-175. The conclusion from this figure is that Yucca Mountain is in a region of extraordinary low strain energy release. The text does not include the necessary disclaimers to warn that this is a statistical sample over a much smaller area than the greater distances and thus subject to statistical uncertainty. It fails to point out that the results are very subject to the size of the largest event in the annulus, and that a single larger event in the nearest 10 km would completely change the picture. Thus the text leaves the impression that the seismic quiesence within 10 km is significant, and this invalid conclusion is repeated in the summary (p329).
F. For the risk analysis, the text does not give enough data to reproduce the results. Perhaps the reports that they reference do contain the needed data, but in a report that aims to be so complete as this one, leaving out this needed information could be interpreted as obsucring the problem.
G. They have proceeded to prepare a risk assessment without discussion of the attenuation model. This is an obvious place where research is needed.
H. Do we have an opinion about the preferred method to assess seismic hazard - ie probabilistic or Appendix A? (p195)
I. Do we plan to assess, independently, the attenuation from the nuclear explosions?

J. Induced seismicity does not include the possibility of seismicity caused by the repository.

1.5 Long-Term Regional Stability With Respect to Tectonic and Geological Processes.

The bottom of p199 lists the problems that could be caused by volcanism near the site.

A. p201. The report tries to have things two ways. On the one hand, it attributed the low heat flow to downward flow of groundwater. Now on p201, it interprets the low heat flow to conclude that silicic volcanism is not likely. See also my comments F and G under section 1.3.

B. p202. What is the link between volcanism and tectonism? What are the implications of volcanism and simultaneous strong earthquakes at the site? It's well known that earthquakes accompany volcanic eruptions. Thus a proper design ought to consider them to occur together.

C. p202. Sill-like basalt intrusions are not considered! Why can't they happen in a big zone of weakness caused by the excavation?

D. p203-204 - these probabilities seem very low to me. Someone needs to check the probabilities.

Starting on p 204, the report considers the likelihood of, and the consequences of, faulting breaching the site.

A. They are correct to connect faulting with changes in water circulation. However, they do not connect with fundamental changes in the water table.

B. As indicated earlier in my review, they have not considered the likelihood of repository-induced faulting.

C. They are correct to recognize (p207) the possibility that seismicity changes significantly with time.

D. p211 - ground motion from nuclear shots: The paragraph at the top gives an impression of conservatism by using an excessively high earthquake ground motion peak acceleration (.75 g). Is the target peak acceleration still the same?

1.6 Drilling and Mining

Section 1.6.2.2 reviews types of borehole logs. This is sort of interesting, and may be useful for the geophysical methods class.

1.7 Mineral and hydrocarbon resources

I looked at the tables and the figures.

1.8 Summary

p330 - repeats invalid conclusion about seismic energy

p330 - Suddenly my suspicions are raised about new estimates of the magnitudes of older earthquakes. This could be interpreted as a device to reduce the overall seismic risk estimates.

p332 - What is the basis for the conclusion that radiation exposure would be small from basalt products of an eruption that violates the integrity of the repository? We ought to double-check those numbers.

Review of parts of the Consultation Draft
Site Characterization Program
by John G. Anderson

1. Sections reviewed

Chapter 8.1 Rationale

2. General comments
2.1 The strategy described here breaks the issues into little fragments. Therefore interrelationships of different physical processes are more difficult to recognize.

3. Major omissions / inadequacies

4. Specific comments
8.1-
-8 "goals". There seems to be a double meaning to this word. On the one hand, the DOE puts the word in quotation marks to indicate that it has a special meaning, namely a guide for the development of the testing program. However, there is also the expectation that if the goal is met, the licensing issue dependent on that goal will be resolved. For this to be true, the "goals" must always be conservative. Therefore, whenever a "goal" is not conservative, we should point it out. By "conservative", I mean where there are uncertainties, design decisions are based on protecting against the less likely events.

-9 needed confidence and current confidence. These are qualitative evaluations of what is known. As such, it will be possible in the future to increase the "current confidence" and give an appearance of progress as a result of the research in the SCP even if no progress has been made. I think these terms are political, not scientific.

5. Recommendations

Review of parts of the Consultation Draft
Site Characterization Program
by John G. Anderson

1. Sections reviewed

Chapter 8.2 Issues
Much of this chapter was just skimmed. Except as noted below, no reason was seen to comment.

8.2.2.4.3 thoroughly reviewed
8.2.2.4.7 thoroughly reviewed
8.2.2.4.16 thoroughly reviewed

2. General comments
These sections are merely very brief overviews of programs that are described in detail in section 8.3... Thus most comments are reserved for that section.

3. Major omissions / inadequacies

Computer modeling is very heavily emphasized. An issue that this brings up is how much we can trust the computer models. I think that the answer depends heavily on the skills of the scientists who do the work. The programs will have to model a very complex phenomenon. In addition, and of equal importance, they will have to project the effects of a wide range of uncertainties in the values of input material properties and boundary conditions.

How many man-years will all this research require?

4. Specific comments
8.2-
-202 In the table, 8.3.1.8.3 aims to give effect of tectonic processes and events on flux rates, on water table elevation, and on local fracture permeability and effective porosity. At face value, this should respond to the concerns that Jerry Szymanski has raised.

-219 These mechanical properties of the rocks will be important for geophysical evaluations.

5. Recommendations

Review of parts of the Consultation Draft
Site Characterization Program
by John G. Anderson

1. Sections reviewed
   8.3.1.4 Rock Mechanics

2. General comments
2.1 My first impression is that it's hard to think of anything that is left out. At the same time, the relevance of many of the investigations may be marginal at best.

3. Major omissions / inadequacies
3.1 The resolution, and the needed resolution of the geophysical methods is not mentioned. As a proposal to NSF this would be very poor because the purpose of throwing all this money at the problem is not really defined. Interpretation of all this data is critical. There is no mention of plans to interpret the data in a "smart" way, for example by means of inverse theoretical methods, so that one can rigorously determine whether the data support the preferred geological interpretations or are merely consistent with them.

3.2 As Jim Brune is pointing out, the response of the earth at very long periods, from earth tides to normal modes to effects of the repository excavation and heating from the radioactive wastes, is a physical measurement that is not made here. The degree of success in predicting the results of this measurement will give an indication of how good the overall stratigraphic model is.

4. Specific comments
8.3.1.4-
-24 The issue of how the drilling modifies the environment that is being sampled is obviously critical. Although the impacts of drilling fluid are explicitly recognized, the impacts of dry techniques are not. For example, it is claimed that the heat from the waste will dry the rock; what will the heat from the drilling do?

-33 Many features refered to in the text are not identified on figure 8.3.1.4-3 as they should.

-32 to -44. No particular comments

-46 to -60 The description of the geophysical methods to be applied is vague, and the resolution of these techniques compared to the objectives of the study are not analyzed. I suspect that the amount of resolution that is needed is not known at this time.

-48 plan to "obtain hydrologic, geologic and geophysical models" of the site: I think the extent of the area under study is too small to take out of the larger context and have a meaningful model.

-48 borehole radar is to be used to "demonstrate the absence of fractures in the unsaturated zone". That sounds suspiciously like the results are assumed in advance.

-50 "petrophysics" - what's that?

-53 What flight elevation for the aeromagnetic survey?

-55 In table 8.3.1.4-4, listing all the geophysical methods, I did not see a gamma spectroscopy survey of the site.

-71 Is fractal analysis an accepted technique to describe fractures? Also, are fractures at the surface representative of fractures at depth? I thought you expect more fractures at the surface due to pressure relief.

-80 I'm not thoroughly familiar with the VSP technique and interpretation of the results, but I have a strong feeling that the capability of VSP to identify fracture density is being overstated.

5. Recommendations

5.1 Subactivity 8.3.1.4.1.1.2.1 should be expanded to consider the effects on hydrologic and other physical parameters of core samples that result from either dry or wet drilling techniques.

Review of parts of the Consultation Draft
Site Characterization Program
by John G. Anderson

1. Sections reviewed
   8.3.1.6 Erosion

2. General comments
   The program concentrates on average rates. A theoretical/experimental understanding of erosion is not planned under this SCP. I think that such an understanding is not necessary in this case.

3. Major omissions / inadequacies

4. Specific comments

5. Recommendations

Review of parts of the Consultation Draft
Site Characterization Program
by John G. Anderson

1. Sections reviewed
   8.3.1.8 Post-closure tectonics
   (pages -1 to -91)

2. General comments
2.1 Quality?
2.2 I am venturing to ask some questions about volcanism even though it is a field that I know little about.

3. Major omissions / inadequacies
not discussed? volcanism causing hydrothermal circulation through the site.

4. Specific comments
8.3.1.8-

-4 Tentative parameter goal implies about one chance in 100 of volcanic eruption that penetrates the repository during the lifetime of the repository.

-5 & -25+ Showing that <0.1% of repository area is disrupted implies a great understanding of the mechanism and pathway of volcanic intrusions. I doubt that can be obtained from field geologic studies. For a volcanic eruption in the basin & range, leading to a small basaltic cone, what is the ratio of volume of intrusive to extrusive volcanics? How thoroughly does the eruption permeate the available subsurface weak zones? Are subsurface weak zones filled first, and only then the eruption becomes extrusive?

-6 Goal that <0.1 probability in 1000 yearsthat > 0.5% of the waste packages will be ruptured by tectonic eventts. In 10,000 years, this corresponds to a probability of less than .65, ie it is not very restrictive. Thus these probabilities are essentially assuming that more likely than not, tectonic events will disrupt the cannisters.

-7 I think the goal to restrict the probability of faulting disrupting the cannisters is best achieved when the tunneling and cannister holes are being emplaced. So long as the big faults are avoided, it should be easy to reroute some drifts to be sure they don't go down fault zones, and to drill holes for the cannisters that are in intact rock! I don't see how minor faults can be identified during the SCP activities. An SCP activity should be to figure out how to get a reliable geologist in on dynamic revision of drift locations and cannister hole locations so that faults are avoided. Perhaps that is mentioned in a different part of the CDSCP.

-8 waste emplacement boreholes might also deform due to creep. This would be the same as folding in an undisturbed environment, but in the disturbed waste repository creep can occur independent of folding.

-13, -15 on what basis do they conclude that an igneous intrusive event has to be within 500 meters of the site to affect the water table? Assuming a uniform spatial distribution of volcanic events, and the current estimate of the probability of one within 500 m, the

probability of one within 5 km could exceed the parameter goal. Can they show that an igneous intrusive event 5 km away will not affect the water table?

-16 & elsewhere The slip rate of less than 0.01 mm/yr, implying an average slip of 1 m/10,000 yrs, does not assure that the tentative parameter goal will be met. If the slip were accomplished by creep, the performance parameter would be met. But if earthquakes occur less often than 10,000 years, with corresponding slip of greater than 1 m, the probability of the earthquake is about the probability of meeting the parameter goal. The tentative parameter goal might not be achieved.

-17 & -79 & -87 The initiating event of changes in stress or strain in the controlled area resulting from episodic faulting... causes changes in the hydrologic properties of the rock mass. ... This is just what Jerry Szymanski is talking about in his model. I don't see experimental assessment of the effect of stress on rock porosity or on the saturated fracture permeability.

-27 & -52 What do we know about the spatial extent of aftershocks from a fault? At times, they are spread out some, but how much? This is crucial for the waste package integrity from faulting. If aftershocks from the Windy Wash or Paintbrush Canyon fault might occur on small faults in the repository, it will have an important impact on these estimates.

-49 I assume that when they refer to a waste package rupture due to igneous intrusion, they mean that the waste package is melted.

-119ff What is the effect of ground water on the heat flow? Elsewhere in the SCP it is suggested that downward percolation reduces the heat flow, apparently significantly.

5. Recommendations

Review of parts of the Consultation Draft
Site Characterization Program
by John G. Anderson

1. Sections reviewed

Chapter 8.3.1.17 Preclosure tectonics

2. General comments

2.1 Quality. It takes less skill to know what needs to be done than to do it. It is easier to know that a car needs to be fixed than it is to fix it well. There are many places where the SCP says that something will be done, but details of the approach are left out. Consequently, you are left with no idea how the research will be done, or who will do it, and no idea if it will be done right. The quality assurance program is not responsive to these problems. All that does is assure that the results obtained are reproducible. It does not assure that the results are done in the best possible way. As a research proposal to NSF, the research in this document, in the parts that I read, would not stand a chance for these reasons.

A good (but not foolproof) way to assure quality is to demand that the results be publishable in a major US journal.

3. Major omissions / inadequacies
3.1 Strong motion seismology:
Inadequate plan to gather more ground motion data
Inadequate plan to predict ground motions from normal faults

4. Specific comments
8.3.1.17-
-3 to -25 This table is impressive in size!

Design or Performance parameter: No quarrels yet.

Goal: I don't know what these goals have to do with the regulatory requirements. They seem rather arbitrary to me so far.

Needed confidence: This is entirely qualitative, & thus not subject to rigorous verification.

Characterization parameter: No quarrels with this column yet

Current estimate

Confidence in current estimate: This is qualitative. As such, it will be easy to state later that the confidence is higher, and thus to demonstrate that the SCP has accomplished something. Thus I see this column and the next one as political, not scientific.

Needed confidence in final values: This is qualitative. See above item.

Key studies

-28 There are several different approaches to setting the seismic design criteria. Two are important to this part of the SCP. I will discusss three in this review. The approach which is not present is a deterministic aproach which would require that the pre-closure facilities should withstand "characteristic earthquakes", ie the types of earthquakes that most often occur on the nearest faults to the repository. The repeat time for these earthquakes is expected to be much greater than 10,000 years in many cases. This approach is similar to what is used for nuclear power plants in the United States. The second approach is what I will call the "SCP-deterministic approach". This is called a deterministic approach in the SCP, but it is apparently differrent from the deterministic approach described above. This can be seen in the more detailed discussion on page -63, and the table on p-13 and the continuation of this table across the rows to p-17. Here the proposal is to design to resist earthquakes which results from 10,000 years accumulation of slip on the active faults of the region. Since the repeat time for earthquakes on these faults is expected to be greater than 10,000 years, the magnitude of the earthquake that would result from 10,000 years accumulation of slip would be somewhat smaller than the characteristic earthquake. The third approach is a probabilistic approach, which would require that the pre-closure facilities withstand the level of ground motion that occurs with probability 10**-3 from all events (p-14). Since there are not a large number of faults nearby, I expect that in this case the probabilistic approach will yield a smaller ground motion than either the deterministic or the SCP-deterministic ground motions. Note the statement that probabilistic methods "will be useful for ... postulating deterministic seismic events." As discussed above, if the probabilistic methods will be used to select the deterministic events, the deterministic events would likely be something less than a "characteristic earthquake".

Thus, for Yucca Mountain, a deterministic approach to the seismic hazard is likely to be more "conservative". By a conservative approach, I mean one that requires a greater level of strength in the design to resist earthquake motions. The level of conservativism is a political judgement, not scientific. Of course, the level of conservatism in such judgements is generally decided upon with the input of the scientific community as well as the general public. As a comment, it is not unreasonable to demand that the repository be designed to withstand seismic standards set by the deterministic approach, as this approach has been used for other critical facilities (nuclear power plants, dams in California). Even the probabilistic approach, which I expect is least conservative, would if properly applied lead to sufficient strength of the Yucca Mountain facilities that earthquakes would have only a tiny chance to trigger release of radioactive materials to the accessible environment. It is a political question whether this chance is acceptable. This comment is intended to point out the consequences of the procedure that is selected.

I am not sure that the authors of the SCP knew what criteria will be used. They seem to be entering the political arena of establishing what the standards are, since in several places they are trying to sell the SCP-deterministic procedure. On page -36, they refer to the 10,000 year cumulative slip earthquake as an explicit way to define the size of the deterministic earthquake; as seen in the discussion above, that is not exactly the case. Also, because of the large recurrence times in southern Nevada, the SCP refers to the

deterministic estimates as "misleading" (pg -63). One interpretation is that they are defining the SCP-deterministic procedure in response to some political agenda, or perhaps in the hope that the NRC will accept it as a less stringent way to satisify the Appendix A regulations that apply to nuclear power plants with resultant savings in cost of preclosure design and construction costs.

-32 Note probabilistic goal, last paragraph. The 5 cm criteria seems to be quite arbitrary. I don't see any obvious reason why a larger threshhold could not be engineered against.

-33 Top. They assume, but do not prove, that the probability of radiation loss to the accessible environment is less than one chance in 10 if 5 cm of faulting occurs in the repository. There is no basis for this statement, so far as I can tell.

-33 3rd paragraph. The meaning of "sympathetic faulting" is ambiguous. If they mean faulting on one fault triggered by ground motions from another earthquake, then this might occur for earthquakes greater than 5 km away. In southern California, my recollection (without checking a map) is that there has been such triggered slip at distances of 30 to 50 km. To my knowledge, there is no way to recognize sites of potential triggered slip in advance, no matter how well the fault is characterized. Nobody knows anything about the ground motions that result from triggered slip.

The other alternative meaning for "sympathetic faulting" is that a complex of disconnected surface fault traces are formed as a result of a single earthquake. If this is the case, then the size of the earthquake is likely to be larger than what one will estimate from the extent of single fault traces.

-34 2nd paragraph. The assumption is that the potential for 7 cm of fault displacement below the ground at the waste handling facilities can be determined from surface exploration. On the contrary, 7 cm of slip can occur in a magnitude 5 earthquake, and most of the time, when a M=5 earthquake is the main shock of a sequence, it is not accompanied by surface rupture. Thus I don't see how the proposed research is able to achieve the goal that has been established.

-36 4th paragraph. I object to characterizing the choice of the "10,000 year cumulative slip earthquake" as merely a more explicit way of defining the maximum earthquake; rather it amounts to a redefinition. See my note for item 28 above.

-60 Investigation 8.3.1.17.3.1.1. Identify relevant earthquake sources. The premise is that all relevant sources can be identified by geophysical techniques. I doubt that such is the case. It would be better to assess the largest magnitude earthquake that can occur in the region without surface expression, and then to assume that such an earthquake can occur directly beneath the site. This latter approach would be consistent with the NRC approach to siting nuclear power plants in a "tectonic province".

-64 Study 8.3.1.17.3.3. Ground motion estimation. The approach to ground motion estimation is to use regressions that apply to California unless it can be proven that data from the Basin and Range contradict such regressions in a statistically significant manner. Since there are only very few strong motion data points from the Great Basin, it is very unlikely that such a contradiction will

occur. On the other hand, it is well known from study of weak motions that attenuation is less severe in the Great Basin than in California. Thus the proposed procedure has the appearance of being likely to underestimate the ground motion from more distant events. For nearby events, these differences in attenuation are not likely to dominate since geometrical spreading, rather than attenuation is a dominant influence. However, there is no certainty that ground motions from normal faulting earthquakes in the Great Basin are similar to those from faults with much larger slip rates in California.

This study does not include any plans to install strong motion instrumentation outside of the Yucca Mountain vicinity. If such an effort were made on a massive scale, there would be a reasonable chance of recording some strong shaking from a major Great Basin earthquake during the duration of the SCP project.

This study does not include any plan to evaluate ground motion from any potential detachment faults.

-68 Activity 8.3.1.17.3.5.1: Identify controlling seismic events. The list of parameters leaves off stress drop.

-71 Probabilistic Seismic Hazard Analysis. The evaluation of seismic sources seems to imply that only one rate of earthquake occurence will be used, and that the only use of alternative models will be to decide how to distribute the events in the model. A better procedure is to include alternative models for the occurence rates of the earthquakes, corresponding to alternative models for the geophysical rate controlling mechanism.

-79 Historical earthquake record. Does not include any pre-instrumental earthquakes.

-82 Induced seismicity. Post-closure tectonics needs to add triggered earthquakes resulting from a rising water table resulting from return of glacial conditions.

Review of parts of the Consultation Draft
Site Characterization Program
by John G. Anderson

1. Sections reviewed
   Chapter 2. Geoengineering.

2. General comments

3. Major omissions / inadequacies

4. Specific comments
2-
-38 What is the source of the in-situ strain rates cited here? Does this account for strain induced by the repository?

5. Recommendations

Comments on the *Consultation Draft Site Characterization Plan (SCP), Yucca Mountain Site, Nevada Research and Development Area, Nevada.*

William A. Peppin, 17 June 1988

Introduction.

I find the SCP to be lyrically and intellectually impressive, and that it discusses in some depth almost any idea I can think of pertinent to understanding the various geotechnical problems at Yucca Mountain. In recognition that the SCP is an outline of a massive research program which will run for the next five to ten years, it seems inappropriate to address specifics: the research will certainly change direction as needed, or as guided by insights and discoveries which inevitably will be made in connection with such a massive investigation. Accordingly, I have decided to keep these comments general in nature, hoping that brevity, the "soul of wit," will render them useful to the State and to the DOE.

These comments are presented in four parts. The first part documents materials I have read from the SCP. The second part details some fundamental criticisms I have of the SCP. The third part gives a discussion of the seismic instrumentation program as outlined in the Preclosure Tectonics section of the SCP (8.3.1.17). The fourth part contains a list of recommendations intermixed with other commentary.

1. Materials Read.

Materials in *Volume I*

Preface, clvi - clviii

Introduction, I-1 - I-15

Chapter 1, Introduction, 1-1 - 1-347

Summary, 2-109 - 2-118 (geoengineering)

Materials in *Volume II*

Summary, 3-220 - 3-240 (hydrology)

Summary, 4-145 - 4-152 (geochemistry)

Summary, 5-102 - 5-106 (climatology and meteorology)

Materials in *Volume III*

Summary, 7-224 - 7-240 (waste package)

Materials in *Volume IV*

8.0 Introduction 8.0-1 - 8.0-10

8.1 Rationale 8.1-1 - 8.1-11

8.2 Issues to be resolved 8.2-1 - 8.2-18

8.2-31 - 8.2-41 (Geology)

8.2-49 - 8.2-54 (Misc, some seismology)

8.2-179, 8.2-181, 8.2-199, 8.2-213, 8.2-222 Program Summaries

8.2-225 - 8.2-232 (Issue Tracking)

Materials in *Volume V*

Postclosure Tectonics

8.3.1.8-1 - 8.3.1.8-44

8.3.1.8-45 - 8.3.1.8-58 (Rupture of cannisters by EQs)

8.3.1.8-59 - 8.3.1.8-90 (Tectonics & hydrology)

8.3.1.8-101 - 8.3.1.8-123 (Volcanics and Geophysics)

8.3.1.9-1 - 8.3.1.9-46 (Human Interference)

Preclosure Tectonics

8.3.1.9-1 - 8.3.1.9-14 (Human interface program)

8.3.1.9-25 - 8.3.1.9-31 (mineral and geothermal res.)

8.3.1.17-1 - 8.3.1.17-43 (Preclosure volcanics)

8.3.1.17-44 - 8.3.1.17-181 (Seismicity, geophysics,tectonics)

Materials in *Volume VI*

8.3.2.1-24 Repository modeling, seismic analysis

Materials in *Volume VII*

8.6 and 8.7 QA, Decontamination, Decommission

2. Fundamental Problems with the SCP.

I identify seven fundamental problems with the SCP. By a "fundamental problem," I mean an area in which the SCP would require substantive modification of the text or a substantial reemphasis in directions taken by the research programs. Briefly, these problems, discussed in succeeding paragraphs are as follows. (i) Over-reliance on computer modelling; (ii) Under-reliance on

empiricism; (iii) Inadequate focusing of attention; (iv) Overmuch detail in Chapter 8; (v) Possible overcommitment of manpower; (vi) Susceptibility to intervention, and (vii) no accounting in the logic diagrams for the discovery of new data and new lines of enquiry.

(i) Over-Reliance on Computer Modeling. The SCP is written as though the problem of site characterization at Yucca Mountain is merely an engineering problem, in which the answers are fairly well known *a priori*. The result is that engineering problems are lumped together with research problems the resolution of which is presently not foreseeable. For example, engineering a waste container falls into the realm of what an engineer can work out fairly exactly using sophisticated computer codes. However, some of the most critical problems in the SCP involve the creation of a "conceptual model" which is then tested using computer codes, e.g., 8.3.1.17.3.4; 8.3.1.17.3.4.2; 8.3.1.2.1.4; 8.3.1.2.2; 8.3.1.2.1.3; 8.3.1.8.3.2.7. We have heard hydrologists tell us that the problem of water flow in unsaturated tuff involves an extremely complex system of nonlinear differential equations. These equations are critically dependent on spatial and temporal variations of a large number of material properties which relate directly and indirectly to the porosity of the unsaturated tuff. Using the fastest computers in the world now available, even producing a finished calculation is a monumental effort. However, we are beset by the burden of knowing that critical parameters for the calculation will almost certainly not be known. Therefore, in the realm of fluid flow in the unsaturated Topopah Springs tuff, and the Calico Hills tuff below, it is almost certain that such calculations will not be able to develop information with a sufficiently "high degree of confidence," to borrow language from Chapter 8.

The situation is similar in modelling weather, erosion, geochemistry, and other areas thought to be areas of critical need. The conceptual model will always need to be tested using some computer code, and these codes will always be extremely complicated. Dependence on computer modeling has the dual problem that it is not always accepted by the NRC and that issues involving quality assurance become extremely burdensome. As an example, I tried to put up a quality-assured program, used in the nuclear industry for computing heat transfer. This code, called NDOT, had been used for critical calculations in the design of nuclear plants. It is relatively short (5,000 lines of FORTRAN), but is quite complicated. In fact, when I tried to compile the program on the VAX 11/780 compiler, I discovered that the code had logical errors in the branching which, if executed, could never have computed correctly. Using a different language compiler (DEC FORTRAN rather than CYBER FORTRAN) led to this discovery. In fact, I suspect that any large code has errors like this that lie undetected. For every model calculation made to support the SCP, the danger of such problems is omnipresent: many of the codes proposed for use are extraordinarily complex and lengthy.

(ii) Underreliance on Empiricism. In the approach to difficult problems, I truly believe that the surest way to go is to base one's decisions on field tests. For example, why try to compute ground motion characteristics at sites in Yucca Mountain? Why not measure them using the sources of nuclear explosions? In determining the rate of fall-off of ground motion with distance, why rely on a curve determined from other areas? Why not just go out and measure the attenuation? In my opinion, the ONLY way that the SCP will discover satisfactory resolution of some of the most critical problems is through testing. NRC (1988) agree with this position in some cases (e.g., at page 23) but evidently not at others (page 1). To me, the strongest part of the SCP are the studies

involving geological investigations, because these are, by their nature, empirical. Activities leading to detailed documentation of surface geology, of downhole properties, or of trenches taken across potentially active faults are certain to increase the level of confidence with regard to the critical issues addressed by the SCP. Examples in the SCP of tectonic studies based on empiricism are 8.3.1.17.3.3.1 and 8.3.1.17.3.3.2, which I think are of value.

Another point in favor of empiricism and against computer modelling of conceptual models is brought out by the very first major objection to the SCP posed by NRC (1988): "The CDSCP does not address the investigations that would be needed to characterize the site with respect to the full range of alternative conceptual models that are consistent with the existing data. Thus, all of the investigations that are significant to the characterization of the site are not considered." This highlights the principal peril of computer modelling. Pandora's box becomes opened, as we are required to provide calculations for any model a person can think of, rather than approach the problem directly using empirical methods.

No issue seems more critical to siting at Yucca Mountain than the ability of waste to percolate through the unsaturated tuff and get into the water table below (and hence escape relatively quickly to the accessible environment). The whole strategy (e.g., Key Issue #1) depends on the ability of the unsaturated tuff to "provide no pathway for the radionuclides to the accessible environment" (10 CFR 960.4-2-1) which will take less than 1,000 years. And indeed, at SCP 8.0-9 is written, "The top-level strategy focuses strongly on the investigations of the characteristics of the flow in the unsaturated zone, relying heavily 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....The investigations of these concepts have the highest priority in the program."

At the most critical points of these investigations, heavy reliance is to be based on computer modelling (SCP 8.3.1.2.1.4; 8.3.1.2.2; 8.3.1.2.2.1.3). There is plenty of laboratory testing, and the exploratory-shaft in-situ experiment (8.3.1.2.2.4.2) is good, but uses water and not radioisotopes.

(iii) Inadequate Focusing of Attention. The basic approach the SCP takes is to identify each federal regulation which pertains to repository siting and proceed, systematically, to address studies toward showing compliance with each of these (in a very long list, the Key Issues, the Issues, and the Information Needs). There is, however, insufficient attention given to an early identification and investigation of those issues which might truly disqualify the site. NRC (1988) writes as follows on this point at page 1f: "High priority should be accorded investigations having the greatest potential for resolving issues associated with features, events, or processes that could lead to the site being considered unlicensable..." There needs to be a fuller discussion, given in the SCP *Overview*, which seeks to identify these critical issues right up front and address them right at the start. Clearly, as the SCP rightly points out, some of these critical issues will take years to resolve. But those which might be resolved up front in, say, less than 18 month's time, should be investigated in a "pre-SCP," perhaps saving a tremendous amount of government money.

(iv) Overmuch Detail in Chapter 8. Chapter 8 approaches all problems as engineering problems (as mentioned above). An "engineering problem" is one which we mostly know how to solve. Consequently, the SCP lays out an extremely detailed procedure for satisfying the information needs and proceeding. The cost of this massive detail is that important points are buried,

overwhelming the reader attempting to get a proper grasp of the material. The elaborate "activities" described in pre- and post-closure tectonics (8.3.1.9 and 8.3.1.17) are largely not interesting to me simply because, as time goes on, these will have to be modified quite drastically. That is why it bothers me much less than most that certain research activities are not listed in the SCP. If anything, far too many are listed.

(v) Possible Overcommitment of Manpower. In view of the previous point, one can ask the question: is it possible to complete the "activities" and fulfill the "information needs" described in the SCP Chapter 8? Are there sufficient numbers of people in this country with the training to do this job? This is not clear from reading the SCP. I recommend that the SCP be revised to include cost and manpower estimates for each of the investigations. This might be quite a revealing exercise, and might convince DOE to be a lot more selective in how they are going to conduct the SCP investigations.

(vi) Susceptibility to Intervention. This is Frank Dickson's point, and I think is is a very powerful one. Provide an intervenor, who desires to block the siting of the waste repository at Yucca Mountain, with a document like the SCP. It really doesn't take much effort for even a half-rate scientist to find areas where the SCP is lacking in some detail, or fails to address somebody's pet project. Therefore, as written the SCP is an endless cornucopia of material for such people. It just isn't humanly possible to address every issue in full detail that a human can think of: we MUST be selective, and we MUST develop a rationale for that selectivity. Otherwise, the game is over: Key Issue 4 (economic viability) will kill the project.

(vii) Future Directions of Research. In Chapter 8 we find detailed listings of logic diagrams, which indicate how the information developed in the numerous studies will be brought together to resolve each licensing issue. At noplace in any of these diagrams is it made clear what effect new, unforeseen evidence will have. In a research program involving so many man-years of effort, it is certain that major discoveries will be made which could completely revise the way in which evidence is brought forward to address the licensing issues. Therefore, one can well ask: why does the SCP attempt to make such detailed predictions about how this open-ended and massive research effort will go? It might make the SCP easier to read and comprehend if it was written in a way which summarized the information to be developed, the key issues, and just listed which information (i.e., which sections of the SCP) would be likely to pertain to each issue. To summarize: are any of those complicated logic diagrams needed at all?

3. Seismic Instrumentation.

The seismic instrumentation program is described in 8.3.1.17.4.1.2 and seems the right level of detail. The proposal is to (1) continue monitoring of the analog southern Great Basin network run by the USGS, (2) assess what additional instrumentation is needed as a sub-task, (3) place an array of strong-motion accelerometers in case of a large local earthquake, and (4) acquisition of a 30-component portable digital array, to be used for special studies. This program contains just about everything we need to do, except the program is known to be lacking in one critical area. We need to acquire data from a minimum of about six 3-component, high dynamic-range digital, permanent digital recording sites, on good rock, and this should be started immediately. Earthquakes are few near Yucca Mountain, and I think it is a big mistake to plan for some

elaborate future data acquisition program when we should have a few of this instruments in the field right now. There is no reason why three of these cannot be the existing state-of-the-art NRDC stations surrounding the test site (analysis of this data is going on now at UNR in connection with other projects.)

In my opinion, the operation of the analog array is important, because it provides continuous monitoring of the Yucca Mountain area. It is presumed that the operation of this array and routine procedures used by the USGS are now under sufficient quality-assurance control that data being collected will meet NRC standards for documentation and trackability.

4. Recommendations.

(i). Experimental Efforts. Three areas of analysis and experimentation occur to me which might lead to the early generation of critical information on Key Issue #1 (ability of the repository to isolate the waste from the accessible environment.) They involve: (a) in situ experimentation in the Topopah Springs tuff using realistic conditions, (b) hydrologic and geochemical analyses of existing NTS radionuclides, and (c) pursuit of the Bish and Vaniman (1985) hypothesis about the water table in Yucca Mountain. The suggestions made here pertain to areas OUTSIDE my area of scientific knowledge and specialization. However, to me these are the most critical issues I can find. In my opinion, there is no element save one involving seismology or geophysics (my area of knowledge) which influences decisions so critical to the performance of the Yucca Mountain site as a waste repository. That is (d) possible intrusion of the repository by renewed volcanism related to the Crater Flat volcanic field.

(a) In Situ Testing in the Topopah Springs Member. Performance of the unsaturated tuff of the Topopah Springs member in affording waste isolation for a long time (projected as 10,000 years in the SCP) is evidently the most pressing site characterization issue for Yucca Mountain. In my opinion, in situ (versus laboratory) testing is needed. I would propose the following kind of test.

Testing drifts would be constructed into several areas of the proposed repository horizon, selected quasi-randomly. There a testing program would be set up to simulate exactly the conditions caused by a ruptured waste cannister. Ground would be heated, waste would be set out on the rock under conditions to be found in the repository, and the migration of the wastes would be closely monitored. At least one site would be selected in the imbricate-faulted section of Yucca Mountain. The waste would be insufficient in volume that its loss down fractures would cause an issue of public safety. The result of this experimentation is to determine the rate and mechanism of waste movement through the unsaturated tuff, and to monitor geochemical reactions. If through discussions with the NRC analog experimentation in G tunnel on Pahute Mesa is acceptable, perform most the experimentation there, with reduced experimentation on site during the time of the exploratory shaft construction.

(b)*Testing of Existing Radionuclide Waste.* At NTS we have a 30-year history of underground testing. Shots have been fired above and below the water table at numerous locations around the test site, including within tuff horizons quite similar to Yucca Mountain. This gives us a 30-year time chronology of how the wastes associated with the underground explosions have migrated from shotpoints within and above the water table. This information can be obtained (or probably is available now in part) through a drilling program about shotpoints both in Yucca Flat and on Pahute and Rainier Mesas.

(c)*Work on the Paleo Water Table.* At pages 3-226ff of the SCP (Volume II) is a discussion of the evidence for fluctuation of the water table at Yucca Mountain

during Quaternary time. Discussed is the evidence on paleo water tables from Thordarson (1983) and Bish and Vaniman (1985). The latter reference proposes a method by which we can determine the high stand of the water table at Yucca Mountain. The idea involves investigation of tuff lithology to exploit the idea that, "...the preservation of open shards and pumice made of nonwelded glass is rare below past water levels (Hoover, 1968)." The SCP goes on to state that, "The observations of Bish and Vaniman (1985) suggest that past water levels beneath Yucca Mountain may never have been more than 100 m higher than the modern water levels." It seems to me that this would be an extremely important result if it can be proved. There have been various proposals made that the water table may have invaded the repository horizon of Yucca Mountain, and the SCP has proposed studies to address these (e.g., 8.3.1.8.3.2.3). But if we could rule this out, the way would be clear to give even sharper focus to the issue of waste isolation at Yucca Mountain, i.e., the performance of the unsaturated tuff. For example, discussion of Yucca Mountain climatology for post-closure performance becomes a moot point (unless, as the SCP shows is unlikely, the issue of enhanced rainfall and consequent enhanced erosional cutting of Yucca Mountain becomes a reasonable possibility).

(d) Active Geotomography for Magma Zones. Investigations are proposed to search for magma bodies using various geophysical techniques (8.3.1.8.1.1.3). I would recommend one area of study that has been used recently with considerable success by J. Zucca of Lawrence Livermore National Laboratory and John Evans of the USGS, and this is active geotomography. Their recent results, as yet unpublished, attempted to characterize magma bodies under Medicine Lake and Newberry calderas, successfully locating some small zones under each of these structures, which are similar to the NTS calderas in character although much more active recently. The cost for such work would be about $1 million for Yucca Mountain, but would probably provide the most reliable evidence on magma zones near Yucca Mountain (if they exist). This with surface geology could possibly provide the basis to rule out, with high confidence, the possibility of intrusion of the repository tuff horizon at Yucca Mountain.

(ii) Time/Cost/Manpower Estimates. As suggested above, I recommend that the SCP provide estimates as to the cost, man-years, and completion time contemplated for the proposed investigations.

(iii) Estimates of Probability of Success. Also missing from (or obscured by) the SCP are discussions which relate to the likelihood of a particular information need being developed to sufficiently high confidence. If the need is for "high confidence" and we presently have "medium confidence," what are the odds of being able to make this transition? Consider, for example, activities in the SCP involving fault characterization about Yucca Mountain. How much will any of this help in establishing, with high confidence, a faulting scenario which ruptures the repository? While work proposed to characterize the identifiable faults (Solitario Canyon; Windy Wash; Bare Mountain; Ghost Dance) is laudable, it is very unlikely than any number of studies (in an area currently aseismic) will lead to resolution of this problem. Therefore, the basis for deciding how many cannisters will be ruptured by a fault will necessarily be based on indirect, probabilistic arguments. I have no idea how anybody is going to decide if/when the studies of local faulting are sufficient to qualify the site (and, ironically, this really doesn't seem to be such a bad problem for the performance of the repository.)

(iv) A Recommended Line of Study. Having heard a number of people speak of the tectonic problems of Yucca Mountain, and heard mention of various scenarios about detachment faulting, I am not persuaded that there is a lot of opportunity to make a discovery that will be of importance to Yucca Mountain

except for two: the nature of strike-slip faulting, and the tectonics of the southern Walker Lane.

As mentioned by NRC (1988), page 55, strike-slip motion on faults, potentially the most significant possible fault motion, has not been characterized (it is not nearly as easy to give geologic documentation for horizontal versus vertical fault offset.) Focal Mechanisms today in the vicinity of Yucca Mountain show mainly strike-slip motion, so characterization of the amount of strike-slip motion on faults near Yucca Mountain will greatly increase the confidence on estimations of ground motion associated with potential earthquakes. The nature of strike-slip motion also relates critically to the problem of the Walker Lane.

Yucca Mountain lies in a somewhat-artificially drawn tectonic province called the Walker Lane, which extends from near Reno down to the southeast past Las Vegas and beyond. For me the most critical tectonic problem at Yucca Mountain is to characterize the nature of this relationship. For example, a few tens of km west of Yucca Mountain we find the extremely fresh, obviously active strike-slip faults of Death Valley, and this activity at Yucca Mountain is either comparable (because it is also in the Walker Lane) or less (as it presently appears based on observable faulting and seismicity near Yucca Mountain.) The SCP does have some investigations aimed at exploring this connection, but these are not focused sufficiently on the main problem. For me, this problem is: can we document a sharp transition from the active faulting of the Death Valley region as we move NE toward Yucca Mountain, or is the transition gradual? If the former, then we might expect a decoupling of stress perturbations at Yucca Mountain resulting from a great earthquake on the eminently-capable faults of Death Valley. The issue here is: can a sudden rejuvenation of seismicity near Death Valley be followed by renewed activity near Yucca Mountain?

This problem is not only important, but amenable to solution. One proposal given in the SCP (8.3.1.17-87 ff) is to run seismic refraction and reflection lines across the transition zone. This can provide the evidence on the nature of the transition mentioned above. Alternately, they can show that the "transition" is illusory, being a function of varying lithological, morphological, and geomorphological conditions. This study, 8.3.1.17.4.3, could perhaps be focussed more toward this line of reasoning.

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Review of the Yucca Mountain Consultation Draft Site Plan- Geophysical Structural Determination

Keith Priestley

Compliance with performance and design criteria for a geologic high level radioactive waste repository requires information on the rock characteristics, stratigraphy, and structure both within the immediate area of the site, and in the wider region about the site. This information can be used directly in the design of the underground facilities to evaluate the site performance related to ground-water travel time, waste package lifetime and radionuclide release to the environment. Information gained from geophysical structural determination is important in regional studies including improvement in earthquake location, identification of concealed faults, evaluation of ground motion attenuation etc.

Discussion of geophysical structural determination are primarily contained in two sections of the consultation draft of the site characterization plan, section 8.3.1.4 Rock Characteristics and section 8.3.1.17 Preclosure Tectonics. The results of studies in section 8.3.1.17 Preclosure Tectonics are also applicable to studies in section 8.3.1.8 Postclosure Tectonics.

SECTION 8.3.1.17-Preclosure Tectonics

Data gained from geophysical structural determinations are important to investigation 8.3.1.17.3 - studies to provide required information on vibratory ground motion that could affect repository design or performance including studies 8.3.1.17.3.1 identification and characterization of earthquake sources that are relevant to a deterministic seismic hazard analysis of the site, and 8.3.1.17.3.4 documentation of systematic effects on surface and subsurface ground motion from local site geology; 8.31.77.3.6 Probabilistic seismic hazard analysis and to investigation 8.3.1.17.4 - Preclosure Tectonic data collection and analysis including studies 8.3.1.17.4.2 Location and recency of faulting near prospective surface facility, 8.3.1.17.4.3 identification and characterization of Quaternary faulting within 100 km of the site, and 8.3.1.17.4.7 subsurface geometry and concealed extensions of Quaternary faults at Yucca Mountain.

Study 8.3.1.17.3.1 -- Relevant earthquake sources

8.3.1.17.3.1.1

ACTIVITY 8.3.17.1.7 -

Identification of relevant earthquake sources

Relevant earthquake sources will be identified through a

synthesis of information including geophysical structural information. Important to this activity are the location and potential activity of buried faults.

Study 8.3.1.17.3.4 -- Effects of local site geology on surface and subsurface motion

ACTIVITY 8.3.1.17.3.4.2 -

Model site effects using the wave properties of the local geology -Theoretical site-effect models will be developed based on measurements of the velocity, attenuation and density structure of the soil and bedrock to a depth of at least 1 km, particularly under Midway Valley.

Study 8.3.1.17.3.6 -- Probabilistic seismic hazard analysis

Activity 8.3.1.17.3.6.7 -- Evaluate earthquake sources--The objective is to determine average rate of earthquake recurrence by characterizing earthquake source by location, shape, depth, and rate.

The data for these studies will primarily be supplied by the data-collection activities in Investigation 8.3.1.17.4 as outlined in Figure 8.3.1.17-5.

Study 8.3.1.17.4.2 - Location and recency of faulting near

the prospective surface facility - Activity 8.3.1.17.4.2.1. The identification of appropriate trench locations will be made primarily using geologic mapping. Areas of supposed Quaternary faulting may also be investigated using shallow seismic refraction and reflection profiling. To this should be added shallow radar profiling. Studies have shown this to be a valuable and economic method for identifying appropriate locations for trenching and for mapping the subsurface continuation of structures between trenches.

Study 8.3.1.17.4.3 Quaternary faulting within 100 km of Yucca Mountain, including the Walker Lake.

Activity 8.3.1.17.4.3.1 - Conduct and evaluate deep geophysical surveys in an east-west transect crossing the Furnace Creek fault zone, Yucca Mountain, and the Walker Lane. A variety of geophysical studies are planned at different locations and scales including deep and shallow seismic reformation; deep, intermediate and shallow seismic reflection; and gravity, magnetic and electrical surveys of the region and the site. These studies are summarized in Tables 8.3.1.17-7 and 8.3.1.17-8. These data collection experiments include:

a) Deep refraction surveys with shot point spacing of 8 to 20 km in the region of Yucca Mountain. The results

from this work to date provide detailed velocity control only to about 12 to 15 km depth.

b) Shallow refraction and reflection surveys of 250-500 m long profiles in the immediate vicinity of Yucca Mountain. The maximum depth of penetration will be 100 m. The number and location of these profiles will be decided on the basis of geologic mapping.

c) A deep reflection survey across Yucca Mountain to image large scale features in the crust. Previous work of this type in the region of Yucca Mountain has produced data of marginal quality and the decision to proceed on this study will be made after the evaluation of preliminary test.

Study 8.3.1.17.4.7 -- Subsurface geometry and concealed extensions of Quaternary faults at Yucca Mountain

Activity 8.3.1.17.4.7.1 Evaluate intermediate depth (2-3 km) reflection and refraction methods and plan potential application of these methods within the site area. This is a planning activity only and the decision to proceed with actual application of these methods will await the review of the preliminary test.

Activity 8.3.1.17.4.7.2 Detailed gravity survey of the site area

to infer the location of faults and continuity of rock units within the site.

Activity 8.3.1.17.4.7.3 Detailed aeromagnetic survey of the site area to infer from this information the location of fault and continuity of rock units within the site.

Activity 8.3.1.17.4.7.4 Detailed ground magnetic survey of specific features within the site to infer the location of faults and continuity of rock units in the vicinity of the shaft and surface facilities

Activity 8.3.1.17.4.7.5 Evaluate surface geoelectric methods and plans potential applications of these methods within the site area to evaluate this method and if useful, plan future activities.

Section 8.3.1.4 Rock Characteristics

Date gained from geophysical structural determination are important to investigations 8.3.1.4.1 development of an integrated drilling program including activities 8.3.1.4.1.1.3 evaluation of drill holes and other subsurface data for the purpose of siting additional drill holes; 8.3.7.4.2 geologic framework of the Yucca Mountain site including activities 8.3.1.4.2.1.2 surface land geophysical surveys, 8.3.1.4.2.1.3

bore hole geophysical surveys, 8.3.1.4.2.2.5 seismic tomography/vertical seismic profiling.

Study 8.3.1.3.1.1 Develop positions on drilling issues that pertain to site characterization.

Activity 8.3.1.4.1.1.3 In the evaluation of drill hole and other subsurface data for the purpose of siting additional drill holes,

the bore holes geophysical method, and surface geophysical methods will play an important role.

Study 8.3.1.4.2.7 -- Characterization of the vertical and lateral distribution of stratigraphic units within the site area.

Activity 8.3.1.4.2.1.2 Surface-based geophysical surveys will be used to help define the lateral and vertical distribution of stratigraphic units and lithostratigraphic subunits of the Yucca Mountain tuff. Table 8.3.1.4-4 summarizes the geophysical studies for program 8.3.1.4.

Activity 8.3.1.4.2.1.3 Borehole geophysical surveys will be conducted to aid the definition and refinement of the location and character of lithostratigraphic units and contact between units and to determine the distribution of rock properties within lithostratigraphic units. A suite of commercially available geophysical logs will be obtained in future drillholes and additional experimental geophysical logs will be obtained.

Activity 8.3.7.4.2.2.5 Seismic tomographical vertical seismic profiling methods will be evaluated and if successful will be used for studying subsurface fracture networks in the region between the surface, boreholes, and underground workings; and to calibrate and relate the seismic propagation characteristics of the host rocks to the fracture patterns observed in boreholes and underground workings, and to extrapolate the observed fracture patterns to the surrounding regions.

Evaluation of Geophysical Structural Studies

Seismic refraction and reflection, seismic tomography, gravity, magnetic, and electric analysis provide data for several investigations in the site characterization plan (SCP) for Yucca Mountain geologic repository. The work discussed, primarily in section 8.3.1.17.4.3.1 is comprehensive in scope, however, the presentation of the details of the work is vague or nonexistent. Because of this vague presentation, it is not possible to critically evaluate the details of the plan of study. Some of the studies discussed in the SCP are underway. For example, many of the longer seismic refraction lines were recorded between 1980 and 1984 by the U.S. Geological Survey, however, more lines are planned for the future. As stated in several places throughout the SCP, many of the geophysical methods proposed have not been tried at Yucca Mountain and much preliminary testing is planned.

Almost all data collection efforts discussed in the SCP are qualified as to location, stating that the final choice of the data collection site awaits further preliminary studies. In addition, many of the methods proposed are qualified by statements that preliminary work will be done to determine the usefulness of a particular geophysical method. For example, seismic reflection results for the Yucca Mountain area have been disappointing to date, and further preliminary work is planned. In the SCP there is no discussion of variations in the data gathering techniques or variations in data processing techniques to improve the abilities of the various geophysical method should standard data collection techniques or processing prove ineffective. Also, should some of the methods prove ineffective, there is no discussion of alternative methods. Virtually all geophysical methods for determining earth structure, seismic, gravity, magnetic, electrical, will be employed for both local studies (scale of 100 meters) and regional studies (scale of 10 to 100 k). One additional method not discussed should be considered. In some areas, shallow radar imaging has proven useful for identifying locations for trenching, for mapping continuity between trenches, and for mapping shallow fault features. This should be considered along with shallow seismic refraction and reflection in trench identification and evaluation studies.

Comments on SCP-CD
by Martha Kane Savage

(Emphasis on seismicity; Results of careful reading of: Overview, all pages; Chapter 1, all pages; Chapter 8.0-1 - 8.0-10, 8.1-1 - 8.1-11, 8.2-1 - 8.2-60, Program Summaries in 8.2; 8.3.1.8, all pages; 8.3.1.17, all pages; 8.3.2.1-24, and of skimming of other sections.)

This review is organized by type of comment, from the most general to the most specific. The first section gives general comments on the SCPCD itself, relating to the style and methods rather than to specific scientific problems. The second section deals with scientific questions that pertain to many sections, while the last section details specific comments on specific sections and pages relating to areas of study that I find lacking.

General Comments on SCPCD

Comment 1.

The major criticism I have about the report is that it is difficult to evaluate whether the planned projects will be carried out successfully. The proposed projects are generally vague, with little discussion of specific methods to be used. Although durations of projects are mentioned, there is no discussion of how many people or which people will be in charge of the various projects, therefore it is difficult to determine whether the project could really be completed in the allotted time.

Suggestion: Be more specific about methods and people involved in the various projects.

Comment 2.

The structure of the report is difficult to follow. Related topics are scattered throughout the report, and some confusion is generated. For instance, arguments in the preclosure tectonics section (8.3.1.17) have been made to leave out certain faults from consideration, based on expectations of movement during the 100-yr preclosure period. Then, in the postclosure tectonics section 8.3.1.8 in which fault movement over 1,000 to 10,000 years is characterized, the plan is to use data collected in the preclosure tectonics program, which has excluded some potentially relevant faults from consideration.

Suggestion: Restructure the report so that preclosure and postclosure are not separated, and/or include summary sections organized by task (e.g., "fault characterization") that describe how the task will be performed, where it will be performed, which people will perform it, how long it will take, and in which hazard-assessment programs (e.g., post-closure or pre-closure hazards) it will be used.

Comment 3.

Performance "Goals" are too vague. There are no disqualifying conditions; Presumably some values of parameters would disqualify the site completely, either by a hazard that would be impossible to engineer against, or by requiring a complete redesign of the facilities such that the expense would be higher than

is presently allowed. If so, some method of stopping the expense of the characterization program once such a disqualifying parameter has been found would be necessary.

Suggestion: In addition to the goals, set up "requirements" that would make the program stop if they were not met.

Comment 4.

Qualitative performance goals are too vague. The resolution of the goals will be a matter of opinion and will need to be documented more rigorously. Similarly, the qualitative nature of the "needed confidence in the performance characteristics" is too vague. This is important because it is stated that the goals are to be used to direct research priorities. In particular, according to the current system apparently no further study will go into projects for which the confidence in the present figures have the same confidence as the needed confidence.

Suggestion: For each parameter, state the reasoning why a particular parameter has been given a low, medium, or high confidence or need for confidence. In particular, if it is deemed that a particular project is not to be studied, give clear arguments supported by appropriate references as to why the present state of knowledge about the subject is sufficient.

Comment 5.

General Comment on parameter goals and characterization parameters: On many occasions, a needed confidence in a parameter goal is stated as "high", but the "needed confidence in final values" of the only listed characterization parameter is listed as "moderate". This violates the common-sense logic of "a chain is only as strong as its' weakest link". If the confidence in the parameter used to characterize the goal is only "moderate", then the confidence in the parameter goal cannot be higher than "moderate". This type of situation is repeated many times, e.g., on page 8.3.1.8-18 the performance parameter of "Effects of fault motion on local fracture permeabilities and effective porosities" is given a high needed confidence. However, the only characterization parameter listed is "Evidence of episodic rock property changes along faults", and is given only a moderate rating for "needed confidence in final values".

Suggestion: If parameter goals and characterization parameters are kept, be consistent and logical in the application.

Comments on Scientific Problems Relating to More Than One Section

Comment 6. Slip Rates

The concept of using slip rates and times of last rupture as cutoff parameters in considering earthquake occurrence probabilities and magnitudes seems ill-advised. In particular, the use of a "10,000 year cumulative slip event" is questionable. As stated on page 8.3.1.17-38 and again on p. 8.3.1.17-83, recurrence intervals for earthquakes in the target area are 10,000 to 100,000 years. Therefore, the total slip released in an earthquake would have been accumulating for 10,000 to 100,000 years, and the "10,000 year cumulative slip event" yields a minimum magnitude for occurrence on the given fault. A more realistic and conservative approach would be to use a 100,000 year cumulative

slip earthquake, or to calculate the maximum earthquake that could be produced by the fault. The recurrence interval can then be included in probabilistic calculations, but the magnitude of the event should be based on a truly conservative estimate of the probable magnitude, which could be determined from the actual slip observed in trenched sections, or from the 100,000 year earthquake.

Recommendation: Using a 100,000 year earthquake would require increasing all values that use slip rates to determine magnitudes of cutoff displacement to be increased by a factor of 10.

Related Comments:

In Section 8.3.1.17.2, of fault displacements, Goal 2 of fault displacement beneath FITS states that the study will consist of "Identification and characterization of faults within 100 m of FITS that have apparent Quaternary slip rates > 0.001 mm/yr or that measurably offest materials that are less than 100,000 yr old." Faults may have recurrence intervals greater than 100,000 years. (Wallace, 1981 describes a "County Dump" fault in New Mexico that has recurrence interval of 90,000-190,000 years, with 4 fault events at 20,000, 120,000, 310,000 and 400,000 years ago). If such a fault is in the area it may have last broken more than 100,000 years ago and still have a probability of breaking in the next 100 or 1,000 years. A fault with recurrence interval of 100,000 years and a slip rate of the given 0.001 mm/yr could slip 10 cm.

Recommendation: identify and characterize all faults within 100 m of FITS and trench to find recurrence intervals and slip in each occurrence. Alternatively, check during construction that no fault cuts the foundations.

For characterization parameters related to waste retrieval, Goal 3 is to "Estimate total probability of exceeding 7 cm displacement on any fault in the area of emplaced waste, considering known and possibly concealed faults and the tectonic interrelationships among local faults". Goal 2 is to find "Surface and subsurface locations of any faults that intersect prospective underground facilities and that have average Quaternary slip rates greater than 0.005 mm/year". If such a fault had a 100,000 year recurrence interval, then 50 cm of slip could be released in one episode, well above the 7 cm of displacement. Such a fault should be considered in the probabilistic calculation, not ignored.

Recommendation: Change goal to characterizing faults with slip rates greater than 0.0005 mm/year, or characterize all faults for recurrence interval and slip.

Section 8.3.1.17.3 describes studies to provide required information on vibratory ground motion that could affect repository design or performance. The following parameters must be changed. Parameter 3. Magnitudes of 10,000-year cumulative slip earthquakes on local earthquake sources.
Parameter 4. Magnitudes of 10,000-year cumulative slip earthquakes on regional earthquake sources.
Parameter 9. (Also section 8.3.1.17.3.5.1) Identification of controlling seismic events--those 10,000-year cumulative slip earthquakes and/or potential largest and closest UNEs ...

Recommendation: Change to 100,000-year cumulative slip earthquake, or maximum magnitude event.

Comment 7. Earthquake Locations: Correlation with Faults and Tectonic Interpretations

Under Study 8.3.1.17.3.1.1, "Identify relevant earthquake sources", page 8.3.1.17-61 states "The likelihood of a buried fault being active will be evaluated considering the spatial correlation of the fault with historical seismicity, the orientation of the feature with respect to measured or inferred crustal stress orientations, ..." As stated earlier in the SCP-CD (chapter 1.4), historical seismicity can be very poorly located. Before 1978, earthquakes were very poorly located. Even after 1978, although the new network distribution improved locations "by an order of magnitude" (Section 1.4), locations may still not be known well enough to rule out the correlation of earthquakes with faults. Therefore the lack of direct correlation of a fault with an earthquake does not mean that the fault is not active; it may merely mean that the earthquake was not well located.

Section 1.4.1 states that Rogers (1987) have "performed an extensive series of computational experiments that show that the peaks in the (depth) distribution are not artifacts of data processing, hypocenter location algorithm, velocity model used, or distribution of depth errors, although the peaks and the minimum shift slightly for some velocity models". Their studies did not convince me that the peaks are not artifacts. They used only two different location programs (HYPO71 and HYPOINVERSE), both of which assume horizontal layering. The structure in the area is obviously not a simple horizontal layered structure. In fact, in an analogous area in the Basin and Range province, Jones (1987) has shown that the assumption of horizontal layers while locating earthquakes in the Basin and Range province leads to location errors greatly in excess of the parameters that come directly from the HYPO71 program that they have used. In their calculations of error distributions they used the output values from HYPO71, which do not take into account possible biases due to velocity models. There was no examination of the residuals at the stations to determine possible effects of lateral velocity variation. Earthquakes on the San Andreas fault often locate off-fault until three-dimensional models of some sort are used to locate the events.

A systematic approach to determining better earthquake locations, either through use of three-dimensional velocity models or "proper" master-event location techniques is in order. For example earthquakes in California align much more closely with faults when 3-D variation in velocity is taken into account, or when a master-event type technique is used to locate the events (e.g., Thurber, 1983). Often aftershock studies don't line up on fault planes until detailed investigations using master-event techniques are conducted (e.g., Mammoth Lakes, Lide and Ryall, 1984; Klein, 1988 personal communication). In Hawaii, locations and focal mechanisms were much better constrained when three-dimensional velocity structures were used to locate the events (Thurber, 1987). The Basin and Range Province obviously does not have a simple layer-cake geometry as is used to locate the events with the HYPO71 program, or even a linear-gradient model as is used with the Hypoinverse program. Therefore, a thorough analysis of the effects of 3-dimensional structure on the locations is needed before lack of correlation of earthquakes with faults can be used as arguments that the faults are inactive, and before any tectonic interpretation is made from the apparent depth distributions of the earthquakes.

Recommendation: Before using earthquake depth distributions or lack of correlation with faults, check out more thoroughly the possible biases that may be brought out by incorrect velocity models and by poorly recorded and located historical seismicity.

Comment 8. Energy Release patterns at Yucca Mountain-Calculations in Geology section.

It has been convincingly shown that Yucca Mountain itself has had less energy release than surrounding regions. However, the pattern of activity in the southern great basin is that of earthquake clustering, where areas that have had few earthquakes in the past will often suddenly begin having more earthquakes. Therefore the energy release pattern is constantly shifting and these results should not be construed to imply that the energy release at Yucca Mountain will always be smaller than in surrounding regions.

Specific Comments on Sections

Comment 9. Activity 8.3.1.17.3.3.1: Select or develop empirical models for earthquake ground motions.

The plan is suggested to examine only published models that have explicit descriptions of the uncertainty in the model predictions. Other published models should also be considered, since they could serve as possible bounds if they are outside the limits of models with better uncertainty predictions.

Comment 10. Activity 8.3.1.17.3.4.1: Determine site effects from ground-motion recordings and 8.3.1.17.3.5.2 Characterize ground motion from the controlling seismic events.

The plan is to use ratios of recorded earthquake spectra at different stations to examine spectral amplification functions. Since it appears that the stations are not in place yet to record the events, it is possible that no large earthquakes will occur in the time between deployment of the instruments and when final decisions need to be made. Some seismologists feel that non-linear effects can occur, whereby amplification of larger motions and smaller motions behave differently (Borcherdt and Singh, 1983). Therefore, we feel that in addition to earthquake spectra, effects of amplification of nuclear explosions should be considered, so that some understanding of larger motions can be made by using nuclear explosions as analogues to earthquakes. In particular, if site amplification from large nuclear explosions is larger than that from smaller earthquakes, the amplification from nuclear explosions must be considered as possibly a more conservative estimate of probable amplification from a large earthquake.

Also, it is not clear where the downhole recordings of ground motion are to be made. Since topography can have a large effect on amplification, it would be best if the downhole recordings could be made at the same location as the proposed repository, or at least in as analogous a location as possible.

Comment 11. Activity 8.3.1.17.3.6.2: Evaluate ground motion probabilities

Parameters needed should also include site effects, since the ground motion probabilities of import are those at the sites affected.

Comment 12. Activity 8.3.1.17.4.1.1 Compile historical earthquake record

Errors in location procedure or velocity model are not included in the uncertainty estimates that are returned from standard location programs. Therefore, in order to evaluate how well an earthquake is located, some indication of the method of location should be given in addition to the hypocenter uncertainty estimate, so that the true uncertainty can be evaluated.

Recommendation: Include an additional parameter that indicates the location method and velocity model used to locate the event. Similarly, the additional parameters for the larger earthquakes should include references to how the parameters were determined.

Comment 13. Activity 8.3.1.17.4.1.2 Monitor current seismicity

As above, since location procedures, magnitude determination procedures and velocity models may be refined, compiled parameters ought also to include references to velocity model used, location method used, station corrections used for location and magnitudes, and magnitude calculation procedure used. The same type of information should be saved for the additional parameters of larger earthquakes.

Comment: Since accurate magnitudes are a crucial parameter in so many applications, a more straightforward procedure than is currently used should be implemented. In particular, if digital recordings at a few stations can be made, then pseudo-Wood Anderson recordings can be made, and with the application of appropriate attenuation curves, much better magnitudes could be achieved.

In addition, as described above, careful systematic relocation of events and examination of station residuals should be performed to distinguish whether seismicity patterns observed are real or artifacts of the present location procedures and velocity models.

Comment 14. Activity 8.3.1.17.4.1.3 Evaluate potential for induced seismicity at the site

Data for activities include surveys of literature on seismicity induced by the impoundment of Lake Mead and on mining-induced seismicity, but not for surveys of literature on seismicity induced by nuclear explosions. We note that several hole collapses (M_L up to 4.8) that are discussed in the literature (McEvilly and Peppin, 1972) are reported as earthquakes in the present historical catalog (Meremonte and Rogers 1981). Before the historical catalog alone is used in the studies, this situation should be corrected.

Suggestion: In analysis of seismicity induced by nuclear explosions include a thorough literature survey as a starting point.

Comment 15.

The interest in active folding is in how folding would change dips of beds. In several places (Coalinga, California and El Asnam, Turkey; Stein and King, 1984: Whittier, California; Haukkson, 1988) folding is accomplished by thrust earthquakes at depth. While the evidence is that most faulting is strike-slip or normal faulting, such a possibility should also be considered for any observed folding, as thrust faulting would affect the seismic hazards.

Comment 16. Section 8.3.1.8.

The value of 5 cm for fault displacement affecting the fault displacement on waste package integrity over a 1,000 year interval is based on the 7.6-cm air gap around the waste package at emplacement. To use this value, they must show that the air gap will be maintained over a 1,000 interval, despite the lithostatic pressure that would tend to close the air gaps through creep. The same comment also holds for the effects of folding.

The parameters for calculating the fault displacement are to be taken from the studies in 8.3.1.17, that have limited earthquakes to be studied by the use of slip

rate calculations. Those limits are not conservative at all, and are even less so when the 1,000 year interval required for lack of rupture of the waste packages is considered.

Comment 17. Effects of igneous intrusions: Should include thermally induced changes in rates of chemical reactions such as corrosion of packages and other changes.

Comment 18. p. 8.3.1.17-28, 3rd paragraph: "Because source events that will be postulated are not likely to change as more refined fault data become available, the resulting motions are expected to provide a stable basis for use in design." There is still controversy about the ages and recurrence intervals of many of the faults as evidenced by the studies discussed in this report aimed at determining such data; therefore, the source events may well be changed in the future and the design must use the latest data available.

Comment 19.

Table 5 in 8.3.1.17, includes a design parameter of motion at 0.5-33 Hz as the frequencies to consider. It is our understanding that radioactive material will be in the air with a crane loading the repository much of the time. The response of a crane would be like that of a pendulum and it would be necessary to include analyses of much lower frequencies to determine the effect on the crane.

Suggestion: Consider lower frequencies, or calculate the possible effects of the radioactive material falling from the crane during an earthquake.

Comment 20. Consideration of vibratory ground motion (p. 8.3.1.17-35). Design-basis ground motions are to be characterized for frequencies significant to facilities important to safety such that there is less than a 10-percent chance of being exceeded during 100 yr. That seems high to me. This implies that if 10 such facilities are built, we expect one of them to experience ground motion in excess of the design parameters.

Comment 21. p 1-191 "Because the entire mapped fault length is assumed to rupture, the estimate of maximum magnitude is conservative". But in the nearby 1932 Cedar Mountains earthquake, surface expressions of faults were much smaller than the inferred extent at depth (Molinari, 1984). It is assumed that the surface rupture was a case of distributed faulting. Therefore using just one mapped fault length is not conservative, since faults may be connected at depth but not at the surface. In addition, in the Mammoth Lakes area, also in the Basin and Range province, six events or swarms ranging from magnitude 5.4 to 6.5 have occurred where no prior surface faulting had been observed (Savage and Cockerham, 1987; Cockerham and Corbett, 1987). Therefore the possibility must be considered that an earthquake up to at least magnitude 6.5 might occur anywhere, regardless of the prevalence of surface faulting.

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Comments from Ute R. Vetter to the topic

Stress Pattern and Source Mechanism of Earthquakes in the Yucca Mountain Area and its Surrounding

General comments to the work as a whole:

My opinion is that the Consultation Draft is a notable "paper", reflecting a thorough work of numerous persons to collect everything what it known until now about the site and its surrounding and suggesting what has to be done to fill existing gaps in knowledge according to what is known today. The Consultation Draft can, taking into account the surely existing time pressure, the fact that it is "only" a draft, and its length, not be expected to be easy to read and to follow through. Since it is done by different people it can neither be uniform nor totally complete. But the same is to say about the writeup of our review which will be equally difficult to read and to use for improvements. Different people studied different parts, sometimes overlapping and wrote their comments in their personnel style and format.

I concentrated on the above mentioned topic.

The area was subject of relatively intensive research since 1977: 182 drillholes and 23 trenches within 10 km of the proposed site were studied. 53 seismic stations within 160 km of Yucca Mountain were installed and monitored (47 stations between 1978 and 1979 and six additional stations in 1980). Results of recent studies and of literature research regarding stress pattern and earthquake mechanisms are compiled in chapters 1.3 and 1.4 (among other topics on the tectonics of the region).

1.3.2.3 (pg. 1-138) Existing stress regime

1.4.1.2 (pg. 1-169) Relationship of seismicity to geologic or tectonic characteristics of the candidate area

Sources of information on stress pattern and magnitude are 1. Earthquake focal mechanisms, 2. in situ stress measurements, 3. observation of nature and orientation of faults. From focal mechanisms: (30 focal mechanisms are available covering the depth range from 0-12 km and magnitudes from 1.1-2.9); the dominating focal mechanisms in the area is strike-slip, indicating that $S_h < S_v < S_H$; the accidental occurrance of normal faulting events ($S_h < S_H < S_v$) indicates that S_H and S_v are similar in magnitude. 5 events are normal faulting.

Comment: 77% of the earthquakes are strike-slip, 17% are oblique with a normal faulting component, 6% are normal faulting on the basis of a 30-60° division in the plunge of the P- and T-axes. Difficult for a determination of the stress pattern in the area from focal mechanisms is the fact that the earthquakes are very small and that there are barely any earthquakes in the Yucca Mountain area itself. Such small earthquakes may not show the existing stress pattern and level accurately.

Fault planes show strong N-S and E-W directions but also NW-SE and NE-SW directions; despite that many small mapped faults in the area show the same directions earthquakes are not directly to associate with specific faults, because the geometry of the faults is unknown at depths of the hypocenters. Focal plane solutions for earthquakes in the vicinity of Yucca Mountain (Figure 1-47) suggest that the average orientation of S_h is about N60°W as in the northern Great Basin.

Comment: Arithmetic mean of T-axes from all 30 focal mechanisms is N50°W, in good accordance with other observations.

From in-situ stress measurements: a) made in 2 areas, one 45 km NNE of Yucca Mountain and one 57 km NE of Yucca Mountain by overcoring methods at depths of 328-442 m: both indicate that at that depth $S_h<S_v<S_H$ (strike slip milieu); b) at Yucca Mountain in situ stress measurements were done in drillholes using hydrofracture methods, eight tests at depths from 846 to 1288 m indicate $S_h<S_H<S_v$ (normal faulting milieu), with S_h direction N60-65°W. In the lower part of one drillhole (1113-1202 m depth) S_h was oriented S80°W

Comment: the only focal mechanism, an oblique slip event with a similar T-axis direction, is originated in the Funeral Mountains, about 50 km SSE of Yucca Mountain (Fig. 1-47)).

The most remarkable result of earlier studies about the stress regime is that the magnitude of S_h is quite low (at drillhole USW G-1 less than the hydrostatic pressure of the fluid column that was present during the drilling - more than 44,000 barrels of drilling fluid flow into neighboring preexisting fractures).

Comment: The statement: "At Yucca Mountain, the measured magnitudes of S_h are near and perhaps even below the minimum values required to provide the lateral support necessary to prevent extensional failure on moderately dipping faults trending parallel to S_H (Stock et al., 1985)" seems to me a very important one. Magnitudes of S_h (least principal stress in case of strike slip or normal faulting regime) are low relatively to S_v (vertical principal stress, which is the greatest principal stress for normal faulting and the intermediate principal stress for strike slip regime). On pg. 1-327 is a comment to this result, that "it could affect the design and construction of the repository, ... S_h values may be close to those at which frictional sliding might be expected on faults striking N25-30°E. Another remark on Pg. 1-328 is important: "The orientation of the existing stress field will affect the geotechnical engineering of the underground repository". These seem to be critical points which require additional study.

Alltogether it is assumed, that the direction of the minimum principal stress, in accordance with the focal mechanisms, is about N60°W, and that the magnitudes of the greatest and the intermediate principal stresses are about equal. It is further concluded, that this stress configuration favors right-lateral strike slip on north-striking faults, normal slip on norteast-striking faults, and left-lateral slip on east-northeast- striking faults.

Comment: M.L. Zoback (1988) inverted the focal mechanisms from Rogers et al. (1983), using the inversion method from Angelier (1979, 1984): the resulting best fitting stress tensor has the following components (plunge/azimuth in degree): 2/31 85/140 5 300, which is a pure strike slip regime, and the ratio between the relative magnitudes of the three components is 0.83, indicating that the intermediate and the greatest principal stresses are nearly equal in size. Angelier (1984) used his method for the determination of the best fitting (reduced) stress tensor with data from a nearby area: he inverted observed fault slip data from a restricted area at Hoover Dam, which resulted in a nearly E-W direction for S_h and a nearly N-S direction for S_H, whereby S_v was the intermediate principal stress, which indicates a pure strike slip regime as is estimated from the earthquakes but an east-westerly extension direction, different from the earthquake data.

Strain measurements after the HANDLEY event in 1970 in a 40x30 km big area, whose southernmost point was 17 km north of Yucca Mountain, resulted in a net

west-southwest to east-northeast contraction instead of an (expected from the "known" stress field) northwest-southeast extension.

Comment: These findings indicate that there seem to exist some variations in the stress field with locality and/or time which may not show up in focal mechanisms, probably especially after big explosions. It may also be that some results are inaccurate.

2.6 Geoengineering - Existing stress regime
(there is some duplication to the statements in chapters 1.3 and 1.4)

It is stated that the Preconstruction state of stress is particularly vital to the determination of the site suitability. It is the "initialized stress state" on which any excavation induced stresses must be superposed. Overcore measurements at Rainier Mesa indicate that in situ stress "may exhibit considerable spatial variation", but this is only a result for shallow tuffs, nevertheless it is at the depth where the constructions and excavations will happen; spatial stress variation is also supported by hydraulic fracturing measurements in two drillholes at Yucca Mountain (e.g. vertical variation in S_h: S_h:S_v = 0.84 at 295 m depth (unsaturated zone), decreasing to 0.47 at 1209 m depth (saturated zone) in drillhole G-2, but in G-1 this ratio is 0.3-0.5 (saturated zone)). The magnitude of S_H at Yucca Mountain is approximately halfway between S_h and S_v, indicating normal faulting regime (based on calculations from hydraulic fracturing, Stock et al., 1985) and is different from the strike-slip regime of the NTS region.

Comment: These two drillholes are the only ones from which information about the stress magnitudes is gathered. The measurements indicate a depth dependence or a dependence on the fluid saturation. More such measurements would be useful. (see 8.3.1.17.4.8.2)

6.1.2.2.2 Conceptual design of a repository - Stress

The magnitude of the vertical principal stress (the greatest at Yucca Mountain) is estimated from the overburden pressure to be 5-10 MPa for repository horizons, it can vary horizontally by 1 MPa (topogr. and density differences), the minimum horiz. stress = least principal stress has a direction N50-65°W and is of the order of 0.3-0.8 S_v, a mean value of 0.55 S_v is assumed for 300 m depth (Stock et al., 1984), the mean S_H value is assumed to 0.65 S_v (varying from 0.3-1.0 S_v), which is directed N25-40°E.

Comment: These estimations are interesting; however, they allow quite a variation in the values of the single principal stresses so that all things considered not much is known yet, but they are good for a start for further measurements and calculations.

Planned Experiments:

8.3.1.15.2.1 Study: Characterization of the site ambient stress conditions

8.3.1.15.2.1.1 :Anelastic strain recovery experiments in core holes

Measurement of strain on (oriented) core, calculation of in situ stress from measured strain and elastic constants.

Comment: It sounds o.k., I cannot judge on completeness and validity of results.

8.3.1.15.2.1.2 :Overcore stress experiments in the exploratory shaft facility

To evaluate the extent to which the ambient stress conditions are redistributed adjacent to excavations, to get initial and boundary conditions for analyses. By

the means of overcoring tests stresses will be measured in two and three dimensions in different vertical level. (Strain will be measured on recovered cores before stress testing, calculation of stress from strain as in ....1).

Comment: also here, it sounds o.k. to me, but I cannot judge whether results will be appropriate, they will at least give information on stress changes very near to the surface for whatever reasons.

8.3.1.17.4.8.1 Evaluate present stress field within the site area

Under description: In situ stress measurements show that at depths up to one km $S_h < S_H < S_v$, indicating a normal faulting regime. On the basis of focal plane solutions for recent earthquakes, however, the "deep" (greater than 1 km depth) stress field is characterized by strike slip. "This is contrary to the general observation that the stress field in the Great Basin province is characterized by a strike-slip regime near the surface and a normal faulting regime at depth" (Vetter and Ryall, 1983).

Comments to this: a) There is nothing contrary to the general observation yet, because the result by Vetter and Ryall, 1983 was also based on earthquakes, which do not happen in general at the surface. Their result was that the earthquakes occurring in the uppermost about 8-9 km of the crust show overwhelmingly strike slip faulting, but the ones below that depth show a stronger tendency to normal faulting. No information was given about the situation in the uppermost 1000 m. These in situ stress measurements are too shallow to contradict the result from the earthquake study, but they give interesting information about the very shallow stress pattern. Despite the fact, that the earthquake focal mechanisms in southern Nevada do not show any obvious change with depth, their mechanisms are in general in accordance with the ones reported in Vetter and Ryall, 1983.

b) So far there are only results from two boreholes existent (see 2.6). The results are different, therefore it is good that stress measurements (hydrofrac) in three more boreholes are planned. The existing results are not yet convincing that indeed at the surface the faulting regime is normal slip but deeper than 1 km it is strike slip.

8.3.1.17.4.8.2. Shallow borehole hydrofrac and triaxial strain recovery methods for the determination of in sity stress

In two drillholes, only 500 to 800 ft deep, magnitude of in situ stress, orientation of induced fractures and borehole breakouts and the triaxial strain in oriented samples of drill core will be measured; one drillhole is situated inside of the site, the other east of it. It is anticipated to evaluate the vertical variation in stress near a possible detachment fault (in the hole east of the site). The fault projects towards Yucca Mountain at depth.

Comment: It is questionable whether so shallow data can be extrapolated to greater depth, but it is an interesting idea to study the possible consequence of a fault on the stress pattern and it is said "this is an evaluation and planning activity only".

8.3.1.17.4.8.3 Evaluate published and unpublished data on paleostress orientation at and proximal to the site

Comment: sounds interesting and o.k. to me

8.3.1.17.4.8.4 Evaluate theoretical stress distributions associated with potential tectonic settings (wrench, normal, detachment faulting)

Comparison between stress measurements and theoretical calculated patterns for the three mentioned models of faulting will be done to assess the applicability of these models.

Comment: sounds o.k. to me; as in many theoretical work, the usefulness of the results is not guarenteed.

Review of Site Characterization Plan, Consultation Draft

by Michael A. Ellis; Task 5.

Sections covered: 8.2.2.4.1/3/16, and 8.3.1.17.4 (Preclosure tectonics)

General Comments

I have two sets of general comments, one concerning the clarity and organization of the CDSCP, the other concerning the substance of the scientific approach.

1: Organization and clarity. The CDSCP is organized in such a complicated and convoluted manner that to properly evaluate every aspect of it is virtually impossible; this is particularly so when trying to understand the various links between studies and activities, or trying to evaluate the proposed time schedules.

The Plan is rather disparate to say the least. Section 8.3.1.17 reads like a list of studies proposed by a group of scientists who seem to be unaware of what their right hand is doing, let alone their colleague's. There is little sign of interaction between studies, albeit there are plenty of cross-references, but little indication that the studies will be interwoven. This is not always the case; parts of this section do present more cohesive studies, but this is to be found among a discipline (such as geology or geophysics) rather than between disciplines.

The language of the Plan is labored, and extremely bureaucratic. The flow charts and most of the tables are hopelessly confusing. A lot of confusion could be avoided if the Plan was written in plain English. I suspect the cause of this is connected with the legal aspects and the requirements made by the NRC, and in some cases is unavoidable.

The most significant point in this category, however, is the implication behind the poor organization, one of poor science. It is generally true that when a thing is poorly understood by someone or some group, the explanation of that thing is mired and confusing. Alternatively, the Plan may have been put together in a hurry, with the result that clarity was sacrificed.

2: The Scientific Approach. There are five classes of criticism discussed below:

1: Neglect of regional structural studies;

2: Misuse of regional studies;

3: Neglect of coupled-process studies;

4: Misuse of qualitative data or assumptions;

5: Misuse of the phrase "state-of-the-art".

1: Neglect of regional structural studies.

There appears to be virtually no attention paid to the regional structural geology, or the regional disposition of lithologies. This aspect is critical for many reasons, not the least being the state of the hydrologic flow system. (This has already been brought to the attention of the DOE, by Schweickert and Ellis of UNR, during the DOE Meeting held in Las Vegas, April 11-15, on Conceptual Models of the Ground Water System in the Yucca Mountain Area.)

Regional structural studies will enable the character of the structures below Yucca Mountain to be postulated with a great deal more certainty than would be otherwise possible. In this respect, geophysical studies are insufficient in predicting deep structure. The Plan does indeed propose an investigation of the Bare Mountain detachment (and other nearby or suspected detachments), but makes no attempt to place these features into a regional context. The neglect of regional studies and the dire consequences of this neglect cannot be over-emphasized.

2: Misuse of regional studies.

There appears a general reluctance to incorporate data 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 surface facilities. For example, active faults within 100 km, but not within the site, are only to be studied if a cursory examination shows that they could sustain earthquakes large enough to cause significant ground accelerations at the site.

This approach will not allow a regional pattern of seismicity (and the related processes such as groundwater flow, or deformation) to be recognized. For example, it is possible, and not unlikely, that there exists a temporal pattern to seismicity with a quasi-periodicity well under ten-thousand years; this pattern may involve whole regions being quiet while an adjacent region is active, followed relatively suddenly by the opposite behaviour.

The best example of this comes from the Middle East (Ambraseys, 1971; Ambraseys and Melville, 1982). These authors have reviewed the original documents of past civilizations in the Eastern Mediterranean basin (Fig. 1) with the intention of enlarging the data base for historical seismicity; two thousand years worth of data is presented. The authors state:

> "... it is clear that during the first five centuries the Border Zone was comparatively quiescent while the Anatolian Zone was active. During the following six centuries the pattern was reversed, only to be reversed again during the eleventh century with a few centuries of overlapping activity. A similar pattern, but with longer periods of overlapping activity, was noticed for the Border Zone and the Dead Sea System."
>
> Ambraseys, 1971, p.379.

These temporal patterns of seismicity activity are in a complex plate interaction zone in the Middle East, and so it may be argued that this is not relevant to Yucca Mountain. On the other hand, the origin of the Basin and Range, and the relation to the San Andreas fault, make this a similarly complex, and poorly understood, region. This also raises the point that the choice of 100 km, made by DOE to define "regional", is completely arbitrary; the extent of the region should be made on geological grounds, and should probably include places such as Pahranagat and Owens Valley.

In order to properly characterize a region it is essential that we have as much of the right information as possible, even if this means studying faults which do not seem capable of sustaining earthquakes that may *directly* affect Yucca Mountain. Ambraseys (op. cit.) also states:

> "... historical data are useful for the study of continental tectonics, of the migration of seismic activity in contiguous tectonic units as well as the interaction between such units. For prediction purposes, however, a much longer period of observations is needed, for which no foreseeable means of data gathering seems likely." Ambraseys, 1971, p. 378.

The means of data gathering Ambraseys refers to is feasible, thanks to modern techniques of age-estimating (dating). We are now able to construct a paleoseismological data base for a region where human records are unavailable, and to take this data base as far back as a few million years. In addition, the analysis of Tertiary sedimentation, and of the subsequent deformation of these sediments, provides us with a further means of establishing long period records of tectonic stability. The CDSCP does not propose any studies in this context, yet clearly these type of analyses can be invaluable and *absolutely* necessary.

3: Neglect of coupled-process studies.

A further criticism may be leveled at the isolated nature of the studies proposed in the Plan. While every attempt has been made in the CDSCP to cross-reference the many proposed studies, activities, investigations, etc., this appears to be no more than lip service in any serious attempt to couple studies. If any part of Szymanski's report is valuable it is this; the possibility that certain properties or processes may be functions of other properties and or processes *not normally considered so* must be taken into account.

There are numerous examples of the isolated nature of studies within the CDSCP. Tables 8.3.1.8. 1-6, and 8.3.1.17. 1-6., repeatedly list various studies, intented to answer specific questions, or to achieve specific goals, yet it is claer that these studies are not motivated by the nature of the problem. In other words, the answer to specific problems are apparently found by dipping into the proverbial well of previously planned studies in the hope that there exists a particular study which addresses the problem. The studies themselves have not been designed to properly address the problems. For example, in Tables 8.3.1.8. -3(a,b), pp 8.3.1.8-9, the study 8.3.1.2.2.9 (Unsaturated zone flow and transport modeling) is mentioned three times, and is presumed to address and supply data to resolve various different problems. The study is a fairly standard model which does not address or appear to be specific to the problems at hand. In some cases, the generic studies may well provide the needed answers, but in general this is probably not true.

4: Misuse of qualitative data or assumptions:

In establishing goals and discussing the reasoning behind various studies, the Plan often presents phrases such as, "seems reasonable", or "is very likely". In association with this the DOE staff present or promise a set of qualitative data. These data are then used, or

promise to be used, to produce mathematically rigorous models, or predictions. This is an approach often taken, usually inadvertantly, by enthusiastic "number crunchers" who produce a lot of results from meagre information, but with a wrapping that makes the result seem somehow indisputable. I regard this as a potentially dangerous scientific methodology This approach will lead to results whose constraints are unclear, thereby rendering them ambiguous at best, and useless at worst.

5: Misuse of the phrase "state-of-the-art":

This phrase is used in section 8.2.2.4 with the impression that DOE's studies are, or intend to be, such. This is certainly not the case at this stage of the Plan.

For example*: No mention is made of the ambiguity of using a roll-over geometry to predict fault geometry (ca. 1986), (in fact, very little mention is made of fault geometry - faults are apparently assumed to be be listric). No mention is made of the new Basin and Range tectonic models by Wernicke (ca. 1987), or Ron and others (ca.1983). No mention is made of the significance of Nick Ambraseys work (see #2 above) (ca. 1971). No mention is made of faulting in a 3-d strain field, or of the implications for stress studies (ca. 1978). There are probably more examples from fields about which I am not as familiar.

* Dates shown in parantheses show when the information became public either through national meetings or in international journals.

Specific Comments

1: p. 8.3.1.17-32; an example of the misuse of qualitative data or assumptions (see general comment #4).

The discussion under the heading, "Consideration of fault displacement" is concerned with the maximum allowable annual probability of a fault displacement of, in this case, 5 cm. The figure of 5 cm is apparently adopted by a means of logical and probably valid reasoning. For example: " . . . the risk resulting from fault displacements in excess of 5 cm . . . is *probably* less than the risk resulting from vibratory ground motions that exceed the design basis for a nuclear power plant" (my italics). It is not the assumption which is disturbing, but the rigorous probabilistic analysis which uses this assumption as a basis. If probabilistic methods are to be used then it is essential that the results are measured against the largest uncertainty in the input, which will probably make the utility of most of these probabilistic analyses highly questionable.

This is only one example of the misuse of qualitative data or assumptions; the CDSCP is in many ways dependent on these types of studies.

2: p. 8.3.1.17-54 & 88; an example of the misuse of regional data (see general comment #2).

Investigation 8.3.1.17.3 (Studies to provide required information on vibratory ground motions that could affect repository design or performance) provides an example of the misuse of regional data. In the numbered paragraph 2 is the phrase, " Identification of earthquake sources within 100 km of the site *that could be relevant to the site* . . ." (my italics). The point in dispute here concerns what is and what is not relevant. To be fair, this particular section is explicitly involved with s.g.m. at the site. Nevertheless this section exemplifies the whole approach to regional analysis, endemic throughout the CDSCP, in that regional studies are only to be used if they have a clear and present-day potential for direct influence at the site. As discussed under general comment #2, regional studies can provide us with a picture of temporal and spatial seismicity which is not available through a cursory analysis.

3: p. 8.3.1.17-79; concerning, Activity 8.3.1.17.4.1.1, Compil(ation) of historical earthquake record.

On p. 80, under Description, the claim is made that "Meremonte and Rogers (1987) . . . provides most of the needed information". This is not true; Meremonte and Rogers (op. cit.) provides a basis for a record, which needs to be more carefully scrutinized (both for the field relations and the modeling techniques). This is particularly so bearing in mind these authors' findings of an anomalous seismic gap at 3 to 4 km, and their contention that most small earthquakes do not fall on known faults. In addition, a historical record should go back further than the instrumental records allow. (See also general comment #2.)
From Ambraseys' (1971) study of two thousand years worth of historical earthquake data in the Middle East, he states:

> " . . . (with respect to) continental tectonics, the formulation of theories on the basis of instrumental data alone, without due consideration of the time-scale involved in certain seismic processes, is bound to lead to erroneous or incomplete results".
>
> Ambraseys, 1971, p. 379.

4: p. 8.3.1.17-151; Study, p. 8.3.1.17.4.7, Subsurface geometry and concealed extensions of Quaternary faults at Yucca Mountain.

Are the high angle faults planar or listric? This question is not addressed in any study or activity. The distribution of strong ground motion following an event is dependent to some degree on the fault geometry. Surface or near-surface deformation is likewise dependent on fault geometry.

5: p. 8.3.1.17-167; Activity p. 8.3.1.17.4.8.4, concerning stress evaluation.

This activity is based on the implicitly assumed, and "well established", relation between fault types and stress environment. I do not believe this is the right approach, but rather the possibility that stress and faults have a much more complex relation than commonly assumed should be incorporated. For example, faulting in three-dimensional strain fields invokes a more complex relation between fault type and stress than does the relatively simple Anderson model (e.g., Reches, 1978). (See also studies by An Yin, 1987.)

References

Ambraseys, N. N., 1971, *Value of Historical Records of Earthquakes*, Nature, 232, pp. 375.

Ambraseys, N. N. and Melville, C. P., 1982, *A History of Persian Earthquakes*, Cambridge University Press, pp. 219.

Reches, Z., 1978, *Analysis of faulting in three-dimensional strain field*, Tectonophysics, 47, p. 109-129.

Recommendations

My general recommendation is that all of the shortcomings in the CDSCP addressed by my general comments, 1 - 5, should be repaired. As the CDSCP stands now the investigations proposed by the DOE will not answer the scientific problems to any degree of satisfaction.

TASK 5: SCP REVIEW BY RICHARD A. SCHWEICKERT

1. Sections covered by this review

Chapter 1:
All sections except 1.4 (pp. 150-198); 300pp.

Chapter 8:
8.0 Introduction; 10 pp.
8.2-8.2.2 Issues to be resolved; 18 pp.
8.2.2.4 Summaries of specific site characterization programs (pp. 179-192); 13 pp.
8.2.2.4.7 Summary of postclosure tectonics site program (pp. 199-202); 3 pp.
8.2.2.4.16 Summary of the preclosure tectonics program (pp. 222-230); 8 pp.
8.3.1.4.2 Investigation: Geologic framework of the Yucca Mountain site (pp. 32-86); 54 pp.
8.3.1.8 Postclosure tectonics program (pp. 1-123, excluding pp. 40-44, 69-70, 91-101); 106 pp.
8.3.1.17 Preclosure tectonics program (pp. 1-192, excluding pp. 54-77); 169 pp.

Total 681 pp.

2. General comments and objections

It is clear that a very large amount of manpower, time, and money have gone into the development of the SCP. Unfortunately, what has resulted from this effort is a document (and plan) that is overwhelmingly long, complicated, and confusing, so much so that it contains countless internal inconsistencies and contradictions. I doubt that even its makers understand the document. It challenges any one person's ability to give a comprehensive review. Nevertheless, here are my impressions.

1. The SCP is not a scientific document. Its entire design has been driven entirely by engineering considerations with little thought devoted to the broader scientific questions which are raised by the proposed repository. However, nearly all of the most critical questions addressed are scientific in nature, and demand a scientific focus.

2. Because it is driven by engineering requirements, the program comes across as unfocussed and fragmented, with no hope of integration, despite claims in the SCP. One wonders what would happen if a disqualifying condition were discovered during site characterization; the program probably could continue along for years before it was made accountable. Not only is there no central scientific focus, there are no built-in periodic decision points to evaluate where we are, to assess whether there are fatal flaws and to decide whether major course changes are necessary.

3. The program, as presented here, is not an objective search for the facts. Throughout, it presupposes a

favorable outcome of site characterization. It tacitly assumes that the data gathering process will automatically lead to compliance and licensing.

4. The method of performance allocation is flawed. It assumes that all information needs can be anticipated well in advance of site characterization, again as if this were merely an engineering problem. It is unrealistic to claim that quantitative statements can be made about expected performance. Furthermore, this program proposes to provide quantitative estimates about many processes for which only educated guesses are possible. The fact that probabilistic estimates can be made for a process does not mean that the estimates are correct or even nearly correct. Furthermore, the estimates could in fact be completely incorrect, especially if nature is less predictable than we hope she is. There will be risks no matter what the estimates are. The question is, are the risks acceptable?

5. There is a questionable ranking of priorities in the program. The identification of potentially adverse or disqualifying features should have highest priority, rather than the routine characterization of the unsaturated and saturated zones of the volcanic sequence.

6. Chapter 1, the factual basis for the SCP, is incomplete, out-of-date, and biased. Many modern references to Great Basin volcanism and extensional tectonics are missing. The state-of-the-art geology of Yucca Mountain (re: Scott and Bonk cross-sections, geometry of faults at Yucca Mountain) and the NTS (re: Robinson's 1984 structural interpretations) are incorrect, ad hoc, and off-the-wall, yet this is not even recognized or acknowledged in the SCP. Chapter 8 contains considerable new information that does not even appear in Chapter 1.

7. The SCP fails to address or discuss coupled processes, and contains no provision for their study. In fact, Geohydrology is organizationally decoupled from Tectonics. The facts that tectonics is partitioned into several unrelated parts of the program makes it unlikely that the program will be able to generate any regional perspective on the processes operative at Yucca Mountain.

3. Specific concerns and questions

Key geological questions that are not addressed by the SCP

1. What is the geometry of Mesozoic thrust faults and prevolcanic normal faults at Yucca Mountain? The answer to this question is essential to understanding boundary conditions of the saturated zone, because at present the distribution of the Paleozoic carbonate aquifer at depth is not known. A related question is why is there about 1 km of relief on the volcanic Paleozoic contact at depth? Is this the result of large pre-volcanic normal faults?

2. What is the geometry and timing of the exposed faults at Yucca Mountain? This is essential to modeling of the unsaturated and saturated zones. Current cross-sections of Scott

and Bonk (1984) are incorrect; they imply contraction of the volcanic rocks rather than extension. There is evidence of significant normal faulting prior to eruption of the Rainier Mesa tuff. This suggests there could even be two significant sets of late Cenozoic faults at Yucca Mountain (pre- and post-Rainier Mesa tuff), with the younger faults possibly strike-slip faults, making it even more imperative to understand the geometry of the faults at depth. A related question is why are some faults aquifers and others aquitards?

3. What is the nature of the vertical displacement field in the Yucca Mountain region? There is a critical need to run regional geodetic levelling lines to understand regional patterns of uplift and subsidence and to place site-specific data in context.

CHAPTER 1

Introduction

p. 1--"all relevant information" is to be included in this chapter; this has not been done.

p. 5--it is unclear whether sections 1.1 through 1.7 provide an adequate foundation for site characterization activities.

p. 28--what is the basis for the statement that tectonism appears to have played a much less significant role in regional landscape evolution during the Quaternary? If anything, Quaternary tectonism has been even more important than during earlier times. Geodetic data are critical to understanding whether vertical tectonism is important. Mojave data seem irrelevant to this question, since the Mojave is a quite separate tectonic province. This applies also to data on pp. 32 and 33.

1.2 Stratigraphy and lithology

p. 42--Schematic or not, this figure is completely unrealistic. It is a poorly constrained restored section drawn for late Paleozoic time, prior to Mesozoic contraction and plutonism, and Cenozoic volcanism and extension. It bears no resemblance to current geological reality.

p. 47--Figure 1-16 is incorrect, since the Yucca Mountain region is characterized by Mississippian clastic rocks of the Antler foreland basin.

p. 48--There are no Eocene volcanic rocks exposed at the NTS.

p. 70--The unconformity between Rainier Mesa and Paintbrush tuffs may be important and may signify an episode of faulting and/or tilting between 11 and 12 m.y.b.p.

p. 73--The presence of basaltic ash along the Bow Ridge and Windy Wash faults strongly suggests a coupling of processes of volcanism and seismic rupturing along faults at Yucca Mountain. These phenomena must be investigated.

p. 79--Future processes at Yucca Mountain are said to include faulting, volcanism, and seismicity. What about tilting,

folding, and hydrothermal activity? It must be admitted that each of these processes is at least possible, and perhaps probable.

1.3 Structural geology and tectonics

1.3.1 Tectonic framework

p. 79-80--This section contains several non sequiturs, and gives the impression it was written by someone unfamiliar with the modern plate tectonic setting.

1.3.2 Tectonic history

p. 84--major Triassic-Jurassic thrust history of the region has been omitted in this discussion.

p. 85-87--this section ignores major pre-20 m.y. extension that occurred in many parts of the Great Basin, and does not discuss geometry, patterns, and timing of normal faults in general, except for the obvious faults at Yucca Mountain. It uses old and out-of-date references for patterns of volcanism and models of extension (p. 88-92).

p. 88--unaccountably says that the southward transgression of volcanism ended near Yucca Mountain about 15-20 m.y. ago, yet major silicic volcanism occurred there between 14 and 10 m.y.b.p.!

p. 98--updated and much younger estimates for the age of the Lathrop Wells cone are now available.

p. 101--the interpretations of thrust faults at NTS by Barnes and Poole (1968) and Carr (1984) are incorrect, as showr by mapping at NTS published in the 1970's. These maps show the CP and Mine Mountain thrusts to be west-vergent structures.

p. 102-103--this section discusses significant pre-middle Miocene extensional faulting, but fails to cite many important references on geometry of extension and of normal faults in the Great Basin.

p. 105 and 126--Figures 1-32 and 1-42--Neither these sections nor the sections of Scott and Bonk (1984) are reasonable, since the cutoff angles between the normal faults and bedding exceed 90 degrees, implying that these are contractional, not extensional, faults! Normal faults could only have this geometry if they developed in previously tilted strata, yet Scott and Bonk (1984) interpreted the faults to have produced the tilting. If their interpretation is correct, the faults at Yucca Mountain must have a considerably lower dip than depicted in these sections. Note that Fig. 1-32 has considerable vertical exaggeration, which should make the faults appear steeper than they are, yet the faults in this figure have a gentler dip than in Fig. 1-42, which has no vertical exaggeration. Therefore, these figures are internally inconsistent.

p. 118ff--this section makes no mention of the possibility or probability that normal faulting may have preceded or accompanied the silicic volcanism, as suggested by regional relations.

p. 144 and 238--major losses of drilling fluid occurred in hole G-1 below 310m, and also hole H-5. These results may have very serious consequences for the presence of high-permeability zones of rubble or fractures in the repository

block. Neither hole was near any mapped faults.

1.4 Seismology of the southern Great Basin and Yucca Mtn

Did not review.

1.5 Long-term regional stability

p. 199--how reasonable is it to exclude processes no longer active from the analysis. How do we know they are no longer active?

p. 205--estimates of age of Lathrop Wells cone cited here are out-of-date and should be revised.

p. 206--it is incorrect to say that there is little water in the unsaturated zone. Values of 60 to 90% saturation have been obtained from this zone.

1.6 Drilling and mining

p. 253 and 257--only a single drillhole at Yucca Mountain penetrated the Paleozoic rocks. It is impossible to characterize the geometry and depth of the Paleozoic carbonate aquifer on the basis of one drillhole. Furthermore, interpretations of Robinson (1985) are completely ad hoc, unconstrained, and off-the-wall.

1.7 Mineral and hydrocarbon resources

p. 316-317--it is incorrect to say that potential source rocks for oil and gas may not have been deposited in the NTS region. These statements ignore the Mississippian Eleana Formation and its regional structural relations where it commonly occurs in the footwall of regional thrust faults. Clearly, rocks of the Eleana Formation could lie at depth beneath Yucca Mountain as they occur at Bare Mountain, in the Calico Hills, and in the CP Hills and Mine Mountain areas. These statements appear to have been written by someone with no knowledge of the regional geology.

p. 319--again, ignores Eleana Formation. Also, statement in middle part of second paragraph contradicts statements in first paragraph and on p. 317. Much more subsurface data on Paleozoic rocks is needed before the question of hydrocarbon potential (and of mineral potential) can be evaluated.

1.8 Summary

p. 322--there is apparently at least a km of variation in depth to Paleozoic rocks beneath Yucca Mountain, yet this significant fact is never discussed, nor are studies proposed to address this. In next to last paragraph, it is noted that the Eleana Formation may lie beneath the northern part of Yucca Mountain, contradicting earlier statements on pp. 316, 317, and 319.

p. 323--middle of page--says that planned studies will identify, characterize, and delineate the upper contact of the subvolcanic rocks. Yet no such studies are described in section 8.3.1.17. Furthermore, no attempt is planned to understand the regional structural framework other than for Quaternary time.

p. 324--bottom--this is an out-of-date view of the extensional history of the Great Basin. There is no evidence that the earlier style of extensional faulting was fundamentally different than modern faulting; furthermore, there is abundant evidence of Neogene and Pleistocene low-angle detachment faulting in the province.

p. 325--first paragraph--it is incorrect to say that extension ceased in southeastern Nevada 10 m.y. ago. Extension is still underway in the entire province, although probably at different rates.

p. 326--what is the evidence for dip of the Ghost Dance fault?

p. 334--<u>one sentence is devoted to the present tectonic model</u>: "a preestablished fault system in which recurrent Quaternary and some Holocene movement has been demonstrated and which is favorably oriented in the existing stress field for future movement." This demonstrates an almost complete lack of understanding of the regional tectonic and neotectonic framework of Yucca Mountain. Furthermore, the highly compartmentalized, unfocussed, and piecemeal investigations proposed in 8.3.1.8 and 8.3.1.17 are insufficient to develop an integrated tectonic synthesis, as claimed on page 334.

p. 336--second paragraph--prejudges a low hydrocarbon potential based on: 1. only a single well penetrating Paleozoic rocks, 2. speculation about regional heat fluxes which is not borne out by new data mentioned on p. 319, but ignored here, 3. largely irrelevant data from Death Valley, and 4. ignoring conditions of producing fields in eastern Nevada that have many similarities to the NTS region.

CHAPTER 8

8.0 Introduction

p.2--DOE assumes that collecting data will automatically resolve issues and lead to qualification of the site. The entire SCP is prejudiced by this attitude. Suppose new discoveries reveal disqualifying features? Presumably, the site characterization process will lurch onward for 12 years regardless. The SCP should give a plan for the necessary studies and evaluations, and then should allow for decision points along the way to review overall progress and to evaluate whether the site is still viable, and whether continued studies should be undertaken.

The whole process of "Performance Allocation" is flawed. It assumes that all information needs can be anticipated well in advance of site characterization, as if this were merely an engineering problem. It is unrealistic to think that

quantitative statements can be made about expected performance. The whole SCP is driven by engineering, rather than scientific, considerations, and is not a scientific program as planned here. Yet most of the critical questions are of a scientific nature, and demand a scientific focus to the program. What this whole process fails to recognize is that the whole is greater than the sum of its parts ("information needs"), and that a broad scientific overview is needed at all stages. Such is not possible under this plan. There is no provision for, or mention of, the search for coupled processes.

p. 5--fracture flow is discounted here, yet fracture flow may be the most significant mechanism.

p. 7--elements of the system: no mention of the long-term stability of the saturated/unsaturated zone boundary; no mention of volcanic and tectonic processes that affect the system.

p. 9--priorities for the SCP are very questionably ranked: Since potentially adverse or disqualifying factors need to be determined, processes or events should have very high, even highest, priority.

8.2 Issues to be resolved

p. 15--says that physical elements of the Yucca Mtn MGDS are the basis for issue resolution strategies, yet it is these very elements that are very poorly known, as shown above and in Chapter 1.

8.2.2.4 Summaries of specific site characterization programs

8.2.2.4.3 Summary of the postclosure rock characterization program

p. 189--assumes that gathering information about rock characteristics will result in compliance.

8.2.2.4.7 Summary of the preclosure site program

This section, especially Fig. 8.2.11, gives very little information about the preclosure tectonics program. The summary is nowhere near as complete as is the summary for the preclosure tectonics program. There is no information given for postclosure tectonics--data collection and analysis.

8.2.2.4.16 Summary of the postclosure tectonics program

A useful summary.

8.3.1.4 Rock properties

8.3.1.4.2 Investigation: Geologic framework of the Yucca Mountain site

p. 32--as noted earlier in this review, Chapter 1 fails to identify many critical areas of insufficient information. This investigation, as outlined, will only provide information on static physical properties (e.g., stratigraphy and structure) of the volcanic rocks at Yucca Mountain. Hydrogeology is thus decoupled here from tectonics, and dynamic processes currently

operative at Yucca Mountain are not considered in this investigation.

p. 33--site area, as defined here, is insufficient to allow an understanding of relevant features and processes. Faults at southern margin of Timber Mountain caldera, and structures in Fortymile Wash will not be considered; furthermore, the area of the great water table "fall" NW of Yucca Mtn will not even be studied. p. 35 contradicts p. 33, and says that the area of investigation will include a larger area than the site. Which is it?

8.3.1.4.2.1 Study: Characterization of the vertical and lateral distribution of stratigraphic units within the site area.

p. 37--this study will only deal with the volcanic rocks! It completely ignores prevolcanic stratigraphic and structural features, which not only are very poorly understood, but also are essential to establishing boundary conditions of saturated zone groundwater flow. How deep will coreholes G-5, G-6, and G-7 be drilled? They should definitely be drilled into Paleozoic basement.

8.3.1.4.2.2 Study: Characterization of the structural features within the site area.

p. 67--Extremely limited in scope, again concentrating only upon the volcanic section and excluding deeper structures from consideration.

p. 72--activity 2.3--borehole evaluation of faults and fractures--what about fractures induced by drilling? How will these be distinguished from natural fractures?

p. 74--Is borehole televiewer logging practical? It will be extremely difficult to extract orientation data from televiewer logs, because orientation of televiewer is difficult to specify exactly, and because of distortions inherent in projecting an image of the walls of a cylindrical surface onto a plane surface.

p. 78--How can fracture aperture be quantified? It is likely to vary markedly along individual fractures and between fractures. What units will be sampled, and where are they located with respect to the repository? How can these results be extrapolated to rocks of the repository block?

8.3.1.4.2.3 Study: Three-dimensional geologic model.

p. 82--Since most of the data is from areas peripheral to the repository block, areas that are atypical of the repository block (by definition), the model will be very unlikely to characterize the geology of the repository block. This is the basic problem: Can the repository be characterized by noninvasive means?

8.3.1.8 Postclosure tectonics

pp. 1-23--tables 8.3.1.8.1-4--goals, performance parameters, performance measures, etc. are virtually incomprehensible! See especially third paragraph, p. 22, and second paragraph, p. 23. Judgments are very subjective, and give no indication of how the numbers ("estimates") were obtained.

p. 27--third paragraph--again presupposes a favorable

outcome. It is assumed that locating and characterizing Quaternary faults in and proximal to the controlled area will demonstrate "that faulting will not lead to significant waste package failure in 1,000 yr". No such thing can be demonstrated. The data can only provide the basis for probabilistic guesses which, unfortunately, could always be wrong.

p. 30--only minor studies on folding are planned. However, folding may be an important process, especially associated with deformation along NE-trending faults, and therefore must be considered very carefully.

8.3.1.8.1 Studies of direct releases from volcanic activity

p. 35--a tectonic model is indeed needed to evaluate structural controls on basaltic volcanic activity, but nowhere is it made clear here or in 8.3.1.17 that a sufficiently comprehensive model will be generated.

8.3.1.8.2 Studies of rupture of waste packages due to tectonic events

p. 46(see also pp. 52-54)--the second initiating event, failure of a waste package due to offset on a fault intersecting waste packages, is extremely simplistic. It assumes fault is a simple, narrow, planar zone, and fails to consider that rupturing could occur over a broad zone with subsidiary fractures, and possibly causing large-scale caveins within the excavation.

p. 49--how can the probability of an intrusion penetrating the repository be constrained? Just because a probability can be estimated, does not mean it is realistic or correct.

p. 55--folding and deformation in the repository horizon--rock characteristics program is of too limited scope to enable evaluation of this problem. This needs a regional examination of folding along faults to determine in which cases faulting is significant. It is significant along NE-trending faults.

8.3.1.8.3 Changes in hydrology due to tectonic events

p. 79--assessment of effect of strain changes on water-table elevation--this relies on models of saturated zone flow which are currently inadequate. Little is known of boundary conditions of zone of saturated flow, and no studies have been planned to address this problem.

8.3.1.8.5 Miscellaneous studies

pp. 110-111--no mention is made of possible linkage or coupling of processes, such as a linkage between volcanic and seismic events, or their combined effects on water table fluctuations. Yet these are important questions that need to be addressed very carefully.

p. 113--new data presented here on the Lathrop Wells cone has not been presented in Chapter 1.

p. 121--investigation of folds in Miocene and younger rocks in the region--this study is out of sequence and out of place, and is clearly an afterthought. It needs to be integrated within the tectonics program.

8.3.1.17 Preclosure tectonics

Table 8.3.1.17-3b--how was it decided that only faults within 5 km of surface facilities would be important?

p. 28--I disagree most strongly that investigations proposed are of sufficient scope and detail to lead to an understanding of important processes. There is no overall scientific focus or coherence to the program, and most studies are site-specific. The program fails to provide a needed regional perspective.

p. 29--the northern ends of these faults are not known, yet no studies are proposed to remedy this. At the southern margin of Timber Mountain caldera, Quaternary deposits may place important constraints on timing of displacement of many of these faults. The Paintbrush Canyon fault extends well into Timber Mountain caldera.

p. 30-31--Figure 8.3.1.17-2 makes it obvious that some form of linkage exists between Bare Mtn and Yucca Mtn faults and the cinder cones in Crater Flat. What is required is a careful comparison of data on time(s) of activity of these features to see how significant the linkage is.

p. 33--how will subsurface geometry of Paintbrush Canyon fault be determined?

p. 34--third paragraph gives an extremely simplistic view of the effects of faulting on the repository. What abou the possibility of major caveins during a seismic rupturin event? Furthermore, how will the excavation itself disrupt stress conditions along faults? Won't the excavation lead to major stress concentrations that could lead to premature failure along faults, rendering ambiguous the use of fault recurrence data to predict earthquakes?

8.3.1.17.1 Studies of volcanic activity

p. 39-41--only a literature survey is planned to evaluate the potential for ash fall at the site. It is highly unlikely that current data are sufficient to make this prediction.

p. 42--there is no data available on ash-fall particle densities from historic silicic volcanic eruptions that can be used for activity 8.3.1.17.1.1.3. This data will have to be acquired.

8.3.1.17.2 Studies of fault displacement

p. 45--characterization parameter 2 is unrealistic. The locations of subsurface faults within the repository block cannot be known without violating the integrity of the block itself.

p. 49--last paragraph--use of stress data to check interrelationships among local faults is completely unrealistic. It would be impossible to collect enough stress data, much less to understand it. Each fault will cause a disruption of the stress field, and therefore it would require an enormous number of data points to specify the stress field around even a singl fault.

p. 51--first paragraph--drilling and coring a fault in

repository block, as proposed here, would compromise the integrity of the block.

8.3.1.17.4 Preclosure tectonics data collection and analysis

This section proposes a synthesis of tectonic processes acting in the site region (development of tectonic models).

p. 78--I agree fully with the statement (last paragraph) that most of the studies are naturally organized about a geological problem, and require a broader focus than the site itself. However, this is not done in this section or any other section of the SCP.

p. 86--activity 8.3.1.17.4.2.2--the primary parameter is the demonstration of the absence of Quaternary faults with more than 10 cm offset... Here again, a favorable result is presupposed.

p. 87--Figure 8.3.1.17-7 makes it clear that the 7.5' Oquadrangles west of Yucca Mountain need to be mapped. These cover Crater Flat and Bare Mountain.

p. 93--third paragraph states the two potential seismic source zones within a 100 km radius are the Walker Lane and the Death Valley-Furnace Creek fault zone, yet fails to consider the Spotted Range-Mine Mountain zone.

8.3.1.17.4.3.2 Activity--evaluate Quaternary faults within 100 km of Yucca Mountain.

This is a very large activity, with 8 major objectives. The description is repetitious and poorly organized. Several of the objectives could easily be combined.

p. 120--activity 8.3.1.17.4.3.5 has some of the same objectives (and therefore is redundant with) activity 8.3.1.17.4.3.2.

8.3.1.17.4.4 Study: Quaternary faulting proximal to the site within northeast-trending fault zones.

This really belongs under 8.3.1.17.4.3.2 and should not be a separate activity. Information is given here that does not appear in Chapter 1. A problem is that only Quaternary displacements are considered, rather than the long-term history and significance of these faults.

8.3.1.17.4.5 Study: Detachment faults at or proximal to Yucca Mountain

This section is unusually well written and well-thought-out.

8.3.1.17.4.6 Study: Quaternary faulting within the site area

No comments

8.3.1.17.4.7 Study: Subsurface geometry and concealed extensions of Quaternary faults at Yucca Mountain

p. 152--first paragraph--use of geophysical methods described here to locate subsurface faults is not realistic. This study does not seem feasible without drilling or exploratory tunneling.

8.3.1.17.4.8 Study: Stress field within and proximal to the site area

No comments

8.3.1.17.4.9 Study: Tectonic geomorphology

No comments

8.3.1.17.4.10 Study: Geodetic leveling

p. 176-177--regional leveling lines should be given a high priority to develop an understanding of the regional vertical displacement field, and for comparison with results at Yucca Mountain.

8.3.1.17.4.11 Study: Characterization of regional lateral crustal movement

p. 179--an inadequate description is given of data to be compiled in this activity. Nor is it shown how this data will be integrated with geodetic data.

8.3.1.17.4.12 Study: Tectonic models and synthesis

p. 182--fourth paragraph--it is highly unlikely that compilation of maps and preparation of geologic cross-sections required by this activity is 50% complete. No such materials have been published, nor have any such results been evident in the Geohydrology program. In fact, not enough regional information is available at present to draw realistic cross-sections.

p. 183--activity 8.3.1.17.4.12.2: Evaluate tectonic models--only Quaternary processes are considered, yet long-term processes are poorly understood and require much more study. This activity is overly limited in scope (p. 184), and fails to consider the regional tectonic setting of major crustal extension in which all of the proposed processes may operate. What is needed is a comprehensive program to investigate the regional Neogene and Quaternary setting of Yucca Mountain.

p. 185--activity 8.3.1.17.4.12.3: Evaluate tectonic disruption sequences--not much description or thought has been given to this activity.

4. General recommendations

1. The SCP should be reorganized around a scientific focus, should have a centralized scientific overview, and should have periodic review and decision points to allow for assessment of potentially fatal flaws and the need for redirection of efforts.

2. Programs should be prioritized so as to reveal any possible fatal flaws as early as possible. Lower priority should be given to routine characterization.

3. Identify as early as possible major uncertainties in data which are unlikely to be eliminated by further study.

4. The present SCP presents no overall conceptual models of the regional tectonic framework of Yucca Mountain. Models should be developed, in a preliminary way, based upon available data, for testing and evaluation.

5. Site characterization should not begin until the SCP is completely revised.

Review of Consultation Draft Site Characterization Plan

Task 7 - Geotechnical and Rock Mass Assessment

Robert J. Watters, Principal Investigator

The following parts of the CDSCP were reviewed. All subdivisions within each of the sections were also reviewed.

Rock Characteristics ----------8.3.1.4

Thermal and Mechanical Properties - 8.3.1.15

Preclosure Tectonics ---------- 8.3.1.17

Planned Site Preparation Studies----8.4

Other sections of the CDSCP were reviewed where subdivisions within particular sections interfaced with the above sections. These sections included :

Introduction----------8.0

Rationale----------8.1

Issues----------8.2

Site Program----------8.3.1

Site Overview----------8.3.1.1

Geohydrology----------8.3.1.2

Summary - Task 7 - Robert J. Watters

1. Overall, the CDSCP has addressed the majority of the issues pertaining to rock characterization, thermal and mechanical characteristics, surface and underground design of the repository. However, key points remain to be addressed.

2. The biggest deficiency is the manner in which the investigation of the Yucca Mountain block is planned. The investigation to establish the lithology, geologic structure, and geomechanical properties of the repository horizon rock mass depends totally on the positioning of the exploratory shafts and the spacing between the cored boreholes which intersect the proposed repository.

3. The position of the shafts is suggestive of "putting the cart in front of the horse" in that the requirements to best investigate the block have been usurped by the needs to a) position the shaft where it best serves the operational needs of the repository and b) save time and money. In its present position the central and southern portion of the block are not investigated. In a good investigation, the investigation establishes the best positions for shafts etc., not the other way around. An exploratory shaft is positioned to maximize the subsurface information.

4. Only 24 cored holes (perhaps less) are planned to be drilled to the repository horizon. These holes will have spacings up to 4200 feet and minimum distances of 2700 feet. With such a large spacing many geotechnical features and rock mass characteristics will be lost or overlooked.

5. The vast majority of boreholes are vertical, even though many of the features of interest, fractures etc., which affect hydrogeology and rock mass behavior are vertical. Hence, these features are either overlooked or minimized.

6. More testing in terms of numbers of tests and locations are needed to better explain rock mass behavior and the range in situ stress magnitudes and orientations.

7. Few details are discussed about "feature of interest drilling" e.g. faults. Geologic structures within the perimeter boundary could well be crucial to the short term stability of the excavations.

8. A heavy emphasis on geostatistical approaches in analyzing the collected data, supports the overall conclusion that the minimum number of boreholes, drifts, tests, and analyses are to be performed. Geostatistical methods are normally performed when scatter of data exists, and the normal refinement of more raw data collection to reduce the scatter can not be utilized, due to time constraints or money. The project is to important to rely heavily on geostatistical analyses.

Comments :

1. Geologic framework and geologic complexity of Yucca Mountain, nature of investigation.

Specifically : a) Location and number of boreholes (8.3.1.4.3.1.1).

Basis :

* Two phases of drilling (12 holes each phase), grid 4200 by 3500 feet, then 2700 by 2700 feet for second phase. Data to be geostatistically assessed (8.3.1.4.3.2.1).

* Spacing is to large for meaningful results. In the mineral industry, spacing is of the order of a 20 to 50 feet square grid, to provide usable data.

Recommendation :

Reduce grid spacing by at least one order of magnitude. Institute "feature of interest" drilling in the first phase of drilling, not as is suggested that it may be used later for sitting additional holes (8.3.1.4.1.1.3).

Specifically : b) Borehole inclination (8.3.1.4.2.2.3)

Basis :

* All holes to be vertical, though several holes may be angled. This procedure will yield results for lithologic spatial distribution but will do little to establish fracture frequency and orientations as majority of fractures are vertical to sub-vertical.

Recommendation :

Drill angled holes at each drill hole location in addition to the vertical hole.

Specifically : c) Exploratory shaft locations (8.3.1.4.2.2.4) and (8.4).

Basis :

* The position of both exploratory shafts and associated test facility are in the northern portion of the proposed repository. The central and southern portions of the repository will not be sampled (8.3.1.15.1).

* The shaft positions appear to have been decided on the requirements for an operational facility not on the best positions to provide input for the design. Position location should be based on site characterization needs, not exclusively by operational requirements.

* Shafts could be situated in the northern and in the southern area of the repository, and still be utilized for operational use if the repository is licenced. Two test facilities could then be constructed which would yield more representative test results. This would help resolve geologic and geoengineering issues before resorting to geostatistical techniques to make up for lack of data due to a limited site investigation.

Recommendation :

* Keep the position of ES1 and ES2 in the present position portion of the repository block and sink two new shafts in the southern portion of the block. Or reposition ES1 and ES2 to a more central location and excavate exploratory drifts to the northern and southern sections of the block with associated test facilities in each portion of the block.

Specifically : d) Geologic mapping of the exploratory shaft and drifts (8.3.1.4.2.2.4).

Basis:

* The thrust of the geologic mapping appears to support the hydrogeologic investigation with no input to the geoengineering or underground design.

* No mention of fractal usage in the mapping of shaft or drifts is included.

* No borehole is to be drilled at the shaft location prior to shaft sinking. Comparison of borehole data to exploratory shaft data would help in developing three dimensional geology and show the limitations of borehole information and where data gathering could be improved.

Recommendations :

* Expand fracture and discontinuity data collection to assist geoengineering and underground support.

* Drill borehole at shaft location and compare data gathered from borehole to that gathered from shaft mapping. Compare fractal studies from shaft to that from surface outcrops.

2. Thermal and mechanical rock properties.

Specifically : a) Establishment of spatial distribution of mechanical and rock properties (8.3.1.15.1).

Basis :

* Large scale in situ tests are to be limited due to time and expense of performing this type of experimentation. Numerical and computer modeling techniques are to be utilized using data from small scale laboratory rock tests.

* Small scale rock tests do not provide quality information. Density and porosity characterization tests (8.3.1.15.1.1.1) will be from 65 cubic centimeter samples which will not be adequate for samples with large lithophysaes. Similarly unconfined compressive tests (8.3.1.15.1.3.1) and shear tests (8.3.1.15.1.4.1) will be performed on small samples. All the tests do not appear to consider adequately the effects of anisotropy within the rock mass.

Recommendation :

* Larger samples should be utilized in tests and results compared with smaller samples to better establish scale effects for input to modeling techniques.

* Oriented samples should be collected to study the effects of anisotropy within the rock mass. Oriented in situ tests should be performed to assess anisotropy effects. Effects of lithophysae and fracture interplay on the reduction of modulus should be assessed.

Specifically : b) Surface fracture network studies (8.3.1.4.2.2.2).

Basis :

* No discussion of the technique used in fractal analysis of roughness, interconnectivity or aperture is contained in the CDSCP, more than one technique exists.

Recommendation :

* Detail the technique.

Specifically : c) Excavation investigation (8.3.1.15.1.5)

Basis :

* Effects of shaft sinking on the surrounding rock mass will not be monitored continuously. Monitoring will be provided below breakout rooms for up to 100 feet (8.3.1.2.2.4.5). This monitoring is aimed at measuring changes in permeability due to stress changes and fracture formation . Shaft construction will increase rock mass permeability, decrease modulus and shear resistance in the vicinity surrounding the excavation.

Recommendation :

* Instrument the bedrock surrounding the shaft location prior to excavation with additional measuring equipment, e.g. strain gauges, acoustic emission equipment, installed in vertical boreholes, as per breakout room procedure.Performance of shaft as it is excavated can then be monitored, and compared with analytical results.

* Spatial zone of ground disturbance around the shaft can be established and this information used for repository design.

3. In situ stress field determination at Yucca Mountain.

Specifically : a) Stress field within and proximal to the site (8.3.1.17.4.8)

Basis :

* Comparing in situ results for establishing the stress field shows important differences between shallow results (obtained from triaxial strain and hydrofrac measurements) and deeper measurements (focal plane analyses).

* Shallow results from depths above one kilometer show Sh < SH < SV, giving rise to dip slip movement on fault planes. Results from depths below this level show Sh < SV < SH, producing strike slip movement on fault surfaces. These differences in the stress field orientations and magnitudes of the stresses are important for assessing the seismic and geologic stability of both the area and stability of the underground excavations.

Recommendation :

* Review all data for errors in analysis for all measurements where practical.

* Locate new locations for shallow and deeper in situ measurements, and install seismic arrays in different geologic materials and structural settings.

Specifically : b) Stress field within the site area (8.3.1.17.4.8.1) and (8.3.1.17.4.8.2).

Basis :

* A medium level of confidence is required for the in situ stress field for design purposes. Presently only a low level of confidence exists (8.3.3.2 and 8.3.2.5).

* Definition of high, medium and low is not given.

* Data obtained in G tunnel, from triaxial strain measurements of the stress field show high stress magnitude changes on comparing welded and non-welded results. Though stress orientations remain constant. These changes are due to changes in modulus in welded, partly, and non-welded tuff. As repository will likely be constructed in areas where tuff is not completely welded, modulus changes will exist, with associated different stress levels.

* Design does not incorporated these effects which may produce shear stresses in excess of shear strength in ribs or roof or floor where pillars exist.

* These excessive stresses may induce :
1. underground instability.
2. localized reactivation of nearby faults, e.g. Ghost Dance or Solitario Faults.

Recommendation :

* Perform triaxial strain tests in test facility and shaft at different elevations in rock materials with different modulus.
* Measure strain rates of different rock materials in juxtaposition after excavation within them, subject to known stress levels.

COMMENTS OF

L. LEHMAN & ASSOCIATES

TECHNICAL REVIEW OF THE DRAFT SITE CHARACTERIZATION PLAN YUCCA MOUNTAIN SITE, NEVADA RESEARCH AND DEVELOPMENT AREA, NEVADA

JANUARY 15, 1987

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COMMENTS ON PORTIONS OF CHAPTER 8

CHAPTER/SECTION NUMBER(S): 8.1.2

CHAPTER/SECTION TITLE(S): Issue Resolution Strategy

PAGE NUMBER(S): 8.1-5, 8.1-6

PARAGRAPH NUMBER(S): 2, Figure 8.1-1

STATEMENT OF ISSUE:

Issue resolution strategy.

DISCUSSION:

As presented in figure form on page 8.1-6, the Issue Resolution Strategy is missing an important feature. A feedback loop should extend from Step 9 "Establish That Information Needs Are Satisfied" back to Step 6 "Develop Testing Strategy, Identify Tests, Variables and Parameters to be Measured". This feedback loop is necessary in case it is determined during Step 9 that a particular information need has not been satisfied. Such situations are highly likely, particularly when dealing with subsurface investigations where unforeseen results are commonplace.

CHAPTER/SECTION NUMBER(S): 8.1.2.2

CHAPTER/SECTION TITLE(S): Performance Allocation

PAGE NUMBER(S): 8.1-7, 8.1-8

PARAGRAPH NUMBER(S): 6, 1

STATEMENT OF ISSUE:

Performance goals.

DISCUSSION:

The use of the performance "goals" is questionable. The DOE defines these goals as guides which will have specific values consistent with licensing strategies. Once these "goals" are attained, then supposedly an issue will be resolved. The DOE however proceeds to caveat this rationale to the extent that it becomes useless. All goals do not have to be met, they are only preliminary, they can be changed. Once again, DOE has rendered a good idea useless. No steps have been outlined as to what happens when goals are not achieved within confidence limits? Does the DOE simply change the goal to meet the value?

CHAPTER/SECTION NUMBER(S): 8.1.2.2

CHAPTER/SECTION TITLE(S): Performance Allocation

PAGE NUMBER(S): 8.1-8

PARAGRAPH NUMBER(S): 3

STATEMENT OF ISSUE:

Indications of confidence.

DISCUSSION:

Typically confidence intervals are statistically rigorous quantities. DOE states that most of their confidence indicators are only qualitative expressions. DOE is trying to make a completely arbitrary process appear to be mathematically grounded.

CHAPTER/SECTION NUMBER(S): 8.1.2.3

CHAPTER/SECTION TITLE(S): Information Needs

PAGE NUMBER(S): 8.1-8

PARAGRAPH NUMBER(S): 4

STATEMENT OF ISSUE:

Parameter goals.

DISCUSSION:

Again, DOE is setting a goal of a specific value for a parameter. Caveats are many; the goal does not have to be met, the goals are preliminary, etc. Again, this implies that if a parameter does not line up to expectations, expectations will simply be lowered.

DOE should be required to have a strategy, which, if a parameter fails a expected goal, that other goals be made much higher in order to compensate the failed goal. No such statements are made by DOE.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.1.2

CHAPTER/SECTION TITLE(S): Assessment of regional hydrogeologic data needs

PAGE NUMBER(S): 8.3.1.2-83

PARAGRAPH NUMBER(S): 2

STATEMENT OF ISSUE:

Two-dimensional, regional flow model to be used for sensitivity analysis.

DISCUSSION:

Two-dimensional, regional flow models have been developed for the Yucca Mountain area. Examples of these include Czarnecki, 1985; Rice, 1984; Czarnecki and Waddell, 1984; and Waddell, 1982.

The SCP should indicate if any of this previous work will be utilized in this activity.

REFERENCES:

Czarnecki, J.B., 1985. Simulated Effects of Increased Recharge on the Ground-Water Flow System of Yucca Mountain and Vicinity, Nevada-California, USGS-WRI-84-4344, Water-Resources Investigations Report, U.S. Geological Survey, Denver, CO.

Czarnecki, J.B., and R.K. Waddell, 1984. Finite-Element Simulation of Ground-Water Flow in the Vicinity of Yucca Mountain, Nevada-California, USGS-WRI-84-4349, Water-Resources Investigations Report, U.S. Geological Survey, Denver, CO.

Rice, W.A., 1984. "Preliminary Two-Dimensional Regional Hydrologic Model of the Nevada Test Site and Vicinity", SAND83-7466, Sandia National Laboratories.

Waddell, R.K., 1982. Two-Dimensional, Steady-State Model of Ground-Water Flow, Nevada Test Site and Vicinity, Nevada-California, USGS-WRI-82-4085, Water-Resources Investigations Report, U.S. Geological Survey, Denver, CO.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.1.3.2

CHAPTER/SECTION TITLE(S): Regional Potentiometric level studies

PAGE NUMBER(S): 8.3.1.2-83, 84

PARAGRAPH NUMBER(S):

STATEMENT OF ISSUE:

Interpreting water level information from wells.

DISCUSSION:

The description of this activity does not make reference to water levels that could reflect confined aquifers in the Nevada Test Site area. Some of the modeling performed previously simulated flow in the deeper units. However, in some cases, wells not completed in the deep units appeared to be used in the calibrations and other output comparisons. These previous studies suffered because of this practice. In future studies when water level maps are eventually developed, careful interpretation of well characteristics will be crucial.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2

CHAPTER/SECTION TITLE(S): Studies to Provide a Description of the Unsaturated Zone Hydrologic System at the Site

PAGE NUMBER(S): 8.3.1.2-112, 113

PARAGRAPH NUMBER(S): 4, 5, 1

STATEMENT OF ISSUE:

Current understanding of unsaturated flow in fractured rock environment.

DISCUSSION:

DOE acknowledges in this section of the SCP how little is known regarding unsaturated flow in fractured rock environments. This situation applies to vapor-phase as well. Given the short time period allowed for Site Characterization, it cannot be realistically expected that this lack of knowledge can be overcome. Basic lab and field investigations cannot be successfully carried out until research is done on what methods might be feasible towards performing these investigations. Rigorous theoretical progress will be necessary as well in order to interpret collected data. Given the extremely long time scales that scientific research normally requires, it is unlikely that a significant amount of information can be generated during Site Characterization.

It seems much wiser to consider sites where traditional porous-media flow occurs. Ground water flow in such areas has been studied successfully for decades. While such sites may or may not be inferior to Yucca Mountain, they will clearly decrease the amount of uncertainty involved in performance assessment evaluations. Given the extreme hazard of high-level waste, reducing uncertainty is of the highest priority.

Using Yucca Mountain as a repository will require a tremendous "leap-of-faith", thereby hoping that "what we don't know won't hurt us". This does not appear to be a wise move.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.1.2

CHAPTER/SECTION TITLE(S): Evaluation of Natural Infiltration

PAGE NUMBER(S): 8.3.1.2-125

PARAGRAPH NUMBER(S): (Parameters)

STATEMENT OF ISSUE:

List of parameters.

DISCUSSION:

It is unclear why the particular six "parameters" are listed in the fashion on page 8.3.1.2-125. While there is nothing inappropriate about such a list, neither does it appear particularly profound. These six terms relate to infiltration in one way or another. However, they do not seem to have encompassed every possible variable relevant to infiltration, nor do they seem to suggest six broad aspects of infiltration. This particular list simply confuses the reader. Such lists are ubiquitous in the SCP.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.1.2

CHAPTER/SECTION TITLE(S): Evaluation of Natural Infiltration

PAGE NUMBER(S): 8.3.1.2-126

PARAGRAPH NUMBER(S): 3

STATEMENT OF ISSUE:

Description of neutron moisture logging study.

DISCUSSION:

There is no discussion of the neutron moisture logging study that specifies the average depths that the existing and future access holes will be employed to, nor is it mentioned if any holes are planned to be emplaced subhorizontally. Subhorizontal boreholes would probably be preferable in monitoring fractures. It is unclear if the boreholes will or do extend into bedrock. Also, the frequency of measurements is not stated. Furthermore, a brief summary of the data gathered to date would have been helpful in order to evaluate the value of this study. Most importantly, there is no discussion of exactly how the results will be used to calculate infiltration rates. It seems logical that changes in water content will be integrated over time at the various depths to calculate cumulative infiltration, however this is not stated in the SCP. Given the short duration of time for site characterization, these details need to be established immediately. Interpreting the data as it is collected will allow problems to arise at a time early enough for their mitigation. This data should not be just archived until some later time. If this latter procedure is followed, it is more and more likely that the data will never be reduced and analyzed.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.1.2

CHAPTER/SECTION TITLE(S): Evaluation of Natural Infiltration

PAGE NUMBER(S): 8.3.1.2-126

PARAGRAPH NUMBER(S): 5

STATEMENT OF ISSUE:

Description of the tritium profiling studies.

DISCUSSION:

It is not stated in the SCP how many tritium samples will be analyzed in this study nor to which borehole locations they correspond to. It must be realized that when dating matrix pore water in a fractured rock environment, it may be possible that younger fracture water may bypass old matrix water during precipitation events. Therefore, results of tritium analyses of matrix water must be interpreted carefully.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.1.2

CHAPTER/SECTION TITLE(S): Evaluation of Natural Infiltration

PAGE NUMBER(S): 8.3.1.2-130

PARAGRAPH NUMBER(S): 5, 6

STATEMENT OF ISSUE:

Usefulness of water balance studies to quantify infiltration at Yucca Mountain.

DISCUSSION:

As is acknowledged in the SCP, it is well established that water balance studies where the error in precipitation rate and or evapotranspiration rate is larger than the infiltration rate, are useless. It is very likely that the prototype water balance study proposed for the USGS will reveal nothing new. In light of these observations, it would not be a good investment of time and resources to pursue this water-balance pilot study.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.1.3

CHAPTER/SECTION TITLE(S): Evaluation of Artificial Infiltration

PAGE NUMBER(S): 8.3.1.2-133

PARAGRAPH NUMBER(S): 2

STATEMENT OF ISSUE:

Double-ring infiltration studies.

DISCUSSION:

DOE plans a series of double ring infiltration tests to be performed on the surface of Yucca Mountain in order to "characterize infiltration rates" spatially. On page 8.3.1.2-133, the SCP states,

> "The term infiltration rate is defined here as the infiltration flux resulting when water, at atmospheric pressure, is made freely available to the unconsolidated material surface."

From this definition, and the lack of references and detail regarding the double-ring method, it appears that DOE does not adequately understand infiltration nor what the method involves.

First of all, infiltration rate is not a constant. Upon introduction of a thin, ponded surface to the soil profile, the infiltration rate will be at a maximum, as time goes on this infiltration rate will decrease and approach the saturated hydraulic conductivity of the soil. Because early-time vertical hydraulic gradients can be substantially larger than unity, the early infiltration rate can be significantly higher than the final value. Therefore, the definition of "infiltration rate" in the SCP is flawed because actual infiltration rates depends on the length of the test. If the test is to be conducted until the infiltration rate levels off at a minimum value, then what is truly being measured is the saturated hydraulic conductivity. It is not clear that DOE realizes this judging by the SCP.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.1.3

CHAPTER/SECTION TITLE(S): Evaluation of Artificial Infiltration

PAGE NUMBER(S): 8.3.1.2-133

PARAGRAPH NUMBER(S): 4

STATEMENT OF ISSUE:

Ponding infiltration studies.

DISCUSSION:

The SCP mentions several parameters and variables that are to be evaluated during the ponding experiments using a neutron moisture meter. These parameters include infiltration rate, flow velocities, matrix/fracture relationships, and unsaturated hydraulic conductivity as a function of water content. Unfortunately, only the last of these parameters include a reference in the SCP as to what method will be used to interpret and analyze the data (Libardi et. al., 1980). Unless similar references to published techniques are established, it is very unlikely the data collection activities will be successfully planned and executed.

REFERENCE(S):

Libardi, P.L., K. Riechardt, D.R. Nielsen and J.W. Diggar, 1980. "Simple Field Methods for Estimating Soil Hydraulic Conductivity", SSSAJ:44 (3-7).

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.1.3

CHAPTER/SECTION TITLE(S): Evaluation of Artificial Infiltration

PAGE NUMBER(S): 8.3.1.2-134

PARAGRAPH NUMBER(S): 5

STATEMENT OF ISSUE:

Details of the Small-Plot-Rainfall-Simulations (SPRS) investigations.

DISCUSSION:

As is the case for much of the infiltration studies described in the SCP - there are no references made to which techniques will be used to perform these studies. The SPRS studies are expected to "determine the complex relations between rainfall, thickness and properties of unconsolidated rock or soil and the development of perched water tables" (p. 8.3.1.2-134).

Because the fractured rock properties are not to be evaluated in these studies, numerous techniques are available from the soil science disciplines to undertake these studies, yet none of these are referenced. It will not be necessary, nor likely worthwhile, in this case to undertake research into these techniques given the existing level of knowledge in soil physics.

It is paramount to performing the SCP activities in an efficient and timely manner that such references specifying analysis techniques and instrumentation be established immediately.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.3

CHAPTER/SECTION TITLE(S): Characterization of percolation in the unsaturated zone -- Surface-based study

PAGE NUMBER(S): 8.3.1.2-138, 139

PARAGRAPH NUMBER(S): 4, 1

STATEMENT OF ISSUE:

Perched water encountered in well USW UZ-1.

DISCUSSION:

The SCP states,

> "No natural perched water has been observed in holes drilled in Yucca Mountain. However, circulating drilling fluid that was last in hole USW G-1 was observed in USW UZ-1, 335m distant."

The tone of this statement indicates that it is an established fact that the perched water is a result of the loss of drilling fluid in hole USW G-1. In Chapter 3 (p. 3-149) of the SCP it is stated, "...because the water was contaminated with drilling fluid polymer used to drill drillhole USW G-1...it was speculated that the perched-water horizon was not natural but a result of drilling drillhole USW G-1...". The first quote implies that there is no question the perched water is <u>completely</u> due to drilling fluids, while the second only speculates about this. Even if drilling polymer was found in the well water, it is possible that some of this perched water was natural and was supplemented by the drilling water. Until more evidence is revealed, it should be considered that natural perched water may have contributed to this occurrence.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.3.1

CHAPTER/SECTION TITLE(S): Matrix hydrologic properties testing

PAGE NUMBER(S): 8.3.1.2-146

PARAGRAPH NUMBER(S): 3

STATEMENT OF ISSUE:

Matrix hydrologic properties testing.

DISCUSSION:

In order to most efficiently perform the testing for moisture-retention curves, relative permeability, and saturated permeability; a comprehensive literature survey is recommended in order to identify which of the various techniques might be most applicable to tuff. It is commonly the case that when a particular testing procedure is developed, only one soil or rock type was utilized as the tested medium. Eventually, several methods become available yet very few are applicable to the entire range of possible porous media. It would be advantageous to focus only on those techniques developed on a soil or rock with similar characteristics to tuff, rather than perhaps a coarse sand for example.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.3.1

CHAPTER/SECTION TITLE(S): Matrix hydrologic properties testing

PAGE NUMBER(S): 8.3.1.2-147 to 148

PARAGRAPH NUMBER(S): all

STATEMENT OF ISSUE:

Reference techniques for matrix hydrologic properties testing.

DISCUSSION:

The SCP includes numerous references to established techniques that will be used to measure matrix hydrologic properties. Given the short duration for the Site Characterization Program - it is very possible that this phase of the program will be the only one completed. Very few of the other hydrologic investigation techniques have been established or apparently even speculated upon. DOE should have in-place, some type of fall back position in case they cannot gain any insight into fracture-flow processes at Yucca Mountain. If this occurs, little more will be known about the site than is known now and placing high-level waste at Yucca Mountain would be a highly speculative undertaking.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.3.2

CHAPTER/SECTION TITLE(S): Size vertical borehole studies

PAGE NUMBER(S): 8.3.1.2-151

PARAGRAPH NUMBER(S): Figure

STATEMENT OF ISSUE:

Locations of vertical boreholes.

DISCUSSION:

Inspection of Figure 8.3.1.2-14 reveals that no vertical boreholes exist or are planned in the northern 3/4 of the perimeter drift area. An obvious concern arises in that no coverage of this large area is planned. Unless there is some overriding issue, boreholes should be installed in that area to gain an insight into the hydrologic character of that area and its subsurface.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.3.2

CHAPTER/SECTION TITLE(S): Size vertical borehole studies

PAGE NUMBER(S): 8.3.1.2-155, 158

PARAGRAPH NUMBER(S): 6, 1

STATEMENT OF ISSUE:

Selection of intervals for packer testing.

DISCUSSION:

The SCP states that multiple test zones will be selected for each hydrogeologic unit for packer nitrogen-injection testing. As part of the Site Characterization Plan, the criteria for selection of these zones should be stated. In other words, will the sampling be planned to assure regular spacing to support statistical analyses? Or will the irregularities be focused upon in order to support worst-case scenarios that might be used to compensate for uncertainty? In any case, how these intervals will be selected should be established.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.3.2

CHAPTER/SECTION TITLE(S): Size vertical borehole studies

PAGE NUMBER(S): 8.3.1.2-158

PARAGRAPH NUMBER(S): 4

STATEMENT OF ISSUE:

Adequacy of psychrometers and heat dissipation probes and other instrumentation in monitoring water potential.

DISCUSSION:

Montazer (1986) calls into question the adequacy of the current vadose zone monitoring regarding soil-water potential due to effects from gravel packs, and silica flour columns in USW UZ-1. Planned borehole completions should be based on the results of previous monitoring in that hole. Gravel packs appear particularly burdensome in regards to monitoring matric potential. Direct contact of monitoring devices with the host rock is obviously preferable although, admittedly, not always possible. DOE's approach to this problem should be outlined in the SCP.

REFERENCE(S):

Montazer, P., 1986. "Application of Hydrologic Techniques in Characterization of Unsaturated, Fractured Rocks" AGU Fall Meeting, San Francisco, CA, 1986.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.3.2

CHAPTER/SECTION TITLE(S): Size vertical borehole studies

PAGE NUMBER(S): 8.3.1.2-158, 159

PARAGRAPH NUMBER(S): all

STATEMENT OF ISSUE:

Pneumatic and liquid-phase borehole testing.

DISCUSSION:

None of the descriptions of the various pneumatic (gas) and liquid-phase testing planned for the vertical boreholes and clusters include any references to fractured-rock testing techniques and data analysis methods developed for the petroleum industry or from previous waste disposal applications. It is acknowledged that established techniques in this field are few in number. However, a starting point is needed, even for the prototype testing. These references should be established to the extent possible before further data collection activities are planned.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.3.3

CHAPTER/SECTION TITLE(S): Solitario Canyon Horizontal Borehole Study

PAGE NUMBER(S): 8.3.1.2-169

PARAGRAPH NUMBER(S): 2

STATEMENT OF ISSUE:

Drilling method of emplacement of the horizontal borehole in Solitario Canyon.

DISCUSSION:

The SCP states that air will be used as the drilling medium in order to preserve the ambient moisture content of the recovered core and cuttings and of the in situ rock mass. While using air is preferable to water, and is therefore the best choice, it must be realized that the introduction of air into the fractured rock mass will likely perturb the ambient conditions, most notably by lowering the relative humidity in the immediate vicinity of the borehole.

It is acknowledged that such a situation is unavoidable, however the monitoring results should be interpreted with this phenomenon in mind.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.3.3

CHAPTER/SECTION TITLE(S): Solitario Canyon Horizontal Borehole Study

PAGE NUMBER(S): 8.3.1.2-170

PARAGRAPH NUMBER(S): 3

STATEMENT OF ISSUE:

Instrumentation of the horizontal borehole.

DISCUSSION:

In order to collect perched or other free water in the unsaturated zone via the Solitario Canyon horizontal borehole study, delicate instrumentation will likely be necessary. The report "Characterization of Infiltration into Fractured, Welded Tuff Using a Small Borehole Data Collection Technique" by W. Linderfelt of the Desert Research Institute, University of Nevada may provide valuable information towards planning this instrumentation. In this study, infiltrating water was successfully sampled from fractures following precipitation events.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.4.1

CHAPTER/SECTION TITLE(S): Intact-Fracture test in the exploratory shaft facility

PAGE NUMBER(S): 8.3.1.2-183

PARAGRAPH NUMBER(S): 4

STATEMENT OF ISSUE:

Intact fracture tracer tests.

DISCUSSION:

The SCP suggests the performance of tracer tests on laboratory samples of fractured tuff in order to investigate matrix diffusion processes. In order to confidently interpret results, tracer tests should be run using two different types of tracers. One tracer should be amenable to matrix diffusion (a standard solute), and the other should be an inert, relatively large particle tracer (such as silica spheres) that will not exhibit diffusive behavior. Comparison of break-through curves of the two different tracers under equal flow conditions will reveal the possibility of matrix diffusion.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.4.1

CHAPTER/SECTION TITLE(S): Intact-Fracture test in the exploratory shaft facility

PAGE NUMBER(S): 8.3.1.2-184

PARAGRAPH NUMBER(S): 2

STATEMENT OF ISSUE:

Prototype testing of discrete fractures in regards to flow-channeling and transport.

DISCUSSION:

A obvious omission in terms of previous studies that could be utilized in studying channelization in fractures, are those described in Neretnieks, 1985. These pioneering studies represent invaluable planning resources for the studies described in this section of the SCP.

REFERENCE(S):

Neretnieks, I., 1985. "Transport in Fractured Rocks" in Hydrogeology of Rocks of Low Permeability - Proceedings of a Symposium Tucson, AZ. January, 1985. International Association of Hydrogeologists.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.4.2

CHAPTER/SECTION TITLE(S): Infiltration tests in the exploratory shaft facility

PAGE NUMBER(S): 8.3.1.2-194

PARAGRAPH NUMBER(S): 4

STATEMENT OF ISSUE:

Emplacement of vertical boreholes in the floor of the infiltration test room.

DISCUSSION:

It does not appear worthwhile to install vertical boreholes in the floor of the infiltration test room. These boreholes could easily compromise the test by acting as preferential conduits for infiltration or otherwise affect the tests. The information planned to be collected from these holes can be obtained adequately from the horizontal boreholes. Understanding fracture flow processes is not established well enough to risk emplacing these boreholes which could distort the test results.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.4.2

CHAPTER/SECTION TITLE(S): Infiltration tests in the exploratory shaft facility

PAGE NUMBER(S): 8.3.1.2-196

PARAGRAPH NUMBER(S): 1

STATEMENT OF ISSUE:

Tracer injection tests of core samples.

DISCUSSION:

The SCP briefly describes planned tracer injection tests to be conducted on core samples with lysimeter sampling along flow paths in order to calculate dispersion and diffusion characteristics of the tuff matrix. The concern here is the implied ease in which this experiment is apparently expected to entail. Retrieving core long enough for instrumenting experiments can sometimes be difficult. Furthermore installing lysimeters into tuffaceous rock core is not simple. Some of these complications should be addressed in the SCP.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.4.2

CHAPTER/SECTION TITLE(S): Infiltration tests in the exploratory shaft facility

PAGE NUMBER(S): 8.3.1.2-197

PARAGRAPH NUMBER(S): 1

STATEMENT OF ISSUE:

Initiation of fracture flow during the infiltration test.

DISCUSSION:

One of the goals of the infiltration test is to investigate the conditions under which fracture flow occurs. The SCP states in this section that the imposed infiltration rate will be increased until the second (middle) level of the three levels of instruments indicate fracture flow. At that point it will be assumed fracture flow has effectively begun.

It would appear that a corollary experiment could be performed previous to the above described steps. This experiment would increase the imposed infiltration rate very gradually, until fracture flow is indicated in the upper (first) level of borehole instrumentation. At this point the infiltration rate should be decreased rather rapidly to zero. The next two levels of instrumentation would then be closely monitored to indicate if the fracture flow is propagated downward, or rather if it is damped out by lateral gradients absorbing the fracture water into the matrix. This type of behavior has been hypothesized as occurring at Yucca Mountain in response to severe precipitation events. DOE has used this hypothesis to indicate that fracture-flow does not penetrate significant distances below the surface, certainly not to repository levels. Performing the suggested experiment above would provide actual evidence either to support or refute this unsubstantiated, yet long-held assertion. The experiment should then be re-run using longer and longer periods of time between the onset of fracture flow and the point when imposed infiltration is decreased to zero. The conditions under which sustained fracture flow occur would then be better understood.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.4.3

CHAPTER/SECTION TITLE(S): Bulk-Permeability tests in the Exploratory shaft facility

PAGE NUMBER(S): 8.3.1.2-213

PARAGRAPH NUMBER(S): 4

STATEMENT OF ISSUE:

Bulk-Permeability test.

DISCUSSION:

Twelve boreholes with multiple packed-off intervals will intersect and/or run parallel to the Bulk-Permeability Test Room. With such a large number of boreholes, data analysis from the large scale test (using the room) must be performed acknowledging the distinct possibility that the boreholes have created unnatural preferential pathways. Despite the packers, a significant percentage of these boreholes will be open to the host rock. For example, if one packed-off interval intersects a major fracture, then flow from the other packed off intervals may be artificially directed to the "connected" packed-off interval via flow essentially along, or very near to, the borehole itself. This situation would tend to focus flow on a few dominant fractures rather than representing flow over a large volume.

An alternative approach to determine bulk permeabilities might be to start with a standard borehole and perform packer tests in that borehole. This borehole could then be over-cored, and replaced with a substantially larger borehole with packer tests then being performed in it. Finally, an excavation on the scale of the Permeability Test Room could be emplaced such that the original borehole location coincides with the room's central axis. The large scale pneumatic test could be performed. This approach would then allow 3 testing scales to be evaluated, and no additional boreholes would be present to distort the testing. The cross-hole testing would be eliminated from this investigation, however this type of testing is included in other activities.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.4.6

CHAPTER/SECTION TITLE(S): Calico Hills Test in the exploratory shaft facility

PAGE NUMBER(S): 8.3.1.2-244

PARAGRAPH NUMBER(S): 1

STATEMENT OF ISSUE:

Investigations regarding possible perched-water conditions.

DISCUSSION:

The cross-hole tests described in this portion of the SCP are intended to evaluate, among other things, the potential for perched conditions in the Topopah Spring welded unit immediately above the Calico Hills unit. The SCP does not discuss how this stratigraphic contact relates to the depth in hole UZ-1 where perched water was encountered previously (Page 3-148, SCP). It is unclear what the origin of this perched was or is, however drilling fluid appears to have played at least a partial role.

Some discussion of this perched water condition in UZ-1 would be appropriate in this section of the SCP.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.4.7

CHAPTER/SECTION TITLE(S): Perched water tests in the exploratory shaft facility

PAGE NUMBER(S): 8.3.1.2-247

PARAGRAPH NUMBER(S): 4

STATEMENT OF ISSUE:

Use of psychrometers to measure soil-moisture potential.

DISCUSSION:

It can reasonably be expected that near saturation conditions will occur in the host rock near any seeps encountered by the exploratory shaft. The SCP states that psychrometers will be used to measure soil-moisture potential in the boreholes installed at these seeps. Unfortunately, psychrometers are not useful in measuring near-saturation soil moisture potential, but rather they can be used at pressures below -2 bars (Hillel, 1980). Use of psychrometers in the vicinity of seeps should therefore be reconsidered.

REFERENCE(S):

Hillel, D., 1980. Fundamentals of Soil Physics, 413 pp. Academy Press, New York, New York.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.5.1

CHAPTER/SECTION TITLE(S): Diffusion tests in the exploratory shaft facility

PAGE NUMBER(S): 8.3.1.2-253

PARAGRAPH NUMBER(S): 6

STATEMENT OF ISSUE:

Analysis of diffusion test.

DISCUSSION:

The SCP states the results of the diffusion test (tracer concentrations as a function of radial distance in the host rock surrounding a borehole) will be analyzed under the assumption that fluid flow does not occur. Inasmuch as the host rock will be initially unsaturated upon introduction of the tracer solution in the borehole, it would appear that fluid flow will occur outward from the free-standing liquid in the borehole. The plans to assume no fluid flow should therefore be re-evaluated. If fluid flow is neglected as planned, it would appear that diffusivity would be over-estimated.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.9

CHAPTER/SECTION TITLE(S): Unsaturated zone flow and transport modeling

PAGE NUMBER(S): 8.3.1.2-272 to 273

PARAGRAPH NUMBER(S): all

STATEMENT OF ISSUE:

Presentation of plans for unsaturated flow and transport modeling.

DISCUSSION:

The "plans" for modeling ground water flow and radionuclide transport in the unsaturated zone as presented in the SCP are essentially generic to any sophisticated modeling study. In other words, DOE is so far from actually performing any technically defensible modeling, that it is unlikely it will ever be done.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.9.1

CHAPTER/SECTION TITLE(S): Preliminary Numerical Modeling of the Site Hydrologic System

PAGE NUMBER(S): 8.3.1.2-274

PARAGRAPH NUMBER(S): 2

STATEMENT OF ISSUE:

Verification and validation of ground water modeling computer codes.

DISCUSSION:

The SCP states that all computer codes will be validated (establishing that the code and parameters adequately represent the site) prior to their application to site problems.

Whereas it would be highly desirable for all codes to be validated, more realistically this validation stage will not be realized for the vast majority unsaturated zone flow and transport codes. This is due to the complexity that the dual porosity tuff media (fractures and matrix), coupled with unsaturated conditions in an arid environment with episodic precipitation, presents.

Furthermore, it is not evident that the Site Characterization program can obtain the necessary input parameters. The vast majority of the planned site characterization tests are novel, and do not even have an established technique(s) to be implemented.

In light of this, numerical simulation of ground water and gaseous phase flow and accompanying radionuclide transport in unsaturated, fractured tuff under non-isothermal conditions will remain largely a guess. This is particularly true given the short duration allowed in the Nuclear Waste Policy Act for data collection and modeling.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.2.10

CHAPTER/SECTION TITLE(S): Unsaturated zone system analysis and integration

PAGE NUMBER(S): 8.3.1.2-279 to 284

PARAGRAPH NUMBER(S): all

STATEMENT OF ISSUE:

Lack of reference to previous modeling work.

DISCUSSION:

The presentation in this section of the SCP regarding the modeling of the unsaturated zone processes at Yucca Mountain, is noticeably devoid of references to the appreciable amount of modeling accomplished to date. It almost appears that DOE plans to start from scratch concerning the modeling. Surely this is not the case, however plans for efficient use of the previous modeling are not evident.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.3

CHAPTER/SECTION TITLE(S): Aquifer Properties

PAGE NUMBER(S): 8.3.1.2-295

PARAGRAPH NUMBER(S): 4

STATEMENT OF ISSUE:

Aquifer pumping tests to determine fracture-flow properties.

DISCUSSION:

This section of the SCP discusses several of the large areas of uncertainty in performing and interpreting hydraulic stress-testing in fractured media. "Catch-22" situations exist in this area in that pre-test analyses (modeling) of the test are sometimes necessary to design the tests adequately. A conceptual model of fracture flow (e.g. channel flow, parallel plate, etc.) must be available as a basis for such a pre-test analysis. However, without pump tests and similar field investigations, it is very difficult to develop a conceptual model. DOE appears to have an appreciation for such situations as reflected in this saturated-zone section of the SCP. Unfortunately, preceding sections of the SCP regarding gas-phase "pump" tests in the unsaturated zone present the plans for these tests as if they are routine. This is hardly the case, particularly so for fractures that may contain two phases (gas and liquid). The unsaturated zone section of the SCP should be presented with the same appreciation for uncertainty as this section.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.3

CHAPTER/SECTION TITLE(S): Synthesis and modeling (site saturated zone)

PAGE NUMBER(S): 8.3.1.2-297

PARAGRAPH NUMBER(S): 2

STATEMENT OF ISSUE:

Lack of reference to the regional modeling section of the SCP.

DISCUSSION:

The presentation in this section of the SCP does not make reference to the regional and sub-regional flow modeling section. Those modeling efforts are intended to provide technical bases (e.g. boundary conditions) for the site saturated zone modeling. Therefore, the site saturated zone modeling should occur after the regional modeling. The SCP should reflect such a chronology.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.3.1.1

CHAPTER/SECTION TITLE(S): Solitario Canyon fault study in the saturated zone

PAGE NUMBER(S): 8.3.1.2-298

PARAGRAPH NUMBER(S): 4

STATEMENT OF ISSUE:

Placement of boreholes for the 30 day pump test.

DISCUSSION:

The SCP suggests placing observation wells W-8 and W-9 on the opposite (west) side of the Solitario Fault from the pumping well W-7. While these wells may prove useful, detecting flow boundaries from pump tests are typically accomplished by having the observation well(s) on the same side of the boundary as the pumping well. A deviation from "normal" drawdown measured in the observation well would then be the indicator of the behavior of the boundary. For example, if the semi-log drawdown slope doubles, or otherwise greatly increases, a flow barrier is indicated. DOE should plan to install an additional observation well(s) between the pumping well and the fault.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.3.1.3

CHAPTER/SECTION TITLE(S): Analysis of previously completed hydraulic-stress tests

PAGE NUMBER(S): 8.3.1.2-310

PARAGRAPH NUMBER(S): 2

STATEMENT OF ISSUE:

Search for a theoretical flow model.

DISCUSSION:

The SCP suggests a theoretical model describing flow in the fractured system at the site will be selected that most closely matches the behavior observed in previous pump tests. While this is a good approach, provisions should be made for the need to consider more than one theoretical model. One model may reflect some aspects better while a different theory may better support other observed behavior. In such a situation, it may be necessary to incorporate the more conservative model due to the large amount of uncertainty that will surely exist regarding fracture flow analyses.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.3.1.5

CHAPTER/SECTION TITLE(S): Testing of the C-hole sites with conservative tracers

PAGE NUMBER(S): 8.3.1.2-320

PARAGRAPH NUMBER(S): 1

STATEMENT OF ISSUE:

Investigating matrix diffusion with tracer tests.

DISCUSSION:

The SCP states that tracer tests will be used at the C-holes site to possibly investigate matrix diffusion. While matrix diffusion can be used to explain the behavior of the "tails" of breakthrough curves of diffusing, conservative tracers; the DOE should consider using non-diffusing tracers also. Comparing results from a diffusing tracer test repeated with a non-diffusing tracer test may provide the best evaluation of matrix diffusion.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.3.1.6

CHAPTER/SECTION TITLE(S): Well testing with conservative tracers throughout the site

PAGE NUMBER(S): 8.3.1.2-325

PARAGRAPH NUMBER(S): 4

STATEMENT OF ISSUE:

Location of possible second multiple-well site for pump-testing and tracer testing.

DISCUSSION:

The SCP suggests a location immediately southwest of the repository block for multiple-well testing if single-well tests are determined to be inadequate. The approach is to select rocks significantly different from those of the C-holes location. Apparently, the reasoning here is to provide a range of values representative of the entire Yucca Mountain area. It may also be important to DOE to avoid drilling an abundance of drill holes in the down gradient area of the site (the southeast).

On the other hand, the properties of the rocks to the southwest may be irrelevant to the performance of the site. For the purposes of performance assessment, a location immediately to the southeast would be better. In addition, completing the wells near the water table may be more useful than 300m below it, as suggested in the SCP. In the area immediately adjacent to the repository, radionuclides will more likely migrate near the water table.

Whatever rationale is behind the suggested location of a second multiple well site should be clearly stated in the SCP.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.3.1.7

CHAPTER/SECTION TITLE(S): Testing of the C-hole sites with reactive tracers

PAGE NUMBER(S): 8.3.1.2-330

PARAGRAPH NUMBER(S): 3

STATEMENT OF ISSUE:

Lack of references to previous sorption studies.

DISCUSSION:

The SCP neglects to mention the significant amount of sorption data (mostly from laboratory batch experiments) available from previous studies. While this section does state an extensive literature search will be undertaken as a first step, other portions of the SCP reflect a more-prepared state of knowledge within DOE. This section needs to be fortified with citations to the important, comprehensive data bases on sorption such as those mentioned by Siegal, et al (1987).

REFERENCES:

Siegal, M., S. Phillips, J. Leckie and W. Kelly, 1987. "Development of a Methodology for Geochemical Sensitivity Analysis for Performance Assessment" Proceedings of DOE/AECL Conference Geostatistical Sensitivity and Uncertainty Methods for Ground-Water Flow and Radionuclide Transport Modeling, San Francisco, CA, September 1987.

CHAPTER/SECTION NUMBER(S): 8.3.1.2.3.3.2

CHAPTER/SECTION TITLE(S): Development of a fracture network model

PAGE NUMBER(S): 8.3.1.2-341

PARAGRAPH NUMBER(S): 2

STATEMENT OF ISSUE:

Equivalent porous medium approach.

DISCUSSION:

Within a fracture flow system, large zones of highly conductive fractures may exist at a scales equal to the scale of interest (kilometers). For this reason, there simply may not be a useful representative elementary volume that can be incorporated into an equivalent porous media (EPM) model. If DOE wishes to pursue the EPM approach, it should be done parallel to other approaches that address discrete zones as well, in case the EPM method proves unworkable.

CHAPTER/SECTION NUMBER(S): 8.3.1.6

CHAPTER/SECTION TITLE(S): Overview of erosion program: Description of the future erosional rates required by the performance and design issue

PAGE NUMBER(S): 8.3.1.6-1 through 8.3.1.6-6

PARAGRAPH NUMBER(S):

STATEMENT OF ISSUE:

Purpose of Chapter 8 and its relation to hypotheses.

DISCUSSION:

In a letter dated March 13, 1987, from DOE to Mr. Robert Loux of the Nevada Nuclear Waste Project Office, DOE states that, "Chapter 8 of the SCP contains a description of the plans for site characterization activities." DOE, however consistently uses Chapter 8 to present hypotheses established elsewhere without also presenting adequate technical data to justify the conclusions. For example, the hypothesis that erosional processes are not expected to effect waste isolation during the post closure period is repeated five times from page 8.3.1.6-1 to 8.3.1.6-6 without proper data presentation or referencing. In fact, the SCP admits a total lack of data on page 8.3.1.6-6: "...very little site-specific information is available that would allow for the quantification for the erosional processes at Yucca Mountain."

This type of undocumented hypothesis presentation not only unjustly establishes conclusions in the readers' (and DOE's) mind, but also downplays the importance of the planned site characterization activities. Chapter 8 should refrain from presenting undocumented hypotheses and concentrate on future characterization needs.

CHAPTER/SECTION NUMBER(S): 8.3.1.6

CHAPTER/SECTION TITLE(S): Overview of erosion program: Description of the future erosional rates required by the performance and design issue

PAGE NUMBER(S): 8.3.1.6-2

PARAGRAPH NUMBER(S): 1

STATEMENT OF ISSUE:

Maximum downwasting rate may be inaccurate.

DISCUSSION:

The SCP states that the "average maximum downwasting rate was estimated to be 2 cm/1000 years (Section 1.1)." Yet on page 8.3.1.6-6 the SCP also states "very little site-specific information is available that would allow for the quantification for erosional processes at Yucca Mountain". DOE's lack of data has led them to speculate on the downwasting rate, which may prove to be inaccurate.

Many geomorphologists believe that mountains in the semiarid climates have the most rapid rates of downwasting found anywhere on earth. This is supported by Langbein and Schumm, 1958, who report areas with 15 cm/year of precipitation (as Yucca Mountain) should downwaste an average of 6 cm/1000 years. This dramatically increases the downwasting rates presented by DOE.

REFERENCE(S):

Langbein, W.B. and S.A. Schumm, 1958. Yield of sediment in relation to mean annual precipitation. American Geophys. Un. Trans. v. 39, pp. 1076-84.

CHAPTER/SECTION NUMBER(S): 8.3.1.6.2

CHAPTER/SECTION TITLE(S): Erosion (Postclosure)/Potential effects of future climatic conditions on locations and rates of erosions

PAGE NUMBER(S): 8.3.1.6-15

PARAGRAPH NUMBER(S): 3

STATEMENT OF ISSUE:

Use of average regional erosion rates.

DISCUSSION:

The SCP addresses "average erosion rates in the region surrounding Yucca Mountain." If the SCP focuses research on obtaining only average regional erosion rates, the results could produce an inaccurate geomorphological scenario of the area. Erosion is not a uniform process and cannot be accurately depicted through average values. Any breach of a repository through erosion will not result from uniform downwasting but severe localized erosion. This type of scenario, not average erosion, should be the focus of the SCP's plans.

CHAPTER/SECTION NUMBER(S): 8.3.1.6.1.1.1

CHAPTER/SECTION TITLE(S): Development of a geomorphic map of Yucca Mountain

PAGE NUMBER(S): 8.3.1.6-10

PARAGRAPH NUMBER(S): all

STATEMENT OF ISSUE:

Study objectives will be difficult to obtain due to construction activities.

DISCUSSION:

To place a lot of value on this study seems unwarranted at this time due to the extreme alteration of deposits which has occurred over the past several years from exploratory operations. Roads run along the top of the mountain and much leveling has occurred for drilling platform construction. Much of the area of concern has been drastically altered by man and may not be representative of pre-man conditions.

CHAPTER/SECTION NUMBER(S): 8.3.1.6.2

CHAPTER/SECTION TITLE(S): Potential effects of future climatic conditions on locations and rates of erosion

PAGE NUMBER(S): 8.3.1.6-16

PARAGRAPH NUMBER(S): 2

STATEMENT OF ISSUE:

Inclusion of human effects in the future erosional processes model.

DISCUSSION:

The SCP introduces models aimed at forecasting future erosion rates relative to future climatic, tectonic and hydrologic trends. Included in these scenarios should be human effects upon erosion.

Human activity as an agent in promoting erosion on and around Yucca Mountain could be profound. Foot and motor vehicle traffic tends to loosen overburden and accelerate erosion. This increased rate of erosion will be a function of the amount and type of human activity and will tend to augment the natural erosionary processes.

CHAPTER/SECTION NUMBER(S): 8.3.1.6.3.1

CHAPTER/SECTION TITLE(S): Evaluation of the effects of future tectonic activity on erosion at Yucca Mountain

PAGE NUMBER(S): 8.3.1.6-22 thru 24

PARAGRAPH NUMBER(S): all

STATEMENT OF ISSUE:

Study 1.17.3.1 seems to have the wrong emphasis.

DISCUSSION:

The emphasis of study 1.17.3.1 is to assess the component of total erosion due to tectonics. This emphasis seems misplaced. Rather the issue is if renewed tectonic activity occurs, what are the effects on repository stability and groundwater transport. Erosion effects should be a low priority endeavor, given a renewed tectonics scenario.

CHAPTER/SECTION NUMBER(S): 8.3.1.12.1

CHAPTER/SECTION TITLE(S): Studies to provide data on regional meteorologic conditions

PAGE NUMBER(S): 8.3.1.12-8

PARAGRAPH NUMBER(S): 3

STATEMENT OF ISSUE:

General trends in parameters.

DISCUSSION:

The SCP states that since some of the data will only be available as several-year summaries, only general trends and averages for certain regions will be derived. The SCP does not get specific as to what these regions are and which data will be trends or averages. This should be known in advance, since independent researchers may have different needs for analysis. Affected parties should have more specific information as to what data will be generated.

CHAPTER/SECTION NUMBER(S): 8.3.1.12.1

CHAPTER/SECTION TITLE(S): Studies to provide data on regional meteorologic conditions

PAGE NUMBER(S): 8.3.1.12-9

PARAGRAPH NUMBER(S): 1

STATEMENT OF ISSUE:

Locations where impacts will be calculated unclear.

DISCUSSION:

Will other population centers that may not be as large as Las Vegas have impacts calculated, such as Pahrump? The SCP should list areas where impacts will be calculated.

CHAPTER/SECTION NUMBER(S): 8.3.1.12.2.1.2

CHAPTER/SECTION TITLE(S): Data summary for input to dose assessments

PAGE NUMBER(S): 8.3.1.12-24

PARAGRAPH NUMBER(S): 5

STATEMENT OF ISSUE:

Sufficiency of input data to terrain dispersion model.

DISCUSSION:

The SCP states that one year's worth of hourly sequential meteorological data will be used as input to calculate X/Q values at each designated receptor.

This could be problematic if the year's worth of data are not representative, i.e., a dry year or a wet year as opposed to an average year.

CHAPTER/SECTION NUMBER(S): 8.3.1.16.1

CHAPTER/SECTION TITLE(S): Flood recurrence intervals and levels at potential locations of surface facilities

PAGE NUMBER(S): 8.3.1.16-8 and 8.3.1.16-12

PARAGRAPH NUMBER(S): 3 and 5

STATEMENT OF ISSUE:

Effectiveness of log-Pearson approach.

DISCUSSION:

To be effective, the log-Pearson approach should have a long historical record. How long a record is available in areas of concern?

CHAPTER/SECTION NUMBER(S): 8.3.1.16.1.1.1

CHAPTER/SECTION TITLE(S): Site flood and debris hazards studies

PAGE NUMBER(S): 8.3.1.16-11

PARAGRAPH NUMBER(S): 4

STATEMENT OF ISSUE:

Debris hazards studies seem unwarranted.

DISCUSSION:

It is usually assumed some debris will be transported during a severe flood. However, to try and quantify the amount and assess a separate damage from the debris versus the flood seems unwarranted. The DOE admits that they do not really know how to go about it yet, since no standard techniques exist. Large forests are not present which could bring a large number of trees or logs into the facility. Rather, we are asking how much sediment do we have to contend with? It would appear that a worse case should be assumed, perhaps equal to flood stage, since such a scenario may still be acceptable, thereby ending this line of analysis. It is more likely that erosion would be more prevalent rather than deposition at Yucca Mountain. It seems unlikely that hazards would be very sensitive to the amount of sediment in the flood.

CHAPTER/SECTION NUMBER(S): 8.3.1.16.2.1.4

CHAPTER/SECTION TITLE(S): Identification and evaluation of potential effects of repository related withdrawals on the local flow system at Yucca Mountain, Nevada

PAGE NUMBER(S): 8.3.1.16-20

PARAGRAPH NUMBER(S): 6

STATEMENT OF ISSUE:

Objectives are not complete.

DISCUSSION:

The objectives should include effects on water supplies of downstream users such as the Amargosa area which is dependent on continuing water supplies for farming.

CHAPTER/SECTION NUMBER(S): 8.3.5.2

CHAPTER/SECTION TITLE(S): Waste retrievability/approach to resolving the issue

PAGE NUMBER(S): 8.3.5.2-3

PARAGRAPH NUMBER(S): 4

STATEMENT OF ISSUE:

Role of affected parties undefined.

DISCUSSION:

The role of affected Parties in the Issue resolution strategy is largely undefined. However, it is of utmost importance that states play a role in the setting of performance goals and in any modification of these goals which may occur at later stages.

CHAPTER/SECTION NUMBER(S): 8.3.5.2

CHAPTER/SECTION TITLE(S): Waste Retrievability

PAGE NUMBER(S): 8.3.5.2-14

PARAGRAPH NUMBER(S): 1

STATEMENT OF ISSUE:

Environment in non-operational areas may be too severe to permit reentry.

DISCUSSION:

The SCP formulates goals which are intended to ensure reentry into the non-operational areas for the purpose of waste retrieval. These goals call for temperatures not exceeding 50°C for up to 50 years beginning after waste emplacement is initiated. These reentry goals do not correspond to another SCP goal, usability for a period of 84 years after waste emplacement is initiated. The lack of uniformity among these goals will results in a 34 year retrieval period where the shafts and drifts will be physically usable, but the severe environment will not permit reentry to commence retrieval operations. The SCP should clarify this discrepancy.

CHAPTER/SECTION NUMBER(S): 8.3.5.2

CHAPTER/SECTION TITLE(S): Waste Retrievability

PAGE NUMBER(S): 8.3.5.2-17

PARAGRAPH NUMBER(S): 3

STATEMENT OF ISSUE:

"Of primary concern is the ability of the host rock ... to provide an acceptable level of shielding during waste removal."

DISCUSSION:

The host rock is not a component of the waste package and cannot be counted on to provide shielding during the waste package removal.

CHAPTER/SECTION NUMBER(S): 8.3.5.2

CHAPTER/SECTION TITLE(S): Waste Retrievability

PAGE NUMBER(S): 8.3.5.2-20

PARAGRAPH NUMBER(S): 2

STATEMENT OF ISSUE:

Analyses of transporter design and performance.

DISCUSSION:

The SCP states "Numerous analyses of the performance and design of the transporter will be needed . . ." This is an obvious assumption. Specific requirements for operator exposure to radiation and other safety features should be listed.

CHAPTER/SECTION NUMBER(S): 8.3.5.2.5

CHAPTER/SECTION TITLE(S): Waste Retrievability - Transport to the Surface

PAGE NUMBER(S): 8.3.5.2-54

PARAGRAPH NUMBER(S): Table 8.3.5.2-12

STATEMENT OF ISSUE:

Waste transport from the repository to the surface.

DISCUSSION:

The SCP discusses the design issues of waste transport underground and unloading at the surface, but does not specifically address the vertical transport of the waste from the repository to the surface together with the accompanying weight limitations. The SCP should present the information needs of the vertical transport system.

CHAPTER/SECTION NUMBER(S): 8.3.5.3

CHAPTER/SECTION TITLE(S): Identification of radiation source characteristics

PAGE NUMBER(S): 8.3.5.3-15

PARAGRAPH NUMBER(S): 3

STATEMENT OF ISSUE:

There is no information regarding scenarios used for the analyses.

DISCUSSION:

These analyses are for normal operating only. What assumptions will be made in these analyses? For example, what is a worse case scenario? Is the analysis to assume no releases from canisters? What about accidents involving dropped canisters?

CHAPTER/SECTION NUMBER(S): 8.3.5.3

CHAPTER/SECTION TITLE(S): Public radiation exposure calculation

PAGE NUMBER(S): 8.3.5.3-17

PARAGRAPH NUMBER(S): 2

STATEMENT OF ISSUE:

Calculation of maximum radiation exposure to the public.

DISCUSSION:

The SCP states that maximum public-dose exposure will evaluate releases from routine operation of the repository and offsite facilities. DOE should also include background radiation in this determination. The combined exposure of all three components should be within applicable limits. This is the only way to truly assure total public exposure is below allowable thresholds.

CHAPTER/SECTION NUMBER(S): 8.3.5.5

CHAPTER/SECTION TITLE(S): Accidental Radiological Releases/Interrelationships of information needs

PAGE NUMBER(S): 8.3.5.5-19

PARAGRAPH NUMBER(S): 1

STATEMENT OF ISSUE:

Worst case scenarios should be used in exposure analyses.

DISCUSSION:

Question one reads: What are credible accident sequences and their respective frequencies . . ." This statement should include credible "worst case" accidents.

In order to adequately construct ventilation systems, and safeguards for workers and the public, DOE should perform its accident exposure analyses on the credible worst case scenario. The present wording allows analyses to be based on "credible accidents", which based on DOE's optimism regarding repository performance, may produce unrealistic accident exposure analyses.

CHAPTER/SECTION NUMBER(S): 8.3.5.8

CHAPTER/SECTION TITLE(S): Strategy for postclosure performance assessment

PAGE NUMBER(S): 8.3.5.8-8

PARAGRAPH NUMBER(S): 4

STATEMENT OF ISSUE:

Can thermal diffusion be ruled out as a driving transport mechanism?

DISCUSSION:

If one assumes a dry environment, then possibly this mechanism can be considered to be minimal. However, current models assume water influx controlled waste-package-release. The high temperature gradients between the waste package and surrounding county rock will almost certainly cause some thermal diffusion effects.

CHAPTER/SECTION NUMBER(S): 8.3.5.8

CHAPTER/SECTION TITLE(S): Strategy for postclosure performance assessment

PAGE NUMBER(S): 8.3.5.8-8, 9

PARAGRAPH NUMBER(S): 5, 6, 1

STATEMENT OF ISSUE:

Most probable boundary condition of percolation flux questionable.

DISCUSSION:

To assume a very small steady state flux within the matrix only has potentially serious ramifications. It has been pointed out many times by various reviewers that reliance on diffusion into the matrix is not well founded for fractured materials such as welded tuff. While this argument may have validity in granitic or other crystalline terrains, it has not been shown valid for tuff. An effort must be made to determine fracture transport conditions. This investigation must be carried out during site characterization. An approach which tries to disprove the steady state assumption should be a part of the strategy, rather than a confirmatory approach.

CHAPTER/SECTION NUMBER(S): 8.3.5.9

CHAPTER/SECTION TITLE(S): Containment by Waste Package

PAGE NUMBER(S): 8.3.5.9-7

PARAGRAPH NUMBER(S): Table 8.3.5.9-1

STATEMENT OF ISSUE:

Water flux goals for waste packages.

DISCUSSION:

It is not clear how the 90% goal was arrived at. Was an analysis done to show that if 90% of canisters met goals there would be no significant effects? What about the other 10% - what kind of releases were considered for these?

CHAPTER/SECTION NUMBER(S): 8.3.5.9

CHAPTER/SECTION TITLE(S): Containment by the Waste Package - Localized Attack

PAGE NUMBER(S): 8.3.5.9-37

PARAGRAPH NUMBER(S): 4

STATEMENT OF ISSUE:

Localized corrosion is not adequately addressed.

DISCUSSION:

Localized corrosion can occur wherever there exist differences between one region of the overpack and another. These may be built in the metal in the form of grain boundary segregation, composition inhomogeneities or second phases, or they may result from the operating conditions in the repository. For example, temperature differences at the metal-backfill interface due to the geometry of the container and/or differences in contact conditions, differences in the chemical composition of moisture contacting different portions of overpack surface arising from the water having percolated through different minerals in the surrounding tuff differences in porosity or in degree of adherence of solid corrosion products, any of these may produce enhanced corrosion at one locality, pitting, or crevice corrosion.

These effects are insidious and difficult to characterize and measure. Difficulty of prediction is compounded by the mineralogical diversity at the tuff site and by the variability of composition and of processing of the commercial alloys designated today as reference and as alternate materials. Localized corrosion in all its manifestations needs very careful study to develop sufficient understanding that predictive models can be developed. The effect of radiation on localized corrosion needs more investigation, as does the question of microbial corrosion. Even in a gamma radiation field, microbial corrosion does not have a zero probability, since it is now known that some microbes can withstand amazingly high levels of radiation.

CHAPTER/SECTION NUMBER(S): 8.3.5.9

CHAPTER/SECTION TITLE(S): Containment by the Waste Package - Stress corrosion cracking

PAGE NUMBER(S): 8.3.5.9-38

PARAGRAPH NUMBER(S): 3

STATEMENT OF ISSUE:

Late stage effects of corrosion is not adequately addressed.

DISCUSSION:

Another set of problems may develop at a much later stage in the waste disposal history if it should happen that the overpack is breached by some corrosion failure mode. Then the inner container will be attacked by the corrosive environment, and since the inner container and the overpack will be in metallic contact, galvanic effects will occur to increase the anodic reactions at one metal and the cathodic reaction at the other.

When the relatively thin inner container is breached, the corrosive environment will suffer a change of chemistry because the waste form will dissolve (in the case of vitrified wastes) or corrode (in the case of clad spent fuel rods). In the latter case the zirconium cladding will absorb hydrogen from the corrosion reaction and it is likely that the hydrides formed thereby will hasten the liberation of radionuclides by virtue of the stresses generated. The modified water chemistry will change the corrosion rate of the overpack and the inner container, which will affect the rate of widening of the breach, and hence the access of radionuclides to the backfill. The transport of radionuclides to the host rock will at this stage be controlled by the characteristics of the backfill after the temperature, radiation, and water intrusion history that it has undergone. It is known that steam treatment at high-temperatures can reduce the swelling capacity of bentonite and can increase its permeability. Channeling is a real possibility, whereby transport to the host rock can be considerably increased in rate.

CHAPTER/SECTION NUMBER(S): 8.3.5.9

CHAPTER/SECTION TITLE(S): Containment by the Waste Package - Metallurgical and Mechanical effects

PAGE NUMBER(S): 8.3.5.9-36

PARAGRAPH NUMBER(S): 2

STATEMENT OF ISSUE:

Types and rates of mechanical degradation are not adequately addressed.

DISCUSSION:

With respect to long-term metallurgical changes during disposal, unresolved issues include strain aging in and near welds, and for the metastable austenitic stainless steels for the tuff repository, martensite may form or low temperature sensitization may occur.

CHAPTER/SECTION NUMBER(S): 8.3.5.9

CHAPTER/SECTION TITLE(S): Containment by the Waste Package - Intergranular attack and intergranular stress corrosion cracking

PAGE NUMBER(S): 8.3.5.9-37

PARAGRAPH NUMBER(S): 3

STATEMENT OF ISSUE:

Interaction of stress with corrosion is not adequately addressed.

DISCUSSION:

The synergistic interaction of stress with corrosion is potentially the most catastrophic failure mode. Residual stresses arising from welding operations or from long-term phase transformation as well as stresses generated thermally or by external forces can interact with hydrogen absorbed by the metal from the cathodic partial of the corrosion process and/or from the radiolysis of water to produce embrittlement of steel, especially at or near the welds. In addition, hydrogen degradation of annealed steel has been found to occur, presumably because of the induced impurity segregation at grain boundaries.

In the earlier portion of the storage life of the waste package, sufficiently high temperatures will be obtained to make hydrogen attack in steel a possibility. The formation of methane and the attendant grain boundary porosity embrittles the steel. Another synergism between stress and environment can develop when water solutions contact the metal, especially stress corrosion cracking of the austenitic steels in the presence of chlorides. It has been found through noted experimentation that where, "metal temperatures are high enough to cause concentration of chlorides on the metal surface, cracking may occur even where the chloride concentration in the surrounding media is only a few parts per million" (Perry et al., 1963). This stress corrosion cracking occurs only for a specific temperature range of greater and solute concentration range. Except for copper, every alloy considered for waste package use undergoes stress corrosion cracking in some environment.

It follows that each alloy must be examined in all credible solutions and temperature ranges, and if the radiation level is to be appreciable, because of relatively thin wall thickness, at the outer surface of the overpack, the effect of radiation on stress corrosion cracking should also be examined. As much understanding of this very complex failure mode should be developed to maximize life prediction ability.

REFERENCE(S):

Perry, Robert H., Cecil H. Chilton, Sidney Kirkpatrick, 1963. Chemical Engineers' Handbook. McGraw-Hill, New York, NY. p. 23-3.

CHAPTER/SECTION NUMBER(S): 8.3.5.9.1.1.4

CHAPTER/SECTION TITLE(S): Containment by Waste Package/ Subactivity 1.4.1.1.4: State of stress in the container

PAGE NUMBER(S): 8.3.5.9-47

PARAGRAPH NUMBER(S): 5

STATEMENT OF ISSUE:

Verification of analyses.

DISCUSSION:

This paragraph states that, "When possible or feasible, the analysis will be supplemented by actual stress measurements on prototype canisters."

This sentence should be rephrased to indicate that actual measurements must be done as a verification of what appears to be a computer analysis. These measurements must be made on actual canisters, not just prototypes or scale models.

CHAPTER/SECTION NUMBER(S): 8.3.5.9.2.1.1

CHAPTER/SECTION TITLE(S): Containment by the Waste Package/ Subactivity 1.4.2.1.1: Establishment of selection criteria and their weighting factors

PAGE NUMBER(S): 8.3.5.9-59

PARAGRAPH NUMBER(S): 2

STATEMENT OF ISSUE:

Criteria for containment objectives should include corrosion caused by microbial action and the radiolytic generation of hydrogen, oxygen and other species.

DISCUSSION:

The near field environmental and thermal degradation modes should include the effects of microbial and radiological effects upon the waste package. It is known that certain microbes can withstand high levels of gamma radiation, so the possibility of microbial corrosion should not be ruled out. Additionally, the radiolytic generation of hydrogen, oxygen and other species due to gamma radiation may affect corrosion as well. The criteria for containment objectives should therefore include two addition items:

g. Resistance to microbial corrosion
h. Resistance to corrosion caused by the radiolytic generation of hydrogen, oxygen and other species.

CHAPTER/SECTION NUMBER(S): 8.3.5.9.3.2.4

CHAPTER/SECTION TITLE(S): Containment by the Waste Package/ Subactivity 1.4.3.2.4: Intergranular attach and intergranular stress corrosion cracking

PAGE NUMBER(S): 8.3.5.9-83

PARAGRAPH NUMBER(S): 2

STATEMENT OF ISSUE:

The intergranular stress corrosion analysis of the austenitic stainless steels is inadequate.

DISCUSSION:

Localized electrochemical attack occurs and progresses preferentially along the grain boundaries of an alloy, usually because the grain boundary regions contain material that is anodic to the central region of the grains. It is now generally accepted in the case of the austenitic stainless steels that some of the chromium combines with the carbon to form chromium carbide which is precipitated at the grain boundaries when the alloy is heated or cooled slowly.

The rate and extent of the formation of the chromium carbide are functions of time, temperature, and carbon content. It occurs during welding in the base metal adjacent to the deposited metal. As a result of the localized impoverishment of chromium at the grain boundaries, preferential corrosion may occur at the grain boundaries in some environments. Although the SCP addresses the carbide precipitation, it should also discuss intergranular attack as a function of chromium carbide formation at the weld/base metal boundaries.

CHAPTER/SECTION NUMBER(S): 8.3.5.9.3.2.5

CHAPTER/SECTION TITLE(S): Containment by the Waste Package/ Subactivity 1.4.3.2.5: Hydrogen entry and embrittlement

PAGE NUMBER(S): 8.3.5.9-87

PARAGRAPH NUMBER(S): all

STATEMENT OF ISSUE:

The analysis of hydrogen-induced degradation mechanisms of the austenitic stainless steel waste package is inadequate.

DISCUSSION:

The SCP fails to identify one important hydrogen-induced degradation mechanism of the austenitic stainless steel waste package. Hydrogen may attack stainless steel when it reacts with iron carbides in the steel to form methane. This degradation mechanism is not considered corrosion and occurs most commonly under dry conditions at elevated temperatures and pressures. Resistance to this type of degradation increases with chromium concentration because of the greater stability of chromium carbides. The SCP should discuss hydrogen induced methane production and its effects upon the waste package.

CHAPTER/SECTION NUMBER(S): 8.3.5.9.3.2.7

CHAPTER/SECTION TITLE(S): Containment by the Waste Package/ Subactivity 1.4.3.2.7: Transgranular Stress Corrosion Cracking

PAGE NUMBER(S): 8.3.5.9-89

PARAGRAPH NUMBER(S): 5

STATEMENT OF ISSUE:

The generation of oxidizing species that are expected to influence the chloride level.

DISCUSSION:

The SCP states on pages 8.3.5.9-89, "The concentration of oxygen, nitrate and other oxidizing species is expected to influence the critical chloride level for crack initiation." The SCP should also address the sources of oxidizing species, since some will be native to the near field environment and some could be generated radiolytically due to gamma radiation. Since the radiolytic generation of oxidizing species could influence the concentration of chloride, the rates of which these species are produced should be examined.

CHAPTER/SECTION NUMBER(S): 8.3.5.10

CHAPTER/SECTION TITLE(S): Engineered Barrier System Release Rates

PAGE NUMBER(S): 8.3.5.10-31

PARAGRAPH NUMBER(S): 4

STATEMENT OF ISSUE:

The SCP underestimates the dissolution rate of spent fuel by a factor of five.

DISCUSSION:

The SCP states that a performance goal of the spent fuel dissolution rate will be "no more than one part in 100,000/year." This grossly contradicts the Yucca Mountain EA on page 6-373, which reports figures of five parts in 100,000/year from two separate studies. The SCP should adopt the established results of the scientific studies or present data and discussion which justifies its lower estimates.

CHAPTER/SECTION NUMBER(S): 8.3.5.10.2.1.2

CHAPTER/SECTION TITLE(S): Engineered Barrier System Release Rates/Subactivity 1.5.2.1.2 - Oxidation of Spent Fuel

PAGE NUMBER(S): 8.3.5.10-40

PARAGRAPH NUMBER(S): 4

STATEMENT OF ISSUE:

No citations for references

DISCUSSION:

The SCP references various sources such as Einziger (1985) and Smith (1985) without adequately documenting the citation. The SCP should provide complete citations of all references at a convenient location for the reader.

CHAPTER/SECTION NUMBER(S): 8.3.5.10.2.2.1

CHAPTER/SECTION TITLE(S): Engineered Barrier System Release Rates/Subactivity 1.5.2.2.1 - Leach Testing of Glass

PAGE NUMBER(S): 8.3.5.10-45

PARAGRAPH NUMBER(S): 5

STATEMENT OF ISSUE:

Inadequacy of leaching water testing.

DISCUSSION:

The SCP reports that, "Water dripping onto and off glass" is an important example of radionuclide release. The SCP tends to concentrate on the chemical degradation of the waste form by leaching water, however, and fails to mention an important mode of degradation mechanical erosion. The consistent dripping of water upon a breached waste canister will have a definite mechanical, as well as chemical erosionary effect upon the waste form. This mechanism should be included in the leach testing.

CHAPTER/SECTION NUMBER(S): 8.3.5.12

CHAPTER/SECTION TITLE(S): Ground-Water Travel Time

PAGE NUMBER(S): 8.3.5.12-15

PARAGRAPH NUMBER(S): 3

STATEMENT OF ISSUE:

Relocation of Repository to maximize fastest groundwater flow path as per Codell, 1986.

DISCUSSION:

The fastest groundwater flow path may be interpreted as being present at the northeast corner of the current facility design since the vitric unit of the Calico Hills tuff is thin or absent in this area. This has prompted the DOE to consider relocating the current repository design position, to avoid this area. This appears to be a good move, but more data regarding what this does to size, loadings, and proximity to faults would be required before the State could agree with such a move.

CHAPTER/SECTION NUMBER(S): 8.3.5.12

CHAPTER/SECTION TITLE(S): Ground-water Travel Time

PAGE NUMBER(S): 8.3.5.12-6

PARAGRAPH NUMBER(S): 1

STATEMENT OF ISSUE:

Resolution of issues.

DISCUSSION:

The DOE strategy states, "If any combination of a single unit and set of processes could be shown to meet the goal of 1,000 years, the issue will be considered resolved." This is on the surface a logical statement and if all affected parties are in agreement on the assumptions used in the analysis, it would be reasonable. However, it should be pointed out that this will probably become a major issue. First of all, the testing proposed for the unsaturated zone is on an accelerated schedule. It is very likely that all information needs will not be satisfied to an acceptable degree of uncertainty. Herein lies the problem, DOE probably will not know the degree to which various processes operate and contribute to the velocity term. Instead, DOE will probably assert that matrix flow is the only feasible flow regime in the unsaturated zone. This will lead to the conclusion that the Topopah Spring member itself will meet the GWTT criteria, and therefore the issue is resolved. Affected parties, however, may argue that the data do not conclusively indicate that fracture flow is insignificant, which would argue against the issue being resolved. Without substantial guarantees laid out in the IRS for state technical issue resolution, such situations will become commonplace.

CHAPTER/SECTION NUMBER(S): 8.3.5.12

CHAPTER/SECTION TITLE(S): Ground-Water Travel Time

PAGE NUMBER(S): 8.3.5.12-15

PARAGRAPH NUMBER(S): 3

STATEMENT OF ISSUE:

Inclusion of the entire Disturbed Zone as a starting point for calculating Ground Water Travel Time.

DISCUSSION:

The SCP states that because of uncertainty, "...it is possible that flow from the entire disturbed zone boundary over the entire site may be included in the distribution of travel time relevant to this issue." This approach would be inconsistent with the intent of the Ground Water Travel Time requirement specifying the "fastest path" of likely radionuclide travel. By including the entire disturbed zone as a starting point, the cumulative distribution function (CDF) for travel time would be inappropriately skewed to the large travel times. The CDF should only be based on the "fastest path" as determined from Site Characterization.

CHAPTER/SECTION NUMBER(S): 8.3.5.12

CHAPTER/SECTION TITLE(S): Ground-Water Travel Time

PAGE NUMBER(S): 8.3.5.12-16

PARAGRAPH NUMBER(S): 2

STATEMENT OF ISSUE:

Reliance on matrix diffusion to determine the fastest path of likely radionuclide travel.

DISCUSSION:

The SCP states that the inclusion of matrix diffusion processes in the Ground Water Travel Time calculation will be exercised if fracture flow is found to be significant at Yucca Mountain. It should be realized that matrix diffusion processes may be very difficult to support technically as is stated by the U.S. NRC in the following quote:

> "The mechanisms of matrix diffusion are difficult to evaluate in the field. Without direct measurements of the appropriate coefficients, estimates of the effect of matrix diffusion would have to be based on mathematical models which are largely untested, using parameters which are difficult or impossible to substantiate" (Codell, 1986).

Furthermore, the Site Characterization program is only allowed a relatively short time for its completion. As described in the SCP (Chapter 8.3.1.2 - Geohydrology), the planned activities do not even include references to using non-diffusing tracers in comparison with diffusing tracers to investigate the possibility of matrix diffusion. In other words, the planned site characterization investigations do not appear to be adequate in order to support reliance on a process the NRC has stated may be virtually impossible to substantiate.

REFERENCE(S):

Codell, R., 1986. "Draft Generic Technical Position on Ground Water Travel Time" U.S. Nuclear Regulatory Commission, Division of Waste Management. June, 1986.

CHAPTER/SECTION NUMBER(S): 8.3.5.12.1

CHAPTER/SECTION TITLE(S): Ground-Water Travel Time/Information Need 1.6.1 - Site Information and design concepts needed to identify the fastest path of likely radionuclide travel and to calculate the ground water travel time along that path

PAGE NUMBER(S): 8.3.5.12-30 thru 35

PARAGRAPH NUMBER(S): Table 8.3.5.12-3

STATEMENT OF ISSUE:

Current evaluation of the importance of parameters for the unsaturated zone.

DISCUSSION:

The desired levels of confidence for the fracture properties would appear to be ranked too low given the importance of determining the extent of fracture flow occurring at the site. If significant recharge is occurring through the unsaturated zone at Yucca Mountain, it is probably occurring via transient, fracture flow episodes. The isolation capabilities of the site are heavily based on the assumption that very little recharge occurs through the unsaturated zone. This assumption would appear to hold if only matrix flow is occurring due to the low hydraulic conductivity of the tuff matrix. However, it is not known if fracture flow occurs. Therefore, determining the fracture flow parameters in Table 8.3.5.12.3 should be given "high" priority.

CHAPTER/SECTION NUMBER(S): 8.3.5.12.2

CHAPTER/SECTION TITLE(S): Ground-Water Travel Time/Information Need 1.6.2 - Calculational methods to predict ground water travel times between the disturbed zone and the accessible environment

PAGE NUMBER(S): 8.3.5.12-42

PARAGRAPH NUMBER(S): 2

STATEMENT OF ISSUE:

Assumption of equilibrium between the matrix and fractures in the composite medium model.

DISCUSSION:

It would appear the composite medium approach of Klavetter and Peters (1986) may be appropriate for steady-state simulations but not for transient cases, especially so for unsaturated flow. As part of the SCP, the DOE should consider what approach will be taken if better models do not become available.

REFERENCE(S):

Klavetter, E.A. and R.R. Peters, 1986. "Fluid Flow in a Fractured Rock Mass". SAND85-0855 Sandia National Laboratories for the U.S. DOE.

CHAPTER/SECTION NUMBER(S): 8.3.5.12.2

CHAPTER/SECTION TITLE(S): Ground-Water Travel Time/Information Need 1.6.2 - Calculational methods to predict ground water travel times between the disturbed zone and the accessible environment

PAGE NUMBER(S): 8.3.5.12-42

PARAGRAPH NUMBER(S): 3

STATEMENT OF ISSUE:

Reference to Wang and Narasimhan, (1985 & 1986) regarding flow along and across fractures.

DISCUSSION:

It should be realized by the DOE that the Wang and Narasimhan simulations were only successful for steady-state or near steady-state flow across fractures at low levels of saturation. Flow along fractures was not simulated adequately. A substantial amount of work needs to be done regarding transient flow conditions in fractures in the presence of partially-saturated matrix, before conclusions can be made regarding infiltration through the unsaturated zone at Yucca Mountain.

REFERENCE:

Wang, J.S.Y. and T.N. Narasimhan, 1985. "Hydrologic Mechanisms Governing Fluid Flow in Partially Saturated, Fractured, Porous Tuff at Yucca Mountain." SAND84-7202 Sandia National Laboratories for the U.S. Department of Energy.

Wang, J.S.Y. and T.N. Narasimhan, 1986. "Hydrologic Mechanisms Governing Partially Saturated Fluid Flow in Fractured Welded Units and Porous Non-Welded Units at Yucca Mountain." SAND85-7114 Sandia National Laboratories .

CHAPTER/SECTION NUMBER(S): 8.3.5.12.2.1.1

CHAPTER/SECTION TITLE(S): Ground Water Travel Time/Development of a theoretical framework for calculating models

PAGE NUMBER(S): 8.3.5.12-44, 45

PARAGRAPH NUMBER(S): all

STATEMENT OF ISSUE:

Sub-activity 1.6.2.1.1 - Theoretical framework.

DISCUSSION:

The fact that development of a mathematical representation of flow at the site has not yet been adequately accomplished, indicates the rudimentary understanding of ground water flow at the site on the part of the DOE. To provide reasonable assurance, as required by the U.S. NRC regarding issues such as satisfying the ground water travel time requirement at Yucca Mountain, will require a much longer period of time for site characterization than is allowed for in the current schedule. Because of the complexity of fluid flow and energy transport processes in unsaturated rocks makes quantitative studies more difficult and less certain than for some other media, the relative favorability of Yucca Mountain as a repository location must be considered diminished.

CHAPTER/SECTION NUMBER(S): 8.3.5.12.3

CHAPTER/SECTION TITLE(S): Ground Water Travel Time/Information Need 1.6.3 - Identification of the paths of likely radionuclide travel from the disturbed zone to the accessible environment, and identification of the fastest path.

PAGE NUMBER(S): 8.3.5.12-50, 51

PARAGRAPH NUMBER(S): all

STATEMENT OF ISSUE:

Determination of the cumulative distribution function (CDF) for ground water travel time.

DISCUSSION:

The SCP describes two methods for determining the CDF for use in demonstrating compliance with the U.S. NRC ground water travel time requirement 10 CFR 60.113(a)(2). This requirement reads,

"The geologic repository shall be located so that the pre-waste emplacement groundwater travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment shall be at least 1000 years or such other travel time may be approved or specified by the Commission."

In draft NRC guidance (Codell, 1986), NRC staff states that this criterion is intended to be easily defined and determined. Also the NRC intends the CDF will become more steep as more information is derived. This would indicate the second CDF approach listed in this part of the SCP is what the NRC had in mind inasmuch as identifying all the paths would not necessarily make the CDF more steep. By developing a CDF for the fastest path only and refining that path, the true intent of the NRC rule would be adhered to. It is clear that all paths should not be used to construct the CDF but only the fastest path.

REFERENCE(S):

U.S. NRC, 1983. Code of Federal Regulations. 10 CFR Part 60.

U.S. NRC, 1986. "Draft Generic Technical Position on Groundwater Travel Time". Division of Waste Management, Office of Nuclear Material Safety and Safeguards. Washington, D.C.

CHAPTER/SECTION NUMBER(S): 8.3.5.12.5

CHAPTER/SECTION TITLE(S): Ground Water Travel Time/Information Need - 1.6.5: Boundary of the disturbed zone

PAGE NUMBER (S): 8.3.5.12-61

PARAGRAPH NUMBER(S): 2

STATEMENT OF ISSUE:

GWTT calculations will use only matrix flow parameters.

DISCUSSION:

Pages 8.3.5.12-40 thru 44 discusses models to be used to predict "groundwater travel times between the disturbed zone and the accessible environment for the purpose of determining pre-waste-emplacement of groundwater travel time."

It appears DOE will only be using a matrix flow code to assess groundwater travel time instead of the dual porosity (special case) code as described earlier (Klavetter and Peters, 1986). This calculation should be done using both methods to determine the more conservative approach.

CHAPTER/SECTION NUMBER(S): 8.3.5.12.5

CHAPTER/SECTION TITLE(S): Ground water travel time/Information Need 1.6.5 - Boundary of the disturbed zone

PAGE NUMBER(S): 8.3.5.12-62

PARAGRAPH NUMBER(S): 3

STATEMENT OF ISSUE:

Extent of the disturbed zone.

DISCUSSION:

The SCP suggests that at Yucca Mountain, the boundary of the disturbed zone will be much less than 50m from the edge of the underground opening. It is clear from this section of the SCP that this assertion is based only on stress-redistribution calculations. It does not take into account thermochemical processes such as hydration/dehydration, phase change, and dissolution of geologic material. Such processes are likely to be important in an unsaturated flow system such as that at Yucca Mountain.

CHAPTER/SECTION NUMBER(S): 8.3.5.13

CHAPTER/SECTION TITLE(S): Total System Performance - A preliminary selection of release-scenario classes for Yucca Mountain repository site

PAGE NUMBER(S): 8.3.5.13-15

PARAGRAPH NUMBER(S): Table 8.3.5.13-3

STATEMENT OF ISSUE:

Anticipated events and processes.

DISCUSSION:

Rapid fracture flow should be used as a means for partial failure of the unsaturated zone barriers (supercategory (C)).

Investigations to date regarding the unsaturated zone at Yucca Mountain have not established whether periods of rapid, fracture flow occur as a recharge mechanism. Downward water velocities in excess of 60 meters/year were calculated by Tyler (1986) based on the work of Clebsch (1961) at Ranier Mesa, also on the Nevada Test Site. Tyler (1986) concludes:

> "... a large number of studies have indicated that soil water movement in the alluvial valleys of the NTS and surrounding areas receiving periodic inundation. Studies in fractured rock environments, although far less in number, indicate the potential for rapid fluid migration is high. Human activities requiring isolation from the underlying groundwater system should be designed with this data in mind."

Based on studies such as Tyler (1986) and Clebsch (1961), and the lack of understanding regarding fracture flow at the Nevada Test Site, episodic fracture flow through the unsaturated zone should be considered to have a probability of greater than 0.1. Therefore, it should be an anticipated process in performance assessments at Yucca Mountain until conclusive evidence indicating otherwise becomes available. At this point, such evidence has clearly not been established. This scenario is different, although the consequences may be similar, from an "altered" hydrogeologic system when, for example, a wetter climate is assumed to exist.

CHAPTER/SECTION NUMBER(S): 8.3.5.13

CHAPTER/SECTION TITLE(S): Total System Performance

PAGE NUMBER(S): 8.3.5.13-34

PARAGRAPH NUMBER(S): 1

STATEMENT OF ISSUE:

Calculation of time period between onset of an event and the start of release.

DISCUSSION:

The SCP states "In those cases where the calculations proves difficult or time consuming, t_p may conservatively be set to zero." While this is reasonable, care must be taken that a large number of parameters are not set this way. This would decrease the validity of the model, leaving it open to criticism of being overly conservative. DOE should clarify "difficult or time consuming" to avoid using this statement as an default loophole.

CHAPTER/SECTION NUMBER(S): 8.3.5.13

CHAPTER/SECTION TITLE(S): Total System Performance

PAGE NUMBER(S): 8.3.5.13-75

PARAGRAPH NUMBER(S):

STATEMENT OF ISSUE:

Steps 4 and 5 are not well explained.

DISCUSSION:

It is not clear how these scenarios can be lumped or described by one model when different processes come into play. Many simplifying assumptions will have to be made to assess effects of faulting or tectonic movements on groundwater flow fields, etc.

CHAPTER/SECTION NUMBER(S): 8.3.5.15

CHAPTER/SECTION TITLE(S): Ground Water Protection

PAGE NUMBER(S): 8.3.5.15-6

PARAGRAPH NUMBER(S): 4

STATEMENT OF ISSUE:

Premature assumption that site aquifers are not vulnerable to contamination within the first 1000 years after waste emplacement.

DISCUSSION:

The SCP assigns a medium level of confidence that contamination from the emplaced waste will not impact the three site aquifers in 1000 years. The current understanding of fluid flow in the unsaturated zone does not warrant "medium" confidence. Rapid rate fracture flow remains a possibility and a recent report by Jerry Szymanski of the DOE raises further uncertainties on isolation abilities of the unsaturated zone.

REFERENCE(S):

Szymanski, Jerry, 1987. "Conceptual Considerations of the Death Valley Groundwater System with Special Emphasis on the Adequacy of This System to Accommodate the High-Level Nuclear Waste Repository". U.S. DOE, Nevada Operations Office.

CHAPTER/SECTION NUMBER(S): 8.3.5.15.1.1

CHAPTER/SECTION TITLE(S): Ground-Water Protection/Determine whether any aquifers near the site meet the Class I or special source criteria

PAGE NUMBER(S): 8.3.5.15-7

PARAGRAPH NUMBER(S): all

STATEMENT OF ISSUE:

Methods to be used in this activity are not defined.

DISCUSSION:

The description given for activities in this section are not complete. The SCP states parameters will be extracted from other investigations and analyzed. No mention is given as to how much data will be synthesized or even how this will be accomplished. It appears the DOE is not sure of how to proceed in satisfying regulatory requirements of 40 CFR 191.16.

COMMENTS OF

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General Comments and Observations on Yucca Mountain CD/SCP

1. Successful development of a underground geological repository for high level radioactive waste will ultimately depend upon positive demonstration in a legal arena that all of the applicable Nuclear Regulatory Commissions regulations have been met. It has been demonstrated on many occasions that nuclear sites with obvious geologic shortcomings (e.g. Bodega Bay, Humboldt Bay, Point Arena, Skagit, San Onofre, Diablo Canyon) or where the geologic system is inadequate to readily resolve the issues (North Anna, Nine Mile Point, Hanford, Trojan, Satsop) will be subjected to long and costly delays. In the January 1988 Consultive Draft Site Characterization Plan (CD/SCP) the DOE appears not to recognize or has purposely ignored several major geologic issues that will most likely make Yucca Mountain more difficult to successfully get through the NRC licensing process than the sites mentioned above.

2. The geotechnical (Earth Sciences) information and proposed characterization plans for Yucca Mountain described in the CD/SCP needs substantial revisions and improvements beyond technical content if the document is to focus on the licensability as the ultimate goal. The text appears to have been carefully contrived to present only positive aspects of existing site information. Adverse information (e.g. active faults in the repository block) is either ignored, scattered into unrelated sections, or treated in a cavalier manner in what appears to be a conscious attempt to hide from the critical licensing issues. The text (including figures and tables) is extremely variable with a considerable amount of unnecessary and distracting detail in many places that could've been treated more succintly and a general lack of detail in those places that obviously need greater exposition. 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 results will effectively be brought back together either inter-disciplinary or more importantly intra-disciplinary. As the CD/SCP document presently stands it provides little confidence that the DOE will develop an objective and sufficient basis for successful NRC licensing of the Yucca Mountain site.

3. The CD/SCP illustrates that the DOE does not appear to understand or are they willing to accept the responsibility of an applicant in the NRC licensing process. NRC Reg. 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 CD/SCP provides for neither of these requirements. Major site specific issues were pointed out by the NRC and the State in their comments on the draft and final Environmental Assessment but appear to have either been ignored or not taken seriously by the DOE in preparing the CD/SCP.

4. Based upon the geological information the DOE has presented in CD/SCP Chapter 1, 2, and 3 it is likely that the Yucca Mountain site will be extremely difficult if not impossible to license. Some of the major reasons for this opinion are (1) The acknowledged existence of 32 active faults within and around the site area (p. 1-127); (2) the acknowledged existence of at least seven active faults within close proximity and transecting the immediate repository area including the surface facilities site (Fig 1-34, p.1-108; Fig. 8.3.1.4-12/13, p.8.3.1.4-92/93; Fig. 8.3.1.14-5/6, p.8.3.1.14-38/39); (3) the probable existence of major active detachment faults beneath the site (p.8.3.1.17-31); (4) the active Ghost Dance Fault with 38 meters of demonstrated offset transecting the proposed repository block (p.1-127); (5) a controlling seismic source, the Paintbrush Canyon fault, with an estimated M 6 1/2 potential at a distance of 1 km or less from the proposed Class I surface facilities (p.8.3.1.17-37); (6) late Pleistocene-Holocene volcanoes within 8 km of the site including the most recently active volcano (Lathrop Wells may be as recent as 6500 years) on direct structural trend with the site (p.1-95/98); (7) a site thats at the intersection of three major tectonic zones, one of which, the Walker Lane, has had a M 7 1/2 earthquake in historical times; (8) a distinct lack of any continuous late Pleistocene - Recent geological strata that can be used to effectively constrain the timing or rates of ongoing tectonism; and (9) a site that is essentially opaque to any of the present state of the art geophysical techniques that have the required resolution.

5. 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 the licensing process, or how they will be publicly addressed before another five-seven years and several billions of dollars have been expended. Some of this type of information may be included in the forthcoming study plans although there is no obvious mechanism to assure this happening. DOE states (p.8.5-26) that "Detailed technical and compliance reviews (of the study plans) will be completed by the DOE. Following these reviews, study plans will then be submitted to the NRC for review and comment and to the State and Indian tribes for their information." It appears that DOE plans to continue their present practice of submitting key documents to the public after the fact and then providing lip service to any comments they don't agree with. DOE further states (p.8.5-87) that "Specific Plans have not been developed for the process through which the DOE and NRC will reach concurrence on technical issues and regulatory requirements. However, it is expected that some of the topical and IR reports may be used as a basis for interaction with NRC." Another example of DOE positive commitment to the licensing process. The obvious attempt to exclude the State, Indian tribes and other effected parties from the process of developing acceptable study plans and in the process of reaching concurrence on technical issues and regulatory requirements does not exactly appear compatible in fact or in spirit with the NWPA or the May, 1987 letter of agreement on "Level of Detail for Site Characterization Plans and Study Plans". In addition there is no indication of what DOE plans to do when major technical issues and regulatory requirements turn out to be unresolvable. This again seems to indicate that the DOE has no intention of making any commitment to the regulatory process unless and until they are forced to do so.

6. The schedule is ambiguous and so vague as to be meaningless. The CD/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. It appears to be irrelevant that much of the critical design information (e.g. design earthquake, matrix vs fracture flow beneath the repository, amount of offset to be expected in the repository, etc.) won't be available until the License Application Design (LAD) is almost completed (Fig. 8.5-3, p.8.5-80A; Fig.8.5-4, p.8.5-86). 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 consideration outside of DOE.

7. The CD/SCP text that was reviewed, especially Chapter 1 and related parts of Chapter 8, reflects an attitude of certainty concerning available information and prospective characterization findings that is unwarranted with respect to information content and inappropriate for the licensing process. The conservatism inherent in the NRC licensing process demands that positive evidence be provided that an adverse condition does not exist. Despite NRC and State comments on the draft and final Environmental Assessment, the CD/SCP is highly insensitive to uncertainties, to alternative interpretations and assumptions, and to the rigorous demands for substantiation in the licensing process.

8. The Yucca Mountain site characterization plans as described in the CD/SCP are fundamentally deficient in providing any type of planned activities concerning qualification of judgement-based parameter values or the trade offs that will have to be made between intra-disciplinary judgement-based parameter values. There are some periodic references to use of "expert judgment" (e.g. Section 8.3.5.17 - NRC Siting Criteria) but no definition of what the DOE considers to be an expert. It is also left unsaid how the DOE "experts" will interact to reach this judgment or the methods that will be employed when major differences develop with the NRC and/or State experts. Some of the other important definitions that appear to be missing are for the words significant (e.g. significant displacement on a fault or on a disturbed zone of faulting in the immediate site area, p.8.3.1.17-32) and adequacy (e.g. examination for adequacy must precede the determination of the presence or absence of the FC [Favorable Condition] p.8.3.5.17-17) and how, when and by whom are these decisions going to be made. As a result of these and other similar shortcomings the overall approach ends up appearing to be directed at proving that the preliminary Environmental Assessment results are correct rather than towards objective discovery of the true nature of the Yucca Mountain site.

COMMENTS OF

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July 23, 1988

Mr. Carl A. Johnson
Agency for Nuclear Projects
Nuclear Waste Project Office
Agency for Nuclear Projects
Capitol Complex
Carson City, Nevada 89710

Dear Mr. Johnson,

Enclosed are my comments on the draft of chapter 7 of the SCP.

Sincerely,

Thomas M. Devine
Associate Professor

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COMMENTS ON CHAPTER 7 OF THE DRAFT OF THE SITE CHARACTERIZATION PLAN

(1) On pg. 7-38, mention is made of the fact that naturally occurring cristobalite at Yucca Mountain undergoes a structural transformation at 225°C ± 25°C from tetragonal to cubic symmetry. This results in a volume increase of ≈ 5%. It is indicated that the effect which the volume change can exert on the environment of the waste package is unknown. However, I think that it is very important to ask, specifically, what effect this phase transformation and the accompanying volume change will have on the stresses acting on the container. If the loading results in the formation of significant tensile stresses then phenomena such as hydrogen assisted cracking and stress corrosion cracking are possible.

(2) The meaning of the phrase "electrochemical ability" which was described on pg.7-64 as one of the virtues of copper-base alloys is unclear.

(3) In the last paragraph on pg. 7-64, in the first and second paragraphs on pg. 7-65, in the second complete paragraph on pg. 7-67, in the second and third paragraphs on pg. 7-69 and, finally, in the second complete paragraph on pg. 7-70, the word "authentic" is used in place of the correct word "austenitic".

(4) The following sentence found at the beginning of the second complete paragraph on pg. 7-66 is poorly worded. "Brittle phases such as sigma reduce the fracture toughness so that ... stresses can initiate cracks..." Fracture toughness describes the resistance of a material to the propagation of a crack. As such, it says nothing at all about the stress required to initiate a crack.

(5) In the second-to-last sentence of section 7.4.2.3.3 on pg. 7-66 the word "microorganism" (i.e., singular) is used. This suggests that there is but one species in question. However, it would seem as though the plural form should be used here.

(6) In the third paragraph on pg. 7-69, the third sentence (which begins with "This precipitation occurs most frequently along grain boundaries...") states that serious degradation can occur "when the precipitate and resulting chromium depleted zones form a continuous network ..." In ascertaining what thermal treatments can result in the sensitization of a stainless steel it is important to realize that continuous chromium-depelted zones can form along grain boundaries which are not continuously covered with carbides.

(7) In the third complete paragraph on pg. 7-69, "MgCl" should be deleted from the sentence which begins with "By far, the transgranular path is ..."

(8) The third sentence of the first paragraph of section 7.4.2.5.2 on pg. 7-72 states

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that "The bent beam configuration was chosen so that the base metal, weld zone, and heat affected zone could all be simultaneously stressed at the same nominal level." This is incorrect. The bent beam sample will provide the same applied stress to the outer surface of each of these zones but, because of the residual stresses introduced during welding and during the cooling of the weld, the total stresses (residual + applied) in each of these zones will be different.

(9) The last paragraph at the bottom of pg. 7-78 states that "It is not clear whether the ionoic content of the water has any effect on susceptibility of stainless steels to IGSCC". This statement is incorrect. Work published in the journal Corrosion by Peter Andresen at the General Electric Company, for example, has shown that there is a very strong relationship between the conductivity of water and the susceptibility of a sensitized stainless steel to IGSCC. In fact, for relatively dilute solutions it appeared as though the susceptibility to IGSCC was independent of the identity of the anion and a function solely of the conductivity of the solution.

(10) On pg. 7-60, the first sentence of section 7.4.2.5.7 states that "work performed as of June 1986 has not shown any tendency for the L-grades of stainless steels to stress corrosion crack intergranularly even when specimens are stressed to and beyond the yield strength and are given heat treatments that favor carbide precipitation." This statement is misleading at best and, most probably incorrect. Work published in the journal Metallurgical Transactions by C. Briant and E. Hall have shown that 316L stainless steel can be sensitized. In addition, 316 stainless steel pipes in a commercial boiling water reactor located in the state of New York have sustained IGSCC in spite of the fact that subsequent failure analysis did not detect the presence of carbides along the grain boundaries.

(11) The comments made in (10) above clearly indicate that more work has to be done to explore and define the combined effects of cold work and carbon content (for low carbon contents, i.e, $\leq 0.03\%$) on the degree of sensitization. That is, it is necessary to determine if there exists a carbon content below which sensitization will not occur. Since significant amounts of straining are introduced into the heat affected zones during the solidification and cooling of the weld, and because plastic deformation greatly accelerates the intergranular precipitation of chromium-rich $M_{23}C_6$, it is essential that the effects of deformation be incorporated into the study of sensitization.

The effects of straining can be studied in several ways. First, prior to isothermal, sensitizing heat treatments samples can be strained to various amounts. The influence of straining can then be ascertained by determining how much influence pre-straining has on the combinations of temperature and time which are required to produce sensitization. Second, samples can be simultaneously exposed to a specific strain-time history and a specific temperature-time history (e.g., through the use of a

"gleibel machine"). The strain-time and temperature-time histories should be those which experimental and/or analytical heat transfer measurements have indicated to exist in the heat affected zone of a particular weld geometry. Third, full scale welds can be formed. Here, the strains produced during the heating, solidification, and cooling of the geometry of the actual weld of interest will act to enhance the precipitation of carbides. By varying the carbon contents of the alloys used in the three tests, it will then be possible to quantitatively determine the synergistic effect of carbon content and strain on the degree of sensitization.

(12) In sections 7.4.2.7.1 and 7.4.2.7.3, the SCP does discuss the phase stability of the weld. However, the SCP does not include sufficient amount of work on the weld itself. It is known that 308 stainless steel, which is the composition most often selected as weld filler for joining adjacent sections of 300 series austenitic stainless steels, can form a large variety of microstructures in the as-welded condition. The microstructure -- in particular, the amount, distribution, and shape of the ferrite phase -- of a weld is somewhat sensitive to the welding parameters (e.g., heat input and torch speed) but is strongly dependent on the precise composition of the 308 stainless steel. Work performed by me has shown that the resistance of the weld itself to sensitization is a strong function of its microstructure. Hence, by virtue of the relationship between the microstructure of a weld and the composition of the weld, the resistance of the weld to sensitization will be a strong function of its composition. In addition, the ferrite phase in 308 stainless steel welds is unstable at temperatures below ≈ 1000-1100°C. Consequently, during low temperature thermal treatments it will decompose. Depending on the temperature of the decomposition, phases such as σ and α' may form. These phases are deleterious to the mechanical properties of the weld. Their presence could adversely affect the ductility and toughness of the weld.

While it is known that σ and α' can form from the decomposition of the ferite phase, the combinations of weld microstructure and thermal treatments which will result in their formation are not known. Thus, the SCP should include a study of the performance of the weld itself in terms of its resistance to sensitization and the formation of embrittling phases. The study should be undertaken in an effort to define the range of composition which welds of 308 stainless steel may posses and still be resistant to sensitization and to the formation of σ and α' under the thermal conditions likely to be experienced by the containers.

(13) A great deal of effort has been expended in the study of LTS (i.e., low temperature sensitization) of austenitic stainless steels by researchers interested in the behavior of pipes in commercial nuclear power reactors. Because of the greater diffusivity of chromium in the ferrite phase than in the austenite phase, and because the transport of chromium is the rate determining step in the precipitation of chromium carbides, it would appear that the potential for LTS of the weld metal itself would be high. Consequently, the SCP should include a specific effort to determine

the resistance of 308 stainless steel welds to LTS.

(14) The discussion in 7.4.2.6.1 is quite correct in mentioning the sensitivity of the results of electrochemical measurements of localized corrosion on the technique used. As a result, the best approach is not to rely on the results of a single test but rather to conduct a large variety of electrochemical tests and direct immersion tests and, to vary widely the values of the test parameters, and look for a consensus among all the results.

In addition, numerous studies of pitting corrosion and crevice corrosion have shown the key role played by metallurgical defects, in particular, inclusions, on the initiation of localized corrosion. Because of the directionality of working during the thermomechanical processing of plates and sheets, the areal fraction of inclusions can vary markedly depending on the orientation of the surface being studied. To be conservative, it is necessary to include in the study an evaluation of the performance of the alloy in its most susceptible orientation.

Furthermore, surface cleanliness and surface finish are also known to play an important role in the initiation of localized corrosion. Consequently, these two variables should also be included in the study of the susceptibility of an alloy to localized corrosion.

(15) In the last paragraph of pg. 7-84, it is stated that "wholesale breakdown of the passive surface occurs" at the pitting potential. This is not true. The attack is highly localized and often occurs, as mentioned above, selectively at the sites of certain inclusions.

(16) In the sequence of events is the waste cannister loaded into the container and then transported to the burial site (as opposed to the waste cannister, all by itself, being transported to the burial site where it is then inserted into the container)? If so, then particular attention should be given to the conditions under which the container is stored and shipped. That is, e.g., is it possible that during storage and/or during shipping the container could be exposed to moisture which could cause a small amount of corrosion and/or stress corrosion cracking which could then predispose it to failure at the burial site?

(17) In view of the ≈ 100 years of vaporization of water which, as mentioned on pg.7-9, can occur around the container, it is important to determine what contents of the water (e.g., salts) will be enriched in the region surrounding the container. These can subsequently be redissolved when temperatures are no longer high enough to vaporize the water approaching the container. Consequently, aqueous solutions that are relatively high in concentrations of these materials can form and come into contact with the container. Thus, it is important that solutions used to evaluate the

corrosion resistance and stress corrossion cracking resistance of the container be employed in the test program of the SCP.

(18) What is the method of attachment of the lifting studs referred to on pg. 7-13? If they are to be welded onto the container, then the chemistry and microstructure of these welds and their influence on the corrosion and stress corrosion cracking resistances and mechanical properties of the welds needs to be thoroughly investigated for the same reasons as discussed in (12) and (13).

Thomas M. Devine 7/23/88

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