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THRU: T. A. Rehm, Assistant for Operations
Office of the Executive Director for Operations (Signed) T. A. Rehm

FROM: Hugh L. Thompson, Jr., Director
Office of Nuclear Material Safety
and Safeguards

SUBJECT: SZYMANSKI REPORT ON THE YUCCA MOUNTAIN SITE

DHLWM staff is aware of and has identified a number of potential geologic and hydrologic issues with respect to tectonic activity (e.g., faults, volcanism) and the groundwater regime at the Yucca Mountain, Nevada site. These concerns have been raised to DOE in numerous technical interactions and are documented in meeting minutes, trip reports, and the NRC staff comments on DOE's Draft and Final Environmental Assessments on the Yucca Mountain site.

Through our interactions with DOE, we have been aware that a DOE staff member, Jerry Szymanski, is preparing a report which will present a conceptual model of the site which integrates a number of geologic and hydrologic concerns and which, if verified by current and/or new data, might raise serious concerns about the suitability of the Yucca Mountain site. It is our understanding that a draft of this report is currently undergoing technical review within the DOE Nevada Project Office. On Thursday, January 21, 1988, Governor Bryan of Nevada held a press conference to reveal the existence of the Szymanski report and accused DOE of concealing the report from Congress and the public.

DHLWM has obtained a copy of the Szymanski report, and staff members are examining it for new concerns or data that could affect their ongoing review of the Consultation Draft Site Characterization Plan (CDSCP) for the Yucca Mountain site and are also preliminarily evaluating the potential significance of the report's conceptual model. Through our ongoing review of the DOE program, we will assure that our previously raised concerns, as well as potentially significant new concerns in the Szymanski report, will be addressed during site characterization. The purpose of site characterization is to obtain site data that will allow a determination of such concerns and the ultimate suitability of the site for a repository.

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Enclosed for your information are the overview sections of the report, namely the introduction and Chapter 5, which contains the conclusions and recommendations. Please note the last paragraph on page 5-7 which states, "It should be recognized that all of the above licensing concerns regarding the Yucca Mountain site are not new concerns. They were raised previously, in one form or another by various parties, most notably by the U.S. Nuclear Regulatory Commission and the State of Nevada. The proposed conceptual model of the flow system reinforces these concerns and provides an uniform theoretical background for these concerns."

Original Signed By

Hugh L. Thompson, Jr., Director
Office of Nuclear Material Safety
and Safeguards

Enclosure:
As stated

OFFICIAL CONCURRENCE AND DISTRIBUTION RECORD

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SUBJECT: SZYMANSKI REPORT ON THE YUCCA MOUNTAIN SITE

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Conceptual Considerations of the Death Valley Groundwater System with Special Emphasis on the Adequacy of This System to Accomodate the High-Level Nuclear Waste Repository.

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Physical Scientist
U.S. Department of Energy
Nevada Operations Office
Waste Management Project Office

Las Vegas, Nevada
November, 1987

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SECTION 1.0.

1.0. INTRODUCTION.

Options seriously considered for the isolation of high-level nuclear wastes that involve geologic media differ primarily in emplacement technique and location. Of these options, emplacement in a deep, excavated cavity, or geologic repository, is the currently favored method.

The most likely means of returning radionuclides from a sealed geologic repository to the biosphere is by dissolution and transport of the radionuclides by groundwater. The potential hazard from buried radionuclides, therefore, depends primarily upon three important aspects: a) the amount and rate of supply of radionuclides to the groundwater; b) the pathways and rate of groundwater movement; and c) the degree of geochemical retardation imposed by the geologic media.

The assessment of sites possibly suitable for a geologic repository must involve a critical evaluation of: a) the performance of the existing geologic system; b) the probable future performance of the natural system, taking into consideration evolutionary changes and potentially disruptive events; and c) the disturbance to the natural system caused by excavation, waste emplacement, sealing, and the presence thereafter of the waste facility. The assessment of risk is possible only if reasonable predictions can be made regarding the repository environment. Because actual tests and demonstrations of repository system behavior cannot be conducted under various changing conditions over representative periods of time, mathematical models must be used to evaluate the long-term behavior of the system.

Traditionally, the scientific community, concerned with development of technology to be used for purposes of achieving the disposal of radioactive materials, considered the repository siting options but only in a context of "stable geologic formations", situated in "tectonically stable areas". Roots of this perception may be related to our, human, inability to fully comprehend tectonic forces and processes and how these factors relate to long-term containment and isolation capabilities of geologic systems. It is fair to state, of course, that these reservations were expressed for saturated conditions alone. The Yucca Mountain site is different; water which is considered to be the most important factor in radionuclide transport is presently available but only in very limited quantities. What is the value of this attribute in light of the volcanotectonic setting of the site?; how do both of these factors balance each other in the context of repository performance and the uncertainties associated with it?. These are the questions which must be answered.

The most important part of understanding the role of tectonic processes, in the context of radionuclide releases, is a phenomenologic linkage between behavior of the fluid flow field which contains dissolved radionuclides and tectonically generated energy and/or substance in various forms and quantities. The subject is poorly known and the means of addressing it require rather difficult mathematical formulations which relate more to thermodynamic concepts of coupled flow than to the traditional hydrogeology.

It is likely that, for an active tectonic environment which involves extension and includes alkalic volcanism, the majority of assumptions utilized to develop mathematical models to describe "simple" groundwater flow systems are of questionable validity. Some of these assumptions are:

- Flow field involves only single phase flow;

- Three dimensional distribution of hydraulic potentials is simple and is fully describable through the configuration of the water table;

- Boundary conditions, with respect to an assumed horizontal base of the flow field, as they exist in time and space are of no importance;

- Boundary problem, as solved for a flow system consisting of surface recharge and discharge areas and composed of a non-deforming porous medium, is adequate to describe all aspects of behavior of the groundwater flow field; and

- Relationship between the flow field in the saturated zone and the flow field in the unsaturated zone is such that, in the unsaturated zone, only downward movement of water is possible.

Notwithstanding these obvious limitations, a position on tectonics and seismicity and how these subjects relate to performance of the high-level nuclear waste repository at the Yucca Mountain site has not been clearly articulated. This is true, in particular, for the relationship between tectonics and the groundwater flow system which, of course, is a key player in the performance of the high-level nuclear waste repository.

The regulatory framework, as it currently exists, tends to emphasize the issue of tectonics. However, both 10 CFR 60 and 10 CFR 960 deal with this issue in terms of vague generalities providing little help in developing siting decisions and site characterization plans. Tectonics and related hydrologic implications may have an important bearing on the compliance of a given disposal system with requirements set forth in 10 CFR 60. Conceivably, all specified performance objectives, either directly or indirectly, are involved, including:

Pre-closure - Retrievability; and

- Operational releases of radioactive materials.

Post-closure - Groundwater travel time;

- Life of waste package;

- Release rates from engineered barriers;

- Release rates to the accessible environment.

Tectonic processes, with equal importance, come into play if one is concerned with compliance of a given disposal system with requirements set forth in 10 CFR 960. Both, pre-closure and post-closure system guidelines may be involved. Tectonics is also important with respect to many technical guidelines, both pre- and post-closure. Directly, tectonic processes govern compliance of a site with tectonic guidelines. Indirectly, other guidelines are also involved. These are: a) rock characteristics; b) geohydrology; and c) erosion.

The main purpose of the analysis presented herein is to offer a proposal regarding the relationship between the tectonics of the Yucca Mountain site region and the groundwater flow system operating at this site and in the region surrounding it. What is intended is to provoke the initiation of an understanding, on a qualitative or conceptual basis, of this groundwater flow field. This understanding could then be used: a) to develop a focused exploration program; b) to perform, if necessary, a re-evaluation of the existing data and positions based on these data; c) to develop a description of the natural system; and d) to develop a rational approach to the performance assessment and the performance allocation process.

The discussions have been divided into four parts. These parts are:

Section 2.0 - Mathematical and Conceptual Models of Groundwater Flow Systems - Statement of the Problem;

Section 3.0 - Conceptual Framework for the Death Valley Flow System;

Section 4.0 - Characteristics of the Death Valley Groundwater System in Light of the Existing Data; and

Section 5.0 - Conclusions and Recommendations.

SECTION 5.0.

CONCLUSIONS AND RECOMMENDATIONS

5.1. Summary and Conclusions.

Having performed the analysis presented in Section 2.0, Section 3.0, and Section 4.0, the following three conclusions seem to be reasonable and warranted at this time:

i) Examination of the extensive data base pertaining to the Death Valley groundwater system, in light of the conceptual framework as established in Section 3.0., reveals that this flow field is considerably different than the flow system currently envisaged by the NNWSI Project. The conceptual model of this flow system, as used in performing site suitability assessments for purposes of developing the Final Environmental Assessment for the Yucca Mountain site and for purposes of establishing an approach to the forthcoming site characterization activities, is far too simple and much too far removed from reality. Simply stated this conceptual model ignores completely the volcano-tectonic setting of the Yucca Mountain site.

The currently adopted conceptual model considers a single phase, steady-state, flow process which is assumed to be fully describable by the Laplace equation. In this model, it is assumed that the water table constitutes a meaningful and durable expression of the characteristics of the flow system. The position of the water table is assumed to be related solely to the volume of fluid passing through the system's boundaries. This volume of fluid is a function of climatic conditions and remains constant as long as these conditions remain unchanged. Consequently, it is assumed that all moisture in the vadose zone is the result of infiltration of a small portion of rainfall. Furthermore, it is assumed that the movement of water involves the mechanism of matrix flow and that this movement occurs under the influence of gravity alone.

Within the context of the currently considered conceptual model the influence of tectonic disruptions is limited to: a) local alteration of stratigraphic relationships; b) additional local fracturing; and, c) minor changes in the altitude of discharge areas relative to the altitude of recharge areas. A tectonically induced change in these factors is relatively small and, therefore, the resulting alterations in the three-dimensional distribution of hydraulic conductivity and of the gradients of hydraulic potentials are likewise small. These alterations can readily be accommodated by minor changes in the position and configuration of the water table. It follows then that, the impact of these alterations on the migration of radionuclides from the repository is small.

A completely different picture emerges if one considers the volcano-tectonic setting of the Yucca Mountain site and of the groundwater system operating at this site. As indicated in Section 3.1., and Section 3.3, the setting of Yucca Mountain contains the continental alkalic basalts of Late Pliocene and Quaternary age. These basalts, as a matter of fact, are trace-element enriched hawaiites with isotopic compositions indicative of the mantle origin. The isotopic and geochemical characteristics of these rocks are best

accounted for by assuming that the convective mass and heat transfer occurs in the upper mantle. From a point of view of regional hydrology, this mantle upwelling appears to be responsible for two very important, tectonophysical factors.

The first factor is high and. most importantly, spatially heterogeneous heat flow. This heat flow and the gravitational hydraulic pressures acting at the flow system boundaries are the energy sources which together are responsible for the movement of groundwater. In a thermodynamic sense, therefore, the flow process is the two phase, heat-fluid coupled, flow or the "mixed" convection flow. In such a flow field, an arbitrary plane adopted as the base of the flow field must be considered as the "flow" boundary with respect to flow of both heat and fluid. Mathematical models used in numerical simulations of the flow process in this field must account for this circumstance, otherwise calculations and interpretations may be grossly misleading and, with reference to the Death Valley flow system, are quite irrelevant.

The second factor is the strain energy which, because of the mantle upwelling, is being supplied into the flow field on continuous basis. The resulting dynamic strain energy field plays an important role in controlling the resistance offered by the fractured medium against the coupled flow of heat and fluid. Near the ground surface, the strain energy field controls the conducting aperture of fractures and, therefore, it also controls the bulk thermal and hydraulic conductivities of the medium. Also controlled are the hydraulic storetivity and the thermal diffusivity of this medium. As the strain energy field changes with time, the thermal and hydraulic parameters also change. Consequently, the entire flow system acts as a three way, H – F – M, coupled thermodynamic continuum. For the purposes of these conceptual considerations, this continuum has been simplified and referred to as the two phase, heat-fluid coupled, flow field developed in the deforming fractured medium.

The continuum evolves through a series of similar evolutionary loops which, for a given area within the flow field, are closely tied to the deformational cycles of this area, Section 3.4.3.. During a single evolutionary loop, the energy balance of the continuum undergoes a remarkable transformation. At the onset of the deformation cycle, the gradients of the in-situ stress are "weak", allowing for existence of "strong" gradients of the in-situ temperature and of the hydraulic potentials. At this time, the water table is high and the flow field shows strong "mixed" convection aspects. With the advance of the deformation, however, the in-situ stress gradients become "stronger" and the fractured medium enters the "dilated" state. The values of the thermal and hydraulic parameters of the fractured medium increase and become time dependent. These time dependent increases in the value of these parameters cause that the gradients of temperature and of hydraulic potentials to "weaken". The water table deepens and, near the ground surface, the flow system looses its strong "mixed" convection or geothermal aspects.

The termination of the deformational cycle is associated with a large, but local discharge of the accumulated distortional strain energy from the system. The in-situ stress gradients "weaken", allowing for the reappearance of the normal "strong" gradients of the in-situ temperature and of the hydraulic potentials.

The water table returns to its high position and the convective heat-fluid flow process returns to its normal intensity. At this time, the bedrock separations which resulted from the discharge of strain energy are being filled with minerals precipitating from the convecting fluids.

As demonstrated in Section 4.0., assumption of the two phase, heat-fluid coupled, flow field developed in the deforming fractured medium is in full accord with all known characteristics of the Death Valley groundwater system. This is in sharp contrast to the conceptual model of this system used to: a) perform assessments of suitability of Yucca Mountain for site characterization; and, b) develop strategies for demonstrating compliance of this site with all applicable Federal regulations. Not accounting for the true nature of the flow field will, undoubtedly, entail serious errors in judgement amounting to a complete misunderstanding and, therefore, misrepresentation of the flow field.

ii) Conceptualization of hydrologic processes operating in the vadose zone of the two phase flow field developed in the deforming fractured medium yields a completely different picture than the one currently envisaged by the NNWSI Project. Two issues of fundamental importance are associated with the possibility that the flow system is developed in the deforming fractured medium. These issues are: a) the mechanism of flow in the vadose zone; and, b) the temporal stability of the water table, including its short and long term aspects, and involving both climatic and tectonic factors. Two other issues of fundamental importance are associated with the possibility that the flow field involves the two phase, heat-fluid coupled, flow process. These issues are: a) the chemistry of the interstitial pore water in the vadose zone; and, b) the spatial and temporal distribution of heat flow through the vadose zone.

There are two relative measures of a tendency toward fracture flow in the vadose zone. These measures are: a) the depth to which the limit equilibrium in-situ stress conditions are developed; and, b) the difference in the degree of rock matrix saturation in the vadose zone and in the "saturated" zone. Results of the in-situ stress determinations performed at Yucca Mountain, Section 4.5., and of the Cooper-Bredehoeft injection tests, Section 4.7.4., indicate that the depth of the limit equilibrium in-situ stress conditions is considerable, more than 1200 m, and is substantially below the water table. Results of laboratory measurements of the degree of rock matrix saturation, Section 4.3., revealed that the difference in the degree of saturation of the rock matrix in the vadose zone, below a depth of approximately 220 m, relative to the degree of the matrix saturation below the water table, is not substantial by any standards. Consequently, in light of these data, an expectation that the movement of water through the vadose zone of Yucca Mountain involves the mechanism of interstitial porous flow does not appear to have a proper foundation. This is true, in particular, if one is concerned with the movement of water through rocks with small interstitial porosity as in the case of the densely welded Topopah Spring Member of the Paintbrush Tuff.

In the case of the deforming fractured medium, the temporal stability of the water table is not only related to global or regional climatic fluctuations, but it is also related to tectonic factors, in particular,

the in-situ stress conditions. As discussed in Section 3.2.3., both short term and long term instabilities of the water table can be expected at the Yucca Mountain site.

The short term instabilities involve several meters, perhaps tens of meters, of displacement of the water table. They are short lived, say days or weeks at most, and occur with a frequency related to the degree of heterogeneity in the local strain energy field. These short lived instabilities are caused by the minor restructuring of the strain energy field which may or may not require an external triggering mechanism. Fault creep, local and temporary uplift or subsidence, vibratory ground motion induced slip, etc. are examples of the manifestation of these restructurings. As discussed in Section 4.1., results of the continuous and periodic measurements of the position of the water table, performed at Yucca Mountain in a number of deep wells during the last 10 years, are not yet available in an accessible and reliable form. Consequently, it is not known whether or not the short lived instabilities of the water table were observed at the Yucca Mountain site. These instabilities, however, are very important because they can directly confirm that the deforming fractured medium is, indeed, involved in the flow process. Furthermore, these instabilities, if occurring with a meaningful frequency and magnitude, would constitute a "pumping" mechanism for gaseous transport through the vadose zone.

The long term displacements of the water table involve tens and perhaps hundreds of meters. They are caused by the large scale restructuring of the strain energy field occurring at the end of a deformation cycle and with a frequency measured in terms of tens of thousands of years. These displacements would directly impact the radionuclide migration path and the radionuclide migration time. In extreme cases, however, these displacements can result in the flooding of the repository and in expulsion of groundwater at the ground surface.

The critical point of the overall conceptual considerations of the flow field at Yucca Mountain is whether or not the geologic record representing Late Pliocene and Quaternary time contains expressions of the large scale displacements of the water table in the past. As discussed in Section 4.8., there are indications that this indeed may be the case. Detailed studies of the calcite-silica-sepiolite vein deposits, however, were not performed. Consequently, the current data base does not allow a conclusive resolution of this question. Nevertheless the possibility that these veins are a record of large scale displacements of the water table in the past is real, and by all means not remote.

The assumption that the Yucca Mountain flow field is developed in the deforming fractured medium and that it involves the two phase flow process, leads to the following question: what is the origin and chemistry of the interstitial water in the vadose zone?. If this assumption is correct then it follows that the interstitial water represents past hydraulic mounds developed in association with the high water levels present at the end of cycles of deformation. The chemistry of this water would be considerably different than the chemistry of water currently passing through fractures of the medium. In the vadose zone, downward movement of the infiltrating rain water may involve the mechanism of interstitial porous flow, but

only during the early stages of deformation when the in-situ stress gradients are "weak" and the fractured medium is in a "relaxed" stage. It is highly unlikely that a significant replacement of the relict interstitial water by the infiltrating rain water could occur at this time. This replacement could be significant, but only during a more advanced state of deformation, when the water table is deeper. At this time, however, the in-situ stress gradients are "strong" and it is unlikely that the infiltration of the water involves the mechanism of interstitial porous flow.

As far as it can be determined, there are no published data pertaining to the chemistry of interstitial waters from the vadose zone of Yucca Mountain. Consequently, there is no basis to either confirm or reject the above hypothesis. Nevertheless, there are some unpublished data which seem to indicate that the chemistry of interstitial water is considerably different than the chemistry of water contained in fractures. These data were obtained by Dr. A. Yang (U.S. Geological Survey, Denver, CO) through chemical analysis of samples of the interstitial water which have been mechanically squeezed out of cores extracted from Yucca Mountain.

It can be expected that the flux of heat through the vadose zone, in the two phase flow field developed in the deforming fractured medium, is very heterogeneous in both the temporal sense and the spatial sense. This heterogeneity is related to the in-situ stress control of the thermal conductivity of the fractured medium. It is likely, therefore, that the intensities of heat flowing through some fractures are very substantial and are variable in time. In this situation, the flow of heat may be an important factor in the local upward movement of vapors and gases through the vadose zone. This heterogeneous heat flow would also complicate the movement of infiltrating rain water.

Very little information concerning the spatial and temporal distribution of heat flux through the vadose zone of Yucca Mountain is available at the present time. The results of measurements of the in-situ temperature, as published, were obtained shortly after the completion of drilling. Consequently, it is very unlikely that the results of these measurements represent a true picture of the spatial distribution of the intensity of heat flow. Also, it appears that the results of repetitive measurements of the in-situ temperature are not yet available and, therefore, little is known with regard to the temporal variability of heat flow.

iii) The conceptual model of the flow field, indicated by the currently available data from the Yucca Mountain site, points toward serious limitations of this site to effectively isolate radionuclides from the biosphere. These limitations are greater by far than those currently recognized by the NNWSI Project. Without recognizing these limitations, the issue resolution strategies, as expressed in the current version of the Site Characterization Plan, are interesting propositions, but are of very limited practical value. The resulting misunderstanding of the hydrologic processes operating in the vadose zone results in overly optimistic assessments of the licensability of the Yucca Mountain site.

In light of the conceptual model of the flow field, as proposed in Section 3.0. and Section 4.0., the

most important licensing concern is the potential rise of the water table. If this tectonically induced rise is possible at all at the Yucca Mountain site, then the geochronologic data presented in Section 4.8., indicate that the annual probability of an occurrence of this rise is more than 10^{-5}, perhaps within a range from 3 x 10^{-4} to 5 x 10^{-4}. In this situation, and in the context of performance requirements set forth in 10 CFR 60 and 40 CFR 191, the rise of the water table constitutes the "anticipated process and event". As such, the rise of the water table must be accounted for in demonstrating compliance of the Yucca Mountain disposal system with three long term performance objectives set forth in 10 CFR 60. These performance objectives are: a) the life of waste package; b) the release rates of radionuclides from the engineered barrier system; and, c) the release of radionuclides into the accessible environment.

The rise of the water table would significantly alter the radionuclide migration path and the radionuclide migration time. Furthermore, the water table rise, by providing substantial volumes of water, would also alter the radionuclide migration rate. Occurrence of the water rise during early stages of the life of the repository, when temperature of the waste packages and of the fractured medium surrounding them is above the boiling point of water, would result in a particularly strong impact on the overall repository performance. Vaporization of water entering the repository would cause substantial increases in the vapor pore pressure and, therefore, would accelerate the gaseous transport from the repository to the ground surface. Subsequent cooling of the repository, to below the boiling point of water, may be accompanied by a long term convective flow of fluids from the repository to the ground surface.

It can be expected that the chemistry of fluids entering the repository, in association with the tectonic rise of water table, is different than the chemistry of fluids currently residing in fractures of the flow system. The impact of the tectonic rise of water table on the life of waste package, therefore, is two-fold. Corrosion of waste packages will be accelerated not only because of the increased amounts of water contacting these packages, but also because of the more adverse chemistry of this water.

The tectonically induced rise of the water table, with a magnitude sufficient to flood the repository, is not the only licensing concern resulting from the proposed conceptual model of flow system. The model indicates significant consequences with respect to the ground water travel time requirement set forth in 10 CFR 60. Compliance of the Yucca Mountain site with this requirement can be demonstrated, but only by assuming that the rain water infiltrates through the vadose zone via the mechanism of interstitial porous flow. In the case of fracture flow, if infiltration occurs at all, the travel time of rain water is, most certainly, substantially less that 10^3 years.

The gaseous transport from the repository to the ground surface is another licensing concern resulting from the proposed conceptual model of the flow system. This transport is caused by the short lived instabilities of the water table and by the heterogeneous heat flow through the vadose zone. The gaseous transport may have some impact on the compliance of the Yucca Mountain site with two performance objectives set forth in 10 CFR 60. These performance objectives are: a) the release rate of radionuclides from the engineered barrier system; and, b) the overall release of radionuclides into the accessible environment.

Finally, the proposed conceptual model requires the chemistry of interstitial pore water in the vadose zone to be different from the chemistry of water currently residing in fractures. The chemistry of interstitial water is important with respect to considerations of regulatory compliance of the Yucca Mountain site. Three long term performance objective, set forth in 10 CFR 60, may be impacted. These performance objectives are: a) the life of waste package; b) the release rates of radionuclides from the engineered barrier system; and, c) the overall radionuclide release from the repository into the accessible environment.

It should be recognized that all of the above licensing concerns regarding the Yucca Mountain site are not new concerns. They were raised previously, in one form or another by various parties, most notably by the U.S. Nuclear Regulatory Commission and the State of Nevada. The proposed conceptual model of the flow system reinforces these concerns and provides an uniform theoretical background for these concerns.

5.2. Recommendations.

The proposed conceptual model of the flow system poses a number of questions regarding suitability of the Yucca Mountain site to accommodate safely the high-level nuclear waste repository. Recognizing the serious nature of these questions, and keeping in mind the long established policy of the U.S. Department of Energy to address the critical suitability issues first, the following four recommendations are offered:

i) A thorough examination should be performed of the data collected during the last 10 years of monitoring the position of the water table at Yucca Mountain. The main purpose of this examination is to establish whether or not short lived instabilities of the water table are occurring at the Yucca Mountain site. Furthermore, it is important to determine the frequency of occurrence of these instabilities as well as their magnitude;

ii) Complete and conclusive investigation of the calcite-silica-sepiolite deposits occurring at the Yucca Mountain site should be performed. This investigation should be carried out in both surface and subsurface and should include extensive radiometric age determinations. The purpose of this investigation is to establish whether or not the geologic record representing the Late Pliocene and Quaternary times contains expression of large scale fluctuations of the water table. Specifically, a firm position must be established whether or not flooding of the repository is the "anticipated process and event" within the context of regulatory requirements set forth in 10 CFR 60 and in 40 CFR 191.

iii) Investigation of the chemistry of water contained in the vadose zone of Yucca Mountain should be performed. It is recommended that a few borings be drilled for this purpose. The boreholes should be drilled with air and the drilling process should be designed to detect the presence of perched waters. If these waters are encountered, the drilling process should be halted and samples obtained for subsequent chemical analysis in the laboratory. The investigation should include chemical analyses of samples of the interstitial pore water mechanically squeezed out from cores following the procedure developed by Dr. A. Yang of the U.S. Geological Survey. The main purpose of these investigations is to establish whether or not: a) the vadose zone contains the perched water; and, b) the perched water and the interstitial pore water are chemically different from the fracture water.

iv) Investigation of the known perched waters occurring in the vadose zone of the Death Valley flow system should be performed. There are two outstanding candidates for this investigation. They are: a) the perched water in the vicinity of Skull Mountain, as described in Section 4.2.; and, b) the apparent hydraulic mound under the Greenwater Range, as discussed in Section 4.8. The main purpose of this investigation is to determine the origin of the water forming both of these hydrologic features. There are only two possibilities. Either they are ordinary meteoric waters infiltrating through the vadose zone, or they are related to the tectonically induced hydraulic mounds. The temperature and chemical composition of these waters should be sufficient to distinguish one from the other.

The investigations recommended above were designed to obtain data which are judged to be required to carry the conceptual considerations undertaken herein to their logical and reliable conclusion. Presence of: a) short lived instabilities of the water table; b) expressions of large scale instabilities of the water table during the last 10^5 years; c) perched waters with chemical compositions indicative of below the water table origin; and, d) meaningful difference in the chemistry of interstitial pore water relative to the fracture water, would confirm that the proposed conceptual model of the flow field is correct. In this situation, serious consideration should be given to abandoning the Yucca Mountain site and declaring it as unsuitable for the purposes of permanent disposal of the high-level nuclear wastes. In all sincerity, the U.S. Government would be well advised to perform the recommended investigations prior to the commitment of substantial resources, such as those associated with the Site Characterization Process and the in-situ testing in the Exploratory Shaft.