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MEMO TO MS

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MEMORANDUM FOR: Lawrence C. Shao, Director Division of Engineering, RES

FROM: Robert E. Browning, Director Division of High-Level Waste Management, NMSS

SUBJECT: HLWM DETAILED RESEARCH NEEDS

The staff of HLWM has identified and listed specific technical concerns that they consider need to be addressed through NRC research in order to support our evaluations of the DOE high-level waste site being investigated at Yucca Mountain, Nevada. The detailed research needs list that is provided as Enclosure 1 has been divided into two categories ("priority" and "other"), and is keyed directly to our current user needs letter (see memorandum from R. Bernero to E. Beckjord, dated February 13, 1989). Also, enclosed are detailed assessments prepared by the staff of the priority concerns that have been identified to date (Enclosure 2) and cross-referenced in Enclosure 1.

These detailed assessments are primarily intended to provide specific objectives that can be used by RES to develop and direct HLWM research support. In addition, they will be used by HLWM to evaluate progress of the research in responding to HLWM needs as requested and described in the memorandum from Beckjord to Thompson, dated December 21, 1988. It should be noted that ongoing research programs appear to fulfill many of the currently identified priority needs (i.e., Needs 1, 2, 3, 4, and 9 at U. of Arizona; Needs 5, 8, 12, 13, 14, 15, and 16 at CNWRA/SNL/ANSTO; Need 10B at SNL; and Need 14 at NSF). However, we have identified some concerns about the effects of site characterization on the integrity of the Calico Hills unit (Need 6), the direct assessment of pre-waste-emplacement groundwater travel time (Need 7), mechanisms and processes that control the location of volcanics (Need 10A), long-term probabilistic seismic hazard estimates (Need 11), and the effects of ground motion on the repository operations area (Need 13) that do not appear to be covered by the present program and should be factored into future planning.

In order to come to closure with regard to our current listing of priority research requirements, it would be helpful if the RES staff could review the priority needs and provide us with the current status of each. One way to facilitate and expedite RES review and comment would be for RES staff to meet with HLWM staff to review each of the priority needs statements. The purpose of the meeting would be to discuss (1) the detailed research needs list, (2)

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the priority research needs, and (3) how current research projects are contributing to the resolution of specific HLWM concerns.

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I appreciate the close and effective working relationship that has been evidenced to date between HLWM and RES staff. Please let me know how you plan to proceed.

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Robert E. Browning, Director Division of High-Level Waste Management, NMSS

Enclosure: As stated

- cc: E. Beckjord, RES R. Bernero, NMSS
 - J. Funches, NMSS

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the priority research needs, and (3) how current research projects are contributing to the resolution of specific HLWM concerns.

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Robert E. Browning, Director Division of High-Level Waste Management, NMSS

Enclosure: As stated

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- cc: E. Beckjord, RES R. Bernero, NMSS
 - J. Funches, NMSS

Enclosure 1

HLWM SPECIFIC RESEARCH NEEDS

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HLWM SPECIFIC RESEARCH NEEDS

A WASTE FORM AND PACKAGING

Al Identification and Assessment of Potential Failure Modes for Waste Packages

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PRIORITY CONCERNS

- Effects of wetting/drying on degradation mechanisms [SEE RESEARCH NEED 15]
- Effects of welding on the degradation of materials [SEE RESEARCH NEED 16]

Other Concerns:

- Degradation of waste package from the inside
- Effects of waste type and origin on degradation mechanisms
- Effects of carbon on stress corrosion cracking
- Effects of (surface) inhomogeneities on the degradation of materials
- Effects of coupled interactions
- Corrosion by microbial processes
- Model validation
- Extrapolation of lab and field data
- A2 <u>Evaluations of Interactions Between Waste Packages and the Repository</u> Environment

PRIORITY CONCERNS

(TO BE DETERMINED)

- Effects of radiation
- Corrosion by microbial processes
- Environment created by interaction with canister, support plate, emplacement dolly, liner, rock bolt material
- Effects of wetting/drying on interactions and environment
- Effects of heat
- Release of carbon-14
- Effects of coupled interactions
- Extrapolation of lab and field data
- Model validation

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A3 Assessment of Corrosion Rates

PRIORITY CONCERNS

(TO BE DETERMINED)

Other Concerns:

- Effects of microbial processes
- Effects of wetting and drying
- Environment of corroded area Vs bulk repository environment
- Kinetics of corrosion
- Factors that initiate localized corrosion
- Stress corrosion cracking (Intergranular Vs Transgranular)
- Coupled interactions
- Extrapolation of lab and field data
- Model validation

A4 Analogs of Leaching and Migration

PRIORITY CONCERNS

(TO BE DETERMINED)

Other Concerns:

- Comparison of lab sorption, mineral stability, leaching and kinetic data with observations of natural and anthropogenic analogs
- Changes in leaching rates with time
- Vapor/gas phase transport
- Effects of oxidation state on leaching and radionuclide release
- effects of wetting and drying
- Coupled interactions
- Extrapolation of data
- Model validation

B REPOSITORY DESIGN AND ROCK MECHANICS

B1 Rock-Mass Sealing

PRIORITY CONCERNS

- Effects of wetting and drying [See Research Need 12]
- Free drainage concept [See Research Need 12]
- Seals as a preferential pathway for gas/vapor/water [See Research Need 12]
- Material properties under repository environment [See Research Need 12]

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- Sealing damaged area around drilled holes and blasted holes [See Research Need 12].
- Coupled interactions [See Research Need 12]
- Seismic effects on seal performance [See Research Need 12]
- Extrapolation of lab and field data [See Research Need 12]
- Model validation [See Research Need 12]

Other Concerns:

- Preferential pathway for carbon-14

EARTH SCIENCES

C1 Analog Studies of Conditions/Processes/Environments

PRIORITY CONCERNS

- Mechanisms and processes controlling Quaternary volcanic/hydro-volcanic systems [See Research Need 10]

Other Concerns:

- Natural and anthropogenic analogs for extrapolation of lab and field experimental sorption and mineral stability data
- Natural and anthropogenic analogs for extrapolation of experimental approaches/methods
- Air flow in unsaturated rock
- How effective is gas flow at depth
- Approaches for mapping underground facilities
- Quaternary age determinations
- Extrapolation of data
- Model validation

C2 Groundwater Chemistry

PRIORITY CONCERNS

- Representative sampling of C1-36, Tc-99, and I-129 in vadose zone [See Research Need 7]
- Zeolites as indicators of water composition [See Research Need 5]

- Evolution of groundwater chemistry (organic/inorganic/microbial)
- Concentration of solutes in groundwater due to evaporation

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- Redox activity
- Gas phase control of pH and oxidation state of groundwater
- The effect of climate changes on groundwater chemistry
- Age determinations
- Nonequilibrium conditions
- Extrapolation of lab and field data
- Model validation

C3 Radionuclide Transport

PRIORITY CONCERNS

- Use of Kds to model sorption [See Research Need 8]
- Presence of H-3, Tc-99, 1-129, and C1-36 as indicator of transport potential at site [See Research Need 7]
- Coupled interactions [See Research Need 8]
- The use of linear differential equations to model nonlinear transport chemistry [See Research Need 8]

Other Concerns:

- The effects of inaccurate thermodynamic properties of key solid phases (zeolites) on modeling sorption
- Colloids as a transport mechanism
- Source term
- Movement of carbon-14
- Vapor/gas phase transport
- Coupling of vapor/gas/liquid phase transport
- Extrapolation of lab and field data
- Model validation

C4 Mineralogy

PRIORITY CONCERNS

(TO BE DETERMINED)

- Stability of zeolites
- Dissolution of minerals causing increasing permeabilities
- Kinetics
- Age determinations
- Extrapolation of lab and field data
- Model validation

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C5 <u>Response of Groundwater Levels and Underground Openings to Strong Ground</u> <u>Motion</u>

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PRIORITY CONCERNS

- Impact of rock mineral stability on seismic response of openings [See Research Need 13]
- Impact of ground motion on rock stability and its effect on waste package [See Research Need 13]
- Extrapolation of lab and field data [See Research Need 13]
- Model validation [See Research Need 13]

Other Concerns:

- Groundwater response to seismic and or fault activities

C6 Groundwater Flow and Radionuclide Transport

PRIORITY CONCERNS

- The reliability of pneumatic tests in determining hydraulic parameters [See Research Need 2]
- Accuracy of surface Vs subsurface based determinations of flux [See Research Need 1]
- What constitutes a representative elementary volume for unsaturated fractured rock [See Research Need 3]
- Moble Vs immobile water [See Research Need 9]
- The initiation of fracture flow in unsaturated fractures rock [See Research Need 4]
- Parameters needed to be measured in order to characterize matrix/fracture flow in fractured unsaturated rock [See Research Need 6]

- Effects of excavation and waste emplacement on groundwater flow
- Effects of shaft and tunnels on air and moisture movement through rock
- Geologic variations that effect flow and transport
- Source term
- Air/vapor/gas movement through Yucca Mt.
- Movement of carbon-14
- Coupled interactions
- The use of linear approximations to evaluate and couple nonlinear flow and transport behavior
- Extrapolation of lab and field data
- Model validation

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C7 Uncertainty in Probabilistic Seismic Hazard Assessment

PRIORITY CONCERNS

- Extrapolation of lab and field data (earthquakes to 10,000 yrs.) [See Research Need 11]

Other Concerns:

- The uncertainty created by the random occurrence of seismic events
- Effects of rock movement on waste packages
- Model validation

C8 Climate Changes and Effects on Unsaturated Flow Conditions

PRIORITY CONCERNS

- Effects of increased rainfall on unsaturated flow [SEE RESEARCH NEED 14]
- Future climate prediction [SEE RESEARCH NEED 14]

Other Concerns:

- Effects of groundwater withdrawal
- Extrapolation of lab and field data
- Model validation

C9 Coupled Interactions of Thermal-Mechanical-Hydrologic Systems

PRIORITY CONCERNS (ALSO SEE A1-4, B1, C3, and C6)

(TO BE DETERMINED)

Other Concerns:

- Effects of coupled interactions on retrievability
- Uncertainties of linear modeling of nonlinear processes and events
- Extrapolation of lab and field data

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- Model validation

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- **D** SYSTEMS PERFORMANCE
- D1 Independent Systems Assessment Methodology for Evaluation of Total System Performance

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PRIORITY CONCERNS

(TO BE DETERMINED)

Other Concerns:

- The use of linear approximations to model nonlinear systems
- Source term
- Evaluation of human factors
- Extrapolation of lab and field data
- Model validation

D2 HLW Preclosure Safety Systems Analysis

PRIORITY CONCERNS

(TO BE DETERMINED)

- Source term
- Evaluation of human factors
- Extrapolation of lab and field data
- Model validation

Enclosure 2

HLWM SPECIFIC RESEARCH NEEDS - DETAILED ASSESSMENTS OF PRIORITY CONCERNS

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The Hydrologic Transport Section staff needs to have a description and an understanding of recommended surface and subsurface methods to determine water flux in unsaturated fractured rock media in climates similar to that at Yucca Mountain.

REASON FOR NEEDED RESEARCH

For an evaluation of a DOE Yucca Mountain performance demonstration the NRC needs to know the accuracy of the calculated ground water flux through the proposed repository. The rate (volume) of flux through the mountain can have a large effect on radionuclide transport and ground water travel time evaluations (mass and velocity), because if characterization activities find that the Topopah Springs matrix is close to saturation, a small increase in the flux through the welded units of Yucca Mountain will cause a significant increase in ground water velocity (due to low matrix permeability). Therefore, it will be important to obtain an accurate determination of flux.

REFERENCES TO NRC PROGRAM

The NRC staff review of the SCP identified DOE plans to estimate flux from surface based studies in SCP Activities 8.3.1.2.2.1.2 and 8.3.1.2.2.1.3 and from subsurface based studies in SCP Study 8.3.1.2.2.3.

ASSOCIATED NRC RESEARCH

D1662, D1672, G1112/University of Arizona - This research is contributing to a general understanding to acceptable methods for determining water flux in unsaturated fractured rock.

DOE RESEARCH OR INVESTIGATIONS

DOE plans to estimate flux from surface based studies in SCP Activities 8.3.1.2.2.1.2 and 8.3.1.2.2.1.3 and from subsurface based studies in SCP Study 8.3.1.2.2.3.

prepared by W.H. Ford (RES2) 7/20/89

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The Hydrologic Transport Section staff has a need for definite criteria to evaluate the appropriateness and accuracy of pneumatic tests (use of air or

gases) for determining hydraulic parameters of water flow in the unsaturated

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REASON FOR NEEDED RESEARCH

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The Hydrologic Transport Section review of the SCP determined that pneumatic tests will be used to determine water flow parameters in several SCP activities, including Activity 8.3.1.2.2.3.2 (Site vertical borehole studies), Activity 8.3.1.2.2.4.1 (Intact-fracture test in the exploratory shaft facility), Activity 8.3.1.2.2.4.3 (bulk-permeability test in the exploratory shaft facility), Activity 8.3.1.2.2.4.4 (Radial borehole tests in the exploratory shaft facility), Activity 8.3.1.2.2.4.9 (Multipurpose-borehole testing near the exploratory shafts, and Activity 8.3.1.2.2.4.10 Hydrologic properties of major faults encountered in main test level of the exploratory shaft facility). The NRC needs to know the capability and accuracy of this technology, because of the large number of important activities that will use this technology to obtain data for compliance demonstration modeling, which the staff must evaluate when it makes a compliance determination.

REFERENCES TO NRC PROGRAM

The NRC review of the DOE Site Characterization Plan found in Activity 8.3.1.2.2.3.1 that preliminary prototype work is needed by DOE to develop and evaluate various testing methods to ensure that matrix hydrologic property data is useful, representative and relevant to modeling flow and contaminate transport. One of the methods for prototype evaluation will be the use of pneumatic testing to determine water permeability, effective porosity, and a representative elementary volume (Activity 8.3.1.2.2.4.3).

ASSOCIATED NRC RESEARCH

D1662, G1112/University of Arizona - This research is contributing to a general understanding of the appropriateness and accuracy of pneumatic tests for determining hydraulic parameters.

DOE RESEARCH OR INVESTIGATIONS

DOE has plans as stated in the SCP (Activity 8.3.1.2.2.3.1, page 8.3.1.2-189) that fluid permeability tests of air permeability, Klinkenberg air permeability at different overburden pressures, specific water permeability, and oil permeability, will be compared. DOE acknowledges that "although water is the primary fluid of interest, air permeability is being evaluated because it is the quickest and least expensive method."

prepared by W.H. Ford (RES1) 7/20/89

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The Hydrologic Transport Section staff has a need to understand how to establish a representative elementary volume for flow and transport in unsaturated fractured rocks.

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REASON FOR NEEDED RESEARCH

One of the objectives of Yucca Mountain site characterization will be to determine a representative elementary volume below which discrete models of individual conduits must be used to model flow and transport from the repository and above which continuum average properties of the hydrology can be used (Activity 8.3.1.2.4.3, Bulk-permeability test in the exploratory shaft facility). This is a very important concept for ground water modeling of Yucca Mountain because it would greatly simplify the modeling process. The NRC needs to evaluate this theory, because it is a significant ground water modeling concept.

REFERENCES TO NRC PROGRAM

At this time it is not practical to model unsaturated zone ground water flow and transport at the scale of the Yucca Mountain site by treating the fractures and matrix separately. An alternative is suggested in the SCP that it is possible to regard the matrix and fractures as separate but overlapping continuum systems or as a single composite continuum. These approaches assume that matrix and fracture properties can be represented as spatial averages over rock mass volumes, whose linear dimensions are very much smaller than the thickness of the hydrogeologic unit, but sufficiently large to include a representative, statistical sample of hydraulically connected fractures. The rock mass volume over which the averaging is performed is commonly designated as a representative elementary volume. If a representative elementary volume can be established unsaturated ground water flow may be described as a single continuum composed of both matrix material and fractures. A ground water model using this type of representative elementary volume might represent the dependence of relative hydraulic conductivity on liquid water potential in an unsaturated porous medium as shown in Figure 3-34; where the combined curve represents how a block of unsaturated fractured rock would be modeled if a representative elementary volume has been demonstrated. SCP Activity 8.3.1.2.2.4.2 (Bulk-permeability test in the exploratory shaft facility, page 8.3.1.2-271) is designed to determine a representative elementary volume for the Yucca Mountain site.

It is also possible that this representative elementary volume concept may be used in performance assessment modeling conducted as part of the Memorandum of Understanding between Research and the Division of Waste Management.

ASSOCIATED NRC RESEARCH

D1672/University of Arizona - This research is contributing to our understanding of how to eastablish a representative elementary volume in conditions like those found at Yucca Mountain.

DOE RESEARCH OR INVESTIGATIONS

In SCP Study 8.3.1.2.2.4 (Characterization of Yucca Mountain percolation in the unsaturated zone exploratory shaft facility study) it is stated that the innovative nature of determining a representative elementary volume is recognized and prototype testing will be performed in support of Activity 8.3.1.2.4.3 (Bulkpermeability test in the exploratory shaft facility), which will be used to demonstrate the concept of an representative elementary volume for Yucca Mt. (page 8.3.1.2-235). Prototyping testing will involve the development of instrumentation, experimental techniques, technical procedures, and analysis techniques.

Prepared by W. Ford (RES3) 7/20/89

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The Hydrologic Transport Section staff needs facts about flow and transport processes and knowledge about parameter measurement techniques to evaluate the current concepts of moisture characteristic relations for fracture/matrix flow in unsaturated fractured rocks.

REASON FOR NEEDED RESEARCH

The Hydrologic Transport Section review of the SCP confirmed the observation that there is little data on unsaturated flow in fractured rock. However. several investigators have speculated on the behavior of flow in unsaturated fractures (Wang and Narasimhan, 1985; Klavetter and Peters, 1986; and Montazer and Wilson, 1984). These researchers model fracture conductivity as a function of fracture aperture distribution, fracture saturation, pressure head, and assume that the pressure heads in the fractures and the matrix are in equilibrium. This means that for flow to occur along the length of the fracture under unsaturated conditions, fracture aperture must be the same size or smaller than matrix pores where fluid flow is occurring. It also means that if the fracture aperture is greater than the largest matrix pore size, flow will not occur along the length of the fracture until the matrix pores are almost saturated. This hypothesis of fracture/matrix flow, will be used to conduct performance assessment evaluations. This means that a fundamental premise of the flow/ transport model has not been experimentally demonstrated.

REFERENCES TO NRC PROGRAM

The NRC review of the DOE Site Characterization Plan found that Activity 8.3.1.2.2.4.2 has the objective of determining the hydrologic conditions that control the occurrence of fluid flow within fractures and matrix.

ASSOCIATED NRC RESEARCH

D1662, D1672, G1112/University of Arizona - This research is contributing to our understanding about parameter measurement techniques to evaluate moisture characteristics/fracture-matrix flow.

DOE RESEARCH OR INVESTIGATIONS

Prototype testing at laboratory and field scales are planned prior to the exploratory shaft tests to confirm this concept of moisture characteristic relations for fracture/matrix flow in unsaturated media. Prototype tests are also planned to develop the technology to conduct these tests in the exploratory shaft. Conceptual and numerical model development for fractured, porous unsaturated media will be a part of the percolation test in the exploratory shaft facility (Activity 8.3.1.2.2.4.2). Further information on prototype testing is contained in Section 3.9.2.1 (page 3-171) of the SCP where it is stated that "Standard field and laboratory methods are not yet available by which to determine the moisture-characteristic relations for variably saturated fractures and fractured rocks. Prototype testing to develop such methods will be conducted on welded tuffs from G-Tunnel which are similar to those expected

to be encountered in the exploratory shaft facility. The benefits of this testing are twofold: first, the program will permit development of quality level 1 methods and procedures for ESF testing, and second, the results of the tests will provide preliminary data regarding the hydrologic behavior of fractured, welded tuff. Thus, preliminary assessment of the appropriateness of the models of flow processes will be possible."

Activity 8.3.1.2.2.4.2 will test the water flow and chemical transport properties of the Topopah Spring welded tuff at the repository horizon to resolve the contributions of fracture and matrix flow under varying artificial percolation rates. This test will try to define conditions for the initiation of significant fracture flow and the propagation of percolation pulses via fracture.

REFERENCES CITED

Klaveter and Peters, 1986, "Estimation of Hydrologic Properties for an Unsaturated, Fractured Rock Mass," SAND84-2642, Sandia National Laboratories, Albuquerque, NM.

Montazer, P. and W. E. Wilson, 1984, "Conceptual Hydrologic Model of Flow in the Unsaturated Zone, Yucca Mountain, Nevada," Water-Resources Investigations Report 84-4343, U.S. Geological Survey, Denver, CO.

Peters, R. R., 1988, "Hydrologic Technical correspondence in Support of the Site Characterization Plan," SAND88-2784, Sandia National Laboratories, Albuquerque, NM.

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, Albuquerque, NM.

prepared by W. H. Ford (RES5) 7/20/89

INCREASING LOG HYDRAULIC CONDUCTIVITY



Figure 3-34. Idealized hydraulic-conductivity characteristic curve for a composite (fracture-matrix) porous medium. Modified from Montazer and Wilson (1984).

INCREASING LIQUID-WATER SATURATION

DECREASING LOG MATRIC POTENTIAL

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The Hydrologic Transport staff needs an appraisal of whether zeolite composition can be used as an independent indicator of matrix water composition in the unsaturated zone at Yucca Mountain.

REASON FOR NEEDED RESEARCH

Current methods of extracting water from the matrix of rocks from the unsaturated zone for determining groundwater compositions are still in the developmental stage (Yang, 1986). These methods include compression, centrifugation, and vacuum distillation of the rocks. Compositions of the pore waters depend on the method of extraction. Thus, for a given rock from the unsaturated zone, the measurement of a unique pore water composition is not yet attainable.

Zeolites are unique aluminosilicate minerals because of their ability to rapidly equilibrate with groundwater at low temperatures. If the thermodynamic constants and isotopic fractionation factors for the exchange reactions involving zeolites and components in the aqueous phase were known, it would be possible to calculate groundwater compositions from zeolite compositions. The potential advantage of this method over the present methods is the relative ease of sampling zeolites. Furthermore, since zeolites are expected to provide the bulk of the sorption capacity of the tuff, knowledge of ion exchange properties is required for accurately modeling transport at the HLW site. The hydrologic transport staff could utilize the zeolite composition method to verify the compositions of ground water in the unsaturated zone determined by DOE and their contractors.

REFERENCE TO NRC PROGRAM

This research is needed for developing the technical position entitled "Chemical Interactions in Unsaturated Fractured Rock." The current approach used by DOE to model chemical interactions in the unsaturated zone is to assume that the chemistry is identical to that in the saturated zone. The staff proposes to determine the limitations of this assumption and develop criteria concerning the modeling of transport processes in the unsaturated zone.

This research would also provide information for the NRC HLW technical review staff for evaluating the following Study Plans:

8.3.1.2.2.7 Hydrochemical characterization of the unsaturated zone

8.3.1.2.2.9 Site unsaturated-zone modeling, synthesis, and integration

ASSOCIATED NRC RESEARCH

CNWRA: The CNWRA has committed to study the application of cryo-electron microscopy and x-ray microanalysis to geochemical characterization of pore waters under Activity 2.2.1.1. of the Geochemistry Project Plan as described in the letter of J. E. Latz to M. Mace on January 13, 1988. In addition, the Center is looking at the thermodynamic properties of zeolites.

ASSOCIATED DOE RESEARCH OR INVESTIGATIONS

The USGS as contractor to the DOE is studying the feasibility of extracting water from rocks from the unsaturated zone by applying pressure. The compositions of the extracted waters are determined using conventional techniques. See DOE studies referenced in Item 3.

REFERENCE

Yang, A., 1986, Summary of Progress Report, Unsaturated Zone Hydrochemistry, February 12, 1986, U.S. Geological Survey.

prepared by J. W. Bradbury 6-8-89

The Hydrologic Transport Section staff needs to know if extending the exploratory shaft into the Calico Hills nonwelded unit, in order to test the hypothesis that flow through fractures and faults in nonwelded tuff (i.e., the Calico Hills nonwelded unit) is negligible, will significantly affect its integrity as a "primary barrier" to radionuclide movement, and if so acceptable alternatives to test the hypothesis.

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REASON FOR NEEDED RESEARCH

The Hydrologic Transport Section staff has to determine the acceptability of the testing program, to be developed and implemented by DOE, to test hypothesis that flow through fractures and faults through the Calico Hills nonwelded unit is negligible. This hypothesis is the fundamental basis for both designating the Calico Hills units as the primary barrier of the geologic setting and assuming that calculation of groundwater travel time and release of radionuclides to the accessible environment using an equivalent porous media approach (in nonwelded tuff units) is appropriate.

REFERENCES TO NRC PROGRAM

The NRC staff review of the Site Characterization Plan for the Yucca Mountain Project found that proposed plans to characterize the geohydrologic properties of the Calico Hills (a nonwelded tuff unit underlying the repository horizon at Yucca Mountain) are limited. Characterization of the unit is limited due to a concern that penetration of the Calico Hills unit within the repository block may affect the performance of the site.

ASSOCIATED NRC RESEARCH

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01672, D1662, G1112/University of Arizona - The past research in unsaturated, fractured rock done by the University of Arizona may contribute to developing the criteria by which a minimum acceptable testing program is determined for standards that the licensing staff could apply to the future testing plan review.

DOE RESEARCH OR INVESTIGATIONS

DOE's current plans for characterizing the Calico Hills units are limited to surface-based studies in vertical boreholes. It is acknowledged in the SCP that the surface-based studies will provide very limited information about the distributions and flow characteristics of fractures and faults in the Calico Hills and thus, are of limited use in supporting the hypothesis of negligible flow through faults and fractures. Development of in situ testing in the Calico Hills as part of an exploratory shaft facility is in abeyance because of a concern that penetration of the unit within the repository block may affect the performance of the site. Alternative approaches (shaft sinking and drifting in the vicinity of the site and various combinations of vertical and angle drillholes and excavation) are being considered. Potential trade-offs between the need to acquire data and the need to preserve site-performance capability

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are being evaluated by DOE with a risk-benefit analysis. Selection of appropriate test options will be made, and consultations with NRC staff held, prior to initiating testing.

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Prepared by J. Pohle 6/18/89

The Hydrologic Transport Section staff needs an appraisal of the appropriateness and the precision/accuracy of using anthropogenic contaminants such as tritium, technetium-99, iodine-129, chlorine-36 (bomb pulse radioisotopes) to directly assess pre-waste-emplacement groundwater travel time.

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REASON FOR NEEDED RESEARCH

The H-T staff needs comprehensive understanding and review criteria for radioisotopic methods, used in the analysis of groundwater flow systems, to make informed reviews of DOE data collection activities and better evaluations of DOE's data interpretations. Such analyses can provide empirical estimates of seepage velocities in the vadose zone, and will lead to improved estimates of recharge to the vadose zone. Recent publications demonstrate the utility of radioisotopes in helping to better understand groundwater flow systems (Phillips et al., 1988; Robertson and Cherry, 1989).

Radioisotopic interpretations may independently validate site flow and transport modeling with respect to present conditions at a repository site, and thus can support projections of future groundwater flow conditions. Information on appropriate methods to determine groundwater background levels of radioisotopes in the Yucca Mt. region is needed to judge the quality of data obtained by planed DOE site characterization activities. Determinations of natural background levels are important for assessing whether radioisotopes observed at depth in site wells are of natural or anthropogenic origin.

As determined in the SCP review, DOE is developing water sampling techniques for the unsaturated zone in a prototype development program. Techniques for collecting uncontaminated hydrochemical samples are important to provide high quality data and reliable hydrogeologic interpretations. NRC's independent knowledge of sampling techniques is needed to conduct informed reviews of DOE's hydrochemical data collection activities.

REFERENCE TO NRC PROGRAMS

This need for Yucca Mt. became apparent during the SCP review. Comment SCP/YUCCA/NMC/COM/9 stated that, consistent with Regulatory Guide 4.17, at sites where human activity may have introduced radioactivity to the ground water, analysis should be done for those radioisotopes that are known or suspected to have been added to the system. Iodine-129 and technetium-99 were not included by DOE in the group of radioisotopes to be analyzed from water samples collected at the water table and from any perched zones. These radioisotopes are among those identified in Appendix A of the EPA release standards. The background levels and variability of these radioisotopes in saturated zones should be assessed as part of site characterization to provide baseline information for a performance confirmation program at Yucca Mt.

Most importantly, the need for radioisotopic evaluations can directly address the requirements of 10 CFR Part 60.113 regarding pre-waste-emplacement groundwater travel time.

ASSOCIATED NRC RESEARCH

There is no ongoing NRC research that directly addresses this research need. Previous work through the University of Arizona has been discontinued. NUREG/ CR-4912 provides an evaluation of methods which might be used to "date" groundwater. As stated in the preface to that report, "If ground-water flow is not affected greatly by human activity in the future and if the repository is sealed against vertical leakage along shafts and drill holes, then geochemical studies, particularly those directed towards 'dating,' provide the most reliable methods of predicting ground-water movement for periods of thousands of years into the future."

WWL (1988) prepared a report for the NRC titled "The Use of Environmental Tracers for the Estimation of Recharge at Yucca Mountain: A Summary." This report is a "critical literature review of the potential to use environmental isotopes to address questions of net infiltration and, ultimately, the flux of water passing through the unsaturated, low permeability, dual porosity rocks of the repository horizon at Yucca Mountain." The NWC report notes that if matrix flow at Yucca Mt. provides the major water pathway, then the travel time is probably very long. However, "if fracture flow occurs to a greater extent than is currently believed, radionuclides could possibly reach the accessible environment in a relatively short time period." From a regulatory perspective, measurements of radioisotopes in the subsurface can provide powerful insight about groundwater travel time in both the vadose and saturated zones.

ASSOCIATED DOE RESEARCH OR INVESTIGATIONS

- 8.3.1.2.2.2 Study: Water movement tracer tests using chloride and Cl-36 measurements of percolation at Yucca Mt. (Tc-99 also discussed under this study)
- 8.3.1.2.2.7 Study: Hydrochemical characterization of the unsaturated zone
- 8.3.1.2.3.2 Study: Characterization of the saturated zone hydrochemistry

DOE's principal emphasis is to use hydrochemistry to help assess recharge. For example, the objective of activity 8.3.1.2 2.2.1 is to quantify the amount of percolation from precipitation into the unsaturated zone. One of the objectives of study 8.3.1.2.2.7 is to provide independent evidence of flow direction, flux, and travel time of water in the unsaturated zone. An objective of activity 8.3.1.2.3.2 is to aid in the identification and quantification of fluxes to, from, and within the saturated zone.

No plans were found in the SCP for the investigation of regional background levels of radioisotopes that are relevant to repository performance. These radioisopes include those listed in the EPA HLW release standards.

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One of the objectives of Activity 8.3.1.2.2.7.2 (aqueous-phase chemical investigations) is to design and implement methods for extracting pore fluids from unsaturated zone tuff units. As stated on SCP page 8.3.1.2-338, various methods will be evaluated during prototype testing.

Yang et al. (1985) performed radioisotopic and isotopic studies in the vadose zone at Yucca Mt. The purpose of their study was to evaluate analytical methods for determining gas constituents in the unsaturated zone of Yucca Mt. Two different collection techniques and analytical methods were used for determining CO_2 concentrations, carbon isotopes, and water vapor. They concluded that CO_2 concentrations measured by both methods were not consistent. They further concluded that the "majority of post-bomb ¹⁴C was observed to a depth of 40 feet (12.2 meters) below surface, and less than pre-bomb activity was measured at and below a depth of 60 feet (18.3 meters)."

REFERENCES

- Davis, S. N. and E. Murphy, 1987. Dating Ground Water and the Evaluation of Repositories for Radioactive Waste: NUREG/CR-4912, NRC Project B6628, U.S. Nuclear Regulatory Commission, Washington, DC, 181 pages.
- Phillips, F. M., J. L. Mattick, and T. A. Duval, 1988. Chlorine 36 and Tritium from Nuclear Weapons Fallout as Tracers for Long-Term Liquid and Vapor Movement in Desert Soils: Water Resources Research, Vol. 24, No. 11, pages 1877-1891.
- Robertson, W. D. and J. A. Cherry, 1989. Tritium as an Indicator of Recharge and Dispersion in a Groundwater System in Central Ontario: Water Resources Research, Vol. 25, No. 6, pages 1097-1109.
- Yang, I. C., H. H. Haas, E. P. Weeks, and D. C. Thorstenson, 1985. Analysis of Gaseous-Phase Stable and Radioactive Isotopes in the Unsaturated Zone, Yucca Mountain, Nevada," in <u>Proceedings of the NWWA Conference on</u> <u>Characterization and Monitoring of the Vadose (Unsaturated) Zone</u>, National Water Well Association, Dublin, Ohio, pp. 488-506.
- Water, Waste and Land, Inc. (WWL), 1988. The Use of Environmental Tracers for the Estimation of Recharge at Yucca Mountain - A Summary: Technical Report #8, NRC Contract No. RS-NMS-85-009, U.S. Nuclear Regulatory Commission, Washington, DC, 86 pages.

REVISED BY: NEIL M. COLEMAN, 8/9/89

- 1 -

The Hydrologic transport staff needs an appraisal of the applicability of existing coupled flow and transport codes to model the performance of a proposed HLW repository at Yucca Mountain.

REASON FOR NEEDED RESEARCH

In its review of the SCP, the NRC staff has expressed concern that the Kd approach chosen by DOE to model transport may not be valid under all conditions expected at Yucca Mountain. A possible alternative approach would be to use a coupled flow and transport model of reactive multichemical components. However, these codes require tremendous memory and CPU time when applied to all but the smallest discretized systems. There are several approaches taken by the codes to determine the coupled transport-flow system. The various approaches prioritize certain parameters over others in the method of solution. Yeh and Tripathi (1989) evaluates the computational limitations of the various approaches and concludes that the Sequential Iteration Approach is the best. However, this evaluation was not made based on the requirements of 10 CFR Part 60. An evaluation is required to demonstrate which codes will be appropriate to support a license application based on the requirements of 10 CFR Part 60.

REFERENCE TO NRC PROGRAMS

Some of the NRC technical staff, in order to develop expertise "in house", are participating in a group that models various systems and/or processes applicable to a nuclear waste repository. This research would demonstrate on which codes the modeling group should focus.

This research would also provide information for the NRC HLW technical review staff for evaluating the following Study Plans:

8.3.1.3.7.1 Retardation Sensitivity Analysis

8.3.1.3.7.2 Demonstration of Applicability of Laboratory Data to Repository Transport Calculations

ASSOCIATED NRC RESEARCH

A1266-SNL/CENTER/D2012-ANSTO. Also, note that the NRC partially funded the work done by Tripathi (B0287 ORNL) on the development of the coupled geochemistry-hydrology code, HYDROGEOCHEM.

ASSOCIATED DOE RESEARCH OR INVESTIGATIONS

See section 2 for applicable Study Plans

REFERENCE

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Yeh, G. T. and V. S. Tripathi, 1989, A critical evaluation of recent developments in hydrogeochemical transport models of reactive multichemical components, Water Resources Research, vol. 25, no. 1, p. 93-108.

Prepared by John Bradbury 7/14/89

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The Hydrologic transport staff needs to know how the physical and chemical parameters of macroscopic groundwater samples compare with those for groundwater in the microscopic pores of the geologic medium at Yucca Mountain?

REASON FOR NEEDED RESEARCH

Both chemical and hydrologic modeling of flow and transport in the unsaturated zone assume that the properties of the groundwater (in situ-microscopic) are the same as "free water" (microscope) (deMarsily, 1986). "Free water" is defined as that which is outside the field of attraction of the solid particles and can be displaced by gravity or pressure gradients. DeMarsily (1986) describes water within 0.5 microns of a solid-liquid interface as "adhesive water" which is attached to the surface of the grains through the influence of forces of molecular attraction. This water can have significantly different properties than free water, such as higher viscosity, higher density, and higher solute concentrations. Additionally, D'Orazio et al., 1989 demonstrates that self diffusion of water in porous glass is strongly enhanced if the pore space is only partially filled. Peters et al., 1984 states that the average pore size in tuffs is on the order of 0.03 microns. Thus, a significant proportion of the groundwater at Yucca Mountain could be "adhesive" water.

Presently, little is known about the differences in properties between the two types of waters, their relative abundances, and their mobility in the unsaturated zone. As a result, modeling of flow and transport is extremely uncertain.

REFERENCE TO NRC PROGRAMS

This research is needed for developing the technical position entitled "Chemical Interactions in Unsaturated Fractured Rock." Furthermore, this research is needed to address uncertainties relating to groundwater travel time derived by age dating techniques.

The information obtained from this research would be used in evaluating all DOE programs relating to flow and transport in the unsaturated zone. In other words, this is fundamental to modeling the site.

ASSOCIATED NRC RESEARCH

D1662 and G1112/University of Arizona - Also, the CNWRA has committed to study the application of cryo-electron microscopy and x-ray microanalysis to geochemical characterization of pore waters under Activity 2.2.1.1. of the Geochemistry Project Plan as described in the letter of J. E. Latz to M. Mace on January 13, 1988.

ASSOCIATED DOE RESEARCH OR INVESTIGATIONS

The USGS as contractor to the DOE is studying the feasibility of extracting water from rocks from the unsaturated zone by applying pressure. The composi-

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tions of the extracted waters are determined using conventional techniques. It is not known whether the water extracted is representative of "free water," "adhesive water," water of hydration, or some combination of the above.

REFERENCES

D'Orazio, F., Bhattachrja, S. and W. P. Halperin (1989) Enhanced Self Diffision of Water in Restricted Geometry, Physical Review Letters Vol. 63, #1, P43-46.

DeMarsily, G., 1986, Quantitative Hydrogeology, Academic Press, Inc., Orlando, p. 23.

Peters, R. R., E. A. Klavetter, I. J. Hall, S. C. Blair, P. R. Heller, and G. W. Gee, 1984, Fracture and Matrix Hydrologic Characteristics of Tuffaceous Materials from Yucca Mountain, Nye County, Nevada, SAND84-1471, Sandia National Laboratories, Albuquergue, NM.

Yang, A., 1986, Summary of Progress Report, Unsaturated Zone Hydrochemistry, February 12, 1986, U.S. Geological Survey.

Prepared by John W. Bradbury

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The Geology-Geophysics Section staff needs:

- A. An appraisal of mechanisms and processes that control the location of volcanics in a geologic setting like the Yucca Mountain mountain site.
- B. An appraisal of the extent of hydrothermal effects associated with volcanics in a geologic setting like the Yucca Mountain mountain site.

REASON FOR NEEDED RESEARCH

Current work in areas of geothermal resources indicate the possibility of lateral migration of geothermal plumes in active volcanic fields through preexisting fracture zones. Because of this possibility it may be difficult to predict or bound the possible zone of influence of hydrothermal activity or subsurface hydrothermal alteration associated with volcanic activity or magma bodies. Due to the proximity of recent basaltic volcanism to the proposed HLW site and the current absence of data to evaluate the presence or absence of subsurface magma bodies in the area, the possibility of hydrovolcanic or phreatomagmatic activity for the proposed site should be addressed and the features and mechanisms influencing such activity need to be understood.

In addition, causes and mechanisms of phreatomagmatic activity need to be examined within the context of waste emplacement. For example, what temperature is necessary to promote such activity and is it possible to produce this type of activity with emplacement of waste, given that other geologic and hydrologic conditions within and near the emplacement area are appropriate for such activity.

REFERENCE TO NRC PROGRAMS

This research will provide input to the proposed volcanic hazards technical position on which work is scheduled to begin in September, 1989. This research could also provide information as input to Standard Format and Content Guides and Standard Review Plans and for the NRC NLW technical staff's review and evaluation of DOE technical reports, alternative tectonic models, and site performance assessments related to tectonics.

ASSOCIATED NRC RESEARCH

A1824/SNL - Also, the Office of Research is conducting analog studies in the area of the Valles Caldera, New Mexico, to identify and characterize the extent of hydrothermal alteration of the rocks, and transport of elements expected in a NLW repository in unsaturated tuff.

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ASSOCIATED DOE RESEARCH OR INVESTIGATIONS

Los Alamos National Laboratory as contractor to the DOE is conducting the site studies related to volcanism. Studies include gathering of field data, geochemical analyses, and evaluation of data integrating mapping, geochemistry, and geomorphology.

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The Geology-Geophysics Section Staff needs an appraisal of the appropriateness and precision/accuracy of probabilistic seismic hazard (PSH) estimates for the long time frame (10,000 years) and how the band of uncertainty associated with the estimates can be reduced.

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Reason for Needed Research

For the post-closure period of high-level waste repository, earthquake events will be combined with other processes and events to form the bases for calculating an overall complementary cumulative distribution function (CCDF). This function should display that the likelihood of radioactive material released to the environment for 10,000 years after disposal for all significant processes and events will not exceed specified EPA values. Compliance with these EPA release requirements is necessary for the commission to issue a license to the applicant to dispose of high-level radioactive waste.

The current methodology, used to estimate the PSH, attempts to extrapolate a relatively short historical earthquake data base (200 to 300 years) far into the future (10000 years). The hazard estimates for these long time frames are highly uncertain and may require quantitatively different assumptions about the earthquake processes. Further the validity of the Poisson's distribution (a random and memoryless process) which has been widely used for the short time frame has to be tested for the long time frame. Models with memory require more knowledge of the earthquake behavior which is not well understood up till now.

Reference to NMSS Programs

This research is needed to support the guidance which the NMSS staff will provide DOE to generate the probabilistic seismic hazard curves. This research can also provide an insight on the strengths and weaknesses in the design and operation for the pre-closure period of the repository.

Associate NRC Research

None - However, NRR has sponsored a probabilistic seismic hazard program for nuclear power plants east of the Rocky Mountains (Bernreuter et al, 1989). The methodology used in this program and the results obtained can form the bases for the long time frame calculations needed for the high-level waste program. NMSS through Sandia National Laboratories conducted a literature review for techniques for Determining Probability of Events and Processes Affecting the Performance of Geologic Repositories (Hunter and Mann, 1989).

Associated DOE Research

The DOE is committed to provide a study plan summarizing the approach they intend to use for calculating probabilistic seismic hazard curves.

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Bernreuter, D. L., J. B. Savy, R. W. Mensing, and T. C. Cheng, Seismic Hazard Characterization of 69 Nuclear Plant Sites East of the Rocky Mountains, NUREG/CR-5250, 1989.

Hunter, R. L., and C. J. Mann, Techniques for Determining Probabilities of Events and Processes Affecting the Performance of Geologic Repositories, NUREG/CR-3964, 1989.

HLWM RESEARCH NEED 12

The Engineering and Rock Mechanics Section staff needs a methodology to allow independent assessment of compliance with 10 CFR 60.134 design criteria related to design, construction, and performance of seals for shafts and boreholes associated with a geologic repository. Specific needs are:

- Effects of wetting and drying
- Free drainage concept
- Seals as a preferential pathway for gas/vapor/water
- Material properties under repository environment
- Sealing damaged area around drilled holes and blasted holes
- Coupled interactions
- Seismic effects on seal performance
- Extrapolation of lab and field data
- Model validation

REASON FOR RESEARCH NEED:

The overall need for this research program is to provide the NRC with a technical capability and the necessary independent experimental data relevant to assessment of sealing of openings in a tuff medium at Yucca Mountain, Nevada. The results of this research will directly support NRC staff review of DOE's license application.

In general the need for this research stems from the requirement:

- 1. To obtain an understanding of the important parameters associated with the performance of seals in a tuff medium. This information is required to assess compliance with 10 CFR 60.134 requirements related to design of repository seals and to post-closure integrity of the engineered barrier system.
- 2. To develop methodology to evaluate, reduce uncertainties, and to independently assess predictions related to the potential for creating preferential pathways around seals for the inflow of groundwater to, or the outflow of radionuclide bearing air from a geologic repository.

The specific technical needs for this research program are:

- To obtain an understanding, through laboratory characterization, of important physical, mechanical, and hydrological properties of materials affecting sealing;
- 2. To obtain an understanding, through laboratory experimentation, of the uncertainties associated with fracture sealing in a tuff medium;

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3. To obtain an understanding, through in-situ field testing, of the uncertainties associated with the impact of construction and seal implacement techniques on seal performance;

To develop technical data for preparing licensing positions related to sealing of shafts and boreholes in a tuff medium.

REFERENCE TO NRC PROGRAMS (I.E., TP's, RULES, MOU, F&CG, LA REV. PLAN):

This research is needed to provide a well defined base from which to evaluate whether a geologic repository can be designed, constructed, and operated without undue risk to the health and safety of the public. Specifically this research is required to develop the solutions and approaches, determined by the NRC staff to be acceptable, for evaluating compliance with seal performance requirements of 10 CFR 60. These solutions and approaches will be codified, as appropriate, in the License Application Review Plan. This research will also provide information for the NRC HLWM review staff for evaluating SCP Study Plan 8.3.3.2.2.1 - "Seal Material Properties Development".

ASSOCIATED NRC RESEARCH:

B6663 Project 4/Center

ASSOCIATED DOE RESEARCH OR INVESTIGATIONS:

NONE

The Engineering and Rock Mechanics Section staff needs a methodology to independently assess compliance with the safety aspects of 10 CFR 60 design criteria for the geologic repository operations area with respect to the effects of strong ground motion from seismic events. This work should be focused upon the effects of depth on the nature of the vibratory spectra in generalized rock media. Specific desired reporting requirements include: (1) a database documenting the effects of both natural earthquakes and artificially-generated seismic events on underground openings; (2) assessment of analytical models/computer codes; (3) jointed rock property evaluation; (4) computer codes validation; (5) development of methodology for evaluating the effects of seismic events on structures, systems, and components important to safety, and on structures important to waste isolation, retrieval, and postclosure performance; and (6) development of the NRC. Specific needs are:

- Impact of rock mineral stability on seismic response of openings
- Impact of ground motion on rock stability and its effect on waste package
- Extrapolation of lab and field data
- Model validation

REASON FOR RESEARCH NEED:

The overall need for this research program is to provide the NRC with a technical capability and the necessary independent experimental data relevant to assessment of the potential effects of seismic events on the performance of the proposed high-level nuclear waste repository at Yucca Mountain, Nevada. The results of this research will directly support review of DOE's license application.

In general the need for this research effort stems from the requirement:

- 1. To obtain an understanding of the important parameters associated with the response of shaft liners and underground repository structures in tuff due to seismic motion. This information is required to address 10 CFR 60 requirements related to repository design, safe operations, waste retrievability, and integrity of the engineered barrier system.
- 2. To obtain an understanding of joint dynamic responses and of the important parameters associated with the response of joints to seismic motion. This information is required to reduce uncertainties associated with determining compliance with the repository design criteria of 10 CFR 60.
- 3. To develop methodology to evaluate, reduce uncertainties, and where possible validate prediction models used in seismic assessment of tuff media. This requirement is associated with decreasing the uncertainties in determining compliance with the preclosure and postclosure performance

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requirements of 10 CFR 60 for a repository in tuff media subject to seismic loadings.

The specific technical needs for this research program effort are:

- 1. To develop a good understanding of the information currently available on seismic effects on shaft and underground structures;
- 2. To assess critically the capabilities and limitations of analytical and numerical modeling methods currently in use;
- 4. To demonstrate by experimental physical model studies the degree of validity of the analytical and numerical models used for seismic analysis in tuff media;
- 5. To identify and assess the key seismic-related parameters that are applicable to the Yucca Mountain Site;
- 6. To develop technical data for preparing licensing positions as they relate to effects of seismic action on an underground repository in tuff media.

REFERENCE TO NRC PROGRAMS (I.E., TP's, RULES, MOU, F&CG, LA REV.PLAN):

This research is needed to provide a well defined base from which to evaluate whether a geologic repository can be designed, built and operated without undue risk to the health and safety of the public. Specifically this research is required to develop the solutions and approaches determined to be acceptable for evaluating the seismic design and construction of safety related preclosure underground facilities and in dealing with postclosure safety problems and safety-related design areas of underground facilities and of seals for shafts and boreholes. These solutions and approaches will be codified as appropriate in the License Application Review Plan. This research will also provide information for the NRC HLWM review staff for evaluating SCP Study Plans including the following:

- Study 8.3.1.9.1.1 "An evaluation of natural processes that could affect the long-term survivability of the surface marker system at Yucca Mountain";
- 2. Study 8.3.1.17.3.1 "Relevant earthquake sources";
- 3. Study 8.3.1.17.3.3 "Ground motion from regional earthquakes and underground nuclear explosions";
- 4. Study 8.3.1.17.3.5 "Ground motion at the site from controlling seismic events";
- 5. Study 8.3.1.17.3.6 "Study probabilistic seismic hazards analyses";
- 6. Study 8.3.1.17.4.1 "Historical and current seismicity".

ASSOCIATED NRC RESEARCH:

NONE.

B6663-Project 4/Center

ASSOCIATED DOE RESEARCH OR INVESTIGATIONS:

NONE.

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The Hydrologic Transport Section needs an assessment of climate models (general circulation models, GCMs) for a recommendation of the most appropriate one for long term future climate prediction, development of disaggregation (spatial and temporal) methods for the GCM grid and time scales to local (site) scales and short time periods, and development of criteria to evaluate assumptions ("scenarios") used for GCM predictions for repository performance evaluations.

REASON FOR NEEDED RESEARCH

The NRC needs to know the anticipated predictive capabilities (particularly precipitation and evapotranspiration) of the "best" general circulation model, for the Yucca Mountain area, for independent assessments and to evaluate those aspects of repository performance that will be based on the long term future predictions made by a similar type model that will be used by DOE. It is known that the existing GCMs are being refined (i.e. addition of more atmospheric layers and representation of ocean circulation) and that additional refinements are contemplated (such as representing the influence of cloud cover). Thus the NRC needs an assessment of the existing well developed GCMs (5 are generally referenced in the literature) [Mitchell, 1989; Shlesinger and Zhao, 1989] and, with consideration of the planned refinements and developments over the next 3-5 years, a recommendation of the best one for NRC's regulatory license review use.

Current GCMs typically use a spatial grid of about 5 degrees latitude by 7 degrees longitude (Mitchell, 1989). These grid dimensions are considerably larger than the Yucca Mountain site (about 3 mi. by 1.5 mi. projected area) and will encompass the region about the site. For some of the modeling exercises, the coarse grid predictions will need to be disaggregated to local area values. Methods to do these disaggregations need to be reviewed and possibly developed.

The NRC needs to know the appropriate criteria for making the assumptions for future climate modeling predictions so that NRC staff can judge the adequacy of the DOE analysis and scenarios of future climate use in compliance demonstration.

REFERENCES TO NRC PROGRAM

The Hydrologic Transport Section review of the SCP found that DOE plans a significant and comprehensive effort to evaluate past climates at the Yucca Mountain site (Refer to SCP Chapter 5 and Section 8.3.1.5). Specific reference by DOE to use of a general circulation model in the evaluation of future performance of the repository is made in Investigation 8.3.1.5.1 (see page 8.3.1.5-39), studies 8.3.1.5.1.5. and 8.3.1.5.1.6.

ASSOCIATED NRC RESEARCH

B7121/NSF, B7096/Center: Note - Office of Research participation in an Interagency Agreement with the National Science Foundation which is sponsoring a study to develop general information about paleoclimate reconstruction, global

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climate modeling, and the application of global climate models to the prediction of future climates, (FIN B7121, "Climates of the Holocene").

DOE RESEARCH OR INVESTIGATIONS

SCP Investigation 8.3.1.5.1.

REFERENCES

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Mitchell, J. F. B., 1989, "The 'Greenhouse' Effect and Climate Change," Reviews of Geophysics, 27, 1, February, pp. 115-139.

Schlesinger, J. E. and Z-C Zhao, 1989, "Seasonal Climatic Changes Induced by Double CO2 as Simulated by the OSU Atmospheric GCM/Mixed-Layer Ocean Model," Journal of Climate, Vol. 2, May, pp. 459-495

Prepared by D. L. Chery 8/14/89

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Materials Section staff needs a quantification of the most likely and/or most severe failure scenario for the waste package in an unsaturated repository environment like that experted at Yucca Mountain. Specifically, an assessment is needed on corrosion and the effects of wetting and drying.

Reason for Needed Research

An understanding of the effects of wetting and drying on the corrosion of metals in repository environment is needed to evaluate if DOE's waste packages will perform as designed.

Under anticipated conditions, a continuous flow of water around waste packages located in the unsaturated repository is not possible. The amount of downward infiltration from the surface and overlying unsaturated media is estimated to provide less than 1 mm per year (Montazer, 1984) as water to drip or seep around the waste packages.

At the elevation (approx. 900 m) of Yucca Mountain, the boiling point of water is about 95 C. Consequently, the waste package will be exposed to air-water vapor mixtures in the first few hundred years until the surface temperature of the waste canister falls below 95 C, which is approximately 300 years for reprocessed waste (or about 400 years for waste package design with packing). In the case of spent fuel, this will happen in more than 1000 years after repository closure (Stein 1984). After these times, liquid phase water will be intermittently in contact with the waste package and the failure mode will be aqueous corrosion. Corrosion of the canisters under wet and dry cycles in repository environment is a very likely failure scenario.

Reference of NRC Program

NRC's program to evaluate DOE's waste package design is to validate and estimate acceptability of DOE's data and analyses on performance compliance. It is therefore necessary to identify the worst failure scenario for the waste package.

This research is needed to develop some evidence that wet and dry cycle corrosion will produce a liquid phase more aggressive than corrosion in the original groundwater or in rocks partially saturated with the groundwater.

Associated NRC Research

B6663-Project 5/Center. Note - The CNWRA has been doing corrosion studies but none specifically addressing effects of wetting and drying on corrosion.

Associated DOE Research or Investigations

The LLNL's corrosion studies are expected to include wetting and drying corrosion. However, little or no data has been published and some data obtained

independently of DOE supported work is needed to validate any data DOE may have produced.

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REFERENCES:

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Montazer, P. and Wilson, W. E., Conceptual Models for Flow Through the Unsaturated Zone at Yucca Mountain, Nevada, USGS-WRI-84, 1984.

Stein, W., Hockman, J. N., and O'Neal, W. C., Thermal Analysis of NNWSI Conceptual Waste Package Designs, UCID-20291, 1984. 1. Research on Extrapolation of Laboratory and Field Data.

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The Materials Section staff needs to quantify the effects of welding on the degradation of metals especially those candidate metals and alloys being considered by DOE for waste packages.

Reason for Needed Research

Welding is the most likely method to be used by the DOE to seal the waste package (mechanical joints are considered inadequate to contain radionuclide release before the waste package fails). Effects of welding on the degradation of metals (e.g. corrosions and material properties) have not been adequately assessed for performance evaluation purpose. These effects can cause prematured failure of the waste packages.

Reference to NRC Programs

This research is needed for quantitatively assessing containment life of DOE's waste packages. These effects need to be quantified for use in the development of NRC's waste package performance compliance evaluation.

Associated NRC Research

B6663-Project 5/Center. Note - The CNWRA has initiated studies on corrosion of DOE candidate metals for waste packages. However, the studies do not include effects of welding on corrosion and on other metal degradation mechanisms.

Associated DOE Research or Investigations

The DOE is considering welding as a prime waste package sealing process. It has not produced any data which can be used to quantitatively assess the effects of welding on metal degradations.

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UNITED STATES NUCLEAR REGULATORY COMMISSION WASHINGTON, D. C. 20555

FEB 13 1989

MEMORANDUM FOR:	Eric S. Beckjord,	Director
•	Office of Nuclear	Regulatory Research

FROM:

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Robert M. Bernero, Director Office of Nuclear Material Safety and Safeguards

SUBJECT: HLWM STATEMENT OF RESEARCH NEEDS

Enclosed for appropriate action is a statement from the Division of High-Level Naste Management (HLWM) of research needed to support the role of the Nuclear Regulatory Commission (NRC) in the national High-Level Waste (HLW) repository program. The enclosed statement is an update of the 1984 statement of research needs and reflects the focus of the program of the Department of Energy (DOE) on one potential site in Nevada.

The HLW research work currently underway (which has evolved through ongoing interactions between RES and HLWM staff), is consistent with the enclosed statement of needed research. For both research currently under contract and new work, priority should be given to research which supports NRC activities identified in SECY-88-285, as follows (in descending order of priority): (1) Activities that reduce regulatory uncertainty (e.g., development of rules and regulatory guides) and (2) activities which develop independent capability of NRC staff to perform repository system performance assessments. Highest schedular attention within each area of priority should be placed on those activities which could significantly impact DOE's site characterization program.

As in the past, HLWM staff will work closely with RES to ensure that existing and future research projects are timely, consistent with identified needs, and integrated with the HLW licensing program in a manner consistent with HLWM programmatic priorities. To assist in this effort, it is requested that all proposed new RES work be accompanied by supporting documentation that addresses:

- (1) The relationship of the scope of the proposed new work to the needs addressed in SECY-88-285,
- (2) The relationship of the schedule of the proposed new work to the schedular needs addressed in SECY-88-285,
- (3) The relationship of the proposed new work to the enclosed user need statement (i.e., specific topics, questions/concerns being addressed), and

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(4) The relationship of the proposed new work to technical work being done by DOE.

I appreciate the close and effective working relationship that has been evidenced to date between HLWM and RES staff. Please contact Ronald L. Ballard (X23455/5-H-1) if you have any questions or comments about the enclosed NMSS Statement of HLWM Research Needs.

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Robert M. Bernero, Director Office of Nuclear Material Safety and Safeguards

Enclosure: As stated

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USER NEED LETTER/

FEB 13 1989

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FROM:

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SUBJECT: HLWM STATEMENT OF RESEARCH NEEDS

Enclosed for appropriate action is a statement from the Division of High-Level Waste Management (HLWM) of research needed to support the role of the Nuclear Regulatory Commission (NRC) in the national High-Level Waste (HLW) repository program. The enclosed statement is an update of the 1984 statement of research needs and reflects the focus of the program of the Department of Energy (DOE) on one potential site in Nevada.

The HLW research work currently underway (which has evolved through ongoing interactions between RES and HLWM staff), is consistent with the enclosed statement of needed research. For both research currently under contract and new work, priority should be given to research which supports NRC activities identified in SECY-88-285, as follows (in descending order of priority): (1) Activities that reduce regulatory uncertainty (e.g., development of rules and regulatory guides) and (2) activities which develop independent capability of NRC staff to perform repository system performance assessments. Highest schedular attention within each area of priority should be placed on those activities which could significantly impact DOE's site characterization program.

As in the past, HLWM staff will work closely with RES to ensure that existing and future research projects are timely, consistent with identified needs, and integrated with the HLW licensing program in a manner consistent with HLWM programmatic priorities. To assist in this effort, it is requested that all proposed new RES work be accompanied by supporting documentation that addresses:

- (1) The relationship of the scope of the proposed new work to the needs addressed in SECY-88-285,
- (2) The relationship of the schedule of the proposed new work to the schedular needs addressed in SECY-88-285,
- (3) The relationship of the proposed new work to the enclosed user need statement (i.e., specific topics, questions/concerns being addressed), and

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(4) The relationship of the proposed new work to technical work being done by DOE.

I appreciate the close and effective working relationship that has been evidenced to date between HLWM and RES staff. Please contact Ronald L. Ballard (X23455/5-H-1) if you have any questions or comments about the enclosed NMSS Statement of HLWM Research Needs.

Robert M. Bernero, Acting Director Office of Nuclear Material Safety and Safeguards

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HLWM STATEMENT OF RESEARCH NEEDS

The following research is needed to support independent reviews and evaluations by NMSS/HLWM of DOE site characterization activities and performance calculations for a deep geologic repository for high-level radioactive waste. The areas of technical work in HLW have been identified by the licensing staff based on its consideration of the findings required by 10CFR60. The specific areas for HLWM research support were selected based primarily on the following criteria:

- ° The research supports development of specific NRC regulations, regulatory guides, technical positions, or performance assessment methodologies,
- The research supports staff analysis of highly uncertain or poorly understood phenomena or processes important to evaluating the safety of a repository that are anticipated to require an independent assessment of their significance, or
- ° The research supports staff analysis of unconventional approaches being used by DOE to collect data or develop models.

A comprehensive set of general technical areas and specific technical problems must be addressed by DOE in its programs to support its license application. NRC research should provide an independent capability for assessment of DOE activities rather than a remedy of deficiencies in the work being conducted by the DOE. The focus of the technical work is to assess the capabilities, limitations, assumptions and uncertainties associated with:

- Identification of failure modes and for quantifying or assessing risks associated with components of the high-level radioactive waste disposal system;
 - Extrapolation of short-term laboratory and field observations to long-term predictions for making the HLW regulatory performance assessments.

While the needs identified focus primarily on the information or capability that is required to independently assess DOE's license application, HLWM research support programs need to be structured to provide interim results as they become available to provide staff guidance, and positions that can be used by the staff in their consultation with DOE.

A. WASTE FORM AND PACKAGING

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1. Identification and Assessment of Potential Failure Modes for Waste Packages

Research is needed to critically evaluate waste package failure modes. These modes should include general corrosion, stress corrosion cracking,

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pitting corrosion, crevice corrosion, and hydrogen embrittlement. The work must permit application of the results to the container materials most likely to be considered by the DOE (currently stainless steel, a nickel alloy, copper, and copper-based alloys), and to the most likely weak points in the packages (currently considered to be the container weldments). Specific reporting requirements include an evaluation of factors in waste package fabrications processes that may adversely affect waste package performance. Studies should document the sensitivity of corrosion rates and mechanical properties to these processes. The results should be presented in a format that will permit the staff to efficiently review DOE fabrication design specifications as they may affect estimates of waste package reliability.

2. Evaluation of Interactions Between Waste Packages and the Repository Environment

Research is needed to identify and critically evaluate the properties of container materials and of environmental parameters that may have a significant influence on the chemical, physical, and radiolytic interactions between waste packages and the repository environment. The work must address how container materials and their alteration products interact with the waste form and how these interactions could affect the release of radionuclides (including synergistic effects). Specific reporting requirements include the identification and the relative importance of properties and parameters in these interactions.

3. Assessment of Corrosion Rates

Research is needed to critically assess methods for extrapolating the results of short-term test data to long-term containment times. As a particular example, pitting corrosion is regarded as a likely failure mode for waste package containers. Work is needed to independently assess the rate of pit growth as a function of heat flux, temperature level, and pit age. Of special importance is the need for identifying mechanisms of pit growth. Specific reporting requirements include criteria for making reliable extrapolations that the staff can use to (1) formulate guidance to the DOE on acceptable prediction techniques and (2) review DOE data on pitting corrosion of HLW package containers. To the extent that pitting data are derived from isothermal tests, reporting should assess the validity of such extrapolations when applied to repository conditions. Reporting should also describe the assumptions and limitations, as well as the laboratory protocols, for all predictive techniques evaluated.

4. Analogs of Leaching and Migration

Research is needed to evaluate the validity of conclusions based on analogs. The work must assess the assumptions that must be made and the limitations of using analogs. The staff anticipates that the DOE may use information derived from analogs to validate models of leaching of the spent fuel and high-level waste form after failure of the containment. Analogs may be found in nature or may be simulated in the laboratory. In the case of natural analogs, it will be necessary to identify those factors which permit identifying particular specimens as valid analogs for the waste package/repository situation. This will involve consideration of (1) the effects of oxidation states and redox kinetics, (2) retardation processes, (3) colloid formation, and (4) organic complexation on the mobility of redox sensitive radionuclides. Specific reporting requirements include the identification of criteria that the staff could use in (1) formulating guidance to the DOE on appropriate analog studies and (2) reviewing DOE data on spent fuel and HLW leaching and migration effects.

B. REPOSITORY DESIGN AND ROCK MECHANICS

1. Rock-Mass Sealing (Sealing of Shafts and Boreholes in the Unsaturated Zone)

Research is needed to evaluate the technical capability to seal shafts, drifts and boreholes as necessary to achieve acceptable repository performance. The work should include a scoping study to estimate the seal performance needed for a repository located in unsaturated tuff, and an assessment of material properties and constriction techniques potentially suitable for achieving the level of seal performance identified. Specific reporting requirements include information suitable for use in a review of DOE's proposed repository design.

C. EARTH SCIENCES

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1. Analog Studies of Conditions/Processes/Environments

Research is needed to evaluate data/information from natural settings and archeologic studies that are related to processes that are being studied in the laboratory. As part of its independent performance assessment capability, NRC must have a basis for comparing laboratory study results with estimates of repository performance over long time periods. There is considerable uncertainty in extropolating such information from laboratory or in-situ field tests to the time scales required for repository performance evaluations. In particular, geochemical studies need to be focused on natural settings where appropriate water/rock/physical-chemical conditions that are relevant to geologic repositories prevail, and, for radionuclide-migration analog studies, where an appropriate source term is available. Specific reporting requirements include an evaluation of the similarities between the natural analog or setting and expected near-and far-field repository environments, and processes being observed under site conditions in the field or laboratory. Research is needed to independently assess information on the evolution of groundwater chemistry resulting from of waste emplacement and the interactions between rock/backfill/water. This information will provide data concerning changes expected in the environment of waste packages for comparison to DOE project-produced data. The technical work should include assessments of rock-surface processes that are involved in the control of the redox state of groundwater and radionuclides. Information is also needed on the kinetics of redox processes, which is important to the understanding of redox conditions of both pre-closure and post-closure groundwater and its effect on waste package stability and radionuclide migration. Specific reporting requirements include the basic data of the experimental work, documentation of the experimental procedures used, including all assumptions and limitations, and a set of criteria that can be used by the licensing staff to help evaluate DOE data, analyses and conclusions concerning the chemical evolution of groundwater over time in both the near-field and the far-field.

3. Radionuclide Transport

Research is needed to evaluate radionuclide source term, and valence effects on radionuclide sorption and solubility. The technical work should include an assessment of the basic behavior of redox-active elements (in both dry and wet environments), radionuclide/rock/water interactions, vapor phase transport, transport pathway identification, and "scaling" problems. Specific reporting requirements include the basic data of the experimental work, documentation of the experimental procedures used, including all assumptions and limitations, and a set of criteria that can be used by the licensing staff to help evaluate DOE data, analyses and conclusions concerning radionuclide transport, isolation of waste, or repository performance.

4. Mineralogy

Research is needed to evaluate rock/backfill/EBS mineralogy (rock/backfill/ water interaction in order to independently review DOE's assessment of releases from the engineered system. The technical work should include an assessment of the physical changes in the backfill that may be expected as a result of changes in backfill mineralogy over time and an assessment of the changes in water chemistry that may result, as well as changes in sorptive capability of the backfill/EBS materials. Specific reporting requirements include the basic data of the experimental work, documentation of the experimental procedures used, including all assumptions and limitations, and a set of criteria that can be used by the licensing staff to help evaluate DOE data, analyses and conclusions concerning backfill/ EBS performance. 5. Response of Groundwater Levels and Underground Openings to Strong Ground Motion

Research is needed to independently assess compliance with the safety aspects of the design criteria for the geologic repository operations area with respect to the effects of strong ground motion from near-field seismic events. Although the geologic repository operations area includes both the surface facilities and the underground openings, this work should be focused on the effects of depth on the nature of the vibratory spectra with depth in a generalized rock media, the effect of the insertion of a network of both vertical and horizontal tubular voids in this media, and boundary conditions between the voids and the media. Specific reporting requirements include (1) a world-wide database of groundwater flow modifications and adjustments in response to fault movement and/or seismic events; (2) recommendations for the instrumentation of sites in tuff or similar rock where documented alterations of the groundwater regime have occurred; (3) predictive models for groundwater response to seismic events; (4) a database documenting the effects of both natural earthquakes and artificially-generated seismic events on underground openings; (5) recommendations for the installation of seismic instrumentation in deep mines, which are similar to the proposed repository by tuff (where earthquakes have been observed); and (6) suitable analytical methods for modelling the static and dynamic response of an underground opening in rock.

6. Groundwater Flow and Radionuclide Transport

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Research is needed to independently assess the effects of the spatial variability on simulations and predictions of three-dimensional groundwater flow and radionuclide transport. In addition, NRC needs the capability to independently simulate those processes, incorporating important stochastic effects. Specific reporting requirements include (1) an evaluation of the importance of performing stochastic analyses of three-dimensional groundwater flow and radionuclide transport during site characterization and performance assessment; (2) techniques for predicting behavior of large scale heterogeneous groundwater systems using measured field data and spatial variability; (3) techniques for estimating error and uncertainty for models; and (4) a comparison of different techniques for incorporating three-dimensional spatial variability into flow and transport models.

7. Uncertainty in Probabilistic Seismic Hazard Assessment

Research is needed to (1) assess uncertainty associated with probabilistic seismic hazard analysis when the data set is not complete; (2) assess the different types of distribution functions which can be issued to fit this data set and to evaluate the advantages and disadvantages of each distribution; and (3) use data from other regions, due to the deficiency of observations at the Yucca Mountain site, for the assessment of

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variation in acceleration expected from regions of compressional tectonics as compared to extensional regions, and for the assessment of applicability of strong ground motion data from strike-slip and thrust earthquakes in California to normal and extensional stress regimes in Nevada. Specific reporting requirements include documenting the data and all of the assumptions and limitations used to arrive at the conclusions in each of the three areas of proposed research.

8. Climate Changes and Effects on Unsaturated Flow Conditions

Research is needed to critically evaluate available methods for projecting future climate changes and likely effects on infiltration at Nevada. The evaluation should, to the extent practical, establish bounds on the range of infiltration rates to be expected during the next 100,000 years and, where bounds cannot be determined, the evaluation should assess the potential for additional DOE research to produce this information in time to support a license application. Specific reporting requirements include the identification of criteria that the staff could use in (1) formulating guidance to DOE, and (2) in reviewing DOE Data. The reporting must identify the assumptions and limitations of the technical approaches used and should provide recommendations on how climate changes and effects can be adequately modeled or their effects estimated.

9. Coupled Interactions of Thermal-Mechanical-Hydrologic Systems

Research is needed to evaluate coupled thermal-mechanical-hydrologic effects over time, particularly in the near-field, and their effects with respect to the performance objectives for containment, radionuclide releases from the engineered system, and radionuclide releases to the accessible environment over 10,000 years. Specific reporting requirements include the identification and evaluation of coupled processes that may be important to meeting the above-cited repository performance objectives. The reporting must identify the assumptions and limitations of the technical approaches used in the studies and should provide recommendations on how coupled processes may be adequately modelled (or their effects estimated/bounded), and analytical approaches that could be used, along with substantive criteria that the licensing staff could apply in implementing the recommended approaches.

D. SYSTEMS PERFORMANCE

1. Independent Systems Assessment Methodology for Evaluation of Total System Performance

Research is needed to critically evaluate analytical models and computer models that combine and predict geologic stability, groundwater flow, radionuclide transport, groundwater concentrations of radionuclides and potential radiation exposures (radiation doses) to individual members of the public. It is essential that the models and codes have a sound

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basis and are accepted by the technical community and have the capability to convolute the predicted responses of all subsystems to the total system performance response. Specific reporting requirements include the development or recommendation of a set of models and computer codes that can be used to independently assess saturated/unsaturated system performance in tuff.

2. HLW Preclosure Safety Systems Analysis

Research is needed to develop a systematic methodology that will identify and qualitatively prioritize the structures, systems, components and operations that are important to safety. NRC regulations specify general design criteria for the structures, systems and components important to safety (both surface and subsurface) during the preclosure phase of repository development (10CFR60.131(b)). The licensing staff must be in a position to independently assess the preclosure safety analysis and requires technical support in developing a methodology for analyzing preclosure safety. Specific reporting requirements include the full documentation of the methodology, and should also include a provision for technology transfer that will permit licensing staff to become familiar with the application of the methodology.