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# CORRELATION OF KEY TECHNICAL ISSUES, KEY TECHNICAL UNCERTAINTIES, AND TECHNICAL SUPPORT NEEDS

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*Prepared/Edited by*

**Robert D. Brient**

**Center for Nuclear Waste Regulatory Analyses**
**San Antonio, Texas**

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# ABBREVIATIONS

| | |
|---|---|
| 2D | Two-Dimensional |
| 3D | Three-Dimensional |
| CCDF | Complementary Cumulative Distribution Function |
| CNWRA | Center for Nuclear Waste Regulatory Analyses |
| DECOVALEX | Development of Coupled Models and their Validation against Experiments in Nuclear Waste Isolation |
| DOE | U.S. Department of Energy |
| EBS | Engineered Barrier System |
| EBSPAC | Engineered Barrier System Performance Assessment Codes |
| EPRI | Electric Power Research Institute |
| GHGC | Geohydrology and Geochemistry |
| GIS | Geographic Information System |
| GLGP | Geology and Geophysics |
| HLW | High-Level Waste |
| IPA | Iterative Performance Assessment |
| LARP | License Application Review Plan |
| KTI | Key Technical Issue |
| KTU | Key Technical Uncertainty |
| NRC | Nuclear Regulatory Commission |
| PA | Performance Assessment |
| PSHA | Probabilistic Seismic Hazard Analysis |
| RDCO | Repository Design, Construction and Operations |
| TMHC | Thermal-Mechanical-Hydrological-Chemical |
| TPA | Total System Performance Assessment (Code) |
| TSPA | Total System Performance Assessment |
| VSIP | Vertical Slice Implementation Plan |
| YM | Yucca Mountain |
| YMR | Yucca Mountain Region |

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# 1 INTRODUCTION

A correlation of Key Technical Uncertainties (KTUs) with Key Technical Issues (KTIs) was conducted by the Center for Nuclear Waste Regulatory Analyses (CNWRA). This correlation was based on the contents of the draft KTI Implementation Plans, which identify the KTUs associated with each vertical slice issue (i.e., the KTI). The Technical Support Needs (Technical Assessment and Research Needs) were extracted from the KTU integration report (Center for Nuclear Waste Regulatory Analyses, 1995). The correlated needs were edited by CNWRA technical staff members for clarity and relevance to the KTI. Section 2 lists the KTUs and Technical Support Needs associated with each of the KTIs, as well as the KTU review type (4 or 5). Those KTUs identified in more than one Vertical Slice Implementation Plan (VSIP) are indicated as "shared." This information is provided in a tabular format as well to assist in future activities, such as prioritizing and scheduling work. Tables in Section 3 list the KTIs, KTUs, and Technical Support Needs according to the responsible CNWRA program element.

The following KTIs have been identified to date, and are addressed in this report. For easy reference, that is, to identify KTUs shared among several KTIs, these KTIs are numbered corresponding to their Subsection numbers (2.1 through 2.10) and Table numbers (2-1 through 2-10) in Section 2 of this report.

1. STRUCTURAL DEFORMATION AND SEISMICITY
2. IGNEOUS ACTIVITY
3. GEOCHEMICAL EFFECTS ON RADIONUCLIDE TRANSPORT WITHIN AND BEYOND THE THERMALLY AFFECTED ZONE
4. HYDROLOGIC CHARACTERIZATION OF STRUCTURAL FEATURES WHICH SIGNIFICANTLY AFFECT WATER AND VAPOR MOVEMENT
5. EVOLUTION OF GROUNDWATER IN THE NEAR-FIELD ENVIRONMENT
6. WASTE PACKAGE DEGRADATION
7. METHODS OF ASSIGNING PROBABILITY TO AND ESTIMATING THE CONSEQUENCES OF DISRUPTIVE SCENARIOS
8. EXPLORATORY STUDIES FACILITY
9. THERMAL-MECHANICAL-HYDROLOGICAL-CHEMICAL COUPLED PROCESSES
10. THERMAL EFFECTS AND REDISTRIBUTION OF MOISTURE

In developing this report, it was noted that the draft KTI Implementation Plans displayed a variety of approaches to the inclusion of KTUs under a KTI. This variety prompted the "Questions on Key Technical Issue Correlation," presented in Section 4 of this report. Resolution of the questions promote the consistency of the KTI Implementation Plans with the available guidance (Nuclear Regulatory Commission, 1995). As the draft VSIPs are revised and eventually approved, this KTI/KTU/Technical Support Needs correlation may require revision as well.

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# 2 KEY TECHNICAL ISSUE CORRELATION

## 2.1 KEY TECHNICAL ISSUE—STRUCTURAL DEFORMATION AND SEISMICITY

Key Technical Uncertainties:

- Development and use of conceptual tectonic models as related to structural deformation (Type 5) (shared with KTI #4)
- Poor resolution of exploration techniques to detect and evaluate structural features (Type 4) (shared with KTI #4)
- Evaluation of faulting mechanisms in alluvium (Type 5)
- Inability to predict the likelihood of earthquake occurrence during the next 10,000 years (Type 4)
- Correlation of earthquakes with tectonic features (Type 5)
- Migrating seismicity between fault systems in the Basin and Range Tectonic Province (Type 5)
- Uncertainty in fault plane solutions (Type 5)

Technical Assessment Needs:

- Evaluate the adequacy of exploration methods used to detect and evaluate subsurface structural features and techniques used for constructing and restoring geological cross-sections and three-dimensional (3D) geological models.
- Perform independent analyses (e.g., reprocessing) of selected geophysical data (e.g., seismic reflection data) to evaluate uncertainties associated with differing interpretations.
- Develop a Geographic Information System (GIS) database of tectonic data that can be used to both evaluate U.S. Department of Energy (DOE) models and interpretations and perform independent analyses and model development.
- Critically assess the DOE interpretations of fault geometry and stratigraphy in the subsurface as they become available.
- Consider how to best represent subsurface structures in models to be used for performance assessment in order to adequately assess potential impacts of the structures and tectonic framework on pre- and post-closure performance of the repository system and its components.

- Perform numerical (e.g., using finite-element technique) modeling to study tectonic processes (such as hangingwall deformation and fault and dike interaction) in order to constrain the range of reasonable interpretations and to determine key parameters that can be used to distinguish between deformation styles in nature.

- Perform graphical visualization and geometric modeling using basic geological data lodged in the ARC/INFO and EARTHVISION GIS databases, to examine the range of tectonic models which appear to be possible using two-dimensional (2D) and 3D representations.

- Investigate the sensitivity of probabilistic seismic hazard analysis (PSHA) to assumptions concerning temporal and spatial seismicity in order to effectively undertake compliance determination in relation to spatial and temporal patterns of seismicity.

- Critically assess the DOE interpretations of the field and laboratory data and conduct independent review of these data in order to form the basis for acceptance or rejection of the data, development of alternative interpretations and to adequately assess potential impacts of faulting and seismicity on pre-closure and post-performance of the repository system and its components.

- Estimate or bracket the nature of past, present and future fault slip to provide a conservative assessment of potential shaking or fault offset effects on the repository. Analyses with SEISM 1.1 computer code could determine the effect on acceleration of assuming a conservative seismic energy radiation pattern from a fault.

Research Needs:

- Perform independent evaluation of structural geologic and seismic data, analyses, and model development (e.g., geometric, kinematic, physical analog) in order to develop an independent basis for compliance determination studies.

- Determine whether the DOE 2D cross-sections and 3D models representing subsurface stratigraphy and structure are adequate and realistic for the tectonic setting of Yucca Mountain (YM) and the central Basin and Range.

- Use DOE data, and in addition, collect select field data on faulting, contemporary strain, uplift, vertical axis rotation, thermal history, and regional tectonic history in order to constrain new structural and tectonic models and to provide a basis for critical evaluation of existing and new models developed by DOE.

- Collect limited geophysical data to address very specific issues, such as dikes in alluvium.

- Construct cross-sections and a 3D geological framework model at the scale of YM and for the subregional and regional tectonic setting. Through development of independent models and alternative interpretations based on published data, DOE data, and data collected by Nuclear Regulatory Commission (NRC)/CNWRA staff, it should be possible to develop compliance determination methods related to faulting (and related surface rupture and earthquake seismicity), to evaluate the reasonableness and conservativeness of the DOE

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interpretations and models, and to provide a context for analyses of possible fault and dike interaction, and studies of groundwater hydrology, geochemistry, and rock mechanics.

- Evaluate uncertainty associated with the extent to which faulting may be present and remain undetected and the potential for activity of existing faults in the present 3D stress field.

- Determine the shapes of earthquake recurrence relationships (the number of earthquakes or given magnitude and larger versus magnitude) on individual faults by monitoring larger aftershocks of earthquakes using portable seismic instrumentation arrays. Develop theoretical methods which explain observations and which can be used to predict recurrence behavior of fault planes that also preserves observed regional recurrence relationships.

- Perform statistical analyses of the historical earthquake record to provide more rigorous identification of earthquake clusters and improved understanding of the pattern of aftershocks and triggered earthquakes. This process appears to be a manifestation of chaos as defined mathematically. Chaos theory methods should be developed to better bound the range of possible predictions while avoiding the current practice of deleting aftershock data from the historical record before using it in PSHA.

- Analyze scaling relationships to provide a basis for evaluation of earthquake recurrence intervals for mapped faults for which there is a limited record or no record of seismicity. Theory to justify the observed scaling relationships must also be derived if predictions of fault plane earthquake recurrence is to be reliable.

- Analyze the paleoseismic record to improve understanding of earthquake magnitude, type, and recurrence in the Yucca Mountain region (YMR), and to aid in understanding the position (spatial and temporal) within the overall patterns of seismicity. The paleoseismic record may indicate distributed fault offsets from a very few large earthquakes originating on a master fault at depth, or more numerous smaller earthquakes on each individual fault. Research to limit potential theoretical models of faulting at depth may be necessary to constrain PSHA to reasonable values.

- Evaluate faulting in alluvium using field studies, analog modeling, and finite element modeling in order to establish a basis for determining the conservativeness of DOE interpretations and the potential for active faults to be present but either undetected or underestimated.

- Develop slip-tendency analysis techniques for interpretation of high-risk fault orientations and evaluation of nodal plane choices. It is anticipated that analysis of several three-component seismic records will be used to assess solutions to test existing and new techniques for selecting nodal planes.

- Utilize portable seismic recording equipment (e.g., PASSCAL) to determine the seismic-energy radiation patterns of larger aftershocks of substantial earthquakes. The instrumentation would be deployed to effectively record high energy beamed through small ranges of azimuth from a fault plane and to better determine the range of azimuths to a fault plane in which directivity effects take place. Aftershock radiation pattern monitoring will also better quantify the amount of seismic energy potentially beamed toward a structure as a consequence of directivity effects.

- Evaluate interrelationships between earthquakes, geologic structure, and tectonic processes, to assess role of emergent versus blind faults as seismic sources. This can be accomplished by performing analyses to compare (in 3D) interpretations of structural geometry, patterns of earthquake seismicity, fault-plane solutions, and *in situ* stress.

## 2.2 KEY TECHNICAL ISSUE—IGNEOUS ACTIVITY

Key Technical Uncertainties:

- Low resolution of exploration techniques to detect and evaluate igneous features (Type 4) (shared with KTI #4)
- Inability to sample igneous features (Type 5)
- Development and use of conceptual tectonic models as related to igneous activity (Type 5) (shared with KTU #4)
- Prediction of future system states (Type 5) (shared with KTIs #3, 4, 5, 7, 10)

Technical Assessment Needs:

- Develop a strategy for evaluation, use, and acceptance or rejection of volcanism probability models.
- Analyze volcanic disruption model sensitivity to input parameters and variables, with particular emphasis on recurrence rate and area impacted by volcanism.
- Implement Iterative Performance Assessment (IPA) models using volcanological models.
- Investigate dike geometries, timing of dike injection, and area affected by intrusion in order to test and bound probability density functions for the areas affected by magmatic events.
- Evaluate the capability of seismic reflection and seismic tomography surveys to identify small subsurface igneous features.
- Formulate links in IPA among volcanism, tectonics, climate, hydrological and geochemical settings of the repository.

Research Needs:

- Identify rates of change in volcanism recurrence rate and patterns of small-volume basaltic volcanism in analogous volcanic fields.
- Develop probability models that capture essential features of basaltic vent distribution.

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- Develop and test models of recurrence rate and vent distribution based on integrated geochemical, tectonic, and geophysical models.

- Develop criteria to characterize the style of small cinder cone basaltic eruptions in order to place limits on the area influenced by volcanic activity.

- Identify or develop geological, geophysical, and geochemical models that can be used to bound probability calculations.

- Independently analyze scenarios of volcanic disruption and evaluate scenario models utilized by the DOE and Electric Power Research Institute (EPRI) in their total system performance assessments (TSPAs) for YM.

- Review and evaluate the basis for the DOE estimates of the probability of occurrence for each scenario.

- Provide improved estimates of scenario probabilities based on site-specific geologic data and information.

- Provide improved models of the physical characteristics and consequences of the disruptive events and processes.

- Identify additional scenarios potentially having direct and indirect effects on repository performance.

- Evaluate different approaches to enhance the likelihood of completeness in the generation of the initial list of events and processes.

## 2.3 KEY TECHNICAL ISSUE—GEOCHEMICAL EFFECTS ON RADIONUCLIDE TRANSPORT WITHIN AND BEYOND THE THERMALLY AFFECTED ZONE

Key Technical Uncertainties:

- Equal or increased capacity of alteration mineral assemblages to inhibit radionuclide migration (Type 4)

- Characterizing the chemistry of the groundwater in the partially-saturated hydrologic zone of Yucca Mountain, Nevada (Type 4)

- Understanding the effects of degree of saturation on geochemical processes such as radionuclide sorption and precipitation and formation of particulates and colloids, and on the transport of radionuclides by particulates, colloids and complexes (Type 4)

- Parametric representation of retardation processes involving radionuclide-bearing particulates, colloids, and complexes (Type 4)

- Determining the alteration of mineral assemblages due to thermal loading (Type 4) (shared with KTI #5)
- Identifying geochemical processes that reduce radionuclide "retardation" (Type 4)
- Determining the magnitude of the effect of the geochemical processes that reduce radionuclide "retardation" (Type 5)
- Identifying geochemical conditions that would inhibit particulate and colloid formation (Type 4)
- Understanding/predicting the effect of groundwater conditions on dissolution of waste form (Type 4)
- Prediction of the evolution of groundwater conditions near and within the Engineered Barrier System (EBS) (Type 5) (shared with KTI #5)
- Identifying geochemical processes that adversely affect the EBS (Type 4) (shared with KTI #5)
- Determining the magnitude of the effect of the geochemical processes that adversely affect the EBS (Type 5) (shared with KTI #5)
- Volatility and stability of chemical species of radionuclides (Type 4)
- Gas flow and gaseous radionuclide transport (Type 4) (shared with KTI #10)
- Prediction of Criticality Events in Waste Packages (Type 4) (shared with KTI #6)
- Prediction of the releases of gaseous radionuclides from waste packages during the containment period and from the EBS during the post-containment period (Type 4) (shared with KTIs #6, 10)
- Prediction of the releases of non-gaseous radionuclides from waste packages during the containment period and from the EBS during the post-containment period (Type 4) (shared with KTIs #6, 10)
- Extrapolation of short-term laboratory and prototype test results to predict long-term performance of waste packages and EBS (Type 5) (shared with KTI #6)
- Conceptual model representations of the natural and engineered systems (Type 4) (shared with KTIs #5, 10)
- Variability in model parametric values (Type 4) (shared with KTIs #5, 10)
- Appropriateness of assumptions and simplification in mathematical models (Type 4) (shared with KTIs #5, 10)

- Validation of mathematical models (Type 5) (shared with KTIs #5, 10)
- Prediction of future system states (i.e., disruptive scenarios) (Type 5) (shared with KTIs # 2, 3, 5, 10)

Technical Assessment Needs:

- Become familiar with available geochemical data, such as mineralogy, mineral chemistry, hydrochemistry for water samples obtained from hydrologically unsaturated cores, and gas compositions. The spatial distribution of these data are important in understanding the different geochemical effects on groundwater chemistry. Although chemical data from the unsaturated zone are difficult to obtain and spatial data distribution is likely to be sparse, the geographical and geological context of these data should be preserved to the extent possible through the use of GIS and 3D hydrogeologic models.
- Become familiar with the methods and models available to describe processes important to radionuclide retardation.
- Become familiar with the current data available for unsaturated zone geochemistry at YM, and methods and models available to describe groundwater chemistry in the partially unsaturated zone.
- Modify models of geochemical processes in the unsaturated zone that may affect mineral and water chemistry and develop new approaches, as necessary.
- Conduct sensitivity studies to determine the extent to which different parameters in the models have the greatest effects on results, and evaluate likely ranges in these parameters to be encountered at YM.
- Become familiar with the methods and models available to describe processes important to transport of the liquid and vapor phase of water.
- Develop an understanding of the effect of backfilling of emplacement drifts on the performance of waste packages, stability of drifts, and retrievability of waste.
- Develop a more general and comprehensive near-field environment model that can fully couple transport and electrochemical processes with aqueous complexing reactions and kinetic reaction of minerals.
- Critically evaluate the role of colloids in the release of radionuclides and the nucleation, stability, and transport of colloids in the geologic medium near the EBS.
- Examine the methodologies for extrapolating short-term laboratory or field performance data to long-term performance through a combination of mechanistic modeling, experimentation, and comparison to relevant natural systems that have operated over long time periods.
- Assess the rate-controlling processes in the dissolution of spent fuel and release of matrix radionuclides.

- Model the release rate of radionuclides from spent fuel.

- Determine the site and design parameters that have significant influence on the calculation of the complementary cumulative distribution function (CCDF) for radionuclide release.

- Characterize parameter variabilities and uncertainties using geostatistical techniques, Monte Carlo simulation, the Fast Probabilistic Performance Assessment and expert judgment.

- Independently evaluate the techniques used by the DOE to account for spatial and temporal variability.

- Investigate techniques for use of expert judgment in characterizing uncertainties in data, models, and future system states.

- Independently analyze scenarios and evaluate scenario models utilized by the DOE and EPRI in their TSPAs for YM.

- Review and evaluate the basis for the DOE estimates of the probability of occurrence for each scenario.

- Evaluate the impact of alternative conceptual models of the hydrogeologic setting and the coupled phenomena that are expected to exist during the postclosure period.

- Investigate the potential impacts of simplifications used in the conceptual models on the results of TSPA calculations and other analyses.

- Perform auxiliary analyses of the controlling processes and determine the sensitivities of associated model parameters.

Research Needs:

- Develop models of sorption processes and other geochemical aspects of unsaturated mass transport.

- Investigate sorption and ion exchange processes, and mineral precipitation/dissolution kinetics through laboratory experiments.

- Evaluate large- and small-scale studies of long-term migration through both fractures and the matrix at natural analog sites.

- Characterize mineral assemblages that may result from thermal alteration of near-field materials and from the interactions between the EBS and natural materials.

- Develop geochemical models for mineral alteration, precipitation/dissolution, sorption, colloidal formation and transport, thermal loading effects, aqueous speciation, and fracture-matrix interactions. These models should be supported by thermodynamic and kinetic data and extensive analysis of site characterization data, data from natural analog sites, and laboratory analyses under variably saturated conditions.

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- Develop models of geochemical processes in the unsaturated zone that may affect mineral and water chemistry.

- Carry out confirmatory and exploratory laboratory investigations of processes such as sorption, ion exchange, and precipitation/dissolution, that may influence system chemistry in the unsaturated zone. Additional studies conducted in natural analog sites may provide insight into critical parameters controlling chemistry in the unsaturated zone in both fractures and matrix.

- Develop and refine geochemical models for reconstructing the evolution of groundwater chemistry in the unsaturated zone. These models should be supported by thermodynamic and kinetic data, extensive analysis of site characterization data, data from natural analog sites, and laboratory experiments to investigate sorption and transport under variably saturated conditions.

- Evaluate appropriate geostatistical and stochastic methods for expressing the spatial variability of parameters.

- Develop the basis for gaining confidence in the model's ability to extrapolate in time and space and, more importantly, for those components that cannot be tested directly.

- Investigate the relevance of possible differences between model predictions and experimental results.

- Develop acceptable methods and approaches for model validation.

- Develop an independent assessment of the evolution of the near-field environment due to thermal output of the waste packages. Specifically, the changes in the chemical composition of the environment near the waste package surface due to evaporation and the resultant redistribution of moisture have to be understood. For this purpose, two-phase fluid transport in a partially saturated medium has to be modeled in combination with multi-component solute transport and reactions.

- Develop an understanding of the changes in chemistry inside defects in the overpack and due to the reaction of fillers and backfill with groundwater that may affect the performance of inner containers, multipurpose canister, and waste form.

- Develop an understanding of the effect of repository operations (grouting, organic fluids, etc.) on the changes in environment, such as groundwater pH, redox conditions, and aqueous species which may be detrimental to the performance of waste packages and waste forms.

- Determine the time at which rewetting of the containers occurs, and determine the chemistry of the condensed phase.

- Determine the possible effects of man-made materials introduced into the natural system on the near-field environment.

- Identify the near-field environment chemistry as affected by components of the EBS, such as grout, microbiological organisms, and container corrosion.

- Understand the effects of design on the thermal fields near the waste packages.

- Determine the role of electrochemical versus chemical dissolution of spent fuel.

- Determine the role of secondary mineral formation on dissolution rate.

- Model the formation of secondary minerals and compare them to those observed in natural analog studies as well as long-term laboratory drip tests.

- Delineate the nature of parameter variability and uncertainties.

- Develop methods for describing the spatial or temporal variability of model parameters.

- Develop scaling theories that permit relating laboratory- or field-scale parameter values to site-scale model parameters.

- Provide improved estimates of scenario probabilities based on site-specific geologic data and information.

- Provide improved models of the physical characteristics and consequences of the disruptive events and processes.

- Identify additional scenarios potentially having direct and indirect effects on repository performance.

- Evaluate different approaches to enhance the likelihood of completeness in the generation of the initial list of events and processes.

- Define and specify "partial validation" requirements for both the detailed and abstracted models used to assess subsystem and total-system performance.

- Define appropriate performance measures or acceptance criteria for partial validation.

- Investigate how results from partial validation studies may be used to determine a model's predictive reliability over large spatial and temporal scales.

- Investigate the proper use of laboratory tests, *in situ* tests, field tests, and natural analogs in a model validation strategy.

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## 2.4 KEY TECHNICAL ISSUE—HYDROLOGIC CHARACTERIZATION OF STRUCTURAL FEATURES WHICH SIGNIFICANTLY AFFECT WATER AND VAPOR MOVEMENT

Key Technical Uncertainties:

- Poor resolution of exploration techniques to detect and evaluate structural features (Type 4) (shared with KTI #1)
- Development and use of conceptual tectonic models as related to structural deformation (Type 5) (shared with KTI #1)
- Low resolution of exploration techniques to detect and evaluate igneous features (Type 4) (shared with KTI #2)
- Development and use of conceptual tectonic models as related to igneous activity (Type 5) (shared with KTI #2)
- Modeling groundwater flow through unsaturated fractured rock caused by the lack of codes tested against field and laboratory data (Type 4) (shared with KTI #10)
- Identifying which conceptual models adequately represent isothermal and nonisothermal liquid and vapor phase movement of water through unsaturated fractured rock at YM (Type 4) (shared with KTI #10)
- Uncertainties associated with determining characterization parameters (Type 4) (shared with KTI #10)
- Developing a conceptual groundwater flow model that is representative of the YM site groundwater flow system (Type 4) (shared with KTI #10)
- Experimental confirmation of the basic physical concepts of groundwater flow through unsaturated fractured rock is needed (Type 5) (shared with KTI #10)
- Development of new data collection and interpretation techniques are required for codes which model groundwater flow through unsaturated fractured rock (Type 5) (shared with KTI #10)
- Developing a mathematical groundwater flow model that is representative of the YM site groundwater flow system (Type 4) (shared with KTI #10)
- Conceptual model representations of the natural and engineered systems (Type 4) (shared with KTIs #3, 5, 10)
- Variability in model parametric values (Type 4) (shared with KTI #3, 5, 10)

- Appropriateness of assumptions and simplification in mathematical models (Type 4) (shared with KTIs #3, 5, 10)

- Validation of mathematical models (Type 5) (shared with KTIs #3, 5, 10)

- Prediction of future system states (Type 5) (shared with KTIs #2, 3, 5, 7, 10)

Technical Assessment Needs:

- Become familiar with the methods and models available to describe processes important to transport of the liquid and vapor phase of water and modify models and develop new approaches as necessary.

- Characterize parameter variabilities and uncertainties using geostatistical techniques, Monte Carlo simulation, the Fast Probabilistic Performance Assessment and expert judgment.

- Independently evaluate the techniques used by the DOE to account for spatial and temporal variability.

- Investigate techniques for use of expert judgment in characterizing uncertainties in data, models, and future system states.

- Independently analyze scenarios and evaluate scenario models utilized by the DOE and EPRI in their TSPAs for YM.

- Review and evaluate the basis for the DOE estimates of the probability of occurrence for each scenario.

- Evaluate the impact of alternative conceptual models of the hydrogeologic setting and the coupled phenomena that are expected to exist during the postclosure period.

- Investigate the potential impacts of simplifications used in the conceptual models on the results of TSPA calculations and other analyses.

- Perform auxiliary analyses of the controlling processes and determine the sensitivities of associated model parameters.

Research Needs:

- Perform independent evaluation of hydrogeologic data, analyses, and model development.

- Determine whether the DOE 2D cross-sections and 3D models representing subsurface hydro-stratigraphy and structure are adequate and realistic for the hydrogeologic setting of YM and the Death Valley Region.

- Use the DOE data, and in addition, collect select field data on faulting, contemporary strain, uplift, vertical axis rotation, thermal history, and regional tectonic history in order to

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constrain new structural and tectonic models and to provide a basis for critical evaluation of existing and new models developed by the DOE.

- Collect limited geophysical data to address very specific issues such as dikes in alluvium.
- Develop 2D vertical cross-sections perpendicular to the hydraulic head contour in the vicinity of YM to investigate the effect of hydrogeologic structure on gradients, flow directions, and velocities.
- Construct a detailed 3D hydrogeologic model of the YM and Death Valley flow system to investigate the effect of the spacial distribution of hydrogeologic properties on the movement of water in both liquid and vapor phases.
- Evaluate uncertainty associated with the extent to which faulting may be present and remain undetected and the potential for activity of existing faults in the present 3D stress field.
- Investigate how the rock matric potential can be accurately measured.
- Evaluate appropriate geostatistical and stochastic methods for expressing the spatial variability of parameters.
- Develop acceptable approaches for characterizing the spatial distribution of infiltration.
- Develop the basis for gaining confidence in the model's ability to extrapolate in time and space and, more importantly, for those components that cannot be tested directly.
- Investigate the relevance of possible differences between model predictions and experimental results.
- Test the appropriateness of field-scale hydraulic parameter estimation techniques.
- Develop acceptable methods and approaches for model validation.
- Delineate the nature of hydraulic parameter variability and uncertainties.
- Develop methods for describing the spatial or temporal variability of model parameters.
- Develop scaling theories that permit relating laboratory- or field-scale parameter values to site-scale model parameters.
- Provide improved estimates of scenario probabilities based on site-specific geologic data and information.
- Provide improved models of the physical characteristics and consequences of the disruptive events and processes.
- Identify additional scenarios potentially having direct and indirect effects on repository performance.

- Evaluate different approaches to enhance the likelihood of completeness in the generation of the initial list of events and processes.

- Define and specify "partial validation" requirements for both the detailed and abstracted models used to assess subsystem and total-system performance.

- Define appropriate performance measures or acceptance criteria for partial validation.

- Investigate how results from partial validation studies may be used to determine a model's predictive reliability over large spatial and temporal scales.

- Investigate the proper use of laboratory tests, *in situ* tests, field tests, and natural analogs in a model validation strategy.

## 2.5 KEY TECHNICAL ISSUE—EVOLUTION OF GROUNDWATER IN THE NEAR-FIELD ENVIRONMENT

Key Technical Uncertainties:

- Prediction of the evolution of groundwater conditions near and within the EBS (Type 5) (shared with KTI #3)

- Prediction of the thermal-mechanical-hydrological-chemical (TMHC) responses of the host rock, surrounding strata, and groundwater system to thermal loads (Type 4) (shared with KTIs #9, 10)

- Prediction of the thermal, mechanical, and hydrological impact on the host rock surrounding the waste package (Type 4) (shared with KTIs #9, 10)

- Determining the alteration of mineral assemblages due to thermal loading (Type 4) (shared with KTI #3)

- Identifying geochemical processes that adversely affect the EBS (Type 4) (shared with KTI #3)

- Determining the magnitude of the effect of the geochemical processes that adversely affect the EBS (Type 5) (shared with KTI #3)

- Conceptual model representations of the natural and engineered systems (Type 4) (shared with KTIs #3, 4, 10)

- Variability in model parametric values (Type 4) (shared with KTIs #3, 4, 10)

- Appropriateness of assumptions and simplification in mathematical models (Type 4) (shared with KTIs #3, 4, 10)

- Validation of mathematical models (Type 5) (shared with KTIs #3, 4, 10)

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- Prediction of future system states (Type 5) (shared with KTIs #2, 3, 4, 7, 10)

Technical Assessment Needs:

- Develop a more general and comprehensive near-field environment model that can fully couple transport and electrochemical processes with aqueous complexing reactions and kinetic reaction of minerals.

- Critically evaluate the role of colloids in the release of radionuclides and the nucleation, stability, and transport of colloids in the geologic medium.

- Develop a rock joint constitutive model.

- Analyze drift stability leading to rock-induced waste package failure for updating SEISMO Module in the IPA code.

- Develop an understanding of the effect of backfilling of emplacement drifts on the performance of waste packages, stability of drifts, and retrievability of waste.

- Develop or modify thermal-mechanical-hydraulic compliance determination codes for subsurface facilities.

- Develop the EBS performance assessment code engineered barrier system performance assessment codes (EBSPAC).

- Develop models and the code modules for the total TSPA. These should include an investigation of the impact of alternative conceptual models of the hydrogeologic setting and the coupled phenomena that are expected to exist during the closure period, and the potential impacts of simplifications used in the conceptual models on the results of TSPA calculations.

- Become familiar with available geochemical data, such as mineralogy, mineral and water chemistry, and gas compositions. Because the available data are likely to be limited, and because the spatial distribution of these data is important in understanding the different geochemical effects on radionuclide retardation, the geographical and geological context of these data should be preserved to the extent possible through the use of GIS and 3D hydrogeologic models.

- Become familiar with the methods and models available to describe processes important to radionuclide retardation. Modify existing geochemical and transport models and develop new approaches as necessary.

- Undertake sensitivity studies to determine the effect of different parameters in the models affect the modeling of radionuclide transport and retardation, and determine those site and design parameters that have a significant effect on calculating the CCDF for radionuclide release.

- Examine the methodologies for extrapolating short-term laboratory or field performance data to long-term performance through a combination of mechanistic modeling, experimentation, and comparison to relevant natural systems that have operated for long time periods.

- Perform auxiliary analyses of the processes controlling groundwater evolution in the near-field and EBS performance and determine the sensitivities of associated model parameters.

- Characterize parameter variabilities and uncertainties using geostatistical techniques, Monte Carlo simulation, the Fast Probabilistic Performance Assessment and expert judgment.

- Independently evaluate the techniques used by the DOE to account for spatial and temporal variability.

- Investigate techniques for use of expert judgment in characterizing uncertainties in data, models, and future system states.

- Independently analyze scenarios and evaluate scenario models used by the DOE and EPRI in their TSPAs for YM. This should also include a review and evaluation of the basis for the DOE estimates of the probability of occurrence for each scenario.

Research Needs:

- Develop an independent assessment of the evolution of the near-field environment due to thermal output of the waste packages. Specifically, the changes in the chemical composition of the environment near the waste package surface due to evaporation and the resultant redistribution of moisture have to be understood. For this purpose, two-phase fluid transport in a partially saturated medium has to be modeled in combination with multi-component solute transport and reactions.

- Develop an understanding of the changes in chemistry inside defects in the overpack and due to the reaction of fillers and backfill with groundwater that may affect the performance of inner containers, multipurpose canister, and waste form.

- Develop an understanding of the effect of repository operations, EBS components, and the introduction of man-made materials (grout, organic fluids, etc.) on the changes in near-field environment, such as groundwater pH, redox conditions, and aqueous species which may be detrimental to the performance of waste packages and waste forms.

- Determine the time at which rewetting of the waste package containers occurs, and determine the chemistry of the condensed phase.

- Understand the effects of design on the thermal fields near the waste packages.

- Develop a methodology for bounding spatial variability of rock and joint properties using a stochastic approach.

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- Determine the long-term effectiveness of rock-bolts and other ground supports under thermal environment.

- Develop a methodology for identification and characterization of important design parameters for underground excavations—a total system approach.

- Develop a technique for extrapolation of laboratory-measured intact rock and joint properties and fracture flow data for field-scale application.

- Perform Development of Coupled Models and their Validation against Experiments in Nuclear Waste Isolation (DECOVALEX) TMH experiments and modeling.

- Identify near-field environment chemistry as altered by the thermal loading on construction materials used for seals and shafts and the host rock leading to alteration in the pathways and chemistry of ingressing groundwaters.

- Investigate sorption and ion exchange processes, and mineral precipitation/dissolution kinetics through laboratory experiments.

- Evaluate large- and small-scale studies of long-term migration through both fractures and the matrix at natural analog sites.

- Characterize mineral assemblages that may result from thermal alteration of near-field materials and from the interactions between the EBS and natural materials.

- Develop geochemical models for mineral alteration, precipitation/dissolution, sorption, colloidal formation and transport, thermal loading effects, aqueous speciation, and fracture-matrix interactions. These models should be supported by thermodynamic and kinetic data and extensive analysis of site characterization data, data from natural analog sites, and laboratory analyses under variably saturated conditions.

- Develop a quantitative methodology to assess the effect of microbial organisms on corrosion.

- Define and specify "partial validation" requirements for both the detailed and abstracted models used to assess subsystem and total-system performance, including how results from partial validation studies may be used to determine predictive reliability over large spatial and temporal scales.

- Investigate the proper use of laboratory tests, *in situ* tests, field tests, and natural analogs in a model validation strategy that includes scaling theories that provide for extending laboratory- and field-scale parameter values to site-scale modeling.

- Delineate the nature of parameter variability and uncertainties.

- Develop methods for describing the spatial or temporal variability of model parameters.

- Provide improved estimates of scenario probabilities based on site-specific geologic data and information.

- Identify additional scenarios potentially having direct and indirect effects on repository performance.

- Evaluate different approaches to enhance the likelihood of completeness in the generation of the initial list of events and processes.

## 2.6 KEY TECHNICAL ISSUE—WASTE PACKAGE DEGRADATION

Key Technical Uncertainties:

- Prediction of thermomechanical effects on the waste package and the EBS (Type 4) (shared with KTIs #8, 9)

- Prediction of environmental effects on the waste package and the EBS (Type 4)

- Prediction of criticality events in waste packages (Type 4) (shared with KTI #3)

- Prediction of release path parameters (such as the size, shape, and distribution of penetrations of waste packages) due to thermomechanical, environmental, or criticality effects (Type 4)

- Prediction of the releases of gaseous radionuclides from waste packages during the containment period and from the EBS during the post-containment period (Type 4) (shared with KTIs #3, 10)

- Prediction of the releases of non-gaseous radionuclides from waste packages during the containment period and from the EBS during the post-containment period (Type 4) (shared with KTIs #3, 10)

- Extrapolation of short-term laboratory and prototype test results to predict long-term performance of waste packages and EBS (Type 5) (shared with KTI #3)

Technical Assessment Needs:

- Analyze drift stability leading to rock-induced waste package failure for updating SEISMO Module in the IPA code.

- Develop an understanding of the effect of backfilling of emplacement drifts on the performance of waste packages, stability of drifts, and retrievability of waste.

- Develop a more general and comprehensive near-field environment model that can fully couple transport and electrochemical processes with aqueous complexing reactions and kinetic reaction of minerals.

- Develop the technical bases for EBSPAC.

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- Critically evaluate the role of colloids in the release of radionuclides and the nucleation, stability, and transport of colloids in the geologic medium.

- Examine the methodologies for extrapolating short-term laboratory or field performance data to long-term performance through a combination of mechanistic modeling, experimentation, and comparison to relevant natural systems that have operated for long time periods.

- Evaluate the effect of interactions between various waste package materials on their performance. This evaluation will include such effects as galvanic corrosion and hydrogen embrittlement.

- Model the effect of long-term thermal exposure and various repository mechanical loads on the mechanical stability of waste package materials and their consequences, including criticality.

- Evaluate the engineering experience in terms of initial defect population after fabrication and reliability of components.

- Systematically evaluate the effect of modifications to the waste package design and the multipurpose canister on repository performance.

- Assess the rate-controlling processes in the dissolution of spent fuel and release of matrix radionuclides.

- Assess the effects of colloids in controlling the transport of radionuclides near the EBS.

Research Needs:

- Determine the effect of long-term exposure of waste packages on the degradation of material properties by phase transformation and grain-boundary segregation leading to reduced corrosion resistance and impact toughness (ductility) of the waste package.

- Develop an independent assessment of the evolution of the near-field environment due to thermal output of the waste packages. Specifically, the changes in the chemical composition of the environment near the waste package surface due to evaporation and the resultant redistribution of moisture have to be understood. For this purpose, two-phase fluid transport in a partially saturated medium has to be modeled in combination with multi-component solute transport and reactions.

- Develop an understanding of the changes in chemistry inside defects in the overpack and due to the reaction of fillers and backfill with groundwater that may affect the performance of inner containers, multipurpose canister, and waste form.

- Develop an understanding of the effect of repository operations and man-made materials (grout, organic fluids, etc.) on the changes in environment, such as groundwater Ph, redox conditions, and aqueous species which may be detrimental to the performance of waste packages and waste forms.

- Determine the time at which rewetting of the containers occurs, and determine the chemistry of the condensed phase.

- Understand the effects of design on the thermal fields near the waste packages.

- Demonstrate the adequacy and conservatism of repassivation potential in predicting the long-term localized corrosion and stress corrosion cracking of austenitic materials.

- Determine the existence of critical potentials for localized corrosion or stress corrosion cracking of other waste package materials.

- Develop a quantitative methodology to assess the effect of microbial organisms on the near-field environment and on the corrosion of EBS components.

- Develop a quantitative understanding of the kinetics of embrittlement of basket material and its affect on criticality control.

- Determine the role of electrochemical versus chemical dissolution of spent fuel.

- Determine the role of secondary mineral formation on dissolution rate of spent fuel by modeling the formation of secondary minerals and compare them to those observed in natural analog studies as well as long-term laboratory drip tests.

## 2.7 KEY TECHNICAL ISSUE—METHODS OF ASSIGNING PROBABILITY TO AND ESTIMATING THE CONSEQUENCES OF DISRUPTIVE SCENARIOS

Key Technical Uncertainty:

- Prediction of future system states (Type 5) (shared with KTIs #2, 3, 4, 5, 10)

Technical Assessment Needs:

- Independently analyze scenarios and evaluate scenario models utilized by the DOE and EPRI in their TSPAs for YM.

- Review and evaluate the basis for the DOE estimates of the probability of occurrence for each scenario.

- Incorporate probability and consequence models into the total system performance assessment code (TPA).

Research Needs:

- Provide improved estimates of scenario probabilities based on site-specific geologic data and information.

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- Provide improved models of the physical characteristics and consequences of the disruptive events and processes.
- Identify additional scenarios potentially having direct and indirect effects on repository performance.
- Evaluate different approaches to enhance the likelihood of completeness in the generation of the initial list of events and processes.

## 2.8 KEY TECHNICAL ISSUE—EXPLORATORY STUDIES FACILITY

Key Technical Uncertainties:

- Prediction of the TMHC responses of the host rock, surrounding strata, and groundwater system to thermal loads (Type 4) (shared with KTIs #5, 9, 10)
- Prediction of the thermal, mechanical, and hydrological impact on the host rock surrounding the waste package (Type 4) (shared with KTIs #5, 9, 10)
- Predicting the long term performance of seals for shafts, ramps, and boreholes (Type 4) (shared with KTI #9)
- Predicting the long term performance of seals for the underground test boreholes (Type 4) (shared with KTI #9)

Technical Assessment Needs:

- Develop a rock joint constitutive model.
- Develop or modify thermal-mechanical (TM) compliance determination codes for subsurface facilities.
- Analyze drift stability leading to rock-induced waste package failure for updating SEISMO Module in the IPA code.
- Develop an understanding of the effect of backfilling of emplacement drifts on the performance of waste packages, stability of drifts, and retrievability of waste.
- Develop or modify TMH compliance determination codes for subsurface facilities.
- Develop the models and the code modules for the TSPA.
- Develop a better understanding of the importance of seals to the overall performance of the repository, taking into account the specific conditions at the YM repository site (including geologic and hydrologic properties of the intact matrix and fractures, infiltration, etc.)

- Evaluate, through sensitivity studies, which parameters (e.g., infiltration, fracture conductivities of the host rock, fracture porosity of the host rock, etc.) would have the largest impact on seal and repository performance, such that guidance can be given to site characterization activities to focus on better characterization of such properties.

Research Needs:

- Develop of a methodology for bounding spatial variability of rock and joint properties using stochastic approach.
- Determine the long-term effectiveness of rock-bolts and other ground supports under thermal environment.
- Develop a methodology for identification and characterization of important design parameters for underground excavations—a total system approach.
- Develop a technique for extrapolation of laboratory measured intact rock and joint properties for field-scale application.
- Perform DECOVALEX TMH experiments and modeling.
- Develop an understanding of the constitutive laws of time-dependent rock properties under heated, variably saturated, and stressed conditions.
- Evaluate long-term TM effects on the performance of seals.
- Evaluate long-term thermal-hydrological effects on the chemical properties of seal materials.
- Evaluate long-term TM (including repetitive seismic load) effects on the surrounding rock mass and seal-rock interface.

## 2.9 KEY TECHNICAL ISSUE—THERMAL-MECHANICAL-HYDROLOGICAL-CHEMICAL COUPLED PROCESSES

Key Technical Uncertainties:

- Prediction of the TMHC responses of the host rock, surrounding strata, and groundwater system to thermal loads (Type 4) (shared with KTIs #5, 8, 10)
- Prediction of the thermal, mechanical, and hydrological impact on the host rock surrounding the waste package (Type 4) (shared with KTIs #5, 8, 10)
- Prediction of thermomechanical effects on the performance of waste packages and the (EBS) (Type 4) (shared with KTIs #6, 8)
- Demonstration of compliance with the requirement to maintain the ability to safely retrieve high-level waste (HLW) (Type 4)

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- Predicting the long term performance of seals for shafts, ramps, and boreholes (Type 4) (shared with KTI #8)

- Predicting the long term performance of seals for the underground test boreholes (Type 4) (shared with KTI #8)

Technical Assessment Needs:

- Develop a rock joint constitutive model.

- Develop or modify TM compliance determination codes for subsurface facilities.

- Analyze drift stability leading to rock-induced waste package failure for updating the SEISMO Module in the IPA code.

- Develop an understanding of the effect of backfilling of emplacement drifts on the performance of waste packages, stability of drifts, and retrievability of waste.

- Develop or modify TMH compliance determination codes for subsurface facilities.

- Develop the EBS performance assessment code EBSPAC.

- Develop the models and the code modules for the TSPA.

- Develop a better understanding of the importance of seals to the overall performance of the repository, taking into account the specific conditions at the YM repository site (including geologic and hydrologic properties of the intact matrix and fractures, infiltration, etc.).

- Evaluate, through sensitivity studies, which parameters (e.g., infiltration, fracture conductivities of the host rock, fracture porosity of the host rock, etc.) would have the largest impact on seal and repository performance, such that guidance can be given to site characterization activities to focus on better characterization of such properties.

- Review and assess ongoing DOE planning activities on waste retrievability.

- Develop or modify TM compliance determination codes for subsurface facilities.

Research Needs:

- Develop of a methodology for bounding spatial variability of rock and joint properties using stochastic approach.

- Determine the long-term effectiveness of rock-bolts and other ground supports under thermal environment.

- Develop a methodology for identification and characterization of important design parameters for underground excavations—a total system approach.

- Develop a technique for extrapolation of laboratory measured intact rock and joint properties for field-scale application.

- Determine the effect of long-term exposure of waste packages on the degradation of material properties by phase transformation and grain-boundary segregation leading to reduced corrosion resistance and impact toughness (ductility) of the waste package.

- Perform DECOVALEX TMH experiments and modeling.

- Develop an understanding of the constitutive laws of time-dependent rock properties under heated, variably saturated, and stressed conditions.

- Develop a technique for extrapolation of laboratory-measured fracture flow data for field-scale application.

- Determine when and the extent of rewetting of the waste package (container) and the chemistry of the condensed phase.

- Identify near-field environment chemistry as altered by the thermal loading on construction materials used for seals and shafts and the host rock leading to alteration in the pathways and chemistry of ingressing groundwaters.

- Evaluate long-term TM effects on the performance of seals.

- Evaluate long-term thermal-hydrological effects on the chemical properties of seal materials.

- Evaluate long-term TM (including repetitive seismic load) effects on the surrounding rock mass and seal-rock interface.

## 2.10 KEY TECHNICAL ISSUE—THERMAL EFFECTS AND REDISTRIBUTION OF MOISTURE

Key Technical Uncertainties:

- Modeling groundwater flow through unsaturated fractured rock caused by the lack of codes tested against field and laboratory data (Type 4) (shared with KTI #4)

- Identifying which conceptual models adequately represent isothermal and nonisothermal liquid and vapor phase movement of water through unsaturated fractured rock at YM (Type 4) (shared with KTI #4)

- Uncertainties associated with determining characterization parameters (Type 4) (shared with KTI #4)

- Developing a conceptual groundwater flow model that is representative of the YM site groundwater flow system (Type 4) (shared with KTI #4)

- Experimental confirmation of the basic physical concepts of groundwater flow through unsaturated fractured rock is needed (Type 5) (shared with KTI #4)

- Development of new data collection and interpretation techniques are required for codes which model groundwater flow through unsaturated fractured rock (Type 5) (shared with KTI #4)

- Developing a mathematical groundwater flow model that is representative of the YM site groundwater flow system (Type 4) (shared with KTI #4)

- Prediction of the TMHC responses of the host rock, surrounding strata, and groundwater system to thermal loads (Type 4) (shared with KTIs #5, 8, 9)

- Prediction of the thermal, mechanical, and hydrological impact on the host rock surrounding the waste package (Type 4) (shared with KTIs #5, 8, 9)

- Prediction of the releases of gaseous radionuclides from waste packages during the containment period and from the EBS during the post-containment period (Type 4) (shared with KTIs #3, 6)

- Prediction of the releases of nongaseous radionuclides from waste packages during the containment period and from the EBS during the post-containment period (Type 4) (shared with KTIs #3, 6)

- Conceptual model representations of the natural and engineered systems (Type 4) (shared with KTIs #3, 4, 5)

- Variability in model parametric values (Type 4) (shared with KTIs #3, 4, 5)

- Appropriateness of assumptions and simplification in mathematical models (Type 4) (shared with KTIs #3, 4, 5)

- Validation of mathematical models (Type 5) (shared with KTIs 3, 4, 5)

- Prediction of future system states (Type 5) (shared with KTIs #2, 3, 4, 5, 7)

- Modeling the formation of perched zones by thermally driven flow (Type 5)

- Prediction of future changes to the hydrologic system resulting from a combination of climatic and tectonic changes and human activities (including heat effects from waste emplacement) (Type 5)

- Gas flow and gaseous radionuclide transport (Type 4) (shared with KTI #3)

Technical Assessment Needs:

- Become familiar with the methods and models available to describe processes important to transport of the liquid and vapor phase of water and modify models and develop new approaches as necessary.

- Undertake sensitivity studies to determine the extent to which different parameters in the models affect various performance related measures.

- Become familiar with the methods and models available to describe processes important to future changes to the hydrologic system resulting from climatic variations, tectonic changes, and human activities and modify conceptual models and develop new approaches as necessary (e.g., using expert elicitation techniques).

- Undertake sensitivity studies to determine the extent to which different parameters in the models affect various performance related measures.

- Develop a rock joint constitutive model.

- Develop or modify TM compliance determination codes for subsurface facilities.

- Analyze drift stability leading to rock-induced waste package failure for updating the SEISMO Module in the IPA code.

- Develop of the EBS subsystem performance assessment models and codes to evaluate the thermal instability effects on waste package materials.

- Develop an understanding of the effect of backfilling of emplacement drifts on the performance of waste packages, stability of drifts, and retrievability of waste.

- Develop or modify TMH compliance determination codes for subsurface facilities.

- Develop the EBS performance assessment code EBSPAC.

- Develop the models and the code modules for the TSPA.

- Assess the rate-controlling processes in the dissolution of spent fuel and release of matrix radionuclides.

- Independently analyze scenarios and evaluate scenario models utilized by the DOE and EPRI in their TSPAs for YM.

- Review and evaluate the basis for the DOE estimates of the probability of occurrence for each scenario.

- Evaluate the impact of alternative conceptual models of the hydrogeologic setting and the coupled phenomena that are expected to exist during the postclosure period.

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- Investigate the potential impacts of simplifications used in the conceptual models on the results of TSPA calculations and other analyses.

- Perform auxiliary analyses of the controlling processes and determine the sensitivities of associated model parameters.

- Determine the site and design parameters that have significant influence on the calculation of the CCDF for radionuclide release.

- Characterize parameter variabilities and uncertainties using geostatistical techniques, Monte Carlo simulation, the Fast Probabilistic Performance Assessment and expert judgment.

- Independently evaluate the techniques used by the DOE to account for spatial and temporal variability.

- Investigate techniques for use of expert judgment in characterizing uncertainties in data, models, and future system states.

Research Needs:

- Investigate how the rock matric potential can be accurately measured.

- Evaluate appropriate geostatistical and stochastic methods for expressing the spatial variability of parameters.

- Develop acceptable approaches for characterizing the spatial distribution of infiltration.

- Develop the basis for gaining confidence in the model's ability to extrapolate in time and space and, more importantly, for those components that cannot be tested directly.

- Investigate the relevance of possible differences between model predictions and experimental results.

- Test the appropriateness of field-scale hydraulic parameter estimation techniques.

- Develop acceptable methods and approaches for model validation.

- Investigate the use of expert elicitation approaches.

- Evaluate methods to predict future human activities.

- Develop of a methodology for bounding spatial variability of rock and joint properties using stochastic approach.

- Determine the long-term effectiveness of rock-bolts and other ground supports under thermal environment.

- Develop a methodology for identification and characterization of important design parameters for underground excavations—a total system approach.

- Develop a technique for extrapolation of laboratory measured intact rock and joint properties for field-scale application.

- Determine the effect of long-term exposure of waste packages on the degradation of material properties by phase transformation and grain-boundary segregation leading to reduced corrosion resistance and impact toughness (ductility) of the waste package.

- Perform DECOVALEX TMH experiments and modeling.

- Develop an understanding of the constitutive laws of time-dependent rock properties under heated, variably saturated, and stressed conditions.

- Develop a technique for extrapolation of laboratory-measured fracture flow data for field-scale application.

- Determine when and the extent of rewetting of the waste package (container) and the chemistry of the condensed phase.

- Identify near-field environment chemistry as altered by the thermal loading on construction materials used for seals and shafts and the host rock leading to alteration in the pathways and chemistry of ingressing groundwaters.

- Determine the role of electrochemical versus chemical dissolution of spent fuel.

- Determine the role of secondary mineral formation on dissolution rate.

- Model the formation of secondary minerals and compare them to those observed in natural analog studies as well as long-term laboratory drip tests.

- Provide improved estimates of scenario probabilities based on site-specific geologic data and information.

- Provide improved models of the physical characteristics and consequences of the disruptive events and processes.

- Identify additional scenarios potentially having direct and indirect effects on repository performance.

- Evaluate different approaches to enhance the likelihood of completeness in the generation of the initial list of events and processes.

- Define and specify "partial validation" requirements for both the detailed and abstracted models used to assess subsystem and total-system performance.

- Define appropriate performance measures or acceptance criteria for partial validation.

- Investigate how results from partial validation studies may be used to determine a model's predictive reliability over large spatial and temporal scales.

- Investigate the proper use of laboratory tests, *in situ* tests, field tests, and natural analogs in a model validation strategy.

- Delineate the nature of parameter variability and uncertainties.

- Develop methods for describing the spatial or temporal variability of model parameters.

- Develop scaling theories that permit relating laboratory- or field-scale parameter values to site-scale model parameters.

The correlations between the KTUs and KTIs presented in Sections 2.1 through 2.10 are summarized in Tables 2-1 through 2-10.

**Table 2-1. Key Technical Issue—Structural Deformation and Seismicity**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Key Technical Uncertainties: | | |
| • Development and use of conceptual tectonic models as related to structural deformation (Type 5) | Geology and Geophysics (GLGP) | Shared with KTI #4 |
| • Poor resolution of exploration techniques to detect and evaluate structural features (Type 4) | GLGP | Shared with KTI #4 |
| • Evaluation of faulting mechanisms in alluvium (Type 5) | GLGP | |
| • Inability to predict the likelihood of earthquake occurrence during the next 10,000 years (Type 4) | GLGP | |
| • Correlation of earthquakes with tectonic features (Type 5) | GLGP | |
| • Migrating seismicity between fault systems in the Basin and Range Tectonic Province (Type 5) | GLGP | |
| • Uncertainty in fault plane solutions (Type 5) | GLGP | |
| Technical Assessment Needs: | | |
| • Evaluate the adequacy of exploration methods used to detect and evaluate subsurface structural features and techniques used for constructing and restoring geological cross-sections and 3D geological models. | GLGP | |
| • Perform independent analyses (e.g., reprocessing) of selected geophysical data (e.g., seismic reflection data) to evaluate uncertainties associated with differing interpretations. | GLGP | |
| • Develop a GIS database of tectonic data that can be used to both evaluate the DOE models and interpretations and perform independent analyses and model development. | GLGP | |
| • Critically assess the DOE interpretations of fault geometry and stratigraphy in the subsurface as they become available. | GLGP | |

Table 2-1. Key Technical Issue—Structural Deformation and Seismicity (cont'd)

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Technical Assessment Needs (cont'd): | | |
| • Consider how to best represent subsurface structures in models to be used for performance assessment in order to adequately assess potential impacts of the structures and tectonic framework on pre- and post-closure performance of the repository system and its components. | GLGP | |
| • Perform numerical (e.g., using finite-element technique) modeling to study tectonic processes (such as hangingwall deformation and fault and dike interaction) in order to constrain the range of reasonable interpretations and to determine key parameters that can be used to distinguish between deformation styles in nature. | GLGP | |
| • Perform graphical visualization and geometric modeling using basic geological data lodged in the ARC/INFO and EARTHVISION GIS databases, to examine the range of tectonic models which appear to be possible using 2D and 3D representations. | GLGP | |
| • Investigate the sensitivity of PSHA to assumptions concerning temporal and spatial seismicity in order to effectively undertake compliance determination in relation to spatial and temporal patterns of seismicity. | GLGP | |
| • Critically assess the DOE interpretations of the field and laboratory data and conduct independent review of these data in order to form the basis for acceptance or rejection of the data, development of alternative interpretations and to adequately assess potential impacts of faulting and seismicity on pre-closure and post-performance of the repository system and its components. | GLGP | |
| • Estimate or bracket the nature of past, present and future fault slip to provide a conservative assessment of potential shaking or fault offset effects on the repository. Analyses with the SEISM 1.1 computer code could determine the effect on acceleration of assuming a conservative seismic energy radiation pattern from a fault. | GLGP | |

**Table 2-1. Key Technical Issue—Structural Deformation and Seismicity (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Research Needs: | | |
| • Perform independent evaluation of structural geologic and seismic data, analyses, and model development (e.g., geometric, kinematic, physical analog) in order to develop an independent basis for compliance determination studies. | GLGP | |
| • Determine whether the DOE 2D cross-sections and 3D models representing subsurface stratigraphy and structure are adequate and realistic for the tectonic setting of YM and the central Basin and Range. | GLGP | |
| • Use the DOE data, and in addition, collect select field data on faulting, contemporary strain, uplift, vertical axis rotation, thermal history, and regional tectonic history in order to constrain new structural and tectonic models and to provide a basis for critical evaluation of existing and new models developed by the DOE. | GLGP | |
| • Collect limited geophysical data to address very specific issues, such as dikes in alluvium. | GLGP | |
| • Construct cross-sections and a 3D geological framework model at the scale of YM and for the subregional and regional tectonic setting. Through development of independent models and alternative interpretations based on published data, DOE data, and data collected by NRC/CNWRA staff, it should be possible to develop compliance determination methods related to faulting (and related surface rupture and earthquake seismicity), to evaluate the reasonableness and conservativeness of the DOE interpretations and models, and to provide a context for analyses of possible fault and dike interaction, and studies of groundwater hydrology, geochemistry, and rock mechanics. | GLGP | |
| • Evaluate uncertainty associated with the extent to which faulting may be present and remain undetected and the potential for activity of existing faults in the present 3D stress field. | GLGP | |

**Table 2-1. Key Technical Issue—Structural Deformation and Seismicity (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Research Needs (cont'd) | | |
| • Determine the shapes of earthquake recurrence relationships (the number of earthquakes or given magnitude and larger versus magnitude) on individual faults by monitoring larger aftershocks of earthquakes using portable seismic instrumentation arrays. Develop theoretical methods which explain observations and which can be used to predict recurrence behavior of fault planes that also preserves observed regional recurrence relationships. | GLGP | |
| • Perform statistical analyses of the historical earthquake record to provide more rigorous identification of earthquake clusters and improved understanding of the pattern of aftershocks and triggered earthquakes. This process appears to be a manifestation of chaos as defined mathematically. Chaos theory methods should be developed to better bound the range of possible predictions while avoiding the current practice of deleting aftershock data from the historical record before using it in PSHA. | GLGP | |
| • Analyze scaling relationships to provide a basis for evaluation of earthquake recurrence intervals for mapped faults for which there is a limited record or no record of seismicity. Theory to justify the observed scaling relationships must also be derived if predictions of fault plane earthquake recurrence is to be reliable. | GLGP | |
| • Analyze the paleoseismic record to improve understanding of earthquake magnitude, type, and recurrence in the YMR, and to aid in understanding the position (spatial and temporal) within the overall patterns of seismicity. The paleoseismic record may indicate distributed fault offsets from a very few large earthquakes originating on a master fault at depth, or more numerous smaller earthquakes on each individual fault. Research to limit potential theoretical models of faulting at depth may be necessary to constrain PSHA to reasonable values. | GLGP | |

**Table 2-1. Key Technical Issue—Structural Deformation and Seismicity (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Research Needs (cont'd) | | |
| • Evaluate faulting in alluvium using field studies, analog modeling, and finite element modeling in order to establish a basis for determining the conservativeness of the DOE interpretations and the potential for active faults to be present but either undetected or underestimated. | GLGP | |
| • Develop slip-tendency analysis techniques for interpretation of high-risk fault orientations and evaluation of nodal plane choices. It is anticipated that analysis of several three-component seismic records will be used to assess solutions to test existing and new techniques for selecting nodal planes. | GLGP | |
| • Utilize portable seismic recording equipment (e.g., PASSCAL) to determine the seismic-energy radiation patterns of larger aftershocks of substantial earthquakes. The instrumentation would be deployed to effectively record high energy beamed through small ranges of azimuth from a fault plane and to better determine the range of azimuths to a fault plane in which directivity effects take place. Aftershock radiation pattern monitoring will also better quantify the amount of seismic energy potentially beamed toward a structure as a consequence of directivity effects. | GLGP | |
| • Evaluate interrelationships between earthquakes, geologic structure, and tectonic processes, to assess role of emergent versus blind faults as seismic sources. This can be accomplished by performing analyses to compare (in 3D) interpretations of structural geometry, patterns of earthquake seismicity, fault-plane solutions, and *in situ* stress. | GLGP | |

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**Table 2-2. Key Technical Issue—Igneous Activity**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Key Technical Uncertainties: | | |
| • Low resolution of exploration techniques to detect and evaluate igneous features (Type 4) | GLGP | Shared with KTI #4 |
| • Inability to sample igneous features (Type 5) | GLGP | |
| • Development and use of conceptual tectonic models as related to igneous activity (Type 5) | GLGP | Shared with KTI #4 |
| • Prediction of future system states (Type 5) | Performance Assessment (PA) | Shared with KTIs #3,4,5,7,10 |
| Technical Assessment Needs: | | |
| • Develop a strategy for evaluation, use, and acceptance or rejection of volcanism probability models. | GLGP | |
| • Analyze volcanic disruption model sensitivity to input parameters and variables, with particular emphasis on recurrence rate and area impacted by volcanism. | GLGP | |
| • Implement IPA models using volcanological models. | GLGP/PA | |
| • Investigate dike geometries, timing of dike injection, and area affected by intrusion in order to test and bound probability density functions for the areas affected by magmatic events. | GLGP | |
| • Evaluate the capability of seismic reflection and seismic tomography surveys to identify small subsurface igneous features. | GLGP | |
| • Formulate links in IPA among volcanism, tectonics, climate, hydrological and geochemical settings of the repository. | PA | |
| Research Needs: | | |
| • Identify rates of change in volcanism recurrence rate and patterns of small-volume basaltic volcanism in analogous volcanic fields. | GLGP | |
| • Develop probability models that capture essential features of basaltic vent distribution. | GLGP | |

Table 2-2. Key Technical Issues—Igneous Activity (cont'd)

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Research Needs (cont'd): | | |
| • Develop and test models of recurrence rate and vent distribution based on integrated geochemical, tectonic, and geophysical models. | GLGP | |
| • Develop criteria to characterize the style of small cinder cone basaltic eruptions in order to place limits on the area influenced by volcanic activity. | GLGP | |
| • Identify or develop geological, geophysical, and geochemical models that can be used to bound probability calculations. | GLGP | |
| • Independently analyze scenarios of volcanic disruption and evaluate scenario models utilized by the DOE and EPRI in their TSPAs for YM. | GLGP/PA | |
| • Review and evaluate the basis for the DOE estimates of the probability of occurrence for each scenario. | PA | |
| • Provide improved estimates of scenario probabilities based on site-specific geologic data and information. | PA | |
| • Provide improved models of the physical characteristics and consequences of the disruptive events and processes. | PA | |
| • Identify additional scenarios potentially having direct and indirect effects on repository performance. | PA | |
| • Evaluate different approaches to enhance the likelihood of completeness in the generation of the initial list of events and processes. | PA | |

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**Table 2-3. Key Technical Issue—Geochemical Effects on Radionuclide Transport Within and Beyond the Thermally Affected Zone**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Key Technical Uncertainties: | | |
| • Equal or increased capacity of alteration mineral assemblages to inhibit radionuclide migration (Type 4) | Geohydrology and Geochemistry (GHGC) | |
| • Characterizing the chemistry of the groundwater in the partially-saturated hydrologic zone of Yucca Mountain, Nevada (Type 4) | GHGC | |
| • Understanding the effects of degree of saturation on geochemical processes such as radionuclide sorption and precipitation and formation of particulates and colloids, and on the transport of radionuclides by particulates, colloids and complexes (Type 4) | GHGC | |
| • Parametric representation of retardation processes involving radionuclide-bearing particulates, colloids, and complexes (Type 4) | GHGC | |
| • Determining the alteration of mineral assemblages due to thermal loading (Type 4) | GHGC | Shared with KTI #5 |
| • Identifying geochemical processes that reduce radionuclide "retardation" (Type 4) | GHGC | |
| • Determining the magnitude of the effect of the geochemical processes that reduce radionuclide "retardation" (Type 5) | GHGC | |
| • Identifying geochemical conditions that would inhibit particulate and colloid formation (Type 4) | GHGC | |
| • Understanding/predicting the effect of groundwater conditions on dissolution of waste form (Type 4) | GHGC/EBS | |
| • Prediction of the evolution of groundwater conditions near and within the EBS (Type 5) | GHGC/EBS | Shared with KTI #5 |
| • Identifying geochemical processes that adversely affect the EBS (Type 4) | GHGC/EBS | Shared with KTI #5 |
| • Determining the magnitude of the effect of the geochemical processes that adversely affect the EBS (Type 5) | GHGC/EBS | Shared with KTI #5 |

**Table 2-3. Key Technical Issue—Geochemical Effects on Radionuclide Transport Within and Beyond the Thermally Affected Zone (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Key Technical Uncertainties (cont'd): | | |
| • Volatility and stability of chemical species of radionuclides (Type 4) | GHGC | |
| • Gas flow and gaseous radionuclide transport (Type 4) | GHGC | Shared with KTI #10 |
| • Prediction of Criticality Events in Waste Packages (Type 4) | EBS/Repository Design, Construction and Operations (RDCO) | Shared with KTI #6 |
| • Prediction of the releases of gaseous radionuclides from waste packages during the containment period and from the EBS during the post-containment period (Type 4) | EBS/GHGC | Shared with KTIs #6,10 |
| • Prediction of the releases of non-gaseous radionuclides from waste packages during the containment period and from the EBS during the post-containment period (Type 4) | EBS/GHGC | Shared with KTIs #6,10 |
| • Extrapolation of short-term laboratory and prototype test results to predict long-term performance of waste packages and EBS (Type 5) | EBS | Shared with KTI #6 |
| • Conceptual model representations of the natural and engineered systems (Type 4) | PA | Shared with KTIs #5,10 |
| • Variability in model parametric values (Type 4) | PA | Shared with KTIs #5,10 |
| • Appropriateness of assumptions and simplification in mathematical models (Type 4) | PA | Shared with KTIs #5,10 |
| • Validation of mathematical models (Type 5) | PA | Shared with KTIs #5,10 |
| • Prediction of future system states (i.e., disruptive scenarios) (Type 5) | PA | Shared with KTIs #2,3,5,10 |

Table 2-3. Key Technical Issue—Geochemical Effects on Radionuclide Transport Within and Beyond the Thermally Affected Zone (cont'd)

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Technical Assessment Needs: | | |
| • Become familiar with available geochemical data, such as mineralogy, mineral chemistry, hydrochemistry for water samples obtained from hydrologically unsaturated cores and gas compositions. The spatial distribution of these data are important in understanding the different geochemical effects on groundwater chemistry. Although chemical data from the unsaturated zone are difficult to obtain and spatial data distribution is likely to be sparse, the geographical and geological context of these data should be preserved to the extent possible through the use of GIS and 3D hydrogeologic models. | GHGC | |
| • Become familiar with the methods and models available to describe processes important to radionuclide retardation. | GHGC | |
| • Become familiar with the current data available for unsaturated zone geochemistry at YM, and methods and models available to describe groundwater chemistry in the partially unsaturated zone and modify models of geochemical processes in the unsaturated zone that may affect mineral and water chemistry and develop new approaches, as necessary. | GHGC | |
| • Conduct sensitivity studies to determine the extent to which different parameters in the models have the greatest effects on results, and evaluate likely ranges in these parameters to be encountered at YM. | GHGC | |
| • Become familiar with the methods and models available to describe processes important to transport of the liquid and vapor phase of water. | GHGC | |
| • Develop an understanding of the effect of backfilling of emplacement drifts on the performance of waste packages, stability of drifts, and retrievability of waste. | EBS/RDCO | |
| • Develop a more general and comprehensive near-field environment model that can fully couple transport and electrochemical processes with aqueous complexing reactions and kinetic reaction of minerals. | EBS/GHGC | |

**Table 2-3. Key Technical Issue—Geochemical Effects on Radionuclide Transport Within and Beyond the Thermally Affected Zone (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Technical Assessment Needs (cont'd): | | |
| • Critically evaluate the role of colloids in the release of radionuclides and the nucleation, stability, and transport of colloids in the geologic medium near the EBS. | EBS/GHGC | |
| • Examine the methodologies for extrapolating short-term laboratory or field performance data to long-term performance through a combination of mechanistic modeling, experimentation, and comparison to relevant natural systems that have operated for long time periods. | EBS | |
| • Assess the rate-controlling processes in the dissolution of spent fuel and release of matrix radionuclides. | EBS | |
| • Model the release rate of radionuclides from spent fuel. | EBS | |
| • Determine the site and design parameters that have significant influence on the calculation of the CCDF for radionuclide release. | EBS | |
| • Characterize parameter variabilities and uncertainties using geostatistical techniques, Monte Carlo simulation, the Fast Probabilistic Performance Assessment and expert judgment. | PA | |
| • Independently evaluate the techniques used by the DOE to account for spatial and temporal variability. | PA | |
| • Investigate techniques for use of expert judgment in characterizing uncertainties in data, models, and future system states. | PA | |
| • Independently analyze scenarios and evaluate scenario models utilized by the DOE and EPRI in their TSPAs for YM. | PA | |
| • Review and evaluate the basis for the DOE estimates of the probability of occurrence for each scenario. | PA | |
| • Evaluate the impact of alternative conceptual models of the hydrogeologic setting and the coupled phenomena that are expected to exist during the postclosure period. | PA | |

**Table 2-3. Key Technical Issue—Geochemical Effects on Radionuclide Transport Within and Beyond the Thermally Affected Zone (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Technical Assessment Needs (cont'd): | | |
| • Investigate the potential impacts of simplifications used in the conceptual models on the results of TSPA calculations and other analyses. | PA | |
| • Perform auxiliary analyses of the controlling processes and determine the sensitivities of associated model parameters. | PA | |
| Research Needs: | | |
| • Develop models of sorption processes and other geochemical aspects of unsaturated mass transport. | GHGC | |
| • Investigate sorption and ion exchange processes, and mineral precipitation/dissolution kinetics through laboratory experiments. | GHGC | |
| • Evaluate large- and small-scale studies of long-term migration through both fractures and the matrix at natural analog sites. | GHGC | |
| • Characterize mineral assemblages that may result from thermal alteration of near-field materials and from the interactions between the EBS and natural materials. | GHGC | |
| • Develop geochemical models for mineral alteration, precipitation/dissolution, sorption, colloidal formation and transport, thermal loading effects, aqueous speciation, and fracture-matrix interactions. These models should be supported by thermodynamic and kinetic data and extensive analysis of site characterization data, data from natural analog sites, and laboratory analyses under variably saturated conditions. | GHGC | |
| • Develop models of geochemical processes in the unsaturated zone that may affect mineral and water chemistry. | GHGC | |

**Table 2-3. Key Technical Issue—Geochemical Effects on Radionuclide Transport Within and Beyond the Thermally Affected Zone (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Research Needs (cont'd): | | |
| • Carry out confirmatory and exploratory laboratory investigations of processes such as sorption, ion exchange, and precipitation/dissolution, that may influence system chemistry in the unsaturated zone. Additional studies conducted in natural analog sites may provide insight into critical parameters controlling chemistry in the unsaturated zone in both fractures and matrix. | GHGC | |
| • Develop and refine geochemical models for reconstructing the evolution of groundwater chemistry in the unsaturated zone. These models should be supported by thermodynamic and kinetic data, extensive analysis of site characterization data, data from natural analog sites, and laboratory experiments to investigate sorption and transport under variably saturated conditions. | GHGC | |
| • Evaluate appropriate geostatistical and stochastic methods for expressing the spatial variability of parameters. | PA | |
| • Develop the basis for gaining confidence in the model's ability to extrapolate in time and space and, more importantly, for those components that cannot be tested directly. | PA | |
| • Investigate the relevance of possible differences between model predictions and experimental results. | PA | |
| • Develop acceptable methods and approaches for model validation. | PA | |
| • Develop an independent assessment of the evolution of the near-field environment due to thermal output of the waste packages. Specifically, the changes in the chemical composition of the environment near the waste package surface due to evaporation and the resultant redistribution of moisture have to be understood. For this purpose, two-phase fluid transport in a partially saturated medium has to be modeled in combination with multi-component solute transport and reactions. | GHGC | |

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**Table 2-3. Key Technical Issue—Geochemical Effects on Radionuclide Transport Within and Beyond the Thermally Affected Zone (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Research Needs (cont'd): | | |
| • Develop an understanding of the changes in chemistry inside defects in the overpack and due to the reaction of fillers and backfill with groundwater that may affect the performance of inner containers, multipurpose canister, and waste form. | EBS | |
| • Develop an understanding of the effect of repository operations (grout, organic fluids, etc.) on the changes in environment, such as groundwater pH, redox conditions, and aqueous species which may be detrimental to the performance of waste packages and waste forms. | GHGC/EBS | |
| • Determine the time at which rewetting of the containers occurs, and determine the chemistry of the condensed phase. | EBS | |
| • Determine the possible effects of man-made materials introduced into the natural system on the near-field environment. | GHGC | |
| • Identify the near-field environment chemistry as affected by components of the EBS, such as grout, microbiological organisms, and container corrosion. | GHGC/EBS | |
| • Understand the effects of design on the thermal fields near the waste packages. | EBS | |
| • Determine the role of electrochemical versus chemical dissolution of spent fuel. | EBS | |
| • Determine the role of secondary mineral formation on dissolution rate. | PA | |
| • Model the formation of secondary minerals and compare them to those observed in natural analog studies as well as long-term laboratory drip tests. | PA | |
| • Delineate the nature of parameter variability and uncertainties. | PA | |
| • Develop methods for describing the spatial or temporal variability of model parameters. | PA | |

**Table 2-3. Key Technical Issue—Geochemical Effects on Radionuclide Transport Within and Beyond the Thermally Affected Zone (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Research Needs (cont'd): | | |
| • Develop scaling theories that permit relating laboratory- or field-scale parameter values to site-scale model parameters. | PA | |
| • Provide improved estimates of scenario probabilities based on site-specific geologic data and information. | PA | |
| • Provide improved models of the physical characteristics and consequences of the disruptive events and processes. | PA | |
| • Identify additional scenarios potentially having direct and indirect effects on repository performance. | PA | |
| • Evaluate different approaches to enhance the likelihood of completeness in the generation of the initial list of events and processes. | PA | |
| • Define and specify "partial validation" requirements for both the detailed and abstracted models used to assess subsystem and total-system performance. | PA | |
| • Define appropriate performance measures or acceptance criteria for partial validation. | PA | |
| • Investigate how results from partial validation studies may be used to determine a model's predictive reliability over large spatial and temporal scales. | PA | |
| • Investigate the proper use of laboratory tests, *in situ* tests, field tests, and natural analogs in a model validation strategy. | PA | |

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**Table 2-4. Key Technical Issue—Hydrologic Characterization of Structural Features which Significantly Affect Water and Vapor Movement**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Key Technical Uncertainties: | | |
| • Poor resolution of exploration techniques to detect and evaluate structural features (Type 4) | GLGP | Shared with KTI #1 |
| • Development and use of conceptual tectonic models as related to structural deformation (Type 5) | GLGP | Shared with KTI #1 |
| • Low resolution of exploration techniques to detect and evaluate igneous features (Type 4) | GLGP | Shared with KTI #2 |
| • Development and use of conceptual tectonic models as related to igneous activity (Type 5) | GLGP | Shared with KTI #2 |
| • Modeling groundwater flow through unsaturated fractured rock caused by the lack of codes tested against field and laboratory data (Type 4) | GHGC | Shared with KTI #10 |
| • Identifying which conceptual models adequately represent isothermal and nonisothermal liquid and vapor phase movement of water through unsaturated fractured rock at YM (Type 4) | GHGC | Shared with KTI #10 |
| • Uncertainties associated with determining characterization parameters (Type 4) | GHGC | Shared with KTI #10 |
| • Developing a conceptual groundwater flow model that is representative of the YM site groundwater flow system (Type 4) | GHGC | Shared with KTI #10 |
| • Experimental confirmation of the basic physical concepts of groundwater flow through unsaturated fractured rock is needed (Type 5) | GHGC | Shared with KTI #10 |
| • Development of new data collection and interpretation techniques are required for codes which model groundwater flow through unsaturated fractured rock (Type 5) | GHGC | Shared with KTI #10 |
| • Developing a mathematical groundwater flow model that is representative of the YM site groundwater flow system (Type 4) | GHGC | Shared with KTI #10 |
| • Conceptual model representations of the natural and engineered systems (Type 4) | GHGC | Shared with KTIs #3,5,10 |

**Table 2-4. Key Technical Issue—Hydrologic characterization of structural features which significantly affect water and vapor movement (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Key Technical Uncertainties (cont'd): | | |
| • Variability in model parametric values (Type 4) | PA | Shared with KTIs #3,5,10 |
| • Appropriateness of assumptions and simplification in mathematical models (Type 4) | PA | Shared with KTIs #3,5,10 |
| • Validation of mathematical models (Type 5) | PA | Shared with KTIs #3,5,10 |
| • Prediction of future system states (Type 5) | PA | Shared with KTIs #2,3,5,7,10 |
| Technical Assessment Needs: | | |
| • Become familiar with the methods and models available to describe processes important to transport of the liquid and vapor phase of water and modify models and develop new approaches as necessary. | GHGC | |
| • Characterize parameter variabilities and uncertainties using geostatistical techniques, Monte Carlo simulation, the Fast Probabilistic Performance Assessment and expert judgment. | PA | |
| • Independently evaluate the techniques used by the DOE to account for spatial and temporal variability. | PA | |
| • Investigate techniques for use of expert judgment in characterizing uncertainties in data, models, and future system states. | PA | |
| • Independently analyze scenarios and evaluate scenario models utilized by the DOE and EPRI in their TSPAs for YM. | PA | |
| • Review and evaluate the basis for the DOE estimates of the probability of occurrence for each scenario. | PA | |
| • Evaluate the impact of alternative conceptual models of the hydrogeologic setting and the coupled phenomena that are expected to exist during the postclosure period. | PA | |
| • Investigate the potential impacts of simplifications used in the conceptual models on the results of TSPA calculations and other analyses. | PA | |

**Table 2-4. Key Technical Issue—Hydrologic characterization of structural features which significantly affect water and vapor movement (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Technical Assessment Needs (cont'd): | | |
| • Perform auxiliary analyses of the controlling processes and determine the sensitivities of associated model parameters. | PA | |
| Research Needs: | | |
| • Perform independent evaluation of hydrogeologic data, analyses, and model development. | GHGC | |
| • Determine whether the DOE 2D cross-sections and 3D models representing subsurface hydro-stratigraphy and structure are adequate and realistic for the hydrogeologic setting of YM and the Death Valley Region. | GHGC | |
| • Use the DOE data, and in addition, collect select field data on faulting, contemporary strain, uplift, vertical axis rotation, thermal history, and regional tectonic history in order to constrain new structural and tectonic models and to provide a basis for critical evaluation of existing and new models developed by the DOE. | GLGP | |
| • Collect limited geophysical data to address very specific issues such as dikes in alluvium. | GLGP | |
| • Develop 2D vertical cross-sections perpendicular to the hydraulic head contour in the vicinity of YM to investigate the effect of hydrogeologic structure on gradients, flow directions, and velocities. | GHGC | |
| • Construct a detailed 3D hydrogeologic model of the YM and Death Valley flow system to investigate the effect of the spacial distribution of hydrogeologic properties on the movement of water in both liquid and vapor phases. | GHGC | |
| • Evaluate uncertainty associated with the extent to which faulting may be present and remain undetected and the potential for activity of existing faults in the present 3D stress field. | GLGP | |
| • Investigate how the rock matric potential can be accurately measured. | GHGC | |

**Table 2-4. Key Technical Issue—Hydrologic characterization of structural features which significantly affect water and vapor movement (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Research Needs (cont'd): | | |
| • Evaluate appropriate geostatistical and stochastic methods for expressing the spatial variability of parameters. | PA | |
| • Develop acceptable approaches for characterizing the spatial distribution of infiltration. | GHGC | |
| • Develop the basis for gaining confidence in the model's ability to extrapolate in time and space and, more importantly, for those components that cannot be tested directly. | PA | |
| • Investigate the relevance of possible differences between model predictions and experimental results. | PA | |
| • Test the appropriateness of field-scale hydraulic parameter estimation techniques. | GHGC | |
| • Develop acceptable methods and approaches for model validation. | PA | |
| • Delineate the nature of hydraulic parameter variability and uncertainties. | GHGC | |
| • Develop methods for describing the spatial or temporal variability of model parameters. | PA | |
| • Develop scaling theories that permit relating laboratory- or field-scale parameter values to site-scale model parameters. | PA | |
| • Provide improved estimates of scenario probabilities based on site-specific geologic data and information. | PA | |
| • Provide improved models of the physical characteristics and consequences of the disruptive events and processes. | PA | |
| • Identify additional scenarios potentially having direct and indirect effects on repository performance. | PA | |
| • Evaluate different approaches to enhance the likelihood of completeness in the generation of the initial list of events and processes. | PA | |

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**Table 2-4. Key Technical Issue—Hydrologic characterization of structural features which significantly affect water and vapor movement (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Research Needs (cont'd): | | |
| • Define and specify "partial validation" requirements for both the detailed and abstracted models used to assess subsystem and total-system performance. | PA | |
| • Define appropriate performance measures or acceptance criteria for partial validation. | PA | |
| • Investigate how results from partial validation studies may be used to determine a model's predictive reliability over large spatial and temporal scales. | PA | |
| • Investigate the proper use of laboratory tests, *in situ* tests, field tests, and natural analogs in a model validation strategy. | PA | |

**Table 2-5. Key Technical Issue—Evolution of Groundwater in the Near-Field Environment**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Key Technical Uncertainties: | | |
| • Prediction of the evolution of groundwater conditions near and within the EBS (Type 5) | GHGC/EBS | Shared with KTI #3 |
| • Prediction of the TMHC responses of the host rock, surrounding strata, and groundwater system to thermal loads (Type 4) | RDCO | Shared with KTIs #9,10 |
| • Prediction of the thermal, mechanical, and hydrological impact on the host rock surrounding the waste package (Type 4) | RDCO/EBS | Shared with KTIs #9,10 |
| • Determining the alteration of mineral assemblages due to thermal loading (Type 4) | GHGC | Shared with KTI #3 |
| • Identifying geochemical processes that adversely affect the EBS (Type 4) | GHGC/EBS | Shared with KTI #3 |
| • Determining the magnitude of the effect of the geochemical processes that adversely affect the EBS (Type 5) | GHGC/EBS | Shared with KTI #3 |
| • Conceptual model representations of the natural and engineered systems (Type 4) | PA | Shared with KTIs #3,4,10 |
| • Variability in model parametric values (Type 4) | PA | Shared with KTIs #3,4,10 |
| • Appropriateness of assumptions and simplification in mathematical models (Type 4) | PA | Shared with KTIs #3,4,10 |
| • Validation of mathematical models (Type 5) | PA | Shared with KTIs #3,4,10 |
| • Prediction of future system states (Type 5) | PA | Shared with KTIs #2,3,4,7,10 |
| Technical Assessment Needs: | | |
| • Develop a more general and comprehensive near-field environment model that can fully couple transport and electrochemical processes with aqueous complexing reactions and kinetic reaction of minerals. | GHGC/EBS | |
| • Critically evaluate the role of colloids in the release of radionuclides and the nucleation, stability, and transport of colloids in the geologic medium. | GHGC/EBS | |

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**Table 2-5. Key Technical Issue—Evolution of Groundwater in the Near-Field Environment (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Technical Assessment Needs (cont'd): | | |
| • Develop a rock joint constitutive model. | RDCO | |
| • Analyze drift stability leading to rock-induced waste package failure for updating the SEISMO Module in the IPA code. | RDCO | |
| • Develop an understanding of the effect of backfilling of emplacement drifts on the performance of waste packages, stability of drifts, and retrievability of waste. | RDCO | |
| • Develop or modify TMH compliance determination codes for subsurface facilities. | RDCO | |
| • Develop the EBS performance assessment code EBSPAC. | EBS | |
| • Develop models and the code modules for the TSPA. These should include an investigation of the impact of alternative conceptual models of the hydrogeologic setting and the coupled phenomena that are expected to exist during the closure period, and the potential impacts of simplifications used in the conceptual models on the results of TSPA calculations. | PA | |
| • Become familiar with available geochemical data, such as mineralogy, mineral and water chemistry, and gas compositions. Because the available data are likely to be limited, and because the spatial distribution of these data is important in understanding the different geochemical effects on radionuclide retardation, the geographical and geological context of these data should be preserved to the extent possible through the use of GIS and 3D hydrogeologic models. | GHGC | |
| • Become familiar with the methods and models available to describe processes important to radionuclide retardation, and modify existing geochemical and transport models and develop new approaches as necessary. | GHGC | |

**Table 2-5. Key Technical Issue—Evolution of Groundwater in the Near-Field Environment (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Technical Assessment Needs (cont'd): | | |
| • Undertake sensitivity studies to determine the effect of different parameters in the models affect the modeling of radionuclide transport and retardation, and determine those site and design parameters that have a significant effect on calculating the CCDF for radionuclide release. | GHGC | |
| • Examine the methodologies for extrapolating short-term laboratory or field performance data to long-term performance through a combination of mechanistic modeling, experimentation, and comparison to relevant natural systems that have operated over long time periods. | EBS | |
| • Perform auxiliary analyses of the processes controlling groundwater evolution in the near-field and EBS performance and determine the sensitivities of associated model parameters. | EBS/GHGC | |
| • Characterize parameter variabilities and uncertainties using geostatistical techniques, Monte Carlo simulation, the Fast Probabilistic Performance Assessment and expert judgment. | PA | |
| • Independently evaluate the techniques used by the DOE to account for spatial and temporal variability. | PA | |
| • Investigate techniques for use of expert judgment in characterizing uncertainties in data, models, and future system states. | PA | |
| • Independently analyze scenarios and evaluate scenario models used by the DOE and EPRI in their TSPAs for YM. This should also include a review and evaluation of the basis for the DOE estimates of the probability of occurrence for each scenario. | PA | |

**Table 2-5. Key Technical Issue—Evolution of Groundwater in the Near-Field Environment (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Research Needs: | | |
| • Develop an independent assessment of the evolution of the near-field environment due to thermal output of the waste packages. Specifically, the changes in the chemical composition of the environment near the waste package surface due to evaporation and the resultant redistribution of moisture have to be understood. For this purpose, two-phase fluid transport in a partially saturated medium has to be modeled in combination with multi-component solute transport and reactions. | EBS/GHGC/ RDCO | |
| • Develop an understanding of the changes in chemistry inside defects in the overpack and due to the reaction of fillers and backfill with groundwater that may affect the performance of inner containers, multipurpose canister, and waste form. | EBS | |
| • Develop an understanding of the effect of repository operations, EBS components, and the introduction of man-made materials (grout, organic fluids, etc.) on the changes in near-field environment, such as groundwater pH, redox conditions, and aqueous species which may be detrimental to the performance of waste packages and waste forms. | EBS/RDCO | |
| • Determine the time at which rewetting of the waste package containers occurs, and determine the chemistry of the condensed phase. | EBS | |
| • Understand the effects of design on the thermal fields near the waste packages. | EBS | |
| • Develop a methodology for bounding spatial variability of rock and joint properties using a stochastic approach. | RDCO | |
| • Determine the long-term effectiveness of rock-bolts and other ground supports under thermal environment. | RDCO | |
| • Develop a methodology for identification and characterization of important design parameters for underground excavations—a total system approach. | RDCO | |

**Table 2-5. Key Technical Issue—Evolution of Groundwater in the Near-Field Environment (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Research Needs (cont'd): | | |
| • Develop a technique for extrapolation of laboratory-measured intact rock and joint properties and fracture flow data for field-scale application. | RDCO | |
| • Perform DECOVALEX TMH experiments and modeling. | RDCO | |
| • Identify near-field environment chemistry as altered by the thermal loading on construction materials used for seals and shafts and the host rock leading to alteration in the pathways and chemistry of ingressing groundwaters. | GHGC | |
| • Investigate sorption and ion exchange processes, and mineral precipitation/dissolution kinetics through laboratory experiments. | GHGC | |
| • Evaluate large- and small-scale studies of long-term migration through both fractures and the matrix at natural analog sites. | GHGC | |
| • Characterize mineral assemblages that may result from thermal alteration of near-field materials and from the interactions between the EBS and natural materials. | GHGC | |
| • Develop geochemical models for mineral alteration, precipitation/dissolution, sorption, colloidal formation and transport, thermal loading effects, aqueous speciation, and fracture-matrix interactions. These models should be supported by thermodynamic and kinetic data and extensive analysis of site characterization data, data from natural analog sites, and laboratory analyses under variably saturated conditions. | GHGC | |
| • Develop a quantitative methodology to assess the effect of microbial organisms on corrosion. | EBS | |
| • Define and specify "partial validation" requirements for both the detailed and abstracted models used to assess subsystem and total-system performance, including how results from partial validation studies may be used to determine predictive reliability over large spatial and temporal scales. | PA | |

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**Table 2-5. Key Technical Issue—Evolution of Groundwater in the Near-Field Environment (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Research Needs (cont'd): | | |
| • Investigate the proper use of laboratory tests, *in situ* tests, field tests, and natural analogs in a model validation strategy that includes scaling theories that provide for extending laboratory- and field-scale parameter values to site-scale modeling. | PA | |
| • Delineate the nature of parameter variability and uncertainties. | PA | |
| • Develop methods for describing the spatial or temporal variability of model parameters. | PA | |
| • Provide improved estimates of scenario probabilities based on site-specific geologic data and information. | PA | |
| • Identify additional scenarios potentially having direct and indirect effects on repository performance. | PA | |
| • Evaluate different approaches to enhance the likelihood of completeness in the generation of the initial list of events and processes. | PA | |

**Table 2-6. Key Technical Issue—Waste Package Degradation**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Key Technical Uncertainties: | | |
| • Prediction of thermomechanical effects on the waste package and the EBS (Type 4) | EBS | Shared with KTIs #8,9 |
| • Prediction of environmental effects on the waste package and the EBS (Type 4) | EBS | |
| • Prediction of criticality events in waste packages (Type 4) | EBS | Shared with KTI #3 |
| • Prediction of release path parameters (such as the size, shape, and distribution of penetrations of waste packages) due to thermomechanical, environmental, or criticality effects (Type 4) | EBS | |
| • Prediction of the releases of gaseous radionuclides from waste packages during the containment period and from the EBS during the post-containment period (Type 4) | EBS | Shared with KTIs #3,10 |
| • Prediction of the releases of non-gaseous radionuclides from waste packages during the containment period and from the EBS during the post-containment period (Type 4) | EBS | Shared with KTIs #3,10 |
| • Extrapolation of short-term laboratory and prototype test results to predict long-term performance of waste packages and EBS (Type 5) | EBS | Shared with KTI #3 |
| Technical Assessment Needs: | | |
| • Analyze drift stability leading to rock-induced waste package failure for updating the SEISMO Module in the IPA code. | RDCO | |
| • Develop an understanding of the effect of backfilling of emplacement drifts on the performance of waste packages, stability of drifts, and retrievability of waste. | RDCO/EBS | |
| • Develop a more general and comprehensive near-field environment model that can fully couple transport and electrochemical processes with aqueous complexing reactions and kinetic reaction of minerals. | EBS | |
| • Develop the technical bases for EBSPAC. | EBS | |

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**Table 2-6. Key Technical Issue—Waste Package Degradation (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Technical Assessment Needs (cont'd): | | |
| • Critically evaluate the role of colloids in the release of radionuclides and the nucleation, stability, and transport of colloids in the geologic medium. | EBS | |
| • Examine the methodologies for extrapolating short-term laboratory or field performance data to long-term performance through a combination of mechanistic modeling, experimentation, and comparison to relevant natural systems that have operated over long time periods. | EBS | |
| • Evaluate the effect of interactions between various waste package materials on their performance. This evaluation will include such effects as galvanic corrosion and hydrogen embrittlement. | EBS | |
| • Model the effect of long-term thermal exposure and various repository mechanical loads on the mechanical stability of waste package materials and their consequences, including criticality. | EBS | |
| • Evaluate the engineering experience in terms of initial defect population after fabrication and reliability of components. | EBS | |
| • Systematically evaluate the effect of modifications to the waste package design and the multipurpose canister on repository performance. | EBS | |
| • Assess the rate-controlling processes in the dissolution of spent fuel and release of matrix radionuclides. | EBS | |
| • Assess the effects of colloids in controlling the transport of radionuclides near the EBS. | EBS | |
| • Determine the effect of long-term exposure of waste packages on the degradation of material properties by phase transformation and grain-boundary segregation leading to reduced corrosion resistance and impact toughness (ductility) of the waste package. | EBS | |

Table 2-6. Key Technical Issue—Waste Package Degradation (cont'd)

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Research Needs: | | |
| • Develop an independent assessment of the evolution of the near-field environment due to thermal output of the waste packages. Specifically, the changes in the chemical composition of the environment near the waste package surface due to evaporation and the resultant redistribution of moisture have to be understood. For this purpose, two-phase fluid transport in a partially saturated medium has to be modeled in combination with multi-component solute transport and reactions. | EBS | |
| • Develop an understanding of the changes in chemistry inside defects in the overpack and due to the reaction of fillers and backfill with groundwater that may affect the performance of inner containers, multipurpose canister, and waste form. | EBS | |
| • Develop an understanding of the effect of repository operations and man-made materials (grout, organic fluids, etc.) on the changes in environment, such as groundwater pH, redox conditions, and aqueous species which may be detrimental to the performance of waste packages and waste forms. | EBS | |
| • Determine the time at which rewetting of the containers occurs, and determine the chemistry of the condensed phase. | EBS | |
| • Understand the effects of design on the thermal fields near the waste packages. | EBS | |
| • Demonstrate the adequacy and conservatism of repassivation potential in predicting the long-term localized corrosion and stress corrosion cracking of austenitic materials. | EBS | |
| • Determine the existence of critical potentials for localized corrosion or stress corrosion cracking of other waste package materials. | EBS | |
| • Develop a quantitative methodology to assess the effect of microbial organisms on the near-field environment and on the corrosion of EBS components. | EBS | |

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Table 2-6. Key Technical Issue—Waste Package Degradation (cont'd)

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Research Needs (cont'd): | | |
| • Develop a quantitative understanding of the kinetics of embrittlement of basket material and its affect on criticality control. | EBS | |
| • Determine the role of electrochemical versus chemical dissolution of spent fuel. | EBS | |
| • Determine the role of secondary mineral formation on dissolution rate of spent fuel by modeling the formation of secondary minerals and compare them to those observed in natural analog studies as well as long-term laboratory drip tests. | EBS | |

**Table 2-7. Key Technical Issue—Methods of Assigning Probability to and Estimating the Consequences of Disruptive Scenarios**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Key Technical Uncertainty: | | |
| • Prediction of future system states (Type 5) | PA | Shared with KTIs #2,3,4,5,10 |
| Technical Assessment Needs: | | |
| • Independently analyze scenarios and evaluate scenario models utilized by the DOE and EPRI in their TSPAs for YM. | PA | |
| • Review and evaluate the basis for the DOE estimates of the probability of occurrence for each scenario. | PA | |
| • Incorporate probability and consequence models into the TPA. | PA | |
| Research Needs: | | |
| • Provide improved estimates of scenario probabilities based on site-specific geologic data and information. | PA | |
| • Provide improved models of the physical characteristics and consequences of the disruptive events and processes. | PA | |
| • Identify additional scenarios potentially having direct and indirect effects on repository performance. | PA | |
| • Evaluate different approaches to enhance the likelihood of completeness in the generation of the initial list of events and processes. | PA | |

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**Table 2-8. Key Technical Issue—Exploratory Studies Facility**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Key Technical Uncertainties: | | |
| • Prediction of the TMHC responses of the host rock, surrounding strata, and groundwater system to thermal loads (Type 4) | RDCO | Shared with KTIs #5,9,10 |
| • Prediction of the thermal, mechanical, and hydrological impact on the host rock surrounding the waste package (Type 4) | RDCO | Shared with KTIs #5,9,10 |
| • Predicting the long term performance of seals for shafts, ramps, and boreholes (Type 4) | RDCO | Shared with KTI #9 |
| • Predicting the long term performance of seals for the underground test boreholes (Type 4) | RDCO | Shared with KTI #9 |
| Technical Assessment Needs: | | |
| • Develop a rock joint constitutive model. | RDCO | |
| • Develop or modify TM compliance determination codes for subsurface facilities. | RDCO | |
| • Analyze drift stability leading to rock-induced waste package failure for updating the SEISMO Module in the IPA code. | RDCO | |
| • Develop an understanding of the effect of backfilling of emplacement drifts on the performance of waste packages, stability of drifts, and retrievability of waste. | RDCO | |
| • Develop or modify TMH compliance determination codes for subsurface facilities. | RDCO | |
| • Develop the models and the code modules for the TSPA. | RDCO/PA | |
| • Develop a better understanding of the importance of seals to the overall performance of the repository, taking into account the specific conditions at the YM repository site (including geologic and hydrologic properties of the intact matrix and fractures, infiltration, etc.) | RDCO | |

Table 2-8. Key Technical Issue—Exploratory Studies Facility (cont'd)

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Technical Assessment Needs (cont'): | | |
| • Evaluate, through sensitivity studies, which parameters (e.g., infiltration, fracture conductivities of the host rock, fracture porosity of the host rock, etc.) would have the largest impact on seal and repository performance, such that guidance can be given to site characterization activities to focus on better characterization of such properties. | RDCO | |
| Research Needs: | | |
| • Develop of a methodology for bounding spatial variability of rock and joint properties using stochastic approach. | RDCO | |
| • Determine the long-term effectiveness of rock-bolts and other ground supports under thermal environment. | RDCO | |
| • Develop a methodology for identification and characterization of important design parameters for underground excavations—a total system approach. | RDCO | |
| • Develop a technique for extrapolation of laboratory measured intact rock and joint properties for field-scale application. | RDCO | |
| • Perform DECOVALEX TMH experiments and modeling. | RDCO | |
| • Develop an understanding of the constitutive laws of time-dependent rock properties under heated, variably saturated, and stressed conditions. | RDCO | |
| • Evaluate long-term TM effects on the performance of seals. | RDCO | |
| • Evaluate long-term thermal-hydrological effects on the chemical properties of seal materials. | RDCO | |
| • Evaluate long-term TM (including repetitive seismic load) effects on the surrounding rock mass and seal-rock interface. | RDCO | |

Table 2-9. Key Technical Issue—Thermal-Mechanical-Hydrological-Chemical Coupled Processes

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Key Technical Uncertainties: | | |
| • Prediction of the TMHC responses of the host rock, surrounding strata, and groundwater system to thermal loads (Type 4) | RDCO | Shared with KTIs #5,8,10 |
| • Prediction of the thermal, mechanical, and hydrological impact on the host rock surrounding the waste package (Type 4) | RDCO | Shared with KTIs #5,8,10 |
| • Prediction of thermomechanical effects on the performance of waste packages and the (EBS) (Type 4) | RDCO | Shared with KTIs #6,8 |
| • Demonstration of compliance with the requirement to maintain the ability to safely retrieve HLW (Type 4) | RDCO | |
| • Predicting the long term performance of seals for shafts, ramps, and boreholes (Type 4) | RDCO | Shared with KTI #8 |
| • Predicting the long term performance of seals for the underground test boreholes (Type 4) | RDCO | Shared with KTI #8 |
| Technical Assessment Needs: | | |
| • Develop a rock joint constitutive model. | RDCO | |
| • Develop or modify of TM compliance determination codes for subsurface facilities. | RDCO | |
| • Analyze drift stability leading to rock-induced waste package failure for updating the SEISMO Module in the IPA code. | RDCO | |
| • Develop an understanding of the effect of backfilling of emplacement drifts on the performance of waste packages, stability of drifts, and retrievability of waste. | EBS/RDCO | |
| • Develop or modify TMH compliance determination codes for subsurface facilities. | RDCO | |
| • Develop the EBS performance assessment code EBSPAC. | EBS | |
| • Develop the models and the code modules for the TSPA. | RDCO/PA | |

**Table 2-9. Key Technical Issue—Thermal-mechanical-hydrological-chemical coupled processes (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Technical Assessment Needs (cont'd): | | |
| • Develop a better understanding of the importance of seals to the overall performance of the repository, taking into account the specific conditions at the YM repository site (including geologic and hydrologic properties of the intact matrix and fractures, infiltration, etc.). | RDCO | |
| • Evaluate, through sensitivity studies, which parameters (e.g., infiltration, fracture conductivities of the host rock, fracture porosity of the host rock, etc.) would have the largest impact on seal and repository performance, such that guidance can be given to site characterization activities to focus on better characterization of such properties. | RDCO | |
| • Review and assess ongoing DOE planning activities on waste retrievability. | RDCO | |
| • Develop or modify TM compliance determination codes for subsurface facilities. | RDCO | |
| Research Needs: | | |
| • Develop of a methodology for bounding spatial variability of rock and joint properties using stochastic approach. | RDCO | |
| • Determine the long-term effectiveness of rock-bolts and other ground supports under thermal environment. | RDCO | |
| • Develop a methodology for identification and characterization of important design parameters for underground excavations—a total system approach. | | |
| • Develop a technique for extrapolation of laboratory measured intact rock and joint properties for field-scale application. | RDCO | |

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**Table 2-9. Key Technical Issue—Thermal-mechanical-hydrological-chemical coupled processes (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Research Needs (cont'd): | | |
| • Determine the effect of long-term exposure of waste packages on the degradation of material properties by phase transformation and grain-boundary segregation leading to reduced corrosion resistance and impact toughness (ductility) of the waste package. | EBS | |
| • Perform DECOVALEX TMH experiments and modeling. | EBS | |
| • Develop an understanding of the constitutive laws of time-dependent rock properties under heated, variably saturated, and stressed conditions. | EBS | |
| • Develop a technique for extrapolation of laboratory-measured fracture flow data for field-scale application. | GHGC | |
| • Determine when and the extent of rewetting of the waste package (container) and the chemistry of the condensed phase. | EBS | |
| • Identify near-field environment chemistry as altered by the thermal loading on construction materials used for seals and shafts and the host rock leading to alteration in the pathways and chemistry of ingressing groundwaters. | RDCO/GHGC | |
| • Evaluate long-term TM effects on the performance of seals. | RDCO | |
| • Evaluate long-term thermal-hydrological effects on the chemical properties of seal materials. | RDCO | |
| • Evaluate long-term TM (including repetitive seismic load) effects on the surrounding rock mass and seal-rock interface. | RDCO | |

**Table 2-10. Key Technical Issue—Thermal Effects and Redistribution of Moisture**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Key Technical Uncertainties: | | |
| • Modeling groundwater flow through unsaturated fractured rock caused by the lack of codes tested against field and laboratory data (Type 4) | GHGC | Shared with KTI #4 |
| • Identifying which conceptual models adequately represent isothermal and nonisothermal liquid and vapor phase movement of water through unsaturated fractured rock at YM (Type 4) | GHGC | Shared with KTI #4 |
| • Uncertainties associated with determining characterization parameters (Type 4) | GHGC | Shared with KTI #4 |
| • Developing a conceptual groundwater flow model that is representative of the YM site groundwater flow system (Type 4) | GHGC | Shared with KTI #4 |
| • Experimental confirmation of the basic physical concepts of groundwater flow through unsaturated fractured rock is needed (Type 5) | GHGC | Shared with KTI #4 |
| • Development of new data collection and interpretation techniques are required for codes which model groundwater flow through unsaturated fractured rock (Type 5) | GHGC | Shared with KTI #4 |
| • Developing a mathematical groundwater flow model that is representative of the YM site groundwater flow system (Type 4) | GHGC | Shared with KTI #4 |
| • Prediction of the TMHC responses of the host rock, surrounding strata, and groundwater system to thermal loads (Type 4) | RDCO | Shared with KTIs #5,8,9 |
| • Prediction of the thermal, mechanical, and hydrological impact on the host rock surrounding the waste package (Type 4) | RDCO | Shared with KTIs #5,8,9 |
| • Prediction of the releases of gaseous radionuclides from waste packages during the containment period and from the EBS during the post-containment period (Type 4) | EBS | Shared with KTIs #3,6 |

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Table 2-10. Key Technical Issue—Thermal Effects and Redistribution of Moisture (cont'd)

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Key Technical Uncertainties (cont'd): | | |
| • Prediction of the releases of non-gaseous radionuclides from waste packages during the containment period and from the EBS during the post-containment period (Type 4) | EBS | Shared with KTIs #3,6 |
| • Conceptual model representations of the natural and engineered systems (Type 4) | PA | Shared with KTIs #3,4,5 |
| • Variability in model parametric values (Type 4) | PA | Shared with KTIs #3,4,5 |
| • Appropriateness of assumptions and simplification in mathematical models (Type 4) | PA | Shared with KTIs #3,4,5 |
| • Validation of mathematical models (Type 5) | PA | Shared with KTIs #3,4,5 |
| • Prediction of future system states (Type 5) | PA | Shared with KTIs #2,3,4,5,7 |
| • Modeling the formation of perched zones by thermally driven flow (Type 5) | GHGC | |
| • Prediction of future changes to the hydrologic system resulting from a combination of climatic and tectonic changes and human activities (including heat effects from waste emplacement) (Type 5) | GHGC | |
| • Gas flow and gaseous radionuclide transport (Type 4) | GHGC | Shared with KTI #3 |
| Technical Assessment Needs: | | |
| • Become familiar with the methods and models available to describe processes important to transport of the liquid and vapor phase of water and modify models and develop new approaches as necessary. | GHGC | |
| • Undertake sensitivity studies to determine the extent to which different parameters in the models affect various performance related measures. | GHGC | |
| • Become familiar with the methods and models available to describe processes important to future changes to the hydrologic system resulting from climatic variations, tectonic changes, and human activities. | GHGC | |

**Table 2-10. Key Technical Issue—Thermal Effects and Redistribution of Moisture (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Technical Assessment Needs (cont'd): | | |
| • Modify conceptual models and develop new approaches as necessary (e.g., using expert elicitation techniques). | GHGC | |
| • Undertake sensitivity studies to determine the extent to which different parameters in the models affect various performance related measures. | GHGC | |
| • Develop a rock joint constitutive model. | RDCO | |
| • Develop or modify TM compliance determination codes for subsurface facilities. | RDCO | |
| • Analyze drift stability leading to rock-induced waste package failure for updating the SEISMO Module in the IPA code. | RDCO | |
| • Develop an understanding of the effect of backfilling of emplacement drifts on the performance of waste packages, stability of drifts, and retrievability of waste. | RDCO/EBS | |
| • Develop or modify TMH compliance determination codes for subsurface facilities. | RDCO | |
| • Develop the EBS performance assessment code EBSPAC. | EBS | |
| • Develop the models and the code modules for the TSPA. | PA | |
| • Assess the rate-controlling processes in the dissolution of spent fuel and release of matrix radionuclides. | EBS | |
| • Independently analyze scenarios and evaluate scenario models utilized by the DOE and EPRI in their TSPAs for YM. | PA | |
| • Review and evaluate the basis for the DOE estimates of the probability of occurrence for each scenario. | PA | |
| • Evaluate the impact of alternative conceptual models of the hydrogeologic setting and the coupled phenomena that are expected to exist during the postclosure period. | GHGC | |

**Table 2-10. Key Technical Issue—Thermal Effects and Redistribution of Moisture (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Technical Assessment Needs (cont'd): | | |
| • Investigate the potential impacts of simplifications used in the conceptual models on the results of TSPA calculations and other analyses. | PA | |
| • Perform auxiliary analyses of the controlling processes and determine the sensitivities of associated model parameters. | PA | |
| • Determine the site and design parameters that have significant influence on the calculation of the CCDF for radionuclide release. | PA | |
| • Characterize parameter variabilities and uncertainties using geostatistical techniques, Monte Carlo simulation, the Fast Probabilistic Performance Assessment and expert judgment. | PA | |
| • Independently evaluate the techniques used by the DOE to account for spatial and temporal variability. | PA | |
| • Investigate techniques for use of expert judgment in characterizing uncertainties in data, models, and future system states. | PA | |
| Research Needs: | | |
| • Investigate how the rock matric potential can be accurately measured. | GHGC | |
| • Evaluate appropriate geostatistical and stochastic methods for expressing the spatial variability of parameters. | GHGC | |
| • Develop acceptable approaches for characterizing the spatial distribution of infiltration. | GHGC | |
| • Develop the basis for gaining confidence in the model's ability to extrapolate in time and space and, more importantly, for those components that cannot be tested directly. | PA | |
| • Investigate the relevance of possible differences between model predictions and experimental results. | PA | |
| • Test the appropriateness of field-scale hydraulic parameter estimation techniques. | GHGC | |

**Table 2-10. Key Technical Issue—Thermal Effects and Redistribution of Moisture (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Research Needs (cont'd): | | |
| • Develop acceptable methods and approaches for model validation. | PA | |
| • Investigate the use of expert elicitation approaches. | PA | |
| • Evaluate methods to predict future human activities. | PA | |
| • Develop of a methodology for bounding spatial variability of rock and joint properties using stochastic approach. | PA | |
| • Determine the long-term effectiveness of rock-bolts and other ground supports under thermal environment. | PA | |
| • Develop a methodology for identification and characterization of important design parameters for underground excavations—a total system approach. | PA | |
| • Develop a technique for extrapolation of laboratory measured intact rock and joint properties for field-scale application. | PA | |
| • Determine the effect of long-term exposure of waste packages on the degradation of material properties by phase transformation and grain-boundary segregation leading to reduced corrosion resistance and impact toughness (ductility) of the waste package. | EBS | |
| • Perform DECOVALEX TMH experiments and modeling. | RDCO | |
| • Develop an understanding of the constitutive laws of time-dependent rock properties under heated, variably saturated, and stressed conditions. | RDCO | |
| • Develop a technique for extrapolation of laboratory-measured fracture flow data for field-scale application. | GHGC | |
| • Determine when and the extent of rewetting of the waste package (container) and the chemistry of the condensed phase. | EBS | |

**Table 2-10. Key Technical Issue—Thermal Effects and Redistribution of Moisture (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Research Needs (cont'd): | | |
| • Identify near-field environment chemistry as altered by the thermal loading on construction materials used for seals and shafts and the host rock leading to alteration in the pathways and chemistry of ingressing groundwaters. | GHGC/EBS | |
| • Determine the role of electrochemical versus chemical dissolution of spent fuel. | EBS | |
| • Determine the role of secondary mineral formation on dissolution rate. | EBS | |
| • Model the formation of secondary minerals and compare them to those observed in natural analog studies as well as long-term laboratory drip tests. | EBS | |
| • Provide improved estimates of scenario probabilities based on site-specific geologic data and information. | PA | |
| • Provide improved models of the physical characteristics and consequences of the disruptive events and processes. | PA | |
| • Identify additional scenarios potentially having direct and indirect effects on repository performance. | PA | |
| • Evaluate different approaches to enhance the likelihood of completeness in the generation of the initial list of events and processes. | PA | |
| • Define and specify "partial validation" requirements for both the detailed and abstracted models used to assess subsystem and total-system performance. | PA | |
| • Define appropriate performance measures or acceptance criteria for partial validation. | PA | |
| • Investigate how results from partial validation studies may be used to determine a model's predictive reliability over large spatial and temporal scales. | PA | |
| • Investigate the proper use of laboratory tests, *in situ* tests, field tests, and natural analogs in a model validation strategy. | PA | |

**Table 2-10. Key Technical Issue—Thermal Effects and Redistribution of Moisture (cont'd)**

| Key Technical Uncertainties/ Technical Support Needs | Responsible Element | Shared KTUs |
|---|---|---|
| Research Needs (cont'd): | | |
| • Delineate the nature of parameter variability and uncertainties. | PA | |
| • Develop methods for describing the spatial or temporal variability of model parameters. | PA | |
| • Develop scaling theories that permit relating laboratory- or field-scale parameter values to site-scale model parameters. | PA | |

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# 3 CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES PROGRAM ELEMENT CORRELATION

This section of the report lists the KTIs, KTUs, and Technical Support Needs under the CNWRA Program Elements having responsibility for those activities. Although contributions to each KTI are multi-disciplinary, the CNWRA having the lead responsibility for each KTI is identified.

## 3.1 ENGINEERED BARRIER SYSTEM PROGRAM ELEMENT CORRELATION

Key Technical Issue—Geochemical Effects on Radionuclide Transport Within and Beyond the Thermally Affected Zone

Lead Element: GHGC

Key Technical Uncertainties:

- Understanding/predicting the effect of groundwater conditions on dissolution of waste form (Type 4) (with GHGC)
- Prediction of the evolution of groundwater conditions near and within the EBS (Type 5) (with GHGC)
- Identifying geochemical processes that adversely affect the EBS (Type 4)
- Determining the magnitude of the effect of the geochemical processes that adversely affect the EBS (Type 5) (with GHGC)

Technical Assessment Needs:

- Develop an understanding of the effect of backfilling of emplacement drifts on the performance of waste packages, stability of drifts, and retrievability of waste (with RDCO).
- Develop a more general and comprehensive near-field environment model that can fully couple transport and electrochemical processes with aqueous complexing reactions and kinetic reaction of minerals (with GHGC).
- Critically evaluate the role of colloids in the release of radionuclides and the nucleation, stability, and transport of colloids in the geologic medium near the EBS.
- Examine the methodologies for extrapolating short-term laboratory or field performance data to long-term performance through a combination of mechanistic modeling, experimentation, and comparison to relevant natural systems that have operated over long time periods.
- Assess the rate-controlling processes in the dissolution of spent fuel and release of matrix radionuclides.

- Model the release rate of radionuclides from spent fuel.

- Determine the site and design parameters that have significant influence on the calculation of the complementary CCDF for radionuclide release.

- Develop an understanding of the changes in chemistry inside defects in the overpack and due to the reaction of fillers and backfill with groundwater that may affect the performance of inner containers, multipurpose canister, and waste form.

- Develop an understanding of the effect of repository operations (grouting, organic fluids, etc.) on the changes in environment, such as groundwater pH, redox conditions, and aqueous species which may be detrimental to the performance of waste packages and waste forms (with GHGC).

- Determine the time at which rewetting of the containers occurs, and determine the chemistry of the condensed phase.

- Identify the near-field environment chemistry as affected by components of the EBS, such as grout, microbiological organisms, and container corrosion (with GHGC).

- Understand the effects of design on the thermal fields near the waste packages.

- Determine the role of electrochemical versus chemical dissolution of spent fuel.

- Determine the role of secondary mineral formation on dissolution rate.

- Model the formation of secondary minerals and compare them to those observed in natural analog studies as well as long-term laboratory drip tests.

Key Technical Issue—Evolution of Groundwater in the Near-Field Environment

Lead Element: GHGC

Key Technical Uncertainties:

- Prediction of the evolution of groundwater conditions near and within the EBS (Type 5) (with GHGC)

- Prediction of the thermal, mechanical, and hydrological impact on the host rock surrounding the waste package (Type 4) (with GHGC)

- Identifying geochemical processes that adversely affect the EBS (Type 4) (with GHGC)

- Determining the magnitude of the effect of the geochemical processes that adversely affect the EBS (Type 5) (with GHGC)

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Technical Assessment Needs:

- Develop a more general and comprehensive near-field environment model that can fully couple transport and electrochemical processes with aqueous complexing reactions and kinetic reaction of minerals (with GHGC).

- Develop the EBS performance assessment code EBSPAC.

- Examine the methodologies for extrapolating short-term laboratory or field performance data to long-term performance through a combination of mechanistic modeling, experimentation, and comparison to relevant natural systems that have operated over long time periods.

- Perform auxiliary analyses of the processes controlling groundwater evolution in the near-field and EBS performance and determine the sensitivities of associated model parameters.

Research Needs:

- Develop an independent assessment of the evolution of the near-field environment due to thermal output of the waste packages. Specifically, the changes in the chemical composition of the environment near the waste package surface due to evaporation and the resultant redistribution of moisture have to be understood. For this purpose, two-phase fluid transport in a partially saturated medium has to be modeled in combination with multi-component solute transport and reactions.

- Develop an understanding of the changes in chemistry inside defects in the overpack and due to the reaction of fillers and backfill with groundwater that may affect the performance of inner containers, multipurpose canister, and waste form.

- Develop an understanding of the effect of repository operations, EBS components, and the introduction of man-made materials (grout, organic fluids, etc.) on the changes in near-field environment, such as groundwater pH, redox conditions, and aqueous species which may be detrimental to the performance of waste packages and waste forms.

- Determine the time at which rewetting of the waste package containers occurs, and determine the chemistry of the condensed phase.

- Understand the effects of design on the thermal fields near the waste packages.

- Develop a quantitative methodology to assess the effect of microbial organisms on corrosion.

Key Technical Issue—Waste Package Degradation

Lead Element: EBS

Key Technical Uncertainties:

- Prediction of thermomechanical effects on the waste package and the EBS (Type 4)

- Prediction of environmental effects on the waste package and the EBS (Type 4)
- Prediction of criticality events in waste packages (Type 4)
- Prediction of release path parameters (such as the size, shape, and distribution of penetrations of waste packages) due to thermomechanical, environmental, or criticality effects (Type 4)
- Prediction of the releases of gaseous radionuclides from waste packages during the containment period and from the EBS during the post-containment period (Type 4)
- Prediction of the releases of non-gaseous radionuclides from waste packages during the containment period and from the EBS during the post-containment period (Type 4)
- Extrapolation of short-term laboratory and prototype test results to predict long-term performance of waste packages and EBS (Type 5)

Technical Assessment Needs:

- Develop an understanding of the effect of backfilling of emplacement drifts on the performance of waste packages, stability of drifts, and retrievability of waste (with RDCO).
- Develop a more general and comprehensive near-field environment model that can fully couple transport and electrochemical processes with aqueous complexing reactions and kinetic reaction of minerals.
- Develop the technical bases for EBSPAC.
- Critically evaluate the role of colloids in the release of radionuclides and the nucleation, stability, and transport of colloids in the geologic medium.
- Examine the methodologies for extrapolating short-term laboratory or field performance data to long-term performance through a combination of mechanistic modeling, experimentation, and comparison to relevant natural systems that have operated over long time periods.
- Evaluate the effect of interactions between various waste package materials on their performance. This evaluation will include such effects as galvanic corrosion and hydrogen embrittlement.
- Model the effect of long-term thermal exposure and various repository mechanical loads on the mechanical stability of waste package materials and their consequences, including criticality.
- Evaluate the engineering experience in terms of initial defect population after fabrication and reliability of components.
- Systematically evaluate the effect of modifications to the waste package design and the multipurpose canister on repository performance.

- Assess the rate-controlling processes in the dissolution of spent fuel and release of matrix radionuclides.

- Assess the effects of colloids in controlling the transport of radionuclides near the EBS.

Research Needs:

- Determine the effect of long-term exposure of waste packages on the degradation of material properties by phase transformation and grain-boundary segregation leading to reduced corrosion resistance and impact toughness (ductility) of the waste package.

- Develop an independent assessment of the evolution of the near-field environment due to thermal output of the waste packages. Specifically, the changes in the chemical composition of the environment near the waste package surface due to evaporation and the resultant redistribution of moisture have to be understood. For this purpose, two-phase fluid transport in a partially saturated medium has to be modeled in combination with multi-component solute transport and reactions.

- Develop an understanding of the changes in chemistry inside defects in the overpack and due to the reaction of fillers and backfill with groundwater that may affect the performance of inner containers, multipurpose canister, and waste form.

- Develop an understanding of the effect of repository operations and man-made materials (grout, organic fluids, etc.) on the changes in environment, such as groundwater Ph, redox conditions, and aqueous species which may be detrimental to the performance of waste packages and waste forms.

- Determine the time at which rewetting of the containers occurs, and determine the chemistry of the condensed phase.

- Understand the effects of design on the thermal fields near the waste packages.

- Demonstrate the adequacy and conservatism of repassivation potential in predicting the long-term localized corrosion and stress corrosion cracking of austenitic materials.

- Determine the existence of critical potentials for localized corrosion or stress corrosion cracking of other waste package materials.

- Develop a quantitative methodology to assess the effect of microbial organisms on the near-field environment and on the corrosion of EBS components.

- Develop a quantitative understanding of the kinetics of embrittlement of basket material and its effect on criticality control.

- Determine the role of electrochemical versus chemical dissolution of spent fuel.

- Determine the role of secondary mineral formation on dissolution rate of spent fuel by modeling the formation of secondary minerals and compare them to those observed in natural analog studies as well as long-term laboratory drip tests.

Key Technical Issue—Thermal-Mechanical-Hydrological-Chemical Coupled Processes

Lead Element: RDCO

Technical Assessment Needs:

- Develop an understanding of the effect of backfilling of emplacement drifts on the performance of waste packages, stability of drifts, and retrievability of waste (with RDCO).

- Develop the EBS performance assessment code EBSPAC.

- Determine when and the extent of rewetting of the waste package (container) and the chemistry of the condensed phase.

Key Technical Issue—Thermal Effects and Redistribution of Moisture

Key Technical Uncertainties:

- Prediction of the releases of gaseous radionuclides from waste packages during the containment period and from the EBS during the post-containment period (Type 4)

- Prediction of the releases of non-gaseous radionuclides from waste packages during the containment period and from the EBS during the post-containment period (Type 4)

Technical Assessment Needs:

- Develop an understanding of the effect of backfilling of emplacement drifts on the performance of waste packages, stability of drifts, and retrievability of waste (with RDCO).

- Develop the EBS performance assessment code EBSPAC.

- Assess the rate-controlling processes in the dissolution of spent fuel and release of matrix radionuclides.

- Determine the effect of long-term exposure of waste packages on the degradation of material properties by phase transformation and grain-boundary segregation leading to reduced corrosion resistance and impact toughness (ductility) of the waste package.

- Determine when and the extent of rewetting of the waste package (container) and the chemistry of the condensed phase.

- Identify near-field environment chemistry as altered by the thermal loading on construction materials used for seals and shafts and the host rock leading to alteration in the pathways and chemistry of ingressing groundwaters (with GHGC).

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- Determine the role of electrochemical versus chemical dissolution of spent fuel.

- Determine the role of secondary mineral formation on dissolution rate.

- Model the formation of secondary minerals and compare them to those observed in natural analog studies as well as long-term laboratory drip tests.

## 3.2 GEOHYDROLOGY AND GEOCHEMISTRY PROGRAM ELEMENT CORRELATION

Key Technical Issue—Geochemical Effects on Radionuclide Transport Within and Beyond the Thermally Affected Zone

Lead Element: GHGC

Key Technical Uncertainties:

- Equal or increased capacity of alteration mineral assemblages to inhibit radionuclide migration (Type 4)

- Characterizing the chemistry of the groundwater in the partially-saturated hydrologic zone of Yucca Mountain, Nevada (Type 4)

- Understanding the effects of degree of saturation on geochemical processes such as radionuclide sorption and precipitation and formation of particulates and colloids, and on the transport of radionuclides by particulates, colloids and complexes (Type 4)

- Parametric representation of retardation processes involving radionuclide-bearing particulates, colloids, and complexes (Type 4)

- Determining the alteration of mineral assemblages due to thermal loading (Type 4)

- Identifying geochemical processes that reduce radionuclide "retardation" (Type 4)

- Determining the magnitude of the effect of the geochemical processes that reduce radionuclide "retardation" (Type 5)

- Identifying geochemical conditions that would inhibit particulate and colloid formation (Type 4)

- Understanding/predicting the effect of groundwater conditions on dissolution of waste form (Type 4) (with EBS)

- Prediction of the evolution of groundwater conditions near and within the EBS (Type 5)

- Identifying geochemical processes that adversely affect the EBS (Type 4) (with EBS)

- Determining the magnitude of the effect of the geochemical processes that adversely affect the EBS (Type 5) (with EBS)

- Volatility and stability of chemical species of radionuclides (Type 4)

- Gas flow and gaseous radionuclide transport (Type 4)

- Prediction of the releases of gaseous radionuclides from waste packages during the containment period and from the EBS during the post-containment period (Type 4) (with EBS)

- Prediction of the releases of non-gaseous radionuclides from waste packages during the containment period and from the EBS during the post-containment period (Type 4) (with EBS)

Technical Assessment Needs:

- Become familiar with available geochemical data, such as mineralogy, mineral chemistry, hydrochemistry for water samples obtained from hydrologically unsaturated cores and gas compositions. The spatial distribution of these data are important in understanding the different geochemical effects on groundwater chemistry. Although chemical data from the unsaturated zone are difficult to obtain and spatial data distribution is likely to be sparse, the geographical and geological context of these data should be preserved to the extent possible through the use of GIS and 3D hydrogeologic models.

- Become familiar with the methods and models available to describe processes important to radionuclide retardation.

- Become familiar with the current data available for unsaturated zone geochemistry at YM, and methods and models available to describe groundwater chemistry in the partially unsaturated zone.

- Modify models of geochemical processes in the unsaturated zone that may affect mineral and water chemistry and develop new approaches, as necessary.

- Conduct sensitivity studies to determine the extent to which different parameters in the models have the greatest effects on results, and evaluate likely ranges in these parameters to be encountered at YM.

- Become familiar with the methods and models available to describe processes important to transport of the liquid and vapor phase of water.

- Develop an understanding of the effect of backfilling of emplacement drifts on the performance of waste packages, stability of drifts, and retrievability of waste (with RDCO).

- Develop a more general and comprehensive near-field environment model that can fully couple transport and electrochemical processes with aqueous complexing reactions and kinetic reaction of minerals (with EBS).

- Critically evaluate the role of colloids in the release of radionuclides and the nucleation, stability, and transport of colloids in the geologic medium near the EBS (with EBS).

Research Needs:

- Develop models of sorption processes and other geochemical aspects of unsaturated mass transport.

- Investigate sorption and ion exchange processes, and mineral precipitation/dissolution kinetics through laboratory experiments.

- Evaluate large- and small-scale studies of long-term migration through both fractures and the matrix at natural analog sites.

- Characterize mineral assemblages that may result from thermal alteration of near-field materials and from the interactions between the EBS and natural materials.

- Develop geochemical models for mineral alteration, precipitation/dissolution, sorption, colloidal formation and transport, thermal loading effects, aqueous speciation, and fracture-matrix interactions. These models should be supported by thermodynamic and kinetic data and extensive analysis of site characterization data, data from natural analog sites, and laboratory analyses under variably saturated conditions.

- Develop models of geochemical processes in the unsaturated zone that may affect mineral and water chemistry.

- Carry out confirmatory and exploratory laboratory investigations of processes such as sorption, ion exchange, and precipitation/dissolution, that may influence system chemistry in the unsaturated zone. Additional studies conducted in natural analog sites may provide insight into critical parameters controlling chemistry in the unsaturated zone in both fractures and matrix.

- Develop and refine geochemical models for reconstructing the evolution of groundwater chemistry in the unsaturated zone. These models should be supported by thermodynamic and kinetic data, extensive analysis of site characterization data, data from natural analog sites, and laboratory experiments to investigate sorption and transport under variably saturated conditions.

- Develop an independent assessment of the evolution of the near-field environment due to thermal output of the waste packages. Specifically, the changes in the chemical composition of the environment near the waste package surface due to evaporation and the resultant redistribution of moisture have to be understood. For this purpose, two-phase fluid transport in a partially saturated medium has to be modeled in combination with multi-component solute transport and reactions.

- Develop an understanding of the effect of repository operations (grouting, organic fluids, etc.) on the changes in environment, such as groundwater pH, redox conditions, and aqueous species which may be detrimental to the performance of waste packages and waste forms (with EBS).

- Determine the possible effects of man-made materials introduced into the natural system on the near-field environment.

- Identify the near-field environment chemistry as affected by components of the EBS, such as grout, microbiological organisms, and container corrosion (with EBS).

Key Technical Issue—Hydrologic Characterization of Structural Features which Significantly Affect Water and Vapor Movement

Lead Element: GHGC

Key Technical Uncertainties:

- Modeling groundwater flow through unsaturated fractured rock caused by the lack of codes tested against field and laboratory data (Type 4)

- Identifying which conceptual models adequately represent isothermal and nonisothermal liquid and vapor phase movement of water through unsaturated fractured rock at YM (Type 4)

- Uncertainties associated with determining characterization parameters (Type 4)

- Developing a conceptual groundwater flow model that is representative of the YM site groundwater flow system (Type 4)

- Experimental confirmation of the basic physical concepts of groundwater flow through unsaturated fractured rock is needed (Type 5)

- Development of new data collection and interpretation techniques are required for codes which model groundwater flow through unsaturated fractured rock (Type 5)

- Developing a mathematical groundwater flow model that is representative of the YM site groundwater flow system (Type 4)

Technical Assessment Needs:

- Become familiar with the methods and models available to describe processes important to transport of the liquid and vapor phase of water and modify models and develop new approaches as necessary.

- Characterize parameter variabilities and uncertainties using geostatistical techniques, Monte Carlo simulation, the Fast Probabilistic Performance Assessment and expert judgment.

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Research Needs:

- Perform independent evaluation of hydrogeologic data, analyses, and model development.
- Determine whether the DOE 2D cross-sections and 3D models representing subsurface hydro-stratigraphy and structure are adequate and realistic for the hydrogeologic setting of YM and the Death Valley Region.
- Develop 2D vertical cross-sections perpendicular to the hydraulic head contour in the vicinity of YM to investigate the effect of hydrogeologic structure on gradients, flow directions, and velocities.
- Construct a detailed 3D hydrogeologic model of the YM and Death Valley flow system to investigate the effect of the spacial distribution of hydrogeologic properties on the movement of water in both liquid and vapor phases.
- Investigate how the rock matric potential can be accurately measured.
- Develop acceptable approaches for characterizing the spatial distribution of infiltration.
- Test the appropriateness of field-scale hydraulic parameter estimation techniques.
- Delineate the nature of hydraulic parameter variability and uncertainties.
- Develop methods for describing the spatial or temporal variability of model parameters.
- Develop scaling theories that permit relating laboratory- or field-scale parameter values to site-scale model parameters.

Key Technical Issue—Evolution of Groundwater in the Near-Field Environment

Lead Element: GHGC

Key Technical Uncertainties:

- Prediction of the evolution of groundwater conditions near and within the EBS (Type 5) (with EBS)
- Determining the alteration of mineral assemblages due to thermal loading (Type 4)
- Identifying geochemical processes that adversely affect the EBS (Type 4) (with EBS)
- Determining the magnitude of the effect of the geochemical processes that adversely affect the EBS (Type 5) (with EBS)

Technical Assessment Needs:

- Develop a more general and comprehensive near-field environment model that can fully couple transport and electrochemical processes with aqueous complexing reactions and kinetic reaction of minerals.

- Critically evaluate the role of colloids in the release of radionuclides and the nucleation, stability, and transport of colloids in the geologic medium (with EBS).

- Become familiar with available geochemical data, such as mineralogy, mineral and water chemistry, and gas compositions. Because the available data are likely to be limited, and because the spatial distribution of these data is important in understanding the different geochemical effects on radionuclide retardation, the geographical and geological context of these data should be preserved to the extent possible through the use of GIS and 3D hydrogeologic models.

- Become familiar with the methods and models available to describe processes important to radionuclide retardation. Modify existing geochemical and transport models and develop new approaches as necessary.

- Undertake sensitivity studies to determine the effect of different parameters in the models affect the modeling of radionuclide transport and retardation, and determine those site and design parameters that have a significant effect on calculating the CCDF for radionuclide release.

- Perform auxiliary analyses of the processes controlling groundwater evolution in the near-field and EBS performance and determine the sensitivities of associated model parameters (with EBS).

Research Needs:

- Develop an independent assessment of the evolution of the near-field environment due to thermal output of the waste packages. Specifically, the changes in the chemical composition of the environment near the waste package surface due to evaporation and the resultant redistribution of moisture have to be understood. For this purpose, two-phase fluid transport in a partially saturated medium has to be modeled in combination with multi-component solute transport and reactions (with EBS and RDCO).

- Identify near-field environment chemistry as altered by the thermal loading on construction materials used for seals and shafts and the host rock leading to alteration in the pathways and chemistry of ingressing groundwaters.

- Investigate sorption and ion exchange processes, and mineral precipitation/dissolution kinetics through laboratory experiments.

- Evaluate large- and small-scale studies of long-term migration through both fractures and the matrix at natural analog sites.

- Characterize mineral assemblages that may result from thermal alteration of near-field materials and from the interactions between the EBS and natural materials.

- Develop geochemical models for mineral alteration, precipitation/dissolution, sorption, colloidal formation and transport, thermal loading effects, aqueous speciation, and fracture-matrix interactions. These models should be supported by thermodynamic and kinetic data and extensive analysis of site characterization data, data from natural analog sites, and laboratory analyses under variably saturated conditions.

Key Technical Issue—Thermal-Mechanical-Hydrological-Chemical Coupled Processes

Lead Element: RDCO

Research Needs:

- Identify near-field environment chemistry as altered by the thermal loading on construction materials used for seals and shafts and the host rock leading to alteration in the pathways and chemistry of ingressing groundwaters.

Key Technical Issue—Thermal Effects and Redistribution of Moisture

Lead Element: GHGC

Key Technical Uncertainties:

- Modeling groundwater flow through unsaturated fractured rock caused by the lack of codes tested against field and laboratory data (Type 4)

- Identifying which conceptual models adequately represent isothermal and nonisothermal liquid and vapor phase movement of water through unsaturated fractured rock at YM (Type 4)

- Uncertainties associated with determining characterization parameters (Type 4)

- Developing a conceptual groundwater flow model that is representative of the YM site groundwater flow system (Type 4)

- Experimental confirmation of the basic physical concepts of groundwater flow through unsaturated fractured rock is needed (Type 5)

- Development of new data collection and interpretation techniques are required for codes which model groundwater flow through unsaturated fractured rock (Type 5)

- Developing a mathematical groundwater flow model that is representative of the YM site groundwater flow system (Type 4)

- Modeling the formation of perched zones by thermally driven flow (Type 5)

- Prediction of future changes to the hydrologic system resulting from a combination of climatic and tectonic changes and human activities (including heat effects from waste emplacement) (Type 5)

- Gas flow and gaseous radionuclide transport (Type 4)

Technical Assessment Needs:

- Become familiar with the methods and models available to describe processes important to transport of the liquid and vapor phase of water and modify models and develop new approaches as necessary.

- Undertake sensitivity studies to determine the extent to which different parameters in the models affect various performance related measures.

- Become familiar with the methods and models available to describe processes important to future changes to the hydrologic system resulting from climatic variations, tectonic changes, and human activities and modify conceptual models and develop new approaches as necessary (e.g., using expert elicitation techniques).

- Undertake sensitivity studies to determine the extent to which different parameters in the models affect various performance related measures.

- Evaluate the impact of alternative conceptual models of the hydrogeologic setting and the coupled phenomena that are expected to exist during the postclosure period.

Research Needs:

- Investigate how the rock matric potential can be accurately measured.

- Evaluate appropriate geostatistical and stochastic methods for expressing the spatial variability of parameters.

- Develop acceptable approaches for characterizing the spatial distribution of infiltration.

- Test the appropriateness of field-scale hydraulic parameter estimation techniques.

- Develop a technique for extrapolation of laboratory-measured fracture flow data for field-scale application.

- Identify near-field environment chemistry as altered by the thermal loading on construction materials used for seals and shafts and the host rock leading to alteration in the pathways and chemistry of ingressing groundwaters.

## 3.3 GEOLOGY AND GEOPHYSICS PROGRAM ELEMENT CORRELATION

Key Technical Issue—Structural Deformation and Seismicity

Lead Element: Geology and Geophysics (GLGP)

Key Technical Uncertainties:

- Development and use of conceptual tectonic models as related to structural deformation (Type 5)
- Poor resolution of exploration techniques to detect and evaluate structural features (Type 4)
- Evaluation of faulting mechanisms in alluvium (Type 5)
- Inability to predict the likelihood of earthquake occurrence during the next 10,000 years (Type 4)
- Correlation of earthquakes with tectonic features (Type 5)
- Migrating seismicity between fault systems in the Basin and Range Tectonic Province (Type 5)
- Uncertainty in fault plane solutions (Type 5)

Technical Assessment Needs:

- Evaluate the adequacy of exploration methods used to detect and evaluate subsurface structural features and techniques used for constructing and restoring geological cross-sections and 3D geological models.
- Perform independent analyses (e.g., reprocessing) of selected geophysical data (e.g., seismic reflection data) to evaluate uncertainties associated with differing interpretations.
- Develop a GIS database of tectonic data that can be used to both evaluate the DOE models and interpretations and perform independent analyses and model development.
- Critically assess the DOE interpretations of fault geometry and stratigraphy in the subsurface as they become available.
- Consider how to best represent subsurface structures in models to be used for performance assessment in order to adequately assess potential impacts of the structures and tectonic framework on pre- and post-closure performance of the repository system and its components.
- Perform numerical (e.g., using finite-element technique) modeling to study tectonic processes (such as hangingwall deformation and fault and dike interaction) in order to constrain the range of reasonable interpretations and to determine key parameters that can be used to distinguish between deformation styles in nature.

- Perform graphical visualization and geometric modeling using basic geological data lodged in the ARC/INFO and EARTHVISION GIS databases, to examine the range of tectonic models which appear to be possible using 2D and 3D representations.

- Investigate the sensitivity of PSHA to assumptions concerning temporal and spatial seismicity in order to effectively undertake compliance determination in relation to spatial and temporal patterns of seismicity.

- Critically assess the DOE interpretations of the field and laboratory data and conduct independent review of these data in order to form the basis for acceptance or rejection of the data, development of alternative interpretations and to adequately assess potential impacts of faulting and seismicity on pre-closure and post-performance of the repository system and its components.

- Estimate or bracket the nature of past, present and future fault slip to provide a conservative assessment of potential shaking or fault offset effects on the repository. Analyses with the SEISM 1.1 computer code could determine the effect on acceleration of assuming a conservative seismic energy radiation pattern from a fault.

Research Needs:

- Perform independent evaluation of structural geologic and seismic data, analyses, and model development (e.g., geometric, kinematic, physical analog) in order to develop an independent basis for compliance determination studies.

- Determine whether the DOE 2D cross-sections and 3D models representing subsurface stratigraphy and structure are adequate and realistic for the tectonic setting of YM and the central Basin and Range.

- Use the DOE data, and in addition, collect select field data on faulting, contemporary strain, uplift, vertical axis rotation, thermal history, and regional tectonic history in order to constrain new structural and tectonic models and to provide a basis for critical evaluation of existing and new models developed by the DOE.

- Collect limited geophysical data to address very specific issues, such as dikes in alluvium.

- Construct cross-sections and a 3D geological framework model at the scale of YM and for the subregional and regional tectonic setting. Through development of independent models and alternative interpretations based on published data, DOE data, and data collected by NRC/CNWRA staff, it should be possible to develop compliance determination methods related to faulting (and related surface rupture and earthquake seismicity), to evaluate the reasonableness and conservativeness of the DOE interpretations and models, and to provide a context for analyses of possible fault and dike interaction, and studies of groundwater hydrology, geochemistry, and rock mechanics.

- Evaluate uncertainty associated with the extent to which faulting may be present and remain undetected and the potential for activity of existing faults in the present 3D stress field.

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- Determine the shapes of earthquake recurrence relationships (the number of earthquakes or given magnitude and larger versus magnitude) on individual faults by monitoring larger aftershocks of earthquakes using portable seismic instrumentation arrays. Develop theoretical methods which explain observations and which can be used to predict recurrence behavior of fault planes that also preserves observed regional recurrence relationships.

- Perform statistical analyses of the historical earthquake record to provide more rigorous identification of earthquake clusters and improved understanding of the pattern of aftershocks and triggered earthquakes. This process appears to be a manifestation of chaos as defined mathematically. Chaos theory methods should be developed to better bound the range of possible predictions while avoiding the current practice of deleting aftershock data from the historical record before using it in PSHA.

- Analyze scaling relationships to provide a basis for evaluation of earthquake recurrence intervals for mapped faults for which there is a limited record or no record of seismicity. Theory to justify the observed scaling relationships must also be derived if predictions of fault plane earthquake recurrence is to be reliable.

- Analyze the paleoseismic record to improve understanding of earthquake magnitude, type, and recurrence in the YMR, and to aid in understanding the position (spatial and temporal) within the overall patterns of seismicity. The paleoseismic record may indicate distributed fault offsets from a very few large earthquakes originating on a master fault at depth, or more numerous smaller earthquakes on each individual fault. Research to limit potential theoretical models of faulting at depth may be necessary to constrain PSHA to reasonable values.

- Evaluate faulting in alluvium using field studies, analog modeling, and finite element modeling in order to establish a basis for determining the conservativeness of the DOE interpretations and the potential for active faults to be present but either undetected or underestimated.

- Develop slip-tendency analysis techniques for interpretation of high-risk fault orientations and evaluation of nodal plane choices. It is anticipated that analysis of several three-component seismic records will be used to assess solutions to test existing and new techniques for selecting nodal planes.

- Utilize portable seismic recording equipment (e.g., PASSCAL) to determine the seismic-energy radiation patterns of larger aftershocks of substantial earthquakes. The instrumentation would be deployed to effectively record high energy beamed through small ranges of azimuth from a fault plane and to better determine the range of azimuths to a fault plane in which directivity effects take place. Aftershock radiation pattern monitoring will also better quantify the amount of seismic energy potentially beamed toward a structure as a consequence of directivity effects.

- Evaluate interrelationships between earthquakes, geologic structure, and tectonic processes, to assess role of emergent versus blind faults as seismic sources. This can be accomplished by performing analyses to compare (in 3D) interpretations of structural geometry, patterns of earthquake seismicity, fault-plane solutions, and *in situ* stress.

Key Technical Issue—Igneous Activity

Key Technical Uncertainties:

- Low resolution of exploration techniques to detect and evaluate igneous features (Type 4)
- Inability to sample igneous features (Type 5)
- Development and use of conceptual tectonic models as related to igneous activity (Type 5)

Technical Assessment Needs:

- Develop a strategy for evaluation, use, and acceptance or rejection of volcanism probability models.
- Analyze volcanic disruption model sensitivity to input parameters and variables, with particular emphasis on recurrence rate and area impacted by volcanism.
- Implement IPA models using volcanological models (with PA).
- Investigate dike geometries, timing of dike injection, and area affected by intrusion in order to test and bound probability density functions for the areas affected by magmatic events.
- Evaluate the capability of seismic reflection and seismic tomography surveys to identify small subsurface igneous features.

Research Needs:

- Identify rates of change in volcanism recurrence rate and patterns of small-volume basaltic volcanism in analogous volcanic fields.
- Develop probability models that capture essential features of basaltic vent distribution.
- Develop and test models of recurrence rate and vent distribution based on integrated geochemical, tectonic, and geophysical models.
- Develop criteria to characterize the style of small cinder cone basaltic eruptions in order to place limits on the area influenced by volcanic activity.
- Identify or develop geological, geophysical, and geochemical models that can be used to bound probability calculations.
- Independently analyze scenarios of volcanic disruption and evaluate scenario models utilized by the DOE and EPRI in their TSPAs for YM (with PA).

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Key Technical Issue—Hydrologic Characterization of Structural Features which Significantly Affect Water and Vapor Movement

Lead Element: GHGC

Key Technical Uncertainties:

- Poor resolution of exploration techniques to detect and evaluate structural features (Type 4)
- Development and use of conceptual tectonic models as related to structural deformation (Type 5)
- Low resolution of exploration techniques to detect and evaluate igneous features (Type 4)
- Development and use of conceptual tectonic models as related to igneous activity (Type 5)

Research Needs:

- Use the DOE data, and in addition, collect select field data on faulting, contemporary strain, uplift, vertical axis rotation, thermal history, and regional tectonic history in order to constrain new structural and tectonic models and to provide a basis for critical evaluation of existing and new models developed by the DOE.
- Collect limited geophysical data to address very specific issues such as dikes in alluvium.
- Evaluate uncertainty associated with the extent to which faulting may be present and remain undetected and the potential for activity of existing faults in the present 3D stress field.

## 3.4 PERFORMANCE ASSESSMENT PROGRAM ELEMENT CORRELATION

Key Technical Issues—Igneous Activity

Lead Element: GLGP

Key Technical Uncertainties:

- Prediction of future system states (Type 5)

Technical Assessment Needs:

- Implement IPA models using appropriate volcanological models (with GLGP).
- Formulate links in IPA among volcanism, tectonics, climate, hydrological and geochemical settings of the repository.

Research Needs:

- Independently analyze scenarios of volcanic disruption and evaluate scenario models utilized by the DOE and EPRI in their TSPAs for YM (with GLGP).

- Review and evaluate the basis for the DOE estimates of the probability of occurrence for each scenario.

- Provide improved estimates of scenario probabilities based on site-specific geologic data and information.

- Provide improved models of the physical characteristics and consequences of the disruptive events and processes.

- Identify additional scenarios potentially having direct and indirect effects on repository performance.

- Evaluate different approaches to enhance the likelihood of completeness in the generation of the initial list of events and processes.

Key Technical Issue—Geochemical Effects on Radionuclide Transport Within and Beyond the Thermally Affected Zone

Lead Element: GHGC

Key Technical Uncertainties:

- Conceptual model representations of the natural and engineered systems (Type 4)

- Variability in model parametric values (Type 4)

- Appropriateness of assumptions and simplification in mathematical models (Type 4)

- Validation of mathematical models (Type 5)

- Prediction of future system states (i.e., disruptive scenarios) (Type 5)

Technical Assessment Needs:

- Characterize parameter variabilities and uncertainties using geostatistical techniques, Monte Carlo simulation, the Fast Probabilistic Performance Assessment and expert judgment.

- Independently evaluate the techniques used by the DOE to account for spatial and temporal variability.

- Investigate techniques for use of expert judgment in characterizing uncertainties in data, models, and future system states.

- Independently analyze scenarios and evaluate scenario models utilized by the DOE and EPRI in their TSPAs for YM.

- Review and evaluate the basis for the DOE estimates of the probability of occurrence for each scenario.

- Evaluate the impact of alternative conceptual models of the hydrogeologic setting and the coupled phenomena that are expected to exist during the postclosure period.

- Investigate the potential impacts of simplifications used in the conceptual models on the results of TSPA calculations and other analyses.

- Perform auxiliary analyses of the controlling processes and determine the sensitivities of associated model parameters.

Research Needs:

- Evaluate appropriate geostatistical and stochastic methods for expressing the spatial variability of parameters.

- Develop the basis for gaining confidence in the model's ability to extrapolate in time and space and, more importantly, for those components that cannot be tested directly.

- Investigate the relevance of possible differences between model predictions and experimental results.

- Develop acceptable methods and approaches for model validation.

- Delineate the nature of parameter variability and uncertainties.

- Develop methods for describing the spatial or temporal variability of model parameters.

- Develop scaling theories that permit relating laboratory- or field-scale parameter values to site-scale model parameters.

- Provide improved estimates of scenario probabilities based on site-specific geologic data and information.

- Provide improved models of the physical characteristics and consequences of the disruptive events and processes.

- Identify additional scenarios potentially having direct and indirect effects on repository performance.

- Evaluate different approaches to enhance the likelihood of completeness in the generation of the initial list of events and processes.

- Define and specify "partial validation" requirements for both the detailed and abstracted models used to assess subsystem and total-system performance.

- Define appropriate performance measures or acceptance criteria for partial validation.

- Investigate how results from partial validation studies may be used to determine a model's predictive reliability over large spatial and temporal scales.

- Investigate the proper use of laboratory tests, *in situ* tests, field tests, and natural analogs in a model validation strategy.

Key Technical Issue—Hydrologic Characterization of Structural Features which Significantly Affect Water and Vapor Movement

Lead Element: GHGC

Key Technical Uncertainties:

- Conceptual model representations of the natural and engineered systems (Type 4)

- Variability in model parametric values (Type 4)

- Appropriateness of assumptions and simplification in mathematical models (Type 4)

- Validation of mathematical models (Type 5)

- Prediction of future system states (Type 5)

Technical Assessment Needs:

- Characterize parameter variabilities and uncertainties using geostatistical techniques, Monte Carlo simulation, the Fast Probabilistic Performance Assessment and expert judgment.

- Independently evaluate the techniques used by the DOE to account for spatial and temporal variability.

- Investigate techniques for use of expert judgment in characterizing uncertainties in data, models, and future system states.

- Independently analyze scenarios and evaluate scenario models utilized by the DOE and EPRI in their TSPAs for YM.

- Review and evaluate the basis for the DOE estimates of the probability of occurrence for each scenario.

- Evaluate the impact of alternative conceptual models of the hydrogeologic setting and the coupled phenomena that are expected to exist during the postclosure period.

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- Investigate the potential impacts of simplifications used in the conceptual models on the results of TSPA calculations and other analyses.

- Perform auxiliary analyses of the controlling processes and determine the sensitivities of associated model parameters.

Research Needs:

- Evaluate appropriate geostatistical and stochastic methods for expressing the spatial variability of parameters.

- Develop the basis for gaining confidence in the model's ability to extrapolate in time and space and, more importantly, for those components that cannot be tested directly.

- Investigate the relevance of possible differences between model predictions and experimental results.

- Develop acceptable methods and approaches for model validation.

- Develop methods for describing the spatial or temporal variability of model parameters.

- Develop scaling theories that permit relating laboratory- or field-scale parameter values to site-scale model parameters.

- Provide improved estimates of scenario probabilities based on site-specific geologic data and information.

- Provide improved models of the physical characteristics and consequences of the disruptive events and processes.

- Identify additional scenarios potentially having direct and indirect effects on repository performance.

- Evaluate different approaches to enhance the likelihood of completeness in the generation of the initial list of events and processes.

- Define and specify "partial validation" requirements for both the detailed and abstracted models used to assess subsystem and total-system performance.

- Define appropriate performance measures or acceptance criteria for partial validation.

- Investigate how results from partial validation studies may be used to determine a model's predictive reliability over large spatial and temporal scales.

- Investigate the proper use of laboratory tests, *in situ* tests, field tests, and natural analogs in a model validation strategy.

Key Technical Issue—Evolution of Groundwater in the Near-Field Environment

Lead Element: GHGC

Key Technical Uncertainties:

- Conceptual model representations of the natural and engineered systems (Type 4)
- Variability in model parametric values (Type 4)
- Appropriateness of assumptions and simplification in mathematical models (Type 4)
- Validation of mathematical models (Type 5)
- Prediction of future system states (Type

Technical Assessment Needs:

- Develop models and the code modules for the TSPA. These should include an investigation of the impact of alternative conceptual models of the hydrogeologic setting and the coupled phenomena that are expected to exist during the closure period, and the potential impacts of simplifications used in the conceptual models on the results of TSPA calculations.
- Characterize parameter variabilities and uncertainties using geostatistical techniques, Monte Carlo simulation, the Fast Probabilistic Performance Assessment and expert judgment.
- Independently evaluate the techniques used by the DOE to account for spatial and temporal variability.
- Investigate techniques for use of expert judgment in characterizing uncertainties in data, models, and future system states.
- Independently analyze scenarios and evaluate scenario models used by the DOE and EPRI in their TSPAs for YM. This should also include a review and evaluation of the basis for the DOE estimates of the probability of occurrence for each scenario.

Research Needs:

- Define and specify "partial validation" requirements for both the detailed and abstracted models used to assess subsystem and total-system performance, including how results from partial validation studies may be used to determine predictive reliability over large spatial and temporal scales.
- Investigate the proper use of laboratory tests, *in situ* tests, field tests, and natural analogs in a model validation strategy that includes scaling theories that provide for extending laboratory- and field-scale parameter values to site-scale modeling.
- Delineate the nature of parameter variability and uncertainties.

- Develop methods for describing the spatial or temporal variability of model parameters.

- Provide improved estimates of scenario probabilities based on site-specific geologic data and information.

- Identify additional scenarios potentially having direct and indirect effects on repository performance.

- Evaluate different approaches to enhance the likelihood of completeness in the generation of the initial list of events and processes.

Key Technical Issue—Methods of Assigning Probability to and Estimating the Consequences of Disruptive Scenarios

Lead Element: PA

Key Technical Uncertainty:

- Prediction of future system states (Type 5)

Technical Assessment Needs:

- Independently analyze scenarios and evaluate scenario models utilized by the DOE and EPRI in their TSPAs for YM.

- Review and evaluate the basis for the DOE estimates of the probability of occurrence for each scenario.

- Incorporate probability and consequence models into the TPA.

Research Needs:

- Provide improved estimates of scenario probabilities based on site-specific geologic data and information.

- Provide improved models of the physical characteristics and consequences of the disruptive events and processes.

- Identify additional scenarios potentially having direct and indirect effects on repository performance.

- Evaluate different approaches to enhance the likelihood of completeness in the generation of the initial list of events and processes.

Key Technical Issue—Exploratory Studies Facility

Lead Element: RDCO

Technical Assessment Needs:

- Develop the models and the code modules for the TSPA (with RDCO).

Key Technical Issue—Thermal-Mechanical-Hydrological-Chemical Coupled Processes

Lead Element: RDCO

Technical Assessment Needs:

- Develop the models and the code modules for the TSPA (with RDCO).

Key Technical Issue—Thermal Effects and Redistribution of Moisture

Lead Element: GHGC

Key Technical Uncertainties:

- Conceptual model representations of the natural and engineered systems (Type 4)
- Variability in model parametric values (Type 4)
- Appropriateness of assumptions and simplification in mathematical models (Type 4)
- Validation of mathematical models (Type 5)
- Prediction of future system states (Type 5)

Technical Assessment Needs:

- Develop the models and the code modules for the TSPA.
- Independently analyze scenarios and evaluate scenario models utilized by the DOE and EPRI in their TSPAs for YM.
- Review and evaluate the basis for the DOE estimates of the probability of occurrence for each scenario.
- Investigate the potential impacts of simplifications used in the conceptual models on the results of TSPA calculations and other analyses.
- Perform auxiliary analyses of the controlling processes and determine the sensitivities of associated model parameters.

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- Determine the site and design parameters that have significant influence on the calculation of the complementary CCDF for radionuclide release.

- Characterize parameter variabilities and uncertainties using geostatistical techniques, Monte Carlo simulation, the Fast Probabilistic Performance Assessment and expert judgment.

- Independently evaluate the techniques used by the DOE to account for spatial and temporal variability.

- Investigate techniques for use of expert judgment in characterizing uncertainties in data, models, and future system states.

Research Needs:

- Develop the basis for gaining confidence in the model's ability to extrapolate in time and space and, more importantly, for those components that cannot be tested directly.

- Investigate the relevance of possible differences between model predictions and experimental results.

- Develop acceptable methods and approaches for model validation.

- Investigate the use of expert elicitation approaches.

- Evaluate methods to predict future human activities.

- Develop of a methodology for bounding spatial variability of rock and joint properties using stochastic approach.

- Provide improved estimates of scenario probabilities based on site-specific geologic data and information.

- Provide improved models of the physical characteristics and consequences of the disruptive events and processes.

- Identify additional scenarios potentially having direct and indirect effects on repository performance.

- Evaluate different approaches to enhance the likelihood of completeness in the generation of the initial list of events and processes.

- Define and specify "partial validation" requirements for both the detailed and abstracted models used to assess subsystem and total-system performance.

- Define appropriate performance measures or acceptance criteria for partial validation.

- Investigate how results from partial validation studies may be used to determine a model's predictive reliability over large spatial and temporal scales.

- Investigate the proper use of laboratory tests, *in situ* tests, field tests, and natural analogs in a model validation strategy.

- Delineate the nature of parameter variability and uncertainties.

- Develop methods for describing the spatial or temporal variability of model parameters.

- Develop scaling theories that permit relating laboratory- or field-scale parameter values to site-scale model parameters.

## 3.5 REPOSITORY DESIGN, CONSTRUCTION AND OPERATIONS PROGRAM ELEMENT CORRELATION

Key Technical Issue—Geochemical Effects on Radionuclide Transport Within and Beyond the Thermally Affected Zone

Lead Element: GHGC

Key Technical Uncertainties:

- Prediction of criticality events in waste packages (Type 4) (with EBS)

Technical Assessment Needs:

- Develop an understanding of the effect of backfilling of emplacement drifts on the performance of waste packages, stability of drifts, and retrievability of waste (with EBS).

Key Technical Issue—Evolution of Groundwater in the Near-Field Environment

Lead Element: GHGC

Key Technical Uncertainties:

- Prediction of the TMHC responses of the host rock, surrounding strata, and groundwater system to thermal loads (Type 4)

- Prediction of the thermal, mechanical, and hydrological impact on the host rock surrounding the waste package (Type 4)

Technical Assessment Needs:

- Develop a rock joint constitutive model.

- Analyze of drift stability leading to rock-induced waste package failure for updating the SEISMO Module in the IPA code.

- Develop an understanding of the effect of backfilling of emplacement drifts on the performance of waste packages, stability of drifts, and retrievability of waste.

- Develop or modify TMH compliance determination codes for subsurface facilities.

Research Needs:

- Develop an independent assessment of the evolution of the near-field environment due to thermal output of the waste packages. Specifically, the changes in the chemical composition of the environment near the waste package surface due to evaporation and the resultant redistribution of moisture have to be understood. For this purpose, two-phase fluid transport in a partially saturated medium has to be modeled in combination with multi-component solute transport and reactions (with EBS and GHGC).

- Develop an understanding of the effect of repository operations, EBS components, and the introduction of man-made materials (grout, organic fluids, etc.) on the changes in near-field environment, such as groundwater pH, redox conditions, and aqueous species which may be detrimental to the performance of waste packages and waste forms (with EBS).

- Develop a methodology for bounding spatial variability of rock and joint properties using a stochastic approach.

- Determine the long-term effectiveness of rock-bolts and other ground supports under thermal environment.

- Develop a methodology for identification and characterization of important design parameters for underground excavations—a total system approach.

- Develop a technique for extrapolation of laboratory-measured intact rock and joint properties and fracture flow data for field-scale application.

- Perform DECOVALEX TMH experiments and modeling.

Key Technical Issue—Waste Package Degradation

Lead Element: EBS

Technical Assessment Needs:

- Analyze drift stability leading to rock-induced waste package failure for updating the SEISMO Module in the IPA code.

- Develop an understanding of the effect of backfilling of emplacement drifts on the performance of waste packages, stability of drifts, and retrievability of waste (with EBS).

Key Technical Issue—Exploratory Studies Facility

Lead Element: RDCO

Key Technical Uncertainties:

- Prediction of the TMHC responses of the host rock, surrounding strata, and groundwater system to thermal loads (Type 4)
- Prediction of the thermal, mechanical, and hydrological impact on the host rock surrounding the waste package (Type 4)
- Predicting the long term performance of seals for shafts, ramps, and boreholes (Type 4)
- Predicting the long term performance of seals for the underground test boreholes (Type 4)

Technical Assessment Needs:

- Develop a rock joint constitutive model.
- Develop or modify thermal-mechanical (TM) compliance determination codes for subsurface facilities.
- Analyze drift stability leading to rock-induced waste package failure for updating the SEISMO Module in the IPA code.
- Develop an understanding of the effect of backfilling of emplacement drifts on the performance of waste packages, stability of drifts, and retrievability of waste.
- Develop or modify TMH compliance determination codes for subsurface facilities.
- Develop a better understanding of the importance of seals to the overall performance of the repository, taking into account the specific conditions at the YM repository site (including geologic and hydrologic properties of the intact matrix and fractures, infiltration, etc.).
- Evaluate, through sensitivity studies, which parameters (e.g., infiltration, fracture conductivities of the host rock, fracture porosity of the host rock, etc.) would have the largest impact on seal and repository performance, such that guidance can be given to site characterization activities to focus on better characterization of such properties.

Research Needs:

- Develop of a methodology for bounding spatial variability of rock and joint properties using stochastic approach.
- Determine the long-term effectiveness of rock-bolts and other ground supports under thermal environment.

- Develop a methodology for identification and characterization of important design parameters for underground excavations—a total system approach.

- Develop a technique for extrapolation of laboratory measured intact rock and joint properties for field-scale application.

- Perform DECOVALEX TMH experiments and modeling.

- Develop an understanding of the constitutive laws of time-dependent rock properties under heated, variably saturated, and stressed conditions.

- Evaluate long-term TM effects on the performance of seals.

- Evaluate long-term thermal-hydrological effects on the chemical properties of seal materials.

- Evaluate long-term TM (including repetitive seismic load) effects on the surrounding rock mass and seal-rock interface.

Key Technical Issue—Thermal-Mechanical-Hydrological-Chemical Coupled Processes

Lead Element: RDCO

Key Technical Uncertainties:

- Prediction of the TMHC responses of the host rock, surrounding strata, and groundwater system to thermal loads (Type 4)

- Prediction of the thermal, mechanical, and hydrological impact on the host rock surrounding the waste package (Type 4)

- Prediction of thermomechanical effects on the performance of waste packages and the EBS (Type 4)

- Demonstration of compliance with the requirement to maintain the ability to safely retrieve HLW (Type 4)

- Predicting the long term performance of seals for shafts, ramps, and boreholes (Type 4)

- Predicting the long term performance of seals for the underground test boreholes (Type 4)

Technical Assessment Needs:

- Develop a rock joint constitutive model.

- Develop or modify TM compliance determination codes for subsurface facilities.

- Analyze drift stability leading to rock-induced waste package failure for updating the SEISMO Module in the IPA code.

- Develop an understanding of the effect of backfilling of emplacement drifts on the performance of waste packages, stability of drifts, and retrievability of waste (with EBS).

- Develop or modify TMH compliance determination codes for subsurface facilities.

- Develop a better understanding of the importance of seals to the overall performance of the repository, taking into account the specific conditions at the YM repository site (including geologic and hydrologic properties of the intact matrix and fractures, infiltration, etc.).

- Evaluate, through sensitivity studies, which parameters (e.g., infiltration, fracture conductivities of the host rock, fracture porosity of the host rock, etc.) would have the largest impact on seal and repository performance, such that guidance can be given to site characterization activities to focus on better characterization of such properties.

- Review and assess ongoing DOE planning activities on waste retrievability

- Develop or modify TM compliance determination codes for subsurface facilities

Research Needs:

- Develop of a methodology for bounding spatial variability of rock and joint properties using stochastic approach.

- Determine the long-term effectiveness of rock-bolts and other ground supports under thermal environment.

- Develop a methodology for identification and characterization of important design parameters for underground excavations—a total system approach.

- Develop a technique for extrapolation of laboratory measured intact rock and joint properties for field-scale application.

- Perform DECOVALEX TMH experiments and modeling.

- Develop an understanding of the constitutive laws of time-dependent rock properties under heated, variably saturated, and stressed conditions.

- Identify near-field environment chemistry as altered by the thermal loading on construction materials used for seals and shafts and the host rock leading to alteration in the pathways and chemistry of ingressing groundwaters (with GHGC).

- Evaluate long-term TM effects on the performance of seals.

- Evaluate long-term thermal-hydrological effects on the chemical properties of seal materials.

- Evaluate long-term TM (including repetitive seismic load) effects on the surrounding rock mass and seal-rock interface.

Key Technical Issue—Thermal Effects and Redistribution of Moisture

Lead Element: GHGC

Key Technical Uncertainties:

- Prediction of the TMHC responses of the host rock, surrounding strata, and groundwater system to thermal loads (Type 4)
- Prediction of the thermal, mechanical, and hydrological impact on the host rock surrounding the waste package (Type 4)

Technical Assessment Needs:

- Develop a rock joint constitutive model.
- Develop or modify of TM compliance determination codes for subsurface facilities.
- Analyze of drift stability leading to rock-induced waste package failure for updating the SEISMO Module in the IPA code.
- Develop an understanding of the effect of backfilling of emplacement drifts on the performance of waste packages, stability of drifts, and retrievability of waste (with EBS).
- Develop or modify TMH compliance determination codes for subsurface facilities.

Research Needs:

- Perform DECOVALEX TMH experiments and modeling.
- Develop an understanding of the constitutive laws of time-dependent rock properties under heated, variably saturated, and stressed conditions.

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# 4 QUESTIONS ON KEY TECHNICAL ISSUE CORRELATION

This report provides an opportunity to view the draft KTI Implementation Plans as a group, particularly in the context of the associated KTUs, and to assess the degree to which the draft KTI Implementation Plans are consistent with the available guidance (Nuclear Regulatory Commission, 1995). It was noted that some KTUs are not associated with any KTI. Conversely, a number of KTUs were associated with several KTIs. Based on these observations, the following questions were prepared for consideration by the KTI teams and management board. Resolution of these questions may improve the consistency and integration of KTI Implementation Plans.

**General Questions:**

(1) Should the draft KTI Implementation Plans identify those KTUs that are directly associated with a KTI?

Basis: The range of topics of KTUs associated with a KTI varies widely. Some KTIs include KTUs that are directly related to the KTI topic, while other VSIPs include any KTU directly or indirectly having an impact on the KTI. Narrowly focused KTIs should minimize the overlap in KTUs and Technical Support Needs. Alternatively, a vertical slice within a KTI can identify the particular KTUs to be addressed.

(2) Should the five PA-related KTUs be included in KTIs specifically addressing PA issues? If so, should another KTI be identified for including other PA KTUs, or should the disruptive scenario KTI be expanded to cover all PA KTUs?

Basis: The KTI for disruptive scenarios directly addresses one of the PA KTUs. The other four PA related KTUs are not directly addressed by any other KTI. All five PA KTUs are included in four geochemistry and hydrology related KTIs, and are only indirectly related to the KTIs.

(3) Should the two hydrology related KTIs be redefined, or another KTI identified to more directly address range of hydrology related KTUs with minimal overlap?

Basis: The two hydrology related KTIs address two very specific issues; thermally driven flow and structure related flow, but few of the KTUs involve these specific issues. The majority of the hydrology related KTUs involve more general concerns. These more general KTUs are nonetheless included under both hydrology related KTIs. The shared KTUs are:

- Developing a conceptual groundwater flow model that is representative of the YM site groundwater flow system
- Developing a mathematical groundwater flow model that is representative of the YM site groundwater flow system
- Modeling groundwater flow through unsaturated fractured rock caused by the lack of codes tested against field and laboratory data

- Identifying which conceptual models adequately represent isothermal and nonisothermal liquid and vapor phase movement of water through unsaturated fractured rock at YM

- Uncertainties associated with determining characterization parameters

- Experimental confirmation of the basic physical concepts of groundwater flow through unsaturated fractured rock is needed

- Development of new data collection and interpretation techniques are required for codes which model groundwater flow through unsaturated fractured rock

Several KTUs related to hydrology are not associated with any of the KTIs. In the resolution of this question, the following KTUs should be addressed.

- Determining the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment[1]

- Determining the extent of the disturbed zone[2]

- The nature of the large hydraulic gradient located north of YM[3]

- Predicting precipitation and temperature (climate) at the YM site for 10,000 years into the future

- Adverse effects of future groundwater withdrawals on the groundwater flow system

**Question for KTI—Structural Deformation and Seismicity:**

Should the KTUs "Determining magnitude of fault slip and associated seismic shaking at surface and shallow subsurface locations," and "Determining effects of structural deformation and tectonic processes on rock mass properties" proposed in the KTU integration report (Center for Nuclear Waste Regulatory Analyses, 1995) be incorporated into this KTI?

**Question for KTI—Igneous activity**

Should the KTU "Determining the consequences of igneous activity for repository performance" proposed in the KTU integration report (CNWRA, 1995) and its associated Technical Support Needs be incorporated into this KTI?

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[1] Appendix E of the License Application Review Plan (LARP), "Key Technical Uncertainties Associated with Individual Review Plans," erroneously omits these KTUs.

[2] *Ibid.*

[3] *Ibid.*

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**Question for KTI—Geochemical Effects on the Radionuclide Transport Within and Beyond the Thermally Affected Zone**

Should some KTUS be deleted from this KTI because the KTUs and associated Technical Support Needs would be more directly addressed under another KTI?

Basis: Several KTUs listed with this KTI are listed under other KTIs as well. Some of the KTUs may be best addressed under this KTI, but the following appear only indirectly related, and are found under other KTIs as well as this one.

- Prediction of the Evolution of Groundwater Conditions near and within the EBS.
- Identifying geochemical processes that adversely affect the EBS
- Determining the magnitude of the effect of the geochemical processes that adversely affect the EBS
- Gas flow and gaseous radionuclide transport
- Prediction of Criticality Events in Waste Packages
- Prediction of the Releases of Gaseous Radionuclides from Waste Packages during the Containment Period and from the EBS during the Post-Containment Period
- Prediction of the Releases of Non-Gaseous Radionuclides from Waste Packages during the Containment Period and from the EBS during the Post-Containment Period
- Extrapolation of Short-Term Laboratory and Prototype Test Results to Predict Long-Term Performance of Waste packages and EBS

**Question for KTI—Characterization of Structural Features Which Affect Water and Vapor Movement**

Would the following KTUs and their associated Technical Support Needs be more directly addressed under the structural deformation and seismicity or volcanism KTIs?

Basis: This KTI shares a number of KTUs with the KTIs related to structural deformation/seismicity and volcanism, which may be more closely related to these KTUs:

- Poor Resolution of Exploration Techniques to Detect and Evaluate Structural Features
- Development and Use of Conceptual Tectonic Models as Related to Structural Deformation
- Low Resolution of Exploration Techniques to Detect and Evaluate Igneous Features
- Development and Use of Conceptual Tectonic Models as Related to Igneous Activity

**Questions for KTI—Evolution of Groundwater in the Near-Field Environment**

Would the following KTUs and their Technical Support Needs be more appropriate in the KTIs which are more directly related to the KTUs?

Basis: The following KTUs are associated with this KTI, and are also associated with other KTIs which appear to be more closely related:

- Determining the alteration of mineral assemblages due to thermal loading
- Prediction of the TMHC responses of the host rock, surrounding strata, and groundwater system to thermal loads
- Prediction of the thermal, mechanical, and hydrological impact on the host rock surrounding the waste package

**Questions for KTI—Waste Package Degradation**

(1) Would the KTU "Prediction of the thermal, mechanical, and hydrological impact on the host rock surrounding the waste package" and its Technical Support Needs be more appropriately addressed only under the KTI concerning coupled processes?

(2) Would the KTU "Understanding the Effect of Groundwater Conditions on Mode and Rate of Waste Package Corrosion," currently not associated with any KTI, be appropriately addressed by this waste package KTI?

**Question for KTI—The Exploratory Studies Facility**

Would the two KTUs related to thermal-mechanical-hydrological (TMH) be more appropriately addressed only by the TMHC coupled processes KTI?

**Question for KTI—Thermal-Mechanical-Hydrological-Chemical Coupled Processes**

Would the two seal related KTUs be more appropriately addressed only by the KTI on Exploratory Studies Facility design?

**Questions for KTI—Thermal effects and redistribution of moisture**

(1) Would the two KTUs related to TMHC and TMH be more appropriately addressed only by the TMHC coupled processes KTI?

(2) Would the KTUs "Prediction of the Releases of Gaseous Radionuclides from Waste Packages during the Containment Period and from the EBS during the Post-Containment Period" and "Prediction of the Releases of Non-Gaseous Radionuclides from Waste Packages during the Containment Period and from the EBS during the Post-Containment Period" and their Technical Support Needs be more appropriately addressed only by the waste package KTI?

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