DRAFT

UMBRELLA SITE TECHNICAL POSITION

GEOCHEMICAL ISSUES

FOR A HIGH LEVEL WASTE DISPOSAL

FACILITY IN TUFF

Background

In reviewing a license application for a high-level waste geologic repository, the NRC staff is required to determine if the site and design meet the criteria of 10 CFR Part 60. The NRC staff determination will be based on analyses of technical questions in the fields of geology, groundwater flow, geochemical retardation, waste form and waste package, and facility design. During site characterization, the Department of Energy (DOE) will perform laboratory and field investigations to develop the information needed to address these basic technical questions.

Investigations to characterize a geologic repository are complex and involve long lead times. The Nuclear Waste Policy Act of 1983 (NWPA) has established a schedule for site characterization and selection. Specifically, NWPA requires publication of Site Characterization Plans (SCPs) by DOE at an early stage of the process. Subsequent to the receipt of an SCP, the NRC must prepare a formal Site Characterization Analysis (SCA) for each site. Documented site reviews, technical meetings, and single-issue site techncial position papers will precede and supplement the SCA's.

This document establishes the NRC position as to the generic geochemical technical issues with regard to the Nevada Nuclear Waste Storage Investigation (NNWSI). Future Site Technical Positions (STP) will address NRC staff concerns regarding both selected site specific issues and acceptable technical approaches for addressing those issues.

Terminology used by NRC staff to describe issues is as follows:

Site issues are questions about a site that must be resolved to complete licensing assessments of site and design suitability to meet the requirements of 10 CFR Part 60. Site issues can be divided into performance issues and specific issues.

Performance Issues are broad questions concerning both the operational and long term performance of the various elements of the overall geologic repository system (e.g., waste form, container, geologic setting). Performance issues are derived directly from performance objectives in 10 CFR Part 60 (including environmental objectives of 10 CFR Part 51). Development of generic performance issues for a geologic repository is explained in detail in Appendix C of NUREG-0960, "Draft Site Characterization Analysis of the Site Characterization Report for the Basalt Waste Isolation Project," March 1983.

Specific Issues are questions about conditions and processes (information needs) that must be considered to assess performance issues. Performance issues include the integration of numerous specific issues.

Appendix C of NUREG-0960 identifies 12 performance issues which the NRC has determined must be resolved prior to licensing of a high-level waste geologic repository. These issues are as follows:

1. How do the design criteria and conceptual design address releases of radioactive materials to unrestricted areas within the limits specified in 10 CFR 20?

2. How does the design criteria and conceptual design accommodate the retrievability option?

3. When and how does water contact the backfill?

4. When and how does water contact the waste package?

5. When and how does water contact the waste form?

6. When, how, and at what rate are radionuclides released from the waste form?

7. When, how, and at what rate are radionuclides released from the waste package?

8. When, how, and at what rate are radionuclides released from the backfill?

9. When, how, and at what rate are radionuclides released from the near-field?

10. When, how, and at what rate are radionuclides released from the far field to the accessible environment?

11. What is the pre-waste emplacement groundwater travel time along the fastest path of radionuclide travel from the near-field to the accessible environment?

12. Have the NEPA environmental/institutional/siting requirements for nuclear facilities been met?

While these performance issues were originally developed for the Basalt Waste Isolation Project (BWIP) the staff considers that they also apply to the potential NNWSI site.

The next step in the performance analysis approach is identification of the significant conditions and processes that bear on assessment of each of the performance issues. Judgment is involved in determining which conditions and processes are considered significant. Knowledge gained from the staff's review of various related technical data and documents, site visits, technical meetings and research efforts contributed heavily to the particular selection of significant conditions used in developing this STP. Questions about the significant conditions and processes as they pertain to the geochemistry constitute the site issues identified in this position.

Because the geochemistry of the potential tuff site will significantly affect repository performance, geochemistry data obtained during site characterization will be part of the total repository system information needs of the NRC staff, as required to assess the performance elements. Relevant issues concerning the potential NNWSI site are needed by the NRC staff to adequately assess the performance issues. The sequential order in which issues are ident
&ied should
not be interpreted as the order of relative importance.

Technical Position

It is the position of the NRC staff that, based on our current level of knowledge of the NNWSI site, assessment of the Technical Criteria of 10CFR60 with regard to the performance elements of NUREG-0960 requires that, at a minimum, the following issues concerning geochemistry be addressed.

3.0 Geochemistry

3.1. What are the geochemical conditions preceding waste emplacement in the saturated/unsaturated zone?

3.1.1 What is the mineralogy/petrology/chemistry of the backfill and near-field/far-field host rock prior to waste emplacement?

3.1.2 What is the mineralogy/petrology/chemistry along potential release pathways of the near-field/far-field host rock prior to waste emplacement?

3.1.3 What are the geochemical conditions of the groundwater in the near-field/far-field in the saturated/unsaturated zone.

3.2 What are the geochemical conditions/processes following waste emplacement, in the saturated/unsaturated zone?

3.2.1 How are the mineral stabilities of the Yucca Mountain tuffs affected by anticipated changes in the temperature and pressure?

3.2.1.1 How does the rock/groundwater ratio in the backfill and near-field/far-field host rock in the saturated/unsaturated zone change with time?

3.2.1.2 What is the effect of assuming chemical equilibrium in rock/water interactions under various flow regimes in the saturated/unsaturated zone?

3.2.2 What is the anticipated spacial distribution of alteration products due to increased temperatures and altered fluid flow paths.

3.2.3 What are the anticipated changes in the geochemical conditions of the groundwater due to increased temperature within the unsaturated/saturated zone?

3.3 What are the anticipated geochemical processes/conditions affecting release and transport of radionuclides in the saturated/unsaturated zone?

3.3.1 How does solubility/concentration of radionuclides under differing flow regimes affect radionuclide transport?

3.3.1.1 How does precipitation/co-precipitation affect radionuclide migration/retardation from the near-field to the ac &ssible environment through time?

3.3.1.2 How does speciation affect radionuclide solubility?

3.3.1.3 How do colloids/particulates/organics affect the solubility of radionuclides?

3.3.2 What is the importance of reaction and sorption kinetics on radionuclide migration/retardation in the near-field/far-field environment under various flow regimes?

3.3.3 How do redox conditions of the groundwater and redox buffering potential of Fe-Ti oxides affect radionuclide speciation/retardation?

3.3.3.1 What are the effects of gamma and alpha radiolysis products on backfill and near-field/far-field host rock, relevant to radionuclide transport?

3.3.4 How does backfill/near-field/far-field mineralogy (under anticipated flow regimes) influence radionuclide release and migration through time?

3.3.5 How do colloids/particulates/organics under differing flow regimes affect radionuclide migration/retardation in the near-field/far-field through time?

3.3.6 How does matrix diffusion affect radionuclide migration/retardation in the near-field/far-field through time?

3.3.7 How does vapor/aerosol transport affect radionuclide migration/retardation in the nearfield/far-field through time?

DISCUSSION

The rationale for each issue is described in the following discussion. In the discussion, the broadest issues, i. e., those that would appear in the first tier of a hierarchy of issues and sub-issues, are related directly to the performance issues that are listed in the Background section above. Sub-issues are related by technical argument to the issue(s) directly above them in the logic tree.

3.1 What are the geochemical conditions preceding waste emplacement in the saturated/unsaturated zone?

An understanding of the geochemical conditions preceding waste emplacement is necessary in order to evaluate the suitability of a repository for containing waste and retarding the release of radionuclides from the near-field to the accessible environment (performance issue 10). Adverse conditions within the far-field are likely to remain unchanged after waste emplacement, whereas favorable pre-waste conditions in the nearfield may alter to potentially adverse conditions following waste emplacement. Since the geological media is the primary barrier to release of radioactive waste to the accessible environment, it is necessary to understand the pre-emplacement conditions to establish a baseline for prediction of geochemical conditions in the saturated and unsaturated zones under typical repository scenarios. This information is necessary to assess performance issues 9 and 10.

3.1.1 What is the mineralogy/petrology/chemistry of the backfill, disturbed zone/far-field host rock prior to waste emplacement?

The host rock is the primary barrier in geologic waste isolation. Knowledge of the mineralogy, petrology, and chemical composition will lead to an understanding of the genesis and future geochemical stability of the host rock, aid in the evaluation of the effects of waste/rock interactions, and provide information for interpreting the groundwater chemistry.

Backfilling, as discussed here, refers to materials used to fill shafts, tunnels, and disposal rooms. The large man-made cavities, including fracturing around these cavities, represent broad and potentially short pathways to the accessible environment for radionuclides released from the waste package. The pathways should be blocked with engineered barriers that promote geochemical retardation of radionuclide migration to the accessible environment.

3.1.2 <u>What is the mineralogy/petrology/chemistry of secondary minerals along potential release pathways in the near-field/far-field host rock prior to waste emplacement?</u>

Understanding the diagenesis of tuff alteration and secondary mineralization will 1) aid in interpreting the pre-emplacement groundwater chemistry and host rock retardation properties, and 2) provide a baseline for predicting the chemical alteration of the groundwater and host rock that may occur as the result of waste emplacement. An understanding of the existing distribution of alteration products may indicate potential release pathways of radionuclides to the accessible environment.

3.1.3 <u>What are the geochemical conditions of the groundwater in the disturbed zone/far-field in the saturated/unsaturated zone?</u>

Geochemical conditions, in particular temperature, pressure, pH, redox conditions, ionic strength, and presence of complexing ligands, determine which chemical species of radionuclides are most likely to form and determine what reactions are likely to occur. Reactions of radionuclides in solution with components of the backfill, the near-field and far-field host rock, including adsorption and precipitation, will determine the limiting concentrations of soluble species. Present conditions will be necessary for determining conditions in the far-field, and will serve as a baseline for predicting changes resulting from increased temperature and pressure in the nearfield.

3.2 <u>What are the geochemical conditions/processes following waste emplacement in the saturated/unsaturated zone?</u>

The geochemical conditions/properties of the tuff surrounding the repository will be affected by the emplacement of nuclear waste. Construction and increased temperatures in the vicinity of the repository may alter the properties of the tuff to the extent that water is more/less accessible to the waste package and backfill (performance issues 3, 4), affecting the release and transport of radionuclides to the accessible environment (performance issues 8,9,10). It is important to address the geochemical changes in both the saturated and unsaturated zones since the presence of water often has significant effects on the resulting conditions/processes.

3.2.1 How are the mineral stabilities of the Yucca Mountain tuffs affected by anticipated changes in the temperature and pressure?

Many minerals exist in metastable states and the change of temperature, pressure and/or degree of saturation may alter the stability of the minerals in a rock. The alteration products although, often pseudomorphic after the original minerals, generally have different physical/chemical properties, which can affect the initial retardation capacity of the host rock. The effects will depend on the amount and chemistry of water present, and may vary significantly between the saturated and unsaturated zones.

3.2.1.1 How does the rock/groundwater ratio in the backfill/near-field/far-field in the saturated/unsaturated zone change with time?

The mineral stability will depend on the amount of water present in the backfill, near-field/far-field. The degree of induced mineral alteration may vary significantly between the saturated and unsaturated zones. Perched water tables or zones of increased saturation (due to heating and cooling effects) immediately surrounding the repository may generate mineral zonations that could have a significant effect on the performance of the repository with regard to radionuclide migration.

3.2.1.1 What is the effect of assuming chemical equilibrium in rock/water interactions under various flow regimes in the saturated/unsaturated zone?

Chemical equilibrium in rock/water interactions is generally assumed in saturated media where fluid velocities are sufficiently slow to allow equilibration of the rock and water. In the unsaturated zone, it is possible for water to be transported by pulses of fracture flow, porous media flow, and/or by matrix diffusion. The velocity would vary according to the flow regime. If water passes quickly through the rock, there may not be sufficient time for equilibration of the groundwater, which could substantially affect the anticipated geochemical conditions or composition of the groundwater after waste emplacement if equilibrium conditions are assumed. Reaction kinetics become important under these conditions and should be carefully considered.

3.2.2 What is the anticipated spatial distribution of alteration products due to increased temperatures and altered fluid flow paths?

As temperatures of the backfill and near-field/farfield host-rock increase with time, minerals and ionic species in solution will change in an attempt to re-equilibrate with the new conditions. Minerals may dissolve or precipitate thereby altering the mineral distribution along the flow paths. The resultant changes will depend on temperature, groundwater conditions and fluid flow regimes (i.e. diffusion/convection and/or fracture flow). Precipitation of minerals may in turn alter the fluid flow path, and ultimately the migration of radionuclides to the accessible environment.

3.2.3 What are the anticipated changes in the geochemical conditions due to increased temperature within the unsaturated/saturated zone?

Geochemical conditions, in particular temperature, pressure, pH, redox conditions, ionic strength, and the presence of complexing ligands, determine which chemical species of radionuclides are most likely to form and determine what reactions are likely to occur. Reactions of radionuclides in solution with the existing components of the backfill, the near-field and far-field host rock, including adsorption and precipitation, will determine the limiting concentrations of soluble species. Changes in temperature and pressure alter the geochemical conditions of the groundwater which determine the mineral stabilities and may affect radionuclide migration. An assessment of the prevailing geochemical conditions following waste emplacement must be made in order to predict radionuclide migration.

3.3 What are the anticipated geochemical processes/conditions affecting release and transport of the radionuclides in the saturated/unsaturated zone?

Geochemical reaction, processes, and conditions at the waste package surface, in the backfill, the near-field, and the far-field will profoundly affect the release and transport of radionuclides from the repository to the accessible environment (performance issues 6 through 10). Release involves waste package degradation and solubilization of the radionuclides in the waste form. Transport involves mechanical and chemical processes which promote or inhibit radionuclide migration from the repository to the accessible environment. During release and transport, radionuclides will react with the groundwater, the waste container, the backfill, surrounding rocks. The nature of these reactions will determine the significance and extent of the migration of each radionuclide in the waste form.

An understanding of the processes in both the saturated and unsaturated zones is critical since the possibility of radionuclide transport through both zones exists. Conditions and processes may differ significantly the two zones, even though

the same rock type and structures may exist in both zones. The presence or absence of a water saturated rock may significantly alter the geochemical conditions/processes in addition to the changes resulting from potentially different transport mechanisms in each zone.

Geochemical conditions may vary depending on the fluid transport regime, within the unsaturated zone, if the groundwater is not in equilibrium with the host rock. If fractured media flow is the prevalent means of fluid flow in the unsaturated zone, then kinetics of geochemical processes may become more important than equilibrium processes. Based on the kinetics, certain reactions and/or processes may become insignificant in providing a means of radionuclide retardation. If matrix diffusion or porous media flow is the most likely means of fluid flow, then equilibrium processes will be important. These issues must be addressed prior to evaluation of the sub-issues, in determining the rates of release of radionuclides to the accessible environment.

3.3.1 How does solubility of radionuclides under differing flow regimes affect radionuclide transport?

The concentration of a radionuclide in the groundwater may vary with differing flow regimes. The solubility of the radionuclides will affect the migration to the accessible environment. The effects of speciation and precipitation on the transport of radionuclides should be carefully assessed.

3.3.1.1 <u>How does precipitation/co-precipitation affect radionuclide migration/retardation from the near-field to the accessible environment through time?</u>

Under varying conditions, radionuclides in solution may precipitate in the presence of certain inorganic ligands (e.g., carbonate, hydroxyl, sulfide). Parameters controlling precipitation include groundwater composition, rock composition, redox conditions, and pH. Certain radionuclides may co-precipitate by substitution with non-radioactive species such as iron.

3.3.1.2 <u>How does speciation affect radionuclide solublility?</u>

The identities and solubilities of the solid phases and indentities of the solution species likely to form under geologic conditions are needed to determine solution concentrations of radionuclides in a repository groundwater system. Different species of the same element will remain in solution in different concentrations and migrate at different rates.

3.3.1.3 How do colloids /particulates affect solubility of radionuclides?

Some radionuclides, especially hydrolyzable ones, may readily form colloids or pseudocolloids under certain geochemical conditions. These colloids may result from interactions with the waste package. The formation of colloidal species may affect the concentrations and thus the migration of radionuclides in solution.

3.3.3 How do redox conditions/redox buffering potential of Fe-Ti oxides affect radionuclides speciation/retardation?

Radionuclide retardation is a key factor in controlling the release of radionuclides to the accessible environment. Radionuclide retardation is dependent on the radionuclide speciation and the redox condition/buffering potential of the groundwater and the Fe-Ti oxides in the host rock/backfill. Knowledge of the redox conditions/buffering potential of the Fe-Ti oxides is necessary to determine the processes and geochemical conditions that will affect the release of radionuclides. The retardation of the radionuclides is dependent on the geochemical conditions/processes operating in the backfill/host rock after waste emplacement.

3.3.3.1 <u>What are the affects of gamma and alpha radiolysis products on backfill, near-field/far-field host rock relevant to radionuclide retardation?</u>

Gamma and alpha radiolysis products may affect the redox conditions of the backfill, near-field/far-field host rock causing generation of hydrogen, oxygen, and other species that will affect anticipated reactions. These conditions may influence radionuclide speciation and transport.

3.3.4 <u>How does backfill and near-field/far-field mineralogy (under anticipated flow regimes) influence radionuclide migration through time?</u>

The mineralogy of the backfill and the near-field/far-field may play a key role in the retardation of the radionuclides if highly sorptive minerals are present. A good estimate of the location, volume and accessibility of minerals along the likely flow paths is necessary to assess the effect of mineralogy on the radionuclide migration/retardation. Sorption kinetics must be addressed if radionuclide transport occurs in such a way that equilibrium conditions cannot be assumed.

3.3.5 <u>How do colloids/particulates/organics under differing flow regimes affect radionuclide migration/retardation in the near-field/far-field through time?</u>

If the transport pathways involve relatively large openings, geochemical conditions leading to the formation and geochemical stability of colloids and fine particulates may become very important to the prediction of rates of transport of radionuclides. The formation of radionuclide bearing colloids and particulates may enhance the migration of radionuclides to the accessible environment under certain fluid flow regimes. It is necessary to address the likelihood of colloid/particulate formation and transport in the backfill and nearfield/farfield host rocks. The issue of radionuclide transport by organics or microbes as well as their modification of baseline transport parameters must be addressed.

3.3.6 <u>How does matrix diffusion affect radionuclide migration/retardation in the near-field/far-field through time?</u>

Diffusion of radionuclides through the host rock matrix is one possible geochemical process of radionuclide retardation. The likelihood of fluid movement via matrix diffusion and the relative importance as a radionuclide retardation mechanism must be addressed.

3.3.7 How does vapor/aerosol transport affect radionuclide migration/retardation in the near-field/far-field through time?

Spent fuel may contain radionuclides in gaseous phases that could be transported to the accessible environment via fractures or inter-connected pore spaces in the unsaturated zone. Aerosols may be formed due to the drying-wetting effect in the near-field, which may promote transport of soluble radionuclides in a vapor phase. These processes should be understood to assess the role of vapor transport in radionuclide migration.