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Site Technical Position - Repository Design Issues for
The Nevada Nuclear Waste Storage Investigations (NNWSI)

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BACKGROUND

At the time of the license application for a deep geologic repository for high-level nuclear waste, the Department of Energy (DOE) has the responsibility to present and defend a complete licensing assessment of the geologic repository system and its components as required by 10 CFR Part 60. The first licensing action, following the site characterization is the decision on Construction Authorization. To receive authorization to construct the repository, DOE must demonstrate through the Safety Analysis Report (10 CFR 60.21) that there is reasonable assurance that the types and amounts of radioactive materials described in the application can be received, possessed and disposed in a repository of the design proposed without unreasonable risk to the health and safety of the public (10 CFR 60.31(a)). The NRC staff will independently review DOE's description of the proposed geologic repository (10 CFR 60.31(a)(1)) and DOE's assessment of the performance of the site and design with respect to the performance objectives and criteria contained in Subpart E (10 CFR 60.31(a)(2)).

The NRC staff evaluation of DOE's performance assessments will be based on the answers to technical questions concerning groundwater flow, geochemical retardation of radionuclides, waste form and waste package, geologic stability, facility design and retrievability requirement. Answers to these questions should be supported by adequate data and analyses which are specific to the site for which a license application is to be submitted.

In order to provide guidance to the DOE in formulating the site characterization program which can produce the information required to conduct licensing assessment, the NRC staff has identified a series of basic technical questions on performance of the repository. To identify these technical questions or issues the NRC staff has followed the rationale and methodology described in Appendix C of the BWIP Draft Site Characterization Analysis (DSCA), NUREG-0960. This methodology identifies the repository performance elements directly from the performance objectives detailed in 10 CFR 60 (including environmental objectives of 10 CFR 51) and develops a series of broad questions concerning both short-term construction/operation and long-term containment/isolation. These questions are called Performance Issues.

The Performance Issues are generally independent of sites. The next level of detailed questions which takes into consideration the significant variation in conditions and processes from site to site is then generated. Thus for each site, specific issues are developed as a subset of the broad Performance Issues. The Umbrella Site Technical Position (USTP) developed by the NRC staff encompasses all such issues for each technical area.

This Umbrella Site Technical Position has been developed to establish the NRC staff position for the NNWSI site specific technical issues on design. The staff position on the issues provides guidance to the DOE on what the staff considers to be the necessary information for design assessment. Future Site Technical Positions relevant to design will address both the staff concerns regarding selected issues and acceptable technical approaches for addressing those issues.

The repository design has an overriding importance on construction schedule, emplacement of waste, retrieval, and long-term performance of the repository. Therefore, the information on design for the NNWSI site will be an important part of the total information needs of the staff. Issues identified in the following section titled, Technical Position, delineate information concerning design at NNWSI needed by the staff.

The organization of the issues under technical position is as follows: the staff has assigned the number 4 for design issues. Therefore, major design issues are numbered 4.1, 4.2, 4.3 etc. and subissues are designated by additional points and digits.

The issue development followed the sequence related to pre-closure (issue number 4.1 and 4.2) and post closure scenerios (issue number 4.3 thru 4.6) in a general sense. Where applicable the major issues were subdivided with consideration to natural condition, repository induced condition and human induced condition. These conditions may not be apparent in the issues as listed under "Technical Position." Therefore, the reader should read the "Discussion" section of this document for further clarification of each issue. The sequential order in which issues are identified are not necessarily in the order of their relative importance.

TECHNICAL POSITION

It is the position of the NRC staff that, as a minimum, the following design specific issues should be addressed by DOE during site characterization program.

Repository Design Issues

4.1 How does the repository design account for the NRC health and safety criteria for the operational period of the repository?

4.1.1 What are the restricted and unrestricted areas of the geologic repository operations area?

4.1.2 What provisions are taken in the repository design to assure that, during normal operations and retrieval, releases of radioactive material into the air in the restricted area do not exceed limits specified in 10 CFR Part 20?

4.1.3 How do the design criteria and conceptual design address levels of radiation and releases of radioactive materials to the unrestricted areas within the limits specified in 10 CFR Part 20?

4.1.4 What structures, systems, and components are "Important to Safety" as defined in 10 CFR Part 60.2?

4.1.4.1 How are structures, systems, and components "Important to Safety" designed to meet 10 CFR 60.131, 132, 133 criteria?

4.1.5 What are the natural conditions at the site which could preclude safe emplacement of the waste at the selected repository horizon?

4.1.5.1 What are the potential ground water inflow rates if any, into the repository host rock?

4.1.5.2 What is the in situ stress field at the repository host rock?

4.1.5.3 What are the effects of geologic anomalies?

4.1.5.4 What is the ambient temperature of the rock at the repository horizon?

4.1.5.5 What is the thickness and lateral extent of the repository host rock?

4.1.6 What are the effects of potential ground water inflow, in situ stresses, anomalies, creep rates, rock instabilities and ambient temperature on construction of the repository and emplacement of waste?

4.1.7 How are the engineered barrier system design, the seal system design, and the geologic repository design integrated to assure safe emplacement and containment of the waste?

4.1.7.1 How does the repository design contribute to the Waste Package design in meeting its performance objective?

4.1.7.2 How does the repository design contribute to the engineered barrier system in meeting its performance objectives?

4.1.7.3 How does the repository design contribute to the seal system in meeting its performance objective?

4.1.8 How does the repository design permit implementation of a performance confirmation program as per Part F of 10 CFR Part 60?

4.1.8.1 What continuing program of surveillance, measurement, testing and geologic mapping shall be conducted to ensure that geological and design parameters are confirmed as per 10 CFR 60.141?

4.1.8.2 What in situ testing of such features as borehole and shaft seals, and thermal interaction effects of waste package, backfill, rock and groundwater will be conducted?

4.1.8.3 How will variations in expected conditions be incorporated into the design?

4.1.9 What provisions are taken in the repository design for various facilities to assure safe handling and storage of wastes prior to emplacement?

4.1.10 What provisions are taken to implement a program for certifying personnel operating systems and components important to safety?

4.2 <u>How do the repository criteria and conceptual design accomodate the retrievability option?</u>

4.2.1 How do the repository design criteria account for natural conditions such as in situ stresses, heterogeneities and anomalies that affect the ability to retrieve?

4.2.2 How do the repository design criteria account for repository induced conditions that affect the ability to retrieve?

4.2.3 How do thermal-hydrological-mechanical-chemical combined processes affect the ability to retrieve?

4.2.3.1 What effect does the thermal pulse have on creep rates, in situ stresses, and heterogeneities in the host rock?

4.2.3.2 How will spalling in the host rock affect the ability to retrieve?

4.2.3.3 If groundwater is present in the repository and steam is produced, what is the effect on the ability to retrieve?

4.2.3.4 How will the thermal pulse affect the ventilation requirements of the repository and thermal loading on retrieval equipment during the retrievability period?

4.2.4 What effect does backfill have on the ability to retrieve (if backfill is done)?

4.2.4.1 How will backfill be remined in order to remove the waste packages?

4.2.4.2 What are the effects of changes in the physical properties of the backfill on retrieval?

4.2.4.3 What system and system capacity is necessary to precool backfilled rooms prior to retrieval?

4.3 <u>When and how does water contact the engineered barrier system?</u>

4.3.1 What are the geologic features and natural processes which will cause water to contact the engineered barrier system?

4.3.1.1 How much, by what means, and from what sources (if any) is intrusion of water anticipated?

4.3.2 What are the repository-induced changes which will cause water to contact the engineered barrier system?

4.3.2.1 What effect does the excavation of openings have on rock fracturing and permeabilities in the rock mass surrounding the repository?

4.3.2.2 What effects do thermal gradients caused by waste emplacement have on rock fracturing and permeabilities in the rock mass surrounding the repository?

4.3.2.3 How effective will the borehole and shaft seals be in mitigating water inflow to the engineered barrier system?

4.3.2.4 What effect will the support and/or reinforcement system (if used) have on intrusion of water into the repository?

4.3.3 What are the expected effects over time of water contacting the engineered barrier system due to future events such as exploratory borehole drilling, faulting, ground water migration, and boreholes and shaft seal failues?

4.4 <u>When and how does water contact the waste package?</u>

4.4.1 What are the performance objectives of the engineered barrier system?

4.4.1.1 What are the properties of the engineered barrier system?

4.4.2 What are the effects over time of the thermal-hydrological-mechanical-chemical coupled processes on the engineered barrier system properties?

4.4.2.1 What effect over time will the heat and radiation from the waste package have on the hydraulic conductivity, porosity, and permeability of the engineered barrier system?

4.4.2.2 What effect over time will the regional stress field radiation from waste package and anticipated creep rates have on the porosity, permeability and hydraulic conductivity of this engineered barrier system?

4.4.2.3 What effect over time will the groundwater flow and chemical composition of the groundwater have on the properties of the engineered barrier system?

4.5 <u>When, how and at what rate are radionuclides released from the engineered barrier system?</u>

4.5.1 What characteristics of the engineered barrier system will control releases of radionuclides from the engineered barrier system?

4.5.2 How will the placement methods be controlled to ensure that the engineered barrier system will meet its performance objectives?

4.5.3 What effects will thermal-hydrological-mechanical-chemical coupled processes have on the engineered barrier system characteristics and thus the radionuclide release rate, over time?

4.6. <u>When, how, and at what rate are radionuclides released from the disturbed zone?</u>

4.6.1 How will boreholes and shafts affect radionuclide release to the accessible environment?

4.6.1.1 What are the performance objectives for borehole and shaft seals?

4.6.1.2 What are the characteristics of the sealing materials and how will they be affected by the repository environment (geologic characteristics, water infiltration, and temperature)?

4.6.1.3 How will the location and construction of shafts and boreholes in the controlled area affect the likelihood of radionuclide release to the accessible environment?

4.6.1.4 What effect will construction of the shafts (e.g., rock damaged zone, liner effects) boreholes and exploratory testing have on the ability to seal these openings?

4.6.1.5 How will placement methods be controlled to ensure that borehole and shaft seals will meet the performance objectives?

4.6.2 How will borehole and shaft sealing affect radionuclide release to the accessible environment?

4.6.2.1 What effect will rock mass instabilities and groundwater chemical interaction have on the integrity of the sealing system?

4.6.2.2 How will the sealing system prevent the interconnection of overlying aquifers with the repository shaft horizon?

4.6.3 How will the borehole and shaft seal system deterioration over time affect the radionuclide release rate?

4.6.4 What are the effects of thermal loading on the geomechanical properties of the rock in the disturbed zone?

4.6.4.1 How do the changes in geomechanical properties of the host rock affect repository performance?

DISCUSSION

The rationale for each issue is described in the subsequent discussion.

4.1 <u>How does the repository design account for the basic NRC health and safety criteria for the operational period of the repository?</u>

10 CFR Part 60 contains design criteria to be applied to the repository design to comply with the NRC health and safety criteria for the operational period of the repository. These include criteria for both the restricted and unrestricted areas of the geologic repository operations area. DOE should identify those structures, systems and components which are important to safety. The natural and induced geologic conditions and their effects on proper operation of the geologic repository operations area should be considered. The design of different components and the interfaces between these components, as well as the interface between design and performance confirmation testing are all issues which need to be addressed in accordance with the prescribed rules specified in 10 CFR Part 60.

4.1.1 What are the restricted and unrestricted areas of the geologic repository operations area?

In order to apply the criteria of 10 CFR Part 60 to the restricted and unrestricted areas, it is necessary to determine what the boundaries are for these areas. These areas should be determined based on the design for the geologic repository operations area.

4.1.2 What provisions are taken in the repository design to assure that, during normal operations and retrieval, releases of radioactive materials into the air in the restricted area do not exceed limits specified in 10 CFR Part 20?

10 CFR Part 60 §60-131 prescribes that the geologic repository operations area shall be designed to maintain radiation doses, levels and concentrations of radioactive material in air in restricted areas within the limits specified in 10 CFR Part 20. Those criteria can be found in 10 CFR Part 20.103. The criteria will apply to the restricted area during normal operations only.

The retrieval option will possibly require additional provisions. This may be due to handling of contaminated material in the underground facility caused by canister failure. Consideration should be given to problems such as this and what effects these events would have on controlling radioactive material in the restricted area.

4.1.3 How do the design criteria and conceptual design address levels of radiation and releases of radioactive materials to the unrestricted areas within the limits specified in 10 CFR Part 20?

10 CFR Part 60 applies Part 20 limits on levels of radiation and release of radioactive material in the unrestricted areas of the geologic repository operations area. Those criteria can be found in 10 CFR Parts 20.105 and 106. The conceptual design for the geologic repository operations area should identify how levels and releases will be kept below those specified in Part 20 during normal operations of the facility.

4.1.4 What structures, systems, and components are "Important to Safety" as defined in 10 CFR Part 60.2?

10 CFR Part 60.2 defines the term "Important to Safety" with respect to structures, systems, and components important to safety. As part of the conceptual design, all structures, systems, and components important to safety should be identified as well as the methodology used in designating them as "Important to Safety."

4.1.4.1 How are structures, systems, and components "Important to Safety" designed to meet 10 CFR 60.131, 132, 133 criteria?

Once the structures, systems, and components "Important to Safety" have been identified, the design criteria of 10 CFR Part 60 should be applied as appropriate. These criteria should be reflected in the conceptual design.

4.1.5 What are the natural conditions at the site which could preclude safe emplacement of the waste at the selected repository horizon?

The geologic and hydrologic setting of the repository will undergo a screening process designed to enhance the potential for safe waste emplacement. Certain adverse but not disqualifying conditions may survive the screening process. The extent and impact of the condition may not be discernible by the methods used during site screening. During repository development or during waste emplacement, conditions may arise which preclude safe waste emplacement. Potential adverse conditions should be identified and limits placed on the range of conditions which would allow emplacement in the repository.

4.1.5.1 What are the potential ground water inflow rates, if any, into the repository host rock?

Groundwater which may flow into the repository openings needs to be quantified. The sources and impacts of these inflows on waste emplacement should be assessed. Inflows which limit the ability to safely emplace the waste should be quantified for emplacement hole and storage room scales.

4.1.5.2 What are the in situ stresses in the repository host rock?

The in situ stresses in the repository host rock will be a function of the depth and possibly the tectonic history of the geologic horizon. Opening stability is a function of the in situ stresses and the rock mass strength.

4.1.5.3 What are the effects of geologic anomalies?

Geologic anomalies in the form of anomalous zones, shear zones, perched water tables or groundwater pockets, voids, gas pockets, and other variations from the expected geology may preclude safe waste emplacement. Large repository areas may be affected by anomalous zones in the rock mass. These zones may constitute preferential groundwater pathways both in and out of the repository. Gas and groundwater pockets under pressure may represent unstable roof or floor conditions precluding safe emplacment of the waste. The potential effects of the geologic anomalies on containment and isolation of the waste should be defined.

4.1.5.4 What is the ambient temperature of the rock at the repository horizon?

The ambient temperature in the repository horizon has a direct influence on the efficiency of men and equipment, the required ventilation capacity and the stability of openings. Temperatures in excess of those expected may result in rock instabilities in emplacement holes and in storage rooms.

4.1.5.5 What is the thickness and lateral extent of the repository?

The repository horizon will be defined by a limited number of boreholes and by geophysical exploration methods. The extrapolated thickness and lateral extent should be verified to ensure the isolation capability of the repository horizon.

4.1.6 What are the effects of potential groundwater inflow, in situ stresses, anomalies, creep rates, rock mass instabilities and ambient temperature on construction of the repository and emplacement of waste?

As previously discussed the natural conditions at the repository horizon may preclude safe waste emplacement. The effects of natural conditions on construction may include requirements for rock stabilization measures such as rock bolting, decreased extraction ratio, and increased ventilation capacity to allow for high ambient temperature. Other conditions may be identified during repository development which will require design changes to accommodate safe waste emplacement. The range of probable effects resulting from natural conditions needs to be identified.

4.1.7 How are the engineered barrier system design, the seal system design, and the repository design integrated to assure safe emplacement and containment of the waste?

The repository design and the engineered barrier system design work in consort to achieve the performance objectives. The repository is designed to preserve the isolation capabilities of the host media. By limiting changes to the natural conditions, the geologic media becomes an integral part of the containment system. The engineered barrier system, and the seals, should be designed so as not to adversely affect the natural capabilities of the media for containment and isolation of the waste.

4.1.7.1 How does the repository design contribute to the waste package in meeting its performance objective?

The repository design should contribute to the waste package performance by limiting adverse impacts on the waste package such as movements along fractures intersecting emplacement boreholes. Such deformations could result in overstressing or shearing of canisters.

4.1.7.2 How does the repository design contribute to the engineered barrier system in meeting its performance objectives?

The engineered barriers can be positively influenced by the repository design. Room dimensions and roof and floor conditions may be chosen to facilitate construction of the engineered barriers adjacent to the host rock. The configuration of entries and rooms can be designed to promote longer travel time for air and water between engineered barriers. Areas where the repository design contributes to engineered barrier performance should be identified.

4.1.7.3 How does the repository design contribute to the seal system in meeting its performance objectives?

The exploratory boreholes and shafts within the repository operations area will be sealed. The relative contribution of the geologic media and the seal material in meeting containment and isolation objectives requires identification based on the knowledge of both sets of material. The seal system needs to be defined in terms of the influence from the repository construction and operation such as the stresses in the rock mass and the thermal loads applied.

4.1.8 How does the repository design permit implementation of a performance confirmation program as per Part F of 10 CFR Part 60?

As a part of the repository design, a system must be developed for assessing how closely the actual performance compares to the performance predicted during design. The design should allow the instrumentation system to monitor repository performance without interference from repository operations. The performance confirmation program should gather information on the response and interactions between the geologic media and waste form for comparison to baseline data and expected responses.

4.1.8.1 What continuing program of surveillance, measurement, testing and geologic mapping shall be conducted to ensure that geological and design parameters are confirmed as per 10 CFR 60.141?

A program to monitor repository conditions and responses should be developed as a part of repository design. The program should include construction control monitoring systems as well as performance monitoring requirements based upon state-of-the-art practice.

4.1.8.2 What in situ testing of such features as borehole and shaft seals, and thermal interaction effects of waste package, backfill, rock, and groundwater will be conducted?

A program for establishing the response of the components of the repository system contributing to the isolation of the waste will provide details necessary to confirm their performance. The interaction of the components will also provide details of which repository systems are responding as predicted by the design.

4.1.8.3 How will variations in expected conditions be incorporated into the design?

When the testing and monitoring programs indicate variations from the responses or conditions expected, the impact on the repository design will need to be assessed. If the impacts are significant, design revisions may be required. A program for using the information from the monitoring program to modify design will allow resolution of performance discrepancies.

4.1.9 What provisions are taken in the repository design for surface facilities to assure safe handling and storage of wastes prior to emplacement?

Surface facilities should be designed to ensure safe handling and storage of wastes, to ensure that ventilation system protects against radiation exposures and offsite releases, to monitor and control contaminated effluents, to treat radioactive facility wastes, and to facilitate decommissioning.

4.1.10 What provisions are taken to implement a program for certifying personnel operating systems and components important to safety?

Subpart H of 10 CFR Part 60 requires that operations of systems and components that are important to safety be performed only by trained and certified personnel. In addition it requires that the physical condition and general health of certified personnel be such as to minimize risk of health-caused operational errors that could endanger public health and safety.

4.2 <u>How do the repository design criteria and conceptual design accommodate the retrievability option?</u>

Retrieval of the waste is an option that must be maintained for a period of up to 50 years after the initiation of waste placement or until a performance confirmation is completed and accepted by NRC. The design criteria and conceptual design for the repository must allow for the retrievability option.

4.2.1 How do the repository design criteria account for natural conditions such as in-situ stresses, heterogeneities and anomalies that affect the ability to retrieve?

The natural conditions of the rock mass will dictate many of the details of design. The amount of fracturing, heterogeneity, anisotropic properties, anomalous zones, ambient temperature, and other geologic conditions will affect the repository room and emplacement hole dimensions, selection of repository horizon, orientations of opening layout, emplacement and retrieval equipment. The design criteria will need to address how the adverse siting conditions, if present, will affect the ability to retrieve.

4.2.2 How do the repository design criteria account for repository induced, conditions that affect the ability to retrieve?

The excavation and development of a repository results in changes in the existing natural conditions. Stress gradients will develop around the openings. As repository excavation proceeds, the stresses throughout the geologic repository area will be redistributed. The stress conditions at retrieval will be a function of excavation techniques, excavation sequence, and the geologic conditions. Stresses and rock mass stability during retrieval will be influenced by encountered geologic anomalies.

Stability of the rock mass is dependent on the magnitude of the stress components, the rock mass strength, thermal loading and the orientation and geometry of the excavations. Prior to retrieval, some cleanup of pillar slabbing and roof falls may be necessary to allow retrieval equipment to operate in the repository.

4.2.3 How do thermal-hydrological-mechanical-chemical combined processes affect the ability to retrieve?

The influence of interaçtions between the thermal, hydrological, mechanical, and chemical response of the repository horizon to waste emplacement may affect retrieval. The environment at the time of retrieval will influence the type of equipment used, the configuration of repository openings, ventilation requirements, and safety measures. Interactions may result in accelerated creep rates, presence of steam, or decrease in the strength of clay interbeds. The interactions may result in changes in the repository conditions which may require consideration during design.

4.2.3.1 What effect does the thermal pulse have on creep rates, in situ stresses, and heterogeneities and anomalies in the host rock?

The creep rate is a function of the temperature. Wheather this rate is significant or not is not known at this stage. The thermal load imposed by the emplacement of waste will create a thermal gradient in the rock mass. The limits and magnitude of the gradient need to be defined along with resultant thermal expansion and stress changes.

4.2.3.2 How will spalling in the repository affect the ability to retrieve?

Spalling may occur in the form of roof falls, pillar slabbing, or floor heave. The extent of spalling will affect retrieval time, equipment, worker safety, and the ability to relocate a canister for retrieval.

4.2.3.3 If groundwater is present in the repository and steam is produced, what is the effect on the ability to retrieve?

Groundwater within the tuff media will, under a thermal gradient, move toward the heat source. The quantity and conditions of collected water in repository openings needs to be identified. The water concentrations and quantities may affect waste package integrity. If the water is in the form of steam in the backfill or canister hole, appropriate measures for the personnel and equipment operation should be taken.

4.2.3.4 How will the thermal pulse affect the ventilation requirements of the repository and the thermal loading on retrieval equipment during the retrievability period?

Ventilation requirements during retrieval will be a function of rock temperature, backfill conditions and time allowed for precooling. Depending on the magnitude of retrieval, the ventilation capacity of the confined air circuit may need to be enlarged for retrieval. The rock temperature at various times in the retrieval period needs to be defined in terms of the ventilation capacity required for retrieval. The retrieval environment, including temperature, humidity, and air quality will directly affect the type of equipment and the measure taken to keep equipment in operation. Elevated temperatures may preclude the presence of workers leading to a need for remote-controlled equipment. Temperature levels and resultant equipment requirements for retrieval need to be identified.

4.2.4 What effect does backfill have on the ability to retrieve (if backfilling is done)?

The presence of backfill may affect all of the operations necessary to retrieve the waste. Equipment systems, ventilation systems, excavation equipment, and repository facilities will need to consider the backfill during design. Equipment and excavated systems must identify how the increased temperatures will affect their ability to retrieve. Handling and storing backfill during retrieval operations should be considered in the repository design.

4.2.4.1 How will backfill be remined in order to remove the waste packages?

Remining of backfill may require advanced technology to assure proper equipment operation and worker safety. Under the conditions presently expected during retrieval, remining the backfill may need remote-controlled excavation system. The system for remining the backfill needs to be identified.

4.2.4.2 What are the effects of changes in the physical properties of the backfill on retrieval?

The ability of the excavation equipment to remine the backfill will depend on an accurate assessment of the physical properties at the time of retrieval. As a result of possible groundwater migration, consolidation, and thermal effects the backfill will require different handling procedures at the time of retrieval than when placed. The limits of the expected changes and their effects on the retrieval systems require identification.

4.2.4.3 What system and system capacity is necessary to precool backfilled rooms prior to retrieval?

In order to retrieve the waste package the temperature in the repository room will need to be low enough to allow men and equipment to operate efficiently. A system for precooling the room should be defined. The temperature limits for safe retrieval at various times during the retrieval period should be established and the resultant precooling system capacity determined.

4.3 <u>When and how does water contact the engineered barriers system?</u>

The engineered barrier system include the waste package and the underground facility. Water will first contact the engineered barriers. The timeframe in which this occurs and how it occurs has to be considered in that it will eventually affect release rates from the engineered barrier system.

4.3.1 What are the geologic features and natural processes which will cause water to contact the engineered barrier system?

Fracturing of the rock mass may be present or can occur which allows for the introduction of groundwater into the disturbed zone adjacent to the engineered barriers.

4.3.1.1 How much, by what means, and from what sources (if any) is intrusion of water anticipated?

Potential intrusion of water can be classified according to quantity and flow. Sources of water intrusion could include unidentified boreholes, groundwater, and perched water table. Potential water intrusions and their impact on repository operations should be addressed.

4.3.2 What are the repository-induced changes which will cause water to contact the engineered barrier system?

Although the proposed repository horizon is above the groundwater table, the presence of perched water bearing zones is a possibility. The excavation of a repository, the applied thermal loads, and the construction of vertical shafts and borehole may enhance the flow of groundwater into the repository system. The changes in the natural conditions which may contribute to groundwater inflows need to be identified and their impacts assessed.

4.3.2.1 What effect does the excavation of openings have on rock fracturing and permeabilities in the rock mass surrounding the repository?

The excavation of the repository openings will change the in situ stress conditions in the repository horizon and the overlying strata. In overlying and surrounding strata, the change in stress may open existing fractures and enhance permeability. The magnitude of the permeability increase and its effect on inflows need to be identified.

4.3.2.2 What effects do the thermal gradients caused by waste emplacement have on rock fracturing and permeabilities in the rock mass surrounding the repository?

The response of the host medium and the surrounding strata to the imposed thermal loads should be defined in terms of fracture frequency and fracture opening. Expansion of the geologic materials may initially close some fractures. Subsequent cooling may result in the realization of some unrecoverable strains and resultant permeability enhancement. The effects of the thermal pulse on the fractures in the surrounding media and the groundwater in the host medium is needed to assess how water could contact the engineered barrier system.

4.3.2.3 How effective will the borehole and shaft seals be in mitigating water inflow to the engineered barriers?

The borehole and shaft seal design criteria should establish the limit value for inflows through the boreholes and shafts. Long term testing and monitoring of seal conditions may aid in quantifying expected inflows. The potential for inflows is greatest in most cases from these vertical connections to overlying water bearing strata. A logical program for assessing seal effectiveness will aid in ensuring performance confirmation.

4.3.2.4 What effect will the support and/or reinforcement system (if used) have on intrusion of water into the repository?

The presence of rock bolts, shotcrete and/or steel sets may alter the hydrologic conditions in the vicinity of the shaft and repository rooms. Whether these systems create preferential pathways for flow or may impede flow in the case of shotcrete needs to be assessed.

4.3.3 What are the expected effects over time of groundwater contacting the engineered barriers due to future events such as exploratory borehole drilling, faulting, groundwater migration, and boreholes and shaft seal failures?

Siting criteria are designed to limit the detrimental effects of future events. However, over the isolation/containment period, some geologic or human events may result in water reaching the engineered barriers. The events which could possibly lead to water inflows into the repository need to be identified, the inflow quantities estimated, and the consequences defined. The effect on the engineered barrier system need to be identified in terms of reduced performance and loss in isolation capability.

4.4 When and how does water contact the waste package?

The engineered barrier system includes the material surrounding the waste package. The timeframe in which water moves through the part of the engineered barrier system surrounding the waste package will affect the performance timeframe of the waste package and therefore, release rates from the repository.

4.4.1 What are the performance objectives of the engineered barrier system?

Since the performance of the engineered barrier system is based on meeting the EPA standard as part of the overall system, it is important to establish what the performance objectives will be for the engineered barrier system. By establishing what is expected with respect to performance, design criteria can be developed to meet those objectives.

4.4.1.1 What are the properties of the engineered barrier system?

The compatibility of the physical and chemical properties of the engineered barrier system to the tuff environment is an important consideration in design of the engineered barrier system. Therefore, it is important to identify the in situ properties of the engineered barriers in assessing performance of the system.

4.4.2 What are the effects over time of the thermal-hydrological-mechanical-chemical coupled processes on the engineered barrier system properties?

Changes to the engineered barrier system will occur due to the combined processes caused by waste emplacement. The impact of these changes on repository performance will have to be assessed.

4.4.2.1 What effect over time will the heat and radiation from the waste package have on the hydraulic conductivity, porosity, and permeability of the engineered barrier system?

Heat from the waste packages will cause an increase in temperature of the surrounding material. Temperature of this material will increase to a maximum and then gradually decrease. The effects of this thermal pulse on the hydrologic characteristics of the engineered barrier system will have to be assessed. Radiation from the waste package can adversely affect the properties of the engineered barrier system. Changes in characteristics could cause release rates of radionuclides through the engineered barrier system which exceed those specified in 10 CFR 60.113.

4.4.2.2 What effect over time will the regional stress field, radiation from waste package and anticipated creep rates have on the porosity, permeability and hydraulic conductivity of the engineered barrier system?

Changes in the in situ stress field and creep rates may adversely affect the properties of the engineered barrier system. These changes could cause release rates from the engineered barrier system which exceed 10 CFR Part 60 limits.

4.4.2.3 What effect over time will groundwater flow and the chemical composition of the groundwater have on the properties of the engineered barrier system.

Channeling in the engineered barrier system could occur due to groundwater flow in the underground facility after permanent closure. This could allow more water to contact the waste package and therefore affect performance. This could also allow for more releases of radionuclides through the engineered barrier system than was originally designed for. Chemical alterations due to chemical interactions with the groundwater could adversely affect the performance of the engineered barriers. Changes in hydraulic conductivity or sorption capacity would minimize the effectiveness of the engineered barriers.

4.5 <u>When, how, and at what rate are radionuclides released from the engineered barrier system?</u>

Limitation of the radionuclide release rate is a fundamental requirement for a geologic repository. The performance criteria for the engineered barrier system are given in Section 60.113 of 10 CFR Part 60. Before a license can be granted, there must be reasonable assurance that these criteria - that is, that releases of radioactive material and radiation dosages fall within the limits specified in 10 CFR 60.113 - will be met.

4.5.1 What characteristics of the engineered barrier system will control releases of radionuclides.

As part of identifying performance objectives for the engineered barrier system the characteristics of the materials to be used will be identified. It should be shown how these characteristics of the engineered barrier system will limit releases of radionuclides.

4.5.2 How will material placement methods be controlled to ensure that the engineered barrier system will meet its performance objectives?

Placement of the engineered barrier system materials can be a controlling factor in their performance. Proper control of placement methods must be maintained in order to obtain in situ characteristics of the engineered barrier system which will meet performance objectives.

4.5.3 What effects will thermal-hydrological-mechanical-chemical coupled processes have on the engineered barrier system materials characteristics, and thus the radionuclide release rate, over time?

Consideration must be given not only to characteristics of the emplaced engineered barrier system materials but also to the changes in those characteristics caused by repository induced processes.

Heat from the waste packages will cause an increase in temperature of the engineered barrier system. Material temperature will increase to a maximum and then gradually decrease. The effects of this heat pulse on the characteristics of the engineered barrier system will have to be assessed.

The in situ state of stress at the repository host rock is an important parameter in the assessment of engineered barrier system characteristics. Changes to the in situ state of stress due to repository effects must be considered in designing engineered barrier systems.

Chemical alterations due to chemical interactions with the groundwater could also adversely affect the performance of the engineered barriers system.

4.6 <u>When, how, and at what rate are radionuclides released from the disturbed zone?</u>

The repository, after permanent closure, will induce changes to the rock mass. The radial extent to which these changes could adversely affect repository performance is called the disturbed zone. It is important to know the mechanism and rate at which radionuclides will be released from the disturbed zone in order to predict releases to the accessible environment.

4.6.1 How will boreholes and shafts affect radionuclide release to the accessible environment?

Construction of shafts and boreholes in salt alters the natural setting and can create potential pathways for groundwater flow and consequently migration of radionuclides. Since these pathways could adversely affect the isolation capabilities of the repository over the long term, the NRC has required in 10 CFR Part 60 that boreholes and shafts be sealed at permanent closure of the facility. The characteristics of the seal system will be based on the amount of performance DOE will require of the seal system as part of the overall system.

4.6.1.1 What are the performance objectives for borehole and shaft seals?

The design criteria for the seal system will be based on the performance objectives for the system. These performance objectives will be a subpart of the performance objectives for the overall repository system. It is necessary to establish the performance requirements early on so the design and seal material development work can be accomplished.

4.6.1.2 What are the characteristics of the sealing materials and how will they be affected by the repository environment (geologic characteristics, water migration, and temperature,

The compatibility of the physical and chemical characteristics of the seal material to the host rock is an important consideration in seal design.

The effects of the repository environment on seal properties must be addressed.

4.6.1.3 How will the location and construction of shafts and boreholes in the controlled area affect the likelihood of radionuclide release to the accessible environment?

Perturbations to the regional grounwater could occur by sinking shafts and boreholes. These could cause adverse changes to groundwater flow. The location of shafts and boreholes must be considered in respect to how they could adversely affect groundwater flow.

4.6.1.4 What effect will construction of the shafts (e.g., rock damaged zone, liner effects) boreholes and exploratory testing have on the ability to seal these openings?

Construction of shafts, borehole drilling, and exploratory testing will change rock characteristics surrounding the openings. Potential effects are rock damage by excavation and stress redistribution around the opening. The effects of these phenomenon on the ability to seal the openings should be assessed.

4.6.1.5 How will placement methods be controlled to ensure that borehole and shaft seals will meet performance objectives?

The placement techniques used in sealing shafts and boreholes could be a controlling factor in seal performance. Reliability must be obtained in the methods and equipment used for the installation of the seal materials. The reproducibility of results using these methods and equipment must also be demonstrated. This should include field testing of emplacement methods and monitoring of performance of the emplaced seal over time.

4.6.2 How will borehole and shaft sealing affect radionuclide release to the accessible environment?

The NRC has required in 10 CFR Part 60 that boreholes and shafts be sealed at permanent closure of the facility. The sealing system is but one barrier which would contribute to the overall performance standard (the EPA standard) for the repository. The expected performance appropriate for the sealing system is greatly dependent upon design features and site characteristics.

4.6.2.1 What effect will rock mass instability and groundwater chemical interaction have on the integrity of the sealing system?

Possible rock mass instabilities could cause shearing of the system in shafts and boreholes. Effects of deformation on the seal materials and seal system will need to be assessed.

The compatibility of the chemical characteristics of the seal material and the host rock is an important consideration in seal design. Although incompatibility by itself may not be detrimental to the seal system, incompatibility could result in seal deterioration by chemical attack which could result in failure of the seal system. The site specific data of the host rock should be used to develop the seal design for each repository.

4.6.2.2 How will the sealing system prevent the interconnection of overlying aquifers, if any, with the repository shaft horizon?

The excavation of an opening can provide a pathway for groundwater from overlying aquifers into the repository horizon. Therefore, the seal system is very important in preventing inflow from overlying aquifers into the repository horizon.

4.6.3 How will the borehole and shaft seal system deterioration over time affect the radionuclide release rate?

The performance of the seal system over the life span of the repository continues to be an area of involving much uncertainty. The entire plug or seal system must perform satisfactorily over a service life which greatly exceeds the current norm. Tests must be developed and analyses must be performed to show that the seal system will perform for very long periods of time under adverse conditions similar to those which can reasonably be expected at a particular site.

4.6.4 What are the effects of thermal loading on the geomechanical properties of the rock in disturbed zone?

Thermal loading caused by the emplacement of waste in the repository will cause changes in the geomechanical properties in the surrounding rock. The amount and significance of these changes need to be assessed.

4.6.4.1 How do the changes in geomechanical properties of the host rock affect repository performance?

Changes in the geomechanical properties of the host rock could affect repository performance. Stability of the underground openings could be altered due to changes in fracture characteristics, rock strength, and stress distribution. The significance of these changes on repository performance should be assessed.