SITE TECHNICAL POSITION

Groundwater Issues
For The
Nevada Nuclear Waste Storage Investigations

NNWSI STP-1.0

DRAFT

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Division of Waste Management
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Background

In review of an application for Construction Authorization for a high-level waste geologic repository, the NRC staff is required to make a determination if the site and design meet the technical criteria of 10 CFR Part 60. The NRC staff determination will be based on the answers to, and supporting analyses of, technical questions concerning groundwater flow, geochemical retardation, waste form and waste package, geologic stability, and facility design. During the process of Site Characterization, the Department of Energy (DOE) performs the laboratory and field investigations that develop the information needed to address these basic technical questions.

Investigations needed to characterize a geologic repository are complex and involve long lead times. The Nuclear Waste Policy Act of 1982 (The Act) has established a schedule for site characterization and selection. Specifically, The Act 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 technical position papers will precede and supplement the SCA's.

Because of the complexity and long lead times for site characterization investigations, it is essential that activities be organized to make possible an NRC determination of site acceptability. Proper organization necessitates early identification of technical questions relevant to the specific site. Therefore, this document establishes the NRC position as to the essential technical questions (specific issues) relevant to groundwater at the Nevada Nuclear Waste Storage Investigations (NNWSI) site. Future Site Technical Positions relevent to groundwater will address both

NRC staff concerns regarding selected specific issues and acceptable technical approaches for addressing those specific issues.

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

Site issues are defined as questions about a specific site that must be answered or resolved to complete licensing assessments of the site and design suitability in terms of 10 CFR 60. Site issues are not necessarily controversial questions. 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, waste package, geologic setting). Performance issues are derived directly from performance objectives in 10 CFR 60 (including environmental objectives of 10 CFR 51). Development of 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 generally are questions about conditions and processes (information needed) that must be considered in assessing the performance issues. Performance issues include the integration of numerous specific issues. Performance issues establish the relationship between specific issues discussed in this Site Technical Position and the performance objectives of 10 CFR 60.

Performance issues for a geologic repository, as developed in NUREG-0960 are:

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 do the design criteria and conceptual design accomodate 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 disturbed zone?

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

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

12. Have the NEPA Environmental/Institutional/Siting requirements for nuclear facilities been met?

Because groundwater is a primary transporting agent for radionuclide migration, information on the groundwater system collected during site characterization at NNWSI will be part of the total repository system information needs of the NRC staff required to assess the performance issues. Specific issues identified in the following section delineate information on groundwater at NNWSI needed by the NRC staff to assess adequately the performance issues. The sequential order in which issues are identified 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 10 CFR 60 requires that, at a minimum, the following specific issues concerning groundwater be addressed.

1.0 Groundwater

1.1 What is the nature of the present groundwater system?

1.1.1 What is the conceptual model(s) of the present regional groundwater system?

1.1.1.1 What are the regional boundaries, boundary conditions, recharge and discharge locations, and mechanisms and amounts of recharge that are significant to estimating the hydrogeologic conditions surrounding Yucca Mountain?

1.1.1.2 What are the distributions of measured and interpolated hydrogeologic parameters?

1.1.2 What is the conceptual model(s) of the present Yucca Mountain sub-regional groundwater system (including the near-field)?

1.1.2.1 What are the hydrogeologic limits of the Yucca Mountain groundwater system that are significant to repository performance?

1.1.2.2 What are the recharge and discharge locations, mechanisms, and amounts for the Yucca Mountain groundwater system?

1.1.2.3 What is the hydrochemistry of the Yucca Mountain groundwater system?

1.1.2.4 What is the relationship between the Yucca Mountain groundwater system and any deeper, regional system?

1.1.2.5 What are the hydrogeologic units within that portion of the Yucca Mountain groundwater system that constitutes the unsaturated zone?

1.1.2.5.1 What are the hydrogeologic processes and important hydrogeologic parameters in the unsaturated zone?

1.1.2.5.2 What is the three-dimensional distribution of both measured and interpolated hydrogeologic parameters in the unsaturated zone?

1.1.2.5.3 How and to what extent is groundwater flow in the unsaturated zone affected by structural, hydrostratigraphic and lithologic heterogeneities?

1.1.2.6 What are the hydrogeologic units within that portion of the Yucca Mountain groundwater system that constitutes the saturated zone?

1.1.2.6.1 What are the hydrogeologic processes and important hydrogeologic parameters in the saturated zone?

1.1.2.6.2 What is the three-dimensional distribution of both measured and interpolated hydrogeologic parameters in the saturated zone?

1.1.2.6.3 How and to what extent is groundwater flow in the saturated zone affected by structural, hydrostratigraphic and lithologic heterogeneities?

1.1.3 What mathematical models are used to predict groundwater flow?

1.2 What are the types, probabilities, and nature of natural changes that would affect groundwater flow?

1.2.1 What are the types, probabilities, and nature of climatic changes that would affect groundwater flow?

1.3 What are the types, probabilities, and nature of human-induced changes (excepting repository-induced changes) that would affect groundwater flow?

1.3.1 How does the value of water resources in the area compare with values in other surrounding areas of similar size, and what is the potential for future use?

1.3.2 What are the types, probabilities and nature of water resource development and use that would affect groundwater flow?

1.3.3 What are the types and probabilities of exploratory drilling, mine development or other similar human activities that would affect groundwater flow?

1.4 What are the expected effects over time on groundwater flow paths, velocities and/or fluxes, discharge rates and travel times resulting from repository-induced changes (including underground facility construction, borehole and/or shaft seal failure, thermodynamics, thermal effects on moisture movement and long-term stability, and alteration of fracture filling minerals)?

1.5 What are the expected effects over time on groundwater flow paths, velocities and/or fluxes, discharge rates and travel times of human-induced changes, excepting repository-induced changes (including water resource development, exploratory drilling, mine development for resources or other human activities)?

1.6 What are the expected effects over time on groundwater flow paths, velocities and/or fluxes, discharge rates and travel times resulting from natural changes (including climate, structure, and tectonic stress)?

Discussion

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

1.1 What is the nature of the present groundwater system?

Groundwater is the primary transporting agent for radionuclide migration from a geologic, high-level waste repository. Specifically, 10 CFR 60 requires

- That radionuclide releases conform to such generally applicable standards established by the EPA (§60.112, Performance Objective)

- A specified pre-waste-emplacement groundwater travel time from the disturbed zone to the accessible environment. (§60.113(a)(2), geologic setting)

- That repository siting criteria address a wide range of potentially favorable and unfavorable conditions (§60.122(b) and (c), respectively).*

Evaluation of these requirements depend on an understanding of the components of the groundwater system which are identified, relative to varying levels of scale and detail, in the following issues.

1.1.1 What is the conceptual model(s) of the present regional groundwater system?

The conceptual model of the regional groundwater system, which includes Yucca Mountain, provides the hydrogeologic framework for interpreting the distribution of recharge and discharge areas, general order of magnitude regional flux, and general configuration of the groundwater flow system. It also provides a basis for quantitative, deterministic models of all or portions of the groundwater flow system of which Yucca Mountain is a part.

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*NOTE: Proposed criteria (60.122(b)(7), and (c)) specifically written for the unsaturated zone have been developed and will be issued shortly for public comment. The technical rationale in support of these proposed criteria and which also addresses public comments received in this subject area is presently under development.

1.1.1.1 What are the regional boundaries, boundary conditions, recharge and discharge locations, and mechanisms and amounts of recharge that are significant to estimating the hydrogeologic conditions surrounding Yucca Mountain?

This is the information necessary to estimate the mass balance of the regional groundwater system as well as to establish the general characteristics of groundwater flow into and out of the Yucca Mountain area.

1.1.1.2 What are the distributions of measured and interpolated hydrogeologic parameters?

Flow paths and flow rates are in part a function of the hydraulic properties of an aquifer. The distribution of measured and interpolated hydraulic properties reflect the heterogeneities of the groundwater system. Consequently, these properties will determine to a large extent flow paths and travel times. Measured values are generally more reliable than values obtained indirectly but it is impossible to measure hydrogeologic parameters everywhere, therefore interpolated values or values obtained indirectly from models also must be used in some calculations. An areal description of hydraulic head is necessary to establish hydraulic gradients used in travel time calculations. Hydraulic heads will be used as initial conditions in any quantitative modeling process.

1.1.2 What is the conceptual model(s) of the present Yucca Mountain sub-regional groundwater system (including the near-field)?

Conceptual models are the basis for any quantitative calculation of either groundwater travel times or radionuclide release rates from the repository to the accessible environment. Conceptual models also will serve as the basis for assessing the effect of potential, future perturbations of the groundwater system on groundwater travel times or radionuclide release rates.

Conceptual models of the Yucca Mountain area groundwater flow system are essential to the analysis of both the saturated and unsaturated zones. These conceptual models should be based on sufficient hydrogeologic data derived from the characterization of all aspects of the flow system which significantly influence pre-emplacement groundwater travel times and post-emplacement radionuclide transport from the repository to the accessible environment. All defensible conceptual models of the groundwater flow system need to be enumerated and analyzed.

1.1.2.1 What are the hydrogeologic limits of the Yucca Mountain groundwater system that are significant to repository performance?

Both the unsaturated and saturated environments in Yucca Mountain are expected to have dynamic flow systems. The extent of the flow system from the repository to the accessible environment should be defined. Hydrogeologic conditions both within the flow system and at any boundaries defined when quantifying conceptual models should be determined accurately because these conditions are critical to the calculation of groundwater travel times and transport rate of radionuclides.

1.1.2.2 What are the recharge and discharge locations, mechanisms, and amounts for the Yucca Mountain groundwater system?

The temporal and spatial distribution and rate of recharge and discharge to the groundwater flow system within Yucca Mountain controls, to a large extent, the flux of groundwater in both the unsaturated and saturated zones. The analysis of groundwater flux helps to define the expectable repository impacts because the flux determines the travel time to the accessible environment.

1.1.2.3 What is the hydrochemistry of the Yucca Mountain groundwater system?

In the potentially complex hydrogeologic terrain of Yucca Mountain, delineations of flow paths, travel times, and sources of moisture may be facilitated or supported by the hydrochemistry of the flow systems within both the saturated and unsaturated zones. Valid conceptual models should depend on the interpretation of hydrochemistry and hydrogeology. However, hydrochemical data alone are insufficient as the basis for understanding a flow system.

Hydrochemical data are required also for radionuclide transport considerations. Dissolved ion interactions are important to dissolution and precipitation of radionuclides. Geochemical issues are identified in Site Technical Position 3.0, Geochemistry Issues for the Nevada Nuclear Waste Storage Investigations.

1.1.2.4 What is the relationship between the Yucca Mountain groundwater system and any deeper, regional system?

The identification of all existing groundwater systems is important to an evaluation of long term repository site performance. Deep carbonate rocks beneath and in the vicinity of Yucca Mountain are known to influence regional groundwater flow. Flow paths in the carbonate rock aquifer system are long; transmissivities are relatively high, and regional discharge areas may be localized. An underlying carbonate aquifer, if present, may constitute the most rapid flow path to the accessible environment.

1.1.2.5 What are the hydrogeologic units within that portion of the Yucca Mountain groundwater system that constitutes the unsaturated zone?

In general, the Yucca Mountain groundwater system can be divided into two distinct zones separated by a water table, although this distinction will become more complex if zones of perched water are proven to occur in significant amounts. The unsaturated zone, above the water table, requires a separate evaluation in which emphasis is placed on characterizing those properties which are most important to its conceptualization. Further division of the unsaturated zone into specific hydrogeologic units is necessary to provide a more detailed and accurate picture of the flow system and to permit interpolation of measured data. Those hydrogeologic units susceptible to perched water conditions should be identified. The relationships between hydrogeologic units are fundamental to determining repository performance.

1.1.2.5.1 What are the hydrogeolgic processes and important hydrogeologic parameters in the unsaturated zone?

Groundwater flow rates are a function of the hydraulic properties of, and processes occurring within, the aquifer. Our ability to analyze groundwater movement in deep unsaturated zones is not as sophisticated as our ability to analyze saturated flow. Thus, it is necessary to identify thoroughly the important physical processes to be incorporated in the conceptual model of the unsaturated zone. Hydrogeologic parameters relevant to these processes should then be identified and measured for each hydrogeologic unit in which they are important.

1.1.2.5.2 What is the three-dimensional distribution of both measured and interpolated hydrogeolgic parameters in the unsaturated zone?

The distribution of measured hydrogeologic parameters in the unsaturated zone will play an important role in determining the reliability (uncertainty) of analyses of groundwater flow paths and travel times. Such considerations are important in the structurally and lithologically heterogeneous fractured terrain of the Yucca Mountain area.

1.1.2.5.3 How and to what extent is groundwater flow in the unsaturated zone affected by structural, hydrostratigraphic and lithologic heterogeneities?

The extent or degree of control of groundwater flow rates and directions by structural, hydrostratigraphic and lithologic heterogeneities influences the confidence, or lack thereof, in demonstrated flow paths and travel times based on a given set of measured data. It is important to determine the presence or absence of fractures within the unsaturated zone. Where they are present, their hydraulic function needs to be understood. It is important also to determine the presence or absence of zones of perched water and if present, delineate the extent of such zones. This specific issue, in concert with Issue 1.1.2.5.2, relates directly to identifying representative elemental volumes of fractured rock wherein similar values of effective porosity and unsaturated hydraulic conductivity should be expected.

1.1.2.6 What are the hydrogeologic units within that portion of the Yucca Mountain groundwater system that constitutes the saturated zone?

As stated previously, the Yucca Mountain groundwater system can be divided generally into two distinct zones separated by a water table. The saturated zone, below the water table, requires a separate evaluation so that emphasis may be placed on characterizing those properties which are most important to its conceptualization. Further division of the zone into specific hydrogeologic units is necessary to provide a more detailed and accurate picture of the flow system and to permit interpolation of measured data.

1.1.2.6.1 What are the hydrogeologic processes and important hydrogeologic parameters in the saturated zone?

The need for this type of information pertaining to the unsaturated zone was discussed previously under Issue 1.1.2.5.1. Although the movement of water is driven by the same physical forces (e.g. energy gradients) whether in a saturated or unsaturated environment, there are basic differences in the nature of hydrogeologic parameters which define water flow. The methods and techniques used to characterize these parameters in the two zones also differ. For example, in the unsaturated zone hydraulic conductivity is a function of moisture content. In the saturated zone hydraulic conductivity is constant with respect to moisture content. Therefore, development of an understanding of relationships between the hydrogeologic processes and related hydrogeologic parameters is fundamental to determination of site safety and compliance with performance criteria.

1.1.2.6.2 What is the three-dimensional distribution of both measured and interpolated hydrologeologic parameters in the saturated zone?

The three-dimensional distribution of measured hydrogeologic parameters in the saturated zone will play an important role in determining the reliability (uncertainty) of analyses of groundwater flow paths and travel times because the distribution of measured parameters will determine essentially the geometry of flow paths and travel times as predicted by quantitative models. The distribution of data will be important in the structurally and lithologically heterogeneous, fractured terrain of the Yucca Mountain area. Interpolated values, if judged to be reliable, can be useful in supplementing field data.

In addition, the three-dimensional distribution of measured hydraulic head is important not only in establishing hydraulic gradients necessary for travel time calculations but in establishing the characteristics of vertical flow.

Hydraulic head distribution is necessary in any quantitative modeling process.

1.1.2.6.3 How and to what extent is groundwater flow in the saturated zone affected by structural, hydrostratigraphic and lithologic heterogeneities?

Heterogeneities of lithology, structure or more generally, hydrostratigraphy are potentially the most important factors governing the groundwater flow rates and directions in the saturated zone of the Yucca Mountain area. The extent to which the saturated zone is heterogeneous will determine the confidence in deterministic model flow paths and travel times for a given distribution and density of field data. This issue, in conjunction with Issue 1.1.2.6.2, influences the definition of representative elemental volumes of fractured rock which display similar hydrogeologic characteristics.

1.1.3 What mathematical model(s) are used to predict groundwater flow?

Mathematical models serve two purposes: First, they quantify conceptual models of groundwater flow and they verify compatibility of conceptual models with field measurements. Second, they can predict the future migration rate of radionuclides. It is necessary to show that the mathematical model(s) used are applicable to the site (representative of the physics of the hydrogeological processes being described). Mathematical models frequently are embodied in computer codes.

1.2 What are the types, probabilities, and nature of natural changes that would affect groundwater flow?

Natural processes which may change site conditions in the future and that would change the existing groundwater system need to be considered in determining whether long term performance of the repository will comply with radionuclide release standards. Identification of the types of processes is the necessary first step. Determining probabilities of occurrence of the various types of processes identified is the next step; this step may facilitate the elimination of some processes from further consideration. The nature of these changes is the necessary base for consequence assessment (see Issue 1.6).

1.2.1 What are the types, probabilities, and nature of climatic changes that would affect groundwater flow?

Climatic variations are known to be important natural changes that could affect groundwater flow. Changes in climate have occurred in the past over the same lengths of time in which repository performance will be assessed. Pluvial climates of the Great Basin increased the availability of moisture for runoff and associated hydrologic effects. Therefore, climatic changes which can affect travel times, flow paths and radionuclide releases need to be identified, quantified, and evaluated with respect to probability of occurrence and importance. This serves as a basis for consequence assessment (see Issue 1.6).

1.3 What are the types, probabilities, and nature of human-induced changes (excepting repository-induced changes) that would affect groundwater flow?

Human-induced changes that would affect groundwater flow need to be considered in assessing long term repository performance. Identification of the types of changes, probability of occurrence, and description of the nature of the changes are necessary. If warranted based on probability of occurrence, an assessment of the effects on repository performance also is necessary (see Issue 1.5). Information provided by studies addressing this issue provides the basis for consequence assessment.

1.3.1 How does the value of water resources in the area compare with values in other surrounding areas of similar size, and what is the potential for future use?

Evaluation of the value of water resources within and surrounding the Yucca Mountain area coupled with the historical development of water demand will provide a basis for establishing the probablity and potential magnitude of future water resource development which could impact repository performance.

1.3.2 What are the types, probabilities and nature of water resource development and use that would affect groundwater flow?

Groundwater and surface water exploitation or manipulation could affect groundwater flow rates and paths. Identification of the types water use activities that might occur as well as determination of the probabilities and nature of those water use activities provides a basis for determining necessary consequence assessments (see Issue 1.5).

1.3.3 What are the types and probabilities of exploratory drilling, mine development or other similar human activities that would affect groundwater flow?

Penetration of the land surface is a recognized mode of human-induced change which could impact repository performance. Identification of the types as well as determination of the probabilities of such human activities provides a basis for determining necessary consequence assessments (see Issue 1.5).

1.4 What are the expected effects over time on groundwater flow paths, velocities and/or fluxes, discharge rates and travel times resulting from repository-induced changes (including underground facility construction, borehole and/or shaft seal failure, thermodynamics, thermal effects on moisture movement and long-term stability, and alteration of fracture filling minerals)?

During the process of developing the repository, physical changes will be made in the repository block. In addition, during and after waste emplacement, thermal effects will begin to affect the moisture regime of the repository environment. For example, the environment of the repository (fractured tuffs in the unsaturated zone) creates the potential for moisture migration in both liquid and vapor phases along fractures, faults or other pathways of preferential permeability. The thermal effects may create physical environments in which some minerals become unstable. Considerations such as these should be assessed with respect to the effect on repository performance.

1.5 What are the expected effects over time on groundwater flow paths, velocities and/or fluxes, discharge rates, and travel times of human-induced changes, excepting repository-induced changes (including water resource development, exploratory drilling, mine development for resources or other human activities)?

The expected effects of plausible human-induced changes over time on groundwater flow paths, velocities and/or fluxes, discharge rates and travel times relates directly to the calculation of repository performance as required by 10 CFR 60 and EPA performance standards.

1.6 What are the expected effects over time on groundwater flow paths, velocities and/or fluxes, discharge rates, and travel times resulting from natural changes (including climate, structure, and tectonic stress)?

The expected effects of plausible natural changes over time on groundwater flow paths, velocities and/or fluxes, discharge rates and travel times relates directly to the calculation of repository performance as required by 10 CFR 60 and EPA performance standards.