SITE TECHNICAL POSITION

Groundwater Issues
For The
Nevada Nuclear Waste Storage Investigations

NNWSI STP-1.0

DRAFT

Division of Waste Management
U.S. Nuclear Regulatory Commission

United States Nuclear Regulatory Commission
High-Level Waste Technical Development Branch

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Background

In review of an application for a Construction Authorization for any 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. This process includes preparation of formal Site Characterization Analyses (SCAs) by NRC staff. Supplementing and preceding the SCAs are documented site reviews and technical meetings, and single-issue site technical positions.

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

Terminology used by NRC staff to describe issues may require clarification. A site issue is defined as a question 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 are, generally, questions about conditions and processes (information needed) that must be considered in assessing the performance issues. Therefore, performance issues include the integration of numerous specific issues thus establishing 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 these same performance issues. Specific issues identified in the following section indicate, in a broad but complete manner, 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 relative order of importance.

Technical Position

It is the position of the NRC staff that based on our current level of knowledge of NNWSI, 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, mechanisms and amounts 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 is the extent of the Yucca Mountain groundwater system significant to repository performance and the existing hydrogeological conditions therein?

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 constituting 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 constituting 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 are the mathematical models 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 that would affect ground water flow?

1.3.3 What are the types, probabilities and nature of exploratory drilling, mine development for resources or other human penetrations that would affect groundwater flow?

1.4 What are the expected effects over time on groundwater flow paths, velocities, discharges and travel times resulting from repository-induced changes (including underground facility construction, borehole 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, discharges, and travel times resulting from human-induced changes, excepting repository-induced changes (including water resource development, exploratory drilling, mine development for resources or other human penetrations)?

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

<u>Discussion</u>

In this discussion, the rationale for each issue is described.

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

- Evaluation of radionuclide release for comparison with the EPA standard (§60.112, Performance Objective)

- Evaluation of undisturbed groundwater travel time (§60.113(a)(2), geologic setting)

- Evaluation of a wide range of potentially favorable and unfavorable conditions (§60.112(b) and (c), respectively).

These evaluations 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 understanding the distribution of recharge and discharge areas, general order of magnitude regional flux, and general configuration of the groundwater system. It also provides a basis for quantitative models by establishing general boundary conditons.

1.1.1.1 What are the regional boundaries, boundary conditions, recharge and discharge locations, mechanisms and amounts 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 to and from the Yucca Mountain area.

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

Flow paths and rates are a function of the physical properties of an aquifer. The distribution of measured and interpolated parameters describe the heterogeneities of the groundwater system and thus will determine the reliability, or uncertainty, of flow paths and travel times. Measured values are generally more reliable than estimates but it is impossible to measure hydrogeologic parameters everywhere, therefore interpolated values must also 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 and in any quantitative model calibration process.

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

The conceptual model is the basis for any quantitative evalution of either groundwater travel times or radionuclide release rates from the repository to the accessible environment. The conceptual model will also serve as the basis for assessing the effect of potential, future perturbations of the groundwater system on groundwater travel times or radionuclide release rates.

A valid conceptual model of the Yucca Mountain area groundwater flow system is important for 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 radionuclide transport from the repository to the accessible environment.

1.1.2.1 What is the extent of the Yucca Mountain groundwater system significant to repository performance and the existing hydrogeological conditions therein?

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

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

The distribution, mechanics, and amount 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 groundwater flux helps to define the expectable repository impacts by relating directly to mass rate of flow to the accessible environment, and travel times.

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

In the potentially complex hydrogeologic terrain of Yucca Mountain, determinations of flow paths, travel times, and sources of moisture (e.g. conceptual model) may be indicated or supported by the hydrochemistry of the flow systems within both the saturated and unsaturated zones. Valid conceptual models should depend on the combination of hydrochemistry and hydrogeology. 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 near the Yucca Mountain area are known to be involved in regional groundwater flow. Flow paths in the carbonate rock aquifer system are long; transmissivities are relatively high, and regional discharge areas probably are localized.

An underlying carbonate aquifer, if present, may be the fastest path to the accessible environment. An understanding of potential, vertical components of flow in the saturated tuff will be most useful in assessing this issue.

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

The Yucca Mountain groundwater system can be divided into two distinct zones separated by a water table. The unsaturated zone, above 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 unsaturated zone into specific hydrogeologic units is necessary to provide a more detailed and accurate picture of the flow system and permit interpolation of measured data. 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 physical properties of, and processes occurring within, the aquifer. Our understanding of groundwater movement in deep unsaturated zones is not as advanced as our understanding of saturated flow. Thus, it is necessary that DOE identify correctly 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 varied, 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 also determines the confidence, or lack thereof, in demonstrating flow paths and travel times for a given density 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. This specific issue, in concert with Issue 1.1.2.5.2, relates directly to identifying representative elemental volumes of fractured rock which display similar hydrogeologic behavior in terms of effective porosity and unsaturated hydraulic conductivity.

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

As stated previously, the Yucca Mountain groundwater system can be divided 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 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, albeit relative 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 as well as in the methods and techniques used to characterize these parameters. For example, hydraulic conductivity is a function of degree of saturation. By definition, hydraulic conductivity will be a constant with respect to moisture content in the saturated zone but will be a variable parameter in similar respect to the unsaturated zone. 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 varied, fractured terrain of the Yucca Mountain area. Interpolated values, if judged to be reliable, can be useful in supplementing data sets.

In addition, the three-dimensional description of hydraulic head is important not only in establishing hydraulic gradients used in travel time calculations but in establishing the importance of vertical flow (refer to Issue 1.1.2.4). Hydraulic heads are necessary in any quantitative model calibration 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 that are a function of lithology, structure or more generally, hydrostratigraphy are potentially the most important factors in controlling the groundwater flow rates and directions in the saturated zone of the Yucca Mountain area. The extent or degree of such control will be a factor in determining the confidence in deterministic flow paths and travel times for a given distribution and density of field data. This issue, concomitant with Issue 1.1.2.6.2, relates directly to identifying representative elemental volumes of fractured rock which display similar hydrogeologic behavior in terms of effective porosity and permeability.

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

Mathematical models are needed for two purposes: First, to quantify conceptual models of groundwater flow and verify their self-consistency and agreement with measurements, and, second, to predict the future transport of radionuclides. It is necessary for the DOE to show that the model(s) are applicable to the site (representative of the physics of the hydrogeological processes being described). Mathematical models are frequently 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 in the future and that would affect 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 identified is the next step and may make it possible to eliminate some processes from further consideration. Describing 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?

Of the natural changes that would affect groundwater flow, climatic variations are known to be important. Changes in climate have occurred over the same time frame as required for assessing repository performance. 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 as 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, determination of 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 is also 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 that would affect groundwater flow?

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

1.3.3 What are the types, probabilities and nature of exploratory drilling, mine development for resources or other human penetrations that would affect groundwater flow?

A recognized mode of human-induced changes is penetration of the land surface. Penetration could impact repository performance. Identification of the types as well as determination of the probabilities and nature of human penetrations 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, discharges and travel times resulting from repository-induced changes (including underground facility construction, borehold 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. 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 alteration minerals become unstable. Considerations such as these should be assessed as to the effect on repository performance.

1.5 What are the expected effects over time on groundwater flow paths, velocities, discharges, and travel times resulting from human-induced changes, excepting repository-induced changes (including water resource development, exploratory drilling, mine development for resources or other human penetrations)?

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