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MEMORANDUM FOR: Robert E. Browning, Director
Division of Waste Management, NMSS

FROM: Malcolm R. Knapp, Chief
Geotechnical Branch
Division of Waste Management

SUBJECT: DRAFT UMBRELLA SITE TECHNICAL POSITION ON GEOLOGY FOR NNWSI

Enclosed is the Draft Umbrella Site Technical Position on geology for NNWSI. This Umbrella STP was prepared to fulfill operating plan milestone 5314216.112.

This document is being distributed to the Engineering Branch for technical comments and to the Repository Projects Branch for a general review for consistency. All comments should be forwarded to Phil Justus to be incorporated into the draft for external review.

/S/

Malcolm R. Knapp, Chief
Geotechnical Branch
Division of Waste Management, NMSS

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| NAME | :JTrapp | : | : | :PJustus | :JStarmer | :JPohle | :MKnapp |
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United States Nuclear Regulatory Commission
Geotechnical Branch

# Site Technical Position - Geologic Issues For The Nevada Nuclear Waste Storage Investigations (NNWSI)

## Background

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

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

This document establishes the NRC position as to the generic geologic technical issues with regard to NNWSI. Future Site Technical Positions will address NRC staff concerns regarding both selected site specific issues and acceptable technical approaches for addressing those issues.

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

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

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

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

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

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

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

3. When and how does water contact the backfill?

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

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

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

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

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

9. When, how, and at what rate are radionuclides released from the disturbed zone?

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

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

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

To resolve these issues as they pertain to NNWSI requires a knowledge of the geomorphology, stratigraphy, structural geology, seismology, and geophysics of the proposed site and its surrounding region. In order to provide a framework for the proper geologic evaluation of NNWSI, 5 specific issues and 15 sub-issues have been developed. These issues, which are identified in the following section, identify the generic geologic questions that need to be

resolved and information needs required so that the NRC staff can adequately assess the performance issues.

The order of these issues should not be interpreted as the order of relative importance.

Technical Position

It is the position of the NRC staff that assessment of the technical criteria in 10 CFR Part 60 requires that, at a minimum, the following geologic issues should be addressed for NNWSI:

5.1 How does the geomorphic setting affect waste isolation?

- 5.1.1. What is the present geomorphic setting?
- 5.1.2. What are the nature and rates of present or projected geomorphic processes?
- 5.1.3. What would be the effect on the site of the projected geomorphic processes?

5.2. How does the stratigraphic setting affect waste isolation?

- 5.2.1. What is the present stratigraphic setting?
- 5.2.2. What anticipated and unanticipated processes and events could change the stratigraphic setting?
- 5.2.3. What would be the effect on waste isolation of the projected changes in the stratigraphic setting?

5.3. How does the structural/tectonic setting affect waste isolation?

- 5.3.1. What is the present structural/tectonic setting?
- 5.3.2. What are the nature and rates of present or projected tectonic processes?
- 5.3.3. What would be the effect on the site of the projected tectonic activity?

5.4 How does seismic activity affect waste isolation?

- 5.4.1. What is the nature of seismic activity which has occurred and is occurring in the site region?
- 5.4.2. What is the rate of seismic activity which has occurred and is occurring in the site region?
- 5.4.3. What would be the effect of the postulated seismic events at the site?

5.5 How does human intrusion affect waste isolation?

- 5.5.1. What is the nature of human intrusion activities which have

occurred in the site vicinity?

5.5.2. What is the nature of human intrusion activities which could be projected to occur in the site vicinity?

5.5.3 What would be the effect on the site of the potential human intrusion activities?

The relationship between the geological issues and performance issues is presented in Table 1.

DISCUSSION

The rationale for each issue is presented in the following sections:

5.1 How does the geomorphic setting affect waste isolation?

Geomorphic features directly affect the groundwater flow regime, the chemistry of the groundwater, rate of erosion and deposition, and are often indicators of the local and regional structural geology. The rate of erosion subsequently affects the possibility that the waste package will be exhumed and has an impact on the potential for seismic activity and fault motion due to isostatic adjustment. The nature and rate of all processes must be shown to have no significant affect on waste isolation. The geomorphic features and processes shown to be important in the operational phase must serve as input into the design requirements and therefore will provide information which will be required primarily to satisfy 10 CFR 60.131 and 60.132 and, to a lesser extent, 60.133, 60.134 and 60.135.

Long and short term geomorphic processes must also be understood, as any change in the current geomorphic setting will determine the ability of the site to adequately contain waste during the post-closure period. The effects of these processes over time should be evaluated in light of anticipated climatic variations and potential tectonic activity.

This information is required in order to satisfy 10 CFR 60.131 and 60.132 and to a lesser extent 60.133,60.134 and 60.135. The three sub-issues under Geomorphology are organized to assure that the setting is described, the nature and rates of processes which have or could affect the site are known and the affect on the site has been addressed.

5.1.1. What is the present geomorphic setting?

To understand the geomorphology of a site, it is necessary that a description of the setting be provided. While 10 CFR 60 emphasizes dissolution and erosion (60.122(c)(10) and 60.122(c)(16)), the geomorphic regime must be known in sufficient detail to meet all the requirements of 60.122(a)(2)(i). The specific information needs are as follows:

- 0 Characteristics of the physiographic province in which the site is located.
- 0 Characteristics of the physiographic/geomorphic units and features in the vicinity of the site.
- 0 Relationships between the present geomorphic features and processes and the structural/tectonic features.

5.1.2. What are the nature and rates of present or projected geomorphic processes?

The major emphasis on understanding geomorphic processes and rates must rely on projection of Quaternary processes and events as specified by 60.122(b)(1). Nonetheless, human activity and natural events can both have a profound effect on the geomorphology and must be evaluated. Flood plain occupation, for instance, is a human activity that could drastically alter geomorphic processes and features. Natural events, such as changes in climatic conditions or accelerated rates of tectonic activity, could have a similarly profound effect. In addition, the excavation, construction and operation of the waste repository will have local geomorphic ramifications which must be addressed. The information needs are as follows:

- 0 The nature and rates of erosion and deposition in the site vicinity throughout the Quaternary.
- 0 The nature and rates of mass wasting in the site vicinity throughout the Quaternary.
- 0 The climatic regime throughout the Quaternary.
- 0 The nature of fluvial processes throughout the Quaternary.
- 0 The nature of pluvial lakes within the site vicinity.
- 0 The nature of tectonic activity which could modify existing geomorphic processes or features.
- 0 The potential for, and nature of, human activity which could modify geomorphic processes or features.
- 0 The effects of repository construction, operation and closure on the geomorphic features and processes.

5.1.3. What would be the effect on the site of the projected geomorphic processes?

Those effects of the geomorphic processes shown to be significant during the operational phase will need to be accommodated by proper design and must be adequately evaluated (see 60.122 (a)(ii) and 60.122 (a)(iii)). It is, however, especially important to identify those geomorphic processes and features which affect the post-closure period in order to determine their impact on long term waste isolation. The information needs are as follows:

- 0 The probability of erosion changing the surface water flow regime and thereby modifying erosional and depositional processes.

- 0 The probability of erosion exhuming the waste.
- 0 The probability of flooding or mass wastage in the operations area due to geomorphic activities.
- 0 The probability and nature of glacial events which could modify the geomorphic regime.
- 0 The potential for climatic change.

5.2. How does the stratigraphic setting affect waste isolation?

A stratigraphic unit with spatial, chemical, and physical properties appropriate to the effective isolation of waste must be identified. The three-dimensional geometry of the stratigraphic units at the site is a primary information need for the modeling of groundwater flow in the site area. The mineralogy and petrology of the host unit and surrounding units will affect geochemistry of the groundwater and therefore ultimately affect radionuclide transport. The physical properties of the stratigraphic units (ie. the presence of rock fabric, vesicles, or fracture sets) will affect the direction and magnitude of the hydraulic conductivity as well as help to predict the potential for, and effect of, tectonic or seismic activity in the vicinity of the site. The physical static and dynamic properties of the individual stratigraphic units, along with a description of the type, quantity, and extent of all testing undertaken which could affect engineering design parameters for repository siting and construction, is required.

5.2.1. What is the present stratigraphic setting?

The stratigraphic setting of the proposed site must be described in sufficient detail to satisfy the requirements of 60.111, 60.131, 60.132, 60.133, 60.134, and 60.135. The characteristics of each unit which have a bearing on fluid flow and transport, and therefore determine compliance with 60.112 and 60.113, should be emphasized. The information must be presented so that a clear relationship between rock stratigraphic, hydrostratigraphic, engineering stratigraphic, and lithotectonic units is established. The following information needs pertain to the regional stratigraphic setting, the local stratigraphic setting, the stratigraphy of the repository horizon, and the stratigraphy surrounding proposed shafts. Successively greater levels of detail are required in describing the regional, local, and repository horizon respectively. The information needs are:

- 0 The definition of stratigraphic units (formations and members) on a regional scale and locally within the site.
- 0 The three-dimensional geometry of the defined units within the regional setting, repository site and repository horizon.
- 0 The sedimentological, chemical, static, dynamic and index characteristics of the defined units in the region, site and proposed shafts, along with the spatial variations in these characteristics.

- 0 The groundwater conditions within these defined units.
- 0 The depositional or emplacement history of the defined units.
- 0 The post- and syndepositional alterations which have occurred in the regional and repository site units.
- 0 The effect of diagenesis or metamorphism on each unit (if any).
- 0 The mineralogy and petrology of each unit.
- 0 The presence or absence of rock fabric, foliation, joint and fracture sets, vesicles, or any other intraformational structure which may affect rock strength or anisotropy (with respect to fluid flow or tectonic activity).
- 0 The nature of discontinuities, especially zones of structural weakness within the region and repository site.
- 0 The nature of the bedrock surface, depth of weathering, and potential unrelieved residual stress.

5.2.2. What anticipated and unanticipated proccesses and events operation could change the stratigraphic setting?

Any change in the stratigraphic setting in the vicinity of the site might affect the ability of the repository horizon to contain the waste or significantly alter the groundwater flow regime. Natural events which have the potential to change the stratigraphic setting at NNWSI, such as tectonic/volcanologic or mass wasting, must be evaluated. Human activities or repository construction could alter the stratigraphic setting by changing drainage patterns or groundwater chemistry in such a way that the stability of one or more units is jeopardized. The information needs are:

- 0 The response of the units to ambient conditions.
- 0 The response of the units to anticipated and unanticipated proccesses and events.
- 0 The response of the units to anticipated repository loading conditions.

5.2.3 What would be the effect on waste isolation of the projected changes in the stratigraphic units?

Stratigraphic units having mineral assemblages susceptible to shrinking, slaking, solution, phase changes, diagenetic changes, or other alterations due to the projected loading conditions may require special design considerations or change groundwater flow and transport conditions. The information needs are as follows:

- 0 Location of minerals subject to physical and chemical alteration under anticipated loading (i.e. stratigraphic units, interbeds, joint fillings, etc.).
- 0 The nature of these physical and chemical alterations.

5.3. How does the structural/tectonic setting affect waste isolation?

The local structural geology and regional tectonic setting affect the design and construction of the repository as well as indicate the potential for disruptive events. Knowledge of the structural/tectonic setting provides basic information such that the requirements of 60.131, 60.132, 60.133, and 60.134 can be met, and therefore the performance objectives in 60.111. Furthermore, compliance with the perfomance objectives in 60.112 and 60.113 requires knowledge of credible flow paths and disruptive events, which in turn requires that the locations of structures, discontinuities and zones of weakness be identified. Sufficient detail on the structural/tectonic setting must be given such that compliance with 60.122 (a)(2)(i), (ii), and (iii) can be demonstrated.

5.3.1. What is the present structural/tectonic setting?

Evaluation of the present structural/tectonic setting of the site requires that the static conditions and the mechanism by which the tectonic elements formed can be understood. This information is required for design and flow/transport modeling and for the evaluation of disruptive scenarios and anticipated repository performance. The studies must be responsive to the requirements of 60.122(a)(2). The information needs are:

- A current tectonic model(s) for explaining Basin and Range structures.
- The geomorphic expression of structural features.
- The potential for significant undetected structural features.
- How known and predicted structures fit into the current Basin and Range tectonic model.
- The three-dimensional geometry of known and predicted faults.
- The relationship between basin tilting, fault geometry and the amount of fault displacement.
- The potential for multiple extensional events to have resulted in low angle extensional faults at depth.
- The potential for non-tectonic deformation.
- The relationship between structural/tectonic features and seismic activity.
- Characteristics of potential seismogenic units.
- The nature of fault surfaces, whether mineralized, mylonitized, filled with fault gauge or breccia.
- The relative and absolute ages of all structures in the site region.
- Natural heat flow characteristics in the site region.

5.3.2. What are the nature and rates of present and projected tectonic processes?

A knowledge of the structural/tectonic setting should lead to a model for the nature and rates of current tectonic activity and how these are likely to

change during the post-closure period. The nature and rates of continuing tectonic activity will provide direct input to the determination of the maximum credible earthquake and rates of erosion/deposition. Changes in the tectonic setting could lead to re-evaluation of groundwater flow models, maximum credible earthquake scenario, renewed volcanism, predicted rates of erosion or the stability of the repository horizon. This issue pertains primarily to 60.122(b) (1), but provides input for all adverse conditions relating to tectonics. In addition to the information required by the previous sub-issue, the following information is required:

- 0 The magnitude and orientation of the regional stress field, and how local structures relate to the stress field.
- 0 The magnitude and orientation of the local stress field and its relationship to local faults.
- 0 The relationship between the local stress field and the regional stress field and how this is interpreted
- 0 The relationship between in situ stress measurements and known fault displacements.
- 0 The potential for renewed tectonic activity as determined from in situ stress measurements.
- 0 How the stress field varies with depth.
- 0 The nature and rates of tectonic activity during Basin and Range faulting as determined from stratigraphic relationships.
- 0 The nature and the rates of tectonic deformation derived from seismic activity.
- 0 The nature and rates of deformation (i.e. isostatic adjustment, uplift, tilting and subsidence) occurring in the site area.
- 0 How the nature and rates of tectonic activity is controlled by fractures.

5.3.3 What would be the effect on the site of the projected tectonic activity?

The effects of tectonic activity can adversely affect the flow/transport of radionuclides, and is therefore directly responsive to the requirements of 60.122(c)(3),60.122(c)(4), 60.122(c)(5), and 60.122(c)(20). In addition, tectonic activity must be considered as input to many design related issues. The information needs are:

- 0 The potential - based on the structure, fault geometry, known zones of relative weakness, the tectonic models and the stress field- for the formation of new faults, or for the reactivation of existing faults, in the immediate vicinity of the site.
- 0 The probability that basaltic volcanism in the vicinity of the site could renew displacement on existing faults or create new faults.
- 0 The probability of flooding of the site area due to tectonic or volcanic activity.

- 0 The probability that the groundwater regime will change due to tectonic or volcanic activity.
- 0 How volcanic activity in the vicinity of the site would affect the geothermal gradient, and more specifically, the ambient temperature of the repository horizon.

5.4 How does seismic activity affect waste isolation?

Seismic activity is only a direct concern during the operational phase, and knowledge of its effects is required by 10 CFR 60.131, 60.132 and 60.133. Additionally, a number of potentially adverse conditions (10 CFR 60.122(c)) are attributed to the nature of seismic activity in the vicinity of the site. Indirectly, seismic activity helps define the tectonic regime of the site area and aids in locating structures along which disruptive movement may occur. Disruptive movement could, in turn, modify anticipated pathways for radionuclide migration. The relationship of seismic activity to the tectonic regime is discussed in section 5.3, above.

5.4.1. What is the nature of seismic activity which has occurred and is occurring in the site region?

To make projections on the type and size of seismic events which could affect the site, it is necessary to first develop a historic data base of seismic activity. It is also necessary to define zones which include subsets of the seismic activity that are spatially related and exhibit similar characteristics. This issue is directly responsive to 10 CFR 60.122(c)(12) and provides the framework for determination of the parameters for 60.122(c)(13) and 60.122(c)(14). The information needs are.

- 0 A complete seismic history of the site region, including both natural and induced seismicity(including weapons testing), with descriptions of the effects of earthquakes which have disrupted the geologic setting.
- 0 Models of seismic velocities in the crust.
- 0 Source mechanisms of earthquakes with supporting data.
- 0 Definition of seismic source areas and seismogenic structures within the site region.

5.4.2. What is the rate of seismic activity which has occurred and is occurring in the site region?

In order to more clearly understand the effect of seismicity on the performance objectives of the site, it is necessary to establish the rates of seismic activity in the site region. These rates can be derived from the instrumental seismic history as well as from geologic evidence. The information needs are:

- 0 Datable evidence, such as surface ruptures and sand blows, of large

earthquakes within the region.

- 0 Recurrence rates from regional historical data.
- 0 Variations of recurrence rates among regional seismic sources and structures.

5.4.3. What would be the effect of postulated seismic events at the site?

Knowledge of appropriate postulated seismic events,along with a knowledge of areas subject to undesirable response to these events, can provide the information required to accommodate or mitigate these effects. Most seismic activity, either natural or induced by various forms of human activity, can be accommodated by utilizing appropriate design parameters. Certain effects, however, such as ground rupture, liquefaction and landsliding, may require mitigation by avoidance. The information needs for determining the effects of these postulated events are:

- 0 The maximum credible earthquake(s) expected to affect the site.
- 0 The maximum expected ground motion at the site, resulting from the maximum credible earthquake(s), examined as a function of depth to at least the depth of the repository.
- 0 Postulated catastrophic coseismic events, such as landslides, liquifaction or ground rupture, that could affect the site or site region.
- 0 The ground motion and point of application of induced seismicity.
- 0 The nature of human activities, including weapons testing, which could induce seismicity.

5.5 How does human intrusion affect waste isolation?

The human intrusion scenario must consider three aspects: past activities which may have produced a pathway for waste migration, the ongoing and proposed site exploration activities which could compromise the site and the potential for either inadvertent or deliberate penetrations into or through the repository which could allow release of radionuclides. Those human activities that could result in induced seismicity are discussed in section 5.4.3.

5.5.1 What is the nature of human intrusion activities which have occurred in the site vicinity?

The primary emphasis of this issue is to address the concern of 60.122(c)(18) and 60.122(c)(19), therefore providing information which will be used in addressing the performance objectives of 60.112 and 60.113(a)(2). Areas which have shown a complex drilling and mining history are by nature those with the highest probability of future activities especially under the scenario of loss of records and monuments which identify the site. This information therefore provides a relative basis to start assessing future intrusion scenarios.

The information needs are:

- 0 The locations of boreholes and mines in the vicinty of the site.
- 0 The completion procedures used on these boreholes.
- 0 The status of mines in the area.
- 0 Mine and well production histories.
- 0 The recorded rates of fluid injection/withdrawal in the vicinity of the site.
- 0 The nature of fluids injected or withdrawn.

5.5.2. What is the nature of human intrusion activities which could be projected to occur in the site vicinity?

This issue is formulated primarily to respond directly to 60.122(c)(17) which in turn is to minimize the potential for creating potential pathways for radionuclide travel. In addition, fluid injection and withdrawal, which by itself could modify the ground water flow path, could modify the local stress field thereby creating seismic activity such as occurred at Rangely, Colorado or producing significant changes such as large scale subsidence. The information needs are :

- 0 The known and potential resources which could be present within the site vicinity.
- 0 The economic classification of the resources.
- 0 The potential extraction methods.
- 0 The potential of the setting for fluid injection or withdrawal.
- 0 The status and plans for mines in the area.
- 0 The location and nature of proposed site characterization activities.

5.5.3. What would be the effect on the sites of the potential human intrusion activities?

To evaluate the consequences of human activity upon the site, it is necessary to understand the probability of these events occurring and the subsequent changes in characteristics caused by these activities. This information can be used as a basis to determine the potential for loss of waste isolation. A preferred site is one in which there is a very low to non-existent possibility of human activity creating changes in the waste isolation characteristics. For those sites in which modifications by human intrusion could occur, an assessment must be made regarding the nature and effects of such modifications. The information needs are:

- 0 The probability for, and nature of, flow path modification.
- 0 The probability for, and degree of, vertical ground movement.
- 0 The probability for, and nature of, ground cracking.

TABLE 1

RELATIONSHIP OF GEOLOGIC ISSUES TO PERFORMANCE ELEMENTS

GEOLOGIC ISSUES

| FORMANCE EMENTS | 5.1.1 | 5.1.2 | 5.1.3 | 5.2.1 | 5.2.2 | 5.2.3 | 5.3.1 | 5.3.2 | 5.3.3 | 5.4.1 | 5.4.2 | 5.4.3 | 5.5.1 | 5.5.2 | 5.5.3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| p. 1 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| p. 2 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| p. 3 | X | X | X | X | X | X | X | X | X | | | | X | X | X |
| P. 4 | | | | | | | | X | X | | | | | X | X |
| p. 5 | | | | | | | | X | X | | | | | X | X |
| p. 6 | | | | X | X | X | | X | X | | | | | X | X |
| p. 7 | | | | X | X | X | | X | X | | | | | | |
| p. 8 | | | | X | X | X | | X | X | | | | | X | X |
| p. 9 | X | X | X | X | X | X | X | X | X | | | | X | X | X |
| p. 10 | X | X | X | X | X | X | X | X | X | | | | X | X | X |
| p. 11 | X | X | X | X | X | X | X | X | X | | | | X | X | X |
| p. 12 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |