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To File fm AElzeftawy, NRC

SUMMARY OF
NRC/DOE MEETING
ON
SEISMIC/TECTONIC INVESTIGATIONS

DATE/LOCATION OF MEETING:

December 3-4, 1985
Quality Inn Conference Room
Eastern Avenue/13th Street
Silver Spring, MD 20910

ATTENDEES/ORGANIZATIONAL AFFILIATION:

A list of attendees is attached as Enclosure 1.

BACKGROUND/FACTS:

The meeting was held with the purposes of: (1) Reach agreement on the scope and organization and kinds of information called for by the annotated outline of the "Rationale for Seismic/Tectonic Investigations for Licensing a Nuclear Waste Repository." (2) Discuss example of an approach to implement the annotated outline. A copy of the agenda is attached as Enclosure 2 which gives the topics discussed and the name and organizational affiliation of the presentations. Prior to the meeting DOE provided NRC with a copy of the annotated outline attached as Enclosure 3. In addition, NRC provided DOE with a copy of a talking paper entitled "Points for Discussion with DOE," as a result of NRC staff review of DOE annotated outline, attached as Enclosure 4 to serve as the basis for discussion.

Enclosure 5 consists of all handouts and copies of the view graphs presented: each group of handouts is identified by the person making the presentation and a number which correlates to the presentation shown on Enclosure 2. Members of the DOE and NRC staff marked-up and modified the proposed annotated outline. This agreed upon mark-up is presented in Enclosure 6.

Subsequent discussion led to the observations, agreements, and open items stated below. State and Tribal representatives were present and participated throughout the meeting. They were offered an opportunity to add any observations to this summary and declined to do so.

OBSERVATIONS:

The following observations were made by the NRC staff:

1. The NRC staff reviewed the draft outline provided by the DOE on June 20, 1985, and considers that, in general, this outline will provide the information required by the staff to evaluate the seismo/tectonic portions

of the site characterization plan, provided that the appropriate portions of the outline are implemented in a manner similar to that presented in the presentation "Conceptual Approach to Seismo-Tectonic Assessments for Licensing," Enclosure 5, (subject to the qualification made in observation 2). Areas the DOE might consider modifying or clarifying in the outline are the following:

a) A statement to the effect that any discrepancies between the annotated outline and R.G. 4.17 will be resolved in favor of R.G. 4.17.

b) Based on the DOE presentations of the planned seismo-tectonic evaluations, it appears to the NRC that DOE planning is currently focused on considerations of the generalized approach to the identification of the site-characterization requirements. Site-specific considerations of response of the systems, structures and components and fragility analyses at this time are likely to include large uncertainties due to the pre-conceptual nature of the design. Although DOE has stated in the Annotated Outline that they plan to address uncertainties, the specific methodology to systematically and consistently consider these uncertainties and to quantify total uncertainties has not been identified. These should be identified and discussed in the implementation of the outline.

2. Regarding the presentation, "Conceptual Approach to Seismo-Tectonic Assessments for Licensing" (Enclosure 5), the NRC staff considers that in nearly all cases where processes or phenomena can be defensibly eliminated from further consideration, it would be done on a site-specific rather than a generic basis.

3. In planning tests and investigations to support a demonstration of compliance with 40 CFR 191.13, the NRC staff considers that it is not necessary to establish a quantitative criterion to discriminate between "anticipated processes and events" and "unanticipated processes and events." In demonstrating compliance with 10 CFR 60.113(a), however, it is necessary to identify "anticipated processes and events." The staff considers that these would be best identified through event by event consideration on a site-specific basis.

4. Regarding the use of the terms "anticipated processes and events" and "unanticipated processes and events," for the pre-closure period as was done in the DOE's "strawman" presentation, "Post Closure Assessment of Tectonic Events," the NRC staff notes that it was the Commission's intent in 10 CFR 60 to apply these terms in the post-closure period.

5. The NRC staff notes that issues under consideration in the concurrent NRC/DOE meeting on Quality Assurance programs will provide additional guidance regarding requirements for the pre-closure period.

The following observations were made by the DOE staff:

1. Each DOE project has the option of either incorporating the intent of the outline directly in the SCP or developing a separate supporting document.

2. The NRC encourages DOE to develop its SCP by relating the probability of possible scenarios to releases of radionuclides to the accessible environment (i.e., CCDF concept) for eventual compliance with 10 CFR 60.21(c)(1)(ii)(C). Therefore, the NRC discourages DOE from focusing on seismic/tectonic studies which discriminate between anticipated/unanticipated events on the basis of probability considerations alone. All events leading to releases should be considered. Preliminary risk-based, sensitivity analyses using conceptual models are adequate to make preliminary decisions regarding what investigations need to be considered during site characterization. As the site characterization program proceeds, sensitivity studies would be done and, as a result, specific planned investigations might be dropped and new investigations might be added.

3. Given DOE observation 2, DOE will proceed with development of a preferred approach to comply with 10 CFR 60.113, because this paragraph currently calls for DOE to identify anticipated processes and events.

AGREEMENTS/OPEN ITEMS:

1. The NRC and DOE agree that, as a general rule, the definition of terms to be used in connection with seismic/tectonic investigations shall be those included in 10 CFR 60 and any modifications thereof. By January 31, 1986, NRC will provide to DOE specific comments on the definition of terms proposed. In particular those comments will address applicability of the terms "active fault", "anticipated", and "unanticipated".

2. The NRC and DOE staff agree that the attached Annotated Outline (as modified), "Rationale for Seismic/Tectonic Investigations for Licensing a Nuclear Waste Repository" provides an acceptable rationale from which to determine seismic/tectonic investigations to be conducted during site characterization. In implementing the outline, DOE will fully consider uncertainties.

3. The NRC and DOE agree that an approach similar to that in the presentation, "Conceptual Approach to Seismo-Tectonic Assessments for Licensing," could be useful for identifying site-specific scenarios and for prioritizing events for consideration.

4. The NRC and DOE agree that the need to consider specific pre-closure and post-closure events, processes, and phenomena should be based upon a consideration of their effects on compliance with the performance requirements of 10 CFR 60.

5. The NRC and DOE agree that a meeting to consider the basis for a conceptual approach to relate probability of scenarios to releases (i.e., CCDF) would be of great value. Both parties agree to use their best efforts to organize such a meeting in a timely manner. DOE will propose a date to NRC by January 31, 1986.

12/4/85

Allan Jelacic
Division of Engineering and
Geotechnology
Office of Geologic Repsitories
U. S. Department of Energy
Commission

12/4/85

Seth M. Coplan
Division of Waste Management
Office of Nuclear Material Safety
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12/4/85

Philip Justus
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards
U. S. Nuclear Regulatory Commission

rec'd w/NRC/DOE meeting of 12/3-4/85
Enclosure 1
109.3

ATTENDEES

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SILVER SPRING, MD
DEC 3, 1985

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(over)

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ATTENDEES

Enclosure 1

NRC/DOE SEISMO-TECTONIC MEETING
SILVER SPRING, MD
DEC 4, 1985

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Enclosure 2

AGENDA

SEISMIC/TECTONIC MEETING
SILVER SPRING, MD

DECEMBER 3, 1985

8:30 a.m.	Opening Remarks	Allan Jelacic Philip Justus
8:45 a.m.	Overview presentation of annotated outline for the seismic/tectonic position paper	DOE (1)
9:45 a.m.	Break	
10:00 a.m.	Discussion of definitions of terms listed in the annotated outline	DOE/NRC (2)
12:00	Lunch	
1:00 p.m.	Presentation of conceptual approach to seismic/tectonic assessments for licensing	DOE (2)
2:45 p.m.	Break	
3:00 p.m.	Discussion of conceptual approach	DOE (2)
5:00 p.m.	Adjourn	

DECEMBER 4, 1985

8:30 a.m.	Discussion of points on the annotated outline for the seismic/tectonic position paper	NRC/DOE (3)
9:45 a.m.	Break	
10:00 a.m.	Continue discussion of points on the annotated outline	NRC/DOE (4)
12:00	Lunch	
1:00 p.m.	Preparation of meeting summary and agreement	NRC/DOE
5:00 p.m.	Adjourn	

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Enclosure 2

STATEMENT OF PURPOSE FOR THE SEISMIC/TECTONIC MEETING BETWEEN THE NUCLEAR REGULATORY COMMISSION AND THE DEPARTMENT OF ENERGY ON DECEMBER 3 AND 4, 1985

The purpose of the meeting is: (1) Reach agreement on the scope and organization and kinds of information called for by the annotated outline of the "Rationale for Seismic/Tectonic Investigations for Licensing a Nuclear Waste Repository." (2) Discuss example of an approach to implement the annotated outline.

Enclosure 3

Department of Energy
Washington, D.C. 20585

JUN 20 1985

Mr. Hubert J. Miller, Chief
Repository Projects Branch
Division of Waste Management
Mail Stop 623-SS
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Miller:

The Office of Civilian Radioactive Waste Management has been working with our project offices on developing a rationale for seismic/tectonic investigations for licensing a nuclear waste repository. Attached to this letter is an annotated outline of this rationale which we are providing to you for review.

The attached outline will be used by each of our program offices as guidance on how to determine the significance of seismic/tectonic events at their individual sites. The outline also serves the purpose of developing a DOE program-wide position. This will remove uncertainty with respect to the use of other existing Federal Regulations, such as Appendix A to 10 CFR Part 100, which may not be directly applicable to nuclear waste repository.

Each program office has the option of either incorporating the intent of the outline directly into the site characterization plan (SCP), or developing a "site-specific position paper" to be used as a reference document in the SCP. It is for this reason that the proposed rationale does not directly repeat the information and data needs included in Regulatory Guide 4.17, as these are an integral part of the SCP. We believe that this rationale provides a measure of flexibility in the scope and specific approach to individual seismic/tectonic issues to accomodate the varying relative importance of issues for the different sites.

A DOE/NRC meeting on seismic/tectonic issues has been scheduled for August 20-21. If you wish, we are prepared to meet with you at an earlier date to discuss any questions or comments you may have on the rationale. Dr. Allan Jelacic (252-9362) of my staff is available to arrange a meeting for this purpose.

Ralph Stein

Ralph Stein, Acting Director
Geosciences & Technology Division
Office of Civilian Radioactive
Waste Management

RATIONALE FOR SEISMIC/TECTONIC

INVESTIGATIONS FOR

LICENSING A NUCLEAR WASTE REPOSITORY

RATIONALE FOR SEISMIC/TECTONIC INVESTIGATIONS FOR LICENSING A NUCLEAR WASTE REPOSITORY

CONTENTS

CONTENTS (Cont'd)

OUTLINE

RATIONALE FOR SEISMIC/TECTONIC INVESTIGATIONS FOR LICENSING A NUCLEAR WASTE REPOSITORY

I. INTRODUCTION

- o Purpose: To develop and articulate an approach to resolve seismic and tectonic issues that is consistent with the requirements of 40 CFR 191, 10 CFR 60, and 10 CFR 960.

- o General Framework: The Site Characterization Plan (SCP) is the document that will define the information needed, and the approach to obtaining that information, for ultimate use in the demonstration of compliance. The applicable regulations provide a framework of concepts to be addressed in the demonstration of compliance with the regulations but do not provide specific guidance as to their implementation. The implementation of the regulations requires an analytic exercise wherein the post closure and preclosure aspects of the regulations are examined in light of possible scenarios, site characteristics and known data to determine, in a preliminary fashion, those aspects of the site which could impact the eventual compliance demonstration. This information is used in the development of plans to acquire data during site characterization. This information also provides the base for the ongoing reevaluation of the approach to demonstrate compliance. It is expected that, as data from site characterization become available, scenario probabilities will be defined and necessitate redirection of field activities. One aspect of the above described process is concerned with seismic/tectonic phenomena. This paper will provide an approach and rationale for the seismic/tectonic investigations to be described in detail in Chapter 8 of the SCP; the content of the paper will be incorporated in or

referenced by the SCP. General requirements for site characterization will be included in Chapter VII of this paper. The Safety Analysis Report (SAR) will demonstrate that the information obtained during site characterization and the methods and assumptions used to perform safety analyses reflect reasonable assurance that performance objectives of 10 CFR 60 and radionuclide release standards of 40 CFR 191 have been met.

- o Approach: The approach to resolve seismic/tectonic issues must result in a repository site and design that is safe, environmentally acceptable, cost effective, and located such that credible seismic/tectonic phenomena will not degrade system performance below acceptable limits. Performance assessment, safety analyses, and repository performance confirmation monitoring are the means by which this is demonstrated. Specific distinctions should be made regarding the period of performance; repository preclosure considerations involve both surface and underground facilities during a relatively short operational period, whereas postclosure considerations involve only the underground facilities and geologic setting, but for a much longer isolation time frame. It is envisioned that early interaction with NRC will be required during the preparation of this paper to assure that the developed framework is acceptable.

II. APPLICABLE REGULATIONS AND DEFINITIONS

A. REGULATORY FRAMEWORK

This section will provide a discussion of, and establish the hierarchy for, the application of currently existing regulations relative to seismic/tectonic considerations in the licensing process. The Nuclear Waste Policy Act (NWPA) will be included to establish the procedural baseline for the regulatory process. The three remaining regulations with direct applicability, 40 CFR 191 (draft), 10 CFR 60, and 10 CFR 960 (and other incorporated regulations), will be reviewed and summarized, with focus on

citation of those sections containing seismic/tectonic criteria, or with seismic/tectonic implications.

B. DEFINITIONS

This section will provide a glossary of applicable definitions. Definitions that will be developed should be consistent with those already in existence, such as those found in 10 CFR 60, 10 CFR 960, and 40 CFR 191 (draft). If current wording is unclear for some definitions in existence (for example "active fault" in 10 CFR 960), an interpretation of the intent of the definition is necessary. Those definitions not found in the above regulations will be developed as appropriate. Inconsistencies will be identified and resolutions proposed.

A provisional list of definitions to be included follows:

Definitions

Accessible environment
Active fault
Annual Probability
Anticipated event
Candidate area
Class I structure
Class II structure
Class III structure
Controlled area
Complementary Cumulative Distribution Function (CCDF)
Design earthquake I
Design earthquake II
Design event
Design ground motion
Design spectra
Deterministic analysis
Disturbed zone
Design UNE I (Underground Nuclear Explosion)

Design UNE II (Underground Nuclear Explosion)
Exceedance probability
Expected respository performance
Geologic setting
Hydrologic terms (to be expanded)
Important to safety
Likely consequence of failure
Maximum consequence of failure
Mean return period
Mitigation
Performance assessment
Performance objective
Postclosure earthquake (PCE)
Probabilistic analysis
Probabilistic safety assessment (formerly probabilistic risk assessment)
Reasonably forseeable events
Reasonable assurance
Response spectrum
Retrievability
Scenario
Seismicity
Seismogenic province
Significant tectonic event
Site
Subsurface facilities (shallow and deep)
Surface facilities
Tectonic Processes
Unanticipated event
Very unlikely events

For definitions which are not included in 10 CFR 60, 10 CFR 960, and 40 CFR 191, use will be made, to the extent possible, of equivalent geological, industrial, and mathematical terms.

III. CONCEPTUAL APPROACH TO SEISMIC/TECTONIC ASSESSMENTS FOR LICENSING

A. IDENTIFICATION OF SIGNIFICANT PROCESSES AND EVENTS

1. This section will address the identification of seismic/tectonic processes and significant seismic/tectonic events which may influence safety considerations for the HLW repository regarding its total life cycle. Seismic/tectonic processes which should be considered include: a) volcanism, b) faulting (both fault rupture and earthquake ground motion), c) folding, and d) regional crustal movements and related stress accumulation . Significant seismic/tectonic events are those events which, in light of tectonic history and other characteristics of the site, must be considered in evaluating compliance of the repository with the performance objectives of 10 CFR 60. This may include human-induced ground motion and seismicity. Pre-closure and post-closure performance objectives, with respect to near-surface and subsurface, will require recognition of different sets of seismic/tectonic processes and events.

2. This section will address the formulation of probability based criteria to be used for identifying significant seismic/tectonic events to be considered for pre-closure analyses. On a preliminary basis it will identify seismic/tectonic processes which may be important with respect to these analyses. It will provide the rationale as to why certain processes should be included or excluded, based on either probability or consequences. Further, it will evaluate the potential impact of the relevant processes on pre-closure performance objectives, identify relevant seismic/tectonic processes and events, and reevaluate impact on repository design.

3. This section will identify those seismic/tectonic processes that are indicated by preliminary analyses to be of importance with respect to the post-closure analyses. It will provide the rationale as to why some processes should be included or excluded. For each relevant process it will evaluate potential impact, both direct and indirect, of this process on each post-closure performance objective. This section

will identify controlling seismic/tectonic events including their magnitude, and reevaluate impact on repository design and performance.

B. IDENTIFICATION OF THOSE ISSUES THAT NEED TO BE RESOLVED

This section will identify key issues from the current understanding of site behavior which require seismic/tectonic considerations for their resolution. It will provide the rationale for including and/or excluding certain issues.

Using the established hierarchy, the section will identify the issues that may require seismic/tectonic input. This section is to include: a) performance assessment issues, b) design issues, and c) site characterization issues, and provide the rationale for including and/or excluding certain issues.

For each pertinent issue, the section will identify seismic/tectonic processes and events that must be considered in order to resolve the issue properly. It will provide the rationale and evaluate the potential design and performance impacts.

C. ISSUE RESOLUTION METHODOLOGY

The resolution of pre-closure and post-closure seismic and tectonic issues may require different experimental and analytical techniques because of the different health and safety concerns and the different time periods involved.

1. Pre-closure issues will involve health and safety during operations and retrieval over periods of time up to 100 years. This section will identify specific techniques used for safety analysis, including seismic safety analysis. It will identify specific seismic/tectonic events which, at this time, are considered for the analysis and identify uncertainties and assumptions used in analyses.

The approach to demonstrating compliance could include the following steps:

a. Identify the set of release scenarios for anticipated seismic/tectonic processes and events that might affect safety during operation and retrieval.

b. Conduct failure mode analysis of structures, systems and components important to safety, using event probabilities and seismic design parameters determined according to procedures outlined in Chapter IV C and V B.

c. Determine likely and maximum consequences of failure with respect to radiological safety, considering ranges of parameters that affect these consequences.

d. Analysis of (c) and degree of compliance with release limits.

e. Consideration of uncertainty involved in analyses and effect on (d). Evaluation of impact on design of structures, systems, and components important to safety, and implications regarding design of structures to resist failure.

2. Post-closure issues will involve health and safety concerns for a period up to 10,000 years. Significant post-closure releases arising from seismic/tectonic phenomena must be included in the total system performance assessment that leads to the construction of the empirical Complementary Cumulative Distribution Function (CCDF) described in draft 40 CFR 191. This approach to demonstrating compliance could include the following steps:

a. Identify the set of release scenarios, including scenarios involving seismic/tectonic events and processes for both anticipated and, as appropriate, unanticipated events.

b. Construct mathematical models of each class of scenario; the models predict cumulative release of radioactivity from each class of scenario for the first 10,000 years after closure.

c. Assign probability distributions to the uncertain parameters that appear in the models of the scenarios; these distributions should be based on data pertaining to site tectonics and seismicity as much as possible.

d. Combine mathematical models in a single model, capable of time-dependent simulation, that gives sample values of the total cumulative release to the accessible environment 10,000 years after closure.

e. Exercise the model formed in "d", above, to obtain statistics sufficient to construct the CCDF mentioned in draft 40 CFR 191.

Additionally, post-closure issues will involve other 10 CFR 60 performance objectives. These are groundwater travel time, release rates from engineered barriers, and life of waste package. Resolution of these issues may require seismic/tectonic consideration. The paper will identify those issues and corresponding seismic/tectonic factors. It will identify the analytical techniques to be used; specific seismic/tectonic events which, at this time, are considered in this analysis; and assumptions and uncertainties.

IV. APPROACH FOR IDENTIFYING SIGNIFICANT SEISMIC/TECTONIC EVENTS

A. GENERAL

Preliminary scoping analyses should be performed to identify some or all of the significant seismic/tectonic events. These scoping evaluations should be made in accordance with "B", "C", "D" and "E" below.

B. SUMMARY OF EXISTING DATA BASE RELATED TO SEISMIC/TECTONIC EVENTS

This action will present a synopsis of the current data base; it will also present sets of field observations which a) are subject to alternative interpretations and/or b) may have a significant impact on waste containment and isolation. Included are the following topics:

1. Preclosure (10 CFR 960.5-2-11)

    a. Historical patterns of seismicity (including relationship to known surface features, indications of stress state).

    b. Relief and accumulation of tectonic stress and its effect on emplacement or retrieval operations.

    c. Fault displacement and its effects on: surface and subsurface facilities judged important to safety; operations; and retrieval.

    d. Effects of vibratory ground motion, natural or man induced, on surface or subsurface facilities that are judged important to safety.

2. Postclosure (10 CFR 960.4-2-7)

    a. Tectonic stress (its nature, i.e., tectonic, remnant, residual and gravitational components; orientation and magnitude temporal and spatial variability);

    b. Fault displacement (location, length of surface rupture, movement style and history, amount of slip, secondary effects);

    c. Vibratory ground motion; acceleration and response spectra; time history; relationship to (a) and (b);

d. Volcanism (composition, volume, time-space trends, tectonic setting, relationship to seismicity, geophysical data, eruptive mechanisms, secondary effects);

e. Human induced seismicity and ground motion (size and characteristics of the effect from UNE testing, fluid injection, fluid withdrawal, impoundment, and mining);

f. Secondary effects of seismic/tectonic events (ground-water movement, secondary slip and fracturing, landslides, liquefaction, and erosion);

g. Regional crustal movements and effects on waste isolation (folding, subsidence, uplift, diapirism).

C. ASSESSMENT OF SIGNIFICANCE

Based on professional judgment, including case histories from the region, and performance assessment calculations if available, this section will evaluate significance of the above topics in the context of each performance objective of 10 CFR 60. It will consider the pre-closure time-frame, i.e., operational releases and retrievability; and post-closure, i.e., compliance with 40 CFR 191 release standard, travel time, life of waste package and release rates from engineered barrier.

For the post-closure time frame considerations may include:

1. Relief and accumulation of tectonic stress and its effects on fracture conductivity, permeability, and pore pressure, waste-package integrity, and possible deterioration of seal performance.

2. Fault displacement and its effects on the permeability, fracture, conductivity and pore pressure, waste-package integrity, and disruption of seals.

3. Effects of vibratory ground motion on permability, fracture conductivity, pore pressure, and water movement.

4. Magmatic intrusion or extrusion into the repository proper.

5. Magmatic intrusion or extrusion into the hydrologic system up and down-gradient of the repository and its affect on compliance with 10 CFR 60 performance objectives, and compliance with 40 CFR 191 release standards.

D. UNCERTAINTY CONSIDERATIONS

Assessments of safety must consider the extent of uncertainty that exists throughout any analysis and determine its effects on the conclusion reached in that analyses. Potential sources of uncertainty arise from: understanding of basic phenomena; formulation of constitutive relationships and conceptual models of features events and processes; formulation and execution of mathematical models; and date and date analysis. This section will address the manner by which uncertainty will be reduced in the following arrangement:

1. Conceptual uncertainty.

   Reduce conceptual uncertainties (i.e. fidelity of models to physical reality) through concensus opinion and through consideration of alternative hypotheses, if significant effect on results is shown.

2. Natural uncertainty.

   Reduce numerical uncertainties through the use of site-specific data and concensus opinion. Appropriate numerical and analytical models will be used.

3. Interpretative uncertainty

Discuss how interpretative uncertainty can be reduced by carefully checking and validating formulae and codes; this is the focus of software QA programs advocated by NRC and DOE.

E. RELEVANCE OF EXPECTED EVENTS DURING PRE- AND POSTCLOSURE TIME FRAMES AND IMPACTS ON REPOSITORY DESIGN AND PERFORMANCE.

A comparative evaluation of the significant effects will be provided to offer a perspective on the most important aspects with respect to radiological safety and cost.

V. STRATEGY FOR ISSUE RESOLUTION AND/OR MITIGATION

A. GENERAL

This section will describe the licensing strategy to be employed in resolution of issues related to seismic/tectonic characteristics of the site. It will consider: a) procedures to be used in developing the seismic design parameters; b) engineering design measures; and c) recognition and integration of uncertainties. These measures involve in-depth consideration of possible means of adding confidence in the resolution of issues.

B. SEISMIC DESIGN PARAMETERS

This section will address procedures used to develop seismic design parameters;

Pre-closure - Identify procedures which are judged to be proper for use in developing seismic design parameters. The section will consider vibratory ground motion and surface rupture. It will discuss implementation of the scheme or procedure for classification of structures, systems and components deemed important to safety, and consider complementary

earthquake approaches acceptable for other nuclear facilities. The section will discuss the rationale, alternatives and procedures used for equivalent considerations in other industries.

Post-closure - This section will ascertain the sensitivity of the closed repository to vibratory ground motion and fault displacement, including secondary effects such as impacts on the ground water system. It will consider sealing, waste package, and other engineered and natural barriers. It will present procedures which could be used to develop seismic design parameters for post-closure.

C. ENGINEERING

For certain seismic/tectonic processes and events, a demonstration of compliance with some performance objectives could be achieved through conservative engineering design. This section will identify, in a preliminary fashion, these processes and events and the performance objectives corresponding to them. With respect to mitigation of undesired effects of each seismic/tectonic process and event it will identify available technology, engineering strategy and cost considerations. The discussion will consider allowable thermal loading and relate it to the size of the disturbed zone, mode of emplacement, clearance for tunnels, shafts and emplacement boreholes, etc., location of surface facilities, and design parameters for vibratory ground motion, including support considerations. The section will discuss the iterative aspects assessing compliance and refining design.

D. RECOGNITION AND MITIGATION OF UNCERTAINTIES

This section will discuss the manner in which the following topics are treated:

1. Assessment of uncertainties in event scenarios, conceptual models, mathematical models, and data.

Sources of uncertainty in each category will be identified as considered in analyses, because these will detract from the demonstration of reasonable assurance.

2. Enhance understanding of potentially adverse and favorable site conditions.

   The extent to which potentially adverse and favorable site conditions exist will be evaluated with respect to safety, environment, and cost. The reasonable assurance concept will be employed in judging if sufficient information exists to make decisions leading to licensing. Where information is shown to be inadequate, additional site characterization will be required.

3. Cost impacts as a function of variability.

   An assessment will be performed to evaluate the impact of variability in the estimated or calculated value of seismic loadings on the total cost of the repository. This section will consider appropriate variability of frequency and response spectra within an acceleration range; high frequency and low frequency ground motion will be considered. This section will also consider the cost increments for designing and constructing surface and underground facilities against failure induced by surface rupture.

4. Institute conservatism in operating procedures.

   This section will identify and discuss the operating procedures that may be developed to mitigate the impacts of seismic/tectonic hazards. It will evaluate the effectiveness of these procedures.

5. Institute Performance Confirmation Monitoring Program. This section will describe the monitoring and evaluation for specific performance parameters that will validate conclusions and assumptions made in the

SAR. It will discuss how results will lend confidence to decisions, especially the possible requirement for retrieval.

VI. SEISMIC/TECTONIC EVENTS AND RADIONUCLIDE RELEASE SCENARIOS

A. GENERAL

For each significant seismic/tectonic event as determined in Chapter IV, and with reference to the corresponding performance objective, present results of preliminary performance computations and plans for the final performance assessment. Consider both preclosure and postclosure time frames.

B. PRECLOSURE

For pre-closure the analysis shall include:

1. Scenario identification and analysis;

2. Failure Mode Analysis and design sensitivity;

3. Likely and maximum consequence determination;

4. Analysis of safety and compliance with release limits;

5. Uncertainty assessment.

C. POSTCLOSURE

For post-closure, the analysis shall include:

1. Scenario identification and analysis, emphasizing all aspects of hydrology and radionuclide travel;

2. Likely and maximum consequence determination;

3. Analysis of compliance with release limits;

4. Uncertainty assessment.

The identification of postclosure-release scenarios involving seismic/tectonic phenomenon should proceed by examining the effects of such phenomenon on three things: the hydrology and radionuclide transport aspects of the site; the integrity of the waste package; and the integrity of the engineered-barrier system.

The magnitude and consequences of the effects identified above should be used to further screen release scenarios; this may require calculations of likely and bounding consequences in terms of release from the barriers (waste package, engineered-barriers and the site) to establish their significance.

Special-purpose mathematical models of the significant classes of scenarios identified above should be constructed and combined with the model for expected releases to form a total systems model that can be used to simulate the behavior of the site/repository system under all anticipated, significant events and processes for the next 10,000 years.

VII. REQUIREMENTS FOR SITE CHARACTERIZATION INCLUDING METHODOLOGY AND CRITERIA APPROPRIATE FOR RESOLUTION OF SEISMIC AND TECTONIC ISSUES.

A. TYPES OF ISSUES AND RELATIONSHIP TO REPOSITORY DEVELOPMENT SCHEDULE

The complete set of characterization issues for the project has been derived from considerations of performance and design (10 CFR 60) as well as consideration of siting criteria in 10 CFR 960. This issues hierarchy is an essential prerequisite in identifying data and information needs to be provided during the site characterization process. The site characterization plan (SCP) is being developed to be compatible with the

data and information needs. The data and information must be obtained in a timely manner in order to meet the DOE repository development schedule as required by NWPA.

Within the overall issue hierarchy, some issues specifically address seismic/tectonic concerns, an example is Mission Plan Issue 4.5 relating to the tectonic compatibility of the site with repository construction, operation, and closure. Conversely, there are a number of issues in which the influence of seismic/tectonic processes or events is indirect but is important to resolution.

This section will identify data and information needs related to seismic/tectonic processes or events which, at this time, are judged to be required for satisfactory resolution of each pertinent issue. It will consider all aspects of the issue resolution process, including: a) site characterization; b) engineering design; c) performance assessment; and d) performance confirmation monitoring.

For each issue requiring seismic/tectonic considerations identify when, in relation to the DOE's repository development schedule, evaluation of this issue should be completed.

B. DATA AND INFORMATION NEEDS

1. Site Characterization

Seismic/tectonic data and information needs to be satisfied during the site characterization process pertain to three broad categories. These are: a) for each seismic/tectonic process, estimates of probabililty of occurrence of a given tectonic event; b) impact of this event on containment and isolation; and c) parameters, i.e., physical properties and boundary conditions, which are required in order to quantify impact of this event on a given performance objective. Identify data and information needs as they pertain to these categories and each

applicable site characterization issue. Consider both pre-closure and post-closure performance objectives.

2. Performance Assessment

The performance assessment aspect of the issue resolution process will require its own set of data and information needs related to seismic/tectonic conditions. These may be related to a) evaluating significance of a given tectonic process to waste containment and isolation, e.g., phenomenological understanding of impact of basaltic intrusion and/or faulting on ground-water travel time and/or post-closure releases of radioactivity; b) identification of parameters, i.e., properties and boundary conditions, required for quantification of impact of a given tectonic process with respect to a given performance objective; c) evaluating relationship between impact and size of a given seismic/tectonic event; and d) constitutive relation and model validation. Identify data and information needs for each pertinent performance issue. Consider both pre-closure and post-closure time spans and performance objectives.

The process is iterative in that preliminary models, codes and scenario are used to identify information needed for licensing; as data becomes available from site characterization, models will be refined, codes will become more sophisticated and scenario probabilities will be defined. This could lead to the redefinition of information needed from site characterization. The process results in a defensible performance assessment of the site which forms the basis for demonstration of compliance with the applicable regulations.

3. Design

Identify elements of conceptual design which require seismic/tectonic consideration. Identify range of design options and discuss licensing and cost implications. Identify data and information needs related to seismic/tectonics and which are required in order to demonstrate that a given design decision is adequate. This decision may include: design

parameters, method of construction, location, and material. Consider pre-closure and post-closure aspects of repository design and performance.

VIII. CONCLUSIONS AND RECOMMENDATIONS

Based on analysis and interpretations performed in order to develop this position paper, identify perceived seismic/tectonic events or processes, if any, which represent areas of significant concern in the licensing process. Recommend areas and methods of investigation leading to resolution.

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Enclosure 4

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Points for Discussion with
DOE on "Rationale for Seismic/Tectonic
Investigations for Licensing a
Nuclear Waste Repository"

1. The logic flow in the Table of Contents.

2. Section II B: the intended application of terms identified in the provisional list of definitions.

3. Section III A: criteria to be used to identify significant seismic/tectonic processes.

4. Section III A: methods for evaluating potential impact of seismic/tectonic processes on pre-closure and post-closure performance objectives.

5. Section III A and C: clarification of the terms processes, phenomena, and events.

6. Section III C: inclusion of groundwater travel time in pre-closure as well as post-closure issues.

7. Section IV B: limitations of the ground motion models and the distribution functions.

8. Section IV B: the difference between remnant and residual stress.

9. Section IV C: the consideration of thermal effects on tectonic processes.

10. Section IV D: the role of consensus opinion in reducing conceptual and numerical uncertainties.

11. Section V B: what is meant by complementary earthquake approaches acceptable for other nuclear facilities.

12. Section V B: the specific structures, systems and components important to safety that would be vulnerable to the process.

13. Section V B: the proposed method of fragility analysis that will be used to evaluate the impact based on a pre-conceptual level of design of such structures, system and components.

14. Section VI C: inclusion of shaft and borehole seals in the list of items that should have effects of seismic/tectonic phenomena examined.

15. Section VII B: the adequacy of the conceptual design to allow meaningful analysis.

U.S. DEPARTMENT OF ENERGY

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Nevada Nuclear Waste Storage Investigations PROJECT

OGR

NRC / DOE

SEISMIC/TECTONIC MEETING

WASHINGTON, DC

Enclosure 5

DECEMBER 3 - 4, 1985

UNITED STATES DEPARTMENT OF ENERGY

OVERVIEW OF THE SEISMIC/TECTONIC POSITION PAPER

PRESENTED BY

M.D.Voegele (1)*

* See Enclosure 2

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YUCCA MOUNTAIN

BASIC TERMS: CLARIFICATION

- PROCESS (TECTONIC)

  - AN ACTIVITY CONTRIBUTING TO THE BROAD ARCHITECTURE OF THE OUTER PART OF THE EARTH, THAT IS TO THE REGIONAL ASSEMBLING OF STRUCTURAL OR DEFORMATIONAL FEATURES. EXAMPLES: IGNEOUS ACTIVITY, UPLIFT, SUBSIDENCE, FOLDING, FAULTING

- EVENT (TECTONIC)

  - AN INDIVIDUAL OCCURENCE OF A TECTONIC PROCESS, THE CHARACTERISTICS OF WHICH CAN BE DESCRIBED. EXAMPLES: A MAGNITUDE 5.4 EARTHQUAKE, AN EPISODE OF EXTRUSIVE VOLCANISM

- PHENOMENON (TECTONIC)

  - A GENERAL EFFECT OR MANIFESTATION OF A TECTONIC PROCESS. EXAMPLES: PROCESS: FAULTING; PHENOMENA: DISLOCATION, ALTERATION OF HYDROLOGY, VIBRATORY GROUND MOTION

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YUCCA MOUNTAIN

OVERVIEW OF APPROACH IN SEISMIC TECTONIC POSITION PAPER

- DEVELOP & ARTICULATE AN APPROACH TO RESOLVE SEISMIC & TECTONIC ISSUES THAT IS CONSISTENT WITH 40CFR191, 10CFR60 & 10CFR960

- UNDERSTAND THE REGULATIONS; IN PARTICULAR, DEVELOP USEABLE DEFINITIONS FOR ANTICIPATED & UNANTICIPATED

- PERFORM ASSESSMENT OF SITE:

  - DEFINE THE SITE & ITS RELATIONSHIP TO KNOWN STRUCTURES & GEOLOGIC EFFECTS (PHENOMENA)

  - UNDERSTAND THE GEOCHRONOLOGY OF THE PROCESSES & EVENTS LEADING TO THE STRUCTURES & GEOLOGIC EFFECTS (PHENOMENA)

  - ASCERTAIN PROBABILITIES, SIGNIFICANCE, & CONSEQUENCE OF FUTURE EVENTS MEASURED AGAINST 40CFR191, 10CFR60 & 10CFR960

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SEISMIC/TECTONIC PAPER LOGIC

1. CONCEPTUAL APPROACH (III)

- SIGNIFICANT PROCESS IDENTIFICATION
  - PROBABILITY BASED CRITERIA
  - IDENTIFICATION OF IMPORTANT SEISMIC/TECTONIC PROCESSES BASED ON PRELIMINARY ANALYSES
- IDENTIFICATION OF KNOWN & RELATED KEY ISSUES
  - ESTABLISHED HIERARCHY
  - PA/DESIGN/SITE CHARACTERIZATION
- ISSUE RESOLUTION METHODOLOGY
  - COMPLIANCE DEMONSTRATION
  - PRE & POSTCLOSURE
  - UNCERTAINTY & PROBABILITY TREATMENT
  - LIKELY & MAXIMUM CONSEQUENCES
  - USE OF SCENARIOS
  - ASSESSMENT OF COMPLIANCE
  - MODEL APPLICATION

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SEISMIC/TECTONIC PAPER LOGIC

2. APPROACH FOR IDENTIFICATION OF SIGNIFICANT SEISMIC/TECTONIC EVENTS (IV)

- USE OF PRELIMINARY SCOPING ANALYSES
- PRE & POSTCLOSURE
- INITIAL USE OF EXISTING DATA & HISTORIC INFORMATION
- ASSESSMENT OF SIGNIFICANCE OF PRE & POSTCLOSURE EVENTS
  - COMPARISON TO PERFORMANCE OBJECTIVES & 40CFR191
  - GROUND MOTION, DISPLACEMENT, SECONDARY EFFECTS, VOLCANISM, CRUSTAL MOVEMENTS
- INCORPORATION/TREATMENT OF UNCERTAINTY
  - CONCEPTUAL/NATURAL/INTERPRETIVE

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SEISMIC/TECTONIC PAPER LOGIC

3. SEISMIC/TECTONIC EVENTS & RELEASE SCENARIOS (VI)

- PRESENT RESULTS OF PRELIMINARY ASSESSMENTS
  - BASED ON PREVIOUSLY IDENTIFIED SIGNIFICANT EVENTS
- PRE & POSTCLOSURE
  - INCLUDE UNCERTAINTY ASSESSMENT
  - CONSEQUENCE DETERMINATION
  - COMPLIANCE ASSESSMENT
- USE SYSTEMS APPROACH
  - HYDROLOGY & TRANSPORT
  - WASTE PACKAGE
  - ENGINEERED BARRIER SYSTEM
- TOTAL SYSTEMS MODEL

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SEISMIC/TECTONIC PAPER LOGIC

4. IDENTIFICATION OF SITE CHARACTERIZATION REQUIREMENTS (VII)

- SCHEDULE/TIMING
- INFORMATION NEEDS
- INTER & INTRA ISSUE HIERARCHY RELATIONSHIPS
- DATA & INFORMATION NEED IDENTIFICATION

SEISMIC/TECTONIC
POSITION PAPER DEFINITIONS

NEIL A. NORMAN, PE
BECHTEL NATIONAL, INC.
DECEMBER 3, 1985

(2)

Seismic/Tectonic Position Paper Definitions

- **Adherence to 40CFR191 EPA Final Rule**
- **Consistent with 10CFR60 NRC Regulation**
- **Consideration of 10CFR960 DOE Guideline**

- **Accessible Environment**
  - **the atmosphere**
  - **land surfaces**
  - **surface waters**
  - **oceans**
  - **all of the lithosphere beyond control area**

- **Controlled Area**
  - **surface location**
  - **identified by passive institutional controls**
  - **maximum area 100 sq. kilometers**
  - **maximum perimeter point 5 km from original (pre–closure) waste boundary**

Controlled area means: (1) A surface location, to be identified by passive institutional controls, that encompasses no more than 100 square kilometers and extends horizontally no more than five kilometers in any direction from the outer boundary of the original location of the radioactive wastes in a disposal system; and (2) the subsurface underlying such a surface location. (40 CFR 191.12 g, 9-19-85)

ANTICIPATED EVENT: (Post Closure Likely Disruptive Event)

A natural event, process, or human intrusion that is projected to occur with a cumulative probability greater than 0.1 for the 10,000 year period of regulatory applicability. (40 CFR 191.13, 9-19-85)

"Performance assessment" means an analysis that: (1) Identifies the processes and events that might affect the disposal system; (2) examines the effects of these processes and events on the performance of the disposal system; and (3) estimates the cumulative releases of radionuclides, considering the associated uncertainties, caused by all significant processes and events. These estimates shall be incorporated into an overall probability distribution of cumulative release to the extent practicable. (40 CFR 191.12 q, 9-19-85)

UNANTICIPATED EVENTS (Post Closure Very Unlikely Event)

A natural event, process, or human intrusion action that is projected to occur with a cumulative probability greater than 0.001 but less than 0.1 for the 10,000 year period of regulatory applicability.

Aquifer

An undeground geologic formation, group of formations, or part of a formation that is capable of yielding a significant amount of water to a well or spring. (40 CFR 191.12 i, 9-19-85)

"Significant source of ground water,"

"Special source of ground water,"

- Significant Source of Ground Water
  - less than 10,000 mg/l solids, and
  - within 2,500 feet of surface, and
  - transmissivity greater than 200 gal/da/ft, and
  - hydraulic conductivity greater than 2 gal/da/ft^2, and
  - 10,000 gal/da yield.

- Special Source of Ground Water
  - within or less than 5 km beyond the controlled area, and
  - drinking water supply for thousands of persons, and
  - irreplaceable

CLASS I STRUCTURE: Any structure, system, or component that is important to public safety or waste isolation as defined in 10 CFR 60 and 40 CFR 191.

Conservatism

For the purposes of repository design and licensing conservatism shall include:

- The consideration of all barriers of a disposal system in performance assessments.

- Reasonable limitations on the scope of performance assessments.

- The use of average or "mean" values in expressing the results of performance assessments,

- The types of assumptions regarding the effectiveness of institutional controls; and

- Limiting assumptions regarding the frequency and severity of inadvertent human intrusion into geologic repositories. (40 CFR 191.17 B, 9-19-85)

Design Events

Preclosure natural events, processes, or human induced actions that are relatively likely to occur and which will be used as initiating events for pre-closure safety analyses.

Reasonable Assurance

The result of NRC evaluation of quantitative and qualitative risk assessment results, considering uncertainties, that will permit a finding that the licensed activity will provide adequate protection to the health and safety of the public.

Fed. Register 48-120, 6-21-83
(10 CFR 60 Rules and Regulations)

SEISMIC DEFINITIONS

ACCESSIBLE ENVIRONMENT: The atmosphere, land surfaces, surface waters, oceeans, and all of the lithosphere that is beyond the controlled area (40 CFR 191, Subpart B, 191.12.k 9-19-85)

NOTE: 10 CFR 960 and 10 CFR 60 states: that portion of the lithosphere that is outside the controlled area.

ACTIVE FAULT: To be covered in separate discussion materials.

ANNUAL PROBABILITY: The probability that an event will occur within a one year period.

NOTE: The annual probability is typically related to probability of occurrence over the intended life of a facility.

ANTICIPATED EVENT: (Post Closure Likely Disruptive Event) A natural event, process, or human intrusion that is projected to occur with a cumulative probability greater than 0.1 for the 10,000 year period of regulatory applicability. (40 CFR 191.13, 9-19-85)

NOTE: Proposed interpretation to be covered in separate presentation material.

AQUIFER: An underground geologic formation, groupo of formations, or part of a formation that is capable of yielding a significant amount of water to a well or spring. (40 CFR 191.12 i, 9-19-85)

CANDIDATE AREA: A geologic and hydrologic system within which a geologic repository may be located (10 CFR 60).

NOTE: Candidate Site is defined in 10 CFR 960: An area within a geohydrologic setting that is recommended by the Secretary of of Energy under Section 112 of the Act for site characterization, approved by the President under Section 112 of the Act for characterization or undergoing site characterization under Section 113 of the Act.

CLASS I STRUCTURE: Any structure, system, or component that is important to public safety or waste isolation as defined in 10 CFR 60 and 40 CFR 191.

CLASS II, CLASS III

NOTE: Only one class of structure has been defined; structures not meeting the requirements of Class I are not assigned to a class description.

CONSERVATISM APPROACH: For the purposes of repository design and licensing conservatism shall include:

- The consideration of all barriers of a disposal system in performance assessments.
- Reasonable limitations onthe scope of performance assessments,
- The use of average or "mean" values in expressing the results of performance assessments,
- The types of assumptions regarding the effectiveness of institutional controls; and
- Limiting assumptions regarding the frequency and severity of inadvertent human intrusion into geologic repositories. (40 CFR 191.17 B, 9-19-85)

CONTROLLED AREA: (1) a surface location, to be identified by passive institutional controls, that encompasses no more than 100 square kilometers and extends horizontally no more than five kilometers in any direction from the outer boundary of the original location of the radioactive wastes in a disposal system; and (2) the subsurface underlying such a surface location. (40 CFR 191.12g 9-19-85)

NOTE: 10 CFR 60 refers to a 10 kilometer maximum distance and requires that the area be committed to use as a geologic repository from which incompatible activities would be restricted following permanent closure.

COMPLEMENTARY CUMULATIVE DISTRIBUTION FUNCTION: The probability that releases of radioactivity to the accessible environment will be equal to or greater than a given value. It is developed by subtracting each probability value contributing to the cumulative distribution functinfrom 1.0 The cumulative distribution function is the probability that releases to the accessible environment will be less than a given value. It is developed by integrating the probability density function representing releases, including uncertainties inthis function over all possible releases.

DESIGN EARTHQUAKE: (The Preclosure Seismic Design Event) A maximum earthquake ground motion for use in designing and evaluating structures, systems and components important to safety during the preclosure period. This motion will be determined from a conservative probabilistic model based on the tectonics of the site region.

NOTE: As Class II and Class III facilities are not defined, only a single design earthquake is required.

DESIGN EVENTS: Preclosure natural events, processes, or human induced actions that are relatively likely to occur and which will be used as initiating events for pre-closure safety analyses.

DESIGN GROUND MOTION: Dynamic vibratory ground motion for use as a design event in a preclosure performance calculation. The source of this ground motion may be either natural or human-induced earthquakes.

DESIGN SPECTRA: Incorporated implicity in definition of Response Spectrum.

DESIGN UNDERGROUND NUCLEAR EXPLOSION: The ground motion generated by a UNE that is used in designing and evaluating structures, systems and components that are important to safety during the preclosure period. This motion willbe determined using the predicted largest yield at the predicted closest approach to the site and the best available relatins for UNE ground motion attenuation. The confidence level on the UNE will be such that the hazard will be equivalent to the design earthquake.

DETERMINISTIC ANALYSIS: A method to estimate the maximum credible value of a design parameter reasonably expected at a site. In the case of earthquake ground motion, this is based on a characterization of the site region as containing certain geologic structures capable of causing earthquakes of some maximum magnitude, or as made up of certain seismogenic sources. Sizes of earthquakes and their proximity to structures and sources are considered, but the distributions of earthquakes intime and by magnitude are ignored.

DISTURBED ZONE: That portion of the controlled area, excluding shafts, whose physical or chemical properties are predicted to change as a result of underground facility construction or heat generated by the emplaced radioactive waste such athat the rsultant change of properties could have a significant effect on the performance of the geologic repository. (10 CFR 960)

NOTES: 1) 10 CFR 60 does not explicitly exclude shafts and states; 2) predicted to change, rather than have changed.

EXCEEDANCE PROBABILITY: The probability that an event will occur during a specific preclosure exposure time. For seismic events, "exceedance probability" means the probability that a specifid level of ground motion of specified social or economic consequences of earthquakes, will be exceeded at a site or in a region during a specified exposure time. (Shah et al., "Earthquake Spectra," V01. 1, No. 1, 1984)

EXPECTED REPOSITORY PERFORMANCE: The manner in which the respository is predicted to function, considering those conditions, processes, and events that are likely to prevail or may occur during the time period of interest. (10 CFR 960)

GEOLOGIC SETTING: The geologic, hydrologic, and geochemical systems of the region in which a geologic repository operations area is or may be located. (10 CFR 960, 10 CFR 60)

IMPORTANT TO SAFETY: In reference to structures, systems, and components means those engineered structures, systems, and components essential to the prevention or mitigation of an accident that could result in a radiation dose to the whole body, or any organ, of 0.5 rem or greater at or beyond the nearest boundary of the unrestricted area at any time until the completion of permanent closure. (10 CFR 60)

ISOLATION: Inhibiting transport of radioactive materials so that amounts and concentrations of this material entering the accessible environment will be kept within prescribed limits. (10 CFR 60 A 60.2, 1-1-85)

LIKELY CONSEQUENCE OF FAILURE: The reasonable estimate of a result caused by a scenario postulating a design event and a series of system or component failures.

MAXIMUM CONSEQUENCE OF FAILURE: The most serious performance consequence resulting from any unanticipated event.

MEAN RETURN PERIOD: The average time between design events. For example, it can be the average time between occurrences of a specific acceleration at a site or of an episode of fault offset along an active fault. (after Shah et al.)

MITIGATION: Means (1) avoiding the impact altogether by not taking a certian action or parts of an action; (2) minimizing impacts by limiting the degree or magnitude of the action and its implementation; (3) rectifying the impact by repairing, rehabilitating, or restoring the affected environment; (4) reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; or (5) compensating for the impact by replacing or providing substitute resources or environments. (10 CFR 960)

PERFORMANCE ASSESSMENT: An analysis that: (1) identifies the processes and events that might affect the disposal system; (2) examines the effects of these processes and events on the performance of the disposal system; and (3) estimates the cumulative releases of radionuclides, considering the associated uncertainties, caused by all significant processes and events. These estimates shall be incorporated into an overall probability distribution of cumulative release to the extent practicable. (40 CFR 191)

NOTE: The 10 CFR 960 definition is less restrictive, referring to any analysis that predicts the behavior of a system or system component, under a given set term in the EAs is consistent with the 40 CFR 191 definition.

PERFORMANCE OBJECTIVE OR STANDARD: The predtermined objective or specification used to evaluate the acceptability of each system, structure, or component in a performance calculation. Different performance standards may be suitable for the preclosure and postclosure periods.

POSTCLOSURE EARTHQUAKE: The earthquake reasonably likely to occur at the site during the 10,000-year postclosure isolatinperiod. It is the anticipated seismic event for waste isolation. This motion will be determined from a conservative probabilistic model based on the tectonics of the site region.

PROBABILISTIC ANALYSIS: A method to estimate the exceedance probability of a specified design event on the basis of a characterization of site region geologic structures and seismogenic sources, maximum magnitudes and recurrence statistics for each, and attenuation with distance of design event parameters. The method uses classical statistical processes for determination of means, standard deviations, and confidence levels of determined performance values. Uncertainties in these characterizations may be explicitly incorporated into the analysis.

PROBABILISTIC SAFETY ASSESSMENT: An estimate of the exceedance probability of a specific scenario consequence. It incorporates the results of a probabilistic analysis of a particular design event with an assessment of the likely consequences of that event should it occur. Often, a number of events leading to a particular consequence must be considered for an adequate safety assessment. This type of assessment applies to both preclosure and postclosure analysis.

REASONABLY FORESEEABLE EVENT: An event that is reasonably likely to occur during the period of performance assessment and form which the design bases are derived.

Commentary - This is equivalent to anticipated event? This definition is not required.

REASONABLE ASSURANCE: The required confidence that the NRC performance objectives will be met. (10 CFR 60.122(a)(1))

NOTE: The result of NRC evaluation of quantitative and qualitative risk assessment results, considering uncertainties, that will permit a finding that the licensed activity will provide adequate protection to the health and safety of the public. Fed. Register 48-120, 6-21-83 (10 CFR 60 Rules and Regulations)

RESPONSE SPECTRUM: A set of curves calculated from an earthquake accelerogram that gives values of peak response of a damped linear oscillator as a function of its period of vibration and damping. When curves of this type are used for model analysis design of a free-standing structure, the set of curves becomes a "design response spectrum" or simply "design spectrum."

RETRIEVAL: The act of intentionally removing radioactive waste before repository closure from the underground location at which the waste had been previously emplaced for disposal. (10 CFR 960)

SCENARIO: A proposed sequence of events or conditions of which the resulting consequence is analyzed to determine related consequences.

SEISMICITY: The occurrence of earthquakes in space and time. (Bolt, 1978).1

SEISMOGENIC PROVINCE: A geologic area characterized by a similarity of geologic structure, tectonic setting, and earthquake characteristics.

SIGNIFICANT SOURCE OF GROUND WATER, as used in this Part, means: (1) An aquifer that: (i) Is saturated with water having less than 10,000 milligrams per liter of total dissolved solids; (ii) is within 2,500 feet of the land surface; (iii) has a transmissivity greater than 200 gallons per fday per foot, provided that any formation or part of a formation included within the source of ground water has a hydraulic conductivity greater than 2 gallons per day per square foot; and (iv) is capable of continuously yielding at least 10,000 gallons per day to a pumped or flowing well for a period of a least a year; or (2) an aquifer that provides the primary source of water for a community water system as of the effective date of this Subpart. (40 CFR 191.12 n, 9-19-85)

SIGNIFICANT TECTONIC EVENT: Covered by definitions of design event, unanticipated and anticipated events.

SITE: Potentially acceptable site or candidate site, as appropriate until such time as the controlled area has been established at which time the site and the controlled area are the same. (10 CFR 960)

SITE: An area contained withint the boundary of a location under the effective control of persons possessing or suing spent nuclear fuel or radioactive waste that are involved in any activity operation or process covered by this Subpart (40 CFR 191.02n 9-19-85)

NOTE: The 40 CFR 191 definition applies to the management and storage of spent fuel, high level, or transuranic wastes at any facility regulated by NRC or agreement state. The 10 CFR 960 definition is restricted to a repository site.

SPECIAL SOURCE OF GROUND WATER, as used in this Part, means those Class I ground waters identified in accordance with the Agency's Ground-Water Protection Strategy published in August 1984 that: (1) Are within the controlled area encompassing a disposal system

or are less than five kilometers beyond the controlled area; (2) are supplying drinking water for thousands of persons as of the date that the Department chooses a location within that area for detailed characterization as a potential site for a disposal system (e.g., in accordancef with Section 112(b)(1)(B) of the NWPA; and (3) are irreplaceable in that no reasonable alternative source of drinking water is available to that population. (40 CFR 191.12 o, 9-19-85)

SUBSURFACE (UNDERGROUND) FACILITIES: The underground structure and the rock required for support, including mined openings and backfill materials, but excluding shafts, boreholes, and their seals. (120 CFR 960)

SURFACE FACILITIES: Repository support facilities within the area to which access is controlled for purposes of protection of individuals from exposure to radiation and radioactive materials.

TECTONIC PROCESS: A process or event contributing to the broad architecture of the outer part of the earth; that is to the regional assembling of structural or deformational features and the study of their interrelationships, origins, and evolution through time. Igenous activity, uplift, subsidence, folding, and faulting are examples of tectonic processes.

UNANTICIPATED EVENTS: (Postclosure Very Unlikely Event) A natural event, process, or human intrustion actin that is projected to occur with a cumulative probability greater than 0.001 but less than 0.1 for the 10, 000 year period of regulatory applicability. (40 CFR 191.13, 9-19-85)

NOTE: Proposed interpretations to be covered in separate presentation.

UNRESTRICTED AREA: Any area, access to which is not controlled by the licensee for purposes of protection of individuals fromexposure to radiation and radioactive materials, and any area used for esidential quarters. (10 CFR 60-60.2, 1-1-85)

UNSATURATED ZONE: The subsurfance above the water table. Generally, water in this zone is under less than atmospheric pressure and some of the voids may contain air or other gases at atmospheric pressure. The zone just above the water table may be saturated or nearly saturated but with a pressure of less than one atmosphere. This part of the unsaturated zone is the "capillary fring" or "tension-saturated zone." Local isolated areas within the unsaturated zone, such as flooded areas or perched water bodies, may have water pressure greater than atmospheric. (after 10 CFR 960)

POST-CLOSURE ASSESSMENT OF TECTONIC EVENTS

PRESENTED BY

Chris Pflum

(3)

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Nevada Nuclear Waste Storage Investigations PROJECT

YUCCA MOUNTAIN

PURPOSE, PROBLEM AND PROPOSAL

- **PURPOSE**
  - PROPOSE A COMMON APPROACH TO DEMONSTRATE COMPLIANCE WITH NRC & EPA REGULATIONS WITH RESPECT TO TECTONIC FACTORS
- **PROBLEM**
  - NRC's DEFINITIONS OF ANTICIPATED & UNANTICIPATED EVENTS REQUIRE INTERPRETATION
  - CORRELATION BETWEEN 10CFR60 & 40CFR191 NEEDS TO BE DEFINED
- **PROPOSAL**
  - EQUATE CERTAIN PROVISIONS IN THE NRC & EPA REGULATIONS
  - REQUEST NRC APPROVAL
  - COMPLY WITH THE PROVISIONS CONCURRENTLY

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GENERAL APPROACH

- ASSIGN NUMERICAL PROBABILITIES, THAT ARE CONSISTENT WITH THE EPA STANDARD TO THE NRC TERMS: ANTICIPATED & UNANTICIPATED EVENTS

- ASSESS THE REPOSITORY'S UNDISTURBED PERFORMANCE ASSUMING ANTICIPATED EVENTS

- ASSESS THE CONSEQUENCES OF ANTICIPATED EVENTS ON

  - OPERATIONAL DOSES
  - RETRIEVABILITY
  - CONTAINMENT
  - RELEASE RATE
  - RELEASES

- ASSESS THE CONSEQUENCES OF UNANTICIPATED EVENTS ON RELEASES

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NRC POSITION ON THE CONSISTENCY OF ITS TERMS, ANTICIPATED AND UNANTICIPATED, WITH THE EPA PROBABILITIES

"THE COMMISSION VIEWS THE PROPOSED EPA STANDARD AS BEING DIRECTED TO THE EVALUATION OF RELEASES ARISING OUT OF CATEGORIES THAT WE HAVE DEFINED AS 'ANTICIPATED PROCESSES & EVENTS' & 'UNANTICIPATED PROCESSES & EVENTS'. AS EPA ITSELF RECOGNIZES, THERE CAN ONLY BE ESTIMATES RATHER THAN RIGOROUS DEMONSTRATIONS OF PROBABILITIES OF OCCURRENCE. THE COMMISSION'S TRANSLATION OF THE EPA LANGUAGE INTO QUALITATIVE TERMS (ANTICIPATED & UNANTICIPATED) PROVIDES A CLEARER BASIS FOR JUDGING (BY NRC), UNDER THE ATOMIC ENERGY ACT, WHETHER THERE IS UNREASONABLE RISKS TO THE HEALTH & SAFETY OF THE PUBLIC."
(48FR28194, JUNE 21, 1983)

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RELEASES OVER 10,000 YEARS

(40CFR191)

PROBABILITY ↓

	TABLE 1	10 X TABLE 1	NO LIMIT
ANTICIPATED EVENTS	• PROCESSES THAT ARE EXPECTED • DISRUPTIONS THAT ARE LIKELY • EXAMPLE: HUMAN INTRUSION		
UNANTICIPATED EVENTS		• LIKELY NATURAL DISRUPTIVE EVENTS • EXAMPLE: FAULT MOVEMENT	
EVENTS THAT WILL NOT BE CONSIDERED			• EXAMPLES: – UNPREDICTABLE (e.g., APPEARANCE OF VOLCANOS) – MAJOR GEOLOGIC CHANGES

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ADAPTATION OF EPA PROBABILITIES TO NRC TERMS

ANTICIPATED EVENTS (NRC)

PROBABILITY OF:

- CUMULATIVE RELEASES: Pc < .10 OF EXCEEDING TABLE 1 (EPA)

- ANTICIPATED EVENTS THAT COULD CAUSE THESE RELEASES: Pa ≥ .10 ADAPTATION

UNANTICIPATED EVENTS (NRC)

PROBABILITY OF:

- CUMULATIVE RELEASES: Pc < .001 OF EXCEEDING 10 X TABLE 1 (EPA)

- UNANTICIPATED EVENTS THAT COULD CAUSE THESE RELEASES: .10 > Pu ≥ .001 ADAPTATION

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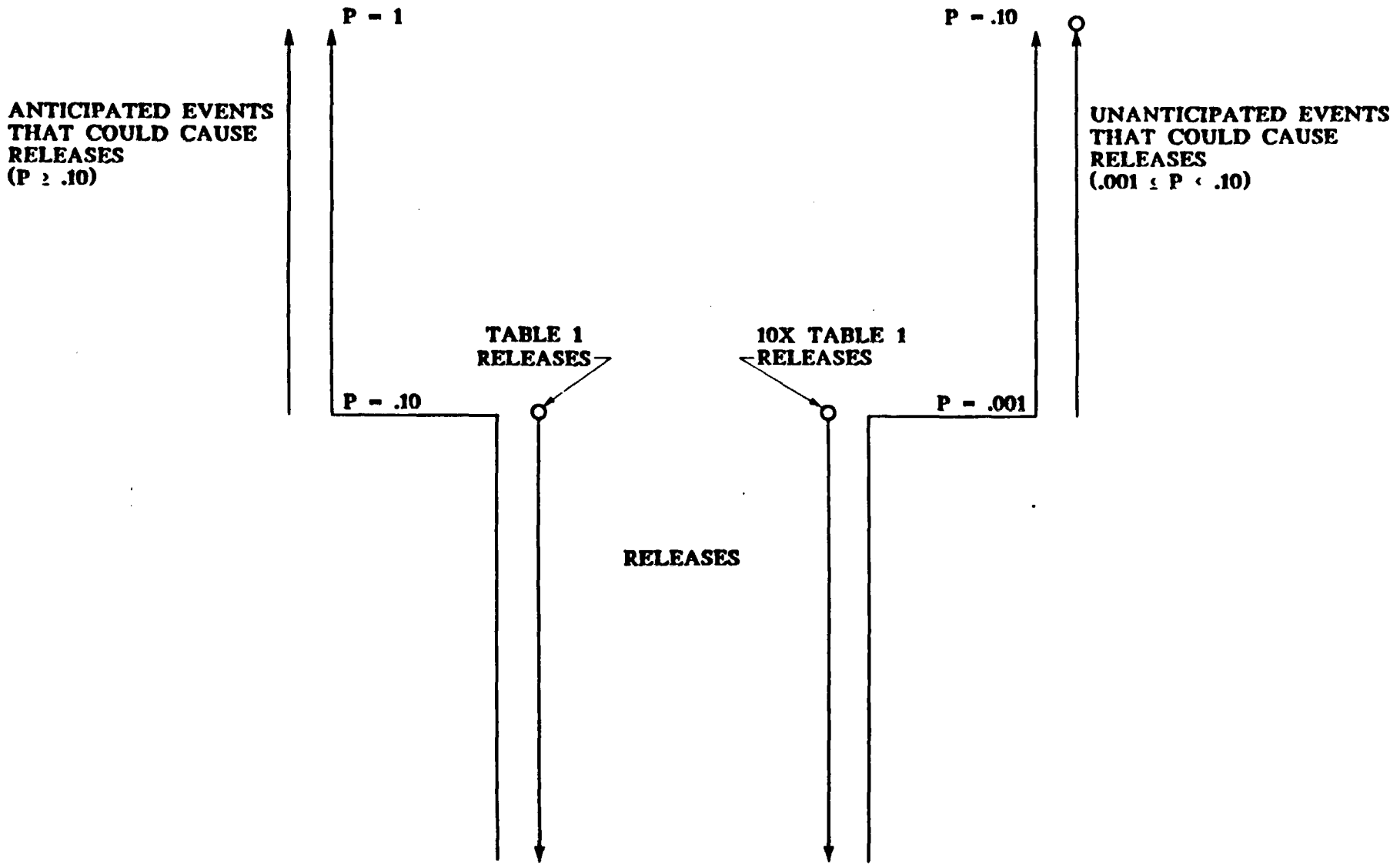
ADAPTATION OF EPA PROBABILITIES TO NRC TERMS



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RELEASES OVER 1,000 YEARS AND 10,000 YEARS (10CFR60)

"ANTICIPATED PROCESSES & EVENTS MEANS THOSE PROCESSES & EVENTS THAT ARE REASONABLY LIKELY TO OCCUR DURING THE PERIOD THE INTENDED PERFORMANCE OBJECTIVE MUST BE ACHIEVED. TO THE EXTENT REASONABLE IN THE LIGHT OF THE GEOLOGIC RECORD, IT SHALL BE ASSUMED THAT THOSE PROCESSES OPERATING IN THE GEOLOGIC SETTING DURING THE QUATERNARY PERIOD CONTINUE TO OPERATE BUT WITH PERTURBATIONS CAUSED BY THE PRESENCE OF EMPLACED RADIOACTIVE WASTE SUPERIMPOSED THEREON." (10CFR60.2)

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WHAT ARE EVENTS THAT ARE REASONABLY LIKELY TO OCCUR?

- OPTIONS FOR THE NNWSI PROJECT POSITION

  - "IDENTIFICATION OF ANTICIPATED (REASONABLY LIKELY) & UNANTICIPATED PROCESSES & EVENTS FOR A PARTICULAR SITE WILL REQUIRE CONSIDERABLE JUDGMENT & WILL NOT BE AMENABLE TO ACCURATE QUANTIFICATION, BY STATISTICAL ANALYSIS, OF THEIR PROBABILITY OF OCCURRENCE" (48FR281984, JUNE 21, 1983)

  - EVENTS ARE REASONABLY LIKELY TO OCCUR IF THEY HAVE GREATER THAN OR EQUAL TO 1 CHANCE IN 10 OF OCCURRING (OUR INTERPRETATION OF 10CFR60 & 40CFR191)

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RELEASES OVER 10,000 YEARS (10CFR60)

"UNANTICIPATED PROCESSES & EVENTS MEANS THOSE PROCESSES & EVENTS AFFECTING THE GEOLOGIC SETTING THAT ARE JUDGED NOT TO BE REASONABLY LIKELY TO OCCUR DURING THE PERIOD THE INTENDED PERFORMANCE OBJECTIVE MUST BE ACHIEVED, BUT WHICH ARE NEVERTHELESS SUFFICIENTLY CREDIBLE TO WARRANT CONSIDERATION. UNANTICIPATED PROCESSES & EVENTS MAY BE EITHER NATURAL PROCESSES OR EVENTS OR PROCESSES & EVENTS INITIATED BY HUMAN ACTIVITIES LICENSED UNDER THIS PART..." (10CFR60.2)

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WHAT ARE EVENTS THAT ARE NOT REASONABLY LIKELY TO OCCUR?

- OPTIONS FOR THE NNWSI PROJECT POSITION

  - "IDENTIFICATION OF ANTICIPATED & UNANTICIPATED (NOT REASONABLY LIKELY TO OCCUR) PROCESSES & EVENTS FOR A PARTICULAR SITE WILL REQUIRE CONSIDERABLE JUDGMENT & WILL NOT BE AMENABLE TO ACCURATE QUANTIFICATION, BY STATISTICAL ANALYSIS, OF THEIR PROBABILITY OF OCCURRENCE" (48FR28194, JUNE 21, 1983)

  - EVENTS ARE NOT REASONABLY LIKELY TO OCCUR IF THEY HAVE LESS THAN 1 CHANCE IN 10 BUT GREATER THAN OR EQUAL TO 1 CHANCE IN 1,000 OF OCCURRING (OUR INTERPRETATION OF 10CFR60 & 40CFR191)

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RELEASES OVER 1,000 YEARS (40CFR191)

- **ASSUME UNDISTURBED PERFORMANCE WHICH IS "...THE PREDICTED BEHAVIOR OF A DISPOSAL SYSTEM, INCLUDING CONSIDERATION OF UNCERTAINTIES IN PREDICTED BEHAVIOR; IF THE DISPOSAL SYSTEM IS NOT DISRUPTED BY HUMAN INTRUSION OR THE OCCURRENCE OF UNLIKELY NATURAL EVENTS." (40CFR101.12(p))**

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WHAT ARE UNLIKELY NATURAL EVENTS?

- OPTIONS FOR THE NNWSI PROJECT POSITION
  - ANY TECTONIC PROCESS (e.g., FAULT MOVEMENT, VOLCANISM) IS AN UNLIKELY NATURAL EVENT. THEREFORE, THE NNWSI PROJECT WILL NOT ASSESS THE CONSEQUENCES OF ANY TECTONIC EVENT WHEN DETERMINING RELEASES OVER 1,000 YEARS (LITERAL READING OF 10CFR191)
  - UNLIKELY EVENTS & UNANTICIPATED EVENTS ARE THE SAME. THEREFORE THE NNWSI PROJECT WILL NOT ASSESS THE CONSEQUENCES OF UNANTICIPATED EVENTS WHEN ASSESSING THE REPOSITORY'S UNDISTURBED PERFORMANCE

AND

LIKELY EVENTS & ANTICIPATED EVENTS ARE THE SAME. THEREFORE THE NNWSI PROJECT WILL ASSESS THE CONSEQUENCES OF ANTICIPATED EVENTS WHEN ASSESSING THE REPOSITORY'S UNDISTURBED PERFORMANCE. ANTICIPATED EVENTS HAVE GREATER THAN OR EQUAL TO 1 CHANCE IN 10 OF OCCURRING (OUT INTERPRETATION OF 10CFR60 & 40CFR191)

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OVER WHAT PERIOD MUST THE PERFORMANCE OBJECTIVES BE ACHIEVED?

- OPERATIONAL EXPOSURES (10CFR60 & 40CFR191) — 100 YEARS
- RETRIEVABILITY OF WASTE (10CFR60) — 100 YEARS
- EPA STANDARD (40CFR191)
  - INDIVIDUAL & GROUNDWATER PROTECTION — 1,000 YEARS
  - 1X RELEASES OF SELECTED RADIONUCLIDES — 10,000 YEARS
  - 10X RELEASES OF SELECTED RADIONUCLIDES — 10,000 YEARS
- CONTAINMENT WITHIN THE WASTE PACKAGE (10CFR60) — 1,000 YEARS
- RELEASE RATE $< 10^{-5}$/YEAR (10CFR60) — 10,000 YEARS
- PRE-WASTE EMPLACEMENT GROUNDWATER TRAVEL TIME (10CFR60) — N/A

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WHAT ANTICIPATED EVENTS SHOULD BE CONSIDERED WHEN ASSESSING THE PERFORMANCE OBJECTIVES?

- P (ANTICIPATED EVENTS) ≥ .10 (OUR PROPOSAL

- PERIOD OVER WHICH THE PERFORMANCE OBJECTIVE MUST BE ACHIEVED
  - = 1,000 YEARS (INDIVIDUAL/ GROUNDWATER PROTECTION* & CONTAINMENT)
  - = 10,000 YEARS (RELEASES & RELEASE RATE)
  - = 100 YEARS (OPERATIONAL DOSES & RETRIEVABILITY)

P (EVENTS TO BE CONSIDERED) ≥ $\frac{\text{P (ANTICIPATED EVENTS)}}{\text{PERIOD OVER WHICH THE PERFORMANCE OBJECTIVE MUST BE ACHIEVED}}$

* THE EPA STANDARD REQUIRES THAT WE ASSUME THE REPOSITORY'S PERFORMANCE IS UNDISTURBED WHEN ASSESSING INDIVIDUAL & GROUNDWATER PROTECTION. UNDISTUBED REPOSITORY PERFORMANCE, BY DEFINITION, EXCLUDES THE CONSIDERATION OF UNLIKELY NATURAL EVENTS. WE WILL THEREFORE ASSESS THE CONSEQUENCES OF ANTICIPATED EVENTS

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CALCULATED PROBABILITIES OF ANTICIPATED EVENTS

PROBABILITY OF ANTICIPATED EVENTS THAT WILL BE CONSIDERED WHEN ASSESSING:

- INDIVIDUAL/GROUNDWATER PROTECTION & CONTAINMENT $\geq \frac{.10}{1000} = 10^{-4}$
- RELEASES & RELEASE RATE $\geq \frac{.10}{10{,}000} = 10^{-5}$
- OPERATIONAL DOSES & RETRIEVABILITY $\geq \frac{.10}{100} = 10^{-3}$

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WHAT UNANTICIPATED EVENTS SHOULD BE CONSIDERED WHEN ASSESSING THE PERFORMANCE OBJECTIVES?

.001 ≤ P (UNANTICIPATED EVENTS) < .1 (OUR PROPOSAL)

- **PERIOD OVER WHICH THE PERFORMANCE OBJECTIVE MUST BE ACHIEVED = 10,000 YEARS (10X RELEASES OF SELECTED RADIONUCLIDES)**

$$\frac{\text{P (LOWER BOUND FOR UNANTICIPATED EVENTS)}}{\text{PERIOD OVER WHICH THE PERFORMANCE OBJECTIVE MUST BE ACHIEVED}} \leq \text{P (EVENTS TO BE CONSIDERED)} < \frac{\text{P (UPPER BOUND FOR UNANTICIPATED EVENTS)}}{\text{PERIOD OVER WHICH THE PERFORMANCE OBJECTIVE MUST BE ACHIEVED}}$$

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CALCULATED PROBABILITIES OF UNANTICIPATED EVENTS

$$10^{-7} = \frac{.001}{10{,}000} \leq P\ (\text{UNANTICIPATED EVENTS}) < \frac{.1}{10{,}000} = 10^{-5}$$

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WHAT WILL NOT BE CONSIDERED?

SINGLE EVENTS: $P < 10^{-7}$ (40CFR191)

SCENARIOS: $P < 10^{-8}$ (40CFR191, APPENDIX B)
(EG $P_1 \times P_2 \times P_3$)

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NNWSI PROJECT POSITION

FOR THE PURPOSES OF COMPLYING WITH 10CFR60 & 40CFR191 THE NNWSI PROJECT WILL:

- **NOT ASSESS THE CONSEQUENCES OF ANY EVENT THAT HAS A PROBABILITY OF LESS THAN 10^{-7}**
- **NOT ASSESS THE CONSEQUENCES OF ANY SCENARIO THAT HAS A PROBABILITY OF LESS THAN 10^{-8}**
- **ASSESS THE CONSEQUANCES OF ANTICIPATED & UNANTICIPATED PROCESSES & EVENTS FOR PURPOSES OF 40CFR191, & WILL ASSESS THE CONSEQUENCES OF ANTICIPATED EVENTS FOR PURPOSES OF DEMONSTRATING COMPLIANCE WITH 10CFR60**
- **EQUATE THE NRC "UNANTICIPATED PROCESS & EVENTS" TO THE EPA PROBABILITIES OF GREATER THAN OR EQUAL TO 10^{-3} BUT LESS THAN 10^{-1}**
- **EQUATE THE NRC "ANTICIPATED PROCESS & EVENTS" TO THE EPA PROBABILITY OF GREATER THAN OR EQUAL TO 10^{-1}**
- **ASSESS THE CONSEQUENCES OF ANTICIPATED EVENTS WHEN ASSESSING THE REPOSITORY'S UNDISTURBED PERFORMANCE**

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PROPOSED NNWSI PROJECT DEFINITIONS OF ANTICIPATED & UNANTICIPATED PROCESSES & EVENTS

	PERFORMANCE OBJECTIVE	PERIOD OVER WHICH THE OBJECTIVE MUST BE ACHIEVED	PROCESSES & EVENTS THAT MUST BE CONSIDERED		PROCESSES & EVENTS THAT WILL NOT BE CONSIDERED
			LIKELY OR ANTICIPATED	UNLIKELY OR UNANTICIPATED	
POST-CLOSURE	EPA STANDARD: (10CFR60.112) - INDIVIDUAL/ GROUNDWATER PROTECTION	1,000 YEARS	A.P. $\geq 10^{-4}$	N/A	N/A
POST-CLOSURE	RELEASES	10,000 YEARS	A.P. $\geq 10^{-5}$ (TABLE 1 RELEASES)	$10^{-7} \leq$ A.P. $< 10^{-5}$ (10 X TABLE 1 RELEASES)	A.P. $< 10^{-7}$
POST-CLOSURE	CONTAINMENT FOR 300-1000 YEARS (10CFR60.113(a)(1)(ii)(A))	1,000 YEARS	A.P. $\geq 10^{-4}$	N/A	N/A
POST-CLOSURE	RELEASE RATE FROM ENGINEERED BARRIER SYSTEM IS LESS THAN 10^{-5}/YEAR (10CFR60.113(a)(1)(ii)(B))	10,000 YEARS	A.P. $\geq 10^{-5}$	N/A	N/A
PRE-CLOSURE	OPERATIONAL DOSES (10CFR60.111)	100 YEARS	A.P. $\geq 10^{-3}$	N/A	N/A
PRE-CLOSURE	RETRIEVABILITY (10CFR60.111)	100 YEARS	A.P. $\geq 10^{-3}$	N/A	N/A
PRE-CLOSURE	PRE-WASTE EMPLACE-MENT GROUND-WATER TRAVEL TIME IS AT LEAST 1,000 YEARS (10CFR60.113(a)(2))	1,000 YEARS	N/A	N/A	N/A

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PROPOSED DEFINITION OF ANTICIPATED PROCESSES FOR WHICH CONSEQUENCES CONSIDERED IN ASSESSING THE NRC PRE-CLOSURE PERFORMANCE OBJECTIVES

APPLICABLE NRC PERFORMANCE OBJECTIVE	PROCESSES & EVENTS THAT MUST BE CONSIDERED	
	ANTICIPATED	UNANTICIPATED
RADIATION EXPOSURE & RELEASE	A.P. $> 10^{-4}$*	NOT CONSIDERED
RETRIEVABILITY CONSEQUENCES	A.P. $> 10^{-4}$*	NOT CONSIDERED

*1 CHANCE IN 100 OVER A 100 YEAR PERIOD OF INTENDED PERFORMANCE.

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REPOSITORY SITING CRITERIA

REACTOR SITING REQUIRMENTS ARE NOT RELEVANT FOR A REPOSITORY OR THE ASSOCIATED SURFACE FACILITIES

A REACTOR REQUIRES ACTIVE CONTROL SYSTEMS THAT MUST FUNCTION TO CONTAIN COOLING WATER IN THE EVENT OF A SEISMIC EVENT

THE REPOSITORY SURFACE FACILITY WILL ONLY DEAL WITH WASTE MATERIAL. THIS MATERIAL NO LONGER CONTAINS THE HEAT, ENERGY OR QUANTITY OF RADIOACTIVE ELEMENTS (INCLUDING GASSES) THAT ARE FOUND IN A REACTOR

ALL OF THE IMPORTANT HANDLING OPERATIONS AT A REPOSITORY SURFACE FACILITY INVOLVE A SINGLE BUILDING

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ACTIVE FAULT: OPTIONS FOR DEFINITION

- ACTIVE FAULT MEANS A FAULT ALONG WHICH THERE IS RECURRENT MOVEMENT, WHICH IS USUALLY INDICATED BY SMALL PERIODIC DISPLACEMENTS OR SEISMIC ACTIVITY (10CFR960)

- CAPABLE FAULT AS DEFINED IN 10CFR100 APPENDIX A:

  - MOVEMENT AT OR NEAR THE GROUND SURFACE AT LEAST ONCE WITHIN THE PAST 35,000 YEARS OR MOVEMENT OF A RECURRING NATURE WITHIN THE PAST 500,000 YEARS
  - A CORRELATION WITH MACRO SEISMICITY
  - A RELATIONSHIP TO A KNOWN CAPABLE FAULT
  - FOR NON CAPABILITY, A STRUCTURAL ASSOCIATION WITH GEOLOGICALLY OLD STRUCTURES

  NOTE: "IS RECURRENT" DOES NOT NECESSARILY IMPLY OR MEAN "OF A RECURRING NATURE" AS USED IN THE DEFINITION

- MOVEMENT IN HOLOCENE TIME

- MOVEMENT IN QUATERNARY TIME

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ACTIVE FAULT: OPTIONS FOR DEFINITION -II

- AVOID TERM ENTIRELY, USE CONCEPTS AS:

  - PRECLOSURE FAULT ON WHICH SLIP IS ANTICIPATED

  OR

  - POSTCLOSURE FAULT ON WHICH SLIP IS UNANTICIPATED

  OR

  - SEISMOGENIC SOURCE OF SIGNIFICANCE FOR DESIGN

NOTE: THIS STILL REQUIRES A CRITERION FOR POTENTIAL FOR SLIP

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SUMMARY OF CONCEPTS:

TREATMENT OF FAULTING

- DEFINE AN EXCLUSIONARY SITING CRITERIA BASED UPON HOLOCENE DISPLACEMENT
- DEFINE SEISMOGENIC SOURCE e.g., MOVEMENT IN HOLOCENE & HAVING SIGNIFICANCE WITH RESPECT TO DESIGN CRITERIA
- DIFFERENCE IN PRECLOSURE & POST CLOSURE FOR SIGNIFICANCE OF A STRUCTURE
- SIGNIFICANCE DEFINED AS A PERCENTAGE OVER THE INTENDED PERIOD OF PERFORMANCE
  - ANTICIPATED - 1 PART IN 10
  - UNANTICIPATED - 1 PART IN 1000
- UNANTICIPATED EVENTS DO NOT APPLY IN PRECLOSURE TIME ACCORDING TO 10CFR60
- PROBLEM IS TO IDENTIFY THE EVENTS THAT HAVE THESE PROBABILITY RANGES
- WE HAVE TO DEVELOP METHODOLOGY TO DEAL WITH EVENTS THAT HAVE THESE RANGES - THIS WILL BE TOPIC OF FUTURE INTERACTIONS WITH NRC STAFF

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CONCEPTUAL APPROACH TO SEISMIC/TECTONIC ASSESSMENTS FOR LICENSING

PRESENTED BY

STEVE BRATT (4)

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OBJECTIVES

IMMEDIATE OBJECTIVE:

Develop a framework for use in the SCP within which tectonic issues and their possible impacts on repository operation and performance can be identified, understood, and related both to each other and to regulatory guidelines.

NNWSI ULTIMATE OBJECTIVES:

Assess the importance of all pertinent tectonically-induced consequences at the Yucca Mountain site.

Focus further study on anticipated (and unanticipated) consequences and causative tectonic processes.

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SEISMIC/TECTONIC ASSESSMENT AT A GENERIC SITE - FLOW DIAGRAM

1. IDENTIFY TECTONIC PROCESSES

2. FOR EACH PROCESS, IDENTIFY ALL GEOLOGIC PHENOMENA POSSIBLE AT A GENERIC LOCATION

3. DEVELOP AN UNDERSTANDING OF EACH PHENOMENON
   - compile observations and theoretical background
   - ascertain conditions necessary for occurrence and effects on surroundings

4. IDENTIFY ALL POSSIBLE CONSEQUENCES OF EACH PHENOMENON AT A GENERIC NUCLEAR WASTE REPOSITORY
   - impacts on repository components
   - impacts on performance objectives

5. ELIMINATE FROM FURTHER CONSIDERATION THOSE PROCESSES OR PHENOMENA UNLIKELY TO ADVERSELY IMPACT COMPLIANCE WITH PERFORMANCE OBJECTIVES AT A GENERIC SITE

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SEISMIC/TECTONIC ASSESSMENT AT A SPECIFIC SITE - FLOW DIAGRAM

1. CONSIDER PROCESSES OR PHENOMENA THAT COULD ADVERSELY IMPACT PERFORMANCE AT A GENERIC REPOSITORY

2. DEVELOP SITE-SPECIFIC UNDERSTANDING OF EACH PHENOMENON
   - compile evidence for presence of occurrence conditions and observations of phenomenon
   - compute expected magnitude of phenomenon and recurrence intervals

3. DEVELOP POSITION ON PHENOMENON AND ASSOCIATED CONSEQUENCES IN LIGHT OF REGULATIONS AND OF GENERIC/SITE SPECIFIC UNDERSTANDING OF PHENOMENON

4. ELIMINATE FROM FURTHER CONSIDERATION THOSE PROCESSES OR PHENOMENA HIGHLY UNLIKELY TO OCCUR AT SPECIFIC SITE OR TO ADVERSELY IMPACT REPOSITORY PERFORMANCE

5. COMPLETE RIGOROUS PERFORMANCE ASSESSMENTS BASED ON SCENARIOS INCLUDING REMAINING PHENOMENA AND CONSEQUENCES

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TABLE

TECTONIC PROCESS	GEOLOGIC PHENOMENA	CONSEQUENCE AT GENERIC SITE	POSITION ASSESSMENT FOR YUCCA MOUNTAIN
Identify tectonic processes. FAULTING STRAIN VOLCANISM	In appendices: -Identify phenomena associated with tectonic processes. -Compile observations. -Develop understanding of physics. -Develop understanding of conditions necessary for occurrence. Conclusions in table.	Identify possible impact of given geological phenomenon on compliance with the following performance objectives: RETRIEVABILITY OPERATIONAL RELEASES LIFE OF WASTE PACKAGE POSTCLOSURE RELEASES RELEASE RATES TRAVEL TIMES	In appendices: -Examine for presence of conditions necessary to foster given consequence. -Compile observations, recurrence intervals, probabilities. Conclusions in table. State position on potential for occurrence of consequence at Yucca Mountain. UNANTICIPATED ANTICIPATED NO FURTHER CONSIDERATION WARRENTED FURTHER INVESTIGATION REQUIRED

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GEOLOGIC PHENOMENA RELATED TO FAULTING

A. Dislocation

B. Vibratory ground motion

C. Strain outside fault zone

D. Trigger volcanism

E. Alter geohydrology (permeability, strain, ground motion, temporary, permanent)

F. Induce other faulting

G. Induce landslides, debris flows, or liquefaction

H. Alter patterns and rates of erosion

I. Alter gaseous diffusion rates

J. Alter dissolution rates

K. Alter geochemistry

L. Man-induced (explosions, water loading, thermal loading, mining)

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SAMPLE GENERIC APPENDIX

APPENDIX E. ALTERATION OF GEOHYDROLOGY ASSOCIATED WITH FAULTING

INTRODUCTION

OBSERVATIONS
- Mine and tunnel flooding
- Fluctuations in water and oil wells
- Anomalous spring and stream flow
- Explosion related perturbations of groundwater
- Geologic evidence of groundwater perturbations in past
- Observational summary

THEORETICAL BACKGROUND
- Dilatancy and coseismic strain release
- Increased fracture flow
- Tilting of aquifer beds by faulting
- Creation or destruction of barriers by faulting
- Perched water
- Compaction of aquifer rocks by shaking
- Flushing of spring conduits by surging flows
- Hydraulic fracturing by pore pressure pulses
- Theoretical summary

OCCURRENCE CONDITIONS

CONCLUSIONS

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SAMPLE SITE SPECIFIC APPENDIX

APPENDIX E. POTENTIAL FOR ALTERATION OF GEOHYDROLOGY ASSOCIATED WITH EARTHQUAKES NEAR YUCCA MT.

INTRODUCTION

GEOHYDROLOGIC CHARACTER NEAR SITE

PRESENCE OF OCCURRENCE CONDITIONS

GEOLOGIC EVIDENCE OF OCCURRENCE

OBSERVATIONS OF PHENOMENON

RISK ASSESSMENT

POSITION ON PHENOMENON

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GEOLOGIC PHENOMENA RELATED TO NON-DISLOCATIONAL STRAIN

A. Uplift
B. Subsidence
C. Folding
D. Ductile flow
E. Alter strain energy
F. Alter geohydrology
G. Alter patterns and rates of erosion
H. Alter geochemistry
I. Man-induced

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GEOLOGICAL PHENOMENA RELATED TO VOLCANISM

A. Extrusive
B. Intrusive
C. Explosive
D. Alter geohydrology
E. Alter patterns and rates of erosion
F. Increase heat flow
G. Induce strain changes
H. Induce dislocations
I. Induce vibratory ground motion

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INCLUSION OF GROUNDWATER TRAVEL TIME IN PRECLOSURE ISSUES

- GROUNDWATER TRAVEL TIME IS IMPORTANT IN POST CLOSURE ANALYSES AS IT IS A BASIC MEASURE OR CHARACTERISTIC OF THE PRIMARY RADIONUCLIDE TRANSPORT MECHANISM. IT IS A FUNDAMENTAL PARAMETER IN THE DEMONSTRATION OF COMPLIANCE WITH 40CFR191
- THE IMPORTANCE OF GROUNDWATER TRAVEL TIME IN PRECLOSURE ANALYSES WOULD BE BASED ON AN ANALOGOUS CALCULATION. IN THIS CASE, THE GOVERNING REGULATION COULD BE 10CFR20 OR 40CFR191 (GROUNDWATER PROTECTION REQUIREMENTS). THE TIME REQUIRED FOR GROUNDWATER TO TRANSPORT RADIONUCLIDES TO A POINT OF ACCESS BY THE PUBLIC SHOULD BE SUFFICIENTLY LONG TO JUSTIFY THE CONCLUSION THAT THIS IS NOT A CREDIBLE PRECLOSURE EVENT
- THE PREWASTE EMPLACEMENT GROUNDWATER TRAVEL TIME PERFORMANCE OBJECTIVE DOES NOT APPLY TO EITHER POST CLOSURE TIME OR PRECLOSURE TIME. IT IS A BASELINE CONDITION EVALUATED USING DATA THAT DESCRIBE THE SITE BEFORE CONSTRUCTION OR OPERATION

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CONSIDERATION OF THERMAL EFFECTS ON TECTONIC PROCESSES

- THE LIST IN SECTION IVC IS NOT COMPLETE, NOR WAS IT INTENDED TO BE

- REPOSITORY INDUCED THERMAL EFFECTS ON TECTONIC PROCESSES IS A VALID CONSIDERATION FOR ASSESSMENT OF SIGNIFICANCE

- THERMAL EFFECTS COULD HAVE BOTH PRECLOSURE & POST CLOSURE IMPLICATIONS

- THERMAL EFFECTS ON TECTONIC PROCESSES ARE A CONSIDERATION FOR THE DETERMINATION OF ALLOWABLE THERMAL LOADING (VC)

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REMNANT & RESIDUAL STRESS

- RESIDUAL STRESSES IN A MATERIAL ARE THOSE STRESSES THAT EXIST IN THE MATERIAL WITHOUT & USUALLY PRIOR TO THE APPLICATION OF EXTERNAL LOADS. MANUFACTURING PROCESSES OR CRYSTALLIZATION ARE COMMON CAUSES OF RESIDUAL STRESS

- REMNANT STRESSES IN A MATERIAL ARE THOSE STRESSES THAT EXIST IN THE MATERIAL DUE TO PREVIOUS APPLICATION OF EXTERNAL LOADS. A POSSIBLE SOURCE OF REMNANT STRESS IS THE VISCO ELASTIC RETARDATION OF EFFECTS OF CHANGES IN STRESS

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YUCCA MOUNTAIN

REDUCING UNCERTAINTY THROUGH CONSENSUS OPINION

- AO IS NOT CLEAR ON THIS TOPIC

- THE INTENT OF THIS SECTION OF AO WAS TO INDICATE THAT CONSENSUS OPINION WOULD BE USED TO EVALUATE THE APPLICABILITY OF ALTERNATE HYPOTHESES & INTERPRETATIONS

- A MORE PROPER STATEMENT MIGHT HAVE BEEN "UNDERSTAND UNCERTAINTY" OR "REDUCE THE UNCERTAINTY IN THE UNCERTAINTY"

- HOWEVER, THERE ARE ONGOING INVESTIGATIONS ABOUT REDUCING UNCERTAINTY THROUGH CONSENSUS OPINION. THE RESULTS OF THESE INVESTIGATIONS WILL BE UTILIZED IF APPLICABLE

Enclosure 6

RATIONALE FOR SEISMIC/TECTONIC INVESTIGATIONS FOR LICENSING A NUCLEAR WASTE REPOSITORY

RATIONALE FOR SEISMIC/TECTONIC INVESTIGATIONS FOR LICENSING A NUCLEAR WASTE REPOSITORY

CONTENTS

Add: Events and Release scenarios →

CONTENTS (Cont'd)

The approach is to be used to guide the preliminary decisions, recognizing existing uncertainties, that are necessary to document the rationale for the planned program described in the SCP

OUTLINE

RATIONALE FOR SEISMIC/TECTONIC INVESTIGATIONS FOR LICENSING A NUCLEAR WASTE REPOSITORY

I. INTRODUCTION

- o Purpose: To develop and articulate an approach to resolve seismic and tectonic issues that is consistent with the requirements of 40 CFR 191, 10 CFR 60, and 10 CFR 960.

- o General Framework: The Site Characterization Plan (SCP) is the document that will define the information needed, and the approach to obtaining that information, for ultimate use in the demonstration of compliance. The applicable regulations provide a framework of concepts to be addressed in the demonstration of compliance with the regulations but do not provide specific guidance as to their implementation. The implementation of the regulations requires an analytic exercise wherein the post closure and preclosure aspects of the regulations are examined in light of possible scenarios, site characteristics and known data to determine, in a preliminary fashion, those aspects of the site which could impact the eventual compliance demonstration. This information is used in the development of plans to acquire data during site characterization. This information also provides the base for the ongoing reevaluation of the approach to demonstrate compliance. It is expected that, as data from site characterization become available, scenario probabilities will be defined and necessitate redirection of field activities. One aspect of the above described process is concerned with seismic/tectonic phenomena. This paper will provide an approach and rationale for the seismic/tectonic investigations to be described in detail in Chapter 8 of the SCP; the content of the paper will be incorporated in or

referenced by the SCP. General requirements for site characterization will be included in Chapter VII of this paper. The Safety Analysis Report (SAR) will demonstrate that the information obtained during site characterization and the methods and assumptions used to perform safety analyses reflect reasonable assurance that performance objectives of 10 CFR 60 and radionuclide release standards of 40 CFR 191 have been met.

- o Approach: The approach to resolve seismic/tectonic issues must result in a repository site and design that is safe, environmentally acceptable, cost effective, and located such that credible seismic/tectonic phenomena will not degrade system performance below acceptable limits. Performance assessment, safety analyses, and repository performance confirmation monitoring are the means by which this is demonstrated. Specific distinctions should be made regarding the period of performance; repository preclosure considerations involve both surface and underground facilities during a relatively short operational period, whereas postclosure considerations involve only the underground facilities and geologic setting, but for a much longer isolation time frame. It is envisioned that early interaction with NRC will be required during the preparation of this paper to assure that the developed framework is acceptable.

II. APPLICABLE REGULATIONS AND DEFINITIONS

A. REGULATORY FRAMEWORK

This section will provide a discussion of, and establish the hierarchy for, the application of currently existing regulations relative to seismic/tectonic considerations in the licensing process. The Nuclear Waste Policy Act (NWPA) will be included to establish the procedural baseline for the regulatory process. The three remaining regulations with direct applicability, 40 CFR 191 (draft), 10 CFR 60, and 10 CFR 960 (and other incorporated regulations), will be reviewed and summarized, with focus on

citation of those sections containing seismic/tectonic criteria, or with seismic/tectonic implications.

B. DEFINITIONS

This section will provide a glossary of applicable definitions. Definitions that will be developed should be consistent with those already in existence, such as those found in 10 CFR 60, 10 CFR 960, and 40 CFR 191 (draft). If current wording is unclear for some definitions in existence (for example "active fault" in 10 CFR 960), an interpretation of the intent of the definition is necessary. Those definitions not found in the above regulations will be developed as appropriate. Inconsistencies will be identified and resolutions proposed.

A provisional list of definitions to be included follows:

Tectonic
Definitions
Add: Defn Process, Event, Phenomena and, review paper for consistent use

Accessible environment
Active fault
Annual Probability
Anticipated event
Candidate area
Class I structure
Class II structure
Class III structure
Controlled area
Complementary Cumulative Distribution Function (CCDF)
Design earthquake I
Design earthquake II
Design event
Design ground motion
Design spectra
Deterministic analysis
Disturbed zone
Design UNE I (Underground Nuclear Explosion)

NRC to provide comments on Def'ns in 6 weeks

Design UNE II (Underground Nuclear Explosion)
Exceedance probability
Expected respository performance
Geologic setting
Hydrologic terms (to be expanded)
Important to safety
Likely consequence of failure
Maximum consequence of failure
Mean return period
Mitigation
Performance assessment
Performance objective
Postclosure earthquake (PCE)
Probabilistic analysis
Probabilistic safety assessment (formerly probabilistic risk assessment)
Reasonably forseeable events
Reasonable assurance
Response spectrum
Retrievability
Scenario
Seismicity
Seismogenic province
Significant tectonic event
Site
Subsurface facilities (shallow and deep)
Surface facilities
Tectonic Processes
Unanticipated event
Very unlikely events

Add Remnant and residual stress

For definitions which are not included in 10 CFR 60, 10 CFR 960, and 40 CFR 191, use will be made, to the extent possible, of equivalent geological, industrial, and mathematical terms.

III. CONCEPTUAL APPROACH TO SEISMIC/TECTONIC ASSESSMENTS FOR LICENSING

A. IDENTIFICATION OF SIGNIFICANT PROCESSES AND EVENTS

1. This section will address the identification of seismic/tectonic processes and significant seismic/tectonic events which may influence safety considerations for the HLW repository regarding its total life cycle. Seismic/tectonic processes which should be considered include: a) volcanism, b) faulting (both fault rupture and earthquake ground motion), c) folding, and d) regional crustal movements and related stress accumulation . Significant seismic/tectonic events are those events which, in light of tectonic history and other characteristics of the site, must be considered in evaluating compliance of the repository with the performance objectives of 10 CFR 60. This may include human-induced ground motion and seismicity. Pre-closure and post-closure performance objectives, with respect to near-surface and subsurface, will require recognition of different sets of seismic/tectonic processes and events.

The development of criteria and any decisions based upon such criteria will be subject to review by the NRC, states, and Tribes, utilizing site specific considerations.

2. This section will address the formulation of probability based criteria to be used for identifying significant seismic/tectonic events to be considered for pre-closure analyses. On a preliminary basis it will identify seismic/tectonic processes which may be important with respect to these analyses. It will provide the rationale as to why certain processes should be included or excluded, based on either probability or consequences. Further, it will evaluate the potential impact of the relevant processes on pre-closure performance objectives, identify relevant seismic/tectonic processes and events, and reevaluate impact on repository design.

3. This section will identify those seismic/tectonic processes that are indicated by preliminary analyses to be of importance with respect to the post-closure analyses. It will provide the rationale as to why some processes should be included or excluded. For each relevant process it will evaluate potential impact, both direct and indirect, of this process on each post-closure performance objective. This section

will identify controlling seismic/tectonic events including their magnitude, and reevaluate impact on repository design and performance.

B. IDENTIFICATION OF THOSE ISSUES THAT NEED TO BE RESOLVED

This section will identify key issues from the current conceptual models and understanding of site behavior which require seismic/tectonic considerations for their resolution. It will provide the rationale for including and/or excluding certain issues.

Using the established hierarchy, the section will identify the issues that may require seismic/tectonic input. This section is to include: a) performance assessment issues, b) design issues, and c) site characterization issues, and provide the rationale for including and/or excluding certain issues.

For each pertinent issue, the section will identify seismic/tectonic processes and events that must be considered in order to resolve the issue properly. It will provide the rationale and evaluate the potential design and performance impacts.

Add Events and Release scenarios → B.5 Explain Role of Ch. 6; Use of models and calculations about consequence

C. ISSUE RESOLUTION METHODOLOGY

The resolution of pre-closure and post-closure seismic and tectonic issues may require different experimental and analytical techniques because of the different health and safety concerns and the different time periods involved.

1. Pre-closure issues will involve health and safety during operations and retrieval over periods of time up to 100 years. This section will identify specific techniques used for safety analysis, including seismic safety analysis. It will identify specific seismic/tectonic events which, at this time, are considered for the analysis and identify uncertainties and assumptions used in analyses.

The approach to demonstrating compliance could include the following steps:

a. Identify the set of release scenarios for anticipated seismic/tectonic processes and events that might affect safety during operation and retrieval.

b. Conduct failure mode analysis of structures, systems and components important to safety, using event probabilities and seismic design parameters determined according to procedures outlined in Chapter IV C and V B.

c. Determine likely and maximum consequences of failure with respect to radiological safety, considering ranges of parameters that affect these consequences.

d. Analysis of (c) and degree of compliance with release limits.

e. Consideration of uncertainty involved in analyses and effect on (d). Evaluation of impact on design of structures, systems, and components important to safety, and implications regarding design of structures to resist failure.

2. Post-closure issues will involve health and safety concerns for a period up to 10,000 years. Significant post-closure releases arising from seismic/tectonic phenomena must be included in the total system performance assessment that leads to the construction of the empirical Complementary Cumulative Distribution Function (CCDF) described in ~~draft~~ 40 CFR 191. This approach to demonstrating compliance could include the following steps:

a. Identify the set of release scenarios, including scenarios involving seismic/tectonic events and processes for both anticipated and, as appropriate, unanticipated events.

b. Construct mathematical models of each class of scenario; the models predict cumulative release of radioactivity from each class of scenario for the first 10,000 years after closure.

c. Assign probability distributions to the uncertain parameters that appear in the models of the scenarios; these distributions should be based on data pertaining to site tectonics and seismicity as much as possible.

d. Combine mathematical models in a single model, capable of time-dependent simulation, that gives sample values of the total cumulative release to the accessible environment 10,000 years after closure.

e. Exercise the model formed in "d", above, to obtain statistics sufficient to construct the CCDF mentioned in draft 40 CFR 191.

Additionally, post-closure issues will involve other 10 CFR 60 performance objectives. These are ~~groundwater travel time,~~ release rates from engineered barriers, and life of waste package. Resolution of these issues may require seismic/tectonic consideration. The paper will identify those issues and corresponding seismic/tectonic factors. It will identify the analytical techniques to be used; specific seismic/tectonic events which, at this time, are considered in this analysis; and assumptions and uncertainties.

IV. APPROACH FOR IDENTIFYING SIGNIFICANT SEISMIC/TECTONIC EVENTS

A. GENERAL

Preliminary scoping analyses should be performed to identify some or all of the significant seismic/tectonic events. These scoping evaluations should be made in accordance with "B", "C", "D" and "E" below.

B. SUMMARY OF EXISTING DATA BASE RELATED TO SEISMIC/TECTONIC EVENTS

This action will present a synopsis of the current data base; it will also present sets of field observations which a) are subject to alternative interpretations and/or b) may have a significant impact on waste containment and isolation. Included are the following topics:

1. Preclosure (10 CFR 960.5-2-11)

    a. Historical patterns of seismicity (including relationship to known surface features, indications of stress state).

    b. Relief and accumulation of tectonic stress and its effect on emplacement or retrieval operations.

    c. Fault displacement and its effects on: surface and subsurface facilities judged important to safety; operations; and retrieval.

    d. Effects of vibratory ground motion, natural or man induced, on surface or subsurface facilities that are judged important to safety.

2. Postclosure (10 CFR 960.4-2-7)

    a. Tectonic stress (its nature, i.e., tectonic, remnant, residual and gravitational components; orientation and magnitude temporal and spatial variability);

    b. Fault displacement (location, length of surface rupture, movement style and history, amount of slip, secondary effects);

    c. Vibratory ground motion; acceleration and response spectra; time history; relationship to (a) and (b);

d. Volcanism (composition, volume, time-space trends, tectonic setting, relationship to seismicity, geophysical data, eruptive mechanisms, secondary effects);

e. Human induced seismicity and ground motion (size and characteristics of the effect from UNE testing, fluid injection, fluid withdrawal, impoundment, and mining);

f. Secondary effects of seismic/tectonic events (ground-water movement, secondary slip and fracturing, landslides, liquefaction, and erosion);

g. Regional crustal movements and effects on waste isolation (folding, subsidence, uplift, diapirism).

Add → The limitations of the ground motion models and associated distribution functions will be identified

C. ASSESSMENT OF SIGNIFICANCE

Based on professional judgment, including case histories from the region, and performance assessment calculations if available, this section will evaluate significance of the above topics in the context of each performance objective of 10 CFR 60. It will consider the pre-closure time-frame, i.e., operational releases and retrievability; and post-closure, i.e., compliance with 40 CFR 191 release standard, travel time, life of waste package and release rates from engineered barrier.

For the post-closure time frame considerations ~~may~~ include; but are not limited to:

1. Relief and accumulation of tectonic stress and its effects on fracture conductivity, permeability, and pore pressure, waste-package integrity, and possible deterioration of seal performance.

2. Fault displacement and its effects on the permeability, fracture, conductivity and pore pressure, waste-package integrity, and disruption of seals.

3. Effects of vibratory ground motion on permability, fracture conductivity, pore pressure, and water movement.

4. Magmatic intrusion or extrusion into the repository proper.

5. Magmatic intrusion or extrusion into the hydrologic system up and down-gradient of the repository and its affect on compliance with 10 CFR 60 performance objectives, and compliance with 40 CFR 191 release standards.

D. UNCERTAINTY CONSIDERATIONS

Assessments of safety must consider the extent of uncertainty that exists throughout any analysis and determine its effects on the conclusion reached in that analyses. Potential sources of uncertainty arise from: understanding of basic phenomena; formulation of constitutive relationships and conceptual models of features events and processes; formulation and execution of mathematical models; and data and data analysis. This section will address the manner by which uncertainty will be ~~reduced~~ Characterized in the following arrangement:

1. Conceptual uncertainty.

~~Reduce~~ Characterize conceptual uncertainties (i.e. fidelity of models to physical reality) through concensus opinion and through consideration of alternative hypotheses, if significant effect on results is shown.

2. Natural uncertainty.

~~Reduce numerical~~ characterize natural uncertainties through the use of site-specific data and concensus opinion. Appropriate numerical and analytical models will be used.

3. Interpretative uncertainty

Discuss how interpretative uncertainty can be ~~reduced~~ characterized by ~~carefully checking and~~ addressing validation of formulae and codes; this is the focus of software QA programs advocated by NRC and DOE.

E. RELEVANCE OF EXPECTED EVENTS DURING PRE- AND POSTCLOSURE TIME FRAMES AND IMPACTS ON REPOSITORY DESIGN AND PERFORMANCE.

A comparative evaluation of the significant effects will be provided to offer a perspective on the most important aspects with respect to radiological safety and cost.

V. STRATEGY FOR ISSUE RESOLUTION AND/OR MITIGATION

A. GENERAL

This section will describe the licensing strategy to be employed in resolution of issues related to seismic/tectonic characteristics of the site. It will consider: a) procedures to be used in developing the seismic design parameters; b) engineering design measures; and c) recognition and integration of uncertainties. These measures involve in-depth consideration of possible means of adding confidence in the resolution of issues.

B. SEISMIC DESIGN PARAMETERS

This section will address procedures used to develop seismic design parameters;

Pre-closure - Identify procedures which are judged to be proper for use in developing seismic design parameters. The section will consider vibratory ground motion and surface rupture. It will discuss implementation of the scheme or procedure for classification of structures, systems and components deemed important to safety, and consider ~~complementary~~ i

alternate earthquake approaches ~~acceptable~~ for ~~other nuclear facilities~~ defining seismic design input for. The section will discuss the rationale, alternatives and procedures used for equivalent considerations in other industries.

Post-closure - This section will ascertain the sensitivity of the closed repository to vibratory ground motion and fault displacement, including secondary effects such as impacts on the ground water system. It will consider sealing, waste package, and other engineered and natural barriers. It will present procedures which could be used to develop seismic design parameters for post-closure.

C. ENGINEERING

For certain seismic/tectonic processes and events, a demonstration of compliance with some performance objectives could be achieved through conservative engineering design. This section will identify, in a preliminary fashion, these processes and events and the performance objectives corresponding to them. With respect to mitigation of undesired effects of each seismic/tectonic process and event it will identify available technology, engineering strategy and cost considerations. The discussion will consider allowable thermal loading and relate it to the size of the disturbed zone, mode of emplacement, clearance for tunnels, shafts and emplacement boreholes, etc., location of surface facilities, and design parameters for vibratory ground motion, including support considerations. The section will discuss the iterative aspects assessing compliance and refining design.

D. RECOGNITION AND MITIGATION OF UNCERTAINTIES

This section will discuss the manner in which the following topics are treated:

1. Assessment of uncertainties in event scenarios, conceptual models, mathematical models, and data.

Sources of uncertainty in each category will be identified as considered in analyses, because these will detract from the demonstration of reasonable assurance.

2. Enhance understanding of potentially adverse and favorable site conditions.

   The extent to which potentially adverse and favorable site conditions exist will be evaluated with respect to safety, environment, and cost. The reasonable assurance concept will be employed in judging if sufficient information exists to make decisions leading to licensing. Where information is shown to be inadequate, additional site characterization will be required.

3. Cost impacts as a function of variability.

   An assessment will be performed to evaluate the impact of variability in the estimated or calculated value of seismic loadings on the total cost of the repository. This section will consider appropriate variability of frequency and response spectra within an acceleration range; high frequency and low frequency ground motion will be considered. This section will also consider the cost increments for designing and constructing surface and underground facilities against failure induced by surface rupture.

4. Institute conservatism in operating procedures.

   This section will identify and discuss the operating procedures that may be developed to mitigate the impacts of seismic/tectonic hazards. It will evaluate the effectiveness of these procedures.

5. Institute Performance Confirmation Monitoring Program. This section will describe the monitoring and evaluation for specific performance parameters that will validate conclusions and assumptions made in the

SAR. It will discuss how results will lend confidence to decisions, especially the possible requirement for retrieval.

VI. SEISMIC/TECTONIC EVENTS AND RADIONUCLIDE RELEASE SCENARIOS

A. GENERAL

For each significant seismic/tectonic event as determined in Chapter IV, and with reference to the corresponding performance objective, present results of preliminary performance computations and plans for the final performance assessment. Consider both preclosure and postclosure time frames.

B. PRECLOSURE

For pre-closure the analysis shall include:

1. Scenario identification and analysis;

2. Failure Mode Analysis and design sensitivity;

3. Likely and maximum consequence determination;

4. Analysis of safety and compliance with release limits;

5. Uncertainty assessment.

C. POSTCLOSURE

For post-closure, the analysis shall include:

1. Scenario identification and analysis, emphasizing all aspects of hydrology and radionuclide travel;

2. Likely and maximum consequence determination;

3. Analysis of compliance with release limits;

4. Uncertainty assessment.

The identification of postclosure-release scenarios involving seismic/tectonic phenomenon should proceed by examining the effects of such phenomenon on three things: the hydrology and radionuclide transport aspects of the site; the integrity of the waste package; and the integrity of the engineered-barrier system, including, as appropriate, boreholes and shaft seals

The magnitude and consequences of the effects identified above should be used to further screen release scenarios; this may require calculations of likely and bounding consequences in terms of release from the barriers (waste package, engineered-barriers and the site) to establish their significance.

Special-purpose mathematical models of the significant classes of scenarios identified above should be constructed and combined with the model for expected releases to form a total systems model that can be used to simulate the behavior of the site/repository system under all anticipated, significant events and processes for the next 10,000 years.

VII. REQUIREMENTS FOR SITE CHARACTERIZATION INCLUDING METHODOLOGY AND CRITERIA APPROPRIATE FOR RESOLUTION OF SEISMIC AND TECTONIC ISSUES.

A. TYPES OF ISSUES AND RELATIONSHIP TO REPOSITORY DEVELOPMENT SCHEDULE

The complete set of characterization issues for the project has been derived from considerations of performance and design (10 CFR 60) as well as consideration of siting criteria in 10 CFR 960. This issues hierarchy is an essential prerequisite in identifying data and information needs to be provided during the site characterization process. The site characterization plan (SCP) is being developed to be compatible with the

data and information needs. The data and information must be obtained in a timely manner in order to meet the DOE repository development schedule as required by NWPA.

Within the overall issue hierarchy, some issues specifically address seismic/tectonic concerns, an example is Mission Plan Issue 4.5 relating to the tectonic compatibility of the site with repository construction, operation, and closure. Conversely, there are a number of issues in which the influence of seismic/tectonic processes or events is indirect but is important to resolution.

This section will identify data and information needs related to seismic/tectonic processes or events which, at this time, are judged to be required for satisfactory resolution of each pertinent issue. It will consider all aspects of the issue resolution process, including: a) site characterization; b) engineering design; c) performance assessment; and d) performance confirmation monitoring.

For each issue requiring seismic/tectonic considerations identify when, in relation to the DOE's repository development schedule, evaluation of this issue should be completed.

B. DATA AND INFORMATION NEEDS

1. Site Characterization

Seismic/tectonic data and information needs to be satisfied during the site characterization process pertain to three broad categories. These are: a) for each seismic/tectonic process, estimates of probabililty of occurrence of a given tectonic event; b) impact of this event on containment and isolation; and c) parameters, i.e., physical properties and boundary conditions, which are required in order to quantify impact of this event on a given performance objective. Identify data and information needs as they pertain to these categories and each

applicable site characterization issue. Consider both pre-closure and post-closure performance objectives.

2. Performance Assessment

The performance assessment aspect of the issue resolution process will require its own set of data and information needs related to seismic/tectonic conditions. These may be related to a) evaluating significance of a given tectonic process to waste containment and isolation, e.g., phenomenological understanding of impact of basaltic intrusion and/or faulting on ground-water travel time and/or post-closure releases of radioactivity; b) identification of parameters, i.e., properties and boundary conditions, required for quantification of impact of a given tectonic process with respect to a given performance objective; c) evaluating relationship between impact and size of a given seismic/tectonic event; and d) constitutive relation and model validation. Identify data and information needs for each pertinent performance issue. Consider both pre-closure and post-closure time spans and performance objectives.

The process is iterative in that preliminary models, codes and scenario are used to identify information needed for licensing; as data becomes available from site characterization, models will be refined, codes will become more sophisticated and scenario probabilities will be defined. This could lead to the redefinition of information needed from site characterization. The process results in a defensible performance assessment of the site which forms the basis for demonstration of compliance with the applicable regulations.

3. Design

Identify elements of conceptual design which require seismic/tectonic consideration. Identify range of design options and discuss licensing and cost implications. Identify data and information needs related to seismic/tectonics and which are required in order to demonstrate that a given design decision is adequate. This decision may include: design

parameters, method of construction, location, and material. Consider pre-closure and post-closure aspects of repository design and performance.

VIII. CONCLUSIONS AND RECOMMENDATIONS

Based on analysis and interpretations performed in order to develop this position paper, identify perceived seismic/tectonic events or processes, if any, which represent areas of significant concern in the licensing process. Recommend areas and methods of investigation leading to resolution.