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ITASCA
Consulting Group, Inc.

30 September 1986

David Tiktinsky - SS623
U.S. Nuclear Regulatory Commission
Division of Waste Management
Washington, D.C. 20555

"NRC Technical Assistance
for Design Reviews"
Contract No. NRC-02-85-002
FIN D1016

Dear David:

Enclosed is Itasca's trip report for the presentation of the review of rock mechanics principles and discussion of outline for suggested review approach for selected sections of the NNWSI Site Characterization Plan attended by Jaak Daemen and Loren Lorig, 17-18 September 1986. Please call me if you have any questions.

Sincerely,

Loren Lorig for RDH

Roger D. Hart
Project Manager

cc: J. Greeves, Engineering Branch
Office of the Director, NMSS
E. Wiggins, Division of Contracts
DWM Document Control Room

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ITASCA TRIP REPORT

ITASCA
Consulting Group, Inc.

DATES: 17-18 September 1986

LOCATION: U.S. Nuclear Regulatory Commission
Silver Spring, Maryland

PURPOSE: Review of Rock Mechanics Principles and Discussion of Outline for Suggested Review Approach for Selected Sections of NNWSI Site Characterization Plan

ATTENDEES: J. Daemen and L. Lorig (Itasca)

PREPARED BY: L. Lorig

SUMMARY

The meetings on 17 and 18 September were attended by NRC Technical Staff from the Rock Mechanics/Design Sections of the Basalt, Tuff, and Salt Programs. At these meetings, rock mechanics principles important to repository design, analysis and performance assessment were presented by L. Lorig and J. Daemen. Following the review of rock mechanics principles on 18 September, L. Lorig and J. Daemen presented written comments on a draft letter from J. J. Linehan to D. C. Vieth (entitled "Status of Open Items — Exploratory Shaft and Construction Letter from NRC, dated April 14,1983, and NNWSI Project/NRC Meeting of August 27-28, 1985") to D. Gupta. Also, a copy of Version 1.00 of the MUDEC manual was given to D. Tiktinsky.

Meetings during the morning and afternoon of 18 September were held with J. Pearring, D. Gupta, and J. Peshel to discuss the outline for a suggested review approach for selected sections of the NNWSI Site Characterization Plan. A copy of a draft outline for two sections (Sections 8.3.2 and 8.3.3) prepared as a result of this meeting is attached.

Following the discussions for the NNWSI SCP Review, the task order addressing systems requiring site characterization was addressed. It was stated that such a task could take anywhere from one day to one year or more. It was concluded that a reasonable

effort could be made in the alloted 4-week time but that the criteria used in selecting which systems are important must be identified first.

Specific Comments

With regard to the suggested review approach for in-situ testing at NNWSI, the following items were agreed upon.

Suggested Review Approach

A suggested review approach should be prepared for the following sections of the Annotated Outline for Site Characterization Plans – Rev. 4, Feb. 1985, prepared by BWIP, NNWSI, SRP, and DOE-HQ:

(1) Section 2.9, Summary (in Chapter 2 – Geoengineering);

(2) Section 6.3, Assessment of Design Information Needs (in Chapter 6 – Conceptual Design of a Repository);

(3) Section 8.3.2, Repository Program (in Chapter 8 - Site Characterization Program); and

(4) Section 8.3.3, Seal System Program (in Chapter 8 - Site Characterization Program).

It was agreed that the following subsections should receive only minor attention.

(1) Section 6.3.3, Backfill;

(2) Section 6.3.7, Design of Surface Facilities;

(3) Section 6.3.8, Repository System Components; and

(4) Section 8.3.2.4, Design Optimization Activities and Tests.

The format of the suggested review approach for each section should follow the NRC Standard Review Plan (NUREG-0800). (See, for example, Section 2.5.4, Stability of Subsurface Materials and Foundations.)

The specific items to be addressed in each section are as follows.

I. Areas of Review — identification of what is to be reviewed in the area of rock mechanics/design

II. Acceptance Criteria

A. Basic Acceptance Criteria — discussion of applicable acceptance criteria as contained in Reg. Guide 4.17, NRC GTPs and NRC STPs, as well as potential licensing issues contained in 10CFR60.

B. Specific Technical Criteria — discussion of technical criteria for assessing the adequacy and completeness of information presented in each section

The following documents were received from NRC during the meetings:

(1) a "pasted up" copy of the latest version of 10CFR60;

(2) a list of selected NRC Products – High Level Waste Program (Sept. 1986); and

(3) Section 2.5 (p. 2-26) to Section 3.11.5 (p. 3-48) of NUREG 1-70(?) describing the required contents for a Safety Analysis Report (SAR).

NRC agreed to furnish a copy of the Nuclear Waste Policy Act, as well as any requested GTPs for use in preparing the Suggested Review Approach to In-Situ Testing at Yucca Mountain.

Respectfully, submitted,

Loren J. Lorig

Loren J. Lorig

COST BREAK-OUT

Labor

Jaak Daemen	16 hrs @ $57.75/hr	$ 924.00
Loren Lorig	16 hrs @ $19.95/hr	319.20
	TOTAL LABOR	$1,243.20

Actual Expenses

Travel

Airfare (to WDC)	
Daemen	$ 338.00
Lorig	389.00
Miscellaneous Travel Expenses	
Daemen (subway)	$ 3.10
Lorig (parking, subway)	21.00

Lodging

Daemen	
(2 nights @ $40.65/night)	$ 81.30
Lorig	
(2 nights @ $40.65/night)	81.30

Meals

Daemen	$ 44.56
Lorig	37.00

Miscellaneous Expenses

Lorig (telephone)	$ 4.38
TOTAL EXPENSES:	$ 999.64

DRAFT OUTLINE

SUGGESTED REVIEW APPROACH TO IN-SITU TESTING AT YUCCA MOUNTAIN

8.3.2 PLANNED TESTS, ANALYSES, AND STUDIES — REPOSITORY PROGRAM

I. AREAS OF REVIEW

NNWSI Repository Program Status (September 1986)

The NNWSI Repository Program has been detailed by MacDougall (1985) and Jackson (1984). Additional information is available from meeting documents ("Subsurface Design Concepts for the NNWSI", Parsons Brinkerhoff, February 1986) and from NRC/NNWSI correspondence. Some proposed testing relating to the repository program is described in NNWSI documents (e.g., Vieth et al, 1985).

Review Preliminaries

Review of Section 8.3.2, Repository Program, will require familiarity with a number of directly-related sections—in particular

Section 1.6, Drilling and Mining — This section will discuss the behavior of excavations at the NTS (particularly, the G-Tunnel) as well as near-by mines.

Chapter 2, Geoengineering

Section 6.1.1, Repository Design Requirements — This section will present the technical requirements and assumptions established as a basis and rationale for repository design.

Section 6.2.6, Subsurface Design

Section 6.3, Assessment of Design Information Needs—in particular,

Section 6.3.2, Design of Underground Openings
Section 6.3.4, Strength of the Rock Mass
Section 6.3.6, Construction

II. ACCEPTANCE CRITERIA

The applicable rules and basic acceptance criteria pertinent to the areas of this section of the SCP are given below.

10CFR60.17, Contents of Site Characterization Plan

This rule requires the applicant to

(1) describe the extent of planned excavations [(a)(2)(i)]; and

(2) describe plans to apply QA to data collection, recording and retention [(a)(2)(v)].

10CFR60.111, Performance of the Geologic Repository Operations Through Permanent Closure

This rule [point (b)] requires the applicant to design the geologic repository operation area "to preserve the option of waste retrieval throughout the period during which wastes are being emplaced and thereafter, until the completion of a performance confirmation program and Commission review of the information obtained from such a program. To satisfy this objective, the geologic repository operations area shall be designed so that any or all of the emplaced waste could be retrieved on a reasonable schedule, starting at any time up to 50 years after waste emplacement operations are initiated...."

10CFR60.133, Additional Design Criteria for the Underground Facility

This section details the design criteria for the entire underground facility.

Regulatory Guide 4.17

The minimum information is presented in Reg. Guide 4.17 as interpreted and agreed to by NRC/DOE in the annotated outline for SCPs (Rev. 4, Feb. 15, 1985).

The information presented in the SCP must be complete and thoroughly documented. The next sections describe criteria which the NRC staff may use to assess whether the information presented in the SCP with regard to planned test analyses and studies is sufficiently complete or documented to determine if the results of planned tests, analyses, and studies will assist in the licensing process.

Specific Technical Criteria

Specific technical criteria required to address potential licensing issues covered by 10CFR60 are as follows.

8.3.2.1 Overview

The overview section will state the purpose of the repository program and provide an overview of the repository program. Of particular concern to the NRC reviewer will be the interrelations and sequencing of the primary activities. The reviewer should determine if spatial or temporal proximity of tests will interfere with obtaining or analyzing results. In addition, the reviewer should assess whether the sequencing of tests progresses in a logical sequence (i.e., from least to most complex). In summary, the reviewer should determine if any of the following potential causes of test interference are likely to be present:

(a) excavation within the zone of influence of another excavation;

(b) excavation too short to avoid influence of end effects; and

(c) test sequencing.

8.3.2.2 Verification or Measurement of Host Rock Environment

This section will identify and describe the SCP tests and analyses which will define the geomechanical environment of the host rock. The objective of these tests will be the measurement (either directly or indirectly) of those properties necessary for modeling the repository designs. The following items should be looked for.

- near-field behavior of rock mass around mined openings

  Monitoring behavior (e.g., convergence) around underground openings is a reliable aid in understanding the mechanical rock mass behavior. The test plan should not be approached as if there were some great risk or uncertainty concerning stability. This should not be a major question requiring resolution at this site. Instead, standard evaluation monitoring should be aimed at confirming the stability.

- modulus of deformation

  Tests aimed at determining the modulus of deformation should always seek to determine at a minimum two elastic parameters, either (E and ν) or K and G. It is not sufficient to simply determine the modulus of deformation (i.e., rock mass – Young's modulus). In addition, it may be necessary to determine more parameters if the rock mass behaves anisotropically.

- rock mass mechanical strength determination

  This important area requires careful review to determine to what extent rock mass mechanical strength is being determined by

  (a) intact rock strength; and

  (b) discontinuity strength.

Determination of the "weak link" may permit characterization to be focused on one of the two constituents.

8.3.2.3 Coupled Interactive Tests

The issue to be addressed here is the extent to which the coupled processes need to be characterized. From the waste isolation point of view, characterization of the effect of coupled processes on radionuclide flux may not be possible or significant enough to warrant detailed definition through field testing. However, with regard to waste containment (e.g., canister loading) and retrievability (i.e., emplacement hole/liner and room stability), characterization of the thermal/mechanical/hydro/chemical environment through testing is desirable and technically more feasible.

The coupled processes are of greatest significance when in close proximity to the excavations and heat sources. The majority of non-linear effects occur in these areas of high temperature and stress gradient. The ability to describe these coupling processes on a large scale through the use of small-scale field testing is open to question. The reliability of tests without independent control of the various coupling parameters and without the ability to characterize the rock mass in detail is probably poor. An important consideration here is the concept of a "disturbed zone", which was introduced in 10CFR60 because it was recognized that adequate characterization of the behavior of that portion of the rock mass subject to high temperature and stress gradients may not be possible. Regarding in-situ testing, NRC gives the following conditions concerning the acceptability of underground testing (Vieth et al, 1985).

- In evaluating overall repository performance, no credit is taken for that portion of the rock that cannot be evaluated adequately without direct testing of coupled thermal effects.

- The components of the natural system, for which performance credit is taken, are characterized adequately for evaluation of overall repository performance.

- Components of the engineered system, such as the waste package, are designed with adequate conservatism to compensate for, or reduce, uncertainties with respect to the coupled thermal, mechanical, hydrologic, and geochemical conditions that will be encountered.

- As with all site characterization tests, the tests that support the design of the engineered system are carried out under conditions that bound repository conditions. This means that the design of the tests takes into account the full range of uncertainty about hydrothermal conditions that are expected to be encountered.

From the waste isolation point of view, it may be reasonable for the site not to take credit for the performance of the disturbed zone where the uncertainties in measurement and evaluation exist. Coupled interactive in-situ testing should, instead, focus on accurately understanding the performance of those components of the natural and engineered systems which affect waste containment and retrievability. These tests should be carried out under conservative ranges of temperature and stress conditions to bound the possible range of rock mass response.

8.3.2.4 Design Optimization

This section describes the design optimization studies and activities which require site characterization. Potential topics include

- refinement of design data needed to resolve design alternatives

- design performance verification for activities such as rock excavation and mining technique, waste package emplacement, and retrieval issues.

The specific areas likely to be discussed are:

(a) demonstration of feasibility of drilling long horizontal holes, replacing and retrieving waste;

(b) evaluation of alternative support systems; and

(c) precise measurements of in-situ stress state

The specific acceptance criteria applicable to potential licensing issues of this section are given in 10CFR60.122(c)(20) - Complex Engineering Measures.

8.3.2.5 Repository Modeling

The section will identify and describe planned repository design model and code development, utilization, verification and validation activities which require site characterization data.

This section potentially could be the subject of a great deal of discussion. The approach to be developed in this section is based on Brady and St. John (1982) and follows recommendations made in the Itasca report on the status of thermomechanical modeling at all three potential repository sites. In particular, the data needs required to validate various equivalent continuum models will be addressed.

8.3.3 PLANNED TESTS, ANALYSES, AND STUDIES — SEAL SYSTEM PROGRAM

I. AREAS OF REVIEW

<u>NNWSI Sealing Status (September 1986)</u>

The NNWSI sealing program has been detailed by Fernandez and Freshley (1984) and Fernandez (1985). Additional information is available from meeting documents (NNWSI/NRC Meeting of 27-28 August 1985) and from NRC/NNWSI correspondence subsequent to this meeting.

Some proposed testing relating to sealing is described in NNWSI documents (e.g., Vieth et al, 1985).

Review Preliminaries

Review of Section 8.3.3, Seal Systems Program, will require familiarity with a number of directly related sections—in particular,

Section 1.6, Drilling and Mining — This section will tabulate the location and characteristics of all drill holes and excavations at and near the site and will provide available information on the effects of the active and abandoned wells, boreholes, and excavations on the principal hydrogeologic units.

Section 6.1.5, Barriers Important to Waste Isolation — This section will provide a description of the repository barriers such as tunnel backfill and repository and borehole seals.

Section 6.2.7, Backfill of Underground Openings

Section 6.2.8, Shaft and Borehole Seals

Section 8.3.5.2, Strategy for Postclosure Performance Assessment — in particular,

8.3.5.2.1, Engineered Barrier Subsystem
8.3.5.2.2, Seal Systems Performance Goals

Supplementary or supporting sections will need to be reviewed, or an assessment of their validity provided by other reviewers, for it is certain that essential input information will have to be obtained from a variety of sources (including, for example, Geoengineering, Hydrology, Geochemistry, Climatology and Meteorology, Repository Design). In sum, seal program review requires fairly comprehensive understanding of a variety of repository aspects. As such, an in-depth seal program review can be obtained only through a multi-disciplinary effort.

II. ACCEPTANCE CRITERIA

The applicable rules and basic acceptance criteria pertinent to the areas of this section of the SCP are given below.

> Rule 10CFR60 (U.S. Nuclear Regulatory Commission, 1983, 1985) requires, in addition to the seals for shafts and boreholes (§60.134), that "the design of the underground facility shall provide for control of water or gas intrusion" (§60.133,d) and that "the design of the underground facility shall incorporate excavation methods that will limit the potential for creating a preferential pathway for groundwater or radioactive waste migration to the accessible environment" (§60.133,f, U.S. Nuclear Regulatory Commission, 1983), or ". . . that will limit the potential for creating a preferential pathway for groundwater to contact the waste package or radionuclide migration to the accessible environment" (unsaturated zone amendment, §60.133,f, U.S. Nuclear Regulatory Commission, 1985).

The information presented in the SCP must be complete and thoroughly documented. The information must be consistent with the requirements presented in Regulatory Guide 4.17, as interpreted and agreed to in the Annotated Outline for Site Characterization Plans Revision 4 (Feb. 15, 1985).

Specific technical criteria required to address potential licensing issues covered by 10CFR60 are as follows

8.3.3.1 Overview

The overview section will state the purpose of the seals program and will provide an overview of the seals program. The section will describe the interrelations and the sequencing of the primary activities of the program.

As pointed out above, and as amplified by specific examples in subsequent sections, a sealing program must be interdisciplinary. It must be highly interactive with the various disciplines from which it will obtain essential information. Many, if not all, of the relevant investigations will have their own objectives—quite independent of the sealing program. Therefore, the information flow mechanisms and channels from the sealing program to "input" disciplines (to ensure that all sealing program information needs will be satisfied) and from the "input" disciplines to the sealing program (to ensure timely and reliable information feedback) should be of particular concern and interest to the NRC reviewers of the sealing program.

Typical examples of information transfer channels of concern are as follows.

- sealing program to/from hydrology — the method by which the sealing program transfers its information needs to hydrology (examples: potential water accumulation above shafts and ramp), potential water inflow along shafts, potential water inflow along faults, degree of salination/ water content in seal locations)

- the assurances that can be given that the hydrology program will obtain information needed by the sealing program

- the place and form of the information transferred to the sealing program (examples of extreme possibility: the sealing program obtains information when hydrology reports are published and come into the public domain, the sealing program has on-site representation and obtains information at the time it is generated)

Similar interactions can be outlined for other repository programs.

8.3.3.2 Seal System Environment

This section will identify and describe the tests and analyses needed to establish the repository seal and backfill environments.

These tests and analyses will define the physical and chemical characteristics that influence the design, installation (construction), and performance of the repository seals.

The major concern for the NRC seal program reviewer will be the completeness of this section as well as the prioritization of various information needs.

Examples are as follows.

- physical environment — temperature, deformations (identification of deformations to which seals/backfill might be subjected), stresses applied to seals/backfill, water pressure, water flow, gas pressure, gas flow

- chemical environment — temperature, rock chemistry (mineralogy), water chemistry, water flow rate, pressure

It would seem highly likely that much of this information will be obtained from other programs. If so, the NRC seal program reviewer might coordinate with reviewers of the various related programs in order to ensure that satisfactory information transfer to the sealing program has taken place. To the extent that data are generated specifically for the sealing program (e.g., tests, analyses), they should be consistent with similar data generated in related programs. This might provide the reviewer with an opportunity for a semi-independent assessment of the validity of the sealing program data.

8.3.3.3 Seal System Components and Interaction Tests

This section will identify and describe the following.

- seal system component tests, including component-environment interaction testing
- repository backfill tests and studies.

Note: The emphasis on seal system component testing hints strongly that no seal system tests are required/proposed. Of particular concern in this regard should be the influence of emplacement procedures on eventual seal system performance.

8.3.3.4 Seal System Design Optimization

This section will identify and describe seal system design optimization activities that will require site characterization data. Potential subjects include the following.

- studies and tests to assist in design concept selection
- development of design requirements
- studies to translate design requirements into specific design descriptions
- development tests to demonstrate the feasibility of fabrication processes and to help verify the designs.

Note: Although "optimization", as such, might not be an NRC interest, this section actually deals with the overall seal system design, particularly as it relates to site-specific features (i.e., as it depends on site characterization data).

NNWSI seal system design topics that will be of particular interest to the NRC seal program reviewer include the following.

- ramp seal system design
- shaft seal system design
- borehole seal system design
- backfill design
- fault seal system design

At least conceptually, all of these form different systems and, hence, need to be addressed separately. Site characterization data required will be the environmental data identified in Section 8.3.3.2. Included, also, will be the "engineering" aspects of the seal design (e.g., seal geometry, seal emplacement, and sealing of the rock around seals).

Note: Is backfill to be addressed here? (Certainly yes, if part of the engineered barrier system.)

Of particular interest to the NRC sealing program reviewer will be "development tests to demonstrate feasibility of fabrication processes". Topics to be addressed include the following.

- whether the tests will be full scale
- whether in situ (at depth)
- description of the performance testing procedures and duration

8.3.3.5 Seal System Modeling

This section will describe planned modeling and code development studies associated with seal system development, utilization, verification, and validation for those tests and studies requiring data from site characterization.

Note: In principle, this could (should?) be an extremely broad aspect of the program—in essence, a miniature version of the repository modeling program. Examples include the following.

- thermodynamic (geochemical) modeling of long-term seal behavior (component changes, consequences for component/hydraulic conductivity, strength)
- flow modeling
- mechanical interaction modeling

Many of the NRC sealing program reviewer concerns will be identical to overall program review concerns —e.g., "validation" in the traditional sense is exceedingly difficult and probably impossible for very long term. Presumably, much of the modeling will be performed with codes developed for other purposes? If so, the review will benefit from multidisciplinary review.

REFERENCES

Brady and St. John (1982)

Fernandez (1985).

Fernandez and Freshley (1984)

Jackson (1984).

MacDougall (1985)

NNWSI/NRC Meeting of 27-28 August 1985

Parsons Brinkerhoff, "Subsurface Design Concepts for the NNWSI", February 1986

Vieth et al, 1985