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**A PEER REVIEW OF THE NEVADA NUCLEAR WASTE STORAGE
INVESTIGATIONS: AUGUST 24-28, 1981**

February 1984

J. F. T. Agapito & Associates, Inc.
Grand Junction, Colorado

Technical Information Center
Office of Scientific and Technical Information
United States Department of Energy

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NEVADA
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FEBRUARY 1984

UNITED STATES DEPARTMENT OF ENERGY
NEVADA OPERATIONS OFFICE-LAS VEGAS, NEVADA

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INTRODUCTION

The Nevada Nuclear Waste Storage Investigations (NNWSI) are a part of the National Waste Terminal Storage (NWTs) program of the U.S. Department of Energy (DOE). The purpose of the NWTs program is to safely dispose of the growing quantities of nuclear waste being accumulated at nuclear power plants in an environmentally acceptable manner. The DOE has determined that the safest and most feasible method currently available to ultimately dispose of such wastes is by storing them in mined geologic repositories. The NNWSI include site-exploration and regional studies of the Nevada Test Site (NTS) area to establish whether a technically acceptable site exists for consideration as a potential location for a commercial, high-level nuclear waste repository.

The NNWSI Project holds peer reviews to obtain independent assessments of the sufficiency and quality of its activities and to obtain additional expert recommendations regarding the continuance or redirection of its activities. These reviews provide management with external feedback on the adequacy of the program of activities being reviewed. The peer reviewer comments and recommendations are reviewed by the DOE and technical Project participants and decisions are made, as appropriate, regarding the workscope, direction, and management of the activities reviewed.

On August 24-28, 1981, a peer review of three major areas of the NNWSI was conducted at the Riviera Hotel in Las Vegas, Nevada. The three investigative areas were: (1) geology/hydrology, (2) geotechnical/geoengineering, and (3) environmental studies. A separate review panel was established for each of the investigative areas which was composed of experts representing appropriate fields of expertise. A total of twenty nationally known or prominent state and local experts served on the three review panels. About 185 people attended the peer review sessions, which were open to the public. Representatives of the DOE Nevada Operations Office, DOE Headquarters, Office of Waste

Isolation--Battelle, U.S. Nuclear Regulatory Commission (and its contractors), and interested firms in the fields of geoengineering and environmental studies were among those in attendance. Some interested citizens and representatives of the local news media also attended the peer review.

Several weeks prior to the meeting, the peer reviewers were each provided with a copy of the following reports to give them current background information:

FY 1979 Peer Review Summaries and Related Documentation, Nevada Nuclear Waste Storage Investigations; U.S. Department of Energy, Nevada Operations Office Report NVO-196-16; June 1980.

Geologic and Hydrologic Investigation of Yucca Mountain Peer Review Documentation, Nevada Nuclear Waste Storage Investigations; U.S. Department of Energy, Nevada Operations Office Report NVO-196-22; April 1981.

Quarterly Report, January through March 1981, Nevada Nuclear Waste Storage Investigations; U.S. Department of Energy, Nevada Operations Office Report NVO-196-25; June 1981.

Evaluation of Tuff as a Medium for a Nuclear Waste Repository: Interim Status Report on the Properties of Tuff; J. K. Johnstone and K. Wolfsberg (Eds.); Sandia National Laboratories Report SAND80-1464; July 1980.

Additional advance information was available to the peer reviewers on request.

At the peer review, the NNWSI Technical Project Officers, Principal Investigators, and technical staff members made detailed presentations on selected subjects according to a schedule developed by polling the peer reviewers, and answered questions about their investigative activities and findings. Slides, viewgraphs, and other visual aids were used extensively during the presentations and in answering questions. Time was allowed after each presentation for NNWSI participants to answer questions posed by the peer reviewers and review attendees. The agenda for the first day provided the peer reviewers

with an overview of the NNWSI, including its current status and plans. During the following four days, the participants were divided into the three panel sessions where they focused on more specialized investigative areas. The panel sessions were concluded in executive sessions (panel peer reviewers only) where the three review panels each summarized their overall assessment and recommendations. Each peer review panel orally presented its assessment and recommendations to the NNWSI Project Manager on August 28, 1981. During the next few weeks, each of the three peer review panels developed written reports presenting their collective comments and recommendations and mailed their final reports to the NNWSI Project Manager.

The NNWSI Project Manager forwarded a copy of the appropriate peer review panel report and the individual peer review correspondence received by the DOE to the responsible Technical Project Officer (TPO) for review and response. The NNWSI Technical Overview Contractor (TOC) then evaluated the panel reports and related correspondence as well as the TPO responses and submitted a summary evaluation of the outcome of the peer review and, as appropriate, made recommendations regarding the need for making programmatic changes. Because the TOC was responsible for overseeing the environmental studies, there is only a TOC response to that panel report.

This report documents all of the review comments received as a result of the August 24-28, 1981, peer review. It also documents the peer reviewers in attendance, the meeting and session agendas, and the abstracts of the Principal Investigators available for presentation at the review as scheduled by the peer reviewers. The correspondence in the appendices contain the comments of the individual peer reviewers on each panel made during the development of the formal panel reports that are presented in the main body of this report. Since it was not requested by the DOE, some of the peer reviewers did not produce individual reports. For instance, the DOE received no individual correspondence from the environmental studies peer reviewers, just the required Panel Report. For the sake of publishing a complete record, the DOE has reproduced all peer reviewer correspondence and reports it received in this document, even though the three panel reports were the only chartered output of this peer review.

PEER REVIEW PROGRAM

Department of Energy
Nevada Operations Office
P. O. Box 14100
Las Vegas, NV 89114

JUL 20 1981

Those on Attached List

NNWSI PROJECT PEER REVIEW

The attached documents are being provided to acquaint you with the Nevada Nuclear Waste Storage Investigations.

Sincerely,

Robert M. Nelson, Jr., Project Manager
Nevada Nuclear Waste Storage Investigations

WMPO:RMN-464

Enclosures:

1979 Peer Review Summaries
1980 Geologic Peer Review
January-March, 1981 Quarterly Report
SNL Document SAND80-1464

cc w/o encls:

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L. D. Ramspott, LLNL, Livermore, CA
B. R. Erdal, LANL, Los Alamos, NM
L. W. Scully, SNL, 4531, Albq., NM
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W. E. Wilson, USGS, Denver, CO
A. R. Hakl, W, NTS
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NNWSI
PROJECT PEER REVIEW

August 24-28, 1981

Riviera Hotel
Montmartre Room
Las Vegas, Nevada

MONDAY, August 24, 1981

8:00 a.m.	Welcome	M. Gates, Mgr, DOE/NV
8:10 a.m.	Introduction	M. Kunich, DOE/NV A. Stephenson, SNL
8:25 a.m.	Scope and Structure of Review	W. Twenhofel
8:35 a.m.	History, Schedule and Plans	R. Lincoln, SNL
10:00 a.m.	BREAK	
10:15 a.m.	Regulatory Criteria and Licensing	J. Neal, SNL
11:00 a.m.	Area Screening	S. Sinnock, SNL
12:00 noon	LUNCHEON	
1:00 p.m.	Geologic/Hydrologic Studies	G. Dixon, USGS W. Carr, USGS W. Wilson, USGS
2:45-3:00 p.m.	BREAK	
4:00 p.m.	Geochemistry and Mineralogy	B. Erdal, LANL B. Crowe, LANL
5:00 p.m.	Weapons Test Seismic	L. Scully, SNL
5:10 p.m.	ADJOURN	
5:30-7:00 p.m.	COCKTAIL HOUR (No Host)	

TUESDAY, August 25, 1981

8:00 a.m.	Geoengineering Studies	L. Tyler, SNL
9:15 a.m.	Environmental Studies	S. Bertram, SNL
10:00 a.m.	BREAK	
10:15 a.m.	Exploratory Shaft Design	D. Nelson, LANL
10:45 a.m.	Repository and Test and Evaluation Facility Design	L. Scully, SNL
11:15 a.m.	Waste Package	L. Ramspott, LLNL K. Johnstone, SNL
11:45 a.m.	Performance Analysis	R. Lincoln, SNL R. Link, SNL
12:15 p.m.	LUNCHEON	
1:30 p.m.	Comments on Items to be con- sidered for Wed. & Thur. Agenda	W. Twenhofel
2:00 p.m.	Executive Session of Peer Reviewers	
4:00 p.m.	Peer Reviewers Meet with Key Project Personnel	

WEDNESDAY, August 26, 1981

8:30 a.m. - 5:00 p.m.	Agenda as defined in Tuesday afternoon session to be posted by 8:00 a.m.
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THURSDAY, August 27, 1981

8:30 a.m. - 2:00 p.m.	Continue Wednesday Agenda
2:30-5:00 p.m.	Executive session of Peer Reviewers

FRIDAY, August 28, 1981

9:00 a.m. - 12:00 noon	Executive session of Peer Reviewers and Key Project Personnel
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GEOTECHNICAL/GEOENGINEERING SESSION

Wednesday, August 26, 1981

		<u>Presentation</u>	<u>Discussion</u>
8:00 A.M.	ENG 4, 5, 6	20	20
8:40 A.M.	ENG 1	10	10
9:00 A.M.	ENG 2	10	10
9:20 A.M.	ENG 3	10	10
9:40 A.M.	Waste package design including ENG 12	10	10
10:00 A.M.	Break		
10:15 A.M.	Panel discussion with Tyler, Scully and Gnirk (Topic: Introduction to the Repository Design Process. How Does Analysis Fit In?)		
11:00 A.M.	ENG 10	10	10
11:20 A.M.	ENG 11	10	10
11:40 A.M.	ENG 8	10	10
12:00 NOON	Lunch Break		
1:30 P.M.	ENG 7	10	10
1:50 P.M.	Interface between far field analysis and per- formance assessment (by R. Link)	20	20
2:30 P.M.	Model Development incl. ENG 9, 13, 14 (by Tyler, Gnirk)	20	20
3:10 P.M.	Break		
3:30 P.M.	Rationale for field test- ing - Purpose (by Tyler, Pratt)	15	15
4:00 P.M.	ENG 16	10	5
4:15 P.M.	ENG 15	20	15
4:50 P.M.	Function and Scope of Exploratory Shaft Inte- gration into Overall Project (by R. Lincoln)	10	20
5:20 P.M.	Criteria for Shaft Design (by D. Nelson)	10	10
5:40 P.M.	Adjourn		

Thursday, August 27, 1981

8:00 A.M. ° Round Table Discussion with Geologists
 ° Continue Wednesday's Discussions

GEOLOGY/HYDROLOGY SESSION

Wednesday, August 26, 1981

ALL PEOPLE PRESENT FOR THEIR SESSION

		<u>Presentation</u>	<u>Discussion</u>
<u>GEOLOGY</u>			
8:00 A.M.	GEO 18, 19, 20	30	40
9:10 A.M.	GEO 13, 14	15	15
9:40 A.M.	GEO 17	10	10
10:00 A.M.	Break		
10:15 A.M.	GEO 21	15	15
10:45 A.M.	Executive Session of Peer Reviewers		
- - - - -			
<u>GEOPHYSICAL</u>			
1:00 P.M.	GEO 29,30	15	15
1:30 P.M.	GEO 31	15	15
2:00 P.M.	GEO 32	15	15
2:30 P.M.	GEO 22	15	15
3:00 P.M.	Break		
3:15 P.M.	Electrical Survey Summary		
4:00 P.M.	Panel discussion with Lappin, Johnstone, Sibbet, Johnson, Thomas, Eaton and Parrish		
6:00 P.M.	Executive Session of Peer Reviewers		

GEOLOGY/HYDROLOGY SESSION

Thursday, August 27, 1981

ALL PEOPLE PRESENT FOR THEIR SESSION

Presentation

Discussion

HYDROLOGY

8:00 A.M.	GEO 28	20	20
8:40 A.M.	GEO 27, 33	15	15
9:10 A.M.	GEO 26	10	10
9:30 A.M.	GEO 23	20	20
10:10 A.M.	Break		
10:30 A.M.	Questions (saturated vs unsaturated and others)		
11:00 A.M.	Executive Session of Peer Reviewers		

GEOCHEMISTRY

1:30 P.M.	GEO 1, 2, 3, 4	20	20
2:10 P.M.	GEO 5, 6	15	15
2:40 P.M.	GEO 7, 8, 9	15	15
3:10 P.M.	Break		
3:30 P.M.	GEO 10, 11, 12	15	15
4:00 P.M.	Executive Session of Peer Reviewers		

ENVIRONMENTAL STUDIES SESSION

Wednesday, August 26, 1981

- 8:30 A.M. Panel discussion of NNWSI program component focus with Lincoln, Bertram, Melancon
- SCR/NEPA requirements for EA, TEF-DEIS and repository DEIS
 - 10 CFR 60/NEPA implications for current and future studies
- 9:30 A.M. Presentation of environmental reports by individual principal investigators (10 minutes each)
- 10:50 A.M. Questions and Answers
(ALL PRINCIPAL INVESTIGATORS PRESENT)
- 12:20 P.M. Lunch
- 2:00 P.M. Executive Session of Peer Reviewers
- - - - -

Thursday, August 27, 1981

- 8:30 A.M. Panel discussion of:
- Performance assessment program by R. Link and R. Lincoln
 - Screening studies by S. Sinnock
- 9:30 A.M. Peer reviewers join Hydrology sub-session
- 11:00 A.M. Panel discussion of Nonradiological Geochemistry questions with B. Erdal and USGS representative
- 11:30 A.M. Open
- 12:00 NOON Lunch
- 2:00 P.M. Executive Session of Peer Reviewers

NNWSI PROJECT PEER REVIEW
ABSTRACTS

August 26-27, 1981

A. GEOLOGY/HYDROLOGY SESSION:

<u>Abstract Number</u>	<u>Title/Abstract</u>	<u>Author/Org.</u>	<u>Length (Minutes)</u>
GEO 1	<u>Chemical Retardation Properties of Tuff: Sorptive Properties and Transport Processes</u> Parameters affecting sorption of radionuclides by tuff include lithology, groundwater composition, temperature, contact time, solution-to-solid ratio, element concentration, and atmosphere. The effects of these parameters on sorption will be discussed, along with some of the techniques used to obtain the information and the kinetics of sorptive processes.	K. Wolfsberg, LANL	20
GEO 2	<u>Chemical Retardation Properties of Tuff: Modeling and Correlation with Lithology</u> Sorption behavior of most radionuclides can be correlated with tuff mineralogy and groundwater composition. A theoretical model for zeolitized samples semi-quantitatively predicts R_d values. Until the sorption mechanism for devitrified and glassy samples is determined, correlation must be based on statistics or empirical models.	M. T. Sykes, LANL	20
GEO 3	<u>Chemical Retardation Properties of Tuff: Groundwater Properties</u> The sorption of waste elements on minerals is largely dependent on the oxidation state and complexing of the waste element, which in turn are dependent on the properties of the groundwater. We are analyzing groundwaters for major ions, trace elements, organics and properties such as pH and Eh. These analysis, together with our modeling efforts, should	A. E. Ogard, LANL	20

<u>Abstract Number</u>	<u>Title/Abstract</u>	<u>Author/Org.</u>	<u>Length (Minutes)</u>
	enable us to describe the mineral assemblage with which the waters are in equilibrium. They should also enable us to estimate the oxidation state, speciation, and complexing of individual waste elements and to calculate their retardation in tuff.		
GEO 4	<u>Chemical Retardation Properties of Tuff: Actinide Behavior</u>	W. R. Daniels, LANL	15
	Various parametric studies of the sorptive behavior of americium, plutonium, and neptunium are in progress. Americium and plutonium tend to sort well on tuff, while neptunium sorbs poorly. Large variations in actinide sorption are observed when experimental conditions are changed, indicating that such behavior may occur under field conditions and also indicating the need for additional study of the chemistry of actinides.		
GEO 5	<u>Fundamental Chemistry of Waste Elements in Solution: Oxidation-Reduction Buffers</u>	A. E. Ogard, LANL	30
	One of the most important variables in the chemistry of waste elements is the oxidation state of the element. Larger differences can be observed in solubilities, complex ion formation, and sorption depending on the oxidation state of the element. We are studying methods for the determination of the oxidation-reduction properties of natural waters and for controlling these properties with buffer systems for both laboratory and field experiments.		
GEO 6	<u>Fundamental Chemistry of Waste Elements in Solution: Plutonium Chemistry</u>	T. W. Newton, LANL	30
	Work is described in which the chemistry of plutonium, dilute in aqueous solutions, has been elucidated by using reactions with selected osmium complexes. Results on the polymerization and hydrolysis of plutonium (IV) are particularly noteworthy.		

<u>Abstract Number</u>	<u>Title/Abstract</u>	<u>Author/Org.</u>	<u>Length (Minutes)</u>
GEO 7	<u>Radionuclide Transport by Aqueous Flow in Tuff: Experimental Studies of Porous Flow</u> <p>The elution of radionuclides through columns of crushed rock provides a simple "first step" to relate laboratory "batch-type" measurements to flowing systems. Several kinds of elution behavior have been observed which suggest that several (probably many) mechanisms are responsible for the migration and retardation of radionuclides.</p>	E. N. Treher, LANL	15
GEO 8	<u>Radionuclide Transport by Aqueous Flow in Tuff: Experimental Studies Using Whole and Fractured Rock Cores</u> <p>In order to study the interactions of radionuclides during transport through rock matrices, we have developed experimental techniques for pumping solutions through solid and cracked rock cores. Information derived in these studies includes rock porosity, liquid flow patterns, and radionuclide retardation.</p>	J. L. Thompson, LANL	15
GEO 9	<u>Radionuclide Transport by Aqueous Flow in Tuff: Modeling of Radionuclide Transport</u> <p>Radionuclide transport by aqueous flow in tuff has been studied in the laboratory using crushed rock columns and solid rock columns. These experiments have been modeled using a one-dimensional flow model similar to the theory of ion exchange chromatography. Simple cations such as cesium and strontium have been shown to behave as expected for ion exchange. Laboratory experiments with flow through an isolated fracture have been compared with the analytic solution to fracture flow with matrix diffusion of T. Neretnicks. Numerical models to describe flow in fractured and porous media appropriate to field experiments are being developed.</p>	R. S. Rundberg, LANL	15

<u>Abstract Number</u>	<u>Title/Abstract</u>	<u>Author/Org.</u>	<u>Length (Minutes)</u>
GEO 10	<u>Hydrothermal Conditions: Mineral Stability</u> Major alteration phases in drill core from the tuff of Yucca Mountain include zeolites, clays, opal, and albite. The occurrence, physical properties, compositions, origins, and thermal stability of these phases, particularly zeolites and clays, are reviewed. Dehydration and phase transformations of the clays and zeolites at relatively low temperatures may affect the ability of tuff to isolate waste through changes in thermomechanical, geochemical, and hydrologic properties.	D. T. Vaniman, LANL	15
GEO 11	<u>Hydrothermal Conditions: "Soak" Tests</u> As part of the evaluation of the time dependence of properties of NTS tuffs, exploratory, "soak tests" subject samples to simulated repository conditions for 2 to 6 months duration. Density, porosity, tensile strength, compressive strength, permeability, thermal conductivity, and mineralogy are determined before and after exposures at temperatures of 80-180°C, continuing pressures of 10 to 20 MPa, and water pore pressures of 0.5 to 5 MPa. Preliminary results indicate substantial changes in porosity, tensile strength, and compressive strength.	J. D. Blacic, LANL	15
GEO 12	<u>Hydrothermal Conditions: Tuff Alteration</u> Tuff samples of varying mineralogy were contacted with ground-water at 150°C in order to assess the degrees and types of mineralogy and textural changes. A scanning electron microscope equipped with energy dispersive analyzer was used to evaluate the changes.	M. L. Sykes, LANL	15
GEO 13	<u>Mineralogy-Petrology: Yucca Mountain Stratigraphy</u> The mineralogical and petrological features of ash flow and bedded tuff are described based on studies of core from the drilling exploration program in Yucca Mountain. The discussion will focus on lateral and vertical variations	B. M. Crowe and F. Caporuscio, LANL	20

<u>Abstract Number</u>	<u>Title/Abstract</u>	<u>Author/Org.</u>	<u>Length (Minutes)</u>
	in primary and secondary mineralogy and textural features of the tuff.		
GEO 14	<u>Mineralogy--Petrology: Mineralogy of Target Horizon(s)</u> The detailed mineralogy and textural features of tuff under consideration as potential repository horizons in Yucca Mountain will be discussed. These include the Topopah Springs Member, the Bullfrog Member, the tuff of Tram, and the lithic-rich tuff.	F. Caporuscio, LANL	20
GEO 15	<u>Volcanism: Regional Geology of the Volcanic Belt</u> The regional geology, volcanic history, and tectonic setting of basaltic volcanism in the southern Great Basin will be described, with emphasis on basalts of the Nevada Test Site region.	B. M. Crowe, LANL	10
GEO 16	<u>Volcanism: Geochemistry</u> The major and trace element geochemistry of basaltic rocks of the Nevada Test Site region will be discussed and compared with basaltic volcanism within the southern Great Basin.	D. T. Vaniman, LANL	10
GEO 17	<u>Volcanism: Volcanic Risk Assessment</u> The results of studies concerned with the risk of future volcanism will be discussed. Data include final refinements of probability calculations and basalt disruption studies undertaken for consequence analyses.	B. M. Crowe, LANL	10
GEO 18	<u>Geologic Investigations: Status of Geologic Exploration at Yucca Mountain</u> The drilling of UE25b-1H to a depth of 4,000 feet and the near-completion of USW-G2 to 4,700 feet provides a framework for examining the lateral continuity and structural complexity of subsurface units underlying the area of interest. Major	R. W. Spengler, USGS	60

<u>Abstract Number</u>	<u>Title/Abstract</u>	<u>Author/Org.</u>	<u>Length (Minutes)</u>
	stratigraphic units indicate only slight changes in thicknesses and lithologic characteristics except in USW-G2 where major faults cut the Bullfrog Member and Tram unit. In addition to the deep exploratory drilling, UE25a-7 was extended from 500 to 1,000 feet in an attempt to intersect the inferred structural discontinuity along the southwestern margin of the prominent wash. USW-GA1 was cored to a depth of 551 feet to provide information about the subsurface characteristics of the hingeline fault.		
GEO 19	<u>Geologic Investigations: Stratigraphic Relations of Crater Flat Tuff, Nevada Test Site</u>	F. M. Byers, Jr., W. J. Carr, P. Orkild, and R. W. Spengler, USGS	25
	The quartz-bearing Crater Flat Tuff comprises in ascending order the Tram unit, the Bullfrog Member, and the Prow Pass Member. The quartz-poor lithic-rich tuff underlies the Crater Flat Tuff drillholes and surface outcrops. At its proposed type locality of Lithic Ridge, it overlies a still older ash-flow tuff, petrographically similar to the Bullfrog, but of reverse magnetic polarity. This older tuff at Lithic Ridge probably correlates with the reversely polarized Crater Flat-type tuff in Yucca Flat and, therefore, is informally named the Tuff of Yucca Flat.		
GEO 20	<u>Geologic Investigations: Paleomagnetic Studies</u>	J. G. Rosenbaum, USGS	20
	Paleomagnetic studies of ash-flow tuffs in and around Yucca Mountain are underway to aid in structural interpretations and stratigraphic correlation. Structural studies have involved the Tiva Canyon and Topopah Spring Members of the Paintbrush Tuff. Interpretation of structural rotation from paleomagnetic measurements in the Topopah have been complicated by unexpected directional changes with depth. Paleomagnetic polarities have proven useful in stratigraphic problems involving the Crater Flat Tuff, and an unusual remanent direction determined for the "Lithic Ridge" tuff in USW-G1 should prove useful in identifying this unit elsewhere.		

<u>Abstract Number</u>	<u>Title/Abstract</u>	<u>Author/Org.</u>	<u>Length (Minutes)</u>
GEO 21	<u>Regional Geologic Investigations: Geomorphology in the Vicinity of Yucca Mountain</u> <p>Objectives of Quaternary studies are (1) fault ages, (2) Quaternary tectonic interpretations, (3) paleo-climatic interpretations, and (4) erosion and deposition rates. Stratigraphy, radioactive age dates, mapping and fault trenching provide the basic data for fault ages. New morphometric techniques provide evidence of Quaternary tectonics. Depositional environments, soils, and history of the Amargosa drainage basin provide evidence of paleo-climates. Maximum entrenchment of surfaces with known ages indicates erosion rates of less than 0.3 m/1,000 years during the past 10 m.y.</p>	D. L. Hoover, USGS	30
GEO 22	<u>Regional Geologic Investigations: Seismological Investigations</u> <p>Seismological studies of the southern Great Basin region are being conducted to assess the seismic and tectonic suitability of the Nevada Test Site region for a nuclear waste repository and to determine the seismic hazard to the facility. A 47-station seismic network has been employed to record current seismicity and the data have been analyzed to determine hypocenters, magnitudes, and focal mechanisms of earthquakes in the Nevada Test Site region. In future studies, dense portable seismograph networks will be deployed to study active zones of interest in greater detail to determine such earthquake parameters as seismic moment and apparent stress in addition to continued operation of the regional network.</p>	A. M. Rogers, USGS	30
GEO 23	<u>Hydrologic Investigations: Hydrologic Modeling</u> <p>A two-dimensional, steady-state model of regional groundwater flow for the Nevada Test Site and vicinity has been completed. Sensitivity analyses have indicated which parameters have the most significant impact on model output. Development of a two-dimensional transport model is underway, including</p>	R. K. Waddell, USGS	60

<u>Abstract Number</u>	<u>Title/Abstract</u>	<u>Author/Org.</u>	<u>Length (Minutes)</u>
	evaluations of the hydrogeology of Jackass Flats, Crater Flat, and the Amargosa Desert.		
GEO 24	<u>Hydrologic Investigations: Paleoclimatic Investigations</u> A recently completed study of fossilized vegetative remains in rat middens of the Nevada Test Site and vicinity has provided a comprehensive view of climatic conditions in southern Nevada over the last 50,000 years. Based on interpretations of plant assemblages in middens at various altitudes, temperatures during full glacial time were probably 6-9°C cooler than modern temperatures, and precipitation was only slightly higher than today (less than 25 percent higher).	W. G. Spaulding, UW	30
GEO 25	<u>Hydrologic Investigations: Mineralogic Evidence for Paleo Water Levels</u> Mineralogy of matrix fines from alluvium was examined to test a hypothesis that mineralogical signatures could be identified that would indicate the position of a former higher water table. However, differences observed in the section are probably due to stratigraphic differences rather than due to former saturation. No chain clays were identified.	B. F. Jones, USGS	20
GEO 26	<u>Hydrologic Investigations: Hydrochemistry of Western Amargosa Desert</u> Interpretations of groundwater chemistry in the western Amargosa Desert, downgradient from Yucca Mountain, have helped define sources of recharge and flow paths. One conclusion is that in the geologic past episodes of groundwater recharge have occurred by runoff infiltrating through the floors of washes such as Fortymile Wash.	H. C. Claassen, USGS	30

<u>Abstract Number</u>	<u>Title/Abstract</u>	<u>Author/Org.</u>	<u>Length (Minutes)</u>
GEO 27	<u>Hydrologic Investigations: Hydrologic Implications of Heat Flow</u> Extremely slow vertical movement of groundwater can be detected by measuring variations in conductive heat flow with depth. Results of heat flow measurements in holes at Yucca Mountain, including USW-G1 and USW-H1, will be described and their hydrologic implications discussed.	J. Sass, USGS	20
GEO 28	<u>Hydrologic Investigations: Yucca Mountain Hydrologic Studies</u> Analyses of hydraulic testing of USW-H1 (Yucca Mountain) and USW-VH1 (Crater Flat) have been completed. The presentation will include a discussion of the hydrologic drilling and testing plan, testing and analytical techniques, and results to date.	F. E. Rush, USGS	60
GEO 29	<u>Geophysical Investigations: Gravity and Magnetics Investigations at Yucca Mountain</u> A new regional isostatic residual gravity map of the area within 100-km of Yucca Mountain shows that the Bouguer gravity low over Yucca Mountain and Crater Flat reported in 1980 is in larger perspective the southernmost part of a large isostatic anomaly which reaches a value of -65 mGal over the Silent Canyon caldera. The isostatic anomaly at the candidate repository site at Yucca Mountain is about -15 mGal. Five detailed gravity profiles across Fortymile Wash were obtained in 1981 to help resolve whether the wash is structurally controlled by faulting or by a syncline as proposed by Carr. Analysis of a truck-mounted magnetometer profile in Drillhole Wash indicates that a magnetic anomaly of 1,200 gamma northeast of G2 drillhole may be caused by the edge of an ash or lava flow at a depth of about 1,000 feet.	H. W. Oliver, USGS	15

<u>Abstract Number</u>	<u>Title/Abstract</u>	<u>Author/Org.</u>	<u>Length (Minutes)</u>
GEO 30	<u>Geophysical Investigations: Regional Aeromagnetic Studies of Southern Nevada</u> We are assembling from three separate sources detailed aeromagnetic data that covers Yucca Mountain and a substantial region around it. An especial objective of this study is to preserve and display the high-frequency component of the data which is the most critical parameter for delineating structure. A compilation and investigation of the regional gravity, aeromagnetics and terrain data of a 20 X 40 area surrounding NTS are being made to provide a regional perspective for the more local studies.	M. F. Kane, USGS	20
GEO 31	<u>Geophysical Investigations: Seismic Exploration Studies</u> Seismic reflection surveys at Yucca Mountain have met with little success. Recent vertical seismic profiles obtained in drillholes USW-G1, USW-H1, and USW-G2 indicate that seismic reflecting horizons are present in the vicinity of these drillholes. Seismic parameter studies will be conducted near these drillholes in September 1981 to determine if seismic reflection surveys are feasible at Yucca Mountain.	D. C. Muller, USGS	45
GEO 32	<u>Geophysical Investigations: P-Wave Delay</u> The seismic study was done at Yucca Mountain, Nevada, where three nuclear explosions northeast of Yucca Mountain were recorded by 100 portable recorders deployed to the south of the shot point. From these recordings travel-time curves were constructed which detailed the crustal structure and revealed 0.5 second near-surface delays in the vicinity of Yucca Mountain. A teleseismic P-wave delay study was also done in southern Nevada and California using 55 seismometers and 85 teleseisms for a total of 2,538 observations. These data have been inverted using the Aki 3-d linear inversion technique and have yielded lithospheric models for NTS and the surrounding area.	J. H. Healy, USGS	20

<u>Abstract Number</u>	<u>Title/Abstract</u>	<u>Author/Org.</u>	<u>Length (Minutes)</u>
GEO 33	<u>Geophysical Investigations: Heat Flow Investigations</u>	J. Sass, USGS	30

The NTS encloses the boundary of the Eureka low (a major heat flow anomaly thought to be of hydrologic origin) within a terrane characterized by typical basin and range heat flow approximately 2 HFU. Recent heat flow determinations suggest considerable variation within the southern part of the test site, however, reliable heat flow determinations in the northern part of the test site are all near 1.5 HFU. This is the value that defines the boundary of the Eureka low. It appears from the available data that the regional lateral water flow characteristic of the northeastern part of the test site gives way to more local convective systems to the southwest.

NNWSI PROJECT PEER REVIEW
ABSTRACTS

August 26-27, 1981

B. GEOTECHNICAL/GEOENGINEERING SESSION:

	<u>Abstract Number</u>	<u>Title/Abstract</u>	<u>Author/Org.</u>	<u>Length (Minutes)</u>
	ENG 1	<u>Mechanical Properties of Tuff: Fracture Properties and Matrix Rate Effects</u> At strain rates between 10^{-7} and 10^{-2} sec $^{-1}$, there is a linear decrease in strength with decreasing strain rate. Coefficients of joint friction are also time-dependent. Joint creep tests show time-dependent healing, enhanced by water.	W. A. Olsson, SNL	20
24	ENG 2	<u>Mechanical Properties of Tuff: Creep</u> For periods of up to 30 days, creep tests on Bullfrog Tuff from UE25A#1, both saturated and dry, appear to be in the transient stage. Extrapolation of results indicates that creep strains will be small during the operational time period.	D. Parrish, RE/SPEC	20
	ENG 3	<u>Mechanical Properties of Tuff: Creep</u> Extrapolation of time-dependent mechanical data indicates that areas of potential failure at 50-100 years may be significantly larger than predicted on the basis of initial thermomechanical modeling.	J. Blacic, LANL	20
	ENG 4	<u>Repository Data Base: Geologic Environment</u> Definition of thermal and mechanical stratigraphy at Yucca Mountain is being hampered by stratigraphic uncertainties encountered in drillhole USW-G2, and by complexities in mechanical testing results.	A. R. Lappin, SNL	20

<u>Abstract Number</u>	<u>Title/Abstract</u>	<u>Author/Org.</u>	<u>Length (Minutes)</u>
ENG 5	<u>Repository Data Base: Thermal Properties</u> Measurement of thermal conductivities indicates that lateral extrapolations from hole to hole are valid, based on porosity, grain density, and mineralogy. Measurements of confined thermal expansion are only partially successful to date.	A. R. Lappin, SNL	20
ENG 6	<u>Repository Data Base: Mechanical Test Comparisons</u> Comparative testing at Terra Tek and SNLA indicates that mechanical subdivision of units may well have to be finer than thermal. Additional testing is underway.	A. R. Lappin, SNL	20
ENG 7	<u>Analysis: Far-Field Thermomechanical</u> Calculations are complete, based on UE25A#1 stratigraphy. Only matrix-mechanical properties were considered. No far-field tensional failure was predicted for CHLW. In the case of spent fuel, tensional failure appeared possible at higher loadings.	D. Parrish, RE/SPEC	20
ENG 8	<u>Analysis: Near-Field Thermomechanical</u> Calculations were performed with ubiquitous and statistical joint models. In general, failure due to excavation was minimal, and the stress field changed only slightly as a result of waste emplacement; this is not true at the highest loadings.	D. Parrish, RE/SPEC R. Johnson, SNL	20
ENG 9	<u>Analysis: Fracture Flow</u> Preliminary analysis indicates that nuclide diffusion into the matrix of wall rock adjacent to fractures in tuff is an important factor in retarding nuclides. Hence, matrix porosity and fracture conductivity play a major role in controlling migration.	D. R. Fortney, SNL	20

<u>Abstract Number</u>	<u>Title/Abstract</u>	<u>Author/Org.</u>	<u>Length (Minutes)</u>
ENG 10	<u>Analysis: Rock-Mass Classification</u> Classification schemes of Bienawaki and Hoek are not mutually compatible, but both indicate no major problems in constructing a tuff repository. A remaining uncertainty is application of these schemes to results of thermo-mechanical modeling.	B. S. Langkopf, SNL	20
ENG 11	<u>Analysis: Very-Near-Field and Near-Field Water Migration</u> Results indicate that (1) there is little need for concern about volatile overpressurings, except in virtually fracture-free rock and (2) fluid flow into workings may significantly suppress operating temperatures.	R. Eaton, SNL	20
ENG 12	<u>Analysis: Waste Package Environment</u> Parametric analysis of thermal and thermal/chemical effects on a reference waste package in tuff have identified potentially high temperatures and backfill instability. Comparisons were made between commercial high-level waste and spent fuel waste forms.	J. K. Johnstone, SNL	20
ENG 13	<u>Analysis: Coupled Modeling</u> Model development is underway to include coupling of thermal, mechanical, and permeability response of a jointed rock mass. A much-independent fracture algorithm has been developed. The 3-D model is partially computerized.	R. Thomas, SNL	20
ENG 14	<u>Analysis: Tuff Dehydration</u> Drying experiments on welded tuff are using a gamma-ray dosimeter to map saturation. Preliminary results indicate that the evaporation-front drying model used previously will have to be amended.	R. Hadley, SNL	20

<u>Abstract Number</u>	<u>Title/Abstract</u>	<u>Author/Org.</u>	<u>Length (Minutes)</u>
ENG 15	<u>Field Testing in G-Tunnel: Preliminary Design of Experiments For the G-Tunnel Underground Facility</u> Model-evaluation experiments include a Small-Diameter Heater (thermal/hydrological) and Unit Cell Canister-Scale (thermal/mechanical/hydrological) tests. Geotechnical experiments are the Heated Block, Rocha Slot, and Thermal Probe.	R. M. Zimmerman, SNL	20
ENG 16	<u>Field Testing in G-Tunnel Water Migration Experiment</u> A field experiment was carried out to assess thermally driven water generation/migration in a nearly saturated welded tuff. A large amount of water was collected during the course of the experiment. Water movement can be explained using a vapor-transport model.	J. K. Johnstone, SNL	20
ENG 17	<u>Exploratory Shaft: Shaft Drilling and Casing</u> The proposed approach to be used for drilling the Exploratory Shaft will be discussed. Topics include large shaft drilling techniques; casing design, fabrication, and installation; grouting of casing, and safety considerations.	T. J. Merson, NTSSO	15
ENG 18	<u>Exploratory Shaft: Shaft Internals</u> This discussion will include a description of the shaft internals, including hoisting systems, emergency personnel escape systems, location and installation of utility lines, and safety considerations.	T. J. Merson, NTSSO	10
ENG 19	<u>Exploratory Shaft: Mining</u> This discussion will describe the proposed techniques for shaft breakout, mining operations, mine design considerations, and safety considerations.	D. C. Nelson, LANL	10

<u>Abstract Number</u>	<u>Title/Abstract</u>	<u>Author/Org.</u>	<u>Length (Minutes)</u>
ENG 20	<u>Exploratory Shaft: Ventilation</u> Ventilation issues will be discussed as they relate to the Exploratory Shaft based on the assumed downhole temperatures of the rock and other requirements. Advantages and disadvantages of alternative systems will be considered.	T. J. Merson, NTSSO	10
ENG 21	<u>Exploratory Shaft: Exploratory Drilling</u> This discussion will describe the equipment and techniques to be used for drilling long, horizontal (or nearly horizontal) boreholes in the proposed target horizon and for recovering the core.	W. L. Sibbitt, LANL	30

NNWSI PROJECT PEER REVIEW
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C. ENVIRONMENTAL STUDIES SESSION:

<u>Abstract Number</u>	<u>Title/Abstract</u>	<u>Author/Org.</u>	<u>Length (Minutes)</u>
ENV 1	<u>Biology</u> A biologic overview of the NNWSI study area based on available documentation will be given. It will include descriptions of the major floral and faunal associations, unique ecosystems, sensitive species, and possible nuisance species. Potential impacts on the biota will be identified. Future site specific work recommended includes surveys to define the distribution and abundance of both sensitive and nuisance species, searches for sources of free water, and assessment of the effects of elevated soil temperatures on flora and fauna.	T. P. O'Parrell, EG&G E. Collins, EG&G	30
ENV 2	<u>Cultural Resources</u> A summary of published and unpublished anthropological and historical literature will be presented to provide insight into the nature of cultural resources in the NNWSI study area. Results of the preconstruction surveys to date will be discussed. The known sites are not considered representative of the potential archeological record that may exist in the project area. Recommendations will be made for systematic cultural resource surveys as well as for the appropriate timing of these surveys and assessments of program impacts on the region's cultural resources.	L. C. Pippin, DRI	30

<u>Abstract Number</u>	<u>Title/Abstract</u>	<u>Author/Org.</u>	<u>Length (Minutes)</u>
ENV 3	<u>Paleontology</u> The fossil material which has been collected at the southwest NTS will be described. The discussion will include the age, environment of deposition and rarity of the fossils. The bibliographic work will also be described. Recommendations will be given for further paleontological work.	J. R. Firby, UNR	30
ENV 4	<u>Meteorology and Air Quality</u> The climatology and meteorology of NTS will be discussed, including present climatology, severe weather events, past climate of the quaternary period, and future climatological expectations. An estimate of the present air quality of the NTS will be given. Information regarding dispersion conditions at the NTS and the applicability of NTS meteorology to dispersion predictions for the study area are presented. Recommendations will be made for NTS preparation. A brief summary of federal and state regulations will also be given.	J. Bowen, DRI	30
ENV 5	<u>On-Site and Off-Site Background Radiation</u> REECo will cover various aspects of environmental radioactivity on NTS. This will include both naturally occurring and residual radioactivity resulting from nuclear testing programs at the Test Site. EPA will provide a radiologic description of off-site areas within the southwest quadrant of an 80 km circle about CP-1 on NTS. This will include historic and current programs carried out by USEPA, population surveys and other relevant information.	W. Scoggins, REECO G. D. Potter, EPA	30
ENV 6	<u>Socioeconomics and Sociology</u> An evaluation will be given of the existing available data relative to the sociological and economic conditions in the communities which may be impacted by the development of a repository. Recommendations will be made concerning	R. Yantis, UNLV J. H. Fray, UNLV	30

<u>Abstract Number</u>	<u>Title/Abstract</u>	<u>Author/Org.</u>	<u>Length (Minutes)</u>
	additional data needs and suggested methods for data acquisition in order to most effectively minimize such impacts on these communities.		
ENV 7	<u>Water Use and Hydrology</u> A summary of available data on hydrology and water resources utilization will be given for the study area. Conclusions regarding the adequacy of information will be discussed and recommendations will be made for future data collection.	R. H. French, DRI	30
ENV 8	<u>Energy and Mineral Resources</u> Historic and present mining activity will be reviewed. The regional resource base will be evaluated, with a brief discussion of resources, reserves and the level of potential future demands. The discussion will conclude with an evaluation of available data and its limitations. The data required for site evaluation will be identified.	E. J. Ball, Consultant	30

GEOLOGICAL/HYDROLOGICAL PANEL REPORT

NNWSI
GEOLOGICAL/HYDROLOGICAL
PEER REVIEW

SESSION CHAIRMAN: W. S. TWENHOFEL

PEER LIAISON: J. T. NEAL

<u>PEER REVIEWER</u>	<u>AFFILIATION</u>
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LARRY T. LARSON	UNIVERSITY OF NEVADA, RENO
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GEORGE A. THOMPSON	STANFORD UNIVERSITY
ROBERT N. FARVOLDEN	UNIVERSITY OF WATERLOO
PAUL R. FENSKE	DESERT RESEARCH INSTITUTE
JOHN B. FARR	WESTERN GEOPHYSICAL CO.
KONRAD B. KRAUSKOPF	STANFORD UNIVERSITY

November 11, 1981

340 Sparrow Way
Carson City, Nv.
89701

Mr. Robert M. Nelson
Waste Management Project Office
U.S. Department of Energy
Nevada Operations Office
P.O. Box 14100
Las Vegas, Nv.
89114

ACTION Win's
INFO _____
R. F. _____
ALL _____
AM: B. C. _____
AND _____

Dear Bob:

Enclosed with this cover is the Summary Peer Reviewer Report-Geologic Division, for the meeting of August 24-28. I mailed it out to each of the reviewers on Oct. 27 and to date have received no response except from Fenske and Ryall (both on campus) and Domenico' (at a meeting in Cincinnati). I suppose, therefore, the summary is agreeable to all. I am sure what with the individual commentary sent you you are in no short supply of things to read.

Sorry that it took so long. Seems Frank Morrison and others were a little late, I was a little later- and so on. Perhaps a better arrangement can be made for next time.

Sincerely,

Lawrence T. Larson

October 27, 1981
340 Sparrow Way
Carson City, Nv.
89701

TO: NNSWI Geologic Sciences Peer Reviewers

FROM: L. T. Larson

SUBJECT: Summary report to be submitted to DOE on August 24-28, 1981 Review

Attached to this memo is the 32 page 'summary' report to be submitted to DOE. I have written a six page introductory section -otherwise the report is a collation of the various sub-committee reports.

If you find that the report does not adequately reflect your views (considering that you have probably also submitted your individual report to Bob Nelson) please let me know ASAP. I will then, probably in the form of an addendum add your comments. If you see something in the report that is flat wrong-your corrective comments will be appreciated by all.

I think, in the light of the past due nature of this report, the best way for me to receive minor corrections is by phone. If you think major re-writing of sections is necessary please first phone and follow up with a letter. I want to get this to DOE by November 10 + so please try and get back to me between Nov. 6 and 10. I will be in Cincinnati at GSA from Oct. 31 to Nov. 5 and we might be able to get some of your comments at that time.

Sincerely,

Larry Larson

P.S. My business phone number is (702) 784-4002 . If you wish to call in the evening try (702) 849-0587 (weekends too).

October 23, 1981

SUMMARY

NNWSI GEOLOGICAL SCIENCES PEER REVIEW REPORT

AUGUST 24-28, 1981 MEETING

LAS VEGAS, NEVADA

Submitted by:

L. T. Larson, Chairman

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Mr. Robert M. Nelson
Waste Management Project Office
U.S. Department of Energy
Nevada Operations Office
P.O. Box 14100
Las Vegas, Nevada 89114

Dear Mr. Nelson:

What follows is a compilation and to a lesser degree a synthesis and distillation of peer review commentary on the NNWSI review meeting of August 24-28, 1981. I have chosen to include the geologic, hydrologic, geophysical and geochemical subcommittee reports with but very slight modification and to summarize the concensus or majority opinions and commentary in an introductory few pages. While my chosen format unavoidably leads to some repetition I believe this is preferable to a complete re-writing during which I should almost unavoidably omit sections, paragraphs, wordings or inferences which other reviewers may strongly believe significant. In this regard and at this point I believe it appropriate to comment that several peer reviewers have mentioned that they do not favor a single overall report mechanism such as this--largely, I believe, because of concerns that a summary will lose senses of urgency and criticality and that one report may not serve as well as nine in conveying strength of meaning and significance of certain recommendations. I think to a degree all of us share this concern and this is yet another reason why I have chosen to provide very little editorial emendation/modification to the sub-committee reports gathered by Messrs. Morrison (Geology), Domenico (Hydrogeology), Ross (Geophysics) and Krauskopf (Geochemistry).

Introduction and Summary

As an initial statement I believe it is a concensus opinion of the peer

reviewers that the High Level Nuclear Waste Repository Program is of a very high level of National importance--so high as to make superior management and the highest level of application of technology absolutely essential. To this end we intend our remarks to be constructive criticism and constructive recommendations.

Although, as you will note later in this report, numerous specific criticisms and several rather specific recommendations have been made on technical subjects, it is the consensus opinion of the Geological Sciences Peer Review Group that, in particular, two aspects of the overall program need immediate and strong attention and significant improvement. One of these is strictly technical and relates to the lack of adequate hydrological information--both qualitatively and quantitatively. The other, expressed in different ways by various peer reviewers but strongly perceived by all, is the need for a substantially improved, firmer, better co-ordinated technical management. Let me expand on each of these needs.

I believe the peer reviewers are unanimous in their opinion that the hydrogeologic nature of the potential repository site and environs is the single most important technical subject and the one most likely either through negative information or lack of information to terminate consideration of Yucca Mountain as a repository. George Thompson said it well: "Like everyone else, I recognized hydrology as a central, overriding question. . . ." Ryall notes that, "Highest priority in the NNWSI program should be to improve the hydrologic investigations." Larson writes that, "Hydrologic characterization is one of the, if not the, most significant aspects to selection of units or zones for consideration of the siting of a TEF." Bill Twenhofel, when asked at the review meeting what single technical item would be most likely to "kill" Yucca Mountain as a repository site, replied hydrology. Yet, with all of this agreement, where is the hydrology/hydrogeology program? The perception of the reviewers can be best summarized by the first paragraph of Pat Domenico's

summary for the reviewers hydrogeologic subcommittee that essentially states that hydrogeology data collection is lagging far behind other phases of the overall project and that with the little available information we do not see hydrology as a reliable input to decisions for the Exploratory Shaft and/or TEF within the presently extant NNWSI time frame. Krauskopf put it a little less technically and more succinctly by saying, "I was surprised at how little hydrological information was available and would concur with the sentiment of my colleagues that Hydrology deserves major emphasis in near term research."

In summary of the peer reviewers suggestions for the hydrologic studies, we are in agreement that major efforts must be immediately undertaken to improve our hydrogeologic knowledge of both the saturated and unsaturated zones and hydrologic units within these zones. We submit that recommendations made in the Hydrogeologic section of this report collated by Pat Domenico are reasonable, timely and in need of implementation. I am sure that the hydrogeologic members of our committee (Messrs. Fenske, Farvolven, Domenico) will be willing to interact and consult with appropriate members of the NNWSI hydrogeological program to this end.

The second, but perhaps from an overall repository program view, most important subject, and one which many peer reviewers were critical of is the technical management-scientific management-technical coordination-technical integration (phrased differently by various reviewers) of the project. I am convinced that the peer reviewers find, with the possible exceptions of aspects of the hydrogeology and reflection seismic efforts, little lacking and much to commend in the quality of the science/engineering efforts being directed toward waste isolation problems and solutions. What we do perceive is a serious lack in the direction of these efforts; in their co-ordination; and in their integration. Thompson writes, ". . . we all recognized weaknesses in coordination and communication among individuals and groups and in some cases a failure to set realistic priorities." Ross comments that, ". . . there is not enough

communication or integration of technical efforts . . ." Morrison is concerned that, "the multi-laboratory approach may be leading into very serious co-ordination problems for the project." Larson notes that, "the program management must find some way to improve individual, discipline and laboratory information transfer." Ryall comments that in 1980 he and several others recommended that scientific management of the program be improved and Ryall made several suggestions. He does not, nor do several others of us apparently, see evidence of such improvement. Farr is even clearer and more definite and elaborates for several pages. In essence Farr strongly believes that, "The single greatest shortcoming in the NNWSI program is the lack of effective technical program direction." He sees several technical imbalances such as the lag in hydrological measurements that effective management would not condone. Farr also makes the point, subscribed to by most reviewers, that lack of technical direction (and integration) or technical optimization is not the same as saying that the fiscal and administrative supervision has been inadequate. Indeed, he and others of us believe these management functions have been performed well. However, our perception remains that research efforts appear isolated or not coordinated either in time or methodology integration and are ill focussed toward the overall problem(s) of defining the existing physical characteristics of a potential repository relative to guidelines within the presently scheduled time frame.

If the above is a major problem and certainly we believe it to be, what can be recommended? It is easy to say improve technical management, but I am sure all of the reviewers realize that doing same is a much greater problem. Farr suggests the Technical Director approach--a person or group (directorate?) with over-riding technical authority. This individual or group could be a private contractor with that sole responsibility, or at least some entity that is "non-involved" with any of the research participants. Alternatively, if this is deemed not feasible, one laboratory or federal agency could be appointed

"technical operator" and given both the responsibility and the authority to achieve research program integration and co-ordination. Morrison suggests, ". . . some sort of committee with a representative from each group (and Nevada Operations Office) could be established with full time members." Thompson recommends the addition of, "a small scientific-engineering team to top management, headed by a senior scientist thoroughly familiar with the project. Members of the team would act as expeditors, traveling when necessary between laboratories and working groups, spotting bottlenecks and having the resources and leverage to move things in the right direction." Ryall, with a slightly different response to the problem suggests the "initiation of a number of integrated reports with the responsibility (and authority) for completing a report assigned to one of the research agencies." He notes that "important factors in this report-writing exercise would be assigning responsibility for the compilation to a single agency, requiring completion of the report in a limited amount of time, restricting the number of people working on the report, and giving the lead agency authority to obtain material from other agencies when such material would contribute to the overall synthesis." Larson suggests that, "consideration be given to regular meetings of liaison and major P.I.'s--preferably at or near the project site--to thresh out problems of integration and common goals, needs and problems."

In summary, while the peer reviewers are not totally cohesive in their recommendation(s), it is clear that we believe it essential to put the pieces of the puzzle together and clearly define priorities, and I believe most of the reviewers concur with the idea of establishing a technical director (directorate) that is aligned to no specific agency involved in the research to perform this function.

As indicated at the start of this report, there are a number of specific technical items on which various peer reviewers have definite opinions as to timeliness and/or methodology (for example, reflection seismic studies).

For these I refer the reader to the appropriate following pages which constitute the various subcommittee reports.

SUMMARY OF COMMENTS OF REVIEW SUBCOMMITTEE ON GEOLOGY

H. F. MORRISON

The geological studies of Yucca Mountain are excellent; the work is well co-ordinated and scientifically admirable. The comments and recommendations that follow are almost all in reference to data that should be added or, as if in a small scale reflection of the overall project, are related to a certain lack of direction to the studies.

In general the work to date has been of a mapping or descriptive nature; it is now necessary to focus the studies toward the specific requirements of a repository site. In broad terms a set of criteria for a site should be put forward and the geological studies directed toward verifying whether or not these criteria can be met.

The Quaternary geology (Hoover, et al.) studies are very well done and should be strongly supported. Still more emphasis should be placed on mapping and dating recent faults. The faults, and jointing and fracture patterns, are needed to compile a three dimensional model of the structure through the repository. The age of the faults will be of fundamental importance in the seismic risk analysis of the area. The latter should be considered a high priority item and if such studies require more trenching then this should definitely be budgeted.

The review committee was surprised to learn that available photo/imagery may not have been reviewed. It is somewhat disturbing that Dr. Gary Oloehft of the USGS reported that a lineament has been found by remote sensing that appears to transect Yucca Mountain. Its presence or absence must be substantiated. All available Landsat, SLAR, SR71 and other imagery must be reviewed and incorporated into the regional and local geologic maps.

The time has also come to begin compilation of the subsurface geology

through three dimensional models of the structure, stratigraphy, mineralogy etc. The characterization of a repository requires the spacial distribution of the different kinds of tuffs (welded, zeolitized etc.) over distances large enough to make repository construction possible. It depends on knowing the fracture orientation and density since this is crucial to the hydrologic models. If this fracture information cannot be obtained from vertical holes (because the fractures may be vertical) then plans should be drawn up for inclined holes. Characterization requires a knowledge of the spatial variations of the rock properties (porosity, permeability), mechanical strengths and mineralogy. It will become rapidly apparent when such a compilation is attempted just how much more information is required and in what form. A majority of the review committee feels that more holes drilled on the periphery of the prospective site will be required before such models can be constructed.

This stage of compilation will also force the integration of the core studies being carried out by various groups. A primary data base will be sections in which well logs and stratigraphy defined by mineralogy and petrology, hydrology, mechanical properties, etc. can be displayed side by side. These sections at each hole will then become the elements in the three dimensional reconstruction. An essential part of this study is a full utilization and integration of the geophysical well logs. This has not been properly done to date.

The important point is that this synthesis of data must begin now, because it will in turn lead to the appropriate focus for further studies.

In somewhat more detail the committee strongly recommends that increased emphasis be placed on the study of the unsaturated Topopah formation. More work on the nature of the lithophase, their degree of interconnection, the mineralogy within the cavities, etc. will be needed to characterize this zone as a potential repository. Strong efforts should be placed on fracture mapping in this zone.

The large diameter hole must be used for geological mapping. It provides

an unparalleled opportunity for acquiring this information even at added cost to the drilling. This latter point, the cost of drilling vs. the scientific information required for site characterization epitomizes one of the serious problems in overall direction. The large hole drilling programs appear to be on a course that is independent of the very studies that are being conducted to site and design the hole!

Finally, and again an indication of the lack of overall co-ordination, there must be some formal overview committee established for handling, distributing and cataloging the core. This precious material is presently shipped around on request for a variety of studies (some of which are duplicate efforts) and apparently not monitored or even very well recorded.

In summary, the geologic studies to date are admirable. The time has come to finish up the maps, get them out to the various groups involved and begin a compilation and integration of the geology and all the other data. At the same time, some hypotheses must be advanced to model the desired characteristics of a repository and the future studies focused and directed toward these objectives.

SUMMARY OF COMMENTS OF REVIEW SUBCOMMITTEE ON GEOPHYSICS

Howard P. Ross, John B. Farr, H. Frank Morrison
Alan Ryall, George A. Thompson

Introduction: This report summarizes the technical comments of the five NNWSI Peer Review geophysicists and additional contributions regarding the NNWSI geophysical program by other members of the Geology-Hydrology Committee. The report integrates the various comments for each geophysical topic and identifies a few specific differences of opinion between committee members. There is general agreement between geophysicists regarding the evaluation of work already completed, the problems to be solved and the priorities for future work. Individual letters of comment may be consulted for added details reflecting an individual reviewer's specialty.

Geophysical studies should make a substantial contribution to the NNWSI geologic studies, especially when drilling is restricted to minimize penetration of the potential repository site. Unfortunately the geologic environment of the Yucca Mountain area gives rise to poor seismic reflection quality (thus far), to complex electrical resistivity data, and to ambiguous responses for some of the other methods. The geophysical studies to date have included several limited efforts with little integration of data sets and other geologic information. The need for better program direction and management to focus on necessary studies, to enforce on schedule reporting, and integrated interpretations is apparent in the geophysical program as it is in other technical work at the NNWSI. The subcommittee notes that similar comments were reported following the 1980 NNWSI Peer Review and that major management and communication problems, as we perceive them, still exist.

Reflection Seismic: The vertical seismic profiling (VSP) reported by Doug Muller included some very positive results. Details of attempted and planned Vibroseis surveys were not presented to the committee. All the geophysicists

recognize that reflection seismic has the greatest potential for providing high-resolution information on stratigraphy and structures in the Yucca Mountain area. It is apparent that the seismic work to date has been compromised by partial efforts - VSP surveys for portions of drill holes rather than total depth, and by inadequate survey and recording equipment. We recognize that reflection seismic work will be difficult and expensive in the geologic environment of the Yucca Mountain area, and there is a good possibility that interpretable reflection data may not be obtained. None the less the geophysicists on the Peer Review Committee are unanimous that a no compromise state of the art reflection survey should have the highest priority of all new geophysical work. Such work should include total depth VSP for available boreholes. John Farr suggests the following parameters as an indication of the type of survey required: high multiplicity (48 fold or more), large source arrays (4-5 vibrators operated simultaneously over many closely spaced source positions), large receiver arrays (144 geophones per detector group in areal patterns feathered to optimize cancellation of long and short wavelength noise), and specialized recording procedures to avoid noise (i.e., recording at night or at sunset when wind noise dies down). Ross notes that high frequencies and short spread lengths may be required to maximize spatial resolution.

The reviewers recommend that there should be no compromise on contractor competence, equipment and experience, and that the most qualified USGS personnel be assigned to this project for survey design, supervision and interpretation. Should initial reflection seismic profiles be successful, then the immediate site area and the entire Yucca Mountain block should be mapped via a grid of seismic lines or a 3-D plan layout.

Refraction Seismic: The detailed refraction profiles (NTS shots) and modeled refraction results represent excellent work and indicate a 1.5 - 2 km offset in basement, in agreement with the detailed gravity data. The panel recommends that Mooney's refraction results should be integrated with Howard Oliver's

regional gravity model, and perhaps with Healy's teleseismic p-residual study to provide a self consistent multiparameter model of the crustal structure for a substantial area surrounding the Yucca Mountain block. George Thompson recommends continued recording of earthquakes and nuclear tests on the multichannel portable instruments in an attempt to better define subvolcanic structure and lithologies. Others feel that this data will have little influence on the siting of the TEF.

In an attempt to help focus the geophysical efforts the panel gives a low priority to additional refraction surveys at the present time. Instead we emphasize the need for a geologically oriented synthesis of existing refraction data with p-wave delay, regional gravity, and other appropriate data. Perhaps contradictions in the existing p-wave data interpretation will be resolved in this manner.

Gravity Studies: Howard Oliver presented an excellent regional gravity map for the area within a 100 km radius of Yucca Mountain. The data have been modeled in a state of the art manner to arrive at a three-dimensional density model and this indicates a major graben-caldera structure. Also presented was a detailed gravity profile across Forty-mile Wash which helps to define structural controls on this important feature. This quality work is an excellent contribution to the geology of the area. John Farr recommends extending the detailed profile up Drill Hole Wash and part of Yucca Mountain. Howard Ross notes that the density contrasts and vertical displacements noted at Forty-mile Wash probably are not present further west and structures within Drill Hole Wash and the Yucca Mountain volcanics will be difficult to map with gravity. Any gravity profiles directed at structural definition of Drill Hole Wash should be as near normal to the wash as practical. Alan Ryall sees no specific need for additional gravity data acquisition and the panel would give a low priority to additional gravity surveys.

The panel strongly encourages an integrated interpretation of the 3-D

gravity model with refraction and teleseismic results. Similarly the detailed gravity profiles may contribute to the interpretation of the electrical resistivity data.

Magnetic Studies: A detailed low level aeromagnetic survey completed at least two years ago has still not been interpreted in a quantitative manner. A single truck mounted magnetometer profile further documents one anomalous area indicated on the airborne survey. Wil Carr notes that the geologists are regularly using and interpreting the airborne data in a qualitative fashion and find the magnetics a most useful data set. As noted at previous Peer Reviews, a quantitative interpretation of this survey is long overdue. If the USGS cannot allocate experienced personnel to complete this relatively minor job then outside industry contractors with a numerical modeling capability should be engaged to do the job.

The single truck mounted magnetometer profile is indeed interesting but "mobile magnetometer profiles" are nothing new, and a single ground profile, not yet interpreted, represents a very limited work effort. Howard Ross would recommend a few days of low level helicopter magnetic surveying in preference to the more limited, erratic profiles of truck mounted or ground magnetic surveys if detailed ground follow up seems warranted by the aeromagnetic data interpretation. The data interpretation should utilize any susceptibility and remanent magnetic data already available on these rocks but need not require a major effort in rock property studies. Once again the Peer Reviewers request a quantitative interpretation of the detailed low level magnetic survey!

Electrical Studies: The committee noted that no specific reports were prepared for the electrical methods and requested status reports on these data. We were disappointed that the electrical program reported in previous years by Don Hoover, USGS, had been discontinued and that no summary interpretative report has yet been written. The electrical resistivity discontinuities are pronounced physical property differences within the tuffs and must be explained

in terms of drill hole results, geophysical logs, and other data.

Jeff Daniels presented results of his hole-to-surface electrical studies. His presentation indicated several specific interpretative products, primarily relating to near surface conductive zones, as a result of a substantial effort in field surveys, program development and interpretative modeling. We understand that reports on this work are currently in the review process. The hole-to-surface results and geophysical well logs (especially resistivity logs) are additional data that must be integrated with surface electrical surveys, gravity, and geologic data as soon as possible. John Farr and Howard Ross encourage the use of outside contractors to effect this if USGS principals (Don Hoover, Jeff Daniels) cannot schedule it in the near term.

The committee recommends no new surface electrical surveys until the integrated interpretation is completed, with one exception. Hole-to-surface resistivity surveys should be completed as new holes are completed and when hole conditions (casing, etc.) permit. Two reviewers, H. F. Morrison and H. Ross, have reservations about achieving substantial model results for hole-to-surface surveys but do recognize the opportunity to obtain detailed electrical data provided by the boreholes.

Borehole Geophysics: The committee did not receive a complete understanding of the borehole geophysics program. Jeff Daniels has apparently completed in depth studies of well logs related to the hole-to-surface studies and indicated substantial physical property characterization of the units logged. Wil Carr indicates that a suite of logs are routinely run in new drill holes and are used by hydrologists in planning hydrologic testing and by geologists in lithologic studies. The reviewers are unanimous in believing a more complete, better organized logging program should be underway.

We envision a full suite of geophysical logs for every hole and the use of this log suite as the primary physical property record for the lithologies cut by the hole. All specific physical property studies, geotechnical core

studies, mineralogic, petrologic and hydrologic results should be related to these logs and should in turn contribute to a better knowledge of the particular log responses. Heat flow and temperature gradient measurements could be included here. The suite of logs should give rise to an overall record of porosity, permeability, fracturing, lithology, etc. for each bore hole.

A well co-ordinated program of borehole geophysics and integrated log interpretation is the Peer Review Panel's second priority for present and future work.

Seismic Risk Analysis: It is apparent to all geophysicists and several other members of the committee that some finite level of seismic hazard must be associated with the Yucca Mountain block and could possibly pose major problems for licensing a future repository here. We understand that exact standards for this matter have not yet been established by the NRC. The committee therefore strongly recommends that a formal Seismic Risk Analysis be initiated. Ongoing microearthquake recording, the seismic record to date, nearby Quaternary fault scarps and other Quaternary geologic studies and tectonic studies, are all important and available elements to this study. We also recommend that a dialogue begin immediately with NRC which addresses the proposed criteria for repository siting with respect to seismic risk. The NRC should then be asked to comment specifically on the in-progress Seismic Risk Analysis for the proposed NNWSI repository area.

Remote Sensing: The panel was told during the geophysical sessions that a "remote sensing linear" transects the Yucca Mountain area, possibly the proposed repository site itself. Details of the rumored anomaly were lacking, but the feature was once the subject of a proposed remote sensing study. We recommend a high priority, but hopefully low cost effort, for the evaluation of the reported linear. Landsat, high altitude infrared (U-2 ?), side look radar or other data are undoubtedly available for preliminary study of this rumored feature. The "linear" would certainly be an issue at site characterization or

licensing time.

Priorities: A brief restatement of the committee's priorities for future geophysical work is in order. They are:

1. Reflection seismic parameter study - a first class effort!
2. Electric log data acquisition and detailed property interpretation.
3. Seismic risk analysis.
4. Remote sensing linear at Yucca Mountain - evaluate and document.
5. Ongoing integration of passive seismic, refraction, gravity and other geophysical data - with geophysical and other geological, hydrological, geochemical and engineering data.

We recognize that much good work has been done and that major difficulties have developed in the application of several geophysical methods. The technology is available to solve most of these problems. The exploration effort must now be focused on those items relating most specifically to site selection, horizon selection, and possible licensing issues.

SUMMARY OF COMMENTS OF REVIEW SUBCOMMITTEE ON GEOCHEMISTRY

K. KRAUSKOPF

The Review Group is impressed by the high quality of the geochemical studies that are under way and by the completeness of the geochemical coverage represented by the listing of research projects that are in progress or planned. All the major factors that might influence migration rates of radionuclides have been considered, and research has been designed to study the factors whose influence remains uncertain. The panel commends particularly the effort in the experimental work to simulate as closely as possible conditions to be expected in a repository.

The panel's chief concern relates to the sheer quantity of geochemical work that is in prospect. To carry out all the research in the detail which seems to be expected will require many years. If site selection and repository construction depend on completion of this work, geochemistry might become a major source of delay. The panel suggests that thought be given to setting priorities among the very numerous geochemical projects, so that those can be emphasized which will aid directly in clarifying some of the uncertainties about possible repository sites at Yucca Mountain. Thought should be given also to the amount of detail that is required in the results from each project. Obviously, for example, one would like to know the thermodynamic properties of plutonium with great accuracy, or the precise values of K_d for different valence states of plutonium under a variety of conditions; but is such accuracy really necessary for a decision as to whether a given site is or is not suitable? One can hope that the planned research will be continued far into the future, after a repository is under construction or in operation, but at present the projects should be pushed and the degree of accuracy should be tailored to the immediate problems of locating an exploratory shaft and a possible repository site.

Experiments that seem to the panel particularly important at present are

those involving ion migration and retardation under conditions duplicating those in a repository, both while the repository is under construction (and therefore open to the air) and later when the repository has been sealed. The panel applauds the intention to supplement laboratory work with experiments in the field, for example the experiment that is to be set up in G tunnel for measuring ion migration along a shear zone.

Studies of ion migration will make possible the setting up of models describing the maximum releases to the environment to be expected for each of the harmful radionuclides. Even though data on ion migration and groundwater flow are still incomplete, the panel thinks that setting up provisional models now would be a useful exercise. Such models would need major changes later, but at present they would help to pinpoint places where additional data, or additional accuracy in existing data, are particularly needed.

A few geochemical activities that were not specifically listed in documents given to the panel are suggested for consideration:

- 1) Samples of groundwater should be collected from each tuff bed that is under consideration for repository siting. The panel is aware that obtaining such samples may be difficult, but considers them important enough to be worth the effort required. Analyses of the samples would give direct information on reaction of water with different varieties of tuff, would serve as guides to water compositions for use in experiments on sorption and ion migration, and would provide evidence regarding possible interconnections of aquifers in the tuff sequence. If the analyses include tritium, estimates could be made of the ages of the groundwater samples.

- 2) It is important to determine whether groundwater in the tuff beds is reducing, because migration of multivalent ions is critically dependent on Eh conditions. The assumption is commonly made that groundwater out of contact with air is necessarily reducing because it is in contact with ferrous minerals or sulfides, but this assumption has recently been questioned for groundwater

in tuffs. One bit of evidence that casts doubt on the assumption is the finding of a little dissolved oxygen in water from one of the wells on Yucca Mountain. The analysis should be checked, particularly to see whether the water containing oxygen had been in contact with air, and oxygen should be looked for in other groundwater samples. If dissolved oxygen is indeed generally present, experiments on possible backfill additives to keep the repository environment reducing will be especially important.

3) Pyrite in small amounts has been reported in lithic fragments in part of the Tram formation. The quantity and distribution of pyrite should be checked, because its presence might make this formation unsuitable for repository construction. If air comes in contact with pyrite on the walls of a shaft or tunnel, the mineral rapidly oxidizes and produces acid with any water present. This would weaken the rock and accelerate corrosion of waste canisters.

4) Experiments on rock alteration and ion migration could be made more similar to a near-repository environment by imposing a temperature gradient on rock through which water is moving. A possible consequence might be the transfer of silica in considerable quantity from the hot to the cold end, with the deposition of opal or chalcedony and hence a marked decrease in permeability.

Beyond these few suggestions the review panel has little to add to the geochemistry program. The program is in excellent hands, and we recommend only that priorities be set among its many parts so that for the near term it can be more directly relevant to current problems of site characterization.

SUMMARY OF COMMENTS OF REVIEW SUBCOMMITTEE ON HYDROGEOLOGY

P. DOMENICO

Drilling and Testing Program

A main observation of the work accomplished thus far in hydrogeology is that the data collection program in drill hole hydrology is lagging far beyond similar programs in other phases of the project. At this current rate of data collection coupled with what little is known concerning the hydrogeology of Yucca Mountain, we do not see hydrogeology as a reliable input to the decision for an exploratory shaft and test facility within the proposed NTS time frame.

A main difficulty, from a hydrogeologic perspective, is that a potential repository horizon of sufficiently low permeability and adequate thickness has not yet been identified. Although some candidate formations have been identified in the few borings to date, the areal coverage of the drill holes is hardly adequate to answer questions regarding continuity of desirable properties. In addition, assuming an adequate repository horizon exists, there remains the question of whether or not there is a possible route to the biosphere that could traverse this three dimensional volcanic system by way of high hydraulic conductivity units. Given this latter state of affairs, proving the volcanic tuff would be equivalent to proving the integrity of the rock unit in which the repository may be placed. In our view, both of these questions can be addressed with a reliable drilling and testing program. We see the following as important elements of this program.

Delineation of Hydrostratigraphic Units: There is need for identification of the significant hydrostratigraphic units in Yucca Mountain that will eventually require hydraulic and chemical testing. Formation identification

is not sufficient by itself in that there is too much stratigraphic and structural variation within a given formation. Hydrostratigraphic units, which are most likely the highly permeable fractured zones within individual formations, will have to be identified in the core or geophysical logs, and ultimately tested hydraulically. This identification process may have to include downhole televiewers, cameras, or acoustic logs, all of which are well suited for delineation of fracture permeability. The continuity of these zones should be determined to the extent possible. Some sort of facies mapping with carefully selected control points, followed by a test program to prove the method, might be a reasonable procedure. For example, a high permeability zone in the upper Bullfrog (?) has been identified via pumping tests in USW-VH1. Does the core or available geophysical logs in other holes attest to the areal continuity of this zone, i.e., is this a major hydrostratigraphic unit for horizontal flow in the Bullfrog or, if not, what information is available on the structural features that may promote vertical transfers across various hydrostratigraphic units. Is this part of the Bullfrog transmissive because of the fracture zone intersected there so that it still may be a candidate unit outside this anomalous area? We contend that if sufficient core and geophysical information is available to provide a stratigraphic section, there exists sufficient information to provide a preliminary hydrostratigraphic section. We thus believe that identification and characterization of the hydrostratigraphic units across Yucca Mountain is a number one priority. Once accomplished, all tests for engineering, hydrologic, and chemical properties can then be made in reference to the physical system identified. According to the NWTS Site Performance Criteria this must be done and we believe that a proposal for accomplishing this task should be presented. In the absence of such a program there appears to be no effective hydrogeological program on a local repository size scale.

Pumping or Injection Tests: Pumping or injection tests have to be conducted in such a way that the packed off zone correlates very well with the hydrostratigraphic units described above. In the pumping test results to date, criteria for selection of the testing zones are not clear. In USW-G1, three of the eight tested zones are in excess of 600 meters in length. In USW-H1, five of the eight tested zones are in excess of 400 meters in length and two of the remaining three are about 200 meters in length. The average hydraulic conductivity reported for these thick sections is somewhat misleading in that the measured transmissivity is divided by the thickness of the tested zone to obtain a so called average hydraulic conductivity. In fractured media, it is not the average over a large saturated thickness that is important, but the permeability of the hydrostratigraphic units within the formation or unit. Obviously, the permeability of potentially high permeability fracture zones can be several orders of magnitude larger than the computed average over a large thickness of formation. This may be exemplified from the preliminary results of USW-VH1, with a measured transmissivity of $2400 \text{ m}^2/\text{day}$ and an average hydraulic conductivity of 5.6 m/day . This average value indicates that the transmissivity was divided by a saturated thickness of 428 m. The main aquifer, however, was reported as being 17 m thick within this sequence of rocks. Hence, if 50% of this measured transmissivity is attributed to this main aquifer, the hydraulic conductivity of this zone is about 70 m/day . It is this conductivity that is important in the transport of radionuclides (as well as shaft construction). In USW-VH1 this high permeability zone corresponds with the top of the Bullfrog. Its continuity, actual hydraulic conductivity, and the vertical and spatial distribution of other such zones, if they exist, has to be detected by an extensive drilling and testing program. Although drilling the Yucca Mountain block is not permitted, four to six

additional hydrologic holes can be sited peripheral to and surrounding the block. This task should take priority over the numerous other requirements associated with drilling and testing, including the location of off site holes for regional piezometric control, or some specialized drilling and testing to determine whether or not localized faulting controls water movement in the reasonably well explored confines of Drill Hole Wash. Both of these have been proposed and both are important in the long term investigation of the Nevada test site. Fractures and faults do indeed add a special complexity to the hydrogeologic analysis of Yucca Mountain and vicinity. We submit, however, that an array of observation wells will be required to establish the hydrologic character of a fault. The test proposed may prove that in fact this fault may be associated with high permeability, but what does this mean with respect to other minor faults and fractures that seem ubiquitous over Yucca Mountain? It may be that the contours of groundwater head may be the only feasible means of establishing the hydraulic character of faults acting as barriers or drains, and that field testing for fault characterization may best be done in an underground facility. We would suggest, eventually, a detailed proposal for the research program designed to investigate faults and fractures.

In short, the main hydrogeologic questions at this stage in the program deal with the pending shaft and test facility construction, which will require prior identification of a potential repository unit in Yucca Mountain and all associated hydraulic problems in shaft emplacement. This means that the distribution and permeability of the hydrostratigraphic units must be known to the extent possible. To proceed with the shaft leading to a test facility without this information is unthinkable. However, no plans were presented as to how the requisite data would be acquired. Could a series of

peripheral holes be drilled with air and or conventional (non-polymer) mud for the exclusive purpose of obtaining hydrogeological and geophysical borehole data? By eliminating the core requirement a much larger number of holes could be drilled in the same time budgeted for a single pair (G3, H3). If the core is required, there is no possibility that multiple holes within the periphery can be drilled, logged, and tested, and therefore no possibility exists for obtaining the required data. We emphasize further that the testing of isolated horizons as described above is a minimum requirement. Vertical communication across the various hydrostratigraphic units will ultimately have to be ascertained. Hence some hole to hole testing may be required, as well as advanced single borehole techniques. However, we do not recommend this at this time, as vertical permeability can ultimately be measured on a meaningful scale via horizontal boreholes and galleries once an underground facility is completed.

Obtaining the drill hole information cited above has apparently not been an easy task. Two reasons may be cited for this. First, the hydrogeology drilling and testing program has not been supported to the extent it requires. Testing takes time and money. It is of little benefit to drill a hole and come away without a whole array of measurements, or measurements that for one reason or another are unreliable. With few exceptions, this has been the experience to date. Virtually all activities in the waste isolation program at Nevada should be secondary to this hydraulic effort, at least for the next few years. That is to say, additional holes for hydrology are required and the existing holes must be retested as described. This drilling and testing cannot be confined to Drill Hole Wash.

A second observation relating to this same problem is that the Survey may not be supported by adequate manpower. Certainly progress of the type

envisioned here will require a careful evaluation of all core and geophysical data, almost constant vigilance in the field, and a constant search for better methods to overcome the mechanical problems encountered in packing. Additionally, further support is required in the area of well hydraulics, especially in the techniques of single borehole testing in saturated horizons. Certainly such expertise exists in the Survey but if the Survey cannot meet the demand for specialized manpower, or if the company responsible for the packing cannot do the job properly, some thought has to be given to subcontracting elsewhere. These data are too important to be compromised. In short, the problem can be resolved with the allocation of money and equipment in the drilling-testing program, and with improved technical assistance. It is managements task to commit the necessary resources to overcome technical problems and the competition for drilling time on NTS.

Hydraulic Head and Chemical Data: In addition to measurements of hydraulic conductivity as discussed above, hydraulic head and chemical character of the water must be ascertained in the various hydrostratigraphic units. In order to be sure that the measurements represent heads at equilibrium between the measuring instrument and the formation, time must be allowed for such equilibrium to be established. We note that in all packer tests to date, not one reliable measurement of hydraulic head in the measurement zone was obtained, presumably due to a lack of sufficient time allotted for this task. Hence, although it is suspected that the potential distribution in Yucca Mountain favors a vertical component of downward movement, it is not yet possible to describe this movement qualitatively or quantitatively. This groundwater regime must be determined.

Chemical information is of secondary importance from a hydraulic perspective in that it may be supportive of hydraulic conclusions regarding barriers

to vertical communication of waters in the various hydrostratigraphic units. If all data are compatible within the framework of a reasonable conceptual model of the system, it is then likely that the system is well understood. In addition, chemical data are of primary importance as input to the waste package program. Also an understanding of the rock-water chemical reactions as deduced from the hydrochemical patterns is prerequisite to using any isotopic method to estimate groundwater ages and flow rates. In the absence of observed water chemistry, which is the current case, there does not exist a sufficient understanding of the mineral-water chemical reactions to provide either water ages or to specify potential radionuclide rock reactions which will affect transport. Reporting Carbon-14 data in terms of unambiguous age interpretations may lead unsophisticated readers to consider them as real ages, but these ages are highly suspect in the absence of insufficient hydrochemical data in the volcanics.

The Topopah Springs Unit

Some part of the Topopah Springs unit may offer promise as a candidate site for several reasons:

- (1) At the high elevations of Yucca Mountain it is in the unsaturated state.
- (2) It is non-zeolitized and therefore does not present problems in mineral stability.
- (3) It is underlain by zeolitized units, which may provide a desirable geochemical barrier (sorbing zone) sufficiently removed from serious perturbations of the thermal regime. Presumably, water movement from the unsaturated zone will have a dominant component of downward movement toward this geochemical barrier.
- (4) It possesses the desirable characteristics of accessibility, lower confining pressures, and lower in situ temperatures.

There are some obvious problems with the Topopah and these include its fractured nature and the ultimate effect on geomechanical and hydrogeological problems. Specialized hydrogeologic testing is required and this will require input from the Survey's specialists on the unsaturated zone. A planning document from the Survey appears to be in order here, with outside review provided to comment on the proposed methodology and utility of the data to be collected.

It follows from all of the above that the unsaturated zone must receive special attention, and this statement holds whether the vault is above or below the water table. Certainly on Yucca Mountain the hydraulic head distribution and water content in the unsaturated zone has to be determined. Water samples should be obtained and analyzed for chemistry and isotopic composition. Sequential neutron logging should be required in selected boreholes. From this, the hydrologic regime of the unsaturated zone may be described. This seems particularly important in the light of the hydraulic head reported in G-2 which suggests an anomaly in the flow regime. Does this represent a significant barrier to flow across Yucca Mountain or is it possible that Yucca Mountain represents a local piezometric high on the regional water table? If the latter is the case, the role of the unsaturated zone in maintaining this high must be ascertained. It is noteworthy that the area of interest, Yucca Mountain, may thus far be associated with two anomalies, the reported high permeability zone along Forty Mile Wash, and the high head in G-2. In addition, the reports of very high water content (90% saturated) of samples from the unsaturated zone are somewhat disquieting. These findings should be verified and accounted for in a physical sense, and will add to an understanding of the saturated-unsaturated flow regime of Yucca Mountain.

We are inclined to agree with most investigators that groundwater recharge through infiltration of precipitation is very low over NTS. Nevertheless, we

are regaled by stories of rapid infiltration during heavy storms and flow into mines following rain in settings that are similar to Yucca Mountain. This matter must be laid to rest for the Yucca Mountain site. Are the fractures open pathways that immediately transmit rain water while the matrix remains saturated (90%) with older water? What is the geohydrologic significance of topography and drainage? Would a change in climate of the sort predicted alter the present regime significantly? What is the role of the major surface channels in groundwater recharge? Would a change in climate of the sort reasonably predicted alter this significantly? With regard to these questions of climate change, the findings of the paleohydrology group indicate that water tables in the discharge area were not much higher than current heights during the Quaternary. What sort of study is required to determine the water table position at Yucca Mountain during this same time period, if such a study is even possible?

Numerical Modeling

The choice of having the groundwater model and now the transport model done by hydrogeologists rather than professional computer science people is a good one. The members of this group know that much better data and hydrogeologic characterization will be required. They are also aware that there will always be significant uncertainty in predictive simulations with respect to travel times from repository to the biosphere. It is their role, and ours, to convince their management and DOE as well not to design a program that places the ultimate burden of proof on site specific model predictions. In this regard, it has been suggested that the models may have more interpretive value than predictive value, especially in the light of data scarcity, both present and future.

The two dimensional regional finite element model presented by Waddell is to provide fluxes at the boundary of a more localized, but also more sophisticated three-dimensional contaminant transport model representing the region of the repository. The only requirement for the regional model, therefore, is that the fluxes that will appear at the boundary of the three-dimensional repository model be as realistic as possible. Areas near the repository site, therefore, must be better defined than areas at great distance from the repository site. That is, although around the fringes of this regional model, Pahute Mesa, for example, recharge areas may be lumped into one large area of evenly distributed recharge, as the repository area is approached, smaller regions of lesser recharge may not be neglected. It was surprising, for example, that Timber Mountain having an elevation comparable to Pahute Mesa with a projected rainfall greater than 10 inches, similar to Pahute Mesa, was not considered to be a recharge area. Cane Spring on Skull Mountain and Topopah Spring on Shoshone Mountain in the southwest quadrant of the Nevada Test Site also suggest active recharge potential in those areas. The heat flow presentation by Sass suggests that even portions of Yucca Mountain may be subject to recharge. At distance from the repository boundaries, these small recharges may be insignificant. Close to the repository boundaries, however, they may significantly alter flow paths and flux. Although the finite element model suggests otherwise, the convergence of flow towards 40 Mile Wash as shown by contours on Wilson's hydrogeological maps of the southwest portion of the Nevada Test Site suggests that there are sources of recharge water on either side, both east and west, of 40 Mile Wash. This is not to challenge the conclusions of Klassen that recharge may have occurred through the wash bottom thousands of years ago. Recharge may occur through the bottom of 40 Mile Wash under exceptional conditions even today.

Contaminant Transport Time

It appears from Klassen's work on the age dating of ground waters, that

the transport time from Yucca Mountain to use points in the Amargosa Desert may well be on the order of several thousand years neglecting retardation, and neglecting dispersion. Fenske does not believe that the contaminant transport time would be as short. Even neglecting retardation due to sorption, much of the flow in a system would be through a double porosity system where the movement will be down fractures but also through interfracture blocks. If interfracture blocks are permeable, then it is necessary hydrodynamically that water flowing down the fractures also flow through interfracture blocks. Since the permeability of interfracture blocks may be finite but small, and since the hydraulic heads cross these blocks will be determined by regional gradient, once the contaminant enters an interfracture block the residence time will be long relative to fracture transport. The interfracture blocks will act as storage cells and retardation cells for the contaminant whether sorption occurs or not. The effect of sorption will be to prolong the stay of contaminant in these interfracture blocks almost indefinitely.

Although, as Larry Larson pointed out, the statement that anything can be engineered may be a rash statement to make, a somewhat modest and modified statement can be made. If a repository is placed in a "reasonable" medium, a medium that has most of the requirements for a repository, the other problems can be engineered around. For example, the saturated zone transport through a repository that will pick up contaminants and move them out of the repository depends upon the hydraulic gradient across the repository as well as the permeability of the backfill material in the repository and the permeability of the host rock. It would be a rather simple matter to reduce the gradient across the repository to essentially zero, by creating a hydrologic short circuit around the repository, a high permeability region such as a tunnel not in any way connected to the repository but surrounding the repository. Water flowing through the high permeability region would equalize heads upstream and downstream from the repository and reduce the gradient to essentially zero across the repository. Under those conditions regardless of the permeability of the backfill, very little water

transporting contaminants could ever move out of the repository into the hydrologic system. A similar system with similar results could be designed for the saturated zone immediately beneath a repository in unsaturated rock.

Other Considerations

There are other considerations that should be mentioned here, most of which have been brought up in previous peer review documentation. These are cited below:

- (1) The mineral stability investigation is excellent. It remains a high priority item in that mineral stability indeed represents a limiting factor for the utilization of the tuffs of Yucca Mountain. It is clear at this stage that irreversible dehydration must be avoided. How much reversible dehydration can be permitted, if any? The answer to this question will constrain the maximum temperature rise in the zeolitized horizons. A more complete modeling effort will be required to ascertain the possibility of excess fluid pressures due to the release of waters of dehydration. This model should include fluid flow as a pressure dissipative mechanism and thermal expansion of fluid as well as a temperature dependent fluid source term as pressure producing mechanisms. Resulting (simulated) fluid pressures have to be examined in the light of potential fracture initiation and propagation. Microfracture development (dilatancy), for example, can occur at reasonably small excess fluid pressures.
- (2) If the Tertiary volcanics retain their candidacy as a potential repository site, the geologic and hydrologic relationships between these rocks and the Paleozoic aquifer must ultimately be determined. This would appear to be a requirement of site characterization.

- (3) Although not specifically listed as a candidate unit, we urge continued work on the unsaturated zone in the alluvium. While attempting to obtain guidelines from NRC on repositories in unsaturated media (presumably in regard to the Topopah Springs Unit) could not similar guidelines be obtained for arid zone unsaturated alluvium characterized by a deep water table? We trust we are not completely locked into Yucca Mountain.
- (4) DOE/NV is to be commended for generating a review process which operates in a frank, friendly, and constructive fashion. Given the excellence of the scientists on the project, there is good cause for optimism. We have one suggestion that might be in the direction of preserving this kind of an attitude. As a peer review committee, we think that one of our tasks might be to provide input to specific planning documents before certain work is attempted, instead of always after the fact. For example, we feel that planning documents in hydrogeology should be prepared on the unsaturated zone investigation, characterization of hydrostratigraphic units, characterization of faults and fractures, etc. Given such documents we can see what exactly is to be done and how it is to be accomplished. This would appear to be the time to provide input to such projects by adding our views, perceptions and even constructive criticisms of the objectives and methodology to be employed. This would give the peer review committee a more "hands on" perspective of the scientific and engineering tasks to be performed.

GEOTECHNICAL/GEOENGINEERING PANEL REPORT

NNWSI
GEOTECHNICAL/GEOENGINEERING
PEER REVIEW

SESSION CHAIRMAN: M. P. KUNICH
PEER LIAISON: J. A. FERNANDEZ

<u>PEER REVIEWER</u>	<u>AFFILIATION</u>
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RICHARD V. WYMAN	UNIVERSITY OF NEVADA, LAS VEGAS
CHRISTOPHER M. ST. JOHN	J.F.T. AGAPITO & ASSOCIATE
ROGER STAEHLE	UNIVERSITY OF MINNESOTA
JOSEPH BUSCH	KAISER ENGINEERS
PETER K. FROBENIUS	BECHTEL NATIONAL, INC.

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CONSULTING GEOTECHNICAL AND MINING ENGINEERS
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GRAND JUNCTION, COLORADO 81501

September 30, 1981

Mr. Robert M. Nelson
Project Manager NNWSI
Department of Energy
Nevada Operation
P. O. Box 14100
Las Vegas, Nevada 89114

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Dear Mr. Nelson:

RE: SUMMARY OF GEOTECHNICAL/GEOENGINEERING PEER REVIEW PANEL

I have now received review comments from each of the members of the Peer Review panel on Geotechnical/Geoengineering aspects of the NNSWI program. As expected, the comments and recommendations are rather diverse, but in essence they confirm the summary that was given orally at the concluding session of the Peer Review.

It was my intention to circulate the enclosed material to panel members prior to submission to you. Unfortunately, the individual contributions reached me more slowly than anticipated and I am now about to leave the U.S. for approximately two weeks. Rather than delaying the process further, I am enclosing the material that I have prepared or collected. However, you should consider the summary to be a draft until I have had an opportunity to discuss its contents with each of the panel members.

It was a pleasure to take part in the Peer Review. I found it to be a very constructive and rewarding experience and look forward to future such activities.

Sincerely yours,

Christopher St. John

CSJ/ft

cc: J.S. Busch - Kaiser Engineers
J. Handin - Texas A. & M. University
P. Frobenius - Bechtel National
R.V. Wyman - University of Nevada
R.W. Staehle - University of Minnesota

SUMMARY OF COMMENTS OF PEER REVIEW PANEL ON GEOTECHNICAL/GEOENGINEERING
ACTIVITIES WITHIN THE NEVADA NUCLEAR WASTE STORAGE INVESTIGATION

The functions of the Peer Review panel that met in Las Vegas between August 24 and August 28, 1981, were interpreted to be:

- o evaluation of the technical quality of the work, and
- o assessment of the adequacy of the program to meet the objectives of the NNTS program in a timely manner

Our overall reaction to material presented during the Peer Review is summarized in the two paragraphs that follow.

We find that the quality of technical and scientific investigations is of a high standard. We are impressed by the quality of the personnel involved in project work and the manner in which material was presented and questions answered.

We are concerned that the program lacks sufficient focus and definition of priorities to meet the critical, national objective of safe disposal of nuclear wastes in a timely manner.

Despite our concern about the focus of the program we are of the opinion that satisfactory methods of disposing of nuclear waste are possible using current technology. We base this opinion on material presented during the NNWSI Peer Review as well as on our familiarity with the wider NNTS program of the DOE.

The paragraphs that follow consist of specific recommendations concerning the NNWSI program as it was presented during the Peer Review. Some of these recommendations can be implemented by NNWSI directly, while others refer to the framework within which NNWSI functions.

We are very concerned that the exploratory shaft may provide almost no information on the rock mass overlying the selected horizon for site investigation. If the shaft is drilled, every effort should be made to evaluate the rock mass remotely, by drilling from the shaft and through instrumentation of the shaft lining. Detailed plans of geotechnical investigation to be conducted from the exploratory shaft and from the "At Depth Test Facility" are urgently required. The timing of institutional milestones should be reassessed if meeting them requires sacrifices in terms of loss of opportunities to obtain essential geotechnical data.

There are serious deficiencies in the information available on the fracturing of the host rock units within the area considered feasible for siting a repository in tuff. We believe that a great deal of valuable information could be obtained from the exploratory shaft but that this information will not be available if the shaft is drilled and lined before the rock mass can be inspected. The only practical alternative to logging in the shaft is to drill inclined holes from the surface. Drilling such inclined holes may be incompatible with a desire to minimize the number of boreholes at the potential site.

The waste package must be clearly defined and must be compatible with the conditions peculiar to emplacement in tuff. We are convinced that it is impractical and undesirable to design a single waste for the NWTs program. The waste package - as well as backfill and excavation, borehole and shaft seals - should be media specific.

The waste package environment is strongly effected by water that will flow from the tuff and backfill in the emplacement holes towards the package. We recommend that additional water migration tests be conducted in the field. These should include use of candidate backfill materials and should be designed to provide confirmation of quantitative descriptions of the dehydration processes that occur.

The time dependent effects upon thermal, mechanical and hydrogeologic properties of tuff are inadequately understood at the present time. Model studies can be used to define the repository environment more precisely and assist in definition of processes that could potentially impact repository performance. We are concerned that any testing that may be required to provide better material descriptions is long term and could therefore limit the rate of process of the program. Accordingly, we recommend that immediate action be taken to determine time dependent effects that could be critical to repository performance.

Since the only certain means for radionuclides to reach the accessible biosphere is through groundwater flow, contaminant transport studies are of particular importance. We do not believe that ground water and transport studies are being given sufficient emphasis at the present time. We agree that there are major uncertainties about release rates from the waste package as well as retardation in the host media, but we suggest that studies be completed to assess release from the repository assuming the worst case for the near field source term and upper and lower bound estimates for retardation. In order to complete these studies, credible values of the rock mass permeability must be obtained for members above and below the potential repository horizon.

We are of the opinion that it is essential that the criteria for design of a repository be clearly defined. These criteria should incorporate a degree of conservatism that is clearly defined in terms of uncertainty in the description of the geologic environment. The criteria should be fully justified and the means by which they were obtained and the manner in which they are intended to be used should be completely described.

Excavations in the tuff exist both on the Nevada Test Site and elsewhere. We recommend that a survey of these excavations be conducted and that the performance of any excavation in materials similar to that which might occur on a tuff repository be determined. Data from this survey could provide direct evidence of the practicality of constructing a repository in tuff as well as providing a basis for using rock mass classification systems for designing excavations and determination of support requirements.

Finally, we observe an emphasis on meeting major institutional milestones rather than upon meeting scientific and technical objectives. This is exemplified by the conflicting requirements for the exploratory shaft. It is essential that the overall objectives of the program and the proposed means of achieving them be clearly defined. Such a framework should provide a basis for integration of the many interrelated components of the NNWSI program. Groups such as MIDAS (Mine Design Study Working Group) should be responsible for development and implementation of the program.

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November 3, 1981

Mr. Robert Nelson,
Project Manager, NNWSI,
Department of Energy,
Nevada Operations,
P. O. Box 14100,
LAS VEGAS,
Nevada 89114.

Dear Mr. Nelson,

re: Summary of Teotechnical/Geoengineering Peer Review Panel

When I forwarded a draft copy of the Peer Review Panel Comments I undertook to contact each member of our panel to enquire whether they accepted my summary as a fair representation of their own written comments and our discussions during the meeting. I can now confirm that the summary is acceptable to each member of the panel and may therefore be regarded as final. There are, however, two points which panel members raised and should be recorded.

Roger Staehle commented that he would like to see more emphasis on the matter of computer modeling. From his comments at the meeting and his subsequent letter to you, dated September 11, you will recall that one of his major concerns was the problem of communication between persons working within the several disciplines that are actively involved in problems associated with storage/disposal of radio-actives wastes. While I fully concur with his opinion and his suggestions that computer modeling would provide a valuable means of communication, I did not mention the matter in the summary because it raises issues which are much broader than those which received emphasis during our meeting. Should we have a second review meeting, concerning NNWSI planning and project coordination, then I believe it would be appropriate to discuss his suggestions in some detail.

Peter Frobenius reminded me of a comment relating to core management that was made during the final session of our meeting. It is more than likely that this issue was raised in the report of another panel, so I have not made any addition to our summary. However, core management is a serious issue. Unless core is adequately stored, protected from pilfering by collectors of "interesting" specimens and thoroughly recorded, much useful information may be lost. All core should be retained as a permanent and visual record of the geologic/geotechnical characteristics of the site and should be available for inspection by parties ranging from the licensing authorities through contractors bidding on shaft sinking and other construction work.

Once again, I apologize for the delay. I was detained at a test mine site in Morocco for the best part of October.

Please note that I have left J.F.T. Agapito and Associates and am participating in the formation of a new company that is specializing in the application of mechanics in a variety of fields, including geotechnical. I shall continue to be based in Grand Junction for a while and can be contacted at the above address.

Sincerely yours,

A handwritten signature in cursive script, reading "Christopher St. John". The signature is written in dark ink and is underlined with a single horizontal line.

Christopher St. John
Vice-President

C.St.J/pd

ENVIRONMENTAL STUDIES PANEL REPORT

NNWSI
ENVIRONMENTAL STUDIES
PEER REVIEW

SESSION CHAIRMAN: H. L. MELANCON
PEER LIAISON: R. C. LINCOLN

<u>PEER REVIEWER</u>	<u>AFFILIATION</u>
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Los Alamos Technical Associates, Inc.

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October 16, 1981

Mr. Robert M. Nelson, Jr.
Project Manager
Nevada Nuclear Waste Storage
Investigations
Department of Energy
Nevada Operations Office
P. O. Box 14100
Las Vegas, NV 89114

Dear Mr. Nelson:

Preston Hunter, Robert Kaufmann and myself have assembled our comments on the Nevada Nuclear Waste Storage Investigations that we reviewed during the week of August 24, 1981. Enclosed is our report which lists the conclusions and recommendations we collectively feel qualified to make.

Our comments and criticisms are meant to be constructive. We are favorably impressed with the accomplishments to date as they have provided a good base for the work still ahead in solving the nation's long-term waste management problem.

We appreciate the opportunity to participate in the peer review and hope that our comments will contribute to the program's successful conclusion.

Sincerely yours,

Helen F. Gram

Helen F. Gram

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HFG:lbh

Enclosure: As cited above

cy: Preston H. Hunter/Robert F. Kaufmann
REE-01-01 File
Central Files

ENVIRONMENTAL STUDIES PEER REVIEW COMMENTS by

Helen F. Gram, Los Alamos Technical Associates, Inc.

Preston H. Hunter, Ford, Bacon, and Davis

Robert F. Kaufmann, Converse Ward Davis Dixon

October 1981

1.0 GENERAL IMPRESSIONS AND OBSERVATIONS

1.1 Communication

Prior to the peer review, the Environmental Peer Review Group (EPRG) received essentially no information concerning the (1) nature of the NNWSI environmental program or (2) the relationship of NNWSI to the national program. These two reference points were particularly important because this was the first environmental review. Reviewers, researchers and management alike need to know the purpose and objectives of the NNWSI and the NWTS program since the primary purpose of environmental studies is to meet NEPA, EPA, and NRC requirements, regardless of how the program is structured to accomplish the multiplicity of tasks. The artificial division between geologic/hydrologic studies and environmental studies and the limited scope of the environmental program contributed to the difficulty of assessing the adequacy of methodology and results to provide the necessary information for environmental assessments and comparison of repository sites.

1.2 Technical Interface

The separation of EPRG from other review groups hindered the flow of information between the various investigators and, consequently, the comprehensiveness of the review. From the studies to date, we sense that the environmental assessment has been equated to an ecological/socioeconomic assessment. Beyond this, the data base must be adequate to support a radiological and a nonradiological assessment of project effects and waste releases on the population at risk (including workers). Since one purpose of the studies is to compare

sites, the methodologies and assumptions upon which comparisons are based, must be clearly documented and consistent if the NWTS program is to be credible to a concerned public.

The difficulty experienced by the EPRG in understanding the regulatory and policy constraints associated with siting, constructing, and operating a high-level waste repository suggest that planning documents are not sufficiently developed to adequately detail data and interface requirements. Planning tools such as data flow charts and compliance time tables, with the scope and purpose of data collection specified, are needed to facilitate effective project management and review. For example, the site characterization report (SCR) is an important document in obtaining the operating licence for a repository. The data requirements for the SCR and preliminary, subsequent NEPA documents will overlap and data bases should be the same. The NNWSI project charts should clearly show the flow of information from SCR to DEISs.

Improved program management may be most important at the NWTS level where site-specific considerations will be accommodated within the national waste management program. Of paramount importance is the necessity to adopt a uniform methodology at the national program level for performance assessment and dose commitment calculations. Since both of these exercises are highly dependent on the methodology and investigator, a common approach is necessary if comparisons between the environmental assessments for the different repository media are to be valid. Where possible, methodologies for radiological and nonradiological assessments should also be consistent for common releases of radionuclides and toxic/hazardous chemicals.

1.3 Program Scope and Competency

Individual presentations by SNL staff and subcontractors were well prepared and presented, reflecting overall competency of the principal

investigators. However, the environmental program lacks breadth and understanding of the interrelationships among the study areas and the NEPA assessment requirements for the NNWSI and NWTs program as a whole.

The primary criteria for assessing adequacy of the environmental studies include a site characterization (with and without repository) and the technical basis and justification for licensing. Any effort beyond these primary goals is excessive. The environmental program needs to focus its scope on the repository, not merely the exploratory shaft. Consequently, potential problem areas, i.e., endangered species, should be identified and resolution strategies should be developed immediately.

The apparent overlap of tasks, particularly in the hydrology area, may not be as advisable and as cost effective as consolidating tasks and accelerating delivery schedules. It is suggested that principal investigators develop a better understanding of how their studies are to be utilized by other investigators to reduce the problem of integrating the multiplicity of data. For example, placing the responsibility for performance assessment and model development with a single project manager would focus tasks on the purpose of certain investigations. One of the most important aspects of developing the performance assessment model is establishing a strong data base and empirical relationships that are critical to understanding the repository regime and predicting repository performance.

Two other observations are made regarding the current NNWSI program plan. 1) For a project as important as a high-level waste repository, there may be significant benefits from sinking more than one exploratory shaft to obtain a clear understanding of the regional subsurface regime. 2) Locating a disposal facility at shallower depths above the water table may be cost effective, particularly for transuranic waste management. Siting a transuranic waste disposal facility near a deep geologic facility could have a favorable impact on the cost, size, and design of a deep geologic repository.

2.0 PROGRAM MANAGEMENT ISSUES

2.1 NEPA Constraints

The National Environmental Policy Act (NEPA) requires an integrated, multidisciplinary approach to assessment of effects significantly affecting the quality of the human environment. In order to bound the repository assessment process and achieve the necessary degree of NWTs and NNWSI program compatibility, there is an obvious need to identify common methodology and data requirements. Although it may be necessary for program management and site characterization reasons to separate geohydrologic and engineering studies from other environmental studies, each area is part of the environmental assessment whole required by the NEPA process. Data collected for reasons other than identifying environmental impacts are not required for NEPA compliance.

Public participation in the environmental assessment process is required by NEPA. With the issuing of the FONSI for the exploratory shaft, the public may perceive that they are being excluded from the NEPA process for the repository. To promote a working relationship with public interest groups, mechanisms for communicating with the public should be in place and utilized at this time. The efforts to date are commendable but more is needed.

2.2 NRC Constraints

The NRC waste repository criteria (10 CFR 60) have at least three requirements that could impact the NNWSI. The environmental significance of these criteria, discussed below, needs to be factored into the NNWSI program.

- (1) NRC criteria favor use of saturated zones. Unsaturated zones present significant technical problems to assess transport, although such zones are abundantly present at

NTS. Furthermore, waste disposal in unsaturated tuff over Paleozoic carbonates is analogous to the situation at the Idaho National Engineering Laboratory (INEL) where there have been political repercussions for defense waste management.

- (2) The requirement of a minimum period of 1000 years for water flow from the waste source to the biosphere appears to be arbitrary. The evidence of a flow period of say 900 years, for example, should not rule out the selection of a site that has other favorable characteristics. The criteria must recognize the degree of uncertainty inherent in such calculations.
- (3) The requirement for a canister with a 1000-year integrity also appears to be unrealistic to accomplish the engineered containment recognized as adequate for minimizing the risk of radionuclide exposure. Not only are arbitrarily selected time periods impossible to monitor, but they also defeat the purpose of the multiple barrier approach to waste isolation. Emphasizing engineered containment is impracticable because it provides the best protection during the period when a repository breach is least likely. Because repository site characteristics and waste packaging factors work together to achieve waste isolation, development and reliance on a 1,000-year integrity container is unwarranted and may also impose significant schedule delays on the program.

2.3 Deliverables/Content/Scheduling Problems

The EPRG feels that the NNWSI project and the NWTS program could benefit from third-party management. Acting as an extension of the DOE/NV management staff, a systems engineering management team is recommended to improve program integration and to get and keep the program on schedule and obtain a license. The team's responsibility would be to review specific technical roles and appropriate scopes of

work for each laboratory/agency and then also monitor the work activities and deliverables to enhance timely program accomplishments. The coordinator role should be especially effective because the team consultant would lack proprietary interest in specific program areas.

3.0 INTERFACE ISSUES

3.1 NNWSI/NTWS Program Coordination

The EPRG is concerned that: (1) The need for site-specific geochemical and geohydrologic studies may not be fully appreciated at the national program level; however, study scopes should not go beyond requirements for model validation. (2) Guidance in methodology selection for calculating doses, commitments and health effects and developing performance assessment scenarios is apparently lacking. Comparison of assessments for the different media can not be valid unless a common approach is used.

3.2 LANL/SNL/LLNL/USGS Integration

The national laboratories and the USGS have very competent researchers conducting thorough site characterizations. However, there appears to be a lack of information transfer between these groups which promotes duplication of effort. The need for greater coordination, for example, was particularly apparent in comparing the environmental program's biology and water use availability studies with the hydrologic studies being conducted for site characterization. Overlapping scopes of work may hinder achieving current milestones.

3.3 Performance Assessment

Performance assessment is the task wherein site geohydrologic data and models and data from the other environmental studies are used to assess the effects of waste releases. Therefore, performance assessment studies are relevant to the environmental review. In-depth appreciation of the dependencies that exist among the

probabilistic/quantitative knowledge of the geologic system, site hydrology and transport of fluid and solutes, and work being done in the area of radiological assessment is not reflected in the present performance assessment program. While EPRG expects that these data will be factored into future evaluations, it is our impression that data requirements may not yet be clearly defined. It also appears that the performance assessment results may not be available when needed in FY83.

The issue of model availability and compatibility affects credibility of the performance assessment. If NWTs certified models (coupled or independent) are to be used for all sites for both near and far field effects and USGS modeling work is not certified or documented in time for the DSCR, what model(s) will be used for performance assessment? In order to develop modeling compatibility between USGS, SNL, and DOE (NWTs), much improved coordination and realistic scheduling is required. Issues of whether simple or layered models will be used and whether USGS site specific or NWTs generic models are applicable also affect the assessment of waste disposal. These issues should be resolved in the near future to avoid delays and duplication of effort, and most importantly, to reflect DOE's competency in nuclear waste management.

We endorse the segregation of consequence and risk analysis results since significant information is lost when only the product of consequence and probability is discussed.

3.4 Other Federal Program Relationships

Other major projects such as the MX Missile project may have a significant impact on the State of Nevada. Such projects can have a direct and indirect impact on the NNWSI program that should be considered in program planning and scenario development for assessing socioeconomic effects in particular. Indirectly, an MX-type project could affect the NNWSI assessment of water resources, area biology, sociology, demography, and economics.

4.0 ENVIRONMENTAL STUDIES

The investigations appear to have been well conducted in terms of staff competency and productivity. A considerable amount of data was assembled and reviewed with the goal being to describe the existing environment and, to a lesser extent, the expected impacts from exploratory shaft construction. Overall, we sense that the NNWSI position on environmental studies is characterized by a relatively small amount of money allocated for specific projects generated from some "good ideas", with the work to be done by locally-based researchers from the University of Nevada System. The use of locally-based researchers was probably a good, cost-effective approach and certainly enhances the public image. However, the question remains as to whether environmental aspects of the NNWSI program constitute a substantive first step in an integrated environmental product, or whether it more closely resembles a dissociated collection of basically credible reports surrounded by unknowns as to what comes next and when.

EPRG felt that study findings were used to good advantage in the area screening analysis. Noticeable shortcomings of the studies include a paucity of specific, prioritized recommendations focused on environmental program objectives. Additional broad research programs are suggested as a result of hydrology work to date whereas undue caution is advanced as a result of endangered plant and animal species identification. The environmental program needs to respond to genuine voids (e.g., meteorology and selection of radiological assessment methodologies) and information exchange (e.g., hydrology). Factoring in of public comments will become increasingly important as the program proceeds to the TFF stage.

EPRG views with considerable concern the potential that certain plants or animals, or archaeological resources may retard or stop progress on a waste facility. Early on, the environmental program scope should encompass at least planning for mitigative action without

any compromising of the repository. Problems should be resolved or critical habitats and resources identified and consciously committed, if necessary, to this extremely high national need - HLW disposal.

Reviewers' comments relative to the completed or additional work in the eight environmental study areas and the area of public participation follow.

Biology

The established floral and faunal baseline appears adequate. The potential for "sensitive" species being reclassified as "endangered" or "threatened" warrants low-key interest with an emphasis on developing mitigative actions and resolutions.

Cultural Resources

Site specific archaeological surveys in proposed drilling or other operating areas is warranted as construction begins. The surveys of mining activities partly duplicates the energy/mineral resources and water use/hydrology scopes of work. No further investigation appears to be warranted except for developing a realistic resource preservation plan for the impacted sites.

Paleontology

EPRG questions whether sufficient basis exists for this study considering the known geology and fossil resources of the NTS and surrounding region. No further work is warranted.

Meteorology and Air Quality

A sufficient data base for air quality modeling is nonexistent. Background air quality data (exclusive of environmental radionuclide monitoring) is similarly absent. Additional data collection for the EACR, EA, and DSCR is necessary; performance assessment that

considers the airborne pathway will require considerable new data for the TEF and repository sites and the meteorological data should be based on at least a one-year sampling period. The NRC requirements for reactors developed in the aftermath of the Three Mile Island release (Reg. Guides 0700 and 0654) could also be required for a repository. Consequently, a reliable air dispersion model for the repository site, that will be used for both radiological and nonradiological assessments, is imperative.

Onsite and Offsite Background Radiation

Site data is sufficient. No additional data collection or interpretation is warranted.

Socioeconomics and Sociology

Potentially significant indirect impacts of a repository on nearby communities and the Amargosa Desert warrant additional evaluation. Provision of adequate public services and water supplies are key issues. However, complex sociological modeling is not warranted for these areas. Attitudinal surveys may be useful to assess public concerns about siting a repository at the NTS. Modeling of concurrent MX-type projects and repository impacts is recommended for the southern Nevada region.

Water Use and Hydrology

Numerous water-related issues were raised which the EPRG considers are more properly related to the technical basis for siting, design, and operation of the repository. Additional work should relate to water rights matters. Significant environmental questions to be resolved include the source of water needed for construction, the effect of water rights on NTS water use, and the impacts of withdrawal on the principal aquifers, with or without further Ash Meadows water development.

Energy and Mineral Resources

No additional off-site evaluations are warranted. On-site work should be limited to the Yucca mountain ES shaft location and to precious mineral assays in particular.

Public Interaction

NEPA's public involvement requirement strongly suggests that SNL and DOE look beyond the exploratory shaft and concentrate on obtaining public comment for the DSCR which is due in early FY 83. The EPRG is impressed with DOE's waste-related public relations program at NVO and particularly the efforts of Robert Nelson. However, the SNL recommendation (via ADM) that an EA is sufficient for the exploratory shaft and that a FONSI would result appears to be presumptuous. The rationale that since this is just another shaft there is no public controversy should be based on opinion polls and public involvement. The EPRG was somewhat surprised by the SNL and DOE staffs' reluctance to increase the public relations effort.

NEPA requires public participation in the scoping of alternatives and consideration of issues of public concern in the DEIS. The DOE/NV public information program should be expanded to enhance a two-way process for exchange of ideas and information. Ground rules should be established in advance for public participation in the decision-making process. Such communication between the public and DOE should begin as soon as the FONSI for the ES is released. A summary information and assessment document should be prepared which emphasizes that the purpose of developmental work conducted prior to scoping was to find solutions to engineering problems rather than decide conclusively the feasibility of a HLW repository. The document should outline the methodology used in assessing engineering problems, and describe how interested parties may participate in the assessment of short- and long-term effects.

5.0 CONCLUSIONS AND RECOMMENDATIONS

In this section, we have listed our most important conclusions regarding the NNWSI Program. Each conclusion is followed by a recommendation which EPRG feels will be helpful in resolving the issue. The conclusions and recommendations are listed according to priority. The first 4 items are the most important and should receive primary consideration. The remainder are listed in order of their decreasing importance.

- Integration of the environmental program with other NNWSI studies and coordination with NWTs programs is inadequate. A possible solution would be to provide overall coordination by a consultant team that lacks proprietary interest in specific program activities.
- The adequacy of the NNWSI environmental investigations to meet NNWSI and NWTs schedules and regulatory requirements is difficult to assess. We recommend greater program emphasis on the specifics of obtaining a license on schedule.
- Environmental studies that address air quality and meteorological monitoring, assessment of certain socioeconomic impacts, and the status of water rights are inadequate. We recommend an air quality monitoring program for nonradiological parameters, meteorological data collection appropriate for modeling ground-level pollutant transport in the area of the exploratory shaft, socioeconomic studies in unincorporated communities near the southwest corner of the NTS, and an attitudinal survey to assess public opinion about the repository.
- There is need for a uniform methodology for calculating dose commitments and health effects as well as developing consistent assumptions for release scenarios. We recommend

selection of a uniform approach to dose commitment and health effects calculations for the entire NWTS program so that release scenarios, dose commitments, and health effects can be compared among DOE documents.

- While environmental studies appear appropriate for an exploratory shaft environmental assessment, studies will have to be expanded to be adequate for a TEF, ADTF, and a repository, as DOE and SNL are aware. We recommend that future studies be carefully prioritized and scoped to provide only data required for the decision process.
- An assessment of direct and indirect environmental impacts of a repository constructed in conjunction with other major federal projects, such as an MX-type project, may become important if the NTS becomes a prime repository location. We recommend a cumulative assessment be conducted of any such project that may be developed at the same time as repository construction/operation.

RESPONSE OF TECHNICAL PROJECT OFFICERS

NNWSI PEER REVIEW, August 24-28, 1981

Program Management and Coordination

In order to upgrade technical management of the NNWSI program within the USGS, meetings were held in Reston, Virginia, December 2-3, to discuss the overall program with higher level management within the USGS. As a result of these meetings, the USGS will designate a Program Coordinator. The sole responsibility of the Program Coordinator will be to focus, integrate, and manage USGS participation (both Geologic Division and Water Resources Division) in the NNWSI program. The Program Coordinator will thus serve as a single contact for purposes of budgeting, planning, and setting of priorities and not be encumbered with day-to-day operational aspects of the program. The Program Coordinator will be available to meet with representatives of DOE, the National Labs, and other contractors to discuss coordination and integration with others working in NNWSI.

The USGS will commit additional manpower to the hydrologic investigations. An additional five hydrologists will be assigned to work in the NNWSI program.

Finally, we recognize the usefulness of developing planning documents prior to conducting various phases of NNWSI, but we question the appropriateness of the peer reviewers providing input to these. Once the peer reviewers become an integral part of the planning process, they then risk compromising their role of objective, outside reviewers. If, on the other hand, the peers are to be involved at all stages, and thus in effect to become a part of the project, then such input is appropriate. This concern is a policy matter for DOE to resolve.

Subcommittee on Geology

Comments regarding lack of overall coordination for handling, distributing, and cataloging core from drill holes should be discussed as there was no formal presentation of core handling procedures at the peer review. We agree with the suggestion that a formal overview committee be established for controlling core distribution. Under the current system, the various laboratories, as well as the USGS, present core sampling requirements prior to drilling of the hole. These requests have been honored except in cases where such sampling would inhibit stratigraphic correlations. The USGS has established a Quality Assurance program whereby every "natural state" sample taken from the drill hole is monitored, cataloged, and recorded prior to distribution. The QA program, however, does not control situations where core samples are collected from storage racks by program participants. In this situation, core samples may be taken without proper cataloging.

Subcommittee on Geophysics

Reflection Seismic:

The positive results of vertical seismic profiling (VSP) led to a seismic parameter study which was fielded in September 1981, subsequent to the Peer Review. Seismic Services Division, a well-site seismic service branch of Birdwell, Inc., was contracted to collect field data in the vicinity of drill

holes USW-G1 and USW-H1 for the purpose of evaluating large areal arrays of geophones for noise cancellation, multiple vibrators, low frequency seismic signals, and to make a test common depth point (CDP) reflection profile. The results are very encouraging. The large geophone arrays appear to be effective for noise cancellation. The test reflection profile indicates reflecting horizons within the depth boundaries of the proposed repository site. Preliminary indications are that the resolution of structure by seismic reflection may be somewhat limited by low frequency reflections.

Hans Ackerman and Lee Pankratz have assembled a systematic and elaborate seismic reflection contract which should begin by mid-March 1982. This contract incorporates an extension of the noise study begun last September to include a program to evaluate the best parameters to use to obtain maximum resolution of reflecting horizons while maintaining continuity for large horizontal distances. This will be a "no compromise state-of-the-art reflection survey." The study has been reviewed several times by outside consultants to ensure practical yet timely results. In addition to the two USGS geophysicists assigned to the work on a dedicated basis, the services of an outside data acquisition specialist is being sought. Approximately 34.4 miles of seismic lines are to be recorded this fiscal year which should help in any initial evaluation.

Refraction Seismic:

We feel integration of refraction results with the regional gravity model as recommended by the peer reviewers cannot be done without further data collection, particularly in the vicinity of the gravity low over Yucca Mountain. Current results show the increased delay in Crater Flat of 1.4-0.9 sec or 0.5 sec generally correlates with a decrease of ~ 15 mGal in gravity and can be explained by 10,000 ft of tuff. Additional data from the Yucca Mountain block itself could be used in conjunction with P-delays and sonic logs as well as seismic refraction/reflection data to build a velocity model. In turn, that model could perhaps be used for control and constraint on a revised gravity interpretation. Work has begun on interpretation of teleseismic results and correlation with gravity and seismicity.

Gravity:

We feel extension of the detailed gravity profile up drill hole wash is not warranted at the present time. A significant amount of time and expense would be necessary to survey in all the stations necessary. If results of the reflection program appear favorable and a reflection line is surveyed in this area, we can meter the line with gravity.

Magnetic Studies:

In order to expedite characterization of the magnetic stratigraphy at Yucca Mountain and vicinity, D. B. Snyder (Menlo Park) has begun working with J. G. Rosenbaum and D. C. Muller (Denver). Present plans are to make field measurements on outcrops and collected cores to test for lateral variations of magnetic members found in drill holes. We also plan to arrange for downhole magnetometer surveys of all major drill holes to obtain in situ remanent data for comparison with core studies.

A quantitative interpretation of the low-level aeromagnetic survey of Yucca Mountain will proceed during FY82. Interpretation of these data have been delayed by personnel constraints and other deadlines.

Electrical Studies:

No additional electrical surveys are planned for FY82. Effort will be directed toward interpretation and summarization of existing electrical data.

Borehole Geophysics:

With the exception of the shallow holes located in drill hole wash, a full suite of commercial geophysical logs has been run in all deep drill holes at Yucca Mountain. The suite routinely consists of caliper, electric, temperature, density, neutron, gamma-ray, and spectral gamma-ray logs. In addition, a vertical seismic profile is being run in all drill holes to aid the surface seismic reflection efforts. Magnetometer, televiwer, tracejector, and borehole gravimeter are used based on drill-hole size and specific need. The commercial logs thus obtained are being interpreted by D. C. Muller. Results of interpretations are being integrated into geologic reports on the drill holes.

Seismic Risk Analysis:

At the present time, we feel the data base is inadequate to finalize a seismic risk analysis. Present studies of seismic risk will continue pending establishment of standards by NRC. It is not the position of the USGS to initiate dialogue with NRC regarding criteria or standards. If dialogue is established between DOE and NRC, the USGS will provide data or input as requested.

Remote Sensing:

The review committee commented on use of available photo imagery and recommend further use of this type of data. The USGS program has been acquiring, and is currently using radar imagery, false-color infrared, landsat photography, and low sun-angle photography. In addition, special contour maps are being developed on analytical plotters from aerial photographs. These data will be digitized for further terrane analyses. Efforts are being made to enhance any linear features through computer processing of landsat photography. Previous data interpretations are currently being evaluated to verify the presence of the previously reported "linear."

Subcommittee on Hydrogeology

Drilling and Testing Program:

A drilling plan is being prepared that will stress identification of hydrologic units and assessment of their three-dimensional distribution. Planned for this fiscal year are four hydrologic test holes peripheral to the block. Initially these will receive "reconnaissance-level" testing, but they will be drilled and left in such a way that, if desired, deepening and (or) detailed testing can be conducted at a later time. The holes will be shallower ($\pm 4,000$ ft) than originally planned; no core will be taken, but a

complete suite of geophysical logs will be run. The initial testing program will allow a general determination of the vertical distribution of hydrologic units in each hole; the geographic distribution of the holes will allow development of a more complete conceptual model of the controls on the occurrence of these hydrologic units, whether stratigraphic, or structural.

As was done in previous holes, tracejector logging while pumping will be used to identify zones of inflow. Results of these and other logs will be used as guides in determining packer settings. Density, neutron, and acoustic logs will be used to identify variations in porosity and permeability. A television camera will be used to locate fractures and perched-water seeps in the unsaturated zone. In sections of uniformly low permeability, long packed-off intervals will provide meaningful values of average hydraulic conductivity. In sections that contain high-permeability zones, shorter packed-off intervals will be used. Even if a packed-off interval contains both low- and high-permeability zones, meaningful judgments can be made of the hydraulic conductivity of the high-permeable zone, based on interpretations of the tracejector survey.

Upon completion of the initial hydraulic tests in each hole, water samples will be obtained by pumping packed-off intervals. In this way the intervals can be pumped at length to obtain a valid water sample while the rig has moved on to drill the next hole. The pumping period for sampling will also be used as a controlled pumping test to determine head and hydraulic properties. Based on a reevaluation of hole conditions at USW-H1, it was determined that the small amount of additional hydraulic information that might be gained from retesting was not warranted by the cost. Instead, a nest of piezometers, isolated from one another by cemented-off zones, will be installed to obtain the vertical distribution of head under steady-state conditions. Similar installations are planned for some of the peripheral holes, once detailed testing is completed.

Adequate assessment of the hydraulic characteristics of faults remains a problem. If encountered, fault zones in the peripheral holes will be packed off and tested. We agree, however, that without an elaborate arrangement of observation and test wells designed specifically to test a particular fault, such testing will probably provide incomplete results. Testing in an underground facility will be done in part by means of horizontal and (or) slanted boreholes. As presently conceived, the purpose of these holes is to investigate the block of rock intended for use as the repository or T.E.F. in order to determine if there are any "surprises" not anticipated from analysis of surface-based drilling. Under this concept, major faults will not be anticipated and the faults bounding the block will purposely not be intercepted. Further evaluation is required to assess how best to determine the hydraulic properties of faults. As recommended by the peer group, we will utilize the horizontal boreholes from an underground facility to determine vertical hydraulic conductivity.

The Survey is taking steps to improve its manpower situation with respect to NNWSI. The Water Resources Division has committed to assigning five additional hydrologists to the program in order to provide both the numbers and expertise required to conduct properly the hydrologic investigations.

Topopah Spring Unit (unsaturated zone):

The USGS has been instructed by the NNWSI Technical Program Officers to develop a comprehensive integrated plan for investigating the unsaturated zone. For unsaturated fractured tuff, obtaining quantitative hydrologic information and modeling the system will be difficult. Most previous hydrologic investigations in the unsaturated zone have been in unconsolidated porous media. Nonetheless, the plan for study of the unsaturated zone will include determination of such hydrologic aspects as water content, water quality, permeability, gaseous diffusion constant, and occurrence of perched zones. The distribution of "hydraulic head" (or matrix potential) is being determined for the matrix by core analysis, but it may not be possible to install tensiometers for in situ determinations of tension in the fractured tuff.

Although quantitative studies and modeling of the unsaturated zone are desirable and should be pursued, the hydrologic concerns regarding this zone may in fact be minor. Experience from the tunnels of Rainier Mesa and our understanding of the hydrogeologic setting at Yucca Mountain suggest that water fluxes in the unsaturated zone are likely to be small. Interstitial water in the matrix of the tuff above the water table moves extremely slowly if at all, and is unlikely to move into fractures or manmade openings. The Topopah Spring unit, largely a fractured, welded tuff, probably contains little perched water in fractures. Even if encountered, such perched water would drain from fractures in a short period of time. The amount of water recharging the system probably averages a few gallons per minute per square mile. Furthermore, any water encountered in a repository can probably be dealt with through drains or other engineering features. The unsaturated zone even if imperfectly understood, represents an additional barrier for hydrologic transport of radionuclides to the accessible environment.

Ground-water age dating of samples from fractures and from the matrix (if obtainable) may provide clues as to recharge mechanisms and rates. Research will continue on the applicability of heat flow studies to understanding water fluxes in the unsaturated zone. To date, no method is known for successfully ascertaining the position of former water tables in tuff at Yucca Mountain, although detailed studies of secondary minerals and devitrification may provide clues.

Modeling:

We agree with the subcommittee that modeling should be done by hydrologists rather than by those with expertise principally in numerical techniques. Our awareness of uncertainty in predictive simulations is demonstrated by our application of sensitivity analyses in the regional flow model and by the development of sensitivity-analysis routines for the transport code.

During calibration of the regional flow model, runs were made in which recharge was assigned to Timber Mountain. No significant effects were observed in areas where potentiometric data existed. Thus, the potentiometric data available at this time neither supported nor denied the existence of recharge beneath Timber Mountain. Therefore, in order to simplify the model, the recharge term at Timber Mountain was ignored. A test hole in northern Fortymile Canyon was drilled in part to provide data near Timber Mountain in

order to help to answer this question. Hydraulic head in this hole was much higher than expected, based on the preliminary potentiometric map; the implications have not yet been evaluated.

Another question concerning recharge involves Fortymile Canyon itself, a major surface drainageway. At the drill hole in the northern part of the canyon, water samples from various depths are being dated to determine when recharge occurred.

The reviewers' discussion of transport through fractured tuff is correct in stating that interfracture blocks will promote retardation. The mechanism they discussed is primarily an extension of hydrodynamic dispersion. The effectiveness of the blocks in providing retardation is a function of the matrix permeability of the block. Probably the most effective retardation is provided when the matrix permeability is within a certain range relative to the fracture permeability. Above that range, the blocks/fractures act more as a porous media; below that range, retardation is hindered since very little of the water will flow in the interfracture blocks.

Experiments performed by LANL indicate that the diffusion mechanism may also be important in tuffaceous rocks, and that sorption experiments must be interpreted accordingly. In an environment where the transport rate may be dominated by molecular diffusion rather than by convection, the high porosity of the tuffaceous rocks provides a large storage volume for radionuclides.

Other Considerations:

USW-G3, at the southern end of the block, will be drilled into pre-Tertiary rocks. Once the depth and lithology of these units are known, consideration will then be given to the extent, methods, and sites of hydrologic testing that might be appropriate, either at G3 or at other holes that might be drilled to pre-Tertiary rocks.

The USGS is continuing its research on unsaturated alluvium at Jackass Flats, supported by USGS funds. Work has been slowed recently by the departure from the Survey of one of the principal investigators, but a search for a replacement is underway in order to continue this effort.

Sandia National Laboratories

Albuquerque, New Mexico 87185

February 3, 1982

Mr. M. P. Kunich, Acting Director
Waste Management Project Office
U.S. Department of Energy
Nevada Operations Office
P.O. Box 14100
Las Vegas, Nevada 89114

Dear Mr. Kunich:

The attached response to comments from the NNWSI Peer Review of August 24-28, 1982, is forwarded per your request of December 23, 1981. If we can be of further assistance in completing the Peer Review process, please call me.

Sincerely,

Richard W. Lynch, Manager
NNWSI Projects
Department 4530

RWL:dss

Attachment

Copy to:
4531 L. W. Scully
4537 J. R. Tillerson
4538 A. E. Stephenson

ACTION WMP
INFO _____
R. F. _____
A. E. _____
A. E. _____

SNL PROJECT RESPONSE TO THE
COMMENTS OF PEER REVIEW PANEL ON GEOTECHNICAL/GEOENGINEERING
ACTIVITIES WITHIN THE NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS

In general, our comments focus on the Summary of the peer reviewers' comments provided by C. M. St. John. However, in some instances we respond to specific comments made by individual peer reviewers.

Response to Summary Comments

Comment: We are very concerned that the exploratory shaft may provide almost no information on the rock mass overlying the selected horizon for site investigation. If the shaft is drilled, every effort should be made to evaluate the rock mass remotely, by drilling from the shaft and through instrumentation of the shaft lining. Detailed plans of geotechnical investigation to be conducted from the exploratory shaft and from the "At Depth Test Facility" are urgently required. The timing of institutional milestones should be reassessed if meeting them requires sacrifices in terms of loss of opportunities to obtain essential geotechnical data.

Response: The NNWSI Project recognizes the need for advanced planning for the Exploratory Shaft and At Depth Test Facility. This is being done with LANL as the project lead. It is questionable whether detailed plans for the ADTF are urgently required at this time since it will not be determined whether NNWSI will construct an ADTF until approximately 1987.

Comment: There are serious deficiencies in the information available on the fracturing of the host rock units within the area considered feasible for siting a repository in tuff. We believe that a great deal of valuable information could be obtained from the exploratory shaft but that this information will not be available if the shaft is drilled and lined before the rock mass can be inspected. The only practical alternative to logging in the shaft is to drill inclined holes from the surface. Drilling such inclined holes may be incompatible with a desire to minimize the number of boreholes at the potential site.

Response: There is no question a definition of the fracture systems at Yucca Mountain needs to be determined. Such information will come from the exploration program. Drilling inclined holes may have some merit. We do not yet know how much data one might get from these holes or where they should be located. We think a single inclined hole would provide the order of magnitude data one needs now for analysis. More detailed information could and should be obtained during or following shaft sinking. Joint models have been developed which can predict the response when site specific data are available.

Comment: The waste package must be clearly defined and must be compatible with the conditions peculiar to emplacement in tuff. We are convinced that it is impractical and undesirable to design a single waste package for the NWTs program. The waste package - as well as backfill and excavation, borehole and shaft seals - should be media specific.

Response: We agree and have so commented to DOE, ONI and ONWI on numerous occasions. Unfortunately, such comments coming from the Project are viewed as self-serving. It would be helpful if the peer reviewers would make such comments directly to the people responsible to the NWTs Program.

Comment: The waste package environment is strongly affected by water that will flow from the tuff and backfill in the emplacement holes towards the package. We recommend that additional water migration tests be conducted in the field. These should include use of candidate backfill materials and should be designed to provide confirmation of quantitative descriptions of the dehydration processes that occur.

Response: Water release and migration continues to be a concern. Model development work continues at SNL and bench scale experiments are to be initiated this fiscal year (FY 82). Small scale experiments will also be conducted in welded and nonwelded tuffs in G-tunnel, NTS.

Comment: The time-dependent effects upon thermal, mechanical and hydrogeologic properties of tuff are inadequately understood at the present time. Model studies can be used to define the repository environment more precisely and assist in definition of processes that could potentially impact repository performance. We are concerned that any testing that may be required to provide better material descriptions is long term and could therefore limit the rate of process of the program. Accordingly, we recommend that immediate action be taken to determine time dependent effects that could be critical to repository performance.

Response: The time-dependent effects are a part of the ongoing Geotechnical Program. The long-term effects on repository design and isolation have always been a part of these investigations. Specifically, the question of creep effects for the operational time are being examined. A proposal is being prepared which is to determine what is the best way to determine 1) if creep is a problem and 2) if so, what is the magnitude of the problem?

Comment: Since the only certain means for radionuclides to reach the accessible biosphere is through groundwater flow, contaminant transport studies are of particular importance. We do not believe that ground water and transport studies are being given sufficient emphasis at the present time. We agree that there are major

uncertainties about release rates from the waste package as well as retardation in the host media, but we suggest that studies be completed to assess release from the repository assuming the worst case for the near field source term and upper and lower bound estimates for retardation. In order to complete these studies, credible values for the rock mass permeability must be obtained for members above and below the potential repository horizon.

Response: We agree. SNL has recently reorganized and augmented its performance assessment staff under the leadership of L. D. Tyler. These studies will be conducted beginning in FY 82.

Comment: We are of the opinion that it is essential that the criteria for design of a repository be clearly defined. These criteria should incorporate a degree of conservatism that is clearly defined in terms of uncertainty in the description of the geologic environment. The criteria should be fully justified and the means by which they were obtained and the manner in which they are intended to be used should be completely described.

Response: The wording of this comment uses design criteria in a manner different from the traditional guidance to an A-E. However, we agree that a summary statement of the constraints on the repository performance, how the constraints are to be factored into the design, and the rationale for the constraints need to be developed quickly. The first draft of the constraints document is being reviewed now. The final document should be available in FY 83.

Comment: Excavations in the tuff exist both on the Nevada Test Site and elsewhere. We recommend that a survey of these excavations be conducted and that the performance of any excavation in materials similar to that which might occur on a tuff repository be determined. Data from this survey could provide direct evidence of the practicality of constructing a repository in tuff as well as providing a basis for using rock mass classification systems for designing excavations and determination of support requirements.

Response: The examination of tunnel systems in tuff should be done with the idea of gaining calibration data for the rock mass classification techniques that are used to examine constructability and support requirements in mines. This study will be initiated in FY 82.

Comment: Finally, we observe an emphasis on meeting major institutional milestones rather than upon meeting scientific and technical objectives. This is exemplified by the conflicting requirements for the exploratory shaft. It is essential that the overall objectives of the program and the proposed means of achieving them be clearly defined. Such a framework should provide a basis for integration of the many interrelated components of the NNWSI program. Groups such as MIDES (Mine Design Study Working Group) should be responsible for development and implementation of the program.

Response: There is no question that the different elements of the program need to be more integrated. The MIDES Working Group cannot be used for this purpose. That group has functioned as an advisory group for Sandia's geotechnical activities. It was not and could not be a Control Board. Since the peer review, that particular group has been disbanded. A performance assessment group has been formed as part of Technical Overview which will provide the integration of technical information. Also, a Technical Integration Group involving Technical Overview and the project participants has been formed which provides a means of communication between the different elements of the program.

Response to Specific Letters

Letter, St. John to Nelson, September 1981

Comment: Engineering Conservatism: A design is made conservative in order to allow for uncertainty in correctly predicting the actual system response. Several means of making a design conservative may be adopted; one being the choice of conservative design criteria. Whatever approach is used, the requirement for conservatism should be clearly related to the degree of uncertainty and the method of achieving conservatism should be defined.

Response: NNWSI engineering design will be accomplished in a conservative manner. A document describing how the philosophy will be implemented will be initiated in FY 82 and completed in FY 83.

Letter, Busch to St. John, September 1, 1981

Comment: Section 60.102(d) of 10 CFR 60 states, "A period of operations follows the issuance of a license by the Commission. The period of operations includes the time during which emplacement of waste occurs; and any subsequent period before permanent closure during which the emplaced wastes are retrievable..."

Section 60.131(h)(2) of 10 CFR 60 states, "Subsurface ventilation. The ventilation system shall be designed to - Permit continuous occupancy of all excavated areas during normal operations through the time of permanent closure."

One interpretation of the above, a seemingly unconscionably costly interpretation, is that subsurface ventilation shall permit continuous occupancy of excavated (and not yet backfilled) areas containing retrievably stored waste. Design consequences of the interpretation are that the subsurface ventilation either shall (at considerable operating cost) maintain the surfaces of all excavated (and not yet backfilled) areas containing retrievably stored waste below some safe temperature (say, 125 F), or shall promptly backfill all areas containing retrievably stored waste (thereby reducing operating costs but making retrievability very complex).

Response: We agree that the ventilation requirements in 10 CFR 60 are confusing at best and may be very restrictive. A clarification should be pursued by DOE/HQ with the NRC. In lieu of a resolution, the engineering is proceeding assuming that the capability to reenter abandoned areas must be maintained but that preparation time will be allowed.

Letter, Wyman to St. John, September 4, 1981

Comment: V. Ultimate repository design: All of the above are to lead to an ultimate design of a proposed repository facility. There are a few areas in which there appears to be no current work that I will mention in this regard:

- a) Backfill of drifts and rooms: A study of the need or lack of need, method of backfill, type and quantity and local sources of backfill materials.
- c) Mining Plan: The operating scheme should take into account the ultimate mining plan. Is mining of the repository to be done at one time, then left open until all canisters are placed 30 years later? Or is mining to proceed at a pace with the emplacement? If excavation is done by some type of mechanical miner, (no blasting) then the ventilation problem and operational scheme will be greatly simplified in concept.

Response: Repository mining, loading, and backfilling: These items are all under current study. They were mentioned at the peer review as topics which were being initiated but had no data available at that time. These studies will be complete in FY 83.

Comment: b) Sealing of faults and open structures: Regardless of the site selection process and detail of exploration it would be inconceivable that a site of 2,000 acres would not have any structural defects of a geologic nature. How to best handle these should be determined in advance and the fact that they will exist made known to any who may take on unrealistic view at a later date.

Response: Repository sealing is currently being studied and these topics will be considered along with shafts and boreholes.

Letter, Handin to St. John

Comment: (1) The hydrological data-base is inadequate, both regionally and locally at Yucca Mountain. I can't imagine how site-selection among the four potential horizons can be done without

knowledge of their groundwater-flow characteristics. Nor can credible far-field performance assessment proceed.

Response: We agree that the hydrological data-base may be inadequate at present. We will perform horizon selection in the required time frame by relying on bounding calculations and sensitivity analyses using that data which is available.

Comment: (2) I am dismayed that so little progress has been made toward the design of a workable waste package. There is no way that the conceptual design exposed to us can meet the NRC criterion. I recognize that this is an NWTs-wide, rather than a local responsibility, but I submit that any effective engineered barrier in the very-near field must be medium-specific.

Response: We agree that design of a tuff-specific waste package must proceed immediately. However, there was a point of confusion at the peer review which apparently still persists. The waste package thermal calculations were presented for a package which is, in effect, a thermal mock-up of a real package. The package described was not intended to be a real conceptual design.

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

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 R.F. _____
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March 5, 1982

Dear Mitch,

Our comments in response to the peer review written summaries are divided into two areas: (1) integration and program directions, and (2) specific comments on technical reviews of the LANL program.

We were most impressed by the quality of peer review comments at the review session. There clearly was major interest in the scientific aspects of the program. We welcomed the scientific expertise of the review committee and their persistence in directing questions about specific technical issues to program scientists. Their comments, both pro and con, provide a valuable external perspective of the progress of the NNWSI program. Our only concern is that the reviews are not scheduled in such a way as to have a useful planning impact on the program. That is, activities and budgets are so firmly implanted by the time of the review that LANL, and we suspect other organizations, have little freedom in readjusting priorities to respond quickly to valid technical comments.

Integration and Program Directions

We view with grave concern the numerous comments concerning the technical integration and uniformity of program directions. We are hopeful the efforts made since the review to improve integration will be successful. These include development of the TIG committee and the formation of cross-organizational working groups such as the committee developing the Test Plan for the Exploratory Shaft.

March 5, 1982

We have cooperative programs underway with the USGS in exploration of the unsaturated zone. Our February memorandum (TWS-CNC7-2/82-4) to the program was written in an attempt to achieve increased integration in core characterization and media studies by establishing a Stratigraphy Working Group composed of all participants working directly with drill core and drill hole data.

With respect to overall program directions, it is imperative that NNWSI funding respond directly to the technical priorities of site investigations. This requires first, establishing those priorities and second, seeing that those priorities are reflected in the funding spread. The peer review comments provide an excellent perspective for establishing those priorities. In our opinion, the most critical technical items now facing the program and those emphasized by the peer review panel include:

- 1) Geological and geophysical investigations of the Yucca Mountain area (Do we have a site?).
- 2) Hydrological Studies (What are the local and regional groundwater pathways and flow rates?).
- 3) What are the mechanisms and rates of transport of waste elements in tuff of Yucca Mountain? (How effectively does the site isolate waste?).

Within these broad problems immediate needs are horizon selection, the exploratory shaft, and studies of the unsaturated zone. Clearly, numerous other topics are important, but the first priority should cover these major topics.

Technical Reviews of the LANL Program

We are very pleased overall by the favorable reviews of our programs. We agree with the need for establishing priorities in the geochemistry programs and our efforts are becoming increasingly focused as we work toward the overall goal of determining rates and mechanisms of waste element transport. Indeed, the Site Characterization Report (SCR) will strongly emphasize this focus. Sensitivity studies of geochemical migration processes are being conducted through our modeling work. As the detailed transport models are developed, we are refining our program to identify areas of

March 5, 1982

adequate and inadequate data. However, we can focus these studies only at the pace dictated by progress in choosing a specific repository horizon and identifying the local transport pathways and processes. We intend for data development and model development to be an iterative processes--each side contributes to continued refinement of the other. We are working directly with the USGS and others in attempts to collect groundwater samples from individual tuff units. Much of the work in groundwater dating is being conducted by the USGS. We are concerned with developing and applying state-of-the-art techniques for dating of waters. With respect to reducing conditions of waters, we have long recognized the importance of this factor and have ongoing work to investigate this concern. We strongly agree with the need for field migration experiments. Such experiments are critical for validating in situ rates of element migration and as a means of verifying laboratory data and the results of modeling studies. Such comments from the peer review committee help us in obtaining proper funding and recognition of these field projects. The NNWSI currently has the only field testing program for waste element transport in the U.S. We were greatly pleased that the peer reviewers felt that the geochemistry effort was in good shape.

We have been concerned with the presence of pyrite (as well as other metallic sulfides in small amounts) in some units of tuff. The occurrence and abundance of these hydrothermal mineralization phases are described in the published drill hole characterization reports. Review comments on the need for imposing a temperature gradient in migration experiments are most useful. We anticipate near-field solution and lateral reprecipitation of some mineral phases that could cause lateral changes in permeability. Future experiments are being designed to examine this concern. We were particularly pleased to see that the peer review panel endorsed our long held and yet not widely received views on the need for mineralogical characterization of tuff. As mentioned earlier, we have recommended to the program (NNWSI) that technical integration of core characterization data, drill hole logs, and media studies can be achieved through development of lithologic and stratigraphic fence diagrams. The comments on integrating the petrologic data with the drilling and drill hole

March 5, 1982

logging studies are most valid--we are working with the USGS to see that this takes place. It will be a critical aspect of developing the stratigraphic fence diagram. We appreciate the peer review support of our concerns with respect to dehydration and stability reactions of secondary phases, particularly clays and zeolites. Assuming reasonable waste loadings (moderate temperature rise) these changes should not adversely affect repository performance. However, dehydration effects may be particularly important in aspects of near-field rock response and water pathways. We are also working toward understanding the past history of alteration of tuff and groundwater movement in Yucca Mountain through detailed clay and zeolite studies. Such studies are necessary to understand the lateral variability of tuff in Yucca Mountain and to forecast future alteration processes, a listed requirement of 10CFR60.

Other Considerations

We agree with the suggested emphasis on the unsaturated zone. It is perhaps premature to focus directly on the Topopah Springs Member due to the high fracture permeability and multiple episodes of calcite and zeolite formation. This is highly suggestive of the past presence of perched water. However, the scientific evidence in support of repository siting in the unsaturated zone is very strong and this should be a program priority. We also agree and stress the importance of inclined drilling to explore and characterize the distribution of fractures in both the saturated and unsaturated zones. We strongly agree with integration of core studies but mildly disagree with the need for a formal committee concerned with the handling, distributing, and cataloging of core. Current policy based on established USGS core library requirements and QA procedures appears adequate.

Sincerely yours,

Bruce R. Erdal

BRE:lm

Attach. a/s

xc: D. C. Hoffman, CNC-DO, MS-760
D. T. Oakley, NP-WM, MS-671
R. C. Lincoln, SNL, Org. 4538

TWS File
BRE File
CRM0(2)

RESPONSE OF TECHNICAL OVERVIEW CONTRACTOR

Sandia National Laboratories

Albuquerque, New Mexico 87185

September 13, 1983

D. L. Vieth, Director
Waste Management Project Office
U.S. Department of Energy
Nevada Operations Office
P.O. Box 14100
Las Vegas, Nevada 89114

Subject: TOC Response to the August 1981 NNWSI Peer Review

Dear Don:

The Technical Overview response to the 1981 Peer Review is enclosed.
The Environmental comments were written by S. G. Bertram and the summary
and comments for the Geological/Hydrological/Geophysical/Geochemical
topics were written by S. Sinnock.

Sincerely,

Thomas O. Hunter, Manager
NNWSI Projects Department 6310

SGBertram:dss

Enclosure

Copy to:

6300 R. W. Lynch
6310 T. O. Hunter
6312 S. Sinnock
6314 S. G. Bertram
6314 File

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COVER LETTER FROM EPRG

Achieving NEPA compliance requires a comprehensive approach that is not reflected in the current work breakdown structure as we understand it. You have our strong support in preparing a program plan that identifies all environmental data requirements and methodologies basic to the necessary NEPA documentation. Without an adequate checklist, data gaps and inconsistencies will become apparent too late to provide the high quality environmental assessment that Sandia and DOE/NVO are capable of presenting to ONI and DOE/Washington.

Response: The three reviewers misunderstood the purpose of the first year's environmental work. The objective of the work was to survey and summarize the existing literature that could provide environmental information. The purpose of the literature survey was three-fold: 1) to characterize the environment of the screening area and vicinity; 2) to support the Area-to-Location Screening; and 3) to identify data gaps and inadequacies in the literature in order to determine the environmental data requirements of the selected location, i.e., to provide a basis for development of a program plan.

ENVIRONMENTAL STUDIES PEER REVIEW COMMENTS

by

Helen F. Gram, Los Alamos Technical Associates, Inc.
Preston H. Hunter, Ford, Bacon and Davis
Robert F. Kaufmann, Converse Ward Davis Dixon

October 1981

1.0 GENERAL IMPRESSIONS AND OBSERVATIONS

1.1 Communication

Prior to the peer review, the Environmental Peer Review Group (EPRG) received essentially no information concerning the (1) nature of the NNWSI environmental program or (2) the relationship of NNWSI to the national program. These two reference points were particularly important because this was the first environmental review.

Response: The EPRG was contracted too late for preliminary information to be provided. Unfortunately, the Peer Review took place prior to the completion of the literature survey reports so that written material was unavailable. However, the EPRG was apprised of the nature of the NNWSI environmental program.

Reviewers, researchers and management alike need to know the purpose and objectives of the NNWSI and the NWTs program since the primary purpose of environmental studies is to meet NEPA, EPA, and NRC requirements, regardless of how the program is structured to accomplish the multiplicity of tasks. The artificial division between geologic/hydrologic studies and environmental studies and the limited scope of the environmental program contributed to the difficulty of assessing the adequacy of methodology and results to provide the necessary information for environmental assessments and comparison of repository sites.

Response: The purpose and objectives of the program were presented. The scope of the work during this first year was limited by the DOE Statement of Position in the Confidence Rulemaking to a literature survey characterization of the screening area. The year's work was not to be used for environmental assessments or for comparison of repository sites, but rather to contribute to NNWSI screening from area to location in order to select that site which would later be compared to others on the basis of site-specific field data not yet collected.

1.2 Technical Interface

The separation of EPRG from other review groups hindered the flow of information between the various investigators and, consequently, the comprehensiveness of the review. From the studies to date, we sense that the environmental assessment has been equated to an ecological/socioeconomic assessment. Beyond this, the data base must be adequate to support a radiological and a nonradiological assessment of project effects and waste releases on the population at risk (including workers). Since one purpose of the studies is to compare sites, the methodologies and assumptions upon which comparisons are based must be clearly documented and consistent if the NWTs program is to be credible to a concerned public.

Response: The EPRG opted for 15-minute introductions to the nine literature surveys. The topics were: background radiation; meteorology and air quality; energy and minerals resources; water resources; paleontology; cultural resources; biology; and socioeconomics. The review approach chosen by the EPRG obscured the project planning phase status.

The difficulty experienced by the EPRG in understanding the regulatory and policy constraints associated with siting, constructing, and operating a high-level waste repository suggest that planning documents are not sufficiently developed to adequately detail data and interface requirements. Planning tools such as data flow charts and compliance time tables, with the scope and purpose of data collection specified, are needed to facilitate effective project management and review. For example, the site characterization report (SCR) is an important document in obtaining the operating license for a repository. The data requirements for the SCR and preliminary, subsequent NEPA documents will overlap and data bases should be the same. The NNWSI project charts should clearly show the flow of information from SCR to DEIS's.

Improved program management may be most important at the NWTs level where site-specific considerations will be accommodated within the national waste management program. Of paramount importance is the necessity to adopt a uniform methodology at the national program level for performance assessment and dose commitment calculations. Since both of these exercises are highly dependent on the methodology and investigator, a common approach is necessary if comparisons between the environmental assessments for the different repository media are to be valid. Where possible, methodologies for radiological and nonradiological assessments should also be consistent for common releases of radionuclides and toxic/hazardous chemicals.

1.3 Program Scope and Competency

Individual presentations by SNL staff and subcontractors were well prepared and presented, reflecting overall competency of the principal investigators. However, the environmental program lacks breadth and understanding of the interrelationships among the study areas and the NEPA assessment requirements for the NNWSI and NWTs program as a whole.

Response: The environmental program breadth was prescribed by DOE in the Confidence Rulemaking for the area study phase.

The primary criteria for assessing adequacy of the environmental studies include a site characterization (with and without repository) and the technical basis and justification for licensing. Any effort beyond these primary goals is excessive. The environmental program needs to focus its scope on the repository, not merely the exploratory shaft. Consequently, potential problem areas, i.e., endangered species, should be identified and resolution strategies should be developed immediately.

Response: The literature surveys identified those topics for which field data would be required, e.g., the biologic species for which searches must be conducted.

The apparent overlap of tasks, particularly in the hydrology area, may not be as advisable and as cost effective as consolidating tasks and accelerating delivery schedules. It is suggested that principal investigators develop a better understanding of how their studies are to be utilized by other investigators to reduce the problem of integrating the multiplicity of data. For example, placing the responsibility for performance assessment and model development with a single project manager would focus tasks on the purpose of certain investigations. One of the most important aspects of developing the performance assessment model is establishing a strong data base and empirical relationships that are critical to understanding the repository regime and predicting repository performance.

Two other observations are made regarding the current NNWSI program plan. 1) For a project as important as a high-level waste repository, there may be significant benefits from sinking more than one exploratory shaft to obtain a clear understanding of the regional subsurface regime. 2) Locating a disposal facility at shallower depths above the water table may be cost effective, particularly for transuranic waste management. Siting a transuranic waste disposal facility near a deep geologic facility could have a favorable impact on the cost, size, and design of a deep geologic repository.

2.0 PROGRAM MANAGEMENT ISSUES

2.1 NEPA Constraints

The National Environmental Policy Act (NEPA) requires an integrated, multidisciplinary approach to assessment of effects significantly affecting the quality of the human environment. In order to bound the repository assessment process and achieve the necessary degree of NWTs and NNWSI program compatibility, there is an obvious need to identify common methodology and data requirements. Although it may be necessary for program management and site characterization reasons to separate geohydrologic and engineering studies from other environmental studies, each area is part of the environmental

assessment whole required by the NEPA process. Data collected for reasons other than identifying environmental impacts are not required for NEPA compliance.

Public participation in the environmental assessment process is required by NEPA. With the issuing of the FONSI for the exploratory shaft, the public may perceive that they are being excluded from the NEPA process for the repository. To promote a working relationship with public interest groups, mechanisms for communicating with the public should be in place and utilized at this time. The efforts to date are commendable but more is needed.

2.2 NRC Constraints

The NRC waste repository criteria (10 CFR 60) have at least three requirements that could impact the NNWSI. The environmental significance of these criteria, discussed below, needs to be factored into the NNWSI program.

- (1) NRC criteria favor use of saturated zones. Unsaturated zones present significant technical problems to assess transport, although such zones are abundantly present at NTS. Furthermore, waste disposal in unsaturated tuff over Paleozoic carbonates is analogous to the situation at the Idaho National Engineering Laboratory (INEL) where there have been political repercussions for defense waste management.
- (2) The requirement of a minimum period of 1000 years for water flow from the waste source to the biosphere appears to be arbitrary. The evidence of a flow period of say 900 years, for example, should not rule out the selection of a site that has other favorable characteristics. The criteria must recognize the degree of uncertainty inherent in such calculations.
- (3) The requirement for a canister with a 1000-year integrity also appears to be unrealistic to accomplish the engineered containment recognized as adequate for minimizing the risk of radionuclide exposure. Not only are arbitrarily selected time periods impossible to monitor, but they also defeat the purpose of the multiple barrier approach to waste isolation. Emphasizing engineered containment is impractical because it provides the best protection during the period when a repository breach is least likely. Because repository site characteristics and waste packaging factors work together to achieve waste isolation, development and reliance on a 1000-year integrity container is unwarranted and may also impose significant schedule delays on the program.

2.3 Deliverables/Content/Scheduling Problems.

The EPRG feels that the NNWSI project and the NWTs program could benefit from third-party management. Acting as an extension of the DOE/NV management staff, a systems engineering management team is recommended to improve program integration and to get and keep the program on schedule and obtain a license. The team's responsibility would be to review specific technical roles and appropriate scopes of work for each laboratory/agency and then also monitor

the work activities and deliverables to enhance timely program accomplishments. The coordinator role should be especially effective because the team consultant would lack proprietary interest in specific program areas.

3.0 INTERFACE ISSUES

3.1 NNWSI/NWTS Program Coordination

The EPRG is concerned that: (1) The need for site-specific geochemical and geohydrologic studies may not be fully appreciated at the national program level; however, study scopes should not go beyond requirements for model validation. (2) Guidance in methodology selection for calculating dose commitments and health effects and developing performance assessment scenarios is apparently lacking. Comparison of assessments for the different media cannot be valid unless a common approach is used.

3.2 LANL/SNL/LLNL/USGS Integration

The national laboratories and the USGS have very competent researchers conducting thorough site characterizations. However, there appears to be a lack of information transfer between these groups which promotes duplication of effort. The need for greater coordination, for example, was particularly apparent in comparing the environmental program's biology and water use/availability studies with the hydrologic studies being conducted for site characterization. Overlapping scopes of work may hinder achieving current milestones.

Response: There is no overlap between biology and hydrology.

3.3 Performance Assessment

Performance assessment is the task wherein site geohydrologic data and models and data from the other environmental studies are used to assess the effects of waste releases. Therefore, performance assessment studies are relevant to the environmental review. In-depth appreciation of the dependencies that exist among the probabilistic/quantitative knowledge of the geology system, site hydrology and transport of fluid and solutes, and work being done in the area of radiological assessment is not reflected in the present performance assessment program. While EPRG expects that these data will be factored into future evaluations, it is our impression that data requirements may not yet be clearly defined. It also appears that the performance assessment results may not be available when needed in FY 83.

The issue of model availability and compatibility affects credibility of the performance assessment. If NWTS certified models (coupled or independent) are to be used for all sites for both near and far field effects and USGS modeling

work is not certified or documented in time for the DSCR, what model(s) will be used for performance assessment? In order to develop modeling compatibility between USGS, SNL, and DOE (NWTs), much improved coordination and realistic scheduling is required. Issues of whether simple or layered models will be used and whether USGS site specific or NWTs generic models are applicable also affect the assessment of waste disposal. These issues should be resolved in the near future to avoid delays and duplication of effort, and most importantly, to reflect DOE's competency in nuclear waste management.

We endorse the segregation of consequence and risk analysis results since significant information is lost when only the product of consequence and probability is discussed.

3.4 Other Federal Program Relationships

Other major projects such as the MX missile project may have a significant impact on the State of Nevada. Such projects can have a direct and indirect impact on the NNWSI program that should be considered in program planning and scenario development for assessing socioeconomic effects in particular. Indirectly, an MX-type project could affect the NNWSI assessment of water resources, area biology, sociology, demography, and economics.

4.0 ENVIRONMENTAL STUDIES

The investigations appear to have been well conducted in terms of staff competency and productivity. A considerable amount of data was assembled and reviewed with the goal being to describe the existing environment and, to a lesser extent, the expected impacts from exploratory shaft construction.

Response: The first year's work was not intended to assess the impacts of the exploratory shaft. The goal was to provide the Environmental Area Characterization Report (EACR) required in the DOE position on the Confidence Rulemaking.

Overall, we sense that the NNWSI position on environmental studies is characterized by a relatively small amount of money allocated for specific projects generated from some "good ideas," with the work to be done by locally based researchers from the University of Nevada System.

Response: The studies were based on requirements identified in ONWI-61, Plan for the Preparation of an Environmental Report for a Geologic Repository, September 1979. Four of the nine studies were conducted by researchers outside the University of Nevada System.

The use of locally based researchers was probably a good, cost-effective approach and certainly enhances the public image. However, the question remains as to whether environmental aspects of the NNWSI program constitute a

substantive first step in an integrated environmental product, or whether it more closely resembles a dissociated collection of basically credible reports surrounded by unknowns as to what comes next and when.

Response: The purposes of the reports were to compile information for the required EACR, to provide input to the Area-to-Location Screening Study, and to provide a basis for planning the environmental program for the location selected. The studies were designed to identify the "unknowns."

EPRG felt that study findings were used to good advantage in the area screening analysis. Noticeable shortcomings of the studies include a paucity of specific, prioritized recommendations focused on environmental program objectives. Additional broad research programs are suggested as a result of hydrology work to date whereas undue caution is advanced as a result of endangered plant and animal species identification. The environmental program needs to respond to genuine voids (e.g., meteorology and selection of radiological assessment methodologies) and information exchange (e.g., hydrology). Factoring in of public comments will become increasingly important as the program proceeds to the TEF stage.

EPRG views with considerable concern the potential that certain plants or animals, or archaeological resources may retard or stop progress on a waste facility. Early on, the environmental program scope should encompass at least planning for mitigative action without any compromising of the repository. Problems should be resolved or critical habitats and resources identified and consciously committed, if necessary, to this extremely high national need -- HLW disposal.

Reviewers' comments relative to the completed or additional work in the eight environmental study areas and the area of public participation follow.

Biology

The established floral and faunal baseline appears adequate. The potential for "sensitive" species being reclassified as "endangered" or "threatened" warrants low-key interest with an emphasis on developing mitigative actions and resolutions.

Response: The information compiled for the NTS is extensive, but there was no baseline for Yucca Mountain as of the date of this peer review.

Cultural Resources

Site specific archaeological surveys in proposed drilling or other operating areas is warranted as construction begins. The surveys of mining activities partly duplicates the energy/mineral resources and water use/hydrology scopes of work. No further investigation appears to be warranted except for developing a realistic resource preservation plan for the impacted sites.

Response: The required BLM Class III survey conducted in 1982 disclosed over 70 potentially significant archaeological sites.

Paleontology

EPRG questions whether sufficient basis exists for this study considering the known geology and fossil resources of the NTS and surrounding region. No further work is warranted.

Response: The researcher overlooked the fossil pack-rat middens on Yucca Mountain. Revision of the report to incorporate locations and descriptions of these is warranted.

Meteorology and Air Quality

A sufficient data base for air quality modeling is nonexistent. Background air quality data (exclusive of environmental radionuclide monitoring) is similarly absent. Additional data collection for the EACR, EA, and DSCR is necessary; performance assessment that considers the airborne pathway will require considerable new data for the TEF and repository sites and the meteorological data should be based on at least a one-year sampling period. The NRC requirements for reactors developed in the aftermath of the Three Mile Island release (Reg. Guides 0700 and 0654) could also be required for a repository. Consequently, a reliable air dispersion model for the repository site, that will be used for both radiological and nonradiological assessments, is imperative.

Response: No additional data is required for the EACR. Additional information for the site selection EIS is needed and planned for.

Onsite and Offsite Background Radiation

Site data is sufficient. No additional data collection or interpretation is warranted.

Response: No data exists for Yucca Mountain.

Socioeconomics and Sociology

Potentially significant indirect impacts of a repository on nearby communities and the Amargosa Desert warrant additional evaluation. Provision of adequate public services and water supplies are key issues. However, complex sociological modeling is not warranted for these areas. Attitudinal surveys may be useful to assess public concerns about siting a repository at the NTS. Modeling of concurrent MX-type projects and repository impacts is recommended for the southern Nevada region.

Water Use and Hydrology

Numerous water-related issues were raised which the EPRG considers are more properly related to the technical basis for siting, design, and operation of the repository. Additional work should relate to water rights matters. Sig-

nificant environmental questions to be resolved include the source of water needed for construction, the effect of water rights on NTS water use, and the impacts of withdrawal on the principal aquifers, with or without further Ash Meadows water development.

Energy and Mineral Resources

No additional off-site evaluations are warranted. On-site work should be limited to the Yucca Mountain ES shaft location and to precious mineral assays in particular.

Response: On-site work should include the entire repository operation area.

Public Interaction

NEPA's public involvement requirement strongly suggests that SNL and DOE look beyond the exploratory shaft and concentrate on obtaining public comment for the DSCR which is due in early FY 83. The EPRG is impressed with DOE's waste related public relations program at NVO and particularly the efforts of Robert Nelson. However, the SNL recommendation (via ADM) that an EA is sufficient for the exploratory shaft and that a FONSI would result appears to be presumptuous. The rationale that since this is just another shaft there is no public controversy should be based on opinion polls and public involvement. The EPRG was somewhat surprised by the SNL and DOE staffs' reluctance to increase the public relations effort.

Response: Although SNL has advised that the public relations effort should be increased to provide two-way communication, public relations is not within the purview of SNL.

NEPA requires public participation in the scoping of alternatives and consideration of issues of public concern in the DEIS. The DOE/NV public information program should be expanded to enhance a two-way process for exchange of ideas and information. Ground rules should be established in advance for public participation in the decision-making process. Such communication between the public and DOE should begin as soon as the FONSI for the ES is released. A summary information and assessment document should be prepared which emphasizes that the purpose of developmental work conducted prior to scoping was to find solutions to engineering problems rather than decide conclusively the feasibility of an HLW repository. The document should outline the methodology used in assessing engineering problems, and describe how interested parties may participate in the assessment of short- and long-term effects.

5.0 CONCLUSIONS AND RECOMMENDATIONS

In this section, we have listed our most important conclusions regarding the NNWSI Program. Each conclusion is followed by a recommendation which EPRG

feels will be helpful in resolving the issue. The conclusions and recommendations are listed according to priority. The first four items are the most important and should receive primary consideration. The remainder are listed in order of their decreasing importance.

- o Integration of the environmental program with other NNWSI studies and coordination with NWTs programs is inadequate. A possible solution would be to provide overall coordination by a consultant team that lacks proprietary interest in specific program activities.
- o The adequacy of the NNWSI environmental investigations to meet NNWSI and NWTs schedules and regulatory requirements is difficult to assess. We recommend greater program emphasis on the specifics of obtaining a license on schedule.
- o Environmental studies that address air quality and meteorological monitoring, assessment of certain socioeconomic impacts, and the status of water rights are inadequate. We recommend an air quality monitoring program for nonradiological parameters, meteorological data collection appropriate for modeling ground-level pollutant transport in the area of the exploratory shaft, socioeconomic studies in unincorporated communities near the southwest corner of the NTS, and an attitudinal survey to assess public opinion about the repository.
- o There is need for a uniform methodology for calculating dose commitments and health effects as well as developing consistent assumptions for release scenarios. We recommend selection of a uniform approach to dose commitment and health effects calculations for the entire NWTs program so that release scenarios, dose commitments, and health effects can be compared among DOE documents.
- o While environmental studies appear appropriate for an exploratory shaft environmental assessment, studies will have to be expanded to be adequate for a TEF, ADTF, and a repository, as DOE and SNL are aware. We recommend that future studies be carefully prioritized and scoped to provide only data required for the decision process.
- o An assessment of direct and indirect environmental impacts of a repository constructed in conjunction with other major federal projects, such as an MX-type project, may become important if the NTS becomes a prime repository location. We recommend a cumulative assessment be conducted of any such project that may be developed at the same time as repository construction/operation.

Sandia National Laboratories

Albuquerque, New Mexico 87185

date: September 12, 1983

to: T. O. Hunter, 6310

from: S. Sinnock, 6312

subject: August 1981 Peer Review of NNWSI Geological/Hydrological/Geophysical/Geochemical Topics: TOC SUMMARY AND COMMENTS

REFERENCE DOCUMENT: Letter and Attachment from L. T. Larson to R. M. Nelson, Dated November 11, 1981

The attachment in the reference document calls attention to two perceived major deficiencies in the NNWSI: (1) a paucity of hydrological data and interpretations; and (2) a general lack of coordinated technical direction. Other minor comments by the Peer Review Panel address means for improving specific technical work elements. This report is restricted to considerations, current in late 1981 and early 1982, of the perceived major deficiencies and leaves the responses to suggestions about individual NNWSI work elements to individual principal investigators.

Hydrological Data Collection

The TOC agrees with the panel that hydrological data collection at the time of the Peer Review was inadequate when considered in relation to its importance for site selection and evaluation decisions. As of this writing, the general suggestion by the panel for an aggressive drilling program to obtain such data has been implemented. A suite of hydrologic test holes peripheral to the exploration block is currently being completed. This program is generally outlined in the USGS response to the Peer Review Panel (letter from G. L. Dixon to R. M. Nelson, dated January 26, 1982). In addition, a plan has been developed for testing hydrological properties of the unsaturated zone. We believe that the current and planned activities will go a long way toward alleviating the deficiencies in hydrological data noted by the panel.

Technical Coordination

In response to peer reviewers' comments about technical direction, an attempt to establish a more coordinated approach to technical activities was made. A Technical Integration Group (TIG) was

established with members representing each of the major technical contributors to the NNWSI. Group meetings were conducted under the direction of an independent "facilitator" and the chairmanship of TOC. In addition, the USGS has established a position solely responsible for coordinating the USGS activities in support of the NNWSI. Currently, W. W. Dudley is capably fulfilling the duties of this position.

However, despite the structure established for dialogue among program participants, a certain lack of program focus will remain until an agreed-upon concept of what a repository should be, should do, and should not do is firmly established. H. F. Morrison put the matter succinctly:

"--what has been lacking up till now has been a concept or a model of what a repository should be" (letter to R. M. Nelson dated October 2, 1981).

Many of the Peer Reviewers had a sense that some or much of the work being performed was unnecessary or irrelevant for repository siting. This problem is not unique to the NNWSI, but is shared throughout the NWTs. Until we know what is required, however, we do not know what is or is not relevant.

EPA has not officially issued any release standards. A proposed version of EPA standards indicates that cumulative releases of curies to the accessible environment should cause no more than 1000 additional "health effects," cumulative over 10,000 years (i.e., 0.1 cancer per year). The rationale and wisdom behind such unprecedented, strict performance limits are questionable, but they set the standard by which we must judge what a repository must be.

The NRC has provided four basic requirements designed to ensure compliance with the eventual EPA generally applicable standards: (1) a waste package that prohibits release of radionuclides for 300 to 1,000 years after repository closure; (2) a repository that limits release of radionuclides to an annual rate one part in 100,000 of the waste inventory at 1,000 years after repository closure; (3) preconstruction groundwater flow time from the repository to the accessible environment of 1,000 years; and (4) a capability for retrieval. The only relevant site information for establishing compliance with the 1,000 year flow time is hydrological. Rock water and rock chemistry will be useful for demonstrating 300 to 1,000 year containment and annual release rates. Thermal and mechanical properties of the rocks will help establish thermal and mechanical environments under which waste packages must survive and tunnel openings must be maintained for the required retrieval periods.

Proposed siting guidelines recently available from the DOE add no substantive requirements to those enumerated by the NRC except the

requirement for burial at depths of at least 200 meters. Thus, according to the current and proposed regulations, we conceivably need only a small number of parameters to demonstrate compliance with performance requirements. The issue is how much data is needed about the few required subjects to provide confidence in performance predictions.

However, numerous technically unsubstantiated claims for "needed data" or "unacceptable conditions" emerge from many scientific quarters including the Peer Review Panel. For example, P. Dominico states, "It is clear at this stage that irreversible dehydration (of zeolites) must be avoided." Such statements, to my knowledge, are not based on any analysis which indicates a mode of system failure due to the single condition addressed. As a consequence such "data criteria" do not help, and may even impede, establishing what a repository must or must not be. After more than a decade of scientific blandishments about the necessity of basic understanding of all possible processes (or its corollary, the disqualifying nature of certain conditions or complexities that defy analytical descriptions from first principles) an unspoken acceptance has emerged of many pseudo-criteria phrased in terms of specific parameters or site features, without demonstrations of their importance to system performance.

To quote Dominico again,

"A main difficulty from a hydrologic perspective, is that a potential repository horizon of sufficiently low permeability and adequate thickness has not been identified."

However, no help is given in establishing what is "sufficient" or "adequate", or even why thickness and low permeability are desirable traits.

Similar unsubstantiated "criteria" from the panel are:

"The characterization of a repository requires the spatial distribution of the different kinds of tuffs (welded, zeolitized, etc.) over distances large enough to make repository construction possible," and

"Characterization requires a knowledge of the spatial variations of the rock properties (porosity, permeability), mechanical strengths, and mineralogy" (Morrison).

Some of the "criteria" are phrased as suggestions:

"its (pyrite) presence might make this formation unsuitable for repository construction." (Krauskoff)

This listing of example "pseudo-criteria" is not meant to imply that they, indeed, are not legitimate criteria, but to point out that loosely tossing about requirements without establishing that such requirements are essential for satisfactory, overall repository performance exacerbates the difficult problem of setting research priorities. For each scientific discipline and sub-discipline, one can find in the waste management literature a number of criteria in the form of data requirements. The TOC has participated in generating lists of such requirements (e.g., DOE/NE-0007, DOE/TIC-11033 and the DOE siting guidelines). However, rarely are these requirements explicitly tied to overall system performance, except in the case of several of DOE's technical guidelines. Generally, enumerated data needs fall into a broad category which can be labeled as "obtaining adequate understanding." Somewhere in the daisy chain of espoused research needs, the explicit relationships between discipline-specific data needs and repository system performance get lost.

Thus, well-intentioned statements by the Peer Review Panel about data needs are, in combination with similar comments by myriad other review groups in and outside the NWTS and NNWSI, a prime source for the difficulty in setting research priorities. It seems that many technical individuals want to know "everything about something", and that, taken together, the need for satisfying everyone is to know "everything about everything". To resolve this dilemma, the TOC recommends that the use of words such as "needs," "must be," "requirements," etc., in the context of research for repository siting and development be abandoned unless the imperative denoted by the words can be demonstrated in terms of a failure mode for the total system performance. Additionally, a performance assessment and accompanying risk evaluation activity should set as a high priority the parametric consideration of the effects of various physical parameters and their variation on the performance of a repository at Yucca Mountain. The analyses should make use of current bounds for parameter values in simple, perhaps one-dimensional, calculations of groundwater flow, nuclide retardation, perhaps dispersion and others, if such others are seen to influence the results. From these calculations, the limits for parameter values required to satisfy release rates established by the EPA can be ascertained in a general way. By comparing these limits to current, reliable bounds, the project may ascertain where additional data are required.

Heretofore, data collection has been driven by scientific questions; hereafter, it needs to be driven by engineering questions. The time has come to firmly establish specific, clearly understandable performance objectives. Then, in the interest of fiscal responsibility, we need to streamline data collection to obtain the minimum data needed to establish conformance with the objectives. For each item of data pursued, the questions that should be answered before obtaining that data are,

"How will the data be used, analytically or subjectively, in evaluating performance?",

"What values for the data are expected?", and

"What values, if found, will result in unacceptable performance with respect to the performance objectives?".

Given that an engineering approach to data collection and management had not been fully adopted by the NNWSI at the time of the Peer Review, there was no firm set of objectives upon which to set research priorities. Now is the time to ascertain the degree of empirical certainty that already exists and to assess performance under these empirical limits. Then data collection can be targeted toward "needs" defined in terms of clear objectives for system components which are directly tied to system performance, rather than in terms of unsubstantiated claims arising from specialized research disciplines.

Historically, it is true, there has been a problem with technical direction in nuclear waste management. The problem will be solved only when technical participants, peer reviewers, and others restrain themselves to establishing the need for data in terms of total system performance. This, in turn, can only be done if "failure" criteria for individual system components are firmly tied to system failure rather than to subcomponent failure. In a repository with many interacting barriers to system failure, this will be an awesome parametric task, but it must be done if the NNWSI is to effectively target its technical investigations on real, rather than imagined, information needs. In summary, the burden of proof for a "need" for data should fall on demonstrating an effect that jeopardizes system performance, rather than as in the past, on demonstrating that the data will ameliorate some limited understanding of physical principles or processes.

The NNWSI is currently undergoing a metamorphosis toward a more engineering, objective oriented approach. The project has written a draft Site Characterization Report which attempts to enumerate the remaining data needs in terms of an "Issues Hierarchy" that ties individual investigative activities to program objectives. In addition, performance assessment and facility design activities are getting off the ground and will serve to focus questions about data needs toward topics which have the most influence on performance or design requirements. By working with the Peer Review Panel and other interested parties, the NNWSI should make significant strides during the next months and years toward refining its Issues Hierarchy and associated investigative tasks, thereby alleviating the national, historical deficiencies of waste management in the area of clear technical direction.

T. O. Hunter, 6310

September 12, 1983

SS:6312:dss

Copy to:
6300 R. W. Lynch
6312 S. Sinnock
6312 File

Sandia National Laboratories

Albuquerque, New Mexico 87185

D. L. Vieth, Director
U. S. Department of Energy
Nevada Operations Office
P. O. Box 14100
Las Vegas, Nevada 89114

Dear Don:

Subject: TOC Response to the August 1981 NNWSI Peer Review

Attached is the Technical Overview response for the
Geotechnical/Geoengineering aspects of the 1981 Peer Review.

Sincerely,

2/1/84

Thomas O. Hunter, Manager
NNWSI Projects Department 6310

JRT:mb

Copy to:
6300 R. W. Lynch
6310 T. O. Hunter
6313 J. R. Tillerson
6313 J. A. Fernandez
6330 J. T. Henderson (NNWSI CF)
6310 File 1.9.4.5

TECHNICAL OVERVIEW CONTRACTOR'S
RESPONSE TO THE COMMENTS OF THE PEER REVIEW
PANEL ON GEOTECHNICAL GEOENGINEERING ACTIVITIES
WITHIN THE NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS

The response provided here specifically addresses the summary comments given by the Peer Review Panel (St. John to R. W. Nelson, 9-30-81). Individual peer reviewer's comments as well as the summary comments can be divided into four major areas: rock mass properties, waste package and waste-package environment definition, performance assessment, and program definition. The majority of comments are directed towards obtaining a better understanding of rock mass properties. Many of the concerns expressed by the peer reviewers will be addressed by the testing associated with the exploratory shaft. The exploratory shaft test plan is currently under preparation and should be completed by February 1984 in draft form. Specific summary comments are addressed below.

Rock Mass Properties

Comments:

We are very concerned that the exploratory shaft may provide almost no information on the rock mass overlying the selected horizon for site investigation. If the shaft is drilled, every effort should be made to evaluate the rock mass remotely, by drilling from the shaft and through instrumentation of the shaft lining. Detailed plans of geotechnical investigation to be conducted from the exploratory shaft and from the "At

Depth Test Facility" are urgently required. The timing of institutional milestones should be reassessed if meeting them requires sacrifices in terms of loss of opportunities to obtain essential geotechnical data.

There are serious deficiencies in the information available on the fracturing of the host rock units within the area considered feasible for siting a repository in tuff. We believe that a great deal of valuable information could be obtained from the exploratory shaft but that this information will not be available if the shaft is drilled and lined before the rock mass can be inspected. The only practical alternative to logging in the shaft is to drill inclined holes from the surface. Drilling such inclined holes may be incompatible with a desire to minimize the number of boreholes at the potential site.

Response:

The exploratory shaft will be sunk using conventional drilling-blast-muck operation. Shaft-wall mapping, photography, hand-specimen sampling, and rock sampling will be repeatedly performed during the shaft sinking operation. Not only will rock mass overlying the selected horizon be characterized in this manner, but also the zone below the repository horizon. In addition, at least two breakouts will be constructed in the ES. Detailed studies are planned in the upper breakout room to assess the mechanical properties of a zone containing a higher lithophysae content than the repository horizon and in the lower breakout workings that more nearly reflect the general repository horizon. Therefore, the concerns expressed by the peer reviewers will be addressed by the exploratory shaft testing.

Comment:

The time dependent effects upon thermal, mechanical and hydrogeologic properties of tuff are inadequately understood at the present time. Model studies can be used to define the repository environment more precisely and assist in definition of processes that could potentially impact repository performance. We are concerned that any testing that may be required to provide better material descriptions is long term and could therefore limit the rate of progress of the program. Accordingly, we recommend that immediate action be taken to determine time dependent effects that could be critical to repository performance.

Response:

Time-dependent effects on tuff properties are being addressed through a continuing laboratory analyses program administered by SNL. These tests concentrate upon strain rate effects as well as constant stress tests. Ongoing tests in G-tunnel on the NTS were specifically developed to resolve issues associated with using welded tuff for a host rock. These issues were summarized by a Mine Design Working Group composed of representatives from different groups involved with the NNWSI. The principal issues defined by this group were pore-water migration in the very-near field, emplacement hole stability, floor performance and room response resulting from thermal and mechanical loads. Creep concerns were not considered to be a principal issue.

Comment:

Evacuations in the tuff exist both on the Nevada Test Site and elsewhere. We recommend that a survey of these evacuations be conducted and that the performance of any excavation in materials similar to that which might occur on a tuff repository be determined. Data from this survey could provide direct evidence of the practicality of constructing a repository in tuff as well as providing a basis for using rock mass classification systems for designing excavations and determination of support requirements.

Response:

Most of the excavations on the NTS are in nonwelded tuff. The NNWSI has constructed drifts in the welded tuff to perform rock mechanics experiments. Those openings in welded tuff have formed the basis for rock mass classification systems and for finite element simulations that have compared the response predicted for openings in Yucca Mountain with the stable openings in G-tunnel. Further evaluation of the welded tuffs in G-tunnel is underway to compare the heated response predicted for waste emplacement holes in Yucca Mountain with the response observed in heater tests (even under more severe heat loading) conducted in G-tunnel.

Waste Package and Waste-Package Environment Definition

Comment:

The waste package must be clearly defined and must be compatible with the conditions peculiar to emplacement in tuff. We are convinced that it is impractical and undesirable to design a single waste for the NWTs program. The waste package - as well as backfill and excavation, borehole and shaft seals - should be media specific.

The waste package environment is strongly effected by water that will flow from the tuff and backfill in the emplacement hole towards the package. We recommend that additional water migration tests be conducted in the field. These should include use of candidate backfill materials descriptions of dehydration processes that occur.

Response:

Work is ongoing at LLNL to develop a waste canister which will be geochemically compatible with a tuffaceous environment. One of the objectives of the small-diameter heater experiments performed in G-tunnel by SNL has been to monitor the possible migration of water and/or vapor into the annulus around the heater. Additional information on water migration mechanisms will be available from the heated block experiment being conducted in G-tunnel. To further enhance the understanding of how the waste package will behave in a welded tuff, a waste-package test series is proposed for the exploratory shaft. It is the intent of the reduced-scale canister heater experiments to investigate the moisture condition in the host rock during the thermal and post-thermal periods and to determine the effects that moisture conditions have on the waste-package system. The planned test series should provide sufficient data to evaluate water migration mechanisms.

Performance Assessment

Comment:

Since the only certain means for radionuclides to reach the accessible biosphere is through groundwater flow, containment transport studies are of particular importance. We do not believe that ground water and transport studies are being given sufficient emphasis at the present time. We agree

that there are major uncertainties about release rates from the waste package as well as retardation in the host media, but we suggest that studies be completed to assess release from the repository assuming the worst case for the near field source term and upper and lower bound estimates for retardation. In order to complete these studies, credible values of the rock mass permeability must be obtained for members above and below the potential repository horizon.

Response:

Significant resources are now being devoted to performance assessment analyses. In addition, field tests from surface boreholes are being conducted at Yucca Mountain to quantify the permeability of the unsaturated zone. Rock mass permeability values will also be obtained through several exploratory shaft tests including bulk permeability tests of the Topopah Spring Member, infiltration tests, hydrogeologic testing of the Tuffaceous Beds of Calico Hills. Additionally, drift and pillar monitoring tests will assess the influence of mining on permeability of the rock mass. The environmental assessment document will synopsise much of the data collected and analyses conducted in this area.

Program Definition

Comment:

We are of the opinion that it is essential that the criteria for design of a repository be clearly defined. These criteria should incorporate a degree of conservatism that is clearly defined in terms to uncertainty in the description of the geologic environment. The criteria should be fully justified and the means by which they were obtained and the manner in which they are intended to be used should be completely described.

Response:

We concur with the comment made in the Lynch to Kunich letter dated, 2-3-82, that a summary document defining the constraints to be placed on a repository is necessary. A design guidelines document is currently under preparation by SNL which will define criteria and data for the A/E to use when designing the repository.

Comment:

Finally, we observe an emphasis on meeting major institutional milestones rather than upon meeting scientific and technical objectives. This is exemplified by the conflicting requirements for the exploratory shaft. It is essential that the overall objectives of the program and the proposed means of achieving them be clearly defined. Such a framework should provide a basis for integration of the many interrelated components of the NNWSI program. Groups such as MIDES (Mine Design Study Working Group) should be responsible for development and implementation of the program.

Response:

The overall guidance and schedule for the NWTS program is given in the Nuclear Waste Policy Act (January 1982). The DOE-NVO has acted to better integrate the NWTS and NNWSI program elements by recently hiring a management support contractor, Science Application Inc. Additionally, in the preparation of a draft site characterization report, issues were identified and technical requirements were defined to show how and in what time frame remaining issues will be addressed. These issues and the plans for their resolution are forming the basis for the NNWSI technical activities.

APPENDIX A: INDIVIDUAL PEER REVIEWER
CORRESPONDENCE ON THE GEOLOGICAL/
HYDROLOGICAL SESSION

STANFORD UNIVERSITY

STANFORD, CALIFORNIA 94305

DEPARTMENT OF GEOPHYSICS
School of Earth Sciences

10 Sept, 1981

Mr. Robert Nelson

Dear Bob:

Our group will have a unified report, of course, but I'd also like to get my comments directly to you, undiluted, on the so-called "management problem." I think it's a communication problem among widely separated laboratories, teams and individuals, each of whom is highly motivated. So here it is and I hope you won't think it too presumptuous.

Cordially,
George

George A. Thompson
421 Adobe Place
Palo Alto, California 94306

September 9, 1981

To: Peer Review Coordinators: Larry Larson (general), Frank Morrison (geology), Howard Ross (geophysics), Konnie Krauskopf (geochemistry), and Pat Domenico (hydrology)

From: George Thompson

Subject: Review of Nevada Nuclear Waste Storage Investigations,
August 24-28, 1981

GENERAL. The scientific, engineering and management talent associated with this project is a great national resource, composed of generally excellent and dedicated people. We are fortunate that many of them became involved in the studies several years ago, because it would be impossible to suddenly recruit such highly competent teams now that waste storage has reached a stage of purposeful urgency.

Yet we all recognized weaknesses in coordination and communication among individuals and groups and in some cases a failure to set realistic priorities. My suggestion for a vigorous attack on this problem is to add a small scientific-engineering team to top management, headed by a senior scientist thoroughly familiar with the project. Members of the team would act as expeditors, traveling when necessary between laboratories and working groups, spotting bottlenecks and having the resources and leverage to move things in the right direction. They would also serve as communication links, helping to air new findings even before reports are written.

The flexible format of this meeting served its purpose well. Providing a bibliography and selected reports to panel members throughout the year would allow them to serve more perceptively. One tends to saturate during an intensive week-long session.

GEOLOGY. The geologic work is admirable: well coordinated and well done. Work is now concentrating on details at Yucca Mt. where many troublesome questions need to be answered. One important goal should be the best possible definition of faults and fractures that may influence the hydrologic regime. This is not an easy task and ingenuity will be taxed. A second important goal, also difficult, is mapping out in three dimensions the stratigraphy and lithologic facies. We did not see coordinated sections relating the stratigraphy, well logs, petrography, engineering tests and other measurements. Viewing these data together is necessary for defining the strategy of further measurements and investigations. Finally the Tonopah Spring Member, as a prime candidate for storage above the water table, demands more emphasis. What is the character, spacing and extent of fractures? Of lithophysal zones? Much critically important information may come from the shaft boring. How can it be logged and studied?

GEOPHYSICS. As the gravity and refraction seismology indicate a basement relief of about 10,000 feet beneath the volcanics these data should be carefully coordinated and interpreted. I would also recommend further recording of earthquakes and nuclear tests on the multichannel portable instruments with this bedrock problem in mind. Is the relief confined to caldera walls? Or additionally, faults? Is the bedrock plutonic? Argillite? Carbonate? Answers to the lithology may not be forthcoming but it's worth a try. The geophysics on a crustal scale should be drawn together and quantitative and consistent alternative interpretations proposed. Data are available on crustal layering, on teleseismic time delays, on delays from local sources, and on regional gravity and magnetics, as well as on geology.

The studies of earthquakes and of quaternary faulting should be analyzed in terms of seismic risk to a repository. Satisfying requirements of the NRC should be a goal of the analysis.

The aeromagnetic map, already useful for qualitative geologic correlation, should be subjected to geometric and physical property modeling, followed by another iteration of geologic interpretation in conjunction with all available measurements of rock magnetization.

Seismic reflection work has the potential for highest-resolution detection of small faults and other structures, perhaps even of lithologic facies. Although difficult and expensive in the geologic environment of the Test Site, the reflection method needs to be definitively tried. Vertical seismic profiling using the best methods and equipment (no compromises) should be extended and geologically interpreted. Further steps should be based upon these results.

Inasmuch as we did not have a comprehensive review of electrical work, I have a limited basis for recommendations, with one exception. Electrical well logging must have a high priority. If it is found that there are important correlations of conductivity with lithology and porosity, then further strategic experiments may be planned.

In situ stress measurements can be valuable both for analysis of seismic risk and for engineering purposes. I recommend that the excellent capabilities of the USGS be utilized for in-hole measurements.

The value of heat flow measurements for hydrologic applications was clearly demonstrated and I recommend that they be continued.

GEOCHEMISTRY. Konrad's summary included my observations and stated the priorities very clearly.

HYDROLOGY. Like everyone else, I recognized hydrology as a central, overriding question regarding the suitability of the site for a repository. Yet on the scale of Yucca Mountain very little is known. The unsaturated zone and the definition of hydrologic units, for example, need intensive studies. Pat stated the case very well and I agree.

George A. Thompson
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Stanford University
Stanford, CA 94305

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RENO, NEVADA 89557

9/10/81

Department of Geological Sciences

Mr. Robert M. Nelson
U.S. Dept. of Energy
P.O. Box 14100
Las Vegas, NV.
89114

Dear Bob:

Enclosed are my individual observations relating to last month's peer review. These will, in part, be included with the overall Geology-Geophysics-Hydrology-Geochemistry report.

I'm afraid I got pretty wordy throughout. I am sending you a copy of mine because I suspect that what I have to say in the Summary and Speculation part (pages 9-12) may well not be included in the overall report since they are rather rank speculation. NOT even sure why I wrote them but guess it is because that's the way I feel. Unless you have good reason to make use of this section in the report that will be published, perhaps it would be better to leave it out.

As always, I enjoyed the session and am looking forward to the next time I will be able to look at the progress of the program.

Sincerely,

L.T. Larson

September 8, 1981
340 Sparrow Way
Carson City, Nevada 89701

Mr. Robert M. Nelson
U. S. Department of Energy
P.O. Box 14100
Las Vegas, Nevada 89114

Dear Mr. Nelson:

The following discussion is directed at those aspects of the NNWSI presented to the Peer Review Panel on August 24-28, 1981. The Peer Reviewers, at the suggestion of Mr. Wm. Twenhofel, have agreed to adopt the format of three group reports: Environmental, Geologic Engineering - Rock Mechanics, and Geology - Geophysics - Hydrology - Geochemistry. General consensus opinions were expressed by each group on August 28 and the written report from the Geology - Geophysics - Hydrology - Geochemistry group (GGHG) of which I am a member will be forwarded when collected and synthesized--not later than October 17, 1981. What is included in this report are my individual observations--most of which are repetitions of the Group report.

Organizational-Meeting Format

I believe the organization of this past meeting to be superior to any prior meeting. The approach of presenting documentation of the overall program and the progress of its numerous aspects during days 1 and 2 and the selection by the Committee of aspects for which they had need for detail on during days 3 and 4 with Committee presentation of views and commentary on day 4 was efficient, effective, and for all involved a great deal of work. Presentations allowed the Committee to select those aspects of the program which appeared to them to be both superior and "in trouble" or lagging. Days 3 and 4 allowed the probing of these areas with the P.I. and team leaders. I cannot, at this time, suggest any superior approach although

the amount of material provided for the digestion of the Reviewers in a short span of time was truly formidable. About my only recommendation in this regard is that a continuing and, if possible, improved effort be made to get essential reports published in the time span between meetings to the reviewers some weeks or at least days before the review period.

Overview Remarks

I am impressed by the overall quality of the science presented. Perhaps because it is my field I found the geologic and mineralogic studies particularly well done. I am concerned, however, about relevancy and co-ordination and/or integration--both internally and with existing information. A couple of examples: I am confident that Tom Newton's (LANL) work on the physical chemistry of Plutonium is good science but, a) is it at all site or media specific? and, b) does it have a clear completion date because I have the distinct feeling such research could, if taken to completion, go on to year 2000. It's a very complex subject and how much must be known for site selection purposes? Also, the mineralogic-alteration research (Wolfsberg, Runberg, Sykes, et. al.) experiments whether batch or column testing or whatever does not appear to have been done under simulation of a temperature gradient foreseeable in an actual repository. While their research clearly shows clinoptilite and other zeolite alteration, does it give any clear idea of what may progressively happen lateral to a canister down a heat gradient logical to occur under TEF or repository conditions? His statement (Wolfsberg?) that he believes 1 or 2 meters of zeolitized tuff would sorb any released radionuclides needs assistance or clarification. Finally, on the matter of co-ordination and integration we were told that there exists a wealth of geologic, rock property, logging and geophysical information within the Weapons Testing program on Pahute Mesa and elsewhere. Has a serious effort been directed toward the use of this data to help site characterize Yucca Mountain? The direct transfer of information may not be possible but surely some of the data can be of use.

Perhaps most importantly, I left the meeting with the distinct impression that, figuratively speaking, the left hand does not understand and/or appreciate what the right hand is doing. The program management must find some way to improve individual, discipline and laboratory information transfer. The formation of PERK, progress or responsibility charts, while necessary, is

not sufficient. I suspect it is natural and expectable for mineralogists not to be excited about hydrology or for hydrologists, while fascinated by water table levels and permeabilities, to be less so for sorbability or mineralogic alterations but someone (or ones) must put these diverse research packages together in order to truly characterize potential repository sites and zones. I do not sense that this has adequately been performed and each P.I. or Laboratory is approaching the overall problem from a parochial view. Although I am sure it is not the case, I at times get the impression that the only time P.I.'s exchange views, problems or successes is at annual peer reviews. Even then the various Laboratories and the Geological Survey components apparently do not cross-fertilize a great deal. I was dismayed when during the geochemistry presentations on the 3rd day a question was asked the audience requesting Sandia input (rock properties I believe) and no one was there--for that matter, as I recall, only Frank Byers and Will Carr of the G.S. were representing that component--everyone else in the room was LANL. Could it be that a significant part of this problem is that few if any of the investigators--geologic, mineralogic, hydrologic, geophysics, geochemical or whatever--actually work and live in Las Vegas and environs near the potential site and thus are both geographically and mentally (from a working with others view) divorced from the overall goal and find sound and comfortable scientific shelter in their specific pieces of the puzzle?

Although I take no pleasure in committees and wonder if the Yucca Mountain site is not already an elephant (elephant = camel designed by a committee), I suggest that consideration be given (it may exist and I don't know of it) to regular meetings of liaison and major P.I.'s--preferably at or near the project site--to thresh out problems of integration and common goals, needs and problems. I also recommend that when new PERK charts are constructed that such individuals be present and capable of "defending" the relevancy, timeliness and degree to which the specific products of projects are focussed on overall site selection/characterization needs. If a particular project/product is found to have little input within a time frame of need to other projects it should be at least a candidate for discontinuance. It is well past time to bring the pieces together.

Geology:

Overall, I have substantial positive commentary on this aspect of the program. The mapping appears to be thoroughly and competently done and we were told the 1:12,000 "detail" surface mapping is on the road to timely completion. The volcanism studies by LANL (Crowe et. al.) are formidable and although I wonder if in some ways the probability calculations are not some esoteric form of mental self abusement, I am not a statistician. I believe little more can be gleaned from volcanism studies with regard to site characterization.

With the completed and/or planned core drilling of G-1, G-2 and G-3 along with UE25-A1 I believe that sufficient core information should exist to correlate geologic units and provide samples for what testing can be done on chunks of core. Spengler's work with the cores and their geologic characterization is excellent and while one never has sufficient information I think 1) additional core holes will not significantly improve geologic correlation unless it were possible to obtain a great many of them; 2) some good geologic data can be obtained from hydrology (non-core) holes; 3) hydrology data is crucial at this stage and is lagging; and 4) rock fracture data (azimuth and angles, etc.) will only be completely satisfactorily obtained from the shaft drill hole or actual openings in the various horizons.

Dave Hoover's quaternary studies seem particularly relevant, timely and broadly useful to the site suitability problem and I strongly suggest that he have major input to the seismic risk analysis that should be initiated and completed prior to shaft drilling scheduled for FY 83/84. In this regard it is necessary that studies of available Landsat, SLAR, SR-71 etc. imagery/photos be done and integrated with rock mapping, quaternary studies, trenching, etc. What is this we heard of a remote sensing lineament transecting Yucca Mountain? It would seem that its presence or absence must be substantiated and can be cheaply and quickly--certainly before 50-odd million dollars are expended on shaft drilling.

We heard conflicting commentary on the Tram unit relative to its pyrite content. Figures of 5% and 0.5% were given--based, I assume, on megascopic core logging in the one case and thin section analysis in the other. The differential may point up the problem of characterizing units with only 3 $\pm$ inch core. Frank Byer's petrographic characterization based on 4 or 5 thin sections

represents an even smaller sampling than the inspection of the entire core. In all hydrologic holes the chips should be examined and logged for sulphide content as well since I believe that any substantial sulphide content may disqualify a unit or zone or bases of reactivity, oxidation, heat production, etc. grounds regardless of other attributes.

Finally, an effort should be made to evaluate the lithophasae of the Topopah Springs member in terms of their mineralogic content, abundance, and degree of interconnection which may relate to permeability. This cannot be done on rotary drill chip samples and is difficult and highly subject to error using core samples. Indirect data may be obtained by hydrologic testing perhaps but just what is fracture permeability and what is lithophasae permeability will remain a question until a much larger scale sample of the unit can be obtained. This, in turn, can only be achieved by actual mine opening(s) off the drilled shaft within the unit.

In summary of the geologic aspects of the program:

1. Remote sensing data interpretation should be done as soon as possible.
2. Quaternary studies should continue along with trenching as needed.
3. The 1:12,000 scale mapping should be completed and integrated with 1-2 above.
4. Core drilling beyond G-3 should be of a lower priority than additional hydrologic drilling/testing.
5. Efforts to characterize all potential repository zones should continue and, if possible, more information should be obtained on the Topopah Springs or units within it regarding fracture density and lithophasae character.
6. Items 1-3 above should be placed into the context of developing a timely seismic risk analysis.
7. Shaft drilling must be done in a manner to allow geologic observation/testing as the units are encountered. More on this later in my summary remarks.

Geophysics:

For detail I defer to commentary by J. Farr, A. Ryall and others.

The gravity model presented appears useful and consideration should be given to: 1) extending at least 1 detail line across Yucca Mountain to the West. The existing detail survey apparently provides good but incomplete

data. Density contrasts (or lack thereof) on Yucca Mountain proper may minimize usefulness of more closely spaced work; and gravity data should be synthesized with other geophysical techniques to achieve a multi-parameter model which must then be placed into a geologically oriented framework.

Emphasis and priority in so far as geophysics is concerned should be given to reflection seismic and down-hole geophysical logging techniques. Reflection seismic work, done either by top USGS personnel or suitable contractor, should be able to provide much useful site characterization data, particularly for the deeper, water saturated zones. If, on other grounds, it is determined that a part of the unsaturated zone (probably a part of the Topopah Springs) is a most likely suitable media for TEF, reflection seismic work would be of a lower priority since it will probably provide but little relevant information on the shallower units. Geophysical down-hole logging techniques, widely used in the Weapons test program, should be vigorously applied in all possible drill holes to attain additional rock properties and to correlate physical parameters with core logging, rock mechanical and hydrologic studies. It may be possible to create a functional "physical" stratigraphy that is more directly relateable with hydrologic results than the geologic formation/member based stratigraphy.

Data obtained on hole to hole and hole to surface geophysical measurements should be completely analyzed and, if possible, modeled. It appeared that in the Peer Review of 1980 this study was providing useful information. Why has it not been completed and apparently terminated?

The paleomagnetic studies are interesting science but, to my mind, have questionable pertinence to site characterization within Yucca Mountain. To quote, "paleomagnetic polarities have proven useful in stratigraphic problems involving the Crater Flat tuff, and . . . for the 'Lithic Ridge' tuff in G-1 should prove useful in identifying this unit elsewhere." Elsewhere is not relevant to Yucca Mountain, and stratigraphic problems of the Crater Flat tuff (at least on Yucca Mountain) should be answerable in a better fashion from lithologic/mineralogic studies of core and cuttings.

Finally, geophysical results must be integrated into the recommended seismic risk analysis mentioned earlier.

Hydrology:

In my opinion and, I believe, as a consensus opinion of the Peer Reviewers,

the hydrologic program is both crucial and lagging in the site characterization studies of Yucca Mountain. Bob Farvolden, Pat Domenico and Paul Fenske will, I am sure, elaborate but my impressions and suggestions are as follows:

- 1) The hydrologic program is lacking useful and essential information throughout and in its present condition can offer little input to the selection of potential repository zones on Yucca Mountain.
- 2) Tests must be devised and implemented to develop a hydrologic stratigraphy not of geologic formations or members but of hydrologic units both within the Topopah Springs and deeper. Existing testing ability seems unable to obtain permeability and flow data for restricted units whether they are within the Topopah Springs or elsewhere. It is my understanding that the hydrologists assigned to the project are essentially "saturated zone hydrologists." If the Topopah Springs (or part of it) is to be considered further, a "unsaturated zone hydrologist" had better be assigned to the problem.
- 3) Hydrologic tests must be made on more restricted stratigraphic zones than the lower 500 meters or the lower 800 meters or the entire saturated zone as recently presented in the hydraulic conductivity viewgraph of USW-HI. Existing data sure gives one very little to go on when it becomes necessary to select a 50 to 100 foot thick zone for TEF excavation.
- 4) Static water levels on surrounding drill holes are totally insufficient for site characterization. Perhaps another hydrologic drill hole should be sited immediately west of Yucca Mountain.
- 5) Once made, the hydrologic tests must be correlated with geologic and petrographic/rock mechanical units. Possibly some of the detail petrographic/lithostratigraphic units should be used to make initial selections for packer tests. Certainly the gross formational or member units should not be utilized without thought being given to possible useable sub-zones that should be independently tested.
- 6) Hydrostratigraphic units must ultimately be defined and for each the permeability, transmissivity, hydraulic head, etc. must be characterized across Yucca Mountain to the extent possible.

The reviewers are sympathetic with the drilling and hole preparation problems encountered in the hydrologic testing program but maintain that hydrologic characterization is one of the, if not the, most significant aspects to selection of units or zones for consideration of the siting of a TEF. Indeed,

it is difficult with the present state of hydrologic knowledge and rock property knowledge to give a strong recommendation to the siting and drilling of the exploratory shaft. Yet, if adequate opportunity for geologic etc. inspection is provided while shaft drilling, the data supplied will be superior to any presently existing.

Geochemistry/Mineralogy:

The completeness and degree of detail going into the geochemistry/mineralogy studies both impress and appall me. It is apparent that given the limited sample available almost all possible studies are on going to mineralogically characterize the geologically recognized units and to geochemically characterize same. What is disturbing to me is the breadth of the studies suggesting lack of ability to prioritize efforts. Can, within the mineralogical/geochemical programs, recognition be made of which studies are of the greatest importance and have the greatest relevance to site characterization on Yucca Mountain? Those so recognized should be concentrated upon and others de-emphasized. I refer you to some of my earlier remarks on relevancy in the overview section of this report.

Specific items/studies within the geochemistry program which should receive increased consideration include:

- 1) Relevancy and timeliness of certain projects--as expressed earlier.
- 2) Studies of rock alteration and ion migration should be continued under conditions as closely simulating the potential repository zones as possible. For example, column experiments could be done under a temperature gradient such as might be anticipated after waste canister loading is completed. Through such experiments it might then be possible to determine and/or estimate not only mass property changes but the rates of such alterations and thus get some handle on the kinetics of the reactions which will effect the various repository rock types.
- 3) Efforts should be continued (already pretty good apparently) to relate geochemical and mineralogic work to site geology and, in the future, to hydrologic units (when such are recognized by the hydrologic program).
- 4) Consideration should be given to increased in situ experimentation with various lithologies encountered in excavations on Pahute Mesa (and elsewhere) that are similar to some or all of those in Yucca Mountain. Heater tests, etc. could be done and at least some semi-quantitative data transferability should be possible.

5) I believe it to be of major importance that, as soon as possible, geochemical determinations and experiments be run in/on waters that are actually obtained from each potential repository zone. This, of course, depends greatly upon success of the hydrological program in setting its packers, etc. and obtaining the required samples. Such samples will provide needed data and/or assurance on:

- 1) Eh-pH conditions in the various zones/units.
- 2) trace element geochemical information and tritium age dating of the waters which, in turn, may provide information on:
- 3) the uniformity of water chemistry/age and thereby the degree to which the various aquifers are interconnected or separated. This information, in turn, will help make decisions on flow regimes.

It is clear, I think, that the requirements of the geochemical groups, the hydrologic group and the geomechanical/rock properties groups are very much inter-twined. The output of one group may be critical input to another, and decisions made by the third (say on rock suitability for excavation, for example) may well be based substantially on fluid flows and rock alterations/chemical conditions determined by other groups in other laboratories. The necessity of excellent inter-laboratory (and G.S.) communications is apparent.

Summary and Speculation:

What I wish to conclude with is a speculative scenario on TEF site selection. I do not intend to repeat remarks made earlier other than to say that when the exploratory shaft is drilled this operation should be done in a manner to allow maximum geologic/geomechanical etc. observation and, wherever possible, side-wall sampling of units at the largest feasible scale. I know the logistical problems are considerable but believe that the information gain possibilities are so great that consideration must be given to trying to find methods whereby such sampling is possible. This leads into my speculation.

The scenario I will set out starts with the prediction that some part of the Topopah Springs unit will be found most suitable (or at least sufficiently suitable to TEF test) of available units on Yucca Mountain to serve as a TEF. My reasons for this "prediction" include:

- 1) It is in the unsaturated zone and groundwater movement (if any) should be dominately down.
- 2) It is non-zeolitized and reactivity problems at realistic heat load levels become less of a problem.
- 3) It is thick and, based on the little available information, relatively continuous.

- 4) It is, in parts at least, fractured. While we know relatively little of this fracturing and it may create prohibitive excavation integrity problems, such fractures (Runberg) may be helpful ultimately since dissolved ions, should they escape from canisters, can be more readily diffused into the tuff since the fractures provide increased surface area available to migrating waters.
- 5) It has a "basal" vitrophyre and this, in turn, is underlain by large thicknesses of zeolitized tuff (Crater Flat, etc.) which would be in the one instance an aquitard and in the other a sorbing zone sufficiently far removed from the heat source (canisters) that mineralogic alterations should be minimal. Such a sorbant zone at some distance below the repository zone would also, I believe, have the effect of minimizing ion transmission in water flow along throughgoing vertical fractures (faults) since a) the walls of the fractures would be zeolites and could sorb the ions; and b) the permeability of the fault zones in the zeolitized rock would probably be less due to the likely development of zeolitized, reactive "gouge" within the fault zones.
- 6) It is relatively shallow and this a) helps with accessibility (see later), and b) leads to lower confining pressures and lower in situ temperatures which would, in turn, allow higher canister heat loads than deeper zones with higher resident heat--provided a top degree temperature limit is prescribed for the TEF.
- 7) Pragmatically (providing rock integrity can be maintained) the Topopah Springs unit or some part of it should be cheaper and safer to utilize (operate) as a repository than other deeper rock units since I believe the possibility exists to excavate the repository in the Topopah Springs by means of a decline from surface which would allow a) larger equipment, b) faster excavation, c) easier and safer canister loading (since handling may be minimized by trucking directly to emplacement site), d) easier (I believe) access for maintenance, e) longer term retrievability (I admit this is arguable), and f) much greater flexibility of loading/retrieving rates than a vertical shaft. It also should be cheaper in mining since you would have to haul the excavated rock and replacement backfill either less distance or you handle it less often with larger equipment.
- 8) The use of a decline plus shaft (this would be the presently scheduled

exploratory shaft) would, I believe, ease ventilation problems by improving circulation with cool air pumped in decline and hot air rising and being exhausted through the shaft. Larger volumes of "cool" air could be more readily supplied through a large decline than by use of another vertical shaft that would be required for all deeper units.

9) Water handling and pumping problems would probably be considerably less in the Topopah Springs than in deeper saturated units. Not only might there be less water but the water would be cooler and would have to be pumped for shorter vertical distances.

All in all, what I see negative about the Topopah is much smaller in number and with one exception much less in apparent significance than for any other presently recognized unit. Negatives include lack of information--we have even less hydrologic data on the Topopah than on deeper units; lack of NRC guidelines on the use of unsaturated media; and, perhaps most critically, we lack sufficient information to know if a durable, large excavation can be made and maintained in any zone of the Topopah. Furthermore, satisfactory information on this later problem will very probably not be obtainable from 3+\" cores or drill chips but only from room excavations.

With the above lengthy preamble I would like to propose for your consideration between now and shaft sinking time the following recommendations and rationale:

1. Take immediate steps to obtain from the NRC guidelines for repositories in unsaturated media.
2. Encourage in every way possible that the hydrologic program start getting some permeability etc. determinations on the Topopah Springs or, more correctly, units within it.
3. Do some rough engineering calculations on permitted decline grades and decline length to, for lack of a better target, the center of the Topopah Springs. Is such a decline economically possible? It seems to me that with the Yucca Mountain topography and the depth to mid-Topopah of 300 meters or so, a 3 or 4% decline should be possible and not prohibitively long but my table-top figuring may be awry.
4. Consideration should be given now to altering the exploratory shaft drilling plans and budget.

The approach that I believe should be considered is to schedule the drill to lower the shaft to a selected part of the Topopah Springs. This selection

should be premised on hydrologic testing and stratigraphic/petrographic studies plus perhaps down-hole geophysical logging in existing holes (through G-3 plus new hydrologic holes). The information will be imperfect but probably little if any less so than for other deeper zones. The drill is then removed and sent to drill weapons test holes or whatever and an exploration drift is driven a short way into Topopah so that rock properties for excavation can be ascertained in situ and water character etc. can be ascertained. If these are favorable, "horizontal" drilling to check uniformity could be done from the drift face and ribs. If this looks good a decision on ADTF/or TEF is made in favor of the Topopah. If excavation/testing, drilling results are poor--return the rig to hole, deepen the shaft to the next "potentially suitable" zone in a lower unit. Repeat. If we are "lucky" and, as reiterated earlier, I believe the Topopah Springs may be favorable, we have saved drilling dollars and potential water problems that might cause difficulties all the way up and down the shaft when saturated zone aquifers are encountered. If "unlucky" the dollar cost increases by remobilization costs and time lost.

I recognize that all of the above is speculative, based on little existing data, and given with little appreciation of logistical problems of obtaining the required drill etc. However, if the decision has been reached that the shaft will be drilled, why should it be drilled through potential repository or ADTF/TEF zones only to pull back up the hole (now probably making water like crazy) to test shallower units? Why not start with the shallowest and potentially (short and long term) cheapest? To me the testing of the Topopah Springs (or some part of it) seems a logical and prudent approach and the present drawback is lack of information on mineability etc. I submit that clear, unequivocal answers to these problems will not be obtained for the Topopah or any other zone (unit) until a sufficient sample is available and this will require more than can be obtained through drilling and testing from the surface.

Respectfully submitted,

L. T. Larson

Registered Professional Geologist

LTL:mss

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DEPARTMENT OF GEOLOGY
School of Earth Sciences

14 September 1981

Dr. Lawrence T. Larson
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University of Nevada
Reno, Nevada 89557

Dear Larry:

Two weeks have passed since the Las Vegas meeting, and no additional comments on geochemistry have come my way. So I am sending you herewith the material I presented at the meeting, with only a few minor changes. Please feel free to edit it in any way that appeals to you, either to correct mistakes or to add details or to make it fit the other manuscripts.

It was a pleasure to see you in Las Vegas, and I hope we'll have a chance to work together again at future meetings of the panel.

Sincerely,

Konrad

Konrad E. Krauskopf

Comments from you, Howard Ross, & John Farr appeared just as I was mailing this letter, but I don't think they require much change in the text

Geochemistry

The Review Group is impressed by the high quality of the geochemical studies that are under way and by the completeness of the geochemical coverage represented by the listing of research projects that are in progress or planned. All the major factors that might influence migration rates of radionuclides have been considered, and research has been designed to study the factors whose influence remains uncertain. The panel commends particularly the effort in the experimental work to simulate as closely as possible conditions to be expected in a repository.

The panel's chief concern relates to the sheer quantity of geochemical work that is in prospect. To carry out all the research in the detail which seems to be expected will require many years. If site selection and repository construction depend on completion of this work, geochemistry might become a major source of delay. The panel suggests that thought be given to setting priorities among the very numerous geochemical projects, so that those can be emphasized which will aid directly in clarifying some of the uncertainties about possible repository sites at Yucca Mountain. Thought should be given also to the amount of detail that is required in the results from each project. Obviously, for example, one would like to know the thermodynamic properties of plutonium with great accuracy, or the precise values of K_d for different valence states of plutonium under a variety of conditions; but is such accuracy really necessary for a decision as to whether a given site is or is not suitable? One can hope that the planned research will be continued far into the future, after a repository is under construction or in operation, but at present the projects should be pushed and the degree of accuracy should be tailored to the immediate problems of locating an exploratory shaft and a possible repository site.

Experiments that seem to the panel particularly important at present are those involving ion migration and retardation under conditions duplicating those in a repository, both while the repository is under construction (and therefore open to the air) and later when the repository has been sealed. The panel applauds the

intention to supplement laboratory work with experiments in the field, for example the experiment that is to be set up in G tunnel for measuring ion migration along a shear zone.

Studies of ion migration will make possible the setting up of models describing the maximum releases to the environment to be expected for each of the harmful radio-nuclides. Even though data on ion migration and groundwater flow are still incomplete, the panel thinks that setting up provisional models now would be a useful exercise. Such models would need major changes later, but at present they would help to pinpoint places where additional data, or additional accuracy in existing data, are particularly needed.

A few geochemical activities that were not specifically listed in documents given to the panel are suggested for consideration:

(1) Samples of groundwater should be collected from each tuff bed that is under consideration for repository siting. The panel is aware that obtaining such samples may be difficult, but considers them important enough to be worth the effort required. Analyses of the samples would give direct information on reactions of water with different varieties of tuff, would serve as guides to water compositions for use in experiments on sorption and ion migration, and would provide evidence regarding possible interconnections of aquifers in the tuff sequence. If the analyses include tritium, estimates could be made of the ages of the groundwater samples.

(2) It is important to determine whether groundwater in the tuff beds is reducing, because migration of multivalent ions is critically dependent on Eh conditions. The assumption is commonly made that groundwater out of contact with air is necessarily reducing because it is in contact with ferrous minerals or sulfides, but this assumption has recently been questioned for groundwater in tuffs. One bit of evidence that casts doubt on the assumption is the finding of a little dissolved oxygen in water from one of the wells on Yucca Mountain. The analysis should be checked, particularly to see whether the water containing oxygen had been in contact with air, and oxygen

should be looked for in other groundwater samples. If dissolved oxygen is indeed generally present, experiments on possible backfill additives to keep the repository environment reducing will be especially important.

(3) Pyrite in small amounts has been reported in lithic fragments in part of the Tram formation. The quantity and distribution of pyrite should be checked, because its presence might make this formation unsuitable for repository construction. If air comes in contact with pyrite on the walls of a shaft or tunnel, the mineral rapidly oxidizes and produces acid with any water present. This would weaken the rock and accelerate corrosion of waste canisters.

(4) Experiments on rock alteration and ion migration could be made more similar to a near-repository environment by imposing a temperature gradient on rock through which water is moving. A possible consequence might be the transfer of silica in considerable quantity from the hot to the cold end, with the deposition of opal or chalcedony and hence a marked decrease in permeability.

Beyond these few suggestions the review panel has little to add to the geochemistry program. The program is in excellent hands, and we recommend only that priorities be set among its many parts so that for the near term it can be more directly relevant to current problems of site characterization.

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DEPARTMENT OF GEOLOGY
School of Earth Sciences

15 September 1981

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Dear Larry:

To supplement the more formal comments on geochemistry that I sent you yesterday, I take it that I owe you some observations on the general conduct of the Las Vegas meeting and the research program as a whole. In making these observations I have the advantage of having seen reviews by Howard Ross, John Farr, George Thompson, and yourself -- and since I agree with most of what is said in these reviews, I think I can be pretty brief. I assume that these remarks will not be submitted to Bob Nelson as they stand, but will simply be incorporated in whatever general statement you prepare.

As a neophyte on the Review Group I found the format of the meeting excellent. The presentations during the first day and a half were remarkably well done, in comparison with similar efforts at other meetings I have attended. The speakers described recent accomplishments and remaining unsettled issues clearly and concisely, without wasting our time by lengthy introductions and repetition of generalities. Then it was a good idea to let us choose from a long list the additional papers we wanted to hear Wednesday and Thursday. Maybe some time could have been saved if we had had the list before we came to the meeting, as John suggests, but this might have been difficult to manage. It was too bad that the audience had to be so large in the geology-hydrology-geophysics section, because questioning of speakers is inhibited in a large crowd, but I don't see how this could have been avoided. I hope that another time it may be possible to set aside a few hours for one-to-one talks between committee members and individual workers on subjects of mutual interest. Such talks would permit more in-depth probing of ideas and research techniques than was possible in the large sessions.

Like other reviewers I was impressed on the one hand by the excellence of the scientific work being done and on the other hand by the inadequacy of overall technical management. Each little project is coming along beautifully, but the organization of projects toward an agreed-upon goal seems to be weak. Priorities are not set and enforced so that important parts of the program can be pushed and less important parts delayed or halted. I learned from conversation with some of the scientists that relations among the various laboratories are generally good and that meetings among workers in particular fields are frequent, but this still doesn't take care of the need for firm overall guidance from the top. George Thompson suggests a "small scientific-engineering team . . . of expeditors"; Howard Ross suggests a standing committee of reviewers; John Farr proposes a "technical director" in one place and "technical direction . . . from a disinterested, private-enterprise group" in another place. Some such organizational change, I think, will be necessary to improve technical management.

Geology. I have little to add to suggestions made by others. The two greatest needs, it seems to me, are (1) more work on the unsaturated zone and (2) a concerted effort to get more details about the extent and continuity of different kinds of tuff.

The unsaturated zone has great appeal in this area because it is very thick and could not be objected to on the usual grounds that the waste would be dangerously close to the surface. Placing a repository above the water table would eliminate all the

Manifold worries about the effects of flowing groundwater. I was told that recharge to the water table is practically limited to higher parts of the general area, particularly Pahute Mesa; in the vicinity of Yucca Mountain movement of water from precipitation completely thru the unsaturated zone occurs rarely or not at all. This conclusion needs checking, and current experiments in shallow excavations in the Tepepah and alluvium should supply the necessary data. If the experiments show that vertical movement of water is slight or nonexistent, attention should be focused on possible repository sites in the unsaturated zone. This will mean, of course, detailed study of the Tepepah Springs formation and alluvium in some of the adjacent flats.

The continuity of different kinds of tuff (welded, argillized, zeolitized) over distances large enough to make repository construction possible has not been demonstrated. This is hardly surprising in view of the great variability of the tuff in drillcores, but to me it is the single greatest lack in geologic information. To get the information will obviously require more drilling, and I think John Farr has a good idea in suggesting that lots of holes be drilled (without using polymer mud and without taking core) around the perimeter of the most promising repository site. Of course the best way to explore the stratigraphy would be to sink an exploratory shaft and drill horizontal holes at its base, but this is such an expensive operation that the peripheral drillholes seem like a wise preliminary. Geophysical logging of present and future drillholes would also be essential.

Geophysics. Here I have nothing to contribute except to echo my colleagues' opinion that seismic reflection work is well worth trying even the prospects for success are not bright, and that borehole logging should receive much more attention than it has been given heretofore.

Hydrology. Again I have nothing to add to the reports you already have in hand. Like my colleagues, I was surprised at how little hydrological information was available, and I would concur with their sentiment that hydrology deserves major emphasis in near-term research. I agree also that acquiring water samples from individual aquifers in the tuff sequence is a matter of first importance.

This is pretty brief, Larry, but if I go on I would just be repeating things that others have said better.

With best regards,

Konrad B. Krauskopf

September 22, 1981

Dear Larry,

Enclosed you will find an integrated report on the comments of Farvolden and myself, further integrated with comments received from Ross, Farr, Thompson, and yourself. You will note that Fenske's input is not included here. I called Paul on September 21 (Monday) and told him about our deadlines and that I was obliged to get this stuff to you. He replied that he needed a few more days on it and then had to have it typed (which he saw as a slight problem) so it looked like I would not get it until the end of next week or so. I would then need more time to integrate and get it all typed and send it off to you. This clearly would put you behind schedule in your integration tasks. So we decided that I would send a copy of our stuff to you and to Paul just as it stands now. Paul will take this copy and integrate his material and pass the final copy directly to you. That will be the final report from the hydrogeology sub-committee. So he has a copy of this also and, presumably, will shortly give it to you with his stuff included. As he is in Reno this seemed the best way to expedite matters. So that's it. Good luck with putting it all together. From what I have seen already, it will not be easy.

Regards,

PAT

HYDROGEOLOGY

Drilling and Testing Program

A main observation of the work accomplished thus far in hydrogeology is that the data collection program in drill hole hydrology is lagging far beyond similar programs in other phases of the project. At this current rate of data collection coupled with what little is known concerning the hydrogeology of Yucca Mountain, we do not see hydrogeology as a reliable input to the decision for an exploratory shaft and test facility within the proposed NTS time frame.

A main difficulty, from a hydrogeologic perspective, is that a potential repository horizon of sufficiently low permeability and adequate thickness has not yet been identified. Although some candidate formations have been identified in the few borings to date, the areal coverage of the drill holes is hardly adequate to answer questions regarding continuity of desirable properties. In addition, assuming an adequate repository horizon exists, there remains the question of whether or not there is a possible route to the biosphere that could traverse this three dimensional volcanic system by way of high hydraulic conductivity units. Given this latter state of affairs, proving the volcanic tuff would be equivalent to proving the integrity of the rock unit in which the repository may be placed. In our view, both of these questions can be addressed with a reliable drilling and testing program. We see the following as important elements of this program.

Delineation of Hydrostratigraphic Units: There is need for identification of the significant hydrostratigraphic units in Yucca Mountain that will eventually require hydraulic and chemical testing. Formation identification

is not sufficient by itself in that there is too much stratigraphic and structural variation within a given formation. Hydrostratigraphic units, which are most likely the highly permeable fractured zones within individual formations, will have to be identified in the core or geophysical logs, and ultimately tested hydraulically. This identification process may have to include downhole televiewers, cameras, or acoustic logs, all of which are well suited for delineation of fracture permeability. The continuity of these zones should be determined to the extent possible. Some sort of facies mapping with carefully selected control points, followed by a test program to prove the method, might be a reasonable procedure. For example, a high permeability zone in the upper Bullfrog (?) has been identified via pumping tests in USW-VH1. Does the core or available geophysical logs in other holes attest to the areal continuity of this zone, i.e., is this a major hydrostratigraphic unit for horizontal flow in the Bullfrog or, if not, what information is available on the structural features that may promote vertical transfers across various hydrostratigraphic units. Is this part of the Bullfrog transmissive because of the fracture zone intersected there so that it still may be a candidate unit outside this anomalous area? We contend that if sufficient core and geophysical information is available to provide a stratigraphic section, there exists sufficient information to provide a preliminary hydrostratigraphic section. We thus believe that identification and characterization of the hydrostratigraphic units across Yucca Mountain is a number one priority. Once accomplished, all tests for engineering, hydrologic, and chemical properties can then be made in reference to the physical system identified. According to the NWTS Site Performance Criteria this must be done and we believe that a proposal for accomplishing this task should be presented. In the absence of such a program there appears to be no effective hydrogeological program on a local repository size scale.

Pumping or Injection Tests: Pumping or injection tests have to be conducted in such a way that the packed off zone correlates very well with the hydrostratigraphic units described above. In the pumping test results to date, criteria for selection of the testing zones are not clear. In USW-G1, three of the eight tested zones are in excess of 600 meters in length. In USW-H1, five of the eight tested zones are in excess of 400 meters in length and two of the remaining three are about 200 meters in length. The average hydraulic conductivity reported for these thick sections is somewhat misleading in that the measured transmissivity is divided by the thickness of the tested zone to obtain a so called average hydraulic conductivity. In fractured media, it is not the average over a large saturated thickness that is important, but the permeability of the hydrostratigraphic units within the formation or unit. Obviously, the permeability of potentially high permeability fracture zones can be several orders of magnitude larger than the computed average over a large thickness of formation. This may be exemplified from the preliminary results of USW-VH1, with a measured transmissivity of $2400 \text{ m}^2/\text{day}$ and an average hydraulic conductivity of 5.6 m/day . This average value indicates that the transmissivity was divided by a saturated thickness of 428 m. The main aquifer, however, was reported as being 17 m thick within this sequence of rocks. Hence, if 50% of this measured transmissivity is attributed to this main aquifer, the hydraulic conductivity of this zone is about 70 m/day . It is this conductivity that is important in the transport of radionuclides (as well as shaft construction). In USW-VH1 this high permeability zone corresponds with the top of the Bullfrog. Its continuity, actual hydraulic conductivity, and the vertical and spatial distribution of other such zones, if they exist, has to be detected by an extensive drilling and testing program. Although drilling the Yucca Mountain block is not permitted, four to six

additional hydrologic holes can be sited peripheral to and surrounding the block. This task should take priority over the numerous other requirements associated with drilling and testing, including the location of off site holes for regional piezometric control, or some specialized drilling and testing to determine whether or not localized faulting controls water movement in the reasonably well explored confines of Drill Hole Wash. Both of these have been proposed and both are important in the long term investigation of the Nevada test site. Fractures and faults do indeed add a special complexity to the hydrogeologic analysis of Yucca Mountain and vicinity. We submit, however, that an array of observation wells will be required to establish the hydrologic character of a fault. The test proposed may prove that in fact this fault may be associated with high permeability, but what does this mean with respect to other minor faults and fractures that seem ubiquitous over Yucca Mountain? It may be that the contours of groundwater head may be the only feasible means of establishing the hydraulic character of faults acting as barriers or drains, and that field testing for fault characterization may best be done in an underground facility. We would suggest, eventually, a detailed proposal for the research program designed to investigate faults and fractures.

In short, the main hydrogeologic questions at this stage in the program deal with the pending shaft and test facility construction, which will require prior identification of a potential repository unit in Yucca Mountain and all associated hydraulic problems in shaft emplacement. This means that the distribution and permeability of the hydrostratigraphic units must be known to the extent possible. To proceed with the shaft leading to a test facility without this information is unthinkable. However, no plans were presented as to how the requisite data would be acquired. Could a series of

peripheral holes be drilled with air and or conventional (non-polymer) mud for the exclusive purpose of obtaining hydrogeological and geophysical borehole data? By eliminating the core requirement a much larger number of holes could be drilled in the same time budgeted for a single pair (G3, H3). If the core is required, there is no possibility that multiple holes within the periphery can be drilled, logged, and tested, and therefore no possibility exists for obtaining the required data. We emphasize further that the testing of isolated horizons as described above is a minimum requirement. Vertical communication across the various hydrostratigraphic units will ultimately have to be ascertained. Hence some hole to hole testing may be required, as well as advanced single borehole techniques. However, we do not recommend this at this time, as vertical permeability can ultimately be measured on a meaningful scale via horizontal boreholes and galleries once an underground facility is completed.

Obtaining the drill hole information cited above has apparently not been an easy task. Two reasons may be cited for this. First, the hydrogeology drilling and testing program has not been supported to the extent it requires. Testing takes time and money. It is of little benefit to drill a hole and come away without a whole array of measurements, or measurements that for one reason or another are unreliable. With few exceptions, this has been the experience to date. Virtually all activities in the waste isolation program at Nevada should be secondary to this hydraulic effort, at least for the next few years. That is to say, additional holes for hydrology are required and the existing holes must be retested as described. This drilling and testing cannot be confined to Drill Hole Wash.

A second observation relating to this same problem is that the Survey may not be supported by adequate manpower. Certainly progress of the type

envisioned here will require a careful evaluation of all core and geophysical data, almost constant vigilance in the field, and a constant search for better methods to overcome the mechanical problems encountered in packing. Additionally, further support is required in the area of well hydraulics, especially in the techniques of single borehole testing in saturated horizons. Certainly such expertise exists in the Survey but if the Survey cannot meet the demand for specialized manpower, or if the company responsible for the packing cannot do the job properly, some thought has to be given to subcontracting elsewhere. These data are too important to be compromised. In short, the problem can be resolved with the allocation of money and equipment in the drilling-testing program, and with improved technical assistance. It is managements task to commit the necessary resources to overcome technical problems and the competition for drilling time on NTS.

Hydraulic Head and Chemical Data: In addition to measurements of hydraulic conductivity as discussed above, hydraulic head and chemical character of the water must be ascertained in the various hydrostratigraphic units. In order to be sure that the measurements represent heads at equilibrium between the measuring instrument and the formation, time must be allowed for such equilibrium to be established. We note that in all packer tests to date, not one reliable measurement of hydraulic head in the measurement zone was obtained, presumably due to a lack of sufficient time allotted for this task. Hence, although it is suspected that the potential distribution in Yucca Mountain favors a vertical component of downward movement, it is not yet possible to describe this movement qualitatively or quantitatively. This groundwater regime must be determined.

Chemical information is of secondary importance from a hydraulic perspective in that it may be supportive of hydraulic conclusions regarding barriers

to vertical communication of waters in the various hydrostratigraphic units. If all data are compatible within the framework of a reasonable conceptual model of the system, it is then likely that the system is well understood. In addition, chemical data are of primary importance as input to the waste package program. Also an understanding of the rock-water chemical reactions as deduced from the hydrochemical patterns is prerequisite to using any isotopic method to estimate groundwater ages and flow rates. In the absence of observed water chemistry, which is the current case, there does not exist a sufficient understanding of the mineral-water chemical reactions to provide either water ages or to specify potential radionuclide rock reactions which will affect transport. Reporting Carbon-14 data in terms of unambiguous age interpretations may lead unsophisticated readers to consider them as real ages, but these ages are highly suspect in the absence of insufficient hydrochemical data in the volcanics.

The Topopah Springs Unit

Some part of the Topopah Springs unit may offer promise as a candidate site for several reasons:

- (1) At the high elevations of Yucca Mountain it is in the unsaturated state.
- (2) It is non-zeolitized and therefore does not present problems in mineral stability.
- (3) It is underlain by zeolitized units, which may provide a desirable geochemical barrier (sorbing zone) sufficiently removed from serious perturbations of the thermal regime. Presumably, water movement from the unsaturated zone will have a dominant component of downward movement toward this geochemical barrier.
- (4) It possesses the desirable characteristics of accessibility, lower confining pressures, and lower in situ temperatures.

There are some obvious problems with the Topopah and these include its fractured nature and the ultimate effect on geomechanical and hydrogeological problems. Specialized hydrogeologic testing is required and this will require input from the Survey's specialists on the unsaturated zone. A planning document from the Survey appears to be in order here, with outside review provided to comment on the proposed methodology and utility of the data to be collected.

It follows from all of the above that the unsaturated zone must receive special attention, and this statement holds whether the vault is above or below the water table. Certainly on Yucca Mountain the hydraulic head distribution and water content in the unsaturated zone has to be determined. Water samples should be obtained and analyzed for chemistry and isotopic composition. Sequential neutron logging should be required in selected boreholes. From this, the hydrologic regime of the unsaturated zone may be described. This seems particularly important in the light of the hydraulic head reported in G-2 which suggests an anomaly in the flow regime. Does this represent a significant barrier to flow across Yucca Mountain or is it possible that Yucca Mountain represents a local piezometric high on the regional water table? If the latter is the case, the role of the unsaturated zone in maintaining this high must be ascertained. It is noteworthy that the area of interest, Yucca Mountain, may thus far be associated with two anomalies, the reported high permeability zone along Forty Mile Wash, and the high head in G-2. In addition, the reports of very high water content (90% saturated) of samples from the unsaturated zone are somewhat disquieting. These findings should be verified and accounted for in a physical sense, and will add to an understanding of the saturated-unsaturated flow regime of Yucca Mountain.

We are inclined to agree with most investigators that groundwater recharge through infiltration of precipitation is very low over NTS. Nevertheless, we

are regaled by stories of rapid infiltration during heavy storms and flow into mines following rain in settings that are similar to Yucca Mountain. This matter must be laid to rest for the Yucca Mountain site. Are the fractures open pathways that immediately transmit rain water while the matrix remains saturated (90%) with older water? What is the geohydrologic significance of topography and drainage? Would a change in climate of the sort predicted alter the present regime significantly? What is the role of the major surface channels in groundwater recharge? Would a change in climate of the sort reasonably predicted alter this significantly? With regard to these questions of climate change, the findings of the paleohydrology group indicate that water tables in the discharge area were not much higher than current heights during the Quaternary. What sort of study is required to determine the water table position at Yucca Mountain during this same time period, if such a study is even possible?

Numerical Modeling

The choice of having the groundwater model and now the transport model done by hydrogeologists rather than professional computer science people is a good one. The members of this group know that much better data and hydrogeologic characterization will be required. They are also aware that there will always be significant uncertainty in predictive simulations with respect to travel times from repository to the biosphere. It is their role, and ours, to convince their management and DOE as well not to design a program that places the ultimate burden of proof on site specific model predictions. In this regard, it has been suggested that the models may have more interpretive value than predictive value, especially in the light of data scarcity, both present and future.

Other Considerations

There are other considerations that should be mentioned here, most of which have been brought up in previous peer review documentation. These are cited below:

- (1) The mineral stability investigation is excellent. It remains a high priority item in that mineral stability indeed represents a limiting factor for the utilization of the tuffs of Yucca Mountain. It is clear at this stage that irreversible dehydration must be avoided. How much reversible dehydration can be permitted, if any? The answer to this question will constrain the maximum temperature rise in the zeolitized horizons. A more complete modeling effort will be required to ascertain the possibility of excess fluid pressures due to the release of waters of dehydration. This model should include fluid flow as a pressure dissipative mechanism and thermal expansion of fluid as well as a temperature dependent fluid source term as pressure producing mechanisms. Resulting (simulated) fluid pressures have to be examined in the light of potential fracture initiation and propagation. Microfracture development (dilatancy), for example, can occur at reasonably small excess fluid pressures.
- (2) If the Tertiary volcanics retain their candidacy as a potential repository site, the geologic and hydrologic relationships between these rocks and the Paleozoic aquifer must ultimately be determined. This would appear to be a requirement of site characterization.

- (3) Although not specifically listed as a candidate unit, we urge continued work on the unsaturated zone in the alluvium. While attempting to obtain guidelines from NRC on repositories in unsaturated media (presumably in regard to the Topopah Springs Unit) could not similar guidelines be obtained for arid zone unsaturated alluvium characterized by a deep water table? We trust we are not completely locked into Yucca Mountain.
- (4) DOE/NV is to be commended for generating a review process which operates in a frank, friendly, and constructive fashion. Given the excellence of the scientists on the project, there is good cause for optimism. We have one suggestion that might be in the direction of preserving this kind of an attitude. As a peer review committee, we think that one of our tasks might be to provide input to specific planning documents before certain work is attempted, instead of always after the fact. For example, we feel that planning documents in hydrogeology should be prepared on the unsaturated zone investigation, characterization of hydrostratigraphic units, characterization of faults and fractures, etc. Given such documents we can see what exactly is to be done and how it is to be accomplished. This would appear to be the time to provide input to such projects by adding our views, perceptions and even constructive criticisms of the objectives and methodology to be employed. This would give the peer review committee a more "hands on" perspective of the scientific and engineering tasks to be performed.

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Alan S. Ryall
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22 September 1981

TO: All Members of the Geology/Hydrology Peer Review Committee

FROM: Alan Ryall, Geophysicist

This memorandum is to set forth my impressions and recommendations on the NNWSI program presented by representatives of DOE, USGS, SNL, LANL and LLNL at the Peer Review meeting in Las Vegas, August 24-28, 1981. In the sections below I have not repeated the comments and recommendations given in our joint report to DOE on 28 August, except for points that I felt needed additional emphasis or clarification.

GENERAL COMMENTS AND RECOMMENDATIONS

Program Management

In regard to program management, I share the concerns described in detail in the 11 September 1981 review by John Farr. Although DOE/Sandia management attempted to convince the panel on 24 and 25 August that coordination of the program had improved, and although we were given a clearer picture of some pieces of the overall effort, it was obvious that recommendations made last year by several panel members have not been followed, and that in some areas interagency coordination and cooperation may even be worse than evidenced previously.

After last year's review I recommended that "scientific management of the program be improved by (1) better definition of problems or factors that are critical to approval of the facility; (2) definition of a program that will converge at some specified time in the future; (3) designation of key people to begin synthesizing results for the various projects and integrating these for various interdisciplinary areas; and (4) assignment of high priority to compilation and wide distribution within the scientific community of reports on the NNWSI." Generally the same recommendations can be made this year, with more urgency since the program seems to be converging on an exploratory shaft before the prerequisite scientific research is completed.

With regard to recommendation (1), each of the stratigraphic members under consideration had one or more characteristics that might prove to be fatal in terms of ultimate selection as a repository site. The Topopah Springs member has high fracture density, Calico Hills is zeolitized, Prow Pass is both zeolitized and fractured, the Bullfrog may have insufficient strength, the Lithic Rich tuff may be too deep, overstressed and hot, and none of the target zones may be as thick or as uniformly welded as originally hoped. The idea that any of these problems can be circumvented by appropriate engineering is probably not correct, and a more coordinated effort is urgently needed to define those conditions that could make a potential site within Yucca Mountain unacceptable.

In regard to recommendation (2), a dialog between NRC and DOE should be initiated at a level that will permit rapid development of a set of licensing criteria for the facility. In some areas (e.g., seismic risk) criteria could probably be developed immediately, based on previous experience of the NRC and known engineering characteristics for the waste isolation facility. In all parts of the program, decision points should be established to focus the research on specific problem areas defined by the licensing criteria, and principal investigators from the four main research agencies should meet regularly to insure that their joint efforts are aimed at satisfying licensing criteria.

The overviews presented by principal investigators on 24 and 25 August indicated some progress in synthesis of results (recommendation 3), but integration of research being done by the different agencies appears to be totally lacking. Worse, some antagonism was displayed that appeared to reflect interagency rivalry rather than lack of excellence in the research. Perhaps the solution to this problem is the one suggested by John Farr: hire a disinterested private enterprise group to provide technical oversight of the program, and let the group have sufficient authority to demand cooperation from the participating agencies.

Another approach would be to initiate a number of integrated reports with the responsibility (and authority) for completing a report assigned to one of the research agencies. For example, most of the regional studies -- geology, geomorphology, seismic refraction, teleseismic delays, etc. -- are essentially complete, and most of this work has been done by the USGS. I suggest that USGS be assigned the task of completing a final report on the regional work, that the report be written in a short time frame by a small number of key individuals working together, and that USGS have authority to recruit key individuals from other agencies if the work being done by those individuals would contribute to an integrated report. Another report should be done summarizing engineering requirements for the at-depth facility, with responsibility for compiling the report assigned to SNL and with contributions from other agencies (e.g., USGS for stratigraphy, LANL for mineralogy, etc.). The important factors in this report-writing exercise would be assigning responsibility for the compilation to a single agency, requiring completion of the report in a limited amount of time, restricting the number of people working on the report, and giving the lead agency authority to obtain material from other agencies when such material would contribute to the overall synthesis.

With regard to recommendation (4), I pointed out last year that peer review should be an ongoing process, and reviewers should be supplied with copies of project reports, reprints and viewgraphs before the annual meetings take place. For the most part, this recommendation was not followed, and the ability of panel members to properly evaluate the program in the limited amount of time (about 14 hours) devoted to technical presentations suffered as a result. In the future, as reports are completed they should be distributed to appropriate members of the review panel, and as parts of the program are completed results should be synthesized into reports that receive wider distribution within the scientific community.

Conduct of the Meeting

This year's meeting was in many respects better than previous reviews. The initial presentations provided an overview of the entire program, and gave panel members a better grasp of the site selection and eventual licensing processes. These sessions could have been shortened somewhat to leave more time for technical presentations; presumably in future years the general program description would not need to be repeated.

I appreciated the opportunity to select material from a "menu" of abstracts, and to have groups of papers summarized by one principal investigator when a summary was appropriate to save time. However, the abstracts in the "menu" were too brief to give a clear idea of the technical content of the papers, and I suggest that abstracts of about one page each be prepared for the next review. In addition, copies of technical reports should be made available to those reviewers who want them, before the next panel meets. If the "menu" format is continued, panel members should have the abstracts in advance, and should be able to request additional presentations in areas not covered by the abstracts (as was done this year in a couple of cases).

By next year, hopefully, a set of decision points will have been constructed that will lead eventually to the answers required for licensing the facility. If so, the next meeting should be organized in a way that will permit the panel members to determine whether or not the various research projects are converging as rapidly as possible on appropriate decision points.

Format of Report

I share John Farr's concern about the "committee-as-a-whole" format we were asked to use in this year's report. Such a format gives equal weight to comments made by individuals and those made by a number of panel members, and does not convey proper emphasis in those areas that were of primary concern to most of the reviewers. I suggest that the report either include our individual reviews as appendices, or that some indication of weighting be given to criticisms and recommendations (for example, the format used by Lincoln in his 20 April 1981 Technical Overview Summary, where he attributed each comment to the individuals who made it).

TECHNICAL COMMENTS AND RECOMMENDATIONS

Geology

In general, the geological work reported by Carr and others is excellent and has the advantage that it is based on many years of experience at NTS. This work should be synthesized during the next few months.

Studies of Quaternary faulting will be essential to define seismic risk at the site. During the next year additional trenching should be undertaken to date the recency of movement on all faults that could be hazardous to the site. If USGS has insufficient manpower to accomplish this, some of the work could be contracted with geological engineering firms that have experience in this area.

Hydrology

Highest priority in the NNWSI program should be to improve the hydrologic investigations. In general there is a lack of data that would be adequate to characterize the site, and progress over the last year has been essentially nil. A number of additional hydrologic wells should be drilled around Yucca Mountain -- without polymer mud, completely logged, and with hydrologic testing at horizons selected on the basis of the well logs. Hydrologic stratigraphy should be identified independently of the geologic stratigraphy. Air permeability and gas diffusion testing should be done to estimate transmissivity within the Topopah Springs member. The program should have higher operational priorities for drilling and testing than it apparently has now. From the problems and lack of progress over the last year, it seems reasonable to recommend that DOE consider contracting some of the work outside the USGS.

Electrical and Magnetic Measurements

A brief report by Howard Oliver indicated that much of the surface electrical measurements program has been dropped, and that Don Hoover, who reported on the electrical program last year, has been transferred to another program in the USGS without synthesizing the large amount of data already collected. If possible, DOE should arrange for Hoover to be returned to the NNWSI program, if only long enough to complete a final report. If necessary, an outside firm should be brought in to assist in the data reduction.

Similar comments apply to the magnetic survey results. The finding of a 300-gamma offset in Yucca Wash was tentatively interpreted as a fault, which could be very important for ultimate licensing of a Yucca Mountain facility. Interpretation of this anomaly should be completed, and additional magnetometer lines should be run over the entire target area.

Gravity and Refraction Measurements

The gravity work reported by Howard Oliver indicated that Yucca Mountain is on the edge of a large gravity low centered on the Silent Canyon caldera, and the excellent refraction data obtained using dense recording lines confirmed a 1.5-2 km offset in the basement, in good agreement with the gravity low. Mooney's refraction results should be combined with Oliver's gravity data to produce a final report on structure in the target area as indicated by these geophysical studies. I see no urgent need to continue collecting gravity and refraction data during the next year.

It would also be useful to interpret the waveforms shown on record sections for the refraction profiles. There were large differences in the character of recordings, clarity of second-arrival onsets, etc., over different parts of the profiles, and these should be interpreted in terms of structure and attenuation in the shallow crust under the Yucca Mountain area.

Teleseismic P-Wave Study

The teleseismic P-residual study reported by Healy indicates the existence of a high-velocity zone, probably in the upper mantle, extending

under a large part of the southern Nevada network including the target area. If this zone is related to depletion of partial melt by eruption through the various volcanic centers on and around NTS, the study could have implications for potential volcanism at the site. This study could be completed within a few months, and does not need to be continued beyond that time.

Seismic Risk

The earthquake problem is one that could have serious implications with regard to licensing of a waste isolation facility at NTS. As soon as possible, the USGS should initiate a formal seismic risk analysis, based on some reasonable modification of the criteria already in existence for siting nuclear power plants. As stated above, Quaternary geology will be essential to understanding the recency of movement on faults in and around NTS, and the geomorphological studies already initiated should be expanded.

The USGS seismic network group, in my view, does not need to continue monitoring the entire southern Nevada region but could instead operate a dense local net to answer questions of seismic risk to surface facilities and to define the level of microearthquake activity on faults near the site. I would not regard as a significant finding the observation that on average only one earthquake with magnitude greater than 2.0 occurs per day in the NTS region -- an even lower level of activity has been observed in Dixie Valley and Pleasant Valley in northern Nevada, both of which were affected by major earthquakes and surface faulting during the historic period. The significance of detecting a magnitude 1.8 shock on one of the faults separating Yucca Mountain and Crater Flat was not discussed. Swarm activity was observed in 1979, but whether or not this activity has implications for active volcanic processes at NTS was not discussed. The USGS investigators noted that the so-called east-west seismic belt at NTS has been mainly defined by a low level of adjacent activity, a characteristic that Nersesov and others (1974) cited as typical of precursory seismicity in the Garm district of central Asia. In general, while the quality of research by the network group is good, the project has so far been a strictly data-gathering effort; during the next year this group should focus its efforts on areas related to the licensing process.

Seismic Reflection

The vertical seismic profiling reported by Muller appears to have the potential for providing high-resolution information on shallow structure beneath the target area. I think seismic reflection should be a top-priority effort and that DOE should contract with the best people available in the US (probably industrial rather than government agency) to continue this work. Downhole work should be completed at all existing holes and as additional holes are drilled around the target area VSP should be done in them. If warranted by the VSP results, a full-scale vibroseis survey should be undertaken -- again using the best people and equipment available. Negotiations with NRC should be reopened to permit the reflection crews to drill shallow holes on Yucca Mountain if these are needed to define the structure at greater depth.

Borehole Geophysics

The excellent borehole geophysics work described by Daniels has the potential for providing crucial information on physical parameters of the rocks at depth -- permeability, porosity, fracture density, degree of welding, etc. Together with improved hydrologic studies and seismic reflection, borehole geophysics should be given highest priority within the NNWSI program. This project, which was apparently affected by budget cuts in FY 1981, should be significantly expanded in the next contract period. The goal of the borehole geophysics work should be eventually to characterize geophysical parameters of a site without the necessity of taking continuous core during drilling. All existing holes should be logged, and there should be detailed interpretation of the logs, integrated with any available information from the core analyses. Hole-to-hole sonic and neutron logs should be conducted wherever nearby holes permit such techniques to be used.

Geochemistry

I have nothing to add to the panel's comments, presented in the review by Konrad Krauskopf.

Exploratory Shaft

Drilling of the ES should be preceded by a pilot hole, and the latter should be logged as completely as possible. The ES itself offers the best opportunity to determine the structural details of various lithologic units at depth, and should be made available for examination as drilling proceeds. The ES should be drilled only into the unsaturated zone, and should be extended only if this zone proves unsuitable as a repository.

Best regards,

Alan Ryall

Engineering Geoscience
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Oct. 2, 1981

Mr. R.M.Nelson
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Nevada Operation Office
P.O.Box 14100
Las Vegas, Nevada 89114

Dear Bob,

I have completed a summary report of the geology review of the Yucca Mountain project and forwarded it to Larry Larsen (copy attached). I have rarely, if ever, worked on a review panel on which all the members had such similarity of opinion. My work in summarizing the comments on the geology really boiled down to choices of whose wording to paraphrase in the compilation.

I feel it is necessary, however, to add my comments to those expressed by many other reviewers about the overall scientific direction of the project. Perhaps the simplest way to do this would be to ask John Farr if I might simply add my signature to his letter since his comments so closely follow my own impressions.

I am very concerned that the multi-laboratory approach may be leading into very serious coordination problems for the project. This is no one's fault because the groups (each of which is doing truly excellent scientific and technical work) will tend to approach the problem from their own perspectives. This can only lead to duplication of effort (evident already in the core studies) and a tendency to disregard the motives or perceptions of others.

This poses a very difficult management problem since I strongly suspect that although this project is not high priority for any of the groups none would cheerfully assign its relevant subgroups to the sole direction of one. Probably this problem is exacerbated by the fact that within each organization the relevant groups are working on other projects at the same time. This is certainly true for some of the USGS projects.

There have been several suggestions for the review panelists on how to deal with this. I regret that I am not familiar enough with interagency protocol (politics?) to offer very constructive ideas. Perhaps some sort of committee with a representative from each group (and Nevada Operations Office) could be established with full time members. It is also evident that Bill Twenhofel has things in far better control than a year ago and since he has only been with you for a short while, he may very well be on the road to getting things straight already.

Finally a word about the scientific direction itself. I think what has been lacking up till now has been a concept or a model of what a repository should be. With such a model, the acquisition of data suddenly takes on much more meaning than it does when one is simply out to see what is there. In the latter approach one simply goes on gathering data because there is no criteria of when to stop. You don't know when you've done enough because you don't know what you're looking for.

I see this failure to have a concept of a repository as the major failure and it is the reason why so many of the participants can continue to do good work but not with coherence.

Larry Larsen gave what he called a speculative scenario on TEF site selection in his thoughtful letter to you. This scenario is akin to the concept and model I discussed. It is in fact, a basic approach of all science. You assemble some observations and form a theory. You then test this theory usually to discover that more directed observations are needed and the theory is refined. Finally theory and observations are compatible and you then have a way to predict what will happen (the physical law has been established).

I hope these comments are useful to you. I have become very interested in this project and am even beginning to have some hope that criteria can be established for a safe repository and that one might even be found. I do hope that such a nationally important study will not bog down for want of the application of a little scientific philosophy.

Yours sincerely,

H.F. Morrison

State of Cal. Registered Geologist
Registered Geophysicist
Professor of Geophysical Engineering

HFM:ag

cc: Larry Larsen

SUMMARY OF COMMENTS OF REVIEW COMMITTEE ON GEOLOGY

H.F. MORRISON

The geological studies of Yucca Mountain are excellent; the work is well coordinated and scientifically admirable. The comments and recommendations that follow are almost all in reference to data that should be added or, as if in a small scale reflection of the overall project, are related to a certain lack of direction to the studies.

In general the work to date has been of a mapping or descriptive nature; it is now necessary to focus the studies toward the specific requirements of a repository site. In broad terms a set of criteria for a site should be put forward and the geological studies directed toward verifying whether or not these criteria can be met.

The Quaternary geology (Hoover et al) studies are very well done and should be strongly supported. Still more emphasis should be placed on mapping and dating recent faults. The faults, and jointing and fracture patterns, are needed to compile a three dimensional model of the structure through the repository. The age of the faults will be of fundamental importance in the seismic risk analysis of the area. The latter should be considered a high priority item and if such studies require more trenching then this should definitely be budgeted.

The review committee was surprised to learn that available photo/imagery may not have been reviewed. It is somewhat disturbing that Dr. Gary Oloehft of the USGS reported that a lineament has been found by remote sensing that appears to transect Yucca Mountain . Its presence or absence must be substantiated. All available Landsat, SLAR, SR71 and other imagery must be reviewed

and incorporated into the regional and local geologic maps.

The time has also come to begin compilation of the subsurface geology through three dimensional models of the structure, stratigraphy, mineralogy etc. The characterization of a repository requires the spatial distribution of the different kinds of tuffs(welded, zeolitized etc.) over distances large enough to make repository construction possible. It depends on knowing the fracture orientation and density since this is crucial to the hydrologic models. If this fracture information cannot be obtained from vertical holes(because the fractures may be vertical)then plans should be drawn up for inclined holes. Characterization requires a knowledge of the spatial variations of the rock properties (porosity, permeability) mechanical strengths and mineralogy. It will become rapidly apparent when such a compilation is attempted just how much more information is required and in what form. A majority of the review committee feels that more holes drilled on the periphery of the prospective site will be required before such models can be constructed.

This stage of compilation will also force the integration of the core studies being carried out by various groups. A primary data base will be sections in which well logs and stratigraphy defined by mineralogy and petrology, hydrology, mechanical properties etc. can be displayed side by side. These sections at each hole will then become the elements in the three dimensional reconstruction. An essential part of this study is a full utilization and integration of the geophysical well logs. This has not been properly done to date.

The important point is that this synthesis of data must begin now, because it will in turn lead to the appropriate focus for further studies.

In somewhat more detail the committee strongly recommends that increased emphasis be placed on the study of the unsaturated Topopah formation. More

work on the nature of the lithophases their degree of interconnection, the mineralogy within the cavities, etc. will be needed to characterize this zone as a potential repository. Strong efforts should be placed on fracture mapping in this zone.

The large diameter hole must be used for geological mapping. It provides an unparalleled opportunity for acquiring this information even at added cost to the drilling. This latter point, the cost of drilling vs. the scientific information required for site characterization epitomizes one of the serious problems in overall direction. The large hole drilling programs appear to be on a course that is independent of the very studies that are being conducted to site and design the hole!

Finally, and again an indication of the lack of overall coordination, there must be some formal overview committee established for handling, distributing and cataloging the core. This precious material is presently shipped around on request for a variety of studies (some of which are duplicate efforts) and apparently not monitored or even very well recorded.

In summary, the geologic studies to date are admirable. The time has come to finish up the maps, get them out to the various groups involved and begin a compilation and integration of the geology and all the other data. At the same time, some hypotheses must be advanced to model the desired characteristics of a repository and the future studies focused and directed toward these objectives.

PAUL R. FENSKE, Ph.D.
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October 7, 1981

Dr. P. A. Domenico
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Champaign, Illinois 61828

Subject: Peer Review of Hydrology for the Proposed High Level Radioactive
Waste Repository in the Southwest Portion of the Nevada Test Site

Dear Pat:

Before writing my review comments, I again reviewed the comments made by the peer reviewers over the last two years that I have been involved with the peer review program. I find that I would not care to modify in any significant way the comments that I have made previously with respect to the Waste Repository on the Nevada Test Site. It is gratifying to note my comments and comments of other reviewers were seriously considered by the contractors. This year, I will confine my comments essentially to hydrology because the people involved in the other aspects of geology related to the repository, such as geophysics and geochemistry, are more qualified to comment in those areas. Any comments that I have, therefore, outside of the immediate area of hydrogeology, will be general. I do not know what the procedure will be for handling those type of comments, however, I see no reason why they might not be included in your report as Chairman of the Hydrogeology Subcommittee.

My general impressions are that:

- 1) Even though I was gratified to see more exchange between the groups involved in the technical aspects of the project, I feel that the overall technical direction could be improved. Too often overlap or lack of goal orientation seemed to appear.
- 2) The development of a waste repository is basically an engineering problem. Although I find the science portion of the effort fascinating, I sense that there is probably scientific overkill in some areas.

Hydrogeological Modeling

Hydrogeological modeling has three aspects. The first is the numerical model. The state of the art of numerical modeling can be considered ubiquitous and fairly well developed. However to apply the numerical model, one requires data input, such as hydraulic heads and measured transmissivities, and a conceptual model. There is not enough input data and perhaps some of it is questionable. The conceptual model, on the other hand, involves essentially subjective judgements of the locations of regions of recharge, high permeability, low permeability, and, less subjectively, regions of discharge.

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702-322-1187

October 7, 1981

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The two dimensional regional finite element model presented by Waddell is to provide fluxes at the boundary of a more localized, but also more sophisticated three-dimensional contaminant transport model representing the region of the repository. The only requirement for the regional model, therefore, is that the fluxes that will appear at the boundary of the three-dimensional repository model be as realistic as possible. Areas near the repository site, therefore, must be better defined than areas at great distance from the repository site. That is, although around the fringes of this regional model, Pahute Mesa, for example, recharge areas may be lumped into one large area of evenly distributed recharge, as the repository area is approached, smaller regions of lesser recharge may not be neglected. It was surprising, for example, that Timber Mountain having an elevation comparable to Pahute Mesa with a projected rainfall greater than 10 inches, similar to Pahute Mesa, was not considered to be a recharge area. Cane Spring on Skull Mountain and Topapah Spring on Shoshone Mountain in the southwest quadrant of the Nevada Test Site also suggest active recharge potential in those areas. The heat flow presentation by Sass suggests that even portions of Yucca Mountain may be subject to recharge. At distance from the repository boundaries, these small recharges may be insignificant. Close to the repository boundaries, however, they may significantly alter flow paths and flux. Although the finite element model suggests otherwise, the convergence of flow towards 40 Mile Wash as shown by contours on Wilson's hydrogeological maps of the southwest portion of the Nevada Test Site suggests that there are sources of recharge water on either side, both east and west, of 40 Mile Wash. This is not to challenge the conclusions of Klassen that recharge may have occurred through the wash bottom thousands of years ago. Recharge may occur through the bottom of 40 Mile Wash under exceptional conditions even today.

The proposed hydrologic test hole, RH1, in 40 Mile Wash, may add substantially to our knowledge of the hydrologic system in the near vicinity of the waste repository site, and, therefore, improve our estimation of the flux into the boundaries of the three-dimensional model representing the repository site. In addition, I suggest that a hole immediately west of the potential repository site in the east edge of Crater Flat be drilled to determine the position of the water table and the possible transmissivity and flow paths of ground water along with heads throughout the section.

At this time one wonders whether the construction of a sophisticated three-dimensional contaminant transport model of the repository site is justified. It will be virtually impossible to obtain the kind of data that will be necessary input to such a model. Models are useful for sensitivity analyses to bound the variations in parameters that can exist within the flow region without causing rapid transport of contaminated water to a point of accessibility to the environment. However, as a predictor of contaminant transport, the model is no more useful than less sophisticated models. That is, knowing the ground water velocity and flow path away from the repository to the discharge area, all one needs, particularly in the far field, is the proper input for a one-dimensional longitudinal transport model.

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Why is a large amount of time and money being spent in fundamental studies of parameters such as sorption and dispersion? Sorption, for example, is being precisely evaluated for a limited number of samples of rock from holes that are not even downstream from the repository. In the area influenced by flow from the repository, almost all hydrological parameters and geochemical parameters are going to vary as a result of location and direction of flow. Therefore, one cannot use a constant hydraulic conductivity, a constant dispersivity, a constant retardation, or consider that specific chemical reactions will uniformly occur. To develop a truly credible model, one must at least have a valid statistical sampling of these parameters in the downstream direction.

These considerations apply equally well to a repository in the saturated or the unsaturated zone. I would modify one of my previous peer review statements about putting the repository in the deep saturated zone. Not because that would not be hydrologically appropriate, but because of the difficulties in constructing a repository at such depths. The repository should be placed in the unsaturated zone where recharge and transport of the contaminant out of the repository to the water table would be required before any transport within the hydrologic system could take place. The time required for transport to the unsaturated zone would add an increment of delay in the appearance of the contaminants at some point assessible to the environment.

Hydrogeologic Testing

The committee in their general statement on August 28, 1981, for the third year in succession, made the point that adequate hydrologic data must be obtained around the proposed site and within the site. The request has been amplified to include hydrologic studies of flow in the unsaturated tuffs as well as endorsing the studies done in the USGS research on flow in the unsaturated alluvium. Transmissivities of hydrostratigraphic units must be measured, and they must be measured in enough locations to provide a statistical sample of the variations of permeability within any one hydrostratigraphic unit. Heads must be carefully measured as the function of depth in the hydrologic system on all sides of the repository. There is no substitute for this data. Hydraulic tests should also be designed to measure vertical permeability and to measure the permeabilities of the "impermeable" units that separate the hydrostratigraphic units. If necessary, a rig must be dedicated to the hydrogeological program so that there is ample time to obtain the required measurements and to experiment and advance the technology to the point that required measurements can be obtained.

Water samples should be collected at the water table to measure both the stable and unstable isotopes, carbon 14 for possible age dating the water, tritium to assess the possibility of recent recharge, and oxygen isotopes to approximately locate the area of recharge. Similar analyses excluding tritium analyses should be carried out for water collected in each hydrostratigraphic unit. Fundamental level studies are required of stable isotopes

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Page Four

and radiocarbon in recharge areas to understand the significance of the stable isotopes and carbon 14 in ground water at Yucca Mountain.

The hydrogeologic data, heads, transmissivities, age dates of water, must be determined to construct even the simplest one-dimensional model of transport of contaminants from the repository to a point accessible to the environment. Last but not least, one needs a method for determining the effective porosity normal to the flow direction, since this parameter is indispensable for calculating the velocity of the ground water and therefore, contaminant transport time.

Other Comments

It appears from Klassen's work on the age dating of ground waters, that the transport time from Yucca Mountain to use points in the Amargosa Desert may well be on the order of several thousand years neglecting retardation, and neglecting dispersion. I do not believe that the contaminant transport time would be as short. Even neglecting retardation due to sorption, much of the flow in a system would be through a double porosity system where the movement will be down fractures but also through interfracture blocks. If interfracture blocks are permeable, then it is necessary hydrodynamically that water flowing down the fractures also flow through interfracture blocks. Since the permeability of interfracture blocks may be finite but small, and since the hydraulic heads cross these blocks will be determined by regional gradient, once the contaminant enters an interfracture block the residence time will be long relative to fracture transport. The interfracture blocks will act as storage cells and retardation cells for the contaminant whether sorption occurs or not. The effect of sorption will be to prolong the stay of contaminant in these interfracture blocks almost indefinitely.

Although, as Larry Larson pointed out, the statement that anything can be engineered may be a rash statement to make, a somewhat modest and modified statement can be made. If a repository is placed in a "reasonable" medium, a medium that has most of the requirements for a repository, the other problems can be engineered around. For example, the saturated zone transport through a repository that will pick up contaminants and move them out of the repository depends upon the hydraulic gradient across the repository as well as the permeability of the backfill material in the repository and the permeability of the host rock. It would be a rather simple matter to reduce the gradient across the repository to essentially zero, by creating a hydrologic short circuit around the repository, a high permeability region such as a tunnel not in any way connected to the repository but surrounding the repository. Water flowing through the high permeability region would equalize heads upstream and downstream from the repository and reduce the gradient to essentially zero across the repository. Under those conditions regardless of the permeability of the backfill, very little water transporting contaminants could ever move out of the repository into the hydrologic system. A similar system with similar results could be designed for the saturated zone immediately beneath a repository in unsaturated rock.

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Summary

Although a three-dimensional model is probably a requirement, I am not convinced that one should continue to put a large amount of effort into the construction of a sophisticated three-dimensional contaminant transport model. Detailed studies of sorption on samples of tuff from the Yucca Mountain site should continue at a reduced level. I am certain that more hydrologic testing has to be done, making accurate measurements of heads and transmissivities of hydrostratigraphic units within the saturated zone and unsaturated permeable units like the Topopah above the saturated zone. Fundamental studies of movement of water through the unsaturated alluvium of the southwest portion of the Nevada Test Site should continue. Isotopic analyses of water, both for stable and radioactive isotopes is extremely important. More important yet is the intelligent interpretation of this data in terms of ground-water velocities, and ground-water flow systems. The interpretation requires isotopic analyses of precipitation samples from potential recharge areas as well as some fundamental studies of C^{14} content of the near surface materials in suspected recharge areas.

If there are any comments or questions regarding this letter, please do not hesitate to call me.

Sincerely yours,

Paul R. Fenske
Hydrogeologist

PRF:sp

cc: R.C. Epis, Colorado School of Mines, Golden, CO
J.B. Farr, Western Geophysical Company, Houston, TX
R.N. Farvolden, University of Waterloo, Waterloo, Ontario, Canada
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L.T. Larson, University of Nevada, Reno, NV
H.F. Morrison, University of California, Berkeley, CA
R.M. Nelson, Jr., Department of Energy, Las Vegas, NV
H.P. Ross, University of Utah, Salt Lake City, UT
A.S. Ryall, University of Nevada, Reno, NV
G.A. Thompson, Stanford University, Stanford, CA

MACKAY SCHOOL OF MINES

"A School of Mineral Resources"

UNIVERSITY OF NEVADA, RENO

RENO, NEVADA 89557

Oct. 8, 1981

Department of Geological Sciences

Dear Al:

Just this morning received Frank Morrison's Geology synthesis. Am enclosing a copy. I will get to the total synthesis when I get back from the field next week.

YOU now have essentially the 'rough' drafts (in fact with a covering page or two probably the final or near final drafts of the peer review report. I doubt, however, if the various peer reviewers would like this particular issue to be bound and published but would prefer to have a chance to look over the thing in toto.

Cheers,

Larry L.

AUGUST 1981 PEER REVIEW
NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS

Geology - Hydrology Committee

Geophysics Subcommittee Report

Howard P. Ross
John B. Farr
H. Frank Morrison
Alan Ryall
George A. Thompson

September 26, 1981

Introduction

This report summarizes the technical comments of the five NNWSI Peer Review geophysicists and additional contributions regarding the NNWSI geophysical program by other members of the Geology - Hydrology Committee. The report integrates the various comments for each geophysical topic and identifies a few specific differences of opinion between committee members. There is general agreement between geophysicists regarding the evaluation of work already completed, the problems to be solved and the priorities for future work. Individual letters of comment may be consulted for added details reflecting an individual reviewer's specialty.

Geophysical studies should make a substantial contribution to the NNWSI geologic studies, especially when drilling is restricted to minimize penetration of the potential repository site. Unfortunately the geologic environment of the Yucca Mountain area gives rise to poor seismic reflection quality (thus far), to complex electrical resistivity data, and to ambiguous responses for some of the other methods. The geophysical studies to date have included several limited efforts with little integration of data sets and other geologic information. The need for better program direction and management to focus on necessary studies, to enforce on schedule reporting, and integrated interpretations is apparent in the geophysical program as it is in other technical work at the NNWSI. The subcommittee notes that similar comments were reported following the 1980 NNWSI Peer Review and that major management and communication problems, as we perceive them, still exist.

Reflection Seismic

The vertical seismic profiling (VSP) reported by Doug Muller included some very positive results. Details of attempted and planned Vibroseis surveys were not presented to the committee. All the geophysicists recognize that reflection seismic has the greatest potential for providing high-resolution information on stratigraphy and structures in the Yucca Mountain area. It is apparent that the seismic work to date has been compromised by partial efforts - VSP surveys for portions of drill holes rather than total depth, and by inadequate survey and recording equipment. We recognize that reflection seismic work will be difficult and expensive in the geologic environment of the Yucca Mountain area, and there is a good possibility that interpretable reflection data may not be obtained. None the less the geophysicists on the Peer Review Committee are unanimous that a no compromise state of the art reflection survey should have the highest priority of all new geophysical work. Such work should include total depth VSP for available boreholes. John Farr suggests the following parameters as an indication of the type of survey required: high multiplicity (48 fold or more), large source arrays (4-5 vibrators operated simultaneously over many closely spaced source positions), large receiver arrays (144 geophones per detector group in areal patterns feathered to optimize cancellation of long and short wavelength noise), and specialized recording procedures to avoid noise (i.e. recording at night or at sunset when wind noise dies down). Ross notes that high frequencies and short spread lengths may be required to maximize spatial resolution.

The reviewers recommend that there should be no compromise on contractor competence, equipment and experience, and that the most qualified USGS personnel be assigned to this project for survey design, supervision and

interpretation. Should initial reflection seismic profiles be successful, then the immediate site area and the entire Yucca Mountain block should be mapped via a grid of seismic lines or a 3-D plan layout.

Refraction Seismic

The detailed refraction profiles (NTS shots) and modeled refraction results represent excellent work and indicate a 1.5 - 2 km offset in basement, in agreement with the detailed gravity data. The panel recommends that Mooney's refraction results should be integrated with Howard Oliver's regional gravity model, and perhaps with Healy's teleseismic p-residual study to provide a self consistent multiparameter model of the crustal structure for a substantial area surrounding the Yucca Mountain block. George Thompson recommends continued recording of earthquakes and nuclear tests on the multichannel portable instruments in an attempt to better define sub-volcanic structure and lithologies. Others feel that this data will have little influence on the siting of the TEF.

In an attempt to help focus the geophysical efforts the panel gives a low priority to additional refraction surveys at the present time. Instead we emphasize the need for a geologically oriented synthesis of existing refraction data with p-wave delay, regional gravity, and other appropriate data. Perhaps contradictions in the existing p-wave data interpretation will be resolved in this manner.

Gravity Studies

Howard Oliver presented an excellent regional gravity map for the area within a 100 km radius of Yucca Mountain. The data have been modeled in a state of the art manner to arrive at a three-dimensional density model and this indicates a major graben-caldera structure. Also presented was a detailed gravity profile across Forty-mile Wash which helps to define structural controls on this important feature. This quality work is an excellent contribution to the geology of the area. John Farr recommends extending the detailed profile up Drill Hole Wash and part of Yucca Mountain. Howard Ross notes that the density contrasts and vertical displacements noted at Forty-mile Wash probably are not present further west and structures within Drill Hole Wash and the Yucca Mountain volcanics will be difficult to map with gravity. Any gravity profiles directed at structural definition of Drill Hole Wash should be as near normal to the wash as practical. Alan Ryall sees no specific need for additional gravity data acquisition and the panel would give a low priority to additional gravity surveys.

The panel strongly encourages an integrated interpretation of the 3-D gravity model with refraction and teleseismic results. Similarly the detailed gravity profiles may contribute to the interpretation of the electrical resistivity data.

Magnetic Studies

A detailed low level aeromagnetic survey completed at least two years ago has still not been interpreted in a quantitative manner. A single truck mounted magnetometer profile further documents one anomalous area indicated on the airborne survey. Wil Carr notes that the geologists are regularly using and interpreting the airborne data in a qualitative fashion and find the magnetics a most useful data set. As noted at previous Peer Reviews, a quantitative interpretation of this survey is long overdue. If the USGS cannot allocate experienced personnel to complete this relatively minor job then outside industry contractors with a numerical modeling capability should be engaged to do the job.

The single truck mounted magnetometer profile is indeed interesting but "mobile magnetometer profiles" are nothing new, and a single ground profile, not yet interpreted, represents a very limited work effort. Howard Ross would recommend a few days of low level helicopter magnetic surveying in preference to the more limited, erratic profiles of truck mounted or ground magnetic surveys if detailed ground follow up seems warranted by the aeromagnetic data interpretation. The data interpretation should utilize any susceptibility and remanent magnetic data already available on these rocks but need not require a major effort in rock property studies. Once again the Peer Reviewers request a quantitative interpretation of the detailed low level magnetic survey!

Electrical Studies

The committee noted that no specific reports were prepared for the electrical methods and requested status reports on these data. We were disappointed that the electrical program reported in previous years by Don Hoover, USGS, had been discontinued and that no summary interpretative report has yet been written. The electrical resistivity discontinuities are pronounced physical property differences within the tuffs and must be explained in terms of drill hole results, geophysical logs, and other data.

Jeff Daniels presented results of his hole-to-surface electrical studies. His presentation indicated several specific interpretative products, primarily relating to near surface conductive zones, as a result of a substantial effort in field surveys, program development and interpretative modeling. We understand that reports on this work are currently in the review process. The hole-to-surface results and geophysical well logs (especially resistivity logs) are additional data that must be integrated with surface electrical surveys, gravity, and geologic data as soon as possible. John Farr and Howard Ross encourage the use of outside contractors to effect this if USGS principals (Don Hoover, Jeff Daniels) cannot schedule it in the near term.

The committee recommends no new surface electrical surveys until the integrated interpretation is completed, with one exception. Hole-to-surface resistivity surveys should be completed as new holes are completed and when hole conditions (casing, etc) permit. Two reviewers, H. F. Morrison and H. Ross, have reservations about achieving substantial model results for hole-to-surface surveys but do recognize the opportunity to obtain detailed electrical data provided by the boreholes.

Borehole Geophysics

The committee did not receive a complete understanding of the borehole geophysics program. Jeff Daniels has apparently completed in depth studies of well logs related to the hole-to-surface studies and indicated substantial physical property characterization of the units logged. Wil Carr indicates that a suite of logs are routinely run in new drill holes and are used by hydrologists in planning hydrologic testing and by geologists in lithologic studies. The reviewers are unanimous in believing a more complete, better organized logging program should be underway.

We envision a full suite of geophysical logs for every hole and the use of this log suite as the primary physical property record for the lithologies cut by the hole. All specific physical property studies, geotechnical core studies, mineralogic, petrologic and hydrologic results should be related to these logs and should in turn contribute to a better knowledge of the particular log responses. Heat flow and temperature gradient measurements could be included here. The suite of logs should give rise to an overall record of porosity, permeability, fracturing, lithology, etc. for each bore hole.

A well coordinated program of borehole geophysics and integrated log interpretation is the Peer Review Panel's second priority for present and future work.

Seismic Risk Analysis

It is apparent to all geophysicists and several other members of the committee that some finite level of seismic hazard must be associated with the Yucca Mountain block and could possibly pose major problems for licensing a future repository here. We understand that exact standards for this matter have not yet been established by the NRC. The committee therefore strongly recommends that a formal Seismic Risk Analysis be initiated. Ongoing micro-earthquake recording, the seismic record to date, nearby Quaternary fault scarps and other Quaternary geologic studies and tectonic studies, are all important and available elements to this study. We also recommend that a dialogue begin immediately with NRC which addresses the proposed criteria for repository siting with respect to seismic risk. The NRC should then be asked to comment specifically on the in-progress Seismic Risk Analysis for the proposed NNWSI repository area.

Remote Sensing

The panel was told during the geophysical sessions that a "remote sensing linear" transects the Yucca Mountain area, possibly the proposed repository site itself. Details of the rumored anomaly were lacking, but the feature was once the subject of a proposed remote sensing study. We recommend a high priority, but hopefully low cost effort, for the evaluation of the reported linear. Landsat, high altitude infrared (U-2 ?), side look radar or other data are undoubtedly available for preliminary study of this rumored feature. The "linear" would certainly be an issue at site characterization or licensing time.

Priorities

A brief restatement of the committee's priorities for future geophysical work is in order. They are:

1. Reflection seismic parameter study - a first class effort!
2. Electric log data acquisition and detailed property interpretation.
3. Seismic risk analysis.
4. Remote sensing linear at Yucca Mountain - evaluate and document.
5. Ongoing integration of passive seismic, refraction, gravity and other geophysical data - with geophysical and other geological hydrological, geochemical, and engineering data.

We recognize that much good work has been done and that major difficulties have developed in the application of several geophysical methods. The technology is available to solve most of these problems. The exploration effort must now be focused on those items relating most specifically to site selection, horizon selection, and possible licensing issues.

Respectfully submitted,

Howard P. Ross

Howard P. Ross

Senior Geophysicist
Univ. Utah Research Institute

**APPENDIX B: INDIVIDUAL PEER REVIEWER
CORRESPONDENCE ON THE GEOTECHNICAL/
GEOENGINEERING SESSION**

KAISER ENGINEERS

KAISER ENGINEERS, INC.
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September 1, 1981

Christopher M. St. John, Associate
J.F.T. Agapito & Associates, Inc.
Suite 340
715 Horizon Drive
Grand Junction, CO 81501

Subject: Peer Review Comments, Review of
Geotechnical/Geoengineering
Nevada Nuclear Waste Storage
Investigation of TUFF
August 24-28, 1981

Dear Christopher:

This letter presents my peer review comments, presented in terms of general TUFF work, specific TUFF program work and the relation of 10 CFR 60 to TUFF work.

GENERAL

Based upon the August 24-28 presentation on TUFF and upon my review of selected documentation on TUFF issued by the Nevada Operations Office, I judge the technical quality of the work on TUFF to be excellent. Further, I conclude that no information has been developed to date which precludes the development of a geological repository in TUFF in accordance with the rules of the Nuclear Regulatory Commission (NRC).

SPECIFIC TUFF PROGRAM WORK

The following paragraphs present my comments on five specific topics which are judged to warrant increased TUFF program emphasis.

1. Water Migration Near Stored Waste (Near Field)

The G-tunnel water experiment in welded TUFF demonstrated the collection of a large amount of thermally driven water in the waste storage hole, presumably because the path of least resistance to vapor flow led water to the storage hole. No fault is found with the proposed future G-tunnel testing to further study near field migration of thermally driven water. Nevertheless, because preferential water accumulation in the waste storage hole conjures up many

scenarios very unfavorable to the near field containment of nuclear waste, I strongly recommend promptly conducting several small hole heater tests to explore near field water migration as a function of such variables as media temperature and waste package design.

2. Nuclear Waste Transport (Far Field)

A favorable conclusion upon completion of the exploratory shaft (ES) program is that the horizon is suitable for a geologic repository. Suitability includes demonstration that nuclear waste transport is below the limits set by the NRC. I recommend that the TUFF program immediately initiate the following three consequence calculations:

- (1) Upper limit nuclear transport - based upon a scenario of total near field nuclear waste release and realistic, upper limit strata properties.
- (2) Most probable nuclear release calculations.
- (3) Most optimistic nuclear release calculations.

Now data may only permit doing the upper limit calculation. However, when strata property data become available from the ES program, it will be practical to make most probable nuclear release calculations, most optimistic nuclear release calculations and to refine the upper limit calculations. The difference between the results of the upper limit calculations and the most optimistic calculations is indicative of the reliability of waste isolation.

3. Time-and-Temperature Dependent Physical Properties (Near Field)

Mining engineers know how to design a mine so that it will remain open for an extended time; that design is helped by the low extraction ratios associated with a repository. A major repository design question is the time-and-temperature dependence of the physical properties which govern repository integrity and closure. The TUFF program should focus upon establishing the time-and-temperature dependence of the near field physical properties before completion of the ES program.

4. Existing Site Excavations

It is recommended that existing site excavations be studied to establish limiting values for the chosen repository horizon and overlaying strata.

5. Repository Design Criteria

It is recommended that the forthcoming repository design criteria include, among other topics, the waste form, the waste package, allowable near field temperatures and required design safety factors (or their equivalent). It is further recommended that the basis of all the criteria be included with the criteria to provide the program rationale for limited interaction of those criteria based upon repository design studies.

10 CFR 60

Section 60.102(d) of 10 CFR 60 states, "A period of operations follows the issuance of a license by the Commission. The period of operations includes the time during which emplacement of waste occurs; and any subsequent period before permanent closure during which the emplaced wastes are retrievable..."

Section 60.131(h)(2) of 10 CFR 60 states, "Subsurface ventilation. The ventilation system shall be designed to - Permit continuous occupancy of all excavated areas during normal operations through the time of permanent closure."

One interpretation of the above, a seemingly unconscionably costly interpretation, is that subsurface ventilation shall permit continuous occupancy of excavated (and not yet backfilled) areas containing retrievably stored waste. Design consequences of the interpretation are that the subsurface ventilation either shall (at considerable operating cost) maintain the surfaces of all excavated (and not yet backfilled) areas containing retrievably stored waste below some safe temperature (say 125 F), or shall promptly backfill all areas containing retrievably stored waste (thereby reducing operating costs but making retrievability very complex).

It is recommended that the TUFF program seek an alternative interpretation of the above, wherein there may be a reasonable delay (say two weeks) before it is necessary to support occupancy of selected excavated (and not yet backfilled) areas containing retrievably stored waste.

Meaningful repository design criteria cannot be complete until the above rules are clarified by an NRC interpretation.

* * *

Christopher M. St. John
September 1, 1981
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I am looking forward to reading the consolidated comments of the geo-technical/geoengineering peer reviewers. Should you wish, I can be reached by phone at (415) 271-4142.

Very truly yours,

KAISER ENGINEERS, INC.

A handwritten signature in dark ink, appearing to read "Joe", with a horizontal line extending to the right.

Joe S. Busch, Ph.D.

JSB:vb

TEXAS A&M UNIVERSITY

COLLEGE OF GEOSCIENCES

COLLEGE STATION, TEXAS 77843

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(713) 845-3251

September 2, 1981

Dr. C. M. St. John
Agapito and Associates, Inc.
715 Horizon Drive, Suite 340
Grand Junction, CO 81501

Dear Chris:

Because our Peer-Review Group discussed the critical geotechnical issues of NNWSI in great detail and because you will be synthesizing our deliberations and common opinions, I shall simply list below what I regard as the most serious deficiencies in the program as a whole.

(1) The hydrological data-base is inadequate, both regionally and locally at Yucca Mountain. I can't imagine how site-selection among the four potential horizons can be done without knowledge of their groundwater-flow characteristics. Nor can credible far-field performance assessment proceed.

(2) I am dismayed that so little progress has been made toward the design of a workable waste package. There is no way that the conceptual design exposed to us can meet the NRC criterion. I recognize that this is a NWTS-wide, rather than a local responsibility, but I submit that any effective engineered barrier in the very-near field must be medium-specific.

(3) Knowledge of the macrofracture (joint) systems is woefully inadequate, owing principally to the obvious fact that small vertical boreholes poorly sample quasi-vertical fractures. Slant holes deserve consideration, for the technique worked well at Stripa.

(4) In this regard especially, but also for site characterization in general, the entire section of rock overlying the potential repository should be examined as carefully as possible within the allowable budget and time frame during the drilling or excavation of the exploratory shaft. Credible, predictive, far-field, thermomechanical/hydrological modeling cannot proceed without input adequate for coupling the thermal, mechanical, and hydrological codes, applicable to the fractured rock-mass.

(5) Owing to the presence of hydrated minerals in tuff, water migration may be a serious problem, especially in the very-near field where ground water will interact with the waste package. If at all practicable, in-situ heater tests should include mock waste-packages.

(6) The complexity of geochemical transport-modeling is potentially overwhelming. Detailed knowledge of such processes as solution/deposition, diffusion, and retardation cannot be gained within a few years. Sensitivity analysis is needed if limited fiscal and human resources are to be wisely focused.

(7) The issue of the time-dependence of pertinent physical properties--especially strength and permeability and their dependence on thermal cracking--remains unresolved. At least a modest study is needed to judge whether further laboratory experiments are required to settle this matter, because thermally-activated processes may well be significant even in the range of 100°-200°C, given times of the order of 10^4 years.

(8) It seems to me that if we are to convince NRC and the public generally that a particular repository should be licensed, we must carry uncertainty analysis through the entire model from performance to consequence to risk. Such an approach would be difficult and costly, but I'd prefer relatively simple codes that could account for uncertainty over 3-D "supercodes" that would probably overload our computer capacity anyhow.

(9) Finally, owing to the urgent national need for licensable, high-level, nuclear-waste repositories and hence the immediate demand for timely and sharply focused investigations, coordination among participants from the three National Laboratories, the Geological Survey, and all their contractors must somehow be improved. The Working Group on Mine-Design Studies seems to be functioning effectively. On the other hand, synthesis of geological, geophysical, and hydrological data is lagging, so that meaningful performance assessment is delayed.

Indeed, the entire NWTS Program badly needs better coordination. I do not mean to imply doubt about the competence of either the managers or the technical staff anywhere in the system. After all, underground waste-isolation is surely among the most perplexing problems that our country has ever had to face, and research and development are evolving rapidly. I am confident that we shall solve the problems--administrative, institutional, and technical--in good time.

Sincerely,

John Handin
Professor

JH/rm

xc: R. M. Nelson

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September 3, 1981

Mr. Robert M. Nelson
Project Manager, NNWSI
Department of Energy
P.O. Box 14100
Las Vegas, NV 89114

Dear Bob:

Enclosed is a copy of my comments to Chris St. John, leader of our Geotechnical Subgroup, regarding our peer review of your NNWSI Program during the week of August 24-28. The format of the meeting is the best yet devised, and I can think of no way to improve it much and still adequately cover the large and growing subject matter. I feel sure that the expert opinions of objective outsiders are useful to you and your staff. There are rewarding by-products too. The superior science and engineering in the Program are exciting to the reviewers, and the opportunity for exchange of ideas among most of your project leaders might not often arise otherwise.

The peer review of 1979, presumably your first, was somewhat disappointing because it was largely post-mortem and happened too late significantly to influence your planning. Even so, we knew that you listened carefully. This year's review, on the contrary, came at a relatively early stage of what had become a sharply focused, site-specific plan, so that we reviewers can feel satisfied that our opinions will be regarded seriously and could be acted upon at least in principle.

I should like to continue my service as a peer reviewer. However, you should know that next month I shall begin consulting for RE/SPEC, one of your contractors. I expect to be working mostly on salt repositories, but I may be asked for advice on some tuff-related geotechnical problems. So, if you perceive any potentially serious conflict of interest, I shall withdraw, of course.

It was good to see you again, and I'll look forward to another visit early next year if you want me there.

Best regards,

John Handin
Professor

JH/rm

enclosure

TEXAS A&M UNIVERSITY

COLLEGE OF GEOSCIENCES

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September 2, 1981

Dr. C. M. St. John
Agapito and Associates, Inc.
715 Horizon Drive, Suite 340
Grand Junction, CO 81501

Dear Chris:

Because our Peer-Review Group discussed the critical geotechnical issues of NNWSI in great detail and because you will be synthesizing our deliberations and common opinions, I shall simply list below what I regard as the most serious deficiencies in the program as a whole.

(1) The hydrological data-base is inadequate, both regionally and locally at Yucca Mountain. I can't imagine how site-selection among the four potential horizons can be done without knowledge of their groundwater-flow characteristics. Nor can credible far-field performance assessment proceed.

(2) I am dismayed that so little progress has been made toward the design of a workable waste package. There is no way that the conceptual design exposed to us can meet the NRC criterion. I recognize that this is a NWTs-wide, rather than a local responsibility, but I submit that any effective engineered barrier in the very-near field must be medium-specific.

(3) Knowledge of the macrofracture (joint) systems is woefully inadequate, owing principally to the obvious fact that small vertical boreholes poorly sample quasi-vertical fractures. Slant holes deserve consideration, for the technique worked well at Stripa.

(4) In this regard especially, but also for site characterization in general, the entire section of rock overlying the potential repository should be examined as carefully as possible within the allowable budget and time frame during the drilling or excavation of the exploratory shaft. Credible, predictive, far-field, thermomechanical/hydrological modeling cannot proceed without input adequate for coupling the thermal, mechanical, and hydrological codes, applicable to the fractured rock-mass.

(5) Owing to the presence of hydrated minerals in tuff, water migration may be a serious problem, especially in the very-near field where ground water will interact with the waste package. If at all practicable, in-situ heater tests should include mock waste-packages.

(6) The complexity of geochemical transport-modeling is potentially overwhelming. Detailed knowledge of such processes as solution/deposition, diffusion, and retardation cannot be gained within a few years. Sensitivity analysis is needed if limited fiscal and human resources are to be wisely focused.

(7) The issue of the time-dependence of pertinent physical properties--especially strength and permeability and their dependence on thermal cracking--remains unresolved. At least a modest study is needed to judge whether further laboratory experiments are required to settle this matter, because thermally-activated processes may well be significant even in the range of 100°-200°C, given times of the order of 10^4 years.

(8) It seems to me that if we are to convince NRC and the public generally that a particular repository should be licensed, we must carry uncertainty analysis through the entire model from performance to consequence to risk. Such an approach would be difficult and costly, but I'd prefer relatively simple codes that could account for uncertainty over 3-D "supercodes" that would probably overload our computer capacity anyhow.

(9) Finally, owing to the urgent national need for licensable, high-level, nuclear-waste repositories and hence the immediate demand for timely and sharply focused investigations, coordination among participants from the three National Laboratories, the Geological Survey, and all their contractors must somehow be improved. The Working Group on Mine-Design Studies seems to be functioning effectively. On the other hand, synthesis of geological, geophysical, and hydrological data is lagging, so that meaningful performance assessment is delayed.

Indeed, the entire NWTS Program badly needs better coordination. I do not mean to imply doubt about the competence of either the managers or the technical staff anywhere in the system. After all, underground waste-isolation is surely among the most perplexing problems that our country has ever had to face, and research and development are evolving rapidly. I am confident that we shall solve the problems--administrative, institutional, and technical--in good time.

Sincerely,

John Handin
Professor

JH/rm

xc: R. M. Nelson

SEP 14 1981

DEPARTMENT OF ENGINEERING

UNIVERSITY OF NEVADA, LAS VEGAS
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September 4, 1981

Christopher M. St. John
J.F.T. Agapito Jr. Associates, Inc.
715 Horizon Drive
Suite 340
Grand Junction, CO 81501

Dear Chris,

RE: NNWS Investigations
Peer Review Comments

I present my remarks, observations and suggestions concerning the present status of the NNWSI, for inclusion in your general report on the geotechnical aspects of the program.

- I. The "Waste Package," Cannister design, backpack and backfill are central to all design questions and decisions. Yet these studies are lagging critically. The lack of a specified heat loading rate is considered to be one reason for the indecision. Part of this indecision can also be traced to a desire to have one single type package that will survive all environments. This is unrealistic in concept and will lead to further delays and needless costs. The storage package must be site-specific in its design.

The backfill is a critical part of the package design as it will determine ultimate heat distribution patterns and dissipation rates. This will also affect the corrosion rate on the cannister exterior, ventilation, maintenance and access problems during the repository access period, and other near-field effects. Yet the "reference backfill" is already shown to be totally unacceptable for the designated use, unless a much lower heat load is to be used than indicated by figures we have been given.

Cannister shell materials and reactions with various types of saturated backfill can be tested with electric heaters in the G-tunnel experiments. It is imperative that this problem be lifted from its apparent low priority and be given adequate funding, technical support and urgency of scheduling. Decisions are urgently required on the cannister and heat loading rate. Otherwise even a prototypical design for a repository may be unrealistic.

- II. Site selection criteria: The fracture permeability of the four designated horizons is unknown. Furthermore, the present program plan is unlikely to produce this critical data. This data can be obtained from the proposed exploratory shaft or by drilling angle holes for exploration.

Studies of failure mechanisms in tuff by Blasic, Parrish, and Olsen are not coordinated and have not delivered a coherent model of likely failure mechanisms during the repository access period. The suggested inventory of tunnels in welded tuff (segments of B tunnel, G tunnel, and possibly others at NTS plus tunnels in welded tuff in the mining districts nearby) should provide some information on tunnel stability and actual failure mechanism at ambient conditions over a long period of time, with and without water saturation.

Repository tunnels should avoid any construction in saturated tuff containing swelling clays. The collapse of U12N.03 is an example to be avoided.

- II. Repository loading scheme: There has been practically nothing reported on schemes for loading the repository at a relatively rapid rate over a period of 30 years. This requires a) approximate knowledge of the size, weights, and radioactive hazards associated with the cannister, b) method of backpacking, and c) rate of loading required. With these data it would be possible to begin brainstorming and conceptual development of loading schemes which would be valuable to have in advance of the TEF, the ADTF and prototypical repository design.
- IV. Radionuclide Transport studies: We were given a long shopping list of proposed research on activity of radionuclides. Dr. John Handin commented that this is a 10 or 20 year program. The nation does not have and cannot afford this time constraint. Critical limiting factors should be selected for study and the decisions based on the "worst cases," I was surprised to learn of the useful studies on water migration from "Cambric" as reported by Larry Ramspott. It would be very helpful to the NNWSI program if there were much greater transfer of data and technology from the weapons program at NTS.

- V. Ultimate repository design: All of the above are to lead to an ultimate design of a proposed repository facility. There are a few areas in which there appears to be no current work that I will mention in this regard:
- a) Backfill of drifts and rooms: A study of the need or lack of need, method of backfill, type and quantity and local sources of backfill materials.
 - b) Sealing of faults and open structures: Regardless of the site selection process and detail of exploration it would be inconceivable that a site of 2,000 acres would not have any structural defects of a geologic nature. How to best handle these should be determined in advance and the fact that they will exist made known to any who may take on unrealistic view at a later date.
 - c) Mining Plan: The operating scheme should take into account the ultimate mining plan. Is mining of the repository to be done at one time, then left open until all cannisters are placed 30 years later? Or is mining to proceed at a pace with the emplacement? If excavation is done by some type of mechanical miner, (no blasting) then the ventilation problem and operational scheme will be greatly simplified in concept.

Realistic design involves "safety factors" regardless of what they are called. This applies to all calculations for the ultimate repository design with respect to expected or unexpected failure.

- VI. Focus and Management: I note a much greater focus on the problem of nuclear waste storage this year as compared with 1980. Yet the question of management continues to arise. Much of this is due to the breadth and complexity of the problem, but it is imperative that there be greater cross feed of data between investigators and that each program be assessed as to its pertinence to nuclear waste storage at NTS.

The question of PERT applicability arose. In my experience PERT is a good tool IF it is used by the management to guide the program and not as an end in itself. It does not, however, point out holes in the program. I have mentioned a few of these that are apparent to me. The program still supports extended research on problems peripheral to nuclear storage, while some problem very central and of immediate concern lack funds or studies.

Christopher St. John
Page Four

I hope you have found my thoughts and remarks to be of value to the program. There is no question in my mind but what this program is of critical importance to the nation and anything we can do to "work the critical path" should be done.

Sincerely,

A handwritten signature in cursive script, appearing to read "Richard V. Wyman".

Richard V. Wyman
Professor of Engineering
Department of Engineering

FVTW/jul

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September 18, 1981

SEP 21 1981

Dr. Christopher M. St. John
J. F. T. Agapito & Associates, Inc.
715 Horizon Drive, Suite 340
Grand Junction, Colorado 81501

Dear Chris:

In accordance with your instructions, I am attaching to this letter copies of my report on our Las Vegas meeting.

I understand you are collecting these reports and will send them on to Dr. Robert M. Nelson and peer committee.

Best regards.

Sincerely,

A handwritten signature in cursive script that reads "Roger W. Staehle".

Roger W. Staehle,
Dean

RWS:mls

Enclosures

UNIVERSITY OF MINNESOTA
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September 11, 1981

Dr. Robert M. Nelson
Director
U.S. Department of Energy
Waste Management Project Office
Las Vegas, Nevada 89114

Dear Bob:

This letter responds to the request that a specific report should be submitted following the August 24 through August 28 meeting in Nevada by the peer consultants.

Before I give my specific comments, several introductory comments are in order.

I was generally impressed with the high quality of scientific work presented at the meeting. I was impressed by the detail and quality of the work and also the presentations themselves. I believe that this program does not lack for either quantity or quality of scientific personnel.

Secondly, the storage of radioactive waste seems to be the primary impediment to reinstituting a major national nuclear program. Thus, there is an overriding incentive to assure that the storage of radioactive waste is developed to a point where the entire national community can be confident of the reliability and facility with which radioactive waste can be stored. This problem may, in fact, be the major single most important national technical problem. It also underlies a major part of our international political strength. Such a perspective, I believe, is the only one that can be taken and further defines the urgency and quality of effort with which this program should move forward.

The engineering capability of safely storing radioactive waste has already been developed; there simply remains to develop an appropriate number of radioactive waste storage facilities.

The most serious issue before us is neither scientific nor technical but, rather, communication. Thus, I concentrate my comments on that problem.

Dr. Robert M. Nelson
September 11, 1981

Page #2 -

Considering communication, we first start with the fact that a large number of organizations are involved in the storage of radioactive waste: national laboratories, commercial vendors, state governments, local governments, federal government, National Academy sponsored committees, and universities.

Secondly, a broad range of disciplines is involved, including the geosciences, civil engineering, mechanical engineering, materials engineering, architecture, chemistry, mining engineering, and physics. In many of these a number of sub-disciplines are involved. Each has in the past considered primarily its own disciplinary area and is unfamiliar with substantial issues in other impinging and related disciplines.

Thirdly, a great deal of information has already been developed by various groups from all over the world - much of it is very high quality and much of it directly applicable.

In view of the broad range of disciplines, organizations, and time covered by the radioactive waste issue, and at the same time the fact that a great deal of necessary information has already been obtained, I believe that present efforts should focus on a communication process which would knit the communities represented by the above together in such a way that they would all become committed to not only the success of the general idea but an acceptable approach. Accordingly, I suggest that a major effort be placed upon developing a 3D computer color model which would have the following characteristics:

- o Showing the relative distance scales associated with the storage of radioactive waste relative to the distance below ground, distances from major habitations, and the general proportional size relative to the state, the nation, and the planet.
- o A time dimension showing both near term and far term.
- o Near field and far field distance relative to the diffusion of radioactivity over time from the waste containers.
- o Properties of the geology including variables of rock chemistry, rock structure, fractures, aquifers.

Dr. Robert M. Nelson
September 11, 1981

Page #3 -

- o Performance parameters including heat density and its time dependence for the waste package.
- o Thermal performance of near field rock.
- o Accident conditions including earthquake, volcanic, accidental penetration.

Such a computer model should be manipulable by anyone and could easily be shown credibly and sensibly to politicians, engineers, scientists, or interested public. The questions they put to the model could then be answered, depending on the questions of accidents, time, distance, and whatever other variables would be appropriate.

I recognize that there are some specific parameters that may not be immediately available, but enough is known in the physical sciences that these can be bounded and approximated within ranges that are acceptable to the scientific and engineering communities.

I believe that this project should receive the highest priority and urgency.

In support of the suggestion above, it also appears that for the same reasons because of the broad ranging nature of this project that greater attention should be given to more precise and focused management of this project. I recognize that many talented people are now involved and that there are efforts to focus already; however, I believe it is now possible to place this project into an engineering time frame where it should be moved ahead forcefully. Such a project needs an aggressive and focused management. While it is inappropriate for me to suggest who that might be, I believe that such a management is possible and absolutely necessary to achieve legitimate and achievable progress.

I believe that if we do not move in these directions of improved communications and management we will progressively lose more good people as well as momentum. Further, if we do not unplug the impediment which has now slowed the nuclear industry to a stop in the United States, it is likely that when this industry is called upon again to produce nuclear power for the United States we will lose this business to other countries.

Dr. Robert M. Nelson
September 11, 1981

Page #4 -

It was a pleasure for me to participate. I would be pleased to supply additional information if necessary.

Sincerely,

Roger W. Staehle,
Dean

RWS:mls

cc:

Bechtel National, Inc.

Engineers — Constructors

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San Francisco, California

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September 21, 1981

Christopher M. St. John
J.F.T Agapito & Associates Inc.
715 Horizon Drive, Suite 340
Grand Junction, Colorado 81501

Dear Chris,

It was a pleasure to participate in the panel discussions of the Geotechnical Engineering Subgroup, which were conducted under your chairmanship at the recent Peer Review of the Nevada Nuclear Waste Storage Investigations, August 24 to August 28, 1981.

Enclosed is my report summarizing my viewpoint concerning the subjects under discussion.

Thank you for your efforts in behalf of the committee. I am looking forward to working with you and the other panel participants in the future.

Sincerely,

Peter Frobenius
Project Engineer
Waste Isolation Pilot Plant

PF/ra

Attachment: Report

REPORT ON REVIEW OF THE
NEVADA NUCLEAR WASTE STORAGE INVESTIGATIONS
AUGUST 24 to AUGUST 28, 1981

Introduction

This report covers my comments concerning the Nevada Nuclear Waste Storage Investigation (NNWSI) Peer Review Meetings, held from August 24 to August 28, 1981 at Las Vegas.

The report is presented in two parts. The first part covers the format of the review meetings, the project status, priorities and planning. The second part covers specific subjects addressed during the Geotechnical Engineering Subgroup meetings.

Review Meeting Format and Content

The review meeting was well organized and scheduled. An extensive span of information was presented in the time available. The project personnel demonstrated a high degree of professional capability and came across as highly motivated to contribute to a successful completion of the project.

Even though the division of the review meeting into subgroups results in a loss of total overview for the reviewers, it appears to be the only practical way in which the wealth of information can be presented in the time available. This will be particularly true for future meetings because the project will expand into even more diverse activities with the initiation of conceptual design. With this development the peer review group itself is likely to become more diverse in background. Collective sessions continue to appear necessary at the beginning and end of the review meetings to pull the meetings together.

Project Status and Priorities

In my opinion, the most important data required for nuclear waste facility siting, design and licensing, are those concerned with stability of the openings and water migration into the facility or to the biosphere. Stress, strain and thermal characteristics as well as long term deformation of the formations under ambient and heated conditions have to be known for the stability investigations. In addition, an assessment of the extent and effect of the rock fractures on stress, strain characteristics both in ambient and heated conditions should be made.

To generate the required predictions on water migration into the nuclear waste facility and to the biosphere, significant water horizons above and below the prospective storage level have to be identified. Data on permeability within the formations and data

concerning the hydraulic interaction between formations through the existing joint/fracture system as well as through any fractures which may be generated by the thermal impulse of the disposed waste, should be available. Some of the basic testing programs such as pump and packer tests on existing bore holes still have to be brought to satisfactory completion. Methods to analyze the flow through the fractured medium around the nuclear waste facility still have to be developed to assess the safety of the facility and the potential release of radioactive material to the biosphere.

Due to the variability of the formations and the resulting large number of conditions which must be investigated, a considerable amount of data need to be obtained before the point is reached when a recommendation on siting can be made and site specific design can be initiated.

Even though several years are still available to perform the required investigations and testing, it would be beneficial to develop detailed work plans, to the extent that they are not in existence at this time. The plans should identify goals and priorities in the areas of investigation to assure a smooth interface with future repository siting, design and licensing.

Project Work Plan

General features of the project work plan were presented during the Peer Review Meeting. The plan presented focused mainly on the major institutional milestones which have to be accomplished within the time constraints imposed on the project by the National Terminal Waste Isolation Program. To provide a better overview, similar work plans should be presented focusing the great number of ongoing technical programs on the overall objectives of the project. Since the NNWSI project is a "first of a kind" facility, there is no established pattern by which the technical effort can be brought to completion. Contrary to a conventional planning and design effort, where a known technical approach is transferred into the time frame of a specific project, planning on the NNWSI will require a high degree of technical judgement. In order to make a realistic assessment of the feasibility to complete the work within the time constraints of the project, the plan has to screen the proposed work to assure its relevancy to the project objectives. At the same time the plan must identify essential technical investigations which may have been overlooked and initiate such work.

It is desirable to break the plan down into sufficient detail to cover distinct areas of project activities such as geology, geochemistry, seismology, environmental studies. Present status of each work item should be indicated, and specific end goals and end dates should be identified. The plans should interface with future design need dates.

In the planning process, advantage should be taken of the verification opportunity provided by the Exploratory Shaft and the At-Depth-Test-Facility program to gain further knowledge in such area as in situ media strength and deformation as well as in situ hydrological and thermal characteristics. This recommendation is based on experience on the WIPP project, where certain features of the design, even such relatively basic ones as the stability and deformation of the underground openings, could not be predicted with absolute assurance based on laboratory testing and analytical methods alone. Verification of the analytical results is obtained by in situ field testing provided in the Exploratory Shaft and At-Depth-Test-Facility at least for the short term aspects of the analysis.

In conclusion, I would like to emphasize the importance of the involvement of those who are responsible for the execution of the plan in the planning effort. The resulting commitment of key project personnel to the plan is the best guarantee for achievement of the project goals.

Geotechnical/Geoengineering Subgroup Comments

During the Geotechnical/Geoengineering Subgroup Meetings several specific subjects were addressed. My comments concerning each item are discussed under separate headings.

Exploratory Shaft

The proposed downhole drilling technique for the 8-foot inner diameter Exploratory Shaft is likely to be the safest and most expedient method of sinking the shaft in the time frame postulated for the project. Furthermore, selecting the downhole drilling technique, the project can take advantage of the expertise and manpower assembled at the Nevada Test Site in this type of shaft sinking. However, when one looks beyond the immediate objective of getting a shaft in place by a certain date, several limitations are associated with the downhole drilling technique:

- a) The downhole drilling technique limits the usefullness of the Exploratory Shaft for hydrologic and geologic exploration of the formations above the selected horizon. The reason is that, in the downhole drilling technique, the shaft will be filled with drilling fluid and may be cased full length before personnel access is permitted.
- b) Because the present state of the art limits shaft diameters to about 10 ft. inside diameter, it is likely that at least the Waste Shaft of the repository, which may require an inside diameter of about 19 feet, may have to be sunk by other methods than downhole drilling. Using the downhole drilling method to complete the Exploratory Shaft would preclude the opportunity of verifying the feasibility of sinking the larger nuclear waste facility shafts.

- c) The outfitted Exploratory Shaft could be utilized in the future for men and material handling for the At-Depth-Test-Facility or the TEF facility. As such the relatively small hoisting capacity of the 8-foot diameter Exploratory Shaft could be a schedule constraint for the construction of the At-Depth-Test-Facility or the TEF.

Regardless of the construction method used for the Exploratory Shaft, further definition of the testing and instrumentation program for the Exploratory Shaft is required. The program should include tests and instrumentation both along the length of the shaft and in the shaft station at the bottom of the shaft. Instrumentation should include piezometers to determine water heads in every formation and stress meters to determine pressures on shaft lining. Test borings by which additional core can be recovered and fracture orientation and frequency in each formation can be determined should be included in the program. Consideration should be given to seismograph installation both at the top and bottom of the shaft to correlate surface and underground seismic response.

MIDAS Project Control Group

The group is composed of principals of the participating project organizations with a high degree of technical expertise in their area of project involvement. The group is concerned with focusing the project on the technical issues, defining tasks for the various project organizations and reviewing work accomplished on a periodic basis. A more conventional name for such a group, that I am familiar with on other large projects, is a "Board of Control". Given the fact that the project is composed of several entities, which are tightly structured in their own organization, a "Board of Control" could make a contribution to coordinate and focus the technical effort of the project group. This would be accomplished by the commitment of the Board members to the project objectives and by their influence in directing work in their respective organization to conform to these objectives.

It appears that the MIDAS group could make a major contribution to the project planning effort. Being aware of their organization's strengths and limitations, the group could set achievable goals for each organizational element of the project. By their commitment to the plan, the MIDAS group could support the execution of the plan on a timely basis.

Waste Package

The two observations which appear most significant are that the Waste package should be site specific and that full scale in situ tests of the package and back fill material under heated conditions appear necessary.

Water Migration

Present uncertainty in predicting near field and far field water migration is due to lack of reliable data on permeability, fracture extent, sorption characteristics and location of significant water horizons above and below the future facility site. A further complication is added to the prediction effort by the fact that the thermal impulse of the disposed waste may cause additional fractures and water migration. Some of the required testing such as pumping tests and packer tests in existing bore holes still has to be completed to provide reliable results. Additional bore holes may be required. Instrumentation and observation of the Exploratory Shaft and the At-Depth-Test-Facility should be utilized to provide added information concerning the constructability of the facility and its shafts. As far as release of radioactive material from the repository to the biosphere through water migration is concerned, it appears difficult to model the migration process with sufficient assurance of accuracy because of the variability of the formations that will be penetrated, the uncertainty of fracture extent and the added uncertainty of the effect of heat on the host rock matrix and the fracture system. In this situation, where long term commitment to costly additional testing may be required, a sensitivity analysis performed early in the investigation, assuming worst case conditions, could serve as an indicator to assess the likelihood of release. Based on this assessment, the decision for further data collection and model development can be made.

Underground Opening Stability and Factor of Safety

In the context of assessing the stability of underground openings, the term "Factor of Safety" was used. Unless the term is clearly defined there is a good possibility for misinterpretation. For example, the term "Factor of Safety" is used in the SME Mining Engineering Handbook to assess the safety factor of the average stress in a room pillar against the unconfined compressive strength of the material. On the other hand, in a finite element analysis of an underground opening the same term may be used to indicate the factor of safety of a local stress condition against the unconfined compressive strength. The factors of safety derived by the two different methods can be different to the extent that the local condition indicates failure while the average condition may still be within acceptable limits. Therefore, it is recommended to carefully coordinate the use of the term "Factor of Safety". The thought expressed by project personnel to define performance constraints rather than "Factor of Safety" requirements in the project criteria for underground excavation has advantages which should be given further consideration.

Creep Characteristics of Tuff

Two papers were presented to the subgroup panel. One paper was written by D. Parrish, RE/SPEC and the other by J. Blasic, LANL. The former paper concludes that creep deformation will not be significant for stress, strain analysis. The latter papers states the opposite view. It appears that the views of the panel on this subject were sought. It is my opinion that long term effects will have to be considered in the analysis assessing long term stability of underground openings and fracture development. However, creep deformations in tuff are relatively small compared to other media. Given the uncertainties introduced by laboratory testing of creep specimens, an educated guess of what the creep deformation will be may be just as practical for the intended use as results from a two-year laboratory test program. This statement is based on recent experience with the uncertainties encountered in utilizing laboratory creep test results for long term stability analysis.

State of the Art

I concur with the opinion expressed by project participants that the rigor applied to the analysis as related to the underground work should be similar in quality as one would expect to find for a major underground hydro project. No basically new techniques of analysis should be mandated for development and use on underground waste facility design. The massive analytical effort may well generate new techniques, but this development should not be constrained by regulations.

Empirical Data on Tunneling Experience in Tuff

I believe that it would be good to conduct a literature search combined with an inventory of known tunnels in tuff, if this has not been done already, to establish an empirical data base on ground support requirements, water permeability and response to seismic shock.

J. F. T. AGAPITO & ASSOCIATES, INC.
CONSULTING GEOTECHNICAL AND MINING ENGINEERS
715 HORIZON DRIVE, SUITE 340
GRAND JUNCTION, COLORADO 81501

September, 1981

TO: Robert M. Nelson,
Project Manager NNWSI

FROM: Christopher M. St. John

RE: PEER REVIEW OF GEOTECHNICAL/GEOENGINEERING ASPECTS OF THE
NEVADA NUCLEAR WASTE STORAGE INVESTIGATION (NNWSI) OF TUFF

Personnel involved in the NNWSI tuff program are to be commended for conducting a technically credible program for investigation of tuff as a potential host medium for geologic disposal of high level nuclear waste. Both general presentations and presentations specific to the geotechnical/gеоengineering aspects of the program were of a high standard and reflected a high level of technical competence on the part of personnel. However, there were some instances of apparent lack of program integration and program focus. These, and more specific technical issues, are addressed in the following paragraphs.

Horizon Selection: The site selection process - presumed at the present time to confirm Yucca mountain as the most promising location - appears to be a very rational approach to making a complex decision involving both technical and non-technical issues. A similar process needs to be defined for horizon selection and implemented at the earliest opportunity. Selection of both site and horizon will go a long way towards focussing activities with the program.

Waste Package: Current investigations of very near field, or canister scale, behavior relate to a waste package that will not meet the criteria of the NRC - either in tuff or any other media. A realistic waste package design is urgently required. This design will very likely be specific to the geochemical environment anticipated in a repository in tuff. Apparently waste package design is largely outside the scope of NNWSI activities. This activity probably requires to take more account of media specific requirements and should be integrated more closely with the media specific programs.

Reference Repository Conditions: A set of reference conditions for the selected horizon, a realistic waste package and a credible set of

performance criteria is urgently required. This would provide a basis for development of much of the rest of the program - including laboratory, field and numerical modeling investigations.

Design Criteria: The geotechnical design criteria need to be defined and expressed in a quantitative manner. The rationale for selection of the criteria must be clearly described and the means of incorporating them in the analysis supporting the repository design must be discussed. Some criteria, such as temperature limits, may be absolute. Others may be applicable only if a particular method of analysis or approach to design is adopted.

Engineering Conservatism: A design is made conservative in order to allow for uncertainty in correctly predicting the actual system response. Several means of making a design conservative may be adopted; one being the choice of conservative design criteria. Whatever approach is used, the requirement for conservatism should be clearly related to the degree of uncertainty and the method of achieving conservatism should be defined.

Rock Mass Classification: Attempts have been made to use rock mass classification systems designed to assist in selection of excavation spans and support requirements. Such classification systems may have some application in the early stages of design of repository excavations in tuff but must be "calibrated" against field experience in similar media. It is suggested that this be done by carrying-out an inventory of excavations in tuff either at the NTS or outside. If excavations in tuff are determined to be of a similar character to that of the expected repository horizon, then rock structure, rock support and other data should be obtained. This effort could be used not only to support use of a rock mass classification system but would also provide a valuable record of field experience of underground construction in tuff.

Rock Mass Fracturing: Apparently there is almost no information available on the natural fracturing of the tuffs other than that fractures are predominantly vertical. The fracture direction, frequency and continuity must be determined for all members on or above the repository horizon. The best opportunity for obtaining this information will occur during sinking of the exploratory shaft. Much of this opportunity will be lost if the shaft is bored. Inclined boreholes provide an alternative, but less satisfactory method of obtaining this data.

Geotechnical Model Development: A clearer definition of how the physical model studies and laboratory studies that are in progress will lead to a constitutive description of tuff is required. Development of a constitutive equation requires that a better definition of the rock mass structure be obtained. Also, an effort should be made to define what modeling will be required to support design, license application and other programmatic functions and to what extent the models need to be verified by field testing.

Field Testing: Field tests should be designed once a set of objectives has been defined. Objectives include demonstration and model verification. Demonstration tests should be as realistic as possible. For example, canister scale tests should be related to a realistic waste package design. Model verification tests should be undertaken only once programmatic needs for such are clearly defined. At the present time it is unclear to what extent or when model verification will be required or how it can be achieved during short term field tests.

G-Tunnel Tests: Tests should be made to verify water migration models and should be undertaken with a realistic waste package.

It is proposed to use CSIRO gauges for stress measurements around heater tests. Since the CSIRO gauges are not temperature compensated and appear to be sensitive to temperature changes as small as occur during overcoring, use of these gauges seems inadvisable.

The ADTF: (Comment) One of the functions of the SCR is to identify for the NRC "the uncertainties and limitations on site - and design - related information developed during site screening, including issues that need further investigation - -". This implies that the function of and scope of the ADTF, which will be the last major experimental investigation prior to license application, must be defined at the time that the SCR is submitted. This places a very tight schedule on ADTF design as the SCR will be prepared largely in 1982, possibly at a time when the site and horizon selection processes are still in progress.

Very Near Field Analysis: It was reported that very shortly after repository backfilling the temperature of water around canisters would be significantly above 100 ° C. The implication was that the repository would be completely saturated and the ground water conditions in the rock mass would have returned to hydrostatic very quickly. This does not seem likely. Also, the time scales used were not consistent with those promulgated in 10CFR Part 60.

Other analysis showed that relatively few fractures in the rock mass around a canister would inhibit fluid pressure increase around the canister. This observation needs to be reconciled with the analysis reported above. Possibly the disagreement results from inadequate definition of the rock mass properties - including fracture permeability and fracture frequency.

Water Migration: Field Tests indicate that significant quantities of water/water vapor will migrate towards a canister. This would appear to be a critical issue of concern for a repository in tuff. Without an adequate method of predicting this migration, the canister environment cannot be predicted. A predictive model should be developed and tested in the field (See note on G-Tunnel, above).

Time Dependent Deformation of Tuff: Conflicting statements about the significance of creep were made. In one hand it was proposed that creep deformation during the repository operational period would be

of the same order of magnitude at the elastic strains. On the other hand, it was suggested that time dependent brittle failure could occur. The latter conclusion was based on a very limited data base and analysis that ignored the ameliorating effect of time dependent deformation and, perhaps, local failure. More realistic analysis is required so that possible consequences of the brittle type of failure discussed can be evaluated. Even if this effect is small, it is essential that the data base on the time dependent deformation of tuff be improved. The long-term effect of time dependent deformation - and time dependence of all material properties - could be much more important than any effects during the operational period.

Performance Assessment: At the present time, relatively little effort appears to be directed towards the prediction of radionuclide migration from the repository in the event of release at the repository horizon. Apparently, such studies will eventually be done as part of a "consequence analysis" following scenario development. However, it is not clear how site and horizon selection can be undertaken without the support of such analysis.

Rock Mass Permeability: The rock mass permeability appears to be inadequately defined at present. This data is urgently required to support performance assessment and for realistic prediction of rates of inflow to the repository excavations. The best opportunity for obtaining this information will occur during sinking of the exploratory shaft.

This completes my specific comments - any of which I should be pleased to amplify as necessary. More general comments are contained within the peer review group summary.