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MEMORANDUM FOR: Hubert J. Miller, Chief
High-Level Waste Technical Development Branch
Division of Waste Management

THRU: Philip S. Justus, Section Leader
Siting Section
High-Level Waste Technical Development Branch
Division of Waste Management

WM Record File 102

WM Project 11
Docket No.
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(Return to WM, 623-SS)

FROM: Tilak R. Verma
High-Level Waste Technical Development Branch
Division of Waste Management

SUBJECT: REPORT ON TRIP TO DENVER FOR WORKSHOP ON REVIEW OF HYDROGEOLOGIC TESTING DATA FOR THE NEVADA TEST SITE

Summary:

Members of the NTS Hydrogeology Team met on January 27 and 28, 1983, in Denver, Colorado, to review the hydrogeological testing data being collected by the U. S. Geological Survey at the Nevada Test Site. Tilak R. Verma, Philip S. Justus, James Mercer, Martin Mifflin and Roy Williams from NRC reviewed the data. A list of documents reviewed by the team is is provided in the Attachment 1.

U. S. Geological Survey provided these documents at the Denver Federal Center. Most of the documents reviewed consisted of preliminary field data, analyses and interpretations in draft form and therefore, no documents were released to the NRC team.

The team review focused on the data and details of hydraulic testing being conducted by the U.S.G.S. in the boreholes drilled at the Yucca Mountain. Details of these tests are provided in Attachments 2 and 3.

The review team, on the basis of the data reviewed, believes that the methodology used by the Geological Survey reflects state-of-the-art technology with respect to hydraulic testing in single holes.

"ORIGINAL SIGNED BY"

Tilak R. Verma
High-Level Waste Technical
Development Branch
Division of Waste Management

Attachments:
As stated

DesireeM 83/03/15

OFC	WMHT	WMHT	WMHT				
NAME	TRVerma:dm	PSJustus	HJMiller				
DATE	03/15/83	03/17/83	03/ /83				

ATTACHMENT 1

Items Observed by Team

1. Quality assurance manuals
2. Sample collection procedure manual
3. Analytical procedures for dissolved inorganics and radioactive constituents manual
4. Borehole geophysical logs for test holes
5. Single and multiple-hole pump tests
6. Slug test results
7. Core description document
8. Borehole flow survey curves (for all holes)
9. K & J distribution charts
10. Hydraulic testing technique manual
11. TAM International drillstem test report for well USW G4
12. Hole design and test plan for G4

ATTACHMENT 2

WILLIAMS & ASSOCIATES, INC.

P.O. Box 48, Viola, Idaho 83872 (208) 883-0153 (208) 875-0147

Hydrogeology • Mineral Resources Waste Management • Geological Engineering • Mine Hydrology

January 31, 1983

Dr. Teek Verma
Waste Management Division
U. S. Nuclear Regulatory Commission
7915 Eastern Avenue
Silver Spring, Maryland 20910

Dear Dr. Verma:

This letter constitues a trip report for Williams and Associates, Inc. The dates of the trip were January 26-28, 1983. The location was Denver Federal Center, Denver, Colorado. The organization visited was the U. S. Geological Survey. The purpose of the trip was to review data that have been obtained by the USGS for the Nevada Test Site as it pertains to a potential high-level radioactive waste repository. Williams and Associates, Inc. was represented by Dr. Roy Williams and Dr. Marty Mifflin.

As you know I have submitted to you in person a list of the documents and data that we reviewed during our site visit to USGS headquarters at the Denver Federal Center. Consequently I will not repeat the list here. The information presented below constitutes my observations with respect to the most important issues pertinent to site characterization as defined during the site visit.

1. The data collected from the boreholes that have been drilled at the site constitute state-of-the-art technology with respect to single hole tests. The borehole geophysical logging program is, in my opinion, state-of-the-art. The drilling technology being implemented at the site should present no problems with respect to interference with this type of data collection and analysis (saturated zone). Specifically, the use of mud drilling techniques for geological holes and the use of air-rotary drilling techniques for hydrologic holes should preclude significant skin effects on hydrologic tests.

2. The single hole pumping tests being conducted at the site definitely are state-of-the-art for single hole hydraulic property testing. The pumping rates are sufficiently high that even with single hole tests a significant portion of each aquifer can be characterized. Multiple hole tests are desirable and additional ones should be implemented at the first appropriate opportunity. It appears, however, that at present primary emphasis should be placed on testing the unsaturated zone rather than on multiple-hole, large-scale tests of the unsaturated zone.

3. The borehole flow survey tests being conducted at the site are of great utility when combined with the borehole geophysical logs in ascertaining

the identity of water yielding units in the boreholes tested. Transmissivity of each unit identified by the borehole flow survey log can be estimated when the borehole survey log is viewed in combination with the results of the pump tests performed over the entire length of the hole. In essence this procedure facilitates the identification of aquifers or water bearing units on a hole by hole basis. The next obvious step is to implement standard pumping test techniques for the purpose of evaluating each of the units identified on a between or among hole basis. We learned during the site visit that such tests are being planned.

4. The slug tests conducted on the low or intermediate permeability zones in each hole constitute a state-of-the-art approach to testing of units that are not aquifers. These units may prove to be important in the future because of their potential role as barriers to radionuclide migration.

5. The borehole geophysical logs that we observed for the unsaturated zone did not enable us to reach definitive conclusions with respect to the occurrence of water in the unsaturated zone. In my opinion this remains an undefined issue which deserves additional attention, both by the NRC and the USGS.

The data presented to us on old vegetation and ancient rat dens in my opinion is not conclusive with respect to the role of glaciers on the hydrology of southern Nevada. We will need more old vegetation and a lot more rat dens if we are to recreate the pluvial environment and thereupon predict a future pluvial environment with any degree of accuracy.

The data presented at the site visit indicate that two-dimensional modeling is the most feasible mechanism for predicting travel times at the Nevada Test Station Site. It appears that the hydrogeology is sufficiently complex that a three dimensional simulation will by necessity be too general to reflect travel paths accurately.

These observations constitute the essence of our opinions with respect to the site visit. If you have any questions or if you wish to discuss any of these issues in greater detail please call.

Sincerely,

Roy E. Williams

Roy E. Williams
Ph. D. Hydrogeology
Registered in Idaho

REW:sl

cc: Marty Mifflin
Jim Osiensky
Elois Wiggins
5 offices listed in contract

ATTACHMENT 3

GeoTrans

Geohydrologic Transport Analysis

February 7, 1983

WM Record File B7378
WM Project
WM Docket No.
Pohle

Rec'd 2-14-

Mr. Jeffrey A. Pohle
Mail Stop 623-SS
Division of Waste Management
U.S. Nuclear Regulatory Commission
Washington, DC 20555

SUBJECT: Contract No. NRC-02-82-047
Hydrogeology of NTS, Project D
FIN No. B-7378-2
Draft Trip Report on NNWSI Hydrogeology Workshop
Letter No. 9

Dear Mr. Pohle:

Enclosed is our draft trip report on the NNWSI hydrogeology workshop. This report covers the meetings in Denver January 17-19, the field trip January 20, and the review of USGS files January 27-28.

The trip report was prepared by Dr. James W. Mercer and myself. Both of us attended the meetings and field trip; Dr. Mercer participated in the file review. In accordance with project quality assurance procedures, the trip report was reviewed by our Vice President for Operations, Dr. Charles R. Faust.

Please call me if you have any questions about this document.

Sincerely,

Benjamin Ross

Benjamin Ross
Senior Research Scientist

BR:dye

Enclosure

cc: Office of the Director, NMSS (Attn: Program Support Branch)
Director, Division of Waste Management
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H.J. Miller
T.R. Verma

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Draft Trip Report
NNWSI Hydrogeology Workshop
January 18-20 and 27-28, 1983

<u>Brief History</u>. DOE began to study the Nevada Test Site (NTS) for high-level radioactive waste storage in April 1977. By the end of 1978 Yucca Mountain had been selected, in part because the weapons people did not want waste disposal to interfere with their work. The Yucca Mountain area is partly on the NTS and partly on Nellis Air Force Base. Most of the data has been collected during 1981-82 and has concentrated on the saturated zone. The decision to consider the variably-saturated zone was made in July 1982.

The USGS is the DOE consultant for geology and hydrology. Los Alamos has responsibility for volcanology, geochemistry/petrology, and the conceptual design of the exploratory shaft (ES). LLL has responsibility for waste form, waste package, and backfill. Finally, Westinghouse has responsibility for waste package, handling, etc; and Sandia has responsibility for performance assessment.

<u>Drilling</u>. G-wells are geology wells that are usually drilled with mud and are cored. The cores are used to determine stratigraphy, structure, and lithology. In addition, laboratory tests are made on the cores to determine permeability, porosity, water content, and bulk density. H-wells are hydrology wells and are drilled primarily using soap and some water (referred to as an air-foam mixture). Water used with the soap and mud comes from well J13 and is tagged with 20 ppm LiCl. When water is encountered during drilling, it cuts the soap and more well

cuttings are brought to the surface. A 16-inch hole is drilled to approximately 100 feet below the water table. The hole is then logged using a suite of geophysical techniques, including caliper and epithermal neutron. A 10-3/4-inch casing is set into the saturated zone and tacked at the bottom with cement. Drilling is then continued to bottom using a 8-1/2 to 8-3/4-inch bit. The saturated zone is not cased. Rig time is approximately $20,000 per day using three shifts so that drilling is 24 hours per day, seven days a week. The well engineering and design is performed by Fenix and Scisson, Inc.; drilling and coring is done by REECo; and testing was performed by Lyons, but is now done by TAM. This is considered a reconnaissance phase and a well is drilled approximately every sixty days.

General Observations on Testing. Three types of testing are performed: (1) single-hole, constant discharge tests, (2) borehole flow survey, and (3) packer injection tests. There have also been two 2-hole constant discharge tests using holes UE25a-1H and UE25b-1H. In summary, these tests are used as follows. The single-hole, constant discharge test is conducted in order to obtain a transmissivity for the entire uncased interval. During the test, after water levels have stabilized, a borehole flow survey is conducted using radioactive tracer injection. This test is used to determine where the flow is coming from and what percentage of the total discharge comes from what interval. The packer injection tests are basically slug tests used to determine the permeabilities of the low- to medium-permeability units identified during the borehole flow survey. The combination of these three tests are used to determine the downhole permeability distribution. The data and results from these tests will be published for each hole. Each hole will have a basic data report and an interpretive report.

More specifics are given below. The pump is set at the bottom of the casing, approximately 1,500 to 2,000 feet below land surface. The maximum pumping rate is limited by equipment to approximately 600 gal/min. Water levels are measured by an instrument similar to an M-scope. Water levels stabilize after about 3-5 days. Both drawdown and recovery are recorded. After stabilization of drawdown, the borehole flow survey is run using Iodine 131. This test is described in detail in Blankennagel (1967).

Once the low- to medium-permeability intervals have been determined from the borehole flow survey, the packer injections tests are run. Inflatable packers are used as well as pressure transducers (called DMR's). Once the packers are in place, the top of the packed-off zone is opened to a column of water. The following three things are measured: (1) pressure, (2) temperature, and (3) barometric pressure. The results are analyzed using the method of Cooper, Bredehoeft, and Papadopulos (1967). These tests can last anywhere from 5 min to approximately one day. Once the test is complete, the tool is moved to the next interval and the test repeated. These tests are state-of-the-art, single-hole tests and appear to be professionally conducted.

Applying this model to the stratigraphy of Figure 1 seems to show very favorable characteristics for the site. The repository would be located in the Topopah Spring Densely Welded unit. The fractures in this unit would be nearly drained of water. What water does flow through them would move very rapidly, implying short contact time with waste canisters. The water would move down to the lower "clastic" unit, which would act as a sort of capillary barrier and absorb water into its pores. The lower "clastic" unit, with its high moisture content, would transmit the water very slowly.

In our view, more measurement and more thought are needed before the above conceptual model is firmly established. One unknown mentioned by the NNWSI team is the interaction between fractures and matrix in the densely welded zone. The NRC team was also more generally concerned about whether soil-science concepts developed in near-surface studies would be applicable to deep unsaturated zones. One issue of particular concern to GeoTrans is the possibility that vapor-phase water movement is important. This would complicate interpretation of hydrogeologic phenomena in the unsaturated zone.

Material Observed. The following were observed during the visit:

(1) Pumping test data for USW-H1, UE25b-1H, and UE25a-1H.

(2) Data from packer injection tests.

(3) Borehole flow survey data.

(4) Geophysical logs.

(5) Procedures manuals, including those describing quality assurance.

(6) TAM drill stem test report (for G4).

(7) Typical hole design and test plan (for pre-Tertiary hole).

Unsaturated Zone Flow - Flow properties of the unsaturated zone vary with the lithology. These variations do not correspond to the stratigraphic units. Basically, there are two types of hydrogeologic units. The central, densely welded zones of the thicker cooling units have well-developed fractures and are quite permeable. These units are good aquifers where they extend below the water table. The other type of unit is composed of poorly welded tuffs. They were referred to as "clastic" units by Bill Wilson (USGS), although they are not really clastic rocks. These units typically correspond to a composite of several stratigraphic units, possibly including ash-fall tuffs, poorly welded upper and lower margins of welded tuff units, and unwelded ash flows. A typical section, showing both stratigraphic and hydrogeologic units, is given in Figure 1.

The USGS' current conceptual model of flow in the unsaturated zone is based on classical soil physics concepts. The vadose zone is divided into three sections. Near the surface, water content fluctuates as a result of precipitation and evapotranspiration. As one goes deeper, these fluctuations damp out and there is a zone in which the water flux is constant and downward. In this zone, pressure head is constant, and there is a driving force of one meter per meter due to gravity. Therefore, the Darcy velocity is equal to the effective hydraulic conductivity. Finally, near the water table there is a zone in which pressure head approaches zero. The variation of pressure head with depth in this model is shown in Figure 2.

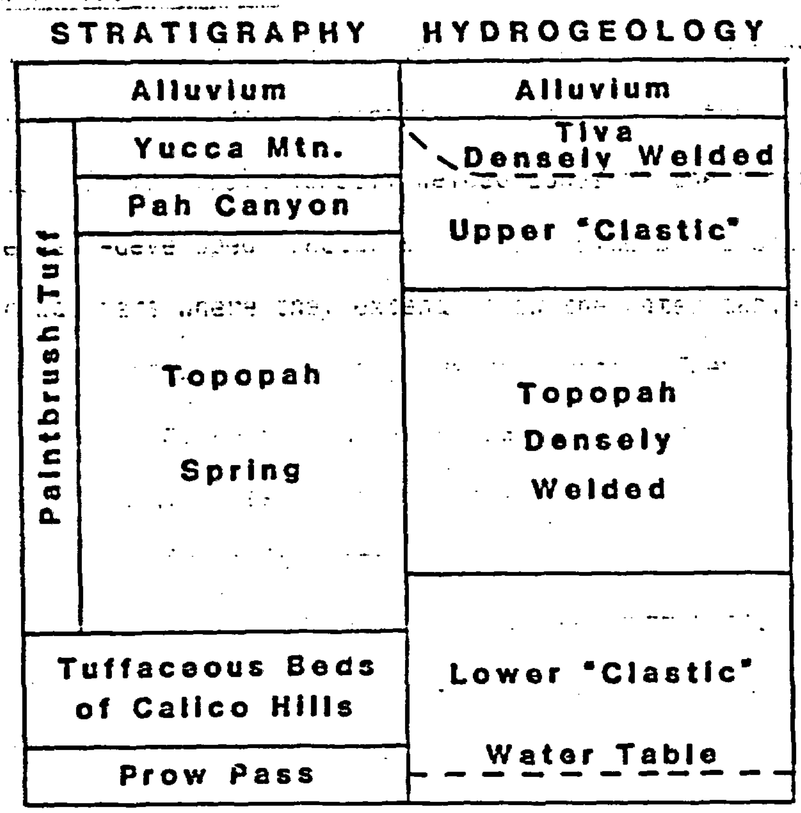

Figure 1. Typical stratigraphic and hydrogeologic column in the unsaturated zone at Yucca Mountain.

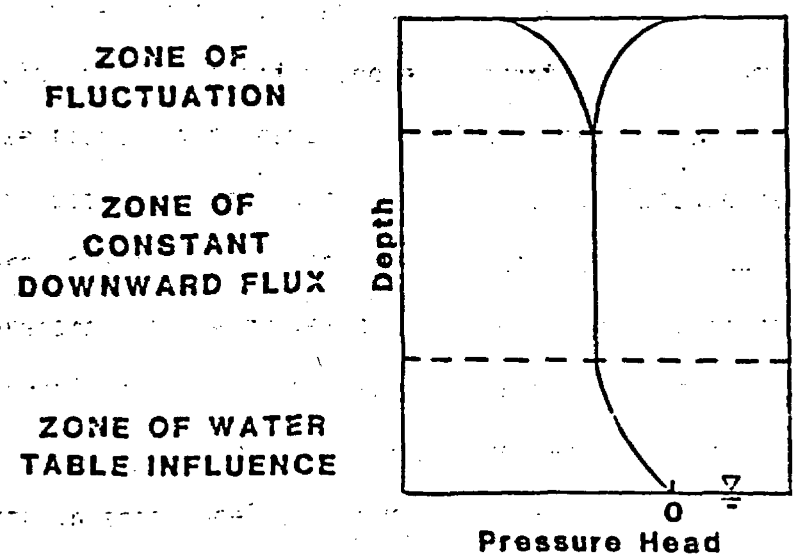

Figure 2. U.S.G.S. conceptual model of water movement in the vadose zone.

The principal issues identified by the USGS are:

- Anisotropy of hydraulic conductivity, and whether it can be described as a tensor at all.
- Surface chemistry in fractures.
- Matrix diffusion.
- Effective porosity.
- Effective surface areas for sorption.
- Relationship between saturated and unsaturated zones.

Performance Assessment. Whereas the USGS is modeling to improve their conceptual ideas concerning Yucca Mountain, Sandia is interested in modeling for performance assessment. The codes that Sandia is considering are as follows: (1) Saturated Flow - USGS codes, SAGUARO, TRACR3D, FEMWATER, VTT, SWENT, and NWFT; (2) Saturated Transport - USGS codes, FEMWASTE, TRACR3D, MMT, SWENT, NWFT, GETOUT, and UCB Codes; (3) Unsaturated Flow - SAGUARO, TRUST, FEMWATER, and TRACR3D; and (4) Unsaturated Transport - FEMWASTE, TRACR3D, and TRUST.

The assumption to date, on which both the exploration program and the preliminary performance assessments have been based, is that flow at Yucca Mountain is toward the East or Southeast. In our view this hypothesis is not yet well established. Principal reasons for uncertainty include:

- Because of the fracture anisotropy, a predominantly eastward gradient might be consistent with a southerly direction of flow.
- As nearly all of the available head measurements represent composite water levels, it is possible that vertical gradients are being misinterpreted as horizontal gradients.
- There is very little control on heads in Crater Flat and northern Yucca Mountain. With current data, the possibility of flow to the southwest cannot be excluded.

Two-Well Aquifer Tests. There were two 2-well aquifer tests performed on wells UE25a-1H and UE25b-1H. These are also the wells where the two-well tracer test is planned. The pumping well was B1. The first test lasted about 25-30 days and the entire uncased interval was tested. In the second test, conducted primarily to obtain a water sample for chemical analysis, a zone was packed off, and the test lasted about the same length as the previous test. Only the data from the first test were presented.

The first test actually consisted of two separate tests. During the first one, the pumping rate changed and so the test was repeated. Both drawdown and recovery data were collected. The pumping rate for the repeated test was 35.8 l/s. One curve that was presented may have displayed boundary (impermeable) effects (our interpretation). No drawdown was observed at well H1, which was monitored during the test. Interpretation for these tests is not yet available.

In addition to these tests, during the pumpage of well H1, a response was measured in well G1. The results could not be interpreted.

General Observations on Geophysical Logs. Most interest was placed on the epithermal neutron log, especially as to what information can be gained on the variably saturated zone. These logs were made before the variably saturated zone was cased off and they are now being repeated with the casing in place. Hydrogen absorbs the energy from the neutrons. Therefore, a low count on the log means that water is present, which in the saturated zone implies a relative amount of porosity. The purpose of using the neutron log in the variably saturated zone is to attempt to identify pearched water zones. The anticipated success of this approach is low because any perched water that existed before the well was drilled has probably run down the hole outside the well casing.

Downhole temperature surveys (in the saturated zone) were also interesting in that in the saturated zone temperature versus depth produced relatively straight lines with an approximate 45° slope, indicating conductive heat flow. That is, only a few intervals showed vertical convective flow, as indicated by a relatively vertical temperature profile. Throughout most of the hole temperatures seem to indicate little vertical fluid flow.

Regional Modeling. The only modeling that has been performed is soon to be published in a USGS Water Resources Investigations by Rick Waddell. This model is referred to as the regional ground-water model. Some salient features and assumptions of this model are:

- treats aquifer as confined system
- considers flow only
- problem is treated as steady state (no change with time)
- code is based on the finite-element method with parameter estimation and sensitivity analysis
- the conceptual model used in this study is based largely on that proposed by Winograd and Thordarson (1975)
- boundary conditions are a mixture of no flow and flux

- a constant head boundary was applied to only one node that represents a point in Alkali Flat
- problem is treated as two-dimensional, areal (flow is horizontal)
- transmissivity is assumed to be isotropic, but allowed to be nonhomogeneous by zones (homogeneity exists within zones)

The code being used for this study was developed by Dick Cooley. The primary documentation is limited to a Survey internal document and several Water Resources Research publications. The purpose of this study was to (1) quantify the conceptual model of Winograd and Thordarson and (2) determine boundary conditions for more detailed transport modeling.

Subregional Modeling. An important area of activity planned for the near future by USGS is "subregional" modeling. This is modeling of the area near Yucca Mountain: eastern Pahute Mesa, Timber and Yucca Mountains, the central Amargosa Desert, Jackass and Crater Flats, and perhaps a portion of Death Valley. The purpose of this work is apparently to locate the flow path of any contaminants that might be released from a repository.

Current plans are to use a two-dimensional porous-flow and transport model. It is a code modified from one developed by Jim Tracy. The extent of documentation is uncertain. The code will simulate both flow and transport, and will use composite hydraulic conductivities and porosities. It is possible that dual-porosity or discrete-fracture models will be used instead. Boundary conditions will be obtained from the regional modeling.