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

August 28, 1986
Contract No. NRC-02-85-008
Fin No. D-1020
Communication No. 77

WM Record File WM-RES D1020 W+A
WM Project 10,11,16
Docket No.
PDR ✓
LPDR B,N,S
Distribution: Pohle
(Return to WM, 623-SS)

Mr. Jeff Pohle
Division of Waste Management
Mail Stop 623-SS
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

RE: NTS

Dear Jeff:

A copy of the review of each of the following documents is enclosed.

1. Carlos, B.A., 1985, Minerals in Fractures of the Unsaturated Zone from Drill Core USW G-4, Yucca Mountain, Nye County, Nevada. Los Alamos National Laboratory, Los Alamos, NM, 55 p.

2. Czarnecki, J.B., 1984, Simulated Effects of Increased Recharge on the Groundwater Flow System of Yucca Mountain and Vicinity, Nevada-California. U.S. Geological Survey prepared in Cooperation with the U.S. Department of Enerrgy, Water Resources Investigations 84-4344.

3. Czarnecki, J., and Waddell, R.K., 1984, Finite Element Simulation of Ground Water Flow in the Vicinity of Yucca Mountain, Nevada-California. U.S. Geological Survey, Water-Resources Investigations Report 84-4349.

4. Johnson, R.L., October 1982, Thermal Analyses for a Nuclear Waste Repository in Tuff Using USW-G1 Borehole Data. Sandia National Laboratories, Albuquerque, NM, SAND82-0170.

5. Johnstone, J.K., Peters, R.R., and Gnirk, P.F., 1984, Unit Evaluation at Yucca Mountain, Nevada Test Site: Summary Report and Recommendation. Sandia National Laboratories, Albuquerque, NM, and Livermore, CA, SAND83-0371.

2701

6. Johnstone, J.K., and Wolfsberg, K., Editors, 1980, Evaluation of Tuff as a Medium for a Nuclear Waste Repository: Interim Status Report on the Properties of Tuff. Sandia National Laboratory, SAND80-1464.

Please contact me if you have any questions concerning these reviews.

Sincerely,

Jim Osiensky/sl

Jim Osiensky

JO:sl

enclosures

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT #: LA-10415-MS

DOCUMENT: Carlos, B.A., 1985, Minerals in Fractures of the Unsaturated Zone from Drill Core USW G-4, Yucca Mountain, Nye County, Nevada. Los Alamos National Laboratory, Los Alamos, NM, 55 p.

REVIEWER: Williams & Associates, Inc.

DATE REVIEW COMPLETED: August 7, 1986

ABSTRACT OF REVIEW: APPROVED BY: Roy E Williams

The report under review describes the minerals present in fractures in drill core from test hole USW G-4, between the depths of 800 ft and 1,770 ft. The report describes the sequence of deposition and the identity of minerals that might be natural barriers to radionuclide migration through the unsaturated zone. The report does not describe the ion exchange capacity of individual minerals present within the fractures.

BRIEF SUMMARY OF DOCUMENT:

The purpose of the report under review is to describe the mineralogy of the fractures in drill core from test hole USW G-4. The mineralogy of fractures between the depths of 800 ft and the static water level at 1,770 ft was examined to identify the minerals within the fractures. The purpose of the investigation was to identify minerals that might be natural barriers to radionuclide migration from a nuclear waste repository at Yucca Mountain.

According to the report, test hole USW G-4 was selected for detailed study of fracture-filling materials because it is located closest to the proposed exploratory shaft in Yucca Mountain. The fracture materials within the core for test hole USW G-4 are believed to be representative of the minerals that can be expected to exist along flow paths within the northeastern

part of the repository.

Test hole USW G-4 was drilled to a total depth of 3,001 ft in 1982. The hole was cored continuously from 22 ft to the total depth. According to the report, the drilling history, lithology of the core, and geophysical logs of the test hole are given in Spengler and others (1984).

The method of study used in the investigation consisted of selecting representative core samples for each interval and each fracture type within an interval. According to the report, samples with the most extensive coatings for each type of fracture were chosen to provide sufficient material for x-ray diffraction analysis. Representative samples also were chosen for scanning electron microscope analyses. According to the report, samples for x-ray diffraction analysis were scraped from fracture surfaces with a steel scraper; a binocular microscope was used to examine the scraped materials. Hand-picked samples from the scraped materials were crushed to a powder in a ceramic mortar and exposed to x-rays either as pressed powder or as smear samples.

According to the report, identifications of the minerals were made by comparing observed patterns with the standard patterns produced by the same x-ray diffraction analysis equipment and by comparing patterns with the standards from the Joint Committee on Powder Diffraction Standards. Thin sections of samples that had sealed fractures were made for microprobe analysis. Imaging and qualitative composition studies were made on a scanning electron microscope.

Pages 12 through 52 of the report present descriptions of the minerals which line the fractures in each stratigraphic unit. The report states that the fracture mineralogy varies greatly between the devitrified, glassy, or zeolitized zones within the host rock. Minerals that are present as fracture fillings include clinoptilolite, quartz, feldspar, mordenite, manganese oxides/hydroxides, heulandite, and calcite. Polymorphs of quartz are present also in some fractures.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

The report under review presents a description of the minerals present within fractures in core from test hole USW G-4. This document is significant with respect to evaluating the potential for retardation of radionuclide movement through the unsaturated zone beneath the proposed repository in Yucca Mountain. It should be of primary interest to geochemists involved in the

evaluation of radionuclide migration through the unsaturated zone at Yucca Mountain.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

The report under review describes the minerals present in the unsaturated zone in fractures in drill core from test hole USW G-4. The primary emphasis of the report is to describe mineral coatings within the fractures; however, the current conceptual model for flow in the unsaturated zone proposed by USGS considers the movement of water through the unsaturated zone to occur solely through the matrix of the tuffs. An understanding of the mineralogy within fractures in the unsaturated zone is important to geochemists involved in evaluating the potential for retardation of radionuclide migration through fractures if the flux rate exceeds 0.5 mm/yr. The report presents descriptions of the minerals present in fractures only. The ion exchange capacity of individual minerals is not evaluated in the report.

SUGGESTED FOLLOW-UP ACTIVITIES

We suggest that the report under review be reviewed by a geochemist familiar with the ion exchange capacity of various zeolites. We suggest also that it would be advisable to request an explanation for studying the retardation characteristics of minerals in fractures when the prevalent USGS conceptual model envisions flow through the matrix of the tuffs.

REFERENCES CITED

Spengler, I.W., and others, 1984, Stratigraphic and Structural Characteristics of Volcanic Rocks in Core Hole USW G-4, Yucca Mountain, Nye County, Nevada. USGS Open-File Report 84-789.

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT #: USGS-WRI-84-4344

DOCUMENT: Czarnecki, J.B., 1984, Simulated Effects of Increased Recharge on the Groundwater Flow System of Yucca Mountain and Vicinity, Nevada-California. U.S. Geological Survey prepared in Cooperation with the U.S. Department of Energy.

REVIEWER: Williams & Associates, Inc.

DATE REVIEW COMPLETED: August 26, 1986

ABSTRACT OF REVIEW: APPROVED BY: Roy Σ Williams

The effect of increased recharge on the groundwater flow system beneath Yucca Mountain was investigated. A 100% increase of precipitation was assumed to increase the recharge 14 times. The finite element code FEMODE was used for simulation, which showed that the water table would rise to no less than 130 m from the repository. A weakness of the analysis is that an empirical relationship which may or may not be valid is used to relate recharge to the precipitation.

BRIEF SUMMARY OF DOCUMENT:

This study was conducted to evaluate the potential effects of possible changes in climatic conditions on the groundwater flow system at Yucca Mountain. Such changes in precipitation could cause increased recharge rates resulting in higher groundwater elevations and possible flooding of the repository.

Two specific questions to be answered in the report were: 1) would increased recharge cause a rise in the water table sufficient to flood the repository at its primary location and 2) would changes in the position of the water table significantly alter the direction and rate of groundwater flow near the primary repository location?

The author discusses the study of Spalding and others (1984) relative to the possible increase of precipitation during climatic changes. The present project was accomplished by use of a finite element computer program called FEMODE, developed by Cooley and Torak (1984). Boundary conditions may be specified as point, line or areally distributed sources or sinks and with either constant flux or constant potential. Flow parameters such as transmissivity and specific storage may be specified for individual elements. Specific storage for this problem was set equal to zero since the solution was not time dependent. A recharge rate of 0.41 m/acre was applied along Fortymile Wash. This value was obtained from the parameter estimation modeling of Czarnecki and Waddell (1984) which also determined that recharge rates in other areas were insignificant. The value of evapotranspiration would increase if the water table rose such as during wet periods, and could even rise to the point that there would be new areas of groundwater discharge. The transmissivity values were obtained from Czarnecki and Waddell (1984).

The land surface was divided into three zones of precipitation. Zone 1 was from 6 to 10 inches per year; Zone 2 was 3 to 6 inches per year; and Zone 3 was less than 3 inches per year. The estimated recharge rate for these regions under present conditions varied from 0 to 2.8 mm/yr. These rates gave an estimated recharge total over the entire area of simulation of approximately 6,000 acre/ft/yr. The method used to estimate recharge under a wetter climate is based on the percentage of recharge increasing with increased precipitation. For a 100% increase of precipitation, the recharge would increase approximately 14 times. The maximum water table rise near the repository is predicted to be 130 m, less than the minimum distance between the base of the repository and the present-day water table. The direction of flux beneath the repository would change very little, but the magnitude of flux would approximately double.

To quote a portion of the conclusions:

> Results of this investigation provide a preliminary basis for estimating the potential effects of possible climatic changes on the groundwater system near a potential site for a nuclear waste repository. However, one of the major assumptions made in this study is that the empirical relationship between increased precipitation and consequent increased recharge is valid. Little basis exists for this assumption. Additional work is needed to document recharge mechanisms and rates and to establish analytical expressions between precipitation rate and associated groundwater recharge rates.

It should be noted that this report does not discuss the recharge through Yucca Mountain which is an important parameter in determining the time of travel between the repository and the saturated zone. The analysis in the present report simply determines the water table elevation that may occur under wetter climates.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

For the adequate design of the repository it is necessary to know the effect of climatic changes on the groundwater flow systems beneath Yucca Mountain. The report under review presents a preliminary analysis of such changes.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

The use of an empirical relationship between rainfall and recharge is a deficiency of this report. At the present time this is the only available method; however, if field data on recharge are obtained during characterization it may be possible to improve on this analysis.

SUGGESTED FOLLOW-UP ACTIVITIES

The effect of increased precipitation on recharge should be investigated by field studies during characterization.

REFERENCES CITED

Cooley, R.L., and Torak, L.J., 1984, referenced in text as written communication.

Spalding, W.G., and others, 1984, Preliminary Assessment of Climatic Change During Late Wisconsin Time, Southern Great Basin and Vicinity: U.S. Geological Survey Water-Resources Investigations Report 84-4328, 40 p.

Czarnecki, J.B., and Waddell, R.K., 1984, Finite-Element Simulation of Groundwater Flow in the Vicinity of Yucca Mountain, Nevada-California: U.S. Geological Survey Water-Resources Investigations Report 84-4349, 38 p.

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT #: USGS-WRI-84-4349

DOCUMENT: Czarnecki, J., and Waddell, R.K., 1984, Finite Element Simulation of Ground Water Flow in the Vicinity of Yucca Mountain, Nevada-California. U.S. Geological Survey, Water-Resources Investigations Report 84-4349.

REVIEWER: Williams & Associates, Inc.

DATE REVIEW COMPLETED: August 26, 1986

ABSTRACT OF REVIEW: APPROVED BY: Roy S. Williams

The report is concerned with the use of a groundwater model to better understand the groundwater flow system in the vicinity of Yucca Mountain, Nevada. Parameter estimation techniques are used to determine transmissivity values. Sensitivity analysis is used to determine the most significant flow parameters. The report uses state-of-the-art techniques for groundwater modeling and makes use of the data that are available at the present time. The authors warn against using their results out of the context of the assumptions presented in the report. Calculated groundwater travel times in the saturated zone of 85 to 17,000 years are presented. Another possible use of information in the report could be for evaluating the water resource. An extensive review of the literature concerning the Nevada Test Site is presented in the report.

BRIEF SUMMARY OF DOCUMENT:

The report describes the use of a groundwater flow model and its application to the region of Yucca Mountain at the Nevada Test Site. This model makes use of parameter estimation techniques to estimate transmissivities within the flow system and to simulate steady state groundwater flow. This model ultimately could be used for estimating travel times in the saturated flow zone as well as for evaluating the effect of future groundwater withdrawal for irrigation.

The model of the groundwater flow system includes recharge/discharge fluxes, boundary fluxes and distribution of hydrologic properties of hydrogeologic units within a three-dimensional framework. The conceptual model used is one proposed by Winograd and Thordarson (1975). The code used is that developed by Cooley (1977, 1979). The parameter estimation technique by Cooley was used to derive values for various flow parameters for zones or nodes defined throughout the modeled area. The parameter values are estimated by minimizing the weighted sum of squared residuals of simulated head. The parameter estimation techniques are not successful in estimating precise values of parameters; however, the importance of various parameters is delineated. The standard area of estimated parameters reflects the ability of the model to determine these parameters. When entering the hydraulic head measurements into the parameter estimation scheme the node closest to a given measurement site is assigned the hydraulic head value at that site or an average value of the surrounding hydraulic head is applied to a central node.

Fluxes, constant head nodes and transmissivities were included as parameters for optimization at various points in the modeled region. Simulations involving constant head and transmissivity parameters, transmissivity parameters only, and one areally distributed flux parameter successfully converged. Simulations with both transmissivity and flux parameters failed to converge. The final selection of parameters involved only transmissivities.

In the final results, a standard error of 7.1 m was obtained. The standard error divided by the range in measured head values is 0.008. Although an individual residual may be small, almost 29 m in one instance, overall agreement between measured and simulated heads is good. The correlation coefficient between measured and simulated heads for final simulation was 0.997. This suggests an excellent representation of the hydrologic system by the model. The principal fluxes specified in the model are distributed areal fluxes at the Franklin Lake Playa (evapotranspiration) and at Fortymile Canyon (infiltration) and as linear distributed flux at Furnace Creek Ranch (seeps and springs). The infiltration at Fortymile Canyon was set as a parameter; however, the flux did not allow model convergence. Estimates of this flux were varied for individual runs until a minimum error variance was achieved. An extensive sensitivity analysis was carried out which resulted in the following three conclusions.

1) Scale sensitivity with respect to both discharge and transmissivity increases as distance from the point of constant head increases.

2) Absolute values of scale sensitivities with respect to transmissivity and flux decrease as transmissivity increases.

3) Scaled sensitivities with respect to both types of parameters are functions of flux.

Travel time calculations also were performed based on the possible range of aquifer thickness and porosity. Calculated travel time along various paths in the saturated zone varies from 86 to 17,000 years. The author's general conclusions are:

1) The presence of barriers in the model greatly affects the orientation of groundwater flow vectors. Few data are available regarding the shape, orientation and extent of the barrier north of Yucca Mountain.
2) The travel time estimation procedure used to determine a possible range in travel time, although not entirely accurate, provides a means of comparing travel times resulting from different values of porosity and thickness.

3) Results of this model need to be used with care, particularly with respect to the prediction of transport of radionuclides. Fluxes provided by this model may be used in a detailed transport model, but results could be misleading if the fluxes are used out of the context of the assumptions and qualifications stated in this report.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

Knowledge of the groundwater flow system may be needed to determine the groundwater travel time. Information on the groundwater resource also is needed to determine the possibility of development of the resource.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

The report has no significant deficiencies.

SUGGESTED FOLLOW-UP ACTIVITIES

No follow-up is needed.

REFERENCES CITED:

Cooley, R.L., 1977, A Method of Estimating Parameters and Assessing Reliability for Models of Steady State Groundwater Flow, 1--Theory and Numerical Properties. Water Resources Research, vol. 13, no. 2, p. 318-324.

Cooley, R.L., 1979, A Method of Estimating Parameters and Assessing Reliability for Models of Steady State Ground Water Flow, 2--Application of Statistical Analysis. Water Resources Research, vol. 15, no. 3, p. 603-617.

Winograd, I.J., and Thordarson, W., 1975, Hydrogeologic and Hydrochemical Framework, South-Central Great Basin, Nevada-California, with Special Reference to the Nevada Test Site. USGS Prof. Paper 712-C, p. C1-C126.

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT #: SAND82-0170

DOCUMENT: Johnson, R.L., October 1982, Thermal Analyses for a Nuclear Waste Repository in Tuff Using USW-G1 Borehole Data. Sandia National Laboratories, Albuquerque, NM.

REVIEWER: Williams & Associates, Inc.

DATE REVIEW COMPLETED: August 26, 1986

ABSTRACT OF REVIEW: APPROVED BY: Roy E Williams

The report analyzes heat flow from a repository located below the water table in welded tuff by means of a finite element computer code. Simulated temperature distributions are presented. The work is not significant to the present proposed location of the repository above the water table.

BRIEF SUMMARY OF DOCUMENT:

This report describes thermal calculations for the temperature distribution in the regions surrounding a nuclear waste repository sited below the water table in welded tuff. The material properties used are those obtained from the USW-G1 borehole. The analysis was performed for two waste forms: 1) high level wastes, and 2) spent fuel, emplaced at two different gross thermal loadings. A finite element code was used to simulate heat from from the source. The computational mesh for both types of waste extended 250 m above and 250 m below the floor of the repository room. The results are in the form of temperature contours or isotherms, and temperature time histories for various points around the room, through the pillar, and up to the upper and lower stratigraphic interfaces. Temperatures were well below the 85°C specified as a limit.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

This report is not significant to the present repository location because it is well above the water table and this analysis is for a repository below the water table.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

The main deficiency is that the analysis is for a repository below the water table.

SUGGESTED FOLLOW-UP ACTIVITIES

No follow-up work is necessary.

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT #: SAND83-0372

DOCUMENT: Johnstone, J.K., Peters, R.R., and Gnirk, P.F., 1984, Unit Evaluation at Yucca Mountain, Nevada Test Site: Summary Report and Recommendation. Sandia National Laboratories, Albuquerque, NM, and Livermore, CA, SAND83-0371.

REVIEWER: Williams & Associates, Inc.

DATE REVIEW COMPLETED: August 26, 1986

ABSTRACT OF REVIEW: APPROVED BY: Roy E. Williams

The report under review presents a unit evaluation of four potential repository horizons at Yucca Mountain. Prior to completion of the report the Topopah Spring Member was selected as the potential repository horizon. Therefore, most of the information presented in the report is outdated and is of little value to the NRC Waste Management Program. The report may be of some interest to mining engineers and geological engineers involved in the construction of the exploratory shaft at Yucca Mountain.

BRIEF SUMMARY OF DOCUMENT:

The report under review presents an evaluation of ranking criteria for four potential repository horizons beneath Yucca Mountain. The potential repository units are the welded, devitrified portions of the Bullfrog and Tram Members of the Crater Flat Tuff, the welded, devitrified Topopah Spring Member of the Paintbrush Tuff, and the non-welded zeolitized tuffaceous beds of Calico Hills. The Topopah Spring Member and the tuffaceous beds of the Calico Hills are above the water table whereas the Bullfrog and Tram Members are below the water table. The four ranking criteria used in the analysis included: (1) radionuclide isolation time, (2) allowable repository gross

thermal loading, (3) excavation stability, and (4) relative economics.

According to the report, formal unit evaluation began at the beginning of fiscal year 1982. The report notes that in the middle of the unit evaluation (July 1982) a programmatic decision, prompted by exploratory shaft design needs, was made selecting the Topopah Spring as the reference case target horizon. Because of this fact, much of the information presented in the report is irrelevant with respect to a potential repository within the Topopah Spring Member.

According to the report, studies for the unit evaluation were limited to those which the authors of the report believed would provide discrimination between units and which had a reasonable probability of being completed successfully with the limited amount of data available. The report notes "some studies were performed in spite of the nearly complete absence of real data or by using very preliminary data because they were deemed crucial to the evaluation. The water travel time estimates are an example of such a study".

Most of the report under review is dedicated to a description of the constructability of the repository in the four potential repository horizons as well as a rock mass classification and a far field thermal/mechanical evaluation. The unit evaluation studies described in the report under the heading "Constructability" deal primarily with the minability of the repository and the stability of the repository once it is constructed. While this section is based on very limited data, some of the information presented in the report may be of interest to mining engineers and geological engineers involved in the repository construction. However, it should be noted that much of the information presented in the report is outdated at the present time.

The section on groundwater travel time estimates presented in the report are outdated and are not applicable to the current conceptual model of the USGS. For example, the authors of the report assumed an infiltration flux of 3 mm/yr. This flux is much higher than current USGS estimates of 0.5 mm/yr. In addition, the report states

> The current hydrologic data from Yucca Mountain do not include information about fracture flow nor are the existing transport codes capable of explicit treatment of fracture flow, especially in the unsaturated zone. Therefore, the travel time estimates in both the saturated and unsaturated zones were based on the assumption of porous flow.

While the infiltration flux of 3 mm/yr is considered by the authors of the report to be conservative, the assumption that all flow occurs through the matrix is non conservative. Under the current USGS conceptual model of unsaturated flow beneath Yucca Mountain, a flux greater than the average saturated matrix hydraulic conductivity of the Topopah Spring Member (0.7 mm/yr) would initiate fracture flow. Ignoring fracture flow with an infiltration flux of 3 mm/yr invalidates the estimates of groundwater travel time presented in the report under review.

According to the report, vertical travel times in the saturated zone from a repository in the Bullfrog range from less than one year up to approximately 225,000 years. Estimated travel times from a repository in the Tram range from 2,200 years to more than 2,260,000 years. These estimates are based on very limited data and are outdated at the present time.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

The report under review is of little value to the NRC Waste Management Program with respect to a proposed repository in the Topopah Spring Member at Yucca Mountain. The Topopah Spring Member was selected as the proposed repository horizon before the report under review was completed. This fact served to outdate most of the material presented in the report prior to its publication. The report may be of some interest to geological engineers and mining engineers involved in the construction of the exploratory shaft at Yucca Mountain.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

The report under review was outdated prior to its publication. The report is of very little value to the NRC Waste Management Program.

SUGGESTED FOLLOW-UP ACTIVITIES

No follow-up activities are suggested.

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT #: SAND80-1464

DOCUMENT: Johnstone, J.K., and Wolfsberg, K., Editors, 1980, Evaluation of Tuff as a Medium for a Nuclear Waste Repository: Interim Status Report on the Properties of Tuff. 134 p.

REVIEWER: Williams & Associates, Inc.

DATE REVIEW COMPLETED: August 26, 1986

ABSTRACT OF REVIEW: APPROVED BY: Roy E. Williams

The report under review presents the interim status of studies of the properties of tuff evaluated from samples obtained from Yucca Mountain and Rainer Mesa (G-Tunnel). The report describes experiments performed as of 1980 on samples of tuff. The report describes also studies proposed at the time this report was written (1980). The report is relatively old and out-dated. Much of the data presented in the report has been up-dated by subsequent reports.

BRIEF SUMMARY OF DOCUMENT:

The report under review is the second in a series of summary briefings to the National Academy of Science Committee on Radioactive Waste Management. The report discusses a series of experiments performed on samples from drill hole UE25a-1 (Yucca Mountain) and test well J-13 (Jackass Flats). Where tuffs have undergone the process of devitrification, the original glass particles have been recrystallized to feldspar plus cristobalite or quartz. The report notes that this alteration process is dominate in densely welded horizons throughout the section. Zeolitization which results from the interaction of glass with groundwater, occurs at the non welded base of the Topopah Spring Member through the non welded bedded tuffs of Calico Hills, and in the non welded portion of the Prow Pass Member. Zeolitization occurs in stratigraphically equivalent horizons in test hole

UE25a-1 and test well J-13. According to the report, stratigraphic units are thinner at test well J-13 than at test hole UE25a-1. The report suggests that the most likely cause of the thinner units is due to greater distance of test well J-13 from source areas rather than paleotopography.

Tuff samples ranging from those containing a significant percentage of zeolites to devitrified tuff containing mainly feldspars and silica minerals were studied to determine the sorptive properties. The results of the study as of 1980 indicate the following:

1) Cesium, strontium and barium sorb better on zeolitized tuff than on devitrified tuff.

2) Plutonium sorbs on both zeolitized and devitrified tuffs.

3) A large range of sorption ratios was noted for americium and lanthanides. The report notes that the sorption ratios do not correlate with mineralogy except that sorption appears highest for tuff containing clay.

4) Sorption of anionic species--iodine, technetium, and uranium was low for all tuffs studied.

5) Sorption ratios generally are lower than desorption ratios for batch determinations. According to the report, strontium, cesium, and barium are thought to sorb and desorb predominantly by an ion exchange mechanism. Lanthanides, actinides, technetium, and uranium show values that differ by more than an order of magnitude.

6) Migration rates evaluated from flow experiments in crushed tuff sometimes are faster than values predicted from batch experiments with the same material.

Experiments were underway (1980) using rock columns containing a single, artificial (saw cut) fracture. Preliminary modeling of nuclide transport through jointed media suggests that intergranular porosity and penetration depth, fracture aperture, fracture length, fluid velocity and sorption distribution coefficient are the primary factors controlling radionuclide transport along fractures.

According to the report, the authors have developed a method for predicting the minimum theoretical matrix thermal conductivity of tuff based on grain density. The authors of the report suggest that by including the porosity, the conductivity of a broad range of tuffs can be predicted routinely to an accuracy of 15% or better. According to the report, thermal expansion measurements based on ambient pressure studies indicate the following:

1) Thermal expansion of devitrified welded tuffs generally is linear with temperature and is independent of both porosity and heating rate. The report notes that the only mineralogic factors that affected expansion behavior were the presence or absence of cristobolite and altered biotite.

2) Non welded tuff generally is characterized by thermal contraction. The report suggests that the contraction appears to be a function of complex dehydration reactions, probably of zeolite, hydrated glass, and/or clay.

Mechanical property studies have been conducted at ambient temperatures. According to the report, emphasis has been placed on the effects of confining pressure, water content, joints, and strain rate. The results of these studies indicate the following:

1) There is a relationship between strain (compressive and tensile) and porosity (degree of welding). The report notes that welded tuff is as much as three times stronger than non welded tuff.

2) The compressive strength of dry welded tuff is about 25% greater than for saturated samples tested under the same conditions.

3) The elastic moduli of tuffs is anisotropic.

4) Preliminary compression tests at 200°C on welded and partially welded tuff show a 30% decrease in strength compared to room temperature data.

5) Both saturated and dry samples of welded tuff show an approximate 6% decrease in compressive strength per decade of decrease in strain rate.

6) The coefficient of friction in artificial fractures is about 9% higher for saturated samples than for dry samples.

According to the report, initial studies of water loss from welded tuff have been performed in order to understand the effect of water loss in canister holes, mine shafts, and pillars when exposed to a drying atmosphere. The model developed for these experiments considers water lost via vapor diffusion through the pores of the rock.

The report describes the in-situ tuff water-migration/heater experiment. According to the report, water was collected continuously during the heating phase (63 days) of the experiment in the heater hole (approximately 60 L) and in two of the three

satellite water collection holes (1.5 and 3.6 L). The report suggests that in the immediate vicinity of the heater hole, water movement occurred by vapor diffusion into the hole; water migration into the satellite holes was believed to be by Darcy flow driven by the high partial pressure of water at the vaporization front. Final results of the in-situ tuff water-migration/heater experiment is presented in Johnstone and others (1985).

According to the report, the nuclide-migration experiment in G Tunnel was initiated at the time this report was being written (1980). The later report by Norris and others (1982) describes the geochemistry studies pertaining to the G Tunnel radionuclide migration experiment.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

The report under review describes the status of studies conducted up to 1980 pertaining to the evaluation of tuff as a medium for a nuclear waste repository. Some of the basic information presented in the report may be of value to the NRC Waste Management Program. However, because of the old age of the report with respect to studies being conducted at the Yucca Mountain site, much of the material presented in the report is out-dated and has been superseded by other reports. The report is an interim status report on the properties of tuff; the DOE's knowledge of the properties has increased significantly since this report was published.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

The report under review is an interim status report on the properties of tuff. The report presents the results of experiments conducted up to 1980. Besides the fact that the report is of limited value because of its relative old age, there are no specific problems, deficiencies or limitation of the report.

SUGGESTED FOLLOW-UP ACTIVITIES

No follow-up activities are recommended.

REFERENCES CITED:

Johnstone, J.K., Hadley, G.R., and Waymire, D.R., 1985, In-Situ Tuff Water Migration/Heater Experiment: Final Report, Sandia National Laboratories, Albuquerque, NM, and Livermore, CA, SAND81-1918, 106 p.

Norris, A.E., and others, 1982, Geochemistry Studies Pertaining to the G-Tunnel Radionuclide Migration Field Experiment. Los Alamos National Laboratory, Los Alamos, NM, LA-9332-MS, 42 p.