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

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Distribution: J Pohle

(Return to WM, 623-SS) Sac

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

RE: NTS

Dear Jeff:
1

I have enclosed enclosed reviews of the following documents:

1. Barr, G.E., 1985, Reduction of the Well Test Data for Test Well USW H-1, Adjacent to Nevada Test Site, Nye County, Nevada: SAND85-0637, Sandia National Laboratories, Albuquerque, New Mexico and Livermore, California, 36 p.

2. Bixler, N.E., 1985, NORIA-A Finite Element Computer Program for Analyzing Water, Vapor, Air and Energy Transport in Porous Media: SAND84-2057, Sandia National Laboratories, Albuquerque, New Mexico 87185 and Livermore, California 94550 for the U.S. Department of Energy

3. Kilbury, R.K., 1984, Water Intake at the Atmosphere-Earth Interface in a Fractured Rock System: Department of Hydrology and Water Resources, University of Arizona, Tucson, AR 85721. Principal investigator Daniel B. Evans for the U.S. Nuclear Regulatory Commission, Department of Radiation Programs and Earth Sciences.

4. Muller, D.C., and Kibler, J.E., 1984, Preliminary Analysis of Geophysical Logs from Drill Hole UE-25p#1, Yucca Mountain, Nye County, Nevada: USGS Open-file Report 84-649, Denver, 14 p.

5. Peters, R.R., Klavetter, E.A., Hall, I.J., Blair, S.C., Heller, P.R., and Gee, G.W., 1984, Fracture and Matrix Hydrologic Characteristics of Tuffaceous Materials from Yucca

2672

Mountain, Nye County, Nevada: SAND84-1471 Sandia National Laboratories, Albuquerque, New Mexico 87185 and Livermore, California 94550, for the U.S. Department of Energy.

6. Travis, B.J., Hodson, S.W., Nuttall, H.E., Cook, T.L., Runberg, R.S., 1984, Preliminary Estimates of Water Flow and Radionuclide Transport in Yucca Mountain: NNWSI Milestone Report, Department of Energy, Nevada Operations Office

If you have any questions concerning these reviews, please call.

Sincerely,

Roy E. Williams /sl

Roy E. Williams

REW:sl

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT: Barr, G.E., 1985, Reduction of the Well Test Data for Test Well USW H-1, Adjacent to Nevada Test Site, Nye County, Nevada: SAND85-0637, Sandia National Laboratories, Albuquerque, New Mexico and Livermore, California, 36 p.

REVIEWER: Williams and Associates, Inc.

DATE REVIEW COMPLETED: November 1985

BRIEF SUMMARY OF DOCUMENT: DATE APPROVED:

The purpose of the report under review is to present an independent analysis of aquifer test data collected by the USGS for well USW H-1. Data reduction for the report under review was conducted with the computer code PUMP (Barr, Miller, and Gonzalez, 1983). A listing of the code used in the report under review is given in Appendix C of the report. The code was used to evaluate the sensitivity of the aquifer test results through changes in hydraulic conductivity and storativity in potential boundary conditions in the vicinity of the well.

The procedure used to evaluate the hydraulic conductivity estimates for well USW H-1 is as follows:

1) Initial values for hydraulic conductivity, storativity, and distance to any hydrogeologic boundary were estimated.

2) Values of hydraulic conductivity and storativity were juggled by trial and error until an approximate fit between the calculated and observed values was found.

3) After a reasonable match between the calculated curves and the actual test data was obtained by juggling the hydraulic conductivity and storativity values, the added effects of potential hydrogeologic boundaries were evaluated.

4) The character of hydrogeologic boundaries (i.e., barrier or recharge) as well as distance from well USW H-1 were juggled

to obtain improved agreement between the calculated curves and the actual test data.

Three pump tests and three recovery tests over the depth intervals of 572 through 688 meters, 687 through 1,829 meters, and 687 through 1,829 meters, and six injections tests over the intervals 687 through through 697 meters, 811 through 1,829 meters, 926 through 1,829 meters, 1,200 through 1,829 meters, 1,407 through 1,829 meters, and 1,621 through 1,829 meters were evaluated by the procedure outlined above.

The report under review notes that the integrated total hydraulic conductivity of the penetrated portion of the saturated zone (687-1,829 meters) obtained by the numerical method (1.67×10^{-7} m/sec) and by Rush and others (1983) (1.16×10^{-7} m/sec) is essentially the same. However, the report notes also that hydraulic conductivity values estimated for individual tests differ from those estimated by Rush and others (1983) by up to an order of magnitude. Storativity values estimated by the numerical method and by Rush and others (1983) differ typically by one order of magnitude. The report under review notes that an upper zone, approximately 100 meters thick, is characterized by relatively high hydraulic conductivities in the range of about 10^{-4} to 10^{-5} m/sec; below this zone, hydraulic conductivity of the volcanic rocks appears to be several orders of magnitude lower.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

The report under review does not present any new data or new interpretations of the data collected from test well USW H-1. Therefore, the significance of the report to the NRC waste management program is in the usual sense.

PROBLEMS, DEFICIENCIES, OR LIMITATIONS OF REPORT:

The report under review claims to provide an independent confirmation of hydraulic conductivity estimates for test well USW H-1. However, because of the nature of the limiting assumptions incorporated into the numerical method (i.e., the same assumptions that are inherent in the theoretical models used by Rush and others (1983) to analyze the test data), it is not surprising that the numerical method would support the estimates of hydraulic conductivity obtained by Rush and others (1983). The major limiting assumption of the numerical method discussed in the report under review and inherent in the theoretical model used by Rush and others (1983) to analyze the test data is that the fractured tuff can be represented by a homogeneous and isotropic porous medium. Another major assumption incorporated into the numerical method is that the packed off intervals of the well were assumed to represent an effective porous medium in a saturated confined aquifer. This assumption requires that deviations of the data plots from the predicted responses, based on the theoretical models, must be due to the effect of hydrogeologic boundary conditions (i.e., barrier boundary or recharge boundary). The numerical method is not capable of evaluating potential effects of leaky-aquifer conditions or the transition from early time to late time in an unconfined aquifer or a double-porosity system.

SUGGESTED FOLLOW-UP ACTIVITY:

No follow-up activity is suggested with respect to the report under review.

REFERENCES CITED:

Rush, F.E., Thordarson, William, and Bruckheimer, Leura, 1983, Geohydrologic and Drill-hole Data for Test Well USWH-1, Adjacent to Nevada Test Site, Nye County, Nevada: USGS Open-file Report 83-141, Denver, 38 p.

Barr, G.E., Miller, W.G., and Gonzalez, D.D., 1983, Interim Report on the Modeling of the Regional Hydraulics of the Rustler Formation: SAND83-0391, Sandia National Laboratories, Albuquerque, New Mexico.

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT: Bixler, N.E., 1985, NORIA-A Finite Element Computer Program for Analyzing Water, Vapor, Air and Energy Transport in Porous Media: SAND84-2057, Sandia National Laboratories, Albuquerque, New Mexico 87185 and Livermore, California 94550 for the U.S. Department of Energy

REVIEWER: Williams and Associates, Inc.

DATE REVIEW COMPLETED: November 1985

BRIEF SUMMARY OF DOCUMENT: DATE APPROVED:

This report describes a finite element computer program that solves four non-linear, parabolic, partial differential equations simultaneously. The four equations describe the transport of water, water vapor, air and energy through partially saturated porous media. The Galerkin finite element method is used for the spatial discretization of two-dimensional domains with planar symmetry or axisymmetry. The time integration is done by a third order predictor correcter scheme that uses error estimates to automatically adjust time step size so as to maintain uniform local time truncation errors throughout the calculation. The user is not required therefore to select time step size except at the first step. Most material properties can either be set to constant values or defined as functions of dependent or independent variables by user supplied subroutines. The report includes discussions of the theory of two phase transport in porous media and the numerical procedure used in NORIA.

GENERAL TECHNICAL DISCUSSION:

Introduction. This section is a general discussion of the various types of finite element and finite difference programs which are available to solve various types of flow problems. The author notes that NORIA is intended for non-isothermal problems in which large gradients are expected in the gas pressure. Other programs which have been developed at Sandia Labs are SAGUARO which considers gas flow but with little or no pressure gradient and MARIAH which is for saturated flow. There are only three other programs that can solve the same types of problems that are solved by NORIA. These are PETROS which is a one-dimensional finite difference program, TUFF which is an integrated finite difference program, and WAVE which is a finite difference program. The author feels that the finite element program NORIA is more suitable than the finite difference programs.

Section 2 Theory and Mathematical Model. The assumptions which the author uses are 1) the two phases consist of a single component in liquid and vapor phases and a second component that is an inert gas. The liquid phase is assumed to be water and the inert gas is assumed to be air, but other constituents can be modeled equally well by NORIA. 2) Both air and vapor are assumed to be ideal; thus the partial pressure of each component is described by the ideal gas law and the partial pressures are additive. 3) The three phases are taken to be in local thermal equilibrium; thus the temperatures of the rock matrix, liquid water and gas are all equal locally. 4) All viscous flow is laminar and obeys Richards equation which is a form of Darcy's law for unsaturated media. 5) The liquid phase behaves as a Boussinesq fluid. In other words, the density is independent of pressure and varies only slightly in proportion to the difference between local temperature and the referenced temperature. 6) The porosity and density of the porous matrix are constant over each material. Up to ten materials are allowed. The remainder of Section 2 is a formulation of the four non-linear partial differential equations which define the flow of the four phases. This formulation appears to be reasonable.

Section 3 Galerkin Finite Element Formulation. This is a fairly standard Galerkin formulation with development of the basis functions, and the use of parametric and subparametric elements. There is also a discussion of the various types of boundary conditions.

Section 4 is the time integration scheme in NORIA. This is quite different than other models currently available. The user only selects an initial time step and all succeeding time steps are adjusted automatically to give the same truncation error in each time step. The time step may be increased or decreased at a particular interation. The basic process is to use a predictor corrector method coupled with a Newton iteration procedure to move ahead in time. The Adams-Bashforth predictor cannot be used in the first two time steps because rates of change of the dependent variables are not known prior to the initial condition. The start-up procedure used is to take two backward difference steps before starting the two step time integration procedure. This process helps to damp out discontinuities that may be present in the initial data.

Section 5 Program Description. The first stage of operation of NORIA involves assigning nodal point locations. The mesh is then generated. Boundary and initial conditions are next specified. The solution procedure then is pursued. Next, derived quantities such as heat or water vapor or air velocities are computed. The output data thus may be plotted as desired. Several different types of meshes such as eight point isoparametric or subparametric elements as well as six node subparametric or isoparametric elements may be used. The options give a great deal of flexibility in fitting a mesh to irregular boundaries. Boundary conditions involve either flux boundaries or constant potential boundaries. There are several options in calculation of derived quantities such as heat fluxes or determination of water vapor and velocities. The plotting package will generate plots of nodal point locations, finite element mesh outlines of materials, contours and profiles of the dependent variables.

The remainder of the report presents the actual specifications of the cards to run the program. On reviewing the use of this program, the obvious question raised is whether the huge amount of data on materials would ever be available to model a field type problem. The program is very large containing 10,000 source statements and must be run on a relatively large computer such as the Cray 1S. Development of the program is a large step that is necessary to define the flow of vapor, liquid water and heat in the neighborhood of the repository. The amount of data required to run the program, however, would be mind boggling.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

The report under review is one of many computer models that are being developed to simulate multiphase flow in porous media.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

There are no major problems or deficiencies in the report. However, the program is very large and will require an immense amount of data to be useful.

SUGGESTED FOLLOW-UP ACTIVITY:

No follow-up activity is suggested at the present time.

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT: Kilbury, R.K., 1984, Water Intake at the Atmosphere-Earth Interface in a Fractured Rock System: Department of Hydrology and Water Resources, University of Arizona, Tucson, AR 85721. Principal investigator Daniel B. Evans for the U.S. Nuclear Regulatory Commission, Department of Radiation Programs and Earth Sciences.

REVIEWER: Williams and Associates, Inc.

DATE REVIEW COMPLETED: November 1985

BRIEF SUMMARY OF DOCUMENT: DATE APPROVED:

This study involves the development of a conceptual model, and experimental work in the field concerning the flow of water into a fractured rock system. A field site consisted of a densely welded tuff outcrop near Patagonia, Arizona. A Fractured Rock Infiltrometer (FRI) was developed and used to measure air and water intake rates in individual fractures in the study area. Analytical methods were developed to calculate fracture apertures from flow of either air or water. The aperture widths calculated from the various experiments ranged from 1 micrometer to approximately 35 micrometers; the widths appear to be normally distributed. A model was developed to simulate flow across the atmosphere-earth boundary. The model input included historical climatic conditions at the study area in terms of rainfall intensity, duration and seasonal variation. The average surface water intake into the fractured rock system was estimated at 2.1 millimeters of water for the period simulated, which is less than one percent of annual precipitation. The intake appears to be more dependent on storm duration than on intensity. The methods developed provide a means of characterizing water intake rates into a fractured rock surface based on rainfall characteristics.

GENERAL TECHNICAL DISCUSSION:

Page 2. The author notes correctly that most studies to date have been limited to characterization and modeling techniques applied within the rock mass, not at interfaces. The purpose of this study was to develop a reliable method for prediction of flow through the fractured rock interface. The principal objectives included: 1) determination of water intake rates at the earth boundary, 2) development and improvement of field and analytical techniques used to determine fracture intake and apertures, 3) classification of average fracture apertures with regard to a statistical distribution, 4) comparison of results from air and water methods of aperture calculation, and 5) development of a model capable of simulating water intake across the atmosphere earth boundary.

Section 3.1.1 Fractured Rock and Infiltrometer Design. The fractured rock infiltrometer is similar to the old double ring infiltrometer in that it has two rings through which infiltration occurs. The assumption is that the flow through the outer ring will maintain the flow through the inner ring in a vertical direction. In the FRI, the device was bolted to the rock and sealed such that there was no flow across the surface of the rock. In this section the author states "The water set-up incorporates a dual chambered system designed to minimize lateral flow at depth, allowing the assumption of vertical flow when measuring water intake from the interior." It is questionable whether vertical flow actually occurs to any great depth in this situation. The author also questions the assumption later in the report.

Figure 3.1 and 4.1 are interchanged but the titles are in the correct places.

Table 3.2, page 23. This table presents data with time for the flow into a particular fracture. The fracture aperture has been calculated from the equations; but the values given change with time. This indicates that the equations may not be valid at small values of time. The fracture aperture eventually reaches a more or less steady value.

On page 25 there are a number of items in the various equations that should be defined. The units are not presented for h_r in equation 3.5 e_w. is not defined and equation 3.7 should read $R_e = e_w \rho v/\mu$.

Section 3.3.2 Analytical Results. The author states that water intake fracture aperture, depth to wetting front, and fluid velocity were calculated for the various experiments. Considerable work with these equations is necessary to see how this was done. The explanation could be improved. It also became apparent here that the analysis assumes that there is no flow into the porous matrix. The author states this later in the report but it probably should be pointed out at the start of the development.

Page 31, Section 3.3.4. A question raised previously in the discussion of the experimental device relative to horizontal flow is discussed in this section.

Page 32, "Sources of experimental error include", there probably should be a seventh item here relative to possible flow into the matrix itself.

Section 4.4 Analytical Results and Comparison. In Figure 4.2 the aperture width as measured by air is plotted versus the aperture width as measured by water. The author states that the results indicate relative agreement between the methods of aperture calculation. However, it appears that the data show that usually the aperture width measured by air is greater than that measured by water. As an example, two points show a smaller width for air, one is the same and seven points show a greater width for air. All the widths were calculated using the cubic law for fluid flow between two plates. In the case of air flow from the FRI, it seems that air very likely flows into the crack and horizontally out from under the test device. Since there is no reason for air to flow downward due to its small specific weight, it would simply flow outward into the atmosphere by the easiest route possible. This is also indicated by the fact that the inflow with air does not change with time. It simply gives a constant value.

With water, on the other hand, the tendency is to move downward into the rock due to gravity and due to the capillary forces in the fracture. Thus with water the flow field is constantly expanding and the rate of flow decreases with respect to time. Use of the cubic law in each case would give some measure of aperture width. It is possible that the nearly consistent difference between the two methods is due to the water flowing into the porous matrix whereas there is no tendency for air to flow into the porous matrix. It appears that the author fails to realize that water is a wetting fluid and air is a non wetting fluid. The physics of flow into a porous material is therefore different due to the different wetting properties.

Section 4.5 Effect of a Wetted Fracture on Fracture Air Intake. In this section the author discusses the use of air after water has been placed in the fracture. As one would expect the air flow is initially low and then increases. This would be due to the fracture being partially wet with water, reducing the cross-sectional area flow to air. After some time, however, the water will evaporate and cause the fracture area to increase to the dry value.

Section 5.1.2 Assumptions and Theoretical Basis. In equation 5.1 q_w is defined as water intake per unit length of fracture. W on the other side of the equation is defined as fracture length. This is inconsistent. Either q_w should be defined as water intake or W should be defined as unit length of fracture.

SIGNIFICANCE TO THE NRC WASTE MANAGEMENT PROGRAM:

The report under review is a topical report of the research being conducted at the University of Arizona. The final results of this research undoubtedly will be important to the NRC Waste Management Program.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

The report makes an important contribution to understanding flow into fractures from rock surfaces. It shows that the cubic law is probably valid and may be used for estimating the aperture width. Factors that should be recognized when relating this to natural infiltration into fractures are 1) many times there is a thin soil mantle over the fractures which would completely change the phenomenon of flow into the fractures; in volcanic tuff the porous matrix itself has permeability and will attract water. It appears that it may be necessary to use some sort of a sprinkling infiltrometer to evaluate the effect of a soil mantle and flow into the porous matrix, on water movement into volcanic tuff.

SUGGESTED FOLLOW-UP ACTIVITY:

The final report and any progress reports should be reviewed when they are released.

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT: Peters, R.R., Klavetter, E.A., Hall, I.J., Blair, S.C., Heller, P.R., and Gee, G.W., 1984, Fracture and Matrix Hydrologic Characteristics of Tuffaceous Materials from Yucca Mountain, Nye County, Nevada: SAND84-1471 Sandia National Laboratories, Albuquerque, New Mexico 87185 and Livermore, California 94550, for the U.S. Department of Energy.

REVIEWER: Williams and Associates, Inc.

DATE REVIEW COMPLETED: November 1985

BRIEF SUMMARY OF DOCUMENT: DATE APPROVED:

This report concerns the measurement of unsaturated flow properties of the tuffaceous materials from Yucca Mountain, Nevada. Yucca Mountain is composed of tuffaceous formations that must be characterized to estimate the rate at which radionuclides would migrate to the water table. In order to determine the flux of water in the unsaturated zone, the unsaturated flow properties of these materials must be known. Tests were run on 19 samples of tuff taken from drill hole USW GU-3 and 29 samples taken from drill hole USW G-4 on the NTS to determine the hydraulic properties in the pressure range of -10 to -1,000 meters. Direct measurement of unsaturated conductivity was not done since this is extremely time consuming. Capillary pressure water retention data were obtained which allows calculation of the unsaturated conductivity. Four samples of unfractured tuff from drill hole USW GU-3 and five fractured samples taken from drill hole USW G-4 were tested at elevated confining pressures to determine saturated conductivity. This report concerns methods used to obtain these data and methods to analyze the results.

MATERIALS AND METHODS:

Pacific Northwest Laboratories (PNL) performed three types of tests. These included 1) water retention tests, 2) unconfined saturated hydraulic conductivity tests, and 3) confined saturated hydraulic conductivity tests. Micromeritics Instrument Corp.

performed mercury intrusion tests to provide a check on the water retention curves determined by psychrometric measurements. Water retention characteristics were obtained on 48 cylinderical samples. These samples were 1.4 x 1.2 cm (diameter by length) that were subcored from the original core samples. Unconfined saturated conductivity tests were also run in the cylinders as well as saturated conductivities at elevated confining pressures. Unfractured samples which were tested at elevated confining pressure consisted of 5.4 x 1.9 cm (diameter by length) wafers. The criteria for selecting the fractured core samples were that the fracture was natural and met the orientation of the fracture testing.

TESTING METHODS:

All samples were vacuum saturated by standard methods before testing with the thermocouple psychrometer. The psychrometer was used to measure potential of the matrix water in the range of 10 to 10,000 meters of water. Samples were weighed to determine the moisture content. The determination of suction head from psychrometer measurements was by use of a relationship from Campbell (1977) The total water potential was equated to the sum of the osmotic, matric, gravitational, pressure, and overburden potential components. In the unsaturated rock sample, the major component of total potential is the matric potential. It should be noted that the neglect of gravitational potential was only for the laboratory testing of the core and not in general for the tuff.

Mercury intrusion tests were performed on 1.2 cm by 2 cm cylinderical samples by standard testing procedures. The sample was first evacuated and mercury then was forced into the pores under a pressure of up to 60,000 psi. The saturation of the mercury was calculated from the volume that had been intruded. The equivalent head or pressure of water was evaluated from the mercury data. In this calculation surface tension of water was used as 72 dynes/cm. This value, however, is the value for pure water; it may be preferable to use the measured surface tension of the water used in the experiments.

Unconfined saturated hydraulic conductivity was measured by a constant head method. The samples were positioned in a specially built plastic permeameter sealed in place with a silicon rubber compound, then vacuum saturated and allowed to soak for 24 hours before testing. Elevated pressures up to 3 bars were used for this experiment. Fractured samples were tested with a confining pressure and pore pressure of 35 and 30 bars, respectively. A pressure difference was introduced across the sample and flow through the sample was measured by either a flow meter or a piston displacement of the pore fluid supply pump.

EXPERIMENTAL RESULTS:

Complete data from all the experiments are presented in the appendix of the report. These data include porosities, densities, hydraulic conductivities, and the water retention characteristics at various suction heads. In several samples, the porosity was not the same as the total water content at saturation. This discrepancy may be due to inaccuracy of the single grain density measured for that particular sample because of tuff material variability within the sample. The samples also may contain small disconnected pores that could not be saturated. For these reasons the maximum volumetric water content rather than porosity was used as a basis on which to calculate the relative saturation.

The mercury intrusion data and psychrometer data generally agree over the pressure range where both tests are valid. In the few cases, there was disagreement; assumptions made to convert the mercury intrusion data may miss important effects due to sample structure and mineralogy that may be present in some samples and not in others. An equation from Van Genuchten (1978) was used to fit the saturation-suction data because it yields an analytical expression which may be used to calculate the unsaturated conductivity. The calculation process was used for unsaturated conductivities because there is no direct way to measure such low values in a reasonable time period. Saturation data versus suction head data, and experimentally fitted curves are presented for all the various units. The data appear to be more consistent than the fitted curves in some cases. The most striking factor about these data are the extremely high displacement or entry pressure heads. These are all greater than 10 m and many are as high as 80 m. There is good discussion of the various individual sample data. The saturated hydraulic conductivity data are presented in plots of porosity versus the conductivity for each sample in the non-welded vitric tuffs. There appears to be a fairly consistent relationship between porosity and hydraulic conductivity. In most of the other materials there is considerable scatter in the data. In one sample there is rapid loss of conductivity noted in pressures between 50 and 150 bars. This effect was caused by a well developed crack and is consistent with crack closure and deformation with increased pressure. Data from fractured tuff samples are presented as a table of conductivity and calculated aperture widths. These aperture widths were calculated from the cubic law and an empirical equation developed for the relation between effective pressure and the change of conductivity due to pressure.

SUMMARY:

The authors give conclusions which are paraphrased below.

1) The relationship between water content and suction head for each individual sample is unique for the specific core matrix material.

2) A comparison of psychrometric and mercury intrusion data for 22 individual samples indicates the two testing methods give results that are for the most part in good qualitative agreement.

3) The data on water content versus suction head data for the limited number of samples taken from a particular rock group form a reasonably coherent group for comparison of Havercamp and Van Genuchten curve fits of data.

Conclusions for the saturated matrix hydraulic conductivity data are as follows:

1) The nonwelded vitric tuff samples had conductivity orders of magnitude higher than those of either the welded tuff samples or the nonwelded zeolitic tuff samples.

2) As individual groups the nonwelded vitric tuff samples and the welded devitrified samples appear to have a general correlation between the porosity and the hydraulic conductivity.

3) The reduction in conductivity as confining pressures increased to approximately lithostatic load is fairly small compared to the reduction due to other factors such as the degree of saturation.

Conclusions for the fracture saturated hydraulic conductivities are as follows:

1) Saturated conductivity of the fractures is several orders of magnitude higher than that of the matrix.

2) Flow through all fractured samples were substantially reduced at elevated pressures.

3) Fractured samples that were composed of strong rock regained 75 to 100 percent of initial conductivity when pressure was lowered to initial levels.

The remainder of the report consists of about 100 pages of tabular data and graphical presentations of these data.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

This report presents a tremendous amount of laboratory data which will be useful in order to understand the flow regime in Yucca Mountain. It should be recognized that these are small samples and therefore represent point values of the various formations. However, the data appear to be consistent, well presented and obtained by well accepted procedures.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

There are not major problems or deficiencies in the report.

SUGGESTED FOLLOW-UP ACTIVITY:

No follow-up activity is suggested at the present time.

REFERENCES CITED:

Campbell, G.S., 1977, An Introduction to Environmental Biophysics: Springer Verlag, New York, New York.

Van Genuchten, R., 1978, Calculating the Unsaturated Hydraulic Conductivity with a New Closed Form Analytical Model: Water Resources Bulletin, Princeton University Press, Princeton University, Princeton, New Jersey.

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT: Muller, D.C., and Kibler, J.E., 1984, Preliminary Analysis of Geophysical Logs from Drill Hole UE-25p#1, Yucca Mountain, Nye County, Nevada: USGS Open-file Report 84-649, Denver, 14 p.

REVIEWER: Williams and Associates, Inc.

DATE REVIEW COMPLETED: November 1985

BRIEF SUMMARY OF DOCUMENT: DATE APPROVED:

The purpose of the report under review is to present a preliminary analysis of the geophysical logs recorded for test well UE-25p#1. Pages 1 through 8 of the report under review describe the geophysical logs that were recorded in the test hole. The limitations of each of the geophysical logs are described also.

The geophysical logs were interpreted in the report under review to indicate that the Topopah Spring Member contains lithophysal and is highly fractured. The report under review concludes, based on uranium levels in the Topopah Spring Member, that the majority of fractures are open and unfilled. The report notes that fracture analysis of core from other drill holes (Spengler and others, 1979; Spengler and others, 1981) indicates also that most of the fractures in the Topopah Spring Member are open. The report under review notes also that the geophysical logs of the Tertiary tuffs encountered in drill hole UE-25p#1 correlate well with logs from other drill holes in the Yucca Mountain area reported by Daniels and Scott (1981), Hagstrum and others (1980), Muller and Kibler (1983), and Spengler and others (1979).

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

The report under review presents a preliminary analysis of the geophysical logs recorded in test well UE-25p#1. The data presented in the report under review are important with respect to the correlation of geophysical logs between test holes and wells at the Yucca Mountain site.

PROBLEMS, DEFICIENCIES, OR LIMITATIONS OF REPORT:

The primary deficiency of the report under review is that the report presents a very basic interpretation of the geophysical logs. The report does not present any information in support of the conclusion that the geophysical logs recorded in test well UE-25p#1 correlate well with the logs from other drill holes in the Yucca Mountain area. This conclusion is very important with respect to the correlation of fracture zones or "aquifers" throughout the Yucca Mountain area.

SUGGESTED FOLLOW-UP ACTIVITY:

The geophysical logs and interpretations presented in the report under review may be significant in the development of a conceptual model for the saturated zone and the unsaturated zone. Attempts should be made to correlate borehole geophysical logs with borehole flow survey logs for each borehole in the Yucca Mountain area.

REFERENCES CITED:

Daniels, J.J., and Scott, J.H., 1981, Interpretation of Geophysical Well Logs from Drill Holes UE25A-4, -5, -6, and -7: USGS Open-file Report 81-389, 46 p.

Hagstrum, J.T., Daniels, J.J., and Scott, J.H., 1980, Interpretation of Geophysical Well Log Measurements in Drill Hole UE25A-1, Nevada Test Site, Radioactive Waste Program: USGS Open-file Report 80-941, 32 p.

Muller, D.C., and Kibler, J.E., 1983, Commercial Geophysical Well Logs from the USWG-1 Drill Hole, Nevada Test Site, Nevada: USGS Open-file Report 83-321, 7 p.

Spengler, R.W., Byers, F.M., Jr., and Warner, J.B., 1981, Stratigraphy and Structure of Volcanic Rocks in Drill Hole USW-G-1, Yucca Mountain, Nye County, Nevada: USGS Open-file Report 81-1349, 50 p.

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WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT: Travis, B.J., Hodson, S.W., Nuttall, H.E., Cook, T.L., Runberg, R.S., 1984, Preliminary Estimates of Water Flow and Radionuclide Transport in Yucca Mountain: NNWSI Milestone Report, Department of Energy, Nevada Operations Office

REVIEWER: Williams and Associates, Inc.

DATE REVIEW COMPLETED: November 1985

BRIEF SUMMARY OF DOCUMENT: DATE APPROVED:

This report examines the effect of lithology and presence of fractures on water flow and radionuclide transport in Yucca Mountain, Nevada. Both analytical and numerical procedures are used to analyze flow and transport in fractured tuff. The numerical programs used include the TRACR3-D code which computes saturated and unsaturated two-phase flow in fractured porous media with transport of radionuclides. The WAFE code which computes water, air, vapor and energy movement in porous media also was used as were analytical solutions for transport of sorptive species down single fractures with matrix diffusion for steady water flow. A sensitivity analysis is used to analyze the sensitivity of water flow and species transport to several physical processes such as fracture flow, matrix potential, diffusion and chemical adsorption. Three questions are considered in the report.

1) How far down can water flow through fractures in unsaturated tuff?

2) How well can the fractured and nonfractured tuff layers retard radionuclide transport?

3) What is the effect of repository heat load on hydrology?

The sensitivity analysis is used for transport along a one-dimensional pathway that passes vertically downward through the densely welded unit (Topopah Spring Member and the bedded tuff) and the lower clastic unit (Calico Hills) and then horizontally in the saturated region through the Prow Pass Member, Bullfrog Member, or Tram Unit.

GENERAL TECHNICAL DISCUSSION:

Fracture Flow:

The authors initially discuss the ten to twenty thousand years travel time through the volcanic tuffs if the flow consists of matrix flow only. However, if there is a possibility of fracture flow, that time must be reduced considerably. The authors develop a conceptual model for flow in the fractures designed to answer the question: Will the recharge water move vertically through unfractured layers and then enter fractures? They note correctly that to enter a fracture from the porous rock, water would have to overcome capillary tension which would require saturations close to one. Their model is designed to determine how far a finite water slug would move down through a fracture before it would move into the porous material. There is a mistake in their initial analysis in that they assume that the capillary pressure in a fracture is equal to twice the surface tension divided by half the fracture width. They mention that this is for a capillary tube; however, the fracture is a two-dimensional problem and the equation should simply be surface tension divided by half the fracture width. In equation 2 on page 7, they do not define which is in the equation. The first solution for this analysis determines that in order for a water slug from the repository to reach the water table through a fracture, the fracture width would have to be much larger than 200 microns or the matrix would have to be almost saturated. Some formations in the matrix are up to 80 to 90 percent of saturation; however, a numerical solution of the equation shows that penetration to hundreds of meters requires either very wide cracks and/or high matrix saturation and/or small values for flow into the matrix. The numerical solution also shows that the analytical solution underestimates the depth reached. Their model does consider a finite length of slug initially. However, this may not be a valid assumption. It may be possible for water to flow continuously into the fracture during a a long duration rainfall event and the model does not appear to cover this possibility. There is discussion of the fact that there are two relatively unfractured layers, the upper clastic and the lower clastic, which lie below the fractured Tiva and fractured Topopah Spring layers, respectively. Water moving down the fractures will encounter these porous layers which will act a buffers controlling the rate at which water flows into the fractures below. For example, water cannot flow into fractures in the Topopah Spring below the Pah Canyon Member any faster than the hydraulic conductivity of the Pah Canyon Member permits.

The authors use a recharge of 8 mm/year, but do not reference the source. They then note that if there is 8 mm of recharge per year there would necessarily be fracture flow through the low permeability fractured regions and there would be alternating layers of porous flow and fracture flow from the surface down to the water table. They state that their interpretation implies that water in the high saturation region should be older than that in the low saturation regions unless the 8 mm recharge rate is high and the true recharge is almost zero. The logic of their reasoning is not obvious. It appears that water toward the bottom of Yucca Mountain would perhaps be older than water at the top, but there does not appear to be a reason why various layers would have different ages of water if the water is moving steadily downward. Using the assumption that most of the conductivity in the fractured layers is due to the fractures, an estimate of about 80 microns is made for the fracture aperture.

The authors next discuss the radionuclide transport based on their previously obtained water flow equations. Several curves are presented of sorption ratio variation for the various radionuclides and retardation factors are given in tabular form. When they actually determine the radionuclide transport they do not assume any water flow into the matrix. In other words, they are ignoring what they previously determined to be conservative. Concentration break through curves are also presented for all radionuclides. Of the ten nuclides considered, the only one that can reach the water table in less than 10,000 years is Technetium-99. The diffusion end of the matrix chemical sorption, and radioactive decay are concluded to prevent any of the other radionuclides from reaching the accessible environment in less than 10,000 years.

The next topic the authors consider is the effect of the heat formation in the repository which is expected to last for perhaps a few hundred years. This heat source will have a profound effect on the local and saturated hydrology. Near the repository, water will evaporate and move outward due to a concentration gradient. It will condense in colder regions and then tend to move towards the repository in liquid phase due to a saturation gradient. This phenomenon may bring about the possibility of a nearly saturated region above the repository in which case the water could flow down through the repository after cooling begins. The heat source may also thermally alter the porous material. The WAFE computer code was used to compute one- and two-dimensional transient two-phase air, vapor, and water flow with heat transport. Water saturation contours, velocity vectors, vapor and air velocities, and temperature contours are presented for 50 and 100 years after closing the repository. The authors conclusions are as follows:

"1) Significant fracture flow can occur in both water tables but only through high saturation, low permeability tuff.

2) Diffusion into the matrix and adsorption have a profound effect on transport. Migration times to the water table for all but one of the important radionuclides are considerably longer than 10,000 years and none of the radionuclides considered reaches the accessible environment in less than 10,000 years.

3) Heat load in partially saturated tuff can result in a dry, steam filled region extending several meters above and below a repository with recharge during cool down phase.

It is very important that the reader bear in mind the various assumptions and simplifications made in this preliminary analysis. Future analyses which include more detail may indicate considerably longer migration times and considerably different heat affects."

SIGNIFICANCE TO THE NRC WASTE MANAGEMENT PROGRAM:

The report under review presents a preliminary conceptual model of experted conditions in the vicinity of the repository. This report may become significant to the NRC Waste Management Program during further analysis of the conditions that can be expected to occur in the vicinity of a repository.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

The report under review presents a preliminary analysis of water flow and radionuclide transport in Yucca Mountain. Problems with the report are noted in the summary.

SUGGESTED FOLLOW-UP ACTIVITY:

The report under review is preliminary in nature. Conceptual models of the conditions that will exist in the immediate vicinity of a repository also are preliminary and should be evaluated as they are developed.