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Communication No. 267

U.S. Nuclear Regulatory Commission
Division of High-Level Waste Management
Technical Review Branch
OWFN - 4H3
Washington, DC 20555

Attention: **Mr. Jeff Pohle, Project Officer**
Technical Assistance in Hydrogeology - Project B (RS-NMS-85-009)

Re: **WWL Response to PO Questions on DOE-NRC-State Workshop on Alternative Conceptual Models**

Dear Mr. Pohle:

Per your request of June 21, 1988, attached please find a letter from Mr. Tom Sniff of Water, Waste and Land (WWL) responding to your questions concerning aspects of DOE's presentations (and Mr. Sniff's responses to those presentations; see NWC Communication No. 263). Mr. Sniff's letter response has been reviewed for technical and managerial content by M. Logsdon of Nuclear Waste Consultants.

Mr. Sniff's letter is essentially self-explanatory, and since questions pertained to specific matters raised at the meeting and Mr. Sniff's understanding of those matters, no additional responses from NWC are necessary. NWC does find Mr. Sniff's response to be clear and concise, and the NWC reviewer found Mr. Sniff's comments on NRC Questions 2 (experiment to assess pressure conditions in matrix and fracture) and 4 (concerning conceptual models) interesting and perceptive. NWC wishes to reemphasize Mr. Sniff's point that an experiment to address pressure conditions in matrix and fracture may provide necessary information for hydraulic evaluations, but will not provide sufficient information on transport characteristics. Furthermore, as Mr. Sniff points out, we already know the answer to this question: pressure equilibrium will exist only for the specialized case of steady-state flow in a dual porosity system with vertical fractures. While a well-designed physical experiment might be interesting (and surely would be very difficult), it is not clear that such an experiment would address a true data need, in the sense used by NWC.

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If you have questions about Mr. Sniff's letter, please contact me.

Respectfully submitted,
NUCLEAR WASTE CONSULTANTS, INC.

Barbara Basse for MJL

Mark J. Logsdon, Project Manager

cc: US NRC - Director, NMSS (ATTN PSB)
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Water, Waste & Land, Inc.
CONSULTING ENGINEERS & SCIENTISTS

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July 1, 1988

Mr. Mark Logsdon
Nuclear Waste Consultants
Denver, Colorado

Dear Mr. Logsdon,

The purpose of this letter is to provide replies to the following questions which were presented in a letter to Nuclear Waste Consultants (NWC) from Mr. Jeff Pohle on June 21, 1988. The questions, as presented in that letter are:

1. How do Peters and Klavetter define a composite continuum?

2. What sort of experiment would evaluate the assumption of a pressure equilibrium between the matrix and fractures?

3. How is a "discrete fracture network" considered in the Wang and Narasimhan method?

4. What does the term "conceptual model" mean to you?

5. What is your understanding of Sinnock's groundwater modeling (nominal case) concern of "scalar relationships"?

<u>Response to Question 1</u>

Peters and Klavetter (1988) define a composite continuum through their use of the macroscopic approach to defining flow. As defined in their report:

> "The macroscopic model assumes that the fracture and matrix hydrologic parameters used are statistically representative of a large volume of rock mass. The characteristic of the internal geometry are implicitly accounted for through the functional relationships between fluid content, conductivity, and pressure difference across interfaces. A fluid continuity equation is written for both the matrix and the fracture systems. The constitutive equations for flow in both systems may be considered to be transform functions that relate the parameters that can be experimentally determined. The continuity equations for the matrix and fracture system are linked, coupling the hydrologic parameters to yield a single continuum equation for the fractured, porous medium."

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Essentially, the fracture system is assumed to be one continuum with the matrix being a second continuum occupying the same space. Each continuum has distinct hydraulic properties. The two continuum are linked by fluid interchange between the two, with this interchange being handled mathematically by a source/sink term in the mass balance equations. This does not assume that the two continuum have the same pressure.

Response to Question 2

The assumption of pressure head equilibrium between a matrix and a fracture system provides a simplified linkage between the general fluid continuity equations for a dual-porosity equivalent continuum. Other relationships are possible between the pressure head in the matrix and the pressure head in the fracture system. However, pressure head equilibrium between the two systems is the simplest assumption.

Peters and Klavetter (1988) concluded that the use of the assumption of pressure head equality is appropriate for site scale modeling as making this assumption greatly simplifies the model required. Using this assumption means that the exchange of water between the matrix and the fracture system occurs so quickly that the pressure heads are always equal within the representative elementary volume. Peters and Klavetter stated that simulations of small-scale problems that explicitly incorporate the fractures and an analytical model of matrix recharge from partially saturated fractures indicate that this assumption is reasonable for the Yucca Mountain site.

As an approximation, Peters and Klavetter (1988) assume that the pressure head in the fractures and the matrix are identical in a plane perpendicular to flow in their analysis of water movement in an unsaturated, fractured rock mass. Peters and Klavetter base this equilibrium assumption on simulations performed by Wang and Narasimhan (1985) and consider four classes of flow in a fracture and matrix system. They assume that the fractures are capable of moving water along their length.

For class 1, water is drained from a system that initially contains saturated matrix and fractures. Peters and Klavetter concluded that if the fractures and matrix desaturate over different pressure head ranges, then under drainage conditions the pressure head in the matrix and the pressure head in the fractures are equal.

For class 2 flow conditions, water is being drained from the system with water moving from block to block by means of the fracture asperities. Again, based on the numerical simulations of Wang and Narasimhan (1985), Peters and Klavetter concluded that a reasonable approximation for the class 2 flow is for pressure equilibrium to exist between the fracture and matrix.

For class 3 flow conditions, water is infiltrating into a rock mass where the matrix is fully saturated. The authors assume that if the matrix and fracture systems saturate over different pressure head ranges, then the matrix pressure head should be able to closely follow the fracture pressure head. Again, a reasonable approximation is that the pressure head in the matrix and fracture are equal.

For class 4 flow conditions, the rock system is being recharged. The matrix saturation is less than one, and the fractures are initially unable to sustain flow along their length. Under these conditions, Peters and Klavetter concluded that the pressure head in the matrix and the fracture system are not equal. They showed that under certain conditions, the extent of this region was small.

It would seem that pressure equilibrium would only be reached between the fracture and the matrix once steady state for the entire system is realized. During a transient process, the pressure in the fracture system would probably be different than the pressure in the matrix system. Indeed, the only case when pressure equilibrium exists between the two systems would be for an idealized system of vertical fractures and steady state flow conditions. With a fracture orientation other than vertical, pressure differences are likely to exist between the fracture and matrix systems even at steady state although the magnitude of pressure difference is probably small.

This problem has been initially addressed by the DOE using numerical models (Wang and Narasimhan, 1985) and would seem to be the appropriate experimental method to continue the evaluation of the pressure equilibrium. A systematic approach would be required, but a series of numerical models using various fracture configurations and properties could be performed. One of the numerical models could be selected for an actual physical, laboratory experiment.

Because of difficulties inherent in the monitoring of the fracture potential, the laboratory experiment should provide matrix potentials and bulk system responses to be compared with the numerical results. Preferably, the matrix material used in the laboratory experiment should be synthetic (such as ceramic) with the instrumentation implanted in the block during the manufacturing process. The fracture(s) could simply be created by cutting into the block. The synthetic material should have a large conductivity to allow the experiment to be conducted in as short a time as possible.

Even if the fractured, unsaturated zone can be treated as an equivalent porous media, the fracture properties must be determined for the transport calculations. The proposed experiment would not yield information on the transport properties of the system. The transport of radionuclides at the Yucca Mountain site will depend on the individual fracture properties among other items.

<u>Response to Question 3</u>

Wang and Narasimhan (1985) simulated the drainage of a fractured, welded tuff cube with the fractures modeled explicitly. In their simulation, the matrix and the fractures were represented by separate saturation and permeability curves. These expressions were used to simulate the drainage of a fractured tuff column using the TRUST numerical model. Discrete vertical and horizontal fractures and intervening matrix blocks were explicitly taken into account.

<u>Response to Question 4</u>

I envision a conceptual model as a simplified version of a real system. Therefore my definition of a conceptual model is "a grouping of ideas, which combined, form a unified system that agrees with the known data and possible processes. These ideas should only be expressed as simple verbal, pictorial, or narrative concepts."

The purpose of a conceptual model is to provide a framework for the development of mathematical expressions. These mathematical expressions are used to describe the past, present, and the future behavior of the model. The validation of a conceptual model occurs if the current state of the real system can be matched by using the mathematical framework. By state, I refer to the physical parameters which exist in a system at a given time. These are similar to the state functions in thermodynamics.

An analogy would be the building of a model aircraft for wind tunnel tests. The conceptual model consists of the initial sketches from which the aircraft model is designed. The wind tunnel tests are analogous to the mathematical validation. The validation process is an iterative process in which the conceptual model provides a framework for mathematical and parameter analyses. These analyses then help to further refine the conceptual model. However, a model can only approach the real version that it is attempting to copy. The same is true of groundwater systems. The detail in the conceptual model can never be equal to the detail in the system which is being modeled.

Validation is a function of what I define as the minimum accepted error (MAE) which can exist between the mathematical representation of the conceptual model state and the state of the real system. The MAE is primarily measured by comparing the potential field predicted by the model with that of the real hydrologic system. Usually, the more data that is available from the real system, the more difficult it becomes for the mathematical model to exactly match that state.

However, once a current match is obtained, then predictions about future states (or previous states) can be made. Validation of the conceptual model occurs again when after a given time period, the predicted state of the system is compared to the realized state at that time. In fact, it is possible that a given state for a real system can be matched within the MAE with numerous conceptual model states. It is up to the professional judgement of the investigators to determine the appropriate conceptual model state, or whether further parameter acquisitions from testing can eliminate some of the possibilities.

Response to Question 5

When Sinnock gave his presentation at the Las Vegas conference, he specifically gave three examples of scalar relationships. These are

1). Measurement scale versus modeling scale
2). Influence of heterogeneity on dispersion
3). Sample averaging effects on geostatistical predictions

By using these particular examples in his overhead slide, I assumed that Sinnock was concerned with the problem of mapping real system parameters into the conceptual model's mathematical framework. For example, a core sample will yield a porosity and a permeability for a discrete volume in a hydrogeologic unit. How do you represent such data in a finite element model? What size of element will have that porosity and permeability?

My basic understanding of what Sinnock was presenting was the problem of trying to incorporate the effects of heterogeneity in the real system into the conceptual model mathematic framework. This can be a problem and a concern with any modeling program.

I hope that these responses have answered Mr. Pohle's questions. If you have any additional requirements, please do not hesitate to contact me.

Sincerely
Water, Waste, and Land, Inc.

Thomas Lyle Sniff
Senior Engineer

References

Peters, R. R. and Klavetter, E. A., 1988. "A Continuum Model for Water Movement in an Unsaturated Fractured Rock Mass," in Water Resources Research, Vol. 24, No. 3, Pages 416-430.

Wang, J. S. Y, and Narasimhan, T. N., 1985. "Hydrologic Mechanisms Governing Fluid Flow in a Partially Saturated, Fractured, Porous Medium," in Water Resources Research, Vol. 21(2), 1861-1874.