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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

AUG 23 1994

Mr. Ronald A. Milner, Acting Director
Office of Program Management and Integration
Office of Civilian Radioactive Waste Management
U.S. Department of Energy, RW 30
1000 Independence Avenue
Washington, D.C. 20585

Dear Mr. Milner:

SUBJECT: REVIEW OF THE U.S. DEPARTMENT OF ENERGY (DOE) STUDY PLAN ON "FLUID FLOW IN UNSATURATED, FRACTURED ROCK (REVISIONS 0 AND 1)" (8.3.1.2.2.8)

On September 1, 1992, DOE transmitted Revision 0 of the subject study plan to the Nuclear Regulatory Commission for review and comment. On December 29, 1992, Revision 0 was superceded by Revision 1. The NRC staff has completed its review of this study plan using the "Review Plan for the NRC Staff Review of DOE Study Plans, Revision 2" (dated March 10, 1993). Based on its review of the study plan, the staff considers the material submitted consistent, to the extent possible, at this time, with the revised NRC-DOE "Level of Detail Agreement and Review Process for Study Plans" (dated March 22, 1993).

A major purpose of the review is to identify concerns with studies, tests, or analyses that, if started, could cause significant and irreparable adverse effects on the site, the site characterization program, or the eventual usability of the data for licensing. Such concerns would constitute "objections," as that term has been used in earlier NRC staff reviews of DOE documents related to site characterization (e.g., "Consultation Draft Site Characterization Plan" and the "Site Characterization Plan (SCP) for the Yucca Mountain Site"). It does not appear that the conduct of the activities described in this study plan will have adverse impacts on repository performance and the review of this study plan identified no objections with any of the activities proposed.

As part of its study plan review, the NRC staff also determines whether or not detailed comments or questions are warranted. The NRC staff's review of the subject study plan has resulted in the identification of five questions. The enclosed comment and questions will be tracked by the NRC staff as open items similar to those previously raised by the NRC staff in its 1989 Site Characterization Analysis.

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Study Plan 8.3.1.2.2.8
Fluid Flow in Unsaturated, Fractured Rock (Revision 1)

Question 1
How will laboratory-scale models and data be used to estimate model parameters in the corresponding site-scale models?

Basis
It is stated that "[t]he principal hydrologic modeling effort, however, and the objective of this study, is to construct mathematical representations to simulate the physical processes which govern fluid flow through partially-saturated fractured rock. The primary function of these models will be to help design and interpret hydrologic and pneumatic tests and to provide information about model parameters that can be incorporated into site-scale models" (Section 2.1.2, page 2.1-2). One of the functions of these models is "to integrate data collected from a variety of scales and estimate model parameters at those scales that are not amenable to direct testing" (Section 3.1.1, page 3.1-1). It is, further, stated that "[b]ecause site-scale models are applied at temporal and spatial scales that are not compatible with scales at which controlled experiments can be conducted, direct comparison with experimental data is not possible for these models" (Section 2.2.1, page 2.2-1). It is well-known that when the same numerical and mathematical model is applied to samples obtained from a site, and to the site itself, constitutive parameters which are required for the site-scale model to match field observations can be orders of magnitude different from the corresponding constitutive parameters in the laboratory-scale model; one explanation attributes this phenomenon to parameter heterogeneity across the site. However, neither the process by which data from a variety of scales will be integrated by the models developed in this study, nor the process by which model parameters will be estimated at scales not amenable to direct testing, are discussed in the study plan. As it is not planned to directly compare site-scale models with experimental data, there is concern that radionuclide mass fluxes may be under-predicted due to inappropriate site-scale parameters, thus affecting predicted releases from the accessible environment.

Recommendation
Explain how laboratory-scale models and data will be used to assign model parameters in the corresponding site-scale models.

ENCLOSURE

Mr. Ronald A. Milner 2 3

If you have any questions concerning this letter, please contact Michael P. Lee at (301) 415-6677.

Sincerely,
/s/
Joseph J. Holonich, Chief
High-Level Waste and Uranium Recovery
Projects Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

Enclosure: As stated

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Study Plan 8.3.1.2.2.8
Fluid Flow in Unsaturated, Fractured Rock (Revision 1)

Question 2
Why have particular modeling strategies been assigned to address particular technical issues?

Basis
This study plan will develop or adapt models to address seven technical issues relevant to studies involved with ground-water flux and ground-water travel time (Section 3.1.4). Table 3.1-1 identifies several modeling strategies to evaluate these technical issues. In any choice of modeling strategies, different conceptual and modeling approaches are excluded and others included. However, it is not clear from the study plan why these modeling strategies have been selected and other modeling approaches have not. For example, Technical Issue (1) will try to, "determine the conditions under which flow within fractures located within the unsaturated zone is likely to occur," will be assigned two modeling strategies, namely the variable-aperture and double porosity models, for resolution. However, the text does not explain why these two modeling strategies were selected over other strategies, such as fracture-network- or channel-based models.

Recommendation
Provide a discussion of why particular modeling strategies has been assigned to address a particular technical issue.

Study Plan 8.3.1.2.2.8
Fluid Flow in Unsaturated, Fractured Rock (Revision 1)

Question 3
Is the method used by Cacas *et al.*(1990), for the determination of fracture network hydraulic aperture distributions, applicable for unsaturated flow?

Basis
Section 3.1.7.2 (page 3.1-14) states that an approach similar to that proposed by Cacas *et al.* (1990) will be used to estimate the fracture hydraulic aperture distributions. This approach replaces the fracture system by a series of interconnected conduits. By introducing an adjustable parameter accounting for the shape of the conduits, this method has been shown to provide for the calibration of a transport model for saturated rock at the Fanay-Augeres site in France. However, in unsaturated rock, a direct recreation of the variance in the observed flow rates may not be possible due to extreme nonlinearities introduced in the flow problem, especially for very small apertures, where the deviations from the cubic law may be more pronounced (Gale *et al.*, 1985).

Recommendation
Explain how the methodology proposed by Cacas *et al.* (1990) will be modified, and why the modified method will be applicable to unsaturated flow conditions.

References
Cacas, M.C., Ledoux, E., de Marsily, G., Tillie, B., Barbreau, A., Durand, E., Feuga, B., and Peaudecerf, P. "Modeling Fracture Flow with a Stochastic Discrete Fracture Network: Calibration and Validation, 1. The Flow Model," *Water Resources Research,* 26(3): 479-489 [1990].

Gale, J.E., Rouleau, A., and Atkinson, L.C., "Hydraulic Properties of Fractures," in International Association of Hydrogeologists, *Proceedings of the Symposium on Hydrogeology of Rocks of Low Permeability*, Tucson, Arizona, Volume XVII, Part 1, pp. 1-16, 1985.

Study Plan 8.3.1.2.2.8
Fluid Flow in Unsaturated, Fractured Rock (Revision 1)

Question 4
How can one build confidence in conceptual models if every time a conceptual model is refuted by experimental data, the experiment is redesigned as inappropriate or not sensitive enough to capture the essence of the model?

Basis
In Section 2.1.3, it is stated that "[i]f experimental and modeled results should not satisfactorily agree, the hypothesis/model may be judged not to be a valid description of the properties and processes under experiment, and may be significantly revised or else considered disproved. The investigators may also reexamine and possibly revise the design of the experiment if they believe that it has not isolated and measured the selected hydrologic parameters with sufficient sensitivity." The above statement is written generally enough that conceptual models, *a priori* assumed to be appropriate, can be proven to be justified by the experimental results. This is because Section 2.1.3 seems to imply that one could, in principle, keep redesigning an experiment until some preconceived conceptual model is proven to be valid. Well-posed, testable hypotheses, and testing criteria can provide the necessary platform for performing such comparisons.

Recommendation
Experiments should be designed with the conceptual models under testing clearly defined. They should be redesigned only in a manner that is well controlled and that leaves the validity of the comparisons intact.

Study Plan 8.3.1.2.2.8
Fluid Flow in Unsaturated, Fractured Rock (Revision 1)

Question 5
What modeling strategies will be used to address technical issues one, two, and five?

Basis
In Tables 3.1-1 and 3.2-1 modeling strategies are identified that will resolve seven technical issues. For issue one this activity will develop or adapt models to determine the conditions under which flow within fractures located within the unsaturated zone is likely to occur. For issue two this activity will develop or adapt models to study the nature of channeling processes and the implications of channeling for the transport of water and radionuclides. For issue five, this activity will develop or adapt models to describe the effect of stress changes on the permeability and relative permeability of rough-walled natural fractures. However, the two tables do not agree in the different modeling strategies that will address technical issues one, two, and five. Therefore, it is not possible to identify which modeling strategies will address these three technical issues.

Table 3.1-1 associates technical issues with modeling strategies for issue resolution, required data, and data source. Table 3.2-1 associates technical issues with modeling strategies for issue resolution, required validation data, and validation data source. If these two tables have correctly identified different strategies for these three technical issues, then validation of modeling results using a modeling strategy which is different from the strategy used to obtain the initial results may not be consistent.

For example, in Table 3-1.1, one modeling strategy used to address technical issue (1) is the double porosity model. Inferences gained from a modeling exercise implementing this strategy, however, may be misleading when compared to results produced using a fracture-network strategy during the validation exercises as indicated in Table 3-1.2. In particular, matrix-fracture interaction effects are explicitly included in the double-porosity model but may or may not be in the fracture-network model. Other inconsistencies such as this could arise when the modeling strategy used in the modeling exercises differs from the strategy used in the validation exercises.

Recommendation
Identify the modeling strategies that will be used to address technical issues one, two, and five. If strategies used in modeling exercises designed to address the technical issue are different from those used in validation exercises, explain how different modeling strategies can be implemented without biasing the process.