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Dear Bill:

I have been wading through the big stacks of materials sent to me from Lynn Deering's office in support of the upcoming ACNW meeting in Las Vegas next week. I have tried to encapsulate the more important comments and questions that I have arrived at, and am sending them to you for your perusal, thought,and possible discussion with me before the meeting on Tuesday.

I would appreciate your input about these items, if you think it necessary, before I ask questions.

My comments below are in the same order and under the same headings as the more pertinent points in the Status Report in Attachment 2 of the document which Lynn Deering sent to you on Nov 29, 1993. This document appears to include the major points of concern to be raised at the upcoming meeting.

Regulations Related to Unsaturated Flow:

- The requirement of a travel time of groundwater flow of at least 1,000 years is in my opinion, still not possible to guarantee at this point without further and much more intensive collection of subsurface hydrogeologic data.
- DOE's likely requirement to include mathematical modeling to to estimate groundwater flux is a moot point. I believe the program is not anywhere near a sufficient understanding of the unsaturated zone hydrogeology, multi-phase flow, fracture distributions and connectivities, and fracture-matrix interactions, to even begin to model the system over a large scale with meaningful results.

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- If, as stated; much of DOE's site characterization is to determine the spatial distribution of moisture flux within the repository block, and to estimate pre-waste groundwater travel times, then much more drilling and exploration of this block is going to be necessary. Right now, the data are too sparse and the travel pathways too poorly delineated to make a large modeling effort worthwhile. Modeling, to be sure, is cheap and enables the investigator to write more papers than field exploration activities allow, but modeling is useless without good field data first. As far as the use of kriging is concerned, it seems that if it were to be useful, it would have to be applied to one bed and not across beds. This would require a sizeable amount of data which might never be sufficient for adequate kriging estimates. Fractals will probably not be useful. There are simply too many discontinuities and unknowns.

Status of NRC Regulatory Concerns and NRC's HLW Hydrology Program:

- The horizontal hole planned for Solitario Canyon is not sufficient to determine if faults acts as conduits or barriers: It would seem to me that holes within the fault and on each side of it would be more useful in dtermining the answer to this question.

- I agree that gas samples should be taken before major excavation begins. In some of the material I have read, there seems to be a concern that there might be large volumes of gas that are exchanged with outside air. This point needs to be investigated.

- The lack of experimental data and confirmation of unsaturaed flow properties, as addressed by William Ford, is one the most vexing of the entire problem of unsaturated flow in Yucca Mountain. More in-situ work should be done to actually drill and instrument holes to determine this.

- Conceptual Flow Model of Yucca Mountain: This really can't be done well until the questions of unsaturated matrix flow, matrix-fracture interchange, fault flow and fracture flow are answered.

- Developing a Mathematical Model of Flow Representative of Yucca Mountain: This certtainly can't be done with any degree of confidence until the conceptual model is formulated, which in turn is dependent upon basic data and experimentally confirmed theory.

- Uncertainty in modeling groundwater flow due to lack of codes tested for unsaturated fractured rock: Such codes as exist are only sufficient for very simple arrangements of fractures. As the literature states, most assume a hydraulic equilibrium between fracture flow and matrix flow. It is apparent that this is not always the case as explained very well in the paper by Nitao, Buschek, and Chesnut.

- Uncertainties in Determining Characterization of Vadose-Zone Parameters: The two major questions to be asked here are (1) How can better characterization be obtained?, and (2) How much work will it take?

- Three-Dimensional Numerical Models: This would be a waste of time at this point. In the first place, the 3-D models that do exist cannot handle anything as large as Yucca Mountain with anything but the simplest of assumptions. Most of such existing codes are only applicable for granular porous media with few, if any, discontinuities. With all the fractures and multi-phase flow in Yucca Mountain, such codes would not be sufficient. In addition, theory of multi-phase flow in Yucca Mountain is not sufficient to support such modeling on a large enough scale to be meaningful.

<u>Unsaturated Flow Conceptual Model:</u>

- Assumptions that (1) Non-welded tuffs have fewer fractures, and (2) that they attenuate flow via matrix imbibition, are questionable. From the data taken so far, these assumptions seem reasonable, but can they be proven for all such beds, and can these ideas be tested in-situ? These are major questions that must be addressed. I am afraid that assumptions alone will not be sufficient in the final analysis.

- Uniform infiltration of 1 - 5 mm/year seems very unrealistic. I doubt that infiltration is uniform considering the numerous fracture and faults. It is also not clear if assmed steady-state matrix flow in really true. It seems reasonable, but has it been proven?

- Assumptions of hydraulic equilibrium between fractures and matrix is unrealistic. Can this relationship be quantified reasonably by in-situ tests?

- What kinds of in-situ testing can be done to answer the question of whether or not faults act as barriers or conduits to flow? It seems to me that this would depend upon the saturation value of the surrounding rock. Perhaps holes in a fault and along each side that were instrumented would help. This would have to be done at more than one site.

- Finding tritium and clorine-36 at significant depths is most worrisome. This probably indicates fairly rapid infiltration from the outside. However, one must be carful in using chlorine-36. Here in Tippecanoe County, we are not sure what causes high concentrations of Cl-36; some may be natural, so its presence must be treated with caution. Movement of drilling fluid 1,000 feet in three years indicates big time fracture flow. Obviously, more work needs to be done in tracking and mapping fractures to the surface or recharge points, but the big question is how to do it. I can't think of any methods except drilling and geophysics.

  It appears that DOE must do much more to elucidate fracture flow pathways.

Vapor Flow:

- If this is to be studied, a whole new methodology will have to be implemented. Could this require tracer gas experiments now to determine just how reasonable an assumption this is? The big question I have is how can we extrapolate from pre-waste vapor flow to that that might take place after emplacement. I believe that it is much easier to anticipate ground water flow than vapor flow. This could be a potentially big problem for DOE if it can be shown that vapor flow is significant. I do not believe that this has yet been shown to be the case.

Potential Climatic Changes:

- This may turn out to be a real problem. The only way to really handle this one is to model climatic changes and their effects on precipitation. There is nothing to calibrate these model with except a very few paleoclimatic markers. This will also have a direct bearing upon the matrix-fracture flow problems. Therefore, it seems to me that this issue gives even greater impetus to deciphering these unsaturated-flow interactions and theories. This may require some large-scale laboratory experiments as well as field studies. I would say that future climatic change is a primary consideration and should be discussed.

Groundwater Age Dating:

- This aspect of research is most necessary and ought to be expanded. This is a fairly low-cost bit of investigation, when compared to other investigations, but like in-situ tracer studies, can yield the most useful information about travel times and pathways. I would stress this kind of investigation as well as the use of tracers.

Apache Leap Studies:

- Are the results of these studies directly transferrable to Yucca Mountain? I would question this before continuing them. I still believe it is best to study phenomena characteristic of Yucca Mountain at Yucca Mountain.

Scaling Studies:

- This may be a moot point. At this point scaling studies may be a waste of time until a bigger and better data base is obtained. The reason is simply that discontinuities caused by fractures and faults are so numerous that attempting to determine the degreee of scaling of unsaturated flow phenomena will likely be unsuccesful. I know of no definitive work on this concept at Yucca Mountain. Scaling can be determined in continuous porous media, especially if it is saturated and if there is lots of data over a wide are with which to work. The paper by Neuman and Zhang shows a new approach that may have some applicability and not require the large amounts of data that kriging and fractal methods require.

Fault Flow:

- By all means accelerate studies of flow in the Ghost Dance and Solitario Canyon Faults. This may require drilling into the faults and instrumenting the holes to determine if they act as barriers or conduits. I would suspect that they could be conduits to major flow in the case of increased precipitation.

I hope that the presentations by Flint and Bodvarsson will put some of these question and concerns in perspective, and perhaps some questions will be answered.

Finally, has anyone considered locating the surface rechrge features such as faults, fractures etc and sealing them to prevent recharge? It seems that it might be possible to divert surface water away from the site in concrete-lined canals or ditches and greatly reduce that amount of potential recharge to the subsurface. This might be a far-fetched idea and I do not intend to bring it up.

Episodal of Periodic Fluctuations in Water Levels:

- As described by Lehman and others, such fluctuating levels are puzzling. I can offer no explanation either. Perhaps this phenomena should be studied enough to determine if it is related to precipitation and if it poses any problem to the repository. Otherwise, it may be just a scientific curiosity.

In summary, in my opinion, the Site Characterization Plan is basically a good one, but more emphsis needs to be put on (1) in-situ data collection of groundwater ages, flow paths, matrix-fracture flow interactions, recharge points, fault flow, and fracture distributions. (2) Constructing of a better conceptual model using the above information, and the (3) Modeling using more realistic parameters obtained above.