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Advisory Committee on Nuclear Waste
Washington, DC 20555

Subject: Consultant Report on the Yucca Mountain High Level Waste Repository Site Characterization Meeting Held by the ACNW in Las Vegas, Nevada on December 14, 1993

Dear Lynn:

Enclosed are my comments on the Yucca Mountain Site Characterization Meeting that was held by the ACNW in Las Vegas on December 14, 1993. I will try to organize my comments around the outline that you provided to the consultants on November 29, 1993. As I understand it, the purpose of the meeting was to examine the current understanding of the processes controlling matrix and fracture flow in the unsaturated zone at Yucca Mountain and the status of data collection and modeling activities. In addition, you asked the working group to: 1) explore the overall strategy that the DOE used to characterize and model flow in the unsaturated zone at Yucca Mountain; 2) evaluate the concerns raised by the State of Nevada on matrix flow vs. fracture flow and alternative conceptional models, and; 3) to comment on any NRC prospectives that were offered at the meeting. First, I will attempt to answer your key questions and issues as listed in the November 29 letter. Your questions are shown in italics with my response following.

What are the mechanisms for infiltration in the unsaturated zone at Yucca Mountain and their current relative significance to site performance?"

After hearing the presentations on the 14th by the DOE, my conclusion with regard to this question is that all of the mechanisms for infiltration are not yet understood. In general, two have been proposed: namely, flow through the matrix in the unsaturated zone at a relatively low rate, and focused flow along faults and fractures. It is important to note that most, if not all, of the characterization effort of DOE has focused on matrix flow. No discussion was held at the meeting, nor did I hear comments about alternative mechanisms for infiltration.

What is known regarding the relationship between precipitation, infiltration, percolation, and recharge at the Yucca Mountain Site, and what is the status of studies underway to ascertain these relationships?

I believe a large effort on the relationship between precipitation, infiltration, percolation and recharge is underway by Allen Flint of the USGS. However, I believe that it will not lead to the reduction of uncertainty in the estimates of flux through the repository, which is the quantity of significance. My opinion is based on two points: First, the location of most of the study areas shown by Dr. Flint did not systematically look for areas of potential focused recharge along fractures. This may be the dominant mechanism of getting water to the repository. In most of the areas that were described, the

surface is covered with unfractured, porous material and in this type of environment it is very likely that much of the water will evaporate directly back off to the atmosphere instead of continuing on down to the repository. However, in the areas where recharge may be focused, and especially areas above or directly on outcrops that contain fractures or faults, it is much more likely that the water would rapidly migrate downward and not be affected by surface evaporation. My second point with regard to this study is that most studies of this nature, and by that I mean surface water balance studies have large irreducible uncertainties associated with them. For example, precise measurements of the upward flux of vapor from the land surface are very difficult to obtain. Other methods, such as just looking at the moisture content and the unsaturated conductivity, or especially chloride mass balance, stable isotope analysis or radioisotope analysis would probably provide much less uncertain estimates.

What significant uncertainties exist regarding infiltration in unsaturated zone flow and transport at Yucca Mountain, and how will they be addressed?

I have difficulty addressing the word "significant" with regard to uncertainty. Let me explain. I believe that large uncertainties are acceptable all the way through repository licensing, if the uncertainties can be shown not to contribute to a violation of the standard. Given that we were only reviewing site characterization in absence of performance assessments. I cannot assess whether or not the uncertainties discussed were significant or not. I can only imply that if increased recharge leads to increased discharge from the repository, that would be significant. I do not believe that the significant uncertainties in that context (i.e., the potential for a fracture flow along discrete parts of individual fractures) are being addressed by this program. Certainly, there was discussion of these issues, but no specific programs designed to address them.

How might these mechanisms and their significance change in the future through environmental modification of the near field repository?

What impact could increased precipitation have, and to what extent have these scenarios been tested?

Obviously, increased precipitation could lead to increased release from the repository. Whether or not these scenarios have been tested was beyond the charter of this particular group which focused on site characterization. However, one point is in order. That is, whether or not increased recipitation will be treated depends totally on the probability distribution (pdf) of recharge currently used by the YMP. This pdf is very low based almost solely on a conceptual model of matrix flow. If climate change is based on an increase in the upper end of the distribution, then climate change would have little effect on site performance. On the other hand, if the recharge pdf would have been based on fracture flow, then the effect of increased precipitation due to climate change would have a much more dramatic effect on the site performance.

How necessary are ongoing studies to assess possible climate change over the next 10,000 years to hydrologists characterizing the unsaturated zone, and to performance assessment modelers?

With respect to Allen Flint's studies, I would say that they are totally divorced from any climate change that could occur over the next 10,000 years. That is because he is not focusing on the key

mechanism of recharge that affect site performance; that is, fracture flow. If one only relied on his studies, then the precipitation could increase dramatically due to climate change and have little effect upon the recharge. However, this is in direct conflict with the evidence provided by isotopic measurements of the groundwater that were taken by Yang of the USGS. Not only are the isotopic measurements much more important to understanding today's conditions, but because they reflect recharge that has occurred over the past, they are also much more important with respect to understanding what future climates could be.

What approaches are being used to evaluate the unsaturated zone hydrology at Yucca Mountain, both passively and actively?

What we heard was a combination of studies based on classic soil physics, that is the measurement of tensions, moisture contents, and unsaturated conductivities used to estimate fluxes through the unsaturated zone, surface studies used to determine the water balance at the near surface which, in turn, would be used to estimate the amount of water available for infiltration, and isotopic measurements which were used to infer how water had arrived at the place of sampling and how long it had taken to get there. Your sub bullet under this question asks, "Do adequate methods exist to obtain hydrologic data needed to support complex and performance assessment modeling at the Yucca Mountain site?" In my opinion, adequacy in this context depends upon the conceptual model that is employed for understanding and simulating the behavior of the Yucca Mountain site. For example, if one were to accept DOE's equivalent porous media concept, then certainly we have adequate methods to characterize that movement of water through the unsaturated zone. On the other hand, if fractures play an important role in channeling water from the surface to the repository and beyond to the water table, then questions arise with regard to the adequacy of methods to characterize fracture flow and the ability to even find and define fractures in this complex geology. In fact, if transport of radionuclides is dominantly along isolated sections of isolated fractures, we have neither the models nor site characterization tools to assess this movement.

What current conceptual models are being considered to model flow in the unsaturated zone at Yucca Mountain?

What is the status of data collection and prototype testing to support use of these models?

As stated previously, the models being used are equivalent porous media models. In one case the geology is represented as a simple porous media (i.e., the tuff matrix is assumed to dominate the migration of water from the surface to the water table), and in the other the geology is represented as an equivalent porous media model where fractures are considered to contribute to the transport of water and radionuclides from the surface to the water table. Note that in this case the fractures are simply represented as a more permeable equivalent porous media with respect to saturated flow and actually as less permeable media with respect to unsaturated conditions. With the regard to the status of data collection and prototype testing needed to support these models, I would say that they are both in the very earliest stages and that no information has been gathered that supports the use of either of these models. On the other hand, the isotopic measurements could be viewed in as evidence against both models. These measurements imply ground-water flow distributions and rates that neither of these models could reproduce. Also, a quick look at the implied rates of ground water

movement indicates that they are faster than any of the simulations produced by the total systems codes to date. (Note: one of the total systems models, WEEPS, assesses discrete fracture flow in a very limited and non-conservative manner but this model was not discussed at this meeting)

What are the interfaces between site characterization and performance assessment modeling of flow in the unsaturated zone?

How will the results of the complex 3-D infiltration modeling will be integrated with performance assessment modeling of flow in the unsaturated zone (WEEPS, Composite porosity models?

How is site characterization data is integrated into performance assessment modeling, and, in turn, how performance assessment is used to drive data collection activities?

As implied by Allen Flint in the meeting, there is no connection between site characterization and performance assessment modeling. He stated, unequivocally, that he had no confidence or belief in any of the total systems performance assessment modeling that had been done to date. He also said that all of his site characterization data was to be used by another model being developed by B. Bodvarssan. The link between the Bodvarssan model and the performance assessment models is undefined at this time and given the structure of these models (i.e., fully 3-D Vs. multiple 1-D columns) linking them will be difficult. Therefore, I would conclude there is no link between performance assessment and site characterization at Yucca Mountain at this time.

What are the current results of groundwater age dating studies? Do they provide evidence of rapid, noncontinuum flow?

How are these results being factored into unsaturated zone testing and analyses?

I believe I have already provided the answer to the first two questions. The results from I. Yang of the USGS indicate rapid noncontinuum movement of water through fractures reaching relatively great depths in short times. These measurements are inconsistent with the results of the work by Allen Flint and the current modeling efforts. As for how these results are being factored into unsaturated zone testing and analyses it appeared that the DOE was attempting to discount them altogether. In fact, Allen Flint implied that these analyses may not be accurate and that retesting would be done in the future. This certainly seems like the wrong focus for the site characterization program. Instead, much more effort should be focused on explaining these results, gathering more of these types of data, and factoring them into performance assessment and further site characterization.

This concludes my response to the specific questions as outlined in your cover letter. Next, I would like to proceed to a brief description of my impressions of the individual talks that were presented on December 14 by the NRC, the DOE and their contractors and, the State of Nevada.

Overview of Apache Leap Research Program by Ernie Harden, University of Arizona

Apache Leap is an NRC research program and therefore its purpose and the basis for my evaluation of this talk is fundamentally different than it is for the DOE YMP presentations. My assumption about the need for independent NRC work at a tiff site is that it should address NRC's key unresolved issues such as understanding the dominate mechanisms for flow through unsaturated fractured tiff or the

adequacy of current techniques used to characterize such a system. In my opinion NRC research should address these issues in such a way that it sheds light on DOE's current approaches and understanding of Yucca Mountain.

This program has been going on since the early 1980's and as yet, I am not aware of one particular technical issue that has been resolved by this program. Instead this program still appears to be just a site characterization exercise. Furthermore, Apache Leap may not be an appropriate analog for Yucca Mountain given that Apache Leap receives 24 centimeters a year of rain and has an ephemeral stream on it. In my opinion any lessons learned at Apache Leap will be difficult to transfer to Yucca Mountain. Therefore, I believe that it would be much more productive to initiate an NRC research project at Yucca Mountain to address the issues that DOE is missing.

DOE Opening Remarks and Introductions by Joe Dlugosz

The only point I would like to make with regard to these opening remarks is the comment made by Mr. Dlugosz that the success of the program was dependent upon the DOE's ability to sample multiple scales in the field. However, none of the remaining talks discuss sampling at different scales, nor was there any talk about scaling up of lab measurements to field scale, or field scale measurements to model scale. In fact, there was no apparent integration or the use of different scales at all.

Regulatory Issues Being Addressed by DOE/YMPO Unsaturated Zone studies by April Gil.

In this talk, Ms. Gill pointed out an important conflict in the NRC/DOE program. Namely, there is an apparent conflict between the siting criteria and the disposal criteria. In fact, the confusion is greater since DOE has its own siting criteria as well as NRC's siting criteria. I think both DOE and NRC should work on this issue to assure consistency between the different sets of criteria, or more importantly, simply eliminate the siting criteria because they have no direct relevance of safety of the site. Another point made by April Gil concerned me greatly is that she said the integration of the different work efforts was to be done by individual work breakdown structure leaders, and, in fact, no-one was in charge of the integration of all of the work. This apparent lack of integration became more and more evident as the talks proceeded.

Overview of DOE/YMPO Studies of the Unsaturated Zone by Mike Chornack

I would like to make only two important points with regard to this talk. First, Mike pointed out that no discussions on gas phase movement would occur at this meeting, because the people were not available. However, this could be one of the most important phenomena occurring at Yucca Mountain, and was extremely important in light of the drilling of the exploratory shaft and the ability to characterize gas phase movement prior to that drilling. The second point that I would like to make is in regard to the exploratory shaft itself. Mike stated that the shaft would stop if the USGS says that it would destroy their ability to understand ambient conditions. Unfortunately, it does not appear that there will be time for the USGS to evaluate whether or not the ambient conditions have been destroyed as the ESF is being developed. For example, it is not sufficient for the USGS just to be taking in monitoring data. They must have time to analyze that data and determine what the data mean with respect to understanding ambient conditions. Certainly, given the timeframe needed to analyze this data, it appears that the ESF will go forward irrespective of the USGS concerns.

DOE/YMPO Characterization of Unsaturated Zone Infiltration by Allen Flint

Dr. Flint provided a detailed description of his characterization efforts which is focused on near-surface water movement through unsaturated soils. In this study a combined water balance and soil physics approach is being applied. However, their is little uncertainty in the quantity of infiltration through soils in this desert environment in the first place. Namely, the rate of infiltration is very close to zero and certainly well within the current probability distribution used in performance assessment; an assessment that already indicates the site complies with the EPA standard. On the other hand, considerable uncertainty remains in the understanding of flow through fractures and recharge under changing climatic conditions. Neither of these important phenomena can be assessed with the current study.

Apart from the study presented by Dr. Flint, comments made by Dr. Flint during the presentation are of particular importance. Dr. Flint stated that he had no faith in the current total system performance assessment models. Further, he went on to say he would not believe the performance assessment models until they incorporated all of the phenomena and processes that he, Dr. Flint, thinks are important. In fact, later he stated that the end use of his data would be a model being developed by B. Bodvarsson. Aside from questioning the usefulness of the performance assessment models, this raises several serious concerns. For one, these statements in and of themselves indicate a total lack of integration between site characterization and performance assessment. On the other hand, it could indicate that the performance assessment modelers know of Dr. Flint's concerns and have chosen not to address them (yet or not at all). It is also possible that Dr. Flint does not understand the purpose of performance assessment is to assess regulatory compliance and not reproduce everything we know or think we know about the natural system.

DOE/YMPO Site Scale Unsaturated Modeling by E. Kwicklis

My understanding is that the goal of this effort is to provide a model that can be used to address processes that may occur on a scale smaller than the "regional" model of Bodvarsson. For example, issues associated with the potential flow rates and patterns associated with fracture flow under varying amounts of recharge is being investigated. In theory, this information would then be used as input or guidance to the development of the larger-scale model(s). At first glance that the approach seems reasonable but the ability and usefulness of doing that transfer is in question due to: 1) the equivalent porous media representation of fracture flow in this model which can not address the potential for non-continuum behavior and; 2) the difficulty in transferring the information of the smaller scale model with its associated uncertainty to the larger scale model. To illustrate this later point take for example the results of this model that indicate that different fractures can contribute to flow under different recharge (climatic) environments. First, this result can not be reproduced by the larger scale model (which is why the smaller-scale model exists). Therefore, if this is an important issue with respect to assessing compliance then the smaller scale model must be used for compliance. One may believe that given the results of the small-scale model one could construct the large-scale model in such a way that as to "bound" the behavior of the small-scale model. However, given the nature of the small-scale model results this would have to be done separately for each set of recharge values. Also the final compliance model must also address parameter uncertainty. Therefore, adapting the large-scale model to be a surrogate of the small-scale model would require performing many small-scale simulations

which vary parameter values and recharge values in order to assure that the surrogate large-scale model captures the total possible behavior of the small-scale model. However, by this point there is no longer a need for the large-scale model because the uncertainty analysis just performed with the small-scale model has already satisfied the compliance needs. On the other hand, if the small-scale model behavior could easily be captured by the large-scale model, then there is no need for the small-scale model in the first place. Also note, the argument is even stronger for the rest of the models in the YMP so-called "pyramid" approach of going from complex models to total systems models.

Finally I would like to re-emphasize that this model is addressing fracture flow through the use of an equivalent porous-media approach to addressing fracture geometries. The potential for non-continuum behavior is not being addressed nor are the potential for momentum effects being accounted for.

DOE/YMPO Hydrochemical Characterization of the Unsaturated Zone by I. Yang

This study has provided the most valuable and enlightening data developed by the project to date because it clearly demonstrates that rapid flow of ground water occurs and that this flow has been transported along discrete interconnected fractures. Collection and analysis of isotopic data should be a major focus of the program because it provides the only direct evidence of the rate and distribution of ground-water flow. In addition, isotopic analysis may provide the most useful information on the potential effects of climate change since it reflects movement under a variety of past climates. Also this is the only data that can be used to assess fracture flow conceptual models. In fact one could argue that this data already rules out the existing conceptual models used by YMPO. Unfortunately, there is an inherent difficulty with trying to capture this type of behavior with existing characterization methods. That is, it is difficult to characterize vertical or nearly vertical movement along discrete fracture with vertical boreholes. Also the possibility that only small parts of a few of fractures may contribute most of the flow will make sampling very difficult.

Although the discussion of gas phase movement was beyond the scope of these meetings Mr. Yang made one very important point in this regard. He stated that it would take four years to get background gas samples. This appears to be in conflict with the ESF schedule and the potential of the ESF to disturb background conditions.

Three-Dimensional Model of Unsaturated Flow by B. Bodvarsson

All of the site characterization data and previous modeling efforts were said to feed this model. This model is to be calibrated with existing data and then used, in turn, to "predict" the measurements to be taken from future boreholes. In theory the error associated with this "prediction" would decrease each time and at some point become acceptable (to the DOE?, to the USGS?, to LBL?, but not to NRC). At this point this three-dimensional model of the entire Yucca Mountain is calibrated with one data point. Among the many questions about this model the most fundamental is why does it exist? This model is the same or very similar scale as the total systems performance assessment model so why not: 1) use the data to directly update the PA model? or 2) why not replace the PA model with this model. In addition, the modeling approach taken in conjunction with statements by A. Flint about Yucca Mountain being deterministic not stochastic paint an interesting picture of the philosophy behind the model development and calibration. The picture seemed to be an overly optimistic one of ignoring

fundamental uncertainties of spatial variability and scale dependence and dependence of model scale on the inference of knowledge. In my opinion, these topics, along with the topic of abstraction from complex to simple models deserves serious attention by the ACNW but it was beyond the scope of this meeting.

Integration of Unsaturated Zone Data Collection, Modeling Studies, and Performance Assessment by C. Newberry

After spending a good part of the meeting trying to figure out how all of the studies fit into performance assessment, I was looking forward to this presentation. Unfortunately, little or nothing was specified about the relationship between any of the work presented and performance assessment. If anything it appeared to be one more program based on the contention that a site is first "characterized" and then modeled. This approach is never ending as "characterized" has no unique definition and is being performed outside of the regulatory needs.

Other topics of note from this discuss included: 1) statements that the process of validation need two codes; and 2) the DOE opinion on the NRC's ground-water travel time requirement. The DOE seems to believe that this part of the multiple barrier requirements is "useless". In addition, the NRC appears to have quite a bit of confusion over this issue. In my opinion, this is a straight forward requirement that directly results from performance assessment. In fact, all of the performance assessment results I am aware of display the exact premise of the requirement. That is, if the travel time is greater than 1,000 years then the site is likely to meet the EPA containment requirement.

Alternative Conceptual Models of Unsaturated Zone Flow at Yucca Mountain by L. Lehman

The main point of this talk is that there are alternative conceptual models with regard to recharge distribution and rate that are not being addressed by the YMPO. In addition, because these models are not being taken into account, the recharge being used by the YMPO is too low. In general I agree with the statements made by Ms. Lehman. While YMPO continues to give lip service to alternative conceptual models, there is little or no evidence that they take the concern seriously.

Their approach is to base their modeling and characterization on their preferred conceptual model while hoping to stumble over evidence for alternative models if it exists. This should be contrasted with an approach that reorients its site characterization and modeling efforts to focus on finding evidence for and against alternative models.

CONCLUDING REMARKS

Most of the my concerns are already discussed in the answers to your questions and in the discussions about each talk. However, one major concern was not discussed. That is the lack of integration within site characterization and between site characterization and performance assessment. Perhaps the best way of explaining my concern is to explain the components of site characterization as I see them. Those components include: 1) a definition of data collection needs; 2) prioritization of data collection efforts; 3) optimization of data collection strategies and; 4) definition of a stopping point. For the YMPO, the site characterization report (SCR) could be considered as the definition of data collection needs but the SCR is a shopping list of all possible data (for one conceptual model) and not a list of data required to achieve regulatory compliance. Given that performance assessment is the means of

assessing compliance, the data requirements should be driven by PA. However, not one speaker mentioned collecting data as a result of a request from PA. Second, there was absolutely no mention of prioritization of data collection. Third, optimization, in terms of spatial location or sequencing of data collection was not discussed. Finally, and most important, there was no mention of a stopping point to the data collection process. in fact several viewgraphs presented logic diagrams for data collection that showed infinite loops. Without the DOE defining these critical elements of site characterization, it does not appear that site characterization will get them to regulatory compliance.

Finally, I would like to call your attention to the references on risk communication that I had previously sent you. As you and I discussed, I believe the DOE could go a long way toward improving their image and the acceptability of their presentations if they would heed the advice contained in those references. If you have any further questions or if you would like me to look in more detail at some of the topics raised (for example, the abstraction of complex to simple models) please contact me at 505-848-0754.

Sincerely,

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