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S.M. Coplan
High-Level Waste Management
Development Branch
U.S. Nuclear Regulatory Commission
Washington, D.C.
20555

Dear Seth:

This report is without benefit of the specific data that was to be made available to the review team in the U.S. Geological Survey offices in Denver, Friday, May 21, 1982. A drilling program of my own was reaching a critical stage that date and required my presence in Nevada. Therefore, this is a summary of my impressions and opinions developed from those data and interpretations offered by the U.S. Geological Survey and other contractors on the D.O.E. high-level waste repository program during the three-day review, and my previous knowledge of the hydrogeology of the NTS and surrounding areas.

My overall impression is that of a partially completed initial phase of hydrogeologic investigation of the Yucca Mountain area that has created a general picture of the saturated zone hydrology (with detailed aspects established to present in varying degrees of certainty). As with similar hydrogeologic investigations requiring relatively deep boreholes, the most useful information is difficult to obtain, uncertainties frequently arise when attempting to interpret collected data, and techniques of drilling and testing often became the key to reliability of the interpretations established from the data collected. Based on the presentations and professional experience represented by the hydrology group of the USGS, I believe that they have a good understanding of the limitations and uncertainties associated with the hydrologic testing to date, and that in general the data developed are being interpreted in a reliable manner.

From the perspective of the SCR, the data presented and associated interpretations of the USGS representatives indicate that a basic picture has been developed on the saturated zone hydrogeology associated with the area of Yucca Mountain. First, with exception of one borehole, a regionally similar position of fluid potential had been established. Uncertainties were recognised with respect to the one anomalous borehole fluid potential, and plans were being formulated to address the uncertainties associated with this finding. Also indicated was a

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plan to locate another hole to establish the relationship of the Hingeline Fault on the groundwater flow field of the Yucca Mountain area. There was considerable discussion of a methodology best suited (in terms of data reliability and cost in terms of time and money) to determine the absence or presence of a vertical component of flow in the vicinity of Yucca Mountain in the tuffs. Three basic approaches (variations of packers and drill stem tests, multiple completion of several zones within one borehole, and more than one borehole) were considered. In my opinion, the best approach to the vertical gradient question is two separate boreholes closely adjacent to one another, but drilled to significantly different depths into the saturated zone. This, in fact, requires only one more borehole next to an existing borehole, or for even greater confidence, two new boreholes next to two existing boreholes. This approach would also allow for developing evidence as to the local lateral variation in permeability within the common zone of penetrated saturation in the adjacent boreholes, and perhaps allow for tests on the vertical permeability.

A problem with one technique being considered by the USGS, that of multiple completions in several horizons in the same borehole, relates to data interpretation if there is no vertical component of flow. It is not difficult to envision the uncertainty created by uniform fluid potential data coming from the multiple hole completions at various depths, and wondering if the separate zones have been in fact isolated from each other.

The data presented with respect to stratigraphy and mappable expression of surface faults in the Yucca Mountain area seemed adequate for site characterization. However, the distribution of subsurface data on fracture density and distribution does not seem adequate for site characterization because it is either highly localized (Drill Hole Wash) or from a few widely distributed holes. In my opinion, Drill Hole Wash and other elongate subparallel linear drainages of similar trend may well be structurally controlled, rather than consequent erosion patterns related to an initial slope. Concentrating subsurface data collection within the erosional valley without systematically doing the same in the adjacent areas beyond the valley and associated trend may bias the fracture ocurrence data. At present, the data base developed from pump tests and other hydrologic tests suggests that permeable zones may not correlate directly to stratigraphic units within the tuffs. Therefore, establishing how fracture permeability varies in three dimensions within and beyond the structurally disturbed zones should be an important subsurface data collection objective. These fracture data are important considerations for both the saturated and unsaturated zone site characterizations.

In a regional sense, the groundwater flow system which underlies Yucca Mountain has not been adequately characterized and defined in my opinion. I believe it important and prudent to reliably delineate the system downgradient from the proposed Yucca Mountain repository to point(s) of discharge. Delineation of the flow system to the discharge area should help develop a better understanding of the flux of the flow system in the near field environment of the repository. Expanded study to the discharge area may provide enough information to compare repository area flux (based on localized pump tests and fluid potential gradients) with discharge environment flux, as well as offer comparative information through hydrogeochemistry and environmental isotope relationships. An increased level of confidence in the basic understanding of the repository area flow system should be the result of the expanded study. In the Yucca Mountain site, this is particulary important for a variety of reasons, one of which is the proximity of groundwater development in the Amargosa Desert about twelve to eighteen miles downgradient from the proposed site.

Another issue as yet unresolved is the relationship of the Yucca Mountain flow system to the NTS/Ash Meadows carbonate aquifer flow system. The presence or absence of vertical flow gradients within the saturated tuff should be first established before deep drilling is done to establish whether the carbonate aquifer extends as far west as Yucca Mountain. If there are no vertical gradients, in my opinion the resources required for such deep drilling are better allocated to other important uncertainties. If the vertical gradients are established in the repository structural block, the deep exploratory hole should be upgradient and a good distance from the proposed repository area. Such a location could miss the underlying unit accepting the Yucca Mountain vertical flow, but a location downgradient or near the site area could compromise site safety if drilling problems occur. Therefore, there needs to be strong evidence indicating the presence before an effort is made to confirm a deep seated flow system in the area.

To elaborate on this problem, my view is that deep drilling at or downgradient of the repository opens up the real possibility of changing the hydrology in the repository area and compromising the site safety. However, drilling the deep exploratory hole for the deepest transmitting zone far enough away to avoid the above problems also increases the possiblity of missing the deep transmitting unit responsible for vertical gradients of the repository block. Therefore, to establish the suitability of a somewhat distant location of the deep test hole aimed at confirmation of the deep carbonate aquifer extent into the repository area, vertical gradients should also be first established at the deep test hole location. This general approach would satisfy (should vertical gradients exist in both areas) the need to identify the deep aquifer extent, and still not create a situation where the repository hydrology could be compromised by the deep hole, no matter what happens to the deep test hole.

In my opinion, the most serious deficiency in the hydrolgeological program is the present state of knowledge of the hydrology of the unsaturated zone in the Yucca Mountain area. It is clear that interest is high for a repository site within the unsaturated zone. However, apart from the geologic cores and fluid losses noted during drilling in the unsaturted zone, there seems to be no data. There is no data on water content in fractures or the porous tuffs, nor data on the hydrogeochemistry (including environmental isotopes, etc.). The hydrology of the unsaturated tuffs of Yucca Mountain, for all practical purposes, seems unknown at this stage. This is a serious deficiency, because there is little or no experience in the borehole collection of such data. The technology of doing so will be under development and the degrees of success, the quality of data, and rate of progress are all subject to considerable uncertainty. The SCR will be rather incomplete and unreliable in an important issue area if this deficiency is not quickly addressed in an effective data collection program. Based on the discussions and responses to questions related to this aspect of the DOE program it is my impression that the USGS has been asked to prepare a proposal addressing this aspect of the Yucca Mountain site in the very near future. However, it is also my impression that there is considerable uncertainty as to how to proceed to plug this knowledge gap in an adequate way. I believe it important for NRC to carefully follow and perhaps interact with DOE and its contractors dealing with unsaturated zone characterization while a plan of action is being established.

In my opinion, based on personal experience in research efforts dealing with unsaturated zone hydrology, the data collection problem is a difficult one and there is perhaps only one good drilling technique to my knowledge which would be suited for the Yucca Mountain unsaturated zone tuffs. It is a technique using special reverse circulation rotary tools, drilling primarily with air. For deep drilling and successful hydrologic sampling, only highly experienced crews with appropriate equipment should be used. Such comments were provided to the USGS for their consideration in developing their proposal. Bill Wilson, USGS, requested and received a brochure from me which describes the technique and identifies one contractor with which I've had favorable experience in this type of test drilling. Other discussion on the same general issue suggested that unsaturated hydrology zone data be established by a shaft or tunnel. I think this approach would yeild too little information (highly localized) to give a reasonable picture of the range of expectable conditions in the repository area. Rather, the shaft/tunnel approach would be appropriate as supplemental information to more widely distributed borehole data. I believe the shaft/tunnel should not be constructed until the repository horizon is firmly established because construction below the repository horizon may compromise site safety.

Related to the same general topic of the unsaturated zone conditions, I received the impression that there was a considerable amount of effort by DOE contractors devoted to models for that environment. One might conclude that the modeling approach may be viewed as the way to characterize the unsaturated zone moisture and radionuclide transport because no serious data collection efforts have been made to the present time. In my opinion, such models as may be developed or adopted, particularly for unsaturated zone transport related questions, cannot take the place of actual hydrologic data in this type of environment of consideration. There is not likely to be general acceptance of unsaturated zone model results without proven calibration in both fractured and porous media (conditions which characterize the tuffs of Yucca Mountain). Such calibration probably will require both field data and laboratory experiments. In the absence of site specific calibration, carefully developed field relationships must be used to judge the unsaturated environment.

A final observation is offered with respect to a high-level waste repository within the fractured tuff of the unsaturated zone. Based on what little is known of the range of possible hydrologic conditions of such an environment, near field conditions of moisture and permeability need to be established with a high level of confidence. Conditions of high temperature at or near atmospheric pressures near the repository insure that any water in the interstices and fractures, and perhaps water from hydrous minerals, will be vaporized and become mobile while in the vapor state. In addition, recharging water would not be able to penetrate the higher temperature core of the heat envelope, and therefore would be redistributed around the envelope. Questions such as how much, where will it migrate to, and what will be carried by the water vapor are paramount, and relate directly back to the need for collection of pertinent field data supported by associated lab experiments. It's not difficult to envision a scenario of rather low permeability porous and fractured tuff with a significant percent of saturation occurring within the waste generated heat envelope. If there were only a few continuously permeable fracture networks occurring within the heat envelope, the majority of the water vapor and associated constituents would travel away from the energy source through these avenues in whatever direction the permeable fracture network allowed. The more limited the number of fracture networks, and the larger the water supply, the longer the migration paths until environments of temperature and pressure allowed condensation, at which regions the water would begin to behave as normal perched water in saturated fractures. Such a scenario illustrates that partly saturated fractured rock clearly represents as different ballgame, and a series of new questions need to be examined in detail. There is reason to believe thick unsaturated zones in certain media may offer the most favorable environments for high-level waste repositories, but it is also clear there can be no substitute for careful documentation of the hydrology of the unsaturated zones, and that perhaps many environments of the unsaturated zone may not prove acceptable.

Another basic uncertainty I recognized relates to the paleohydrology of the Yucca Mountain site. The time frame of consideration is such that climate change is a reasonable assumption that should be made. The late Quaternary pluvial climates of the Great Basin are probably the best guides to possible extreme climates of the future with increased moisture available to hydrologic systems of the areas. Existing NTS area studies are not site specific to Yucca Mountain, and indeed, are known to have a number of uncertainties important to estimating the late Quaternary paleohydrology of the Yucca Mountain site. It would be appropriate for a review of existing studies and the development of a program that may expand those NTS area paleoclimate and paleohydrology studies to cover site specific Yucca Mountain questions of paleoclimate recharge (moisture availability and changed conditions in the unsaturatd and saturated zone). It takes time to develop useful information in these types of efforts. This information should be addressed in the SCR, in my opinion, as pluvial climate paleohydrology will be one of the hydrologic states of the site that needs to be characterized. Just as the unsaturated zone hydrology should not become an afterthought, neither should the pluvial climate paleohydrology. Both are specialized areas of developing techniques and knowledge and are likely to become significant issues in adequate site characterization. In both areas much more work needs to be done within the context of the Yucca Mountain site.

To summarize key aspects, there follows a list of what I feel deserves feedback to DOE and/or its contractors:

1. Establish absence or presence of vertical component of flow in the tuffs by a confident technique.
2. If vertical flow is present, establish what the deeper unit is that is accepting the Yucca Mountain flow.
3. Distribute future borehole locations to test for the possible structural control of elongated linear erosion features.
4. Delineate the downgradient Yucca Mountain flow system in terms of region of active flow and area of discharge.

5. Develop an effective drilling program to obtain unsaturated zone hydrologic data.
6. Identify the hydrogeologic attributes and associated scenarios that characterize favorable unsaturated zone repositories, conversely identify the hydrogeologic attributes unfavorable to unsaturated zone repositories.
7. Develop a paleohydrology assessment program directed at Yucca Mountain.

In all of the above points considerable elaboration is possible, if necessary. However, I have attempted to strike a balance of what I believe to be possible and reasonable in terms of what can and needs to be accomplished without describing exactly how to go about it in great detail. It seems to me, unless specifically requested for details, such a balance is appropriate because there are likely several effective ways to approach a given need. I trust these observations and comments will prove useful and constructive.

Sincerely,

M.D. Mifflin
Hydrogeologist