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S. M. Coplan
High-Level Waste Management Development Branch
Division of Waste Management
U.S. NRC
Washington, DC 20555

Subject: Trip Report to Nevada Test Site, Nevada, 16-19 May 1982, Hydrogeologic Issues

Dear Mr. Coplan:

This report describes the observations and findings that resulted from meetings at the Department of Energy (DOE) office in Las Vegas, Nevada and a visit to Nevada Test Site (NTS). These meetings were conducted as part of the Nuclear Regulatory Commission (NRC) preparations for review of DOE's Site Characteristics Report (SCR) for the Nevada Nuclear Waste Storage Investigations (NNWSI). NRC must review the SCR and prepare a Site Characterization Analysis (SCA) in a timely manner. This report was prepared under Contract No. NRC-02-82-041, established to provide NRC a broad base of hydrogeologic experience.

A management review of this trip report has been conducted as part of IECO's Quality Assurance procedures. The review was performed by J. S. Long, Chief Geologist, who was assisted by Dr. T. L. Steinborn, IECO Project Manager for work performed under Basic Ordering Agreement No. RS-NMS-20-028.

This report describes the findings of meetings in Las Vegas and NTS on 16-19 May 1982. Preparation for the meetings included a review of documents provided by NRC and a meeting with NRC and other consultants to discuss the important hydrogeologic issues for evaluating a repository at the Yucca Mountain site on NTS. The documents included descriptions of the hydrogeologic framework at NTS, the hydrogeologic issues, DOE investigations, and earlier reviews of these investigations.

The IECO staff has been pleased to have the opportunity of assisting NRC on the NNWSI program. Please feel free to contact us if you have any questions on this report or if you require any additional assistance on the NRC Waste Management Program.

Very truly yours,

Daniel Sokol

Daniel Sokol, Ph.D.
Principal Investigator

DS:kml
Attachment: a/s

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NEVADA TEST SITE TRIP REPORT
16-19 May, 1982
Hydrogeologic Issues

1.0 INTRODUCTION

1.1 PURPOSE

The purpose of the trip was to review the status and test plans of the NNWSI project in anticipation of review of the SCR and preparation of the SCA by NRC. The preliminary review meeting with DOE and its contractors is intended to ascertain that all issues pertinent to compliance with 10CFR Part 60 are being considered. This will faciliate a timely comprehensive review of the SCR.

1.2 PARTICIPATION

At least 50 persons attended the meetings, drawn from four categories listed as follows with the number of individuals who signed the attendance list by category:

- o DOE 5 persons
- o DOE Contractor 28 persons
- o NRC 7 persons
- o NRC Contractor 8 persons

2.0 SUMMARY

The regional ground-water flow regime and the hydrogeologic properties of the rock units and structures that control ground-water flow have been identified during previous investigations at NTS and in the current Yucca Mountain investigations. These investigations appear to be

compatible with the requirements of Subpart 60.10 of 10CFR Part 60. Site specific conditions that are important to the hydrogeologic licensing issues are being investigated. The investigation program is proceeding logically and is being modified in response to new information as it becomes available. The hole locations, total hole depths, test intervals, and observation well settings are based on available data at the time each step is planned. The current program is planned to define the head distribution in three dimensions using holes on the periphery of the site. A hole near the center of the Principal Block is needed. However, drilling this hole can be delayed until a shaft location is selected.

The state-of-the-art for predicting and testing water flow and chemical transport in the unsaturated zone of fractured rocks apparently is inadequate to permit full credit to be claimed for retardation of radionuclide migration above the water table if a repository in the unsaturated zone is selected. Field and laboratory tests are needed to quantify the retardation of radionuclides carried in water from the repository through an unsaturated volume to a saturated aquifer. Any true evidence of this sort of retardation could be viewed as a positive host rock characteristic which would enhance the overall performance of the site in isolating waste from the accessible environment. Extensive in situ tests of unsaturated regime retardation would be required for quantitative modifications to overall system performance. If research and development efforts are directed to investigate unsaturated flow and transport phenomena prior to the scheduled license application, then advances in the state-of- the-art may permit credit for barriers to waste migration in the unsaturated zone.

3.0 OBSERVATIONS

The U.S. Geological Survey (USGS) is responsible for hydrogeologic investigations as well as geologic studies of the Yucca Mountain Site. The USGS hydrogeologic study team consists of two groups, coordinated

by W.E. Wilson. One, directed by F. E. Rush, performs site investigations at Yucca Mountain. Regional investigations, including regional modeling, are directed by Rick Waddell. These studies are an extension of more than 20 years of hydrologic investigations at NTS by the USGS.

Previous investigations have defined the regional flow system based on water level contours. Groundwater at the Yucca Mountain site flows generally eastward toward Forty Mile Canyon and then southward to a discharge area either in Ash Meadows or the Amargosa Desert. Exact flow lines have not yet been defined because of the following factors:

- Aligned structural features may introduce large differences in directional permeability so that flow lines are not normal to equipotential lines.

- The contours are based on water levels measured at widely different times extending over a period of many years. Furthermore, some of these measurements may not represent equilibrium.

- Water levels in different aquifers or in different zones within the same aquifer have been used to construct contours. A large vertical gradient exists at some locations; in these wells, the water level is influenced by the method used for well construction. Some wells are open to more than one aquifer; so these water level measurements represent a dynamic level affected by flow in the well between aquifers.

A program is being developed to define the regional flow system more precisely. This will include a reevaluation of older wells and modeling the system, and will include data from exploratory wells at the Yucca Mountain site.

The exploratory program to determine ground-water conditions at the Yucca Mountain site is based primarily on hydrologic bore holes.

Hydrologic holes are used primarily to perform permeability tests and then are completed as observation holes in which water levels are measured and from which water samples are collected. Most of the hydrologic holes are drilled near a geologic hole which has been cored. The construction of adjacent hydrologic and geologic holes at Yucca Mountain is a change in program approach at NTS. Previously, geologic and hydrologic investigations were performed in the same hole. However, that method was considered to be unsatisfactory because selection of hydrologic test intervals had to be made before geologic data could be interpreted, drilling methods were not always compatible, and drilling schedules could not be met. The development of the present program resulted in a lag between the geologic and hydrologic programs. This lag enables the hydrologists to base the program for testing and observation well installation on better geologic data and interpretations.

The array of existing and planned test holes on the site is near the perimeters of two adjacent areas of Yucca Mountain, defined as the Principal Block and an extended block. The Principal Block is an area about 22,000 feet long (north-south) and is as wide as 8,000 feet in the east-west direction. The extended block is a northward extension of about 8,000 feet. A zone 2,000 feet wide has been established within the perimeter of the principal block. This zone is labeled as the 2,000 foot offset on a Yucca Mountain site map shown at the Las Vegas Meeting. With the exception of one hole, G-2, the drill holes are in the 2,000-foot offset or within a few hundred feet of the Principal Block. Drill hole G-2 is at the northern margin of the extended block. The status of each hole, plans for completion, and plans for new holes were presented at the meeting. However, no printed details were provided and the presentation was too rapid for reliable transcription.

The geologic units at the site are well defined, and the gross hydrologic characteristics of each unit are known. The flow in many stratigraphic units is confined chiefly to structural features, generally

fractures, rather than to intergranular spaces. Larger structural features that intercept more than one stratigraphic unit also are significant. A fault west of the Yucca Mountain site may constitute a hydrologic barrier. Southward ground-water flow is postulated west of this fault and eastward ground-water flow is postulated east of the fault. Drilling to determine the presence of the carbonate aquifer at a depth of 6,000 feet has failed to establish the depth or presence of carbonate rocks below the site.

Recharge at the site is estimated from heat flow measurements. The estimate is an average flow rate of 3 mm/year (3 mm^3/square millimeter per year). The downward velocity has not been estimated.

The age of ground water at Yucca Mountain based on carbon-14 dating is 9,400 years. Carbon-14 determinations of water from the discharge areas yield a wide variation of ages.

4.0 INTERPRETATIONS

4.1 STATUS

Current investigations appear to be adequate to define the ground-water systems in a manner that will satisfy licensing requirements; that is these investigations should define the ground-water flow paths, travel time, and release to the accessible environment with sufficient precision and reliability to be compatible with the requirements for licensing established in 10CFR Part 60. The postulated flow system shows converging flow lines in Forty Mile Canyon and Jackass Flats east of the site; contours indicate steeper hydraulic gradients north of Yucca Mountain and Forty Mile Canyon. This flow pattern indicates that permeabilities are higher at the site and in Forty Mile Canyon than in adjacent areas.

The hydrostratigraphic units to be used for modeling and testing have not been completely defined. Hydrostatigraphic units at Nevada test site do not conform to the lithostratigraphic units. They may include a part of, parts of several, or several lithostratigraphic units. Aquifers and aquitards at the Yucca Mountain site can be defined as hydrostratigraphic units. However, in order to model the system adequately, hydrostratigraphic units need to be augmented by hydrostructural units representing structural features that cut across statigraphic units and act as ground-water conduits or barriers.

The presence of deep carbonate aquifers has not been verified at the site. These aquifers are known to underlie the volcanic rocks elsewhere at NTS and in the region. They may be important to the regional system becaue of their relatively high permeability and because of the capacity of radionuclides to form soluble stable carbonate complexes. Nevertheless, their presence at the site would be significant only if they are along a ground-water flowline from the respository to the accessible environment or a flowline that might develop if the hydrologic regime might change in the future. Therefore, if carbonate rocks are not present within the existing or possible flow paths through a proposed repository an effective barrier exists between the repository and the carbonate aquifers. The existence of an effective barrier can be demonstrated if wells that do not penetrate carbonate rocks are drilled to a depth which a valid three-dimensional ground-water model indicates is below any flow path through a proposed repository.

Geologic evidence indicates that the Principal Block is an uplifted fault block. These uplifted blocks in the Basin and Range Province typically are less fractured away from their margins. The investigation program is based on the concept that the relatively undisturbed rocks in the center of the block are stronger and less permeable than rocks at the margins. Therefore a program has been implemented to investigate the periphery of the block.

Extrapolating geologic data to the center of the block results in conservative assumptions with respect to rock mechanics and geohydrology. Rocks in the center of the block can be assumed to be at least as strong and no more permeable than rocks near the margins. This assumption appears reasonable.

Geologic test holes have been drilled in Drill Hole Wash at the northern margin of the Principal Block, at the southern end of the Principal Block, and at the northern end of the Extended Block. Hydrologic testing in these holes has provided permeability data that are considered conservative when extrapolated to the center of the block. Available water levels are composite levels and do not necessarily indicate conditions in any specific hydrologic zone.

The extent and nature of vertical ground-water movements at the site will be defined more precisely by conducting permeability tests in hydrologic test holes now being planned and by measuring water levels in multiple observation wells at locations currently being investigated and planned. This program also may define a system in which some aquifers have different horizontal flow patterns from others. The test program as it is being conducted appears to be adequate to achieve the immediate program objectives.

The effects of structural, stratigraphic, and lithologic heterogeneities on ground-water flow have not yet been defined. A fault west of Yucca Montain appears to be a barrier to ground-water flow. The extent and effects of structural features east of Yucca Mountain are not known. Hydrologic tests holes and monitoring wells are needed in Crater Flat and Forty Mile Canyon to resolve these questions.

The regional chemistry is fairly well defined, but site-specific data are sparse. Chemical and isotopic analyses of water from different zones at the site are needed to assist in the interpretation of water flow. A program of sampling and age dating using uranium daughter product disequilibrium may help to define travel time between the site

and discharge areas. I inquired during the meeting whether such a program is planned. Apparently the geochemical program has not been finalized.

The water budget, including ground-water recharge and discharge locations, mechanisms, and amounts, is not known with precision or reliability. However, the investigation program and modeling efforts appear adequate to define the system by the time the license application will be prepared. These parameter estimates will provide input needed to evaluate the potential future ground-water development in the system, and to assess possible effects of climate changes on ground water flow under and through the repository vicinity.

The mechanics of water flow in both liquid and vapor phases in the unsaturated zone, and of the migration of dissolved solids, particularly in fractured rocks, is not sufficiently well understood to allow credit for any barrier this zone might provide. The unsaturated zone contains perched zones, which are locally saturated, in which flow may be mainly horizontal. The water movement, except in the vapor phase, is generally downward. Current research programs probably will provide methods to measure and evaluate these mechanisms by the time a license application is prepared for a Yucca Mountain site in the unsaturated zone.

4.2 PLANS

The current data collection program emphasizes drill holes in the 2,000-foot wide "offset" of the Principal Block. This concentration of effort is most efficient as long as it is necessary to avoid the repository vicinity. A well in the center of this block is needed with an observation well or wells installed as soon as it can be demonstrated that drilling will not disrupt any existing natural barrier. Water-level contours and ground-water flow directions through the repository based on data from the margins of the block will not be sufficiently precise without these additional data.

The flexibility of planning the drilling and well completion program is laudable. Locations and plans for testing and completing each hydrologic test hole are based on results of the adjacent geologic test hole and on results from previous hydrologic test holes. These data were not provided in sufficient detail to evaluate the specific plans for 1982 and 1983.

Current plans include multiple well completion with as many as five pipes in a single drilled hole with cement set to isolate each zone. Although this type of completion has been successful in some situations, I feet that its use at Yucca Mountain is inadvisable because of low permeability of the formations. Multiple hole completion can demonstrate vertical separation of aquifers and vertical gradients. However, if water levels and water quality are the same in adjacent zones or aquifers, the results are uncertain because of the possibility that the cement seal between zones is not effective. The integrity of the seals cannot be verified immediately in low permeability sequences such as underlie Yucca Mountain. Delay in identifying possible seal failures may result in program delays.

Additional drilling, testing, and observation well sites are needed west of the fault that is assumed to act as a ground-water barrier between Yucca Mountain and Crater Flat. Additional drilling and testing also are required between the site and wells being used in Forty Mile Canyon. Plans to construct regional hydrologic test wells appear to fulfill these requirements.

A deep hole is planned to determine the depth and nature of any rocks of Paleozoic age at the site. A drill location in an upthrown block has been suggested to reduce the depth required to penetrate rocks of Paleozoic age. However, this approch is not valid if any significant faulting predates or is contemporaneous with deposition of the volcanic sequence. In such a situation the thickness of volcanic rocks between identified marker beds in the volcanic sequence may be thicker on the downthrown block of a fault than on the upthrown block. Erosion be-

tween periods of movement may have removed sections of the stratigraphic sequence within or above any carbonate rocks present on the upthrown block.

5.0 INFORMATION NEEDS

The time required for the process of data collection, compilation, interpretation, internal review, peer review, and publication in the program appear to be the greatest impediment to a comprehensive NRC review. Meetings such as the hydrology work sessions on 18 and 19 May are helpful but adequate evaluation of the data requires access to current written and graphic material which are known or can be inferred to be available such as:

- Well logs,
- Completion details of observation wells,
- Hydrographs showing changes in water levels in test holes and water wells in Forty Mile Canyon,
- Cross sections such as the one on the USGS core library wall, adding screened intervals and water levels in wells,
- Data to construct structural contours of aquifer tops and bottoms and isopachs of hydrostratigraphic units, and
- Water analyses, including graphic presentations of common ions and ions and isotopes that may indicate sources of water.

These data should be provided in draft form as they become available, even if not up to formal publication standards.

In addition to the planned drill site locations, at least one well is needed in the center of the Principal Block as soon as the hole can be drilled without affecting the ability of confining beds at the site to function as barriers. Holes also are required in Crater Flat west of the fault to determine the barrier effects of the fault. As many as three holes may be needed to determine the flow pattern west of the barrier. Drill holes and observation wells also are needed between the site and Well J-13 to determine the flow between the site and an existing ground-water source.

A short path to the accessible environment may be provided by perched zones that crop out on the periphery of Yucca Mountain. This will be important if the repository is located in the unsaturated zone above the ground level of the adjacent terrain. These local perched zones must be investigated.

The travel time between waters at the site and at possible discharge areas must be determined. Travel times calculated from aquifer properties should be confirmed by age-dating techniques. Absolute ages of water in discharge areas are significant if the repository is sited in the saturated zone in a ground-water recharge area. Travel time from a repository in the saturated zone to a discharge area should be determined by differences in ages between groundwater at the repository and water at identified discharge areas. If discharge areas are not possitively identified, flow from the repository should be assumed to discharge at the discharge area with the youngest water. Carbon-14 methods have not yielded definitive results. The use of uranium daughter products should be tried.