WILLIAMS & ASSOCIATES, INC.

P.O. Box 48, Viola, Idaho 83872 (208) 883-0153 (208) 875-0147

Hydrogeology • Mineral Resources Waste Management • Geological Engineering • Mine Hydrology

WM DOCKET CONTROL
CENTER

'84 AUG -6 P4:35

DRAFT

August 2, 1984
Contract No. NRC-02-82-046
Fin No. B-7377-2
Communication No. 46

WM Record File
B-7377

WM Project 11
Docket No.
PDR ✓
LPDR X

Distribution:
Pohle

(Return to WM, 623-SS)

Mr. Jeff Pohle
Division of Waste Management
Mail Stop 623-SS
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Jeff:

This letter contains the comments of Williams and Associates, Inc. on selected data reviewed at the NTS data review session held in Denver on July 24, 1984. In those cases where the data file supports a published report by the U.S.G.S., we have combined the review of the document with the review of the data file. Please consider this letter to be our trip report for the aforementioned data review session on NTS.

<u>Well VH-1</u>

This raw data file contains pump test and recovery test results for open hole VH-1 bottomed at a depth of 697.25 feet. All the tests performed were pumping tests or recovery tests. The data were analyzed by the Jacob straight line method or by the Theis log-log curve match method. Pumping test 1 was conducted at a pumping rate of 61.6 gpm for a period of 120 minutes. The test results were considered unanalyzable. I agree. Test 2A was conducted at 53 gpm over an open hole to a

8409070043 840802
PDR WMRES EECWILA
B-7377-2 PDR

depth of 2,500 feet. The nine minute pump test was terminated by a pump failure. The results are considered to be unanalyzable. I agree. Pump test 2B was conducted at a pumping rate of 60 gpm for a period of ten minutes. The semi-log plot was analyzed by the Jacob straight line method which yielded a preliminary T value of 8,600 gpd/ft. The analysist considered this value to be unrealistic; he concluded that the hole was partially plugged because the water emanating from the hole was very dirty. In addition the water level at the beginning of pump test 2A was 15.9 feet higher than the water level at the beginning of pump test 2B. Pump test 2C was conducted for a period of 7.5 minutes. However, the flow meter did not function properly and the test was discarded. Pump test 2D was run for a period of 230 minutes during which time 61.9 feet of drawdown occurred. However the discharge fluctuated widely so the data were not analyzable. Test 2D was conducted for 460 minutes at a very appropriate pumping rate of 1,225 gpm. The semi-log plot shows at least two recharge boundaries to which straight lines were fitted. Three approximate values of T corresponding to the three straight line segments were calculated to be 1,000 gpd/ft, 2,100 gpd/ft, and 85,000 gpd/ft. The latter figure probably reflects a recharge boundary that is considerably more permeable than the rock matrix. The analysist used the pump test recovery data as supporting data to conclude that the T value is 1,250 gpd/ft. In my opinion the analysis is defensible. Pumping test 3 was conducted for a period of 5.9 days. A semi-log plot of the data is difficult to analyze. The transducer was raised 10 feet during the test. An effort to correct the graph for this raise proved to be less than straightforward. The effort essentially went to confusing reversal of drawdown. Consequently very little was derived from this effort. Test 4 was a recovery test from test 3. The recovery curve on a semi-log plot does not look normal. It would be difficult to defend a reliable T value from this curve. Test 5 was a constant Q drawdown test. The semi-log plot does not look normal. Different portions of it can be analyzed using the Jacob method or the specific capacity method. The curve probably is affected by boundaries (more than one). Test 6 was a recovery test from pump test 5. The recovery period lasted 1,300 minutes. The semi-log plot of the recovery curve does not look normal. A T value was calculated using the Jacob method, but it would be difficult to defend. The file contains a report entitled "Temperature Correction". This report describes the method by which temperature in a pumping well is used to correct the water level reading in that well for density changes during pumping. The analyses show that approximately six inches of correction are necessary over a depth of about 1,800 feet. Some of the test's water level readings were corrected for density due to temperature differences; others were not. The unusual nature of the aforementioned curves may be explainable by density variations. This terminates my remarks on the file for well VH-1.

We were presented with certain semi-log graphs of drawdown and recovery data for well H-4. A geohydrology report is in manuscript form for this well. However, the U.S.G.S. was willing to allow us to look at the raw data only. The raw data are presented in the form of the graphs discussed below.

Figure 4--Water level drawdown versus time for pumping test 2, depth interval from 519 to 1,219 m. Figure 4 is a semi-log graph of drawdown in meters versus time after pumping started in minutes. Drawdown continued until four minutes into the test. At that time there was a water level rise of approximately .8 m. At 10 minutes into the test water levels began to decline again with about .6 m of drawdown. At 20 minutes another water level rise occurred. Temperature variations may explain this unusual curve.

Figure 5--Water level drawdown versus time for pumping test 3, depth interval from 519 to 1,219 m. Figure 5 is a semi-log graph of drawdown in meters versus time after pumping started in minutes. The same situation occurred that occurred in the previous figure. Approximately .9 m of drawdown occurred in the first five minutes. At that time a water level rise of approximately .8 m occurred. At 10 minutes into the test water levels began to decline again. Temperature variations may account for this curve.

Figure 6--Water level recovery versus time for pumping test 2, depth interval from 519 to 1,219 m. Figure 6 is a semi-log graph of residual drawdown in meters versus time after pumping stopped in minutes. Residual drawdown increased the first .2 minutes then began to decrease for about .4 minutes and then again began to decrease to approximately 1.4 m approximately 8 minutes into the test. At that time residual drawdown began to decrease continuously until the last measurement approximately 30 minutes into the test.

Figure 7--Water level recovery versus time for pumping test 3, depth interval from 519 to 1,219 m. Figure 7 is a semi-log graph of residual drawdown in meters versus time after pumping stopped in minutes. The first measurement was taken at two minutes into the test. Residual drawdown was approximately .8 m at that time. Residual drawdown increased to approximately 1.5 m approximately 8 minutes into the test, then began to decline to approximately .2 m at 30 minutes into the test, which was the last measurement taken.

Figure 8--Semi-logarithmic graph of water level drawdown versus time for pumping test 6, depth interval from 519 to 1,219 m. Figure 8 is a semi-logarithmic graph of drawdown in meters versus time after pumping started in minutes. The first measurement was taken at one minute into the test. Water level decline was approximately 1.5 m at that time. Drawdown continued until approximately four minutes into the test when water levels

began to rise to approximately .5 m. Water levels fluctuated until approximately 80 minutes into the test at which time water levels began to decline continuously to approximately 4.8 m at approximately 10,000 minutes into the test.

Figure 9--Logarithmic graph of water level drawdown versus time for pumping test 6, depth interval from 519 to 1,219 m. Figure 9 is a log-log graph of drawdown in meters versus time after pumping started in minutes. The first water level measurement was taken at approximately one minute into the test at which time drawdown was 1.5 m. Drawdown increased until approximately four minutes into the test and began to decline until ten minutes into the test and fluctuated and then began to increase again for the duration of the test until approximately 1,000 minutes. This test would be difficult to analyze unless some hydrogeologic explanation for the curves can be developed.

Figure 10--Water level recovery versus time for pumping test 6, depth interval from 519 to 1,219 m. Figure 10 is a semi-log graph of residual drawdown in meters versus time after pumping stopped in minutes over time after pumping started in minutes. Residual drawdown increased from approximately four minutes into the test, which was the first measurement. until approximately 800 minutes into the test. That portion forms a fairly straight line. After 800 minutes into the test the slope steepens significantly until approximately 30,000 minutes into the test. An apparent boundary is indicated.

Figure 11--Borehole flow and temperature survey for test well USW H-4 showing percent of pumping rate produced for intervals from 555 to 1,219 m. Figure 11 is a graph of depth in meters below land surface versus flow rate in l/sec. Figure 11 shows the percentages of flow from each particular unit intersected by the borehole.

Figure 12--Water level recovery versus time during injection tests for depth interval from 555 to 604 m. Figure 12 is a semi-log graph of head in meters above static water level versus time, in minutes. Water levels declined continuously from approximately .4 minutes into the test until the end of the test at 200 minutes. However a somewhat wavy line is drawn through the data. It appears that one or more boundaries are affecting the data.

Figure 13--Water level recovery versus time during injection test for depth interval from 604 to 652 m (full column of water). Figure 13 is a semi-log graph of head in meters above static water level versus time in minutes. The recovery curve in figure 13 has the same characteristic shape as the recovery curve in figure 12. This is to be expected since the only difference between the two tests is that the recovery test of figure 13 included 48 m more of borehole length.

Figure 14--Water level recovery versus time during injection test for depth interval from 604 to 652 m (one-third column of water). Figure 14 is a semi-log plot of head in meters above

static water level versus time in minutes. The first water level measurement was taken approximately .15 minutes. Water levels recovered continuously from that time on to static water level at approximately 50 minutes into the test. However, a straight line cannot be drawn through the data points. The data points form a continuous curve.

Figure 15--Water level recovery versus time during injection test for depth interval from 652 to 701 m. Figure 15 is a semi-log graph of head in meters above the static water level versus time in minutes. The first water level measurement was taken approximately .3 minutes into the test. Water levels recovered continuously from approximately 300 m above static water level to static water level in approximately five minutes. However, the data plot does not form a straight line.

Figure 16--Water level recovery versus time during injection test for depth interval from 703 to 735 m. Figure 16 is a semi-log graph of head in meters above static water level versus time in minutes. The first water level measurement was taken at approximately .3 minutes. Water levels decayed to static water levels by two minutes into the test.

Figure 17--Water level recovery versus time during injection test for depth interval from 735 to 767 m. Figure 17 is a semi-log graph of head in meters above static water level versus time in minutes. The first water level measurement was taken approximately .1 minutes into the test. Water levels decayed

continuously to static by approximately ten minutes into the test.

Figure 18--Water level recovery versus time during injection test for depth interval from 783 to 832 m. Figure 18 is a semi-log graph of head in meters above static water level versus time in minutes. The first water level measurement was taken approximately .2 minutes into the test. Water levels decayed continuously to static by approximately five minutes into the test.

Figure 19--Water level recovery versus time during injection test for depth interval from 832 to 850 m. Figure 19 is a semi-log graph of head in meters above static water level versus time in minutes. The first water level measurement was taken approximately .2 minutes into the test. Water levels decayed to static water level within five minutes of the test.

Figure 20--Water level recovery versus time during injection test for depth interval from 855 to 873 m. Figure 20 is a semi-log graph of head in meters above static water level versus time in minutes. The first water level measurement was taken approximately .2 minutes into the test! water levels decayed to static within approximately four minutes.

Figure 21--Water level recovery versus time during injection test for depth interval from 873 to 892 m. Figure 21 is a semi-log graph of head in meters above static water level versus time in minutes. The first water level measurement was taken

approximately .2 minutes into the test. Water levels decayed to static water level in approximately 10 minutes.

Figure 22--Water level recovery versus time during injection test for depth interval from 892 to 910 m. Figure 22 is a semi-log graph of head in meters above static water level versus time in minutes. The first water level measurement was taken approximately .2 minutes into the test. Water levels decayed to static within approximately 5 minutes.

Figure 23--Water level recovery versus time during injection test for depth interval from 910 to 928 m. Figure 23 is a semi-log graph of head in meters above static water level versus time in minutes. The first water level measurement was taken approximately .2 minutes into the test. Water levels decayed continuously to static within approximately 7 minutes.

Figure 24--Water level recovery versus time during injection test for depth interval from 928 to 1,219 m. Figure 24 is a semi-log graph of head in meters above static water level versus time in minutes. The first water level measurement was taken approximately .3 minutes into the test. Water levels decayed to approximately static within approximately 10 minutes.

Figure 25--Water level recovery versus time during injection test for depth interval from 1,173 to 1,192 m. Figure 25 is a semi-log graph of head in meters above static water level versus time in minutes. The first water level measurement was taken

approximately .2 minutes into the test. Water levels decayed to static within approximately 6 minutes.

Figure 26--Water level recovery versus time during injection test for depth interval from 1,195 to 1,219 m. Figure 26 is a semi-log graph of head in meters above static water level versus time in minutes. The first water level measurement was taken approximately .3 minutes into the test. Water levels decayed to static within approximately 10 minutes.

Initial Head Measurements for the Injection Tests

Figure 12, the initial head measurement was 350.

Figure 13, the initial head was approximately 475 m.

Figure 14, the initial head was approximately 160 m.

Figure 15, the initial head was approximately 300 m.

Figure 16, the initial head was approximately 275 m.

Figure 17, the initial head was approximately 375 m.

Figure 18, the initial head was 350 m.

Figure 19, the initial head was approximately 340 m.

Figure 20, the initial head was approximately 410 m.

Figure 21, the initial head was approximately 380 m.

Figure 22, the initial head was approximately 375 m.

Figure 23, the initial head was approximately 375 m.

Figure 24, the initial head was approximately 330 m.

Figure 25, the initial head was approximately 280 m.

Figure 26, the initial head was approximately 400 m.

According to Jim Robison, the tests that produced the data graphs in figures 12 through 26 are actually slug tests. These are plotted on semi-log plots of head in meters above static water level versus time in minutes. This method of presentation of the data plots could be mistaken to be semi-log plots of constant injection tests rather than slug injection tests on the basis of the data above. The semi-log graphs should consist of time after injection started plotted against the ratio of head at time t to the head at the time injection started (H/H_o).

Well USW H-5

Bentley, C.B., J.H. Robinson and R.W. Spangler, 1983,
Geohydrologic Data for Test Well USW H-5, Yucca Mountain
Area, Nye County, Nevada: U.S.G.S. Open-file Report 83-853.

Well H-5 was drilled to a total depth of 1,219 m on June 23, 1982. Geophysical logs were run in test hole H-5 to define lithology, correlate with logs of nearby wells and collect data on porosity in fractures, obtain fluid levels, locate casing perforations in cement, and guage the diameter of the well.

Hydrologic Testing and Water Sampling, Pumping Tests

Drawdown and recovery tests were conducted in conjunction with four pumping periods, after test well USW H-5 had been drilled to its total depth, cased to 790 m and casing perforated below 707 m. Data plots of the drawdown and recovery tests for the third pumping period, and for the recovery test for the fourth pumping period are presented in figures 4 through 6 in the published document. Drawdown data for pumping periods 1 and 2 are not presented in the published document, presumably because they do not form a straight line or smooth curve as shown in the raw data file. The semi-log plot of drawdown data for pumping period 1 showed that drawdown did not begin until approximately .7 minutes into the test. Water levels decreased at a consistent slope until approximately one minute at which time the slope of the data changed. The slope flattens out until approximately 40 minutes into the test. At that time the data steepens for another 10 minutes and then flattens again until the end of the test at 100 minutes. Overall there are four changes in slope during the duration of the pumping test. A semi-log plot of drawdown data for pumping period 2 indicates that drawdown from approximately .15 minutes until .5 minutes formed a curvalinear line; from .5 minutes to the end of the test at approximately 55 minutes the curve is a fairly straight line and analyzable.

Figure 4 of the published report is a graph of water level drawdown against time for pumping test 3. The depth of interval is from 707 to 1,219 m. This curve is a semi-log graph of water level drawdown in meters versus time after pumping started in minutes. The semi-log plot of the data forms a curvalinear line with the shape very similar to the Theis curve. Unfortunately, this is a semi-log plot.

Figure 5 of the published document is a water level recovery graph for pumping test 3. The depth interval is from 707 to 1,219 m. Again it is a semi-log plot of residual drawdown in meters versus time after pumping stopped in minutes. The semi-log plot again forms a curvalinear line very similar in shape to a Theis curve.

Figure 6 of the published document is a water level recovery graph for pumping test 4. The depth interval is from 707 to 1,219 m. Figure 6 is a semi-log graph of residual drawdown in meters versus time after pumping stopped in minutes. Again the graph forms a curvalinear line with a shape very similar to the Theis type curve.

Packer Injection Test

Packer injection tests were conducted by using inflatable packers to isolate test zones; tests were performed at intervals where hole size and configuration allowed setting of the packers. Water was injected into the interval between two packers or between one packer and the bottom of the hole. Decline of hydraulic head with time was monitored in the isolated interval. Eleven tests were conducted in test well USW H-5 for the intervals between 790 and 1,219 m. Injection curves are plotted in figures 9 through 19 of the published document. The ratio of hydraulic head after injection (H_t) to initial hydraulic head (H_o) is plotted against time since injection began. Semi-log graphs of the water level data for the injection tests form fairly smooth curvalinear curves for figures 9 through 14. Water level data presented in figures 15 and 16 form distorted curvalinear curves on semi-log plots. The reason for the distortion is not explained in the published document. However, the distortions could be attributed to the high initial head during the tests which may have opened fractures within the formation. Water level data presented in figure 17 also are distorted but not to the same degree as figures 15 and 16. Water level data presented in figures 18 and 19 form smooth curvalinear curves.

Note: Figure 7--Borehole flow survey 1 showing percent of total pumping rate produced by intervals. This figure shows that the interval between 700 and 800 m produces most of the water pumped from the well. The interval from 800 to approximately 1,100 m produces much less water. This is probably the reason why the data plots for figures 4, 5, and 6 form curvalinear curves rather than straight line plots for the pump tests.

Well G-1

The drilling polymer used for G-1 had a higher viscosity than the formation water so the results of testing in G-1 are questionable.

Review of Well H-1, Data Report

Rush, F.E., W. Thordarson, and Laura Bruckheimer. 1983.
Geohydrologic and Drillhole Data for Test Well USW H-1,
Adjacent to Nevada Test Site, Nye County, Nevada:
U.S. Geological Survey Open-file Report 83-141.

This review covers the above document in combination with raw data observed at the Data Review Session for NTS held at the U.S.G.S. offices in the Denver Federal Center on July 25, 1984.

This document presents data collected to determine hydraulic properties of the rocks penetrated in test well USW H-1. The report contains data on drilling operations, lithology, borehole geophysics, hydrologic monitoring, core analysis, ground water chemistry, and pumping and injection tests for this well. This review will concentrate on the pumping and injection tests (slug tests). The well is located in Nye County, Nevada, approximately 140 km northwest of Las Vegas. It is located in an easterly draining canyon of Yucca Mountain, northwest of Jackass Flats. The well was drilled to a total depth of 1,829 m on November 22, 1980. The well was drilled with rotary drilling equipment using air, detergent and water for chip removal.

The report contains data on 48 core samples that were removed from the unsaturated and saturated zones. Measurements included density, matrix porosity, pore saturation, and pore water content. Horizontal and vertical saturated hydraulic conductivity measurements were made on samples from the saturated zone. The hydraulic conductivities for the saturated zone ranged from 10^{-4} to 10^{-7} m/day. Matrix porosity ranged from 20 to approximately 30 percent, although a few samples fell outside this range. The tests show that the matrix permeability is several orders of magnitude lower than the permeability values determined from the slug tests and pumping tests discussed below.

The borehole flow survey log presented in the report indicates that the well has three major producing zones. These zones are located between depths of 572 m (the water table) and 655 m, between 690 m and 700 m, and between 740 m and 790 m. These were the zones that received primary attention during pump testing in particular. The borehole flow survey graph presented in the report is not consistent with the borehole flow survev data presented in the raw data file. According to the data file the borehole flow survey was conducted throughout the length of the hole but only the upper 1,000 m of hole data are presented in the subject report. No explanation is given.

Both the report under review and the data presented in the file indicate that the head distribution in the borehole increases vertically with depth. The water level for the depth zone 572 to 688 m above sea level is 729.9 m above sea level. The head reading for the depth zone 1,112 to 1,115 m above sea level is 780.8 m above sea level.

Drawdown and recovery tests were conducted for the interval 570 m to 688 m before casing was set. Two additional pumping tests were conducted between the depths of 687 m and 1,829 m after casing was set to 688 m. Drawdown test data were plotted in the form of drawdown versus time after start of pumping on semilog paper. Recovery test data were plotted with residual drawdown against time on semilog paper. The number of pumping test curves and recovery curves reported in the document under review is in agreement with the number of tests reported in the raw data file. The only difference between the pump test data in the raw data file and the pumping test data in the document under review is that the raw data file contains the drawdown data for well G-1 due to the pumping of well H-1; the report under review makes no reference to this curve. The semilog graphs of drawdown versus time and recovery data versus time should be amenable to analysis by the Jacob straight-line method.

Data for six injection tests for packed-off intervals between depths of 687 m and 1,829 m are presented in the report under review. The ratio of hydraulic head at a given time to initial hydraulic head is plotted against time since injection began. The number of injection (slug) tests in the raw data file is not equivalent to the number of injection tests presented in the report under review. Inspection of the list of tests included in the raw data file reveals that 17 injection tests were attempted in this interval. Of the 17 tests, one test was considered too short for analysis; three tests were not used because the tool failed; two tests were not used because of packer failure; three tests were listed as no good without explanation; and two tests were listed as good with questions. These reasons account for the presentation of only six sets of test results in the document under review. Twenty-nine other tests were either attempted or conducted in well H-1. These tests consisted of swabbing tests and shut-in tests. Shut-in tests are not defined in either the data base or the document. However, the test list in the data base for well H-1 indicates that some of the shut-in tests were considered to be good. Jim Robison's explanation for the shut-in test is that the tubing is evacuated and the shut-in tool opened in order to watch the pressure change as a consequence of opening the tubing to the formation pressure. Alternatively the tubing is evacuated and the tool closed in order to watch the pressure build up between the packers. In any case the decision was made to use only the injection slug tests for which the data are reported in the review. Apparently this was somewhat of an arbitrary decision. but it explains the presentation of only six tests in the document under review.

Review of Well H-1, Interpretative Report

Rush, F.E., W. Thordarson and D.G. Pyles, 1984,
Geohydrology of Test Well USW H-1, Yucca Mountain,
Nye County, Nevada: U.S.G.S. Water Resources
Investigations Report 83-4032.

This document contains the U.S.G.S.'s analysis of the data that are presented in open-file report 83-141. Items of interest that I have not already pointed out in my review of open-file report 83-141 include the following.

1. Table 8 of the document describes the water yielding characteristics of the zone above the water table. It should be noted that water under positive pressure is reasonably common in this drill hole (H-1). Evidence for this statement consists of descriptions of dripping water or small streams of water or seeping water emanating from the walls of the hole.
2. The zone from 652 m to 653 m is the most productive zone in the borehole. The interval from 792 to 1,829 m produced no detectible flow of water as did the no flow zone from 694 m to 736 m. This result is somewhat interesting because the result of the slug injection test revealed transmissivities that suggest that portions of the hole among these depths should have yielded water. The values are indicative of marginal aquifers. The most probable explanation for this inconsistency is that the trace ejector survey was not sensitive enough to detect the flow.

3. Piezometers were installed permanently in well H-1 to measure water levels in four zones. These zones are: 1) 640 m, 2) 738 to 741 m, 3) 1,112 to 1,115 m, and 4) 1,803 to 1,806 m. Water levels in the two shallower piezometers are at essentially the same depth as the composite water level measured prior to piezometer installation. The water level in the deeper zone was approximately 52 m higher than the water level in the shallower zone as of September, 1982.

These data suggest that the vertical movement of water in the hole is upward toward the more permeable zones near the water table. This document states that water below approximately 700 m probably is artesian (confined) because the bedded tuff present at this depth commonly has low permeability. In summary, the water level data indicate that the system at the location of well H-1 is confined and that the vertical component of the potential gradient is directed upward toward two aquifers located at depth intervals 572 to 640 m and 738 to 741 m. The analysis of pumping test data discussed under my review of report 83-141 reflects the fact that the data used fit analytical curve matching techniques reasonably well with one exception. Figure 14 in the report under review presents an attempt to analyze water level drawdown in pumping test 3 in the zone from 687 to 1,829 m using the Theis method. The curve fitting procedure works very poorly for the drawdown curve. It appears that some hydrogeological phenomena is operating that precludes an adequate fit of the field data to the theoretical curves. The other curves and their matches can be defended. The analyses yield transmissivity values for the aforementioned upper two permeable test intervals as follows: The first pumping test over the depth interval 572 to 688 m yielded a transmissivity value of 154 m^2/day. The recovery for this interval yielded a T value of 183 m^2/day. Both these values are the result of applying the Jacobs straight line method and the Theis method to the data. The transmissivity values for the interval 687 to 1,829 m ranged from .41 to 1.6 m^2/day. These numbers apply to the entire section between 687 m and 1,829 m below ground surface. These values can be divided into transmissivity of particular portions of the section by using the transmissivity data in combination with the borehole flow survey log. This was done by the U.S.G.S. and the results presented in Table 11 on the subject report. The results show that the transmissivity of this entire depth interval, even on a permeable unit basis, is very low relative to the aforementioned permeable sections of the Prow Pass Member.

Injection test results and their analysis also are presented in the subject document. The results of the injection tests show that virtually all the permeability in the hole is above the 687 to 694 m depth interval. The quality of the injection test data already have been discussed in my review of open-file report 83-141.

In summary, the issues that are most significant with respect to this review and with respect to the data base examined at the NTS data review session in Denver on July 23-27 are as follows.

1. The portions of the data base that are presented and analyzed in the document are amenable to analysis by the straight line method, the Theis equation or by slug injection test methods. Two of the tests that were analyzed by matching to the Theis equation are marginal with respect to closeness of fit. It is possible to defend more than one match, some of which would suggest that boundaries are present.
2. The shut-in test portion of the data base was omitted in the analysis. The reason for this omission is not presented in the report. A considerable amount of time, money and energy were devoted to conducting the shut-in tests.
3. Seventeen slug injection tests (these tests are incorrectly called injection tests in the report) were conducted in hole H-1 but only six sets of results are presented and analyzed in the document under review. The rationale for omitting the eleven tests included equipment failure, packer failure, and length of test. The omission of all the tests that were omitted can be defended on the basis of the information presented in the data base.
4. The water level data and the analysis of it suggest that the vertical component of the hydraulic gradient is directed

upward in this hole. The aquifer that acts as a "drain" is located near the top of the zone of saturation where the hydraulic head is lower than at the bottom of the hole. Most of the data curves fit the match curves for confined aquifer analysis. This is somewhat surprising for the upper aquifers; the reason for the data not matching water table type curves ought to be addressed.

5. The injection tests in this document and the aformentioned open-file report are actually slug injection tests. They are not injection tests in the usual sense of the word where water is injected into the hole under a constant injection rate or under a constant head.Review of Well UE-25b #1

Review of Well UE-25b #1

Lobmeyer, D.H., M.S. Whitfield, Jr., R.R. Lahoud, and
Laura Bruckheimer, 1983, Geohydrologic Data for
Test Well UE-25b #1, Nevada Test Site, Nye County, Nevada,
U.S.G.S. Open-file Report 83-855.

This document presents the data base for the hydrogeologic testing conducted on test well UE-25b #1. The well is located in Nye County, Nevada, approximately 145 km northwest of Las Vegas on the Nevada Test Site. The well is located in a major wash which trends northwest from 40 Mile Wash on the east flank of Yucca Mountain. During the hydrogeologic testing program, well UE-25a #1 was used as an observation well. This well is located 107 m south-southwest of well UE-25b #1 in the same wash. The total depth of well UE-25b #1 is 1,220 m. The well was drilled with air rotary and foam. Initially the hole was drilled to a depth of 579 m and tested. Subsequently the hole was enlarged, cased and deepened to 1,220 m. The second episode of testing was conducted shortly after deepening. The third episode of testing utilized packers to determine the vertical head distribution for the four most productive zones. The well penetrates the usual sequence of alluvium, Paintbrush tuff, and Crater Flat tuffs. According to the report, the Topapah Springs Member of the Paintbrush tuff, the Bullfrog Member and the Tram Member of the Crater Flats tuff are the most indurated tuffs in the section. Presumably this means they also are the most fractured.

The report contains a section describing the hydrologic properties of core samples obtained from the hole. The tests on the core samples were performed by Sandia National Laboratory. Matrix porosity was measured on 127 core samples from the interval 589 to 1186 m. According to the data presented in the report, the percent porosity is in the order of 23 to 27 percent in the Bullfrog Member and in the upper portion of the Tram Member. Porosity decreases to 10 percent or less in some portions of the Tram Member and in about 20 percent of the Prow Pass Member. Only limited porosity measurements were taken above the Prow Pass Member of the Crater Flats tuff.

Geophysical logs were used to help select hydraulic test intervals. These logs included the down hole televiewer, the SP log and the temperature log.

Water level observations and measurements were made during drilling, during hydraulic testing and after testing was completed. The purposes of the measurements were: 1) to locate possible perched water in the unsaturated zone, 2) to determine depth at which water saturation occurs, and 3) to determine hydraulic heads in the well for specific zones (vertical distribution of hydraulic head). The four most productive zones as identified by tests between packers and by borehole geophysical logs were between the depths of 546 to 583 m, 585 to 622 m, 789 to 826 m, and 848 to 884 m. The water level measurements for these intervals were respectively, 471 m below land surface, 471.3 m below land surface, 471.5 m below land surface and 471.4 m below land surface. These data indicate that the vertical component of the potential gradient is very nearly zero in this well.

The document lists 24 separate tests that were conducted in borehole UE-25b #1. Most of the tests were labeled injection tests, but three of the tests were pumping tests. Most of the injection tests were conducted between straddle packers. All three of the pumping tests were conducted across the open hole without packers. As discussed previously herein, some confusion exists with respect to the term injection tests. The U.S.G.S. is using the term to be synomynous with a slug test. This test is accomplished by opening the tool between two packers or between one packer and the bottom of the hole to a column of water reaching land surface in the tube that connects the tool to the land surface. The decay of the head in the tube is measured by the falling water level or by falling pressure as the water flows into the portion of the section that is being tested between the packers. These tests should not be confused with the standard term injection test which usually means pumping water into a packed off zone either under constant head or at a constant injection rate. This distinction is important because the methods of analysis of the two types of tests are completely different. The radius of the tubing in which the water level was measured as it was allowed to fall was .031 m in all cases. The data are plotted as the ratio of remaining hydraulic head to the original head (h/h_o) against the log of time on semilogarithmic paper. The method of analysis of these data requires that the resulting curve be matched against a family of type curves published in Water Resources Research by Papadopolus, Bredehoeft and Cooper in 1973. The article is entitled "The Analysis of Slug Test Data". The curves for all the tests are presented in the report under review. In my opinion, only a few of the test results will match a type curve closely. Most of the data definitely do not constitute textbook cases.

The pump tests that were conducted at the site were conducted over the interval 471 to 1,220 m. The first test stressed the aquifer at 13.4 l/sec. The relatively low rate was a consequence of the limitations of the pump (15 l/sec). A second pumping test was conducted after the importation of a larger pump. This test pumped the system at 32 l/sec, but the rates ranged from 26.5 to 36.8 l/sec. The third test stressed the system at 35.8 l/sec. As stated previously, well UE-25a #1 was used as an observation well during the pumping tests. This observation well responded to both test 2 and test 3 (the higher pumping rate tests); however the response was so slight that data may be difficult to analyze. They cannot be analyzed at the scale on which they are plotted in this document. In my opinion the test data from the first pumping test cannot be analyzed. The curves contain fluctuations that preclude the application of standard curve matching techniques. With the data available in this report it is not possible to speculate on the causes of the anomalous drawdown data. The drawdown and recovery curves for the second pumping test are more standard in shape; they can be analyzed. However the drawdown data in particular reflect the influence of boundaries. The drawdown data for the third pumping test also can be analyzed, but these data also reflect the influence of boundaries. Recovery data were not taken for the third pumping test because the recovery data for the second pumping test were considered adequate for purposes of hydraulic property determination.

The borehole flow survey for well UE-25b #1 shows the influence of the aforementioned four permeable zones. The graph shows that the productive portions of this borehole are separated by very tight rock. The aforementioned pumping tests were conducted throughout the entire open hole; consequently, the borehole flow survey graph may explain the barrier boundaries that are reflected by the pumping test data. But other hydrogeologic explanations probably can be defined as well.

With the exception of the confusion over the definition of an injection test (versus slug test) it seems to me that this report is written clearly and accurately. I can see no reason to question the test results aside from the fact that the injection tests perhaps may not match appropriate type curves very well.

Review of Well H-6, Data Report

Craig, R.W., R.L. Reed and R.W. Spengler, 1983, Geohydrologic Data for Test Well USW H-6, Yucca Mountain Area, Nye County, Nevada: U.S.G.S. Open-file Report 83-856.

This review covers the above document and the raw data base as examined at the NTS data review session held in Denver, Colorado on July 23-27, 1984. The document under review presents the results of two pumping tests, water level measurements, tests on core samples, a borehole flow survey, packer-injection tests (actually slug injection tests), and chemical analysis of water for borehole H-6.

Analysis of core consisted of measurement of density, matrix porosity, pore saturation, hydraulic conductivity, and pore water content. A total of 67 m of core were collected in the depth interval 333 to 1,220 m. A total of seventeen segments of core were collected. The document does not contain any of the results of the analysis of core.

According to the report, two pumping tests were conducted in the well. Drawdown and recovery analysis were applied to the results. However, Jim Robison revealed that additional tests have been conducted since the report was completed. The results of these tests were not available. The two tests described in the report covered two productive intervals identified on the borehole flow survey log. These intervals extended from the water table at approximately 525 ft to approximately 780 ft. The results of the tests are presented in the form of semilog graphs of drawdown versus time and residual drawdown versus time. The Jacob straight line method of analysis should be applicable to both sets of curves. However, breaks in the curve indicate that a log-log plot of the data would fall beneath the Theis curve at later times. Transmissivity values are not calculated in the report. They have been calculated in the data file but I have agreed not to comment on them. Some of the curves in the data file are presented in the form of log-log plots of drawdown against time for the lower zone extending from approximately 635 m to 780 m. A packer was set approximately at 780 m and at approximately 625 m in order to conduct a pumping test of the lower productive zone. The resulting curves suggest that this zone is leaky for one reason or another. More than one explanation for the apparent leakage is possible. In this context the term leaky must be used with disgression.

During the first pumping test of the entire section, the pumping rate was 28 l/sec for 4,822 minutes. This test was ended prematurely by mechanical failure of the pump. Consequently no recovery data were obtained. Pumping test 2 was run for 2,226 minutes at a pumping rate of 27 l/sec. However, no data are available for the period 116 to 1,789 minutes because the monitoring instrument was removed to allow access for the borehole flow survey tool. A complete recovery curve was obtained. The data should facilitate the assignment of transmissivity values to the entire section of 2,525 m and 800 m.

The borehole flow survey can be used to divide the transmissivity among the two aforementioned permeable depth intervals in the hole. The tests mentioned above that were run subsequent to the preparation of the report under review can be used to check these procedures. The question raised by the three sets of tests is how to interpret the apparent leaky characteristics of the two aquifers in combination or of the lower aquifer. The leaky lower aquifer would make the combined test appear to be leaky even if the upper aquifer is not leaky. None of the tests display the characteristics of delayed yield. Consequently the system must be acting as a confined system.

The packer injection tests were conducted in the well to obtain transmissivity values for the relatively low permeability zone between depths of 803 m and 1,200 m. As explained previously the packer injection tests are in reality slug injection tests that should be analyzed by the Papadopolus-Bredehoeft-Cooper methods. Slug injection tests for the seven intervals are shown in the report. These tests are identified as test 1 in the depth interval 581 to 607 m, test 2 in the depth interval 606 to 640 m, test 7 in the depth interval 835 to 869 m, test 8 in the depth interval 871 to 1,220 m, and test 10, depth interval 1,155 to 1,220 m. Data are plotted in the form of standard slug tests coördinates of H/H_o versus time. Several of the curves probably will not fit type curves very well. Two of the curves (test 7 and test 8) have anomalous humps that should be explained in some manner.

The raw data base examined at the workshop indicates that ten slug injection tests were performed on well USW H-6. Comparison of the report with the data base reveals that test 9, test 6 and test 5 were not used in the report. Examination of the field data suggest that test 5 was not used in the report because it was not run for a sufficient length of time. The total length of the test was 3.9 minutes. The reason for the length of the test is not obvious. Apparently test 6 was not used because the shut-in test following the slug injection test revealed that something had gone wrong with the system. Test 9 was not used because the curves revealed that something had malfunctioned.

The following comments are notes made by Dr. George Bloomsburg on his observations of data for the unsaturated zone and related events that transpired at the subject data review session. These notes have been edited and reviewed by Roy Williams. These notes pertain to the ground water flow analysis modeling of the Franklin Lake playa since this involves unsaturated flow data. These notes also cover the site unsaturated zone hydrology section which primarily consists of data taken from wells UZ-1, G-1, G-2, 25C1 and H-1. All these wells have some sort of data taken will be of interest for classifying the unsaturated flow zone.

July 24, Denver Federal Center

The meeting started about 8:40. The moderator was Bill Dudley of the U.S.G.S. who explained the objectives of the workshop. The primary objective is to prepare the NRC and their consultants for the Environmental Assessment. The discussion during the meeting would be on the facts of the data and not opinions so there should be no analysis or discussion of analysis. After the introductory remarks mentioned previously, we divided up into the various interest groups. For the unsaturated flow analysis, Pete Ornstein of NRC, Scott Tyler of Desert Research Institute, Tom Nicholson of NRC and I talked to Parvez Montaser of the U.S.G.S. We first discussed how we would approach the data review and what we wanted to look at first. We were informed that there were video tapes available of well UZ-1 that we could view to get some idea of the fracture pattern. We viewed the tapes and then discussed various aspects of drilling techniques and cementing techniques and the perched water table during the drilling of UZ-1.

We next looked at the design of the instruments for this well. Basically after the well was drilled, the instrument column was constructed above ground by fastening the psychrometers heat dissipation probes, and pressure measuring devices, to a 4-inch PVC pipe. The cables to the various instruments were then extended up through the pipe. The pipe was placed in the borehole and the borehole was then backfilled. The various instruments were isolated from each other by the use of bentonite backfill; the backfill consisted of silica flour alongside each instrument which provides a very fine-grained material which is relatively inert. For the operation of the psychrometers, the moisture in the parent material must move through the silica sand and affect the vapor pressure of the air at the psychrometer. A complete well log is available showing the location of all the psychrometers and the heat dissipation probes. A neutron log also was obtained of the well before the instruments were placed in position. The neutron log was used to determine the moisture content. The moisture content of the drill cuttings was determined at various elevations by taking the cuttings to the laboratory and using the psychrometer to determine the moisture potential in the cuttings. Data are available for the moisture content and fluid potential of the dry cuttings as well as inplace values from the neutron log and the data from the psychrometers in the hole.. The fluid potential of the top few tens of feet is lower than at greater depths where the Topopah Formation occurs. The potential in the Topopah Formation and the moisture content is relatively constant. Data are available from the psychrometers as well as from the heat dissipation probes for the entire length of hole UZ-1. The time data from the psychrometers were sufficient to determine how long it took for equilibrium to occur. This equilibrium period was as long as 220 days in the case of one level. Other psychrometers did not require as long to reach equilibrium. The heat dissipation probes were placed near the psychrometers. They were also designed to measure the potential in the parent rock. They appear to be satisfactory for up to five bars potential but were not good for the 15 bars for which they were intended. When the heat dissipation probes were installed, they were surrounded with silica flour that was wetted to one bar tension. This was done so that the silica flour would be on the drainage part of the historesis curve. The 90-day equilibrium value from the psychrometer as well as the dissipation probes agree in general with the laboratory data for the general moisture or potential distribution. Considerable scatter is displayed in all these data as one would expect.

All the above discussion pertains to well UZ-1. We next went to the available data on well H-1. For this well, as well as for some other test holes, cores are available which have been investigated in the laboratory for porosity, relative conductivity, and porosity saturation relationships. The pore size distribution was determined by using mercury porosimeters. The saturated conductivities were, in general, determined by gas flow methods because of the very low values of conductivities. These values do have to be corrected to the permeability of water by using the Klinkenburg process. The relative conductivities were then calculated by the Brooks-Corey·relationships and bv the methods of Maulem for determining relative conductivity from the moisture content potential data.

Meeting of July 25, 1984

Tom Nicholson, Pete Orstein, and Scott Tyler and I again met with Parves Montaser. The first data reviewed related to the gas permeability measurements of cores removed from wells G-1 and G-2. These data were plotted as permeability K versus the reciprocal pressure. According to the Klinkenburg effect this is a plot which removes the compressibility and slip flow effect when permeability is measured with a gas. Some of these data appear to have considerable scatter and a consistent difference from what one would ordinarily expect. The expected plot is a straight line. When this straight line is extended to a very large value of pressure, the permeability should be that of a liquid. However, on many of these tests the pressure measurements are erratic and it would be difficult to fit a straight line to the data. In other instances the data appear much as a desaturation problem; as the pressure increases or the saturation decreases, the permeability decreases.

I am very puzzled by these data. Parves stated that this process is worked out in his Ph.D. dissertation. I will need to obtain a copy of it in order to understand just what he has done. Mercury injection was used on the cores to determine the relationship between saturation and pressure. These data may then be used by either the Brooks-Corey or the Maulem relationships to determine the relative permeability pressure relationships. Two of the cores also will have complete laboratory data obtained for the relative conductivity.

Some discussion involved the measurements of gas movement, thermal gradient, thermal conductivity capacity, and vapor movement upward from the water table as measured in well UZ-1. Some discussion also transpired on H-1 and the fact that it was drilled with foam so that the natural moisture content and related properties as measured by the cores in the laboratory is somewhat suspect. We then discussed the UZN wells, a series of relatively shallow holes which are to be used to characterize infiltration conditions. These holes are designed for neutron probes so that moisture content can be measured to depths of 100 feet. These holes will be drilled with no drill pad and there will be minimum surface disturbance. It is hoped that the data obtained from these may be such that the effect of infiltration events can be measured. Some discussion also centered on well UZ-6 and the high construction costs.

On the afternoon of July 25 a discussion was presented by John Cernecke of his data on Franklin Lake playa. The reason for obtaining data on the playa is that a sensitivity analysis of the mathematical modeling and parameter determination has revealed that the amount of evapotranspiration (ET) or discharge from the ground water flow system at Franklin Lake playa is very important to determining the transmissivity values. Consequently they have drilled a number of shallow holes at Franklin Lake playa to measure the moisture content at various depths. These data will provide a means for determining the upward flux through the soil profile which then evaporates from the surface. The water table is relatively shallow over all of this region; it ranges from flowing wells at the northern end to a depth of about 13 feet at the center. The drilled holes show that the vertical gradient is upward. There are four tensiometer nest locations which consist of from two to twelve tensiometers each. The cores which were removed when the tensiometers were put in place will be analyzed in the laboratory for the relative conductivity-moisture content relationships. These data, along with the tensiometer readings, will facilitate determination of the upward flux by simply applying Darcy's law to the upward flow. Another method of determining ET will be based on the Eddy correlation process. This method is basically an energy balance equation that relates to the net radiation sensible heat, soil heat flux, clayton heat of vaporization of water to the evapotranspiration rate. The net radiation is measured with the net radiometer which has an upper half globe for incoming short-wave radiation and a lower half globe for outgoing long-wave radiation. The sensible heat is measured by taking the cross product of air temperature and vertical wind speed ten times per second. The soil heat flux is measured with a plate buried just below the surface of the soil. The thermal conductivity of the plate is approximately equal to that of the soil. The plate measures the temperature gradient vertically across itself to compute heat flux into or out of the ground. A data logger at each installation integrates all the above parameters and records the data. The data obtained for this method so far shows the evapotranspiration to be a maximum of .3 cm/day in the month of June. The Walker-Aken method is another method which will be used for determining ET which is an empirical correlation with elevation. Some discussion ensued about this method as to whether it should be corrected for temperature when the correction is made for a possible 40% increase in precipitation during fluvial times. In general, the results of the modeling effort resulting from this ET computation reportedly agrees fairly well with the field data. However, we did not see any data to prove this.

July 26

We prepared a list of data which we wanted to obtain from Parves Montaser. Tom Nicholson, Pete Ostein and I reviewed these data in detail. We first reviewed the psychrometric data from borehole UZ-1. The final result of this work is plotted as matrix potential versus depth in the hole. Weather data obtained included rainfall, temperature, relative humidity and barometric readings from a weather station in the vicinity of the hole. One question raised was precisely where the weather station is located. In addition to the psychrometers, head dissipation probes also are placed in the hole. The output from the head dissipation probes also are plotted as matrix potential versus time. Nothing appears to be unusual about these data.

We reviewed the design of the UZ-1 hole. This hole is 48 inches in diameter for approximately 10 feet; 36 inches in diameter for another 20 feet; and 17-1/2 inches in diameter over the remainder of its depth. Gas permeability values were reviewed. These data are plotted as permeability in millidarcies versus the inverse inlet pressure. Many of these sets of data appear to have problems. These data should plot as a straight line of positive slope. However, many sets of data have sections of negative slope with minimum and maximum points. These data should be reviewed in great detail and perhaps some of the tests repeated in order to be sure that there are not mistakes or malfunctions of the equipment.

Another factor that should be noted about these data is the wide range of values of permeability in the Topopah Formation. These values range over approximately six orders of magnitude which would make modeling the flow system very difficult. We ran the linear regression on a typical set of data; the resulting correlation coefficient was above .9, which would indicate reasonably good correlation. However, the data do not appear to be consistent. Moisture retention curves from H-6, G-1, and G-2 were reviewed. These data consist of matrix potential versus the volumetric water content. Calculated values of relative permeability as a function of moisture content for G-1 and G-2 also are available. The equations used to calculate the relative permeabilities will be reviewed. It was stated previously by Parves Montaser that relative permeabilities would be determined experimentally on several samples. It would be advisable for the sample from G-2 collected at 1,395 feet to be analyzed for effective permeability in the laboratory because the calculated values do not appear to be consistent with the moisture release curves. It also would be advisable that another sample from G-1 at 500 feet be tested experimentally. This observation also is because the moisture characteristic curve does not appear to be consistent with the calculated relative permeability curve. These data also appear to reflect a wetting process so they require some explanation.

Several plots of permeability as histograms were available also; however, it is not clear from which well they were collected; the permeability values are negative which is not the usual.

A number of questions were raised during the review of the water contents of the cores from the H-1 hole. These questions are: 1) What foam was used for drilling? 2) What is the hydrophobic nature of the surfactant in the foam? 3) What is the effect of the surfactant on surface tension? 4) What is the overall effect of surfactant on water content?

The theoretical fracture computations and the plots of permeability to liquid and gas versus the pressure or saturation were reviewed next. The computer programs that generate these curves appear to work satisfactorily. However, we would like an explanation of the helium porosity experiments mentioned during the review. The techniques, assumptions, and how the test is conducted are the pertinent points.

This completes the observations made by Dr. Bloomsburg.

I am sending this portion of our trip report so that you can digest it expeditiously. I will prepare and send the observations of Jack Hess on hydrochemistry and by Marty Mifflin on the WT wells as soon as I receive them and review them.

If you have any questions, please call.

Sincerely,

Roy E. Williams/sl

Roy E. Williams
Ph.D. Hydrogeology
Registered in Idaho

REW:sl