Analysis of 48-Hour Aquifer Pump Test at Site 10 near Yucca Mountain, Nevada

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ACRONYMS

bgs	below ground surface
DOE	U.S. Department of Energy
EWDP	Early Warning Drilling Program
ft	feet
ft^2/day	square feet per day
ft/ft	feet per feet
gpm	gallons per minute
ISIP	Independent Scientific Investigations Program
NWRPO	Nuclear Waste Repository Project Office
psi	pounds per square inch
psia	pounds per square inch absolute
QA	quality assurance
TP	test plan
WP	work plan

1.0 INTRODUCTION

This report presents field data and data analyses and interpretations for a 48-hour aquifer pump test conducted in February 2002 as part of the Nye County Nuclear Waste Repository Project Office (NWRPO) Independent Scientific Investigation Program (ISIP), which is funded by a cooperative agreement with the U.S. Department of Energy (DOE) to support the evaluation of the high-level nuclear waste repository at Yucca Mountain, Nevada. The purpose of the test was to fill gaps in aquifer parameter data in alluvium and upper Tertiary sediments along a potential flowpath between Yucca Mountain and populated areas of the Town of Amargosa Valley, Nevada.

The aquifer pump test was conducted at Site 10 in Fortymile Wash, approximately 6 miles north of Lathrop Wells. The site consists of NC-EWDP-10S, a dual-screen monitoring well that served as the pumping well for the aquifer test, and NC-EWDP-10P, a nested, dual-completion piezometer that served as an observation well. Both wells were constructed as part of Phase III of the Early Warning Drilling Program (EWDP) and will be referred to as 10S and 10P herein. Figure 1 shows the location of the Site 10 wells in relation to other EWDP wells and boreholes. Figure 2 shows the surface layout of the site.

Detailed subsurface geologic information for the Site 10 wells is found in an NWRPO technical report (NWRPO, 2003). 10S was drilled in October 2001 to a total depth of 900.0 feet (ft) below ground surface (bgs) and completed with two screened intervals, as shown on Figure 3. These intervals are labeled Screens 1 and 2, with Screen 1 referring to the uppermost interval. Screen 1 is located in alternating clayey alluvial sands, gravel, and fine-textured layers; Screen 2 is in a Tertiary volcanic conglomerate.

Well 10P was drilled to a total depth of 910.5 ft bgs in December 2001 and two piezometer strings (i.e., blank casing and screens) were completed, as shown on Figure 4. These screens are at depths corresponding to the screens in 10S. The upper and lower strings in 10P are referred to as shallow or deep (i.e., 10P Shallow). Screen depth intervals and associated sandpacks are summarized in Table 1. Sandpack intervals will be referred to as test zones, or zones, in this report, and corresponding zones in 10S and 10P have been assigned the same zone number.

Drilling, completion, and development procedures that impacted aquifer test results for Site 10 and other EWDP Phase III wells are described in detail in NWRPO (2003). Additional drilling-related information and metadata are on file in the NWRPO Quality Assurance Records Center in Pahrump, Nevada.

The initial plans for Site 10 called for conducting a pump-spinner test followed by a 48-hour constant-rate pump test. The constant-rate pump test permits calculation of aquifer properties, such as transmissivity and well efficiency. The pump-spinner logs permit these aquifer properties to be allocated to individual screened intervals.

2.0 METHODS AND ANALYSIS

2.1 Overview of Aquifer Pump Test Methods

Aquifer pump tests were conducted and data collected in accordance with NWRPO quality assurance (QA) work plans (WPs) and technical procedures (TPs), including the following:

- TP-9.0, *Pump-Spinner in Unscreened Open Boreholes and Screened Boreholes*.
- TP-10.0, *Pumping/Injection Tests of Packed-Off Zones in Unscreened Open Boreholes or in Multiple Screen Boreholes with or without Observation Wells.*
- WP-4.0, *Aquifer Testing Plan for Nye County's Independent Scientific Investigation Program.*

Before aquifer pump tests were conducted at Site 10, background pressure and temperature were monitored in 10S and 10P from February 13 to 18, 2002. Before testing, a 250-pounds-per-square-inch-absolute (psia) Westbay MOSDAX™ pressure/temperature measuring probe was placed above the pump in 10S, and 30-psia MOSDAX sensors were placed in each of the observation strings in 10P. These probes remained in place throughout the tests. The probes were attached to a surface MOSDAX datalogger that recorded downhole pressure and temperature information as well as barometric pressure and temperature at the datalogger. A nominal water density of 0.43275 pounds per square inch per foot (psi/ft) was used to convert the probe readings to equivalent piezometric level, or head. Wellhead elevations of the two wells were obtained from the Yucca Mountain Site Characterization Project (YMP, 2002).

2.2 10S Pump Test Procedures

On February 18 and 19, 2002, an attempt was made to run spinner logs in 10S. The presence of drilling mud and debris in this well prevented running the spinner logs below the upper screen (i.e., Screen 1). Because of the spinner problems, the pump was run again for 1.5 hours on February 20, 2002, to better develop the well and pump out mud and debris. The presence of thick mud below Screen 1 was considered to be a strong indication that production from Screen 2 was minimal. Spinner logging attempted after pumping on February 20 showed no evidence of significant static crossflow. The pump was shut down for 19.5 hours before the 48-hour constant-rate pump test was begun on February 21, 2002.

The pump test was designed to determine the transmissivity and well efficiency of 10S. A summary of the analysis and key data is presented in Appendix A. The test involved pumping 10S at an average rate of 107 gallons per minute (gpm) for 48 hours, beginning at 8:30 am on February 21, 2002, while monitoring the drawdown and subsequent 48-hour recovery in 10S and both strings in 10P. The bottom of the pump was set just above Screen 1 in 10S, at a depth of 641 ft bgs. The test was conducted with both 10S screens open to the wellbore.

The measured pumping rates and computed water level elevations in 10S and 10P during the 48-hour pump test are shown on Figure 5. Pump rates were obtained using a 55-gallon drum and stopwatch. Readings were also taken using a McCrometer™ turbine flow meter. Total production during the test was 306,940 gallons, with a maximum drawdown of 34 ft in 10S. The pumping rates shown on Figure 5 are based on the turbine flow meter and are consistent with the timed volume tests.

2.3 Analysis Approach for 48-Hour Pump Test Data

The analysis of drawdown and recovery data from the 10S pump test is described in this section. During the test and recovery period, the standard deviation of atmospheric pressure readings was only 0.094 psi, which would correspond to a standard deviation in head measurements of 0.22 ft if barometric efficiency were 100 percent. A review of the data indicate that barometric effects during the test were negligible for 10S and the 10P Shallow observation string, and accounted for variability of less than 10 percent of the total head change in the 10P Deep observation string. Accordingly, no barometric corrections were made.

A qualitative review of the pump test data indicated that the data were suitable for detailed analysis. The pressure changes during the pump test and recovery were clearly visible (Figure 5). The maximum drawdown during the test was 34 ft in 10S, 7.7 ft in 10P Shallow, and 1.0 ft in 10P Deep.

2.3.1 Pumping Well Drawdown and Recovery Data for Idealized Flow Regimes

The transient response to a pumping test provides a variety of information as the pressure wave moves sequentially through the area surrounding the well. The initial response, generally on the order of a minute or less, provides essential information about conditions inside the well casing, flow through the well screen, and flow in the gravel or sandpack (i.e., wellbore or skin effects). As the pressure wave propagates outward from the pumping well, the effects of leakage through confining layers, barriers to flow, high permeability regions, and other hydrogeologic conditions can sometimes be determined from the record of pumping and head at the well.

Experience has shown that plotting the logarithmic derivative of the drawdown curve (log-log diagnostic plot) is a powerful tool for providing information about the flow system. Generally the derivative is obtained by second-order finite differencing of data points spaced approximately 20 percent apart in time (Horne, 1995). This methodology has become standard in the petroleum industry, but is only recently becoming more common in the field of hydrogeology.

The log-log diagnostic plot provides important information regarding flow regimes, including the following:

- An initial unit slope (i.e., +1 slope) on both the drawdown or recovery and derivative responses, usually within the first few seconds of a rate change, indicates wellbore storage.
- A later flat line (i.e., 0 slope) in the derivative response indicates radial cylindrical flow. The distance between the drawdown and derivative curves is a measure of wellbore efficiency, or skin effect.
- Multiple stable, flat regions in the derivative response can be caused by flow barriers or multiple layers.
- A positive half-slope (i.e., +½-slope) on the derivative response indicates linear flow between barriers. The distance to the barriers is determined from the time needed to

reach the derivative half-slope, with closer boundaries causing the half-slope to develop more quickly.

- A negative half-slope (i.e., –½-slope) on the derivative response indicates spherical or hemispherical flow.
- A declining derivative response with increasing distance between the derivative and differential head curves is indicative of improved permeability or increased aquifer thickness at greater distance from the well.
- A derivative that tends toward zero, as well as a drawdown or recovery plot that tends toward a constant value, indicates a constant pressure boundary or a source of considerable reservoir energy within the radius of influence of the test.

A few classical drawdown and associated derivative curve trends are illustrated herein; more detailed information is available in Horne (1995). Figure 6 shows example drawdown and derivative curves for several common groundwater analysis models, including a confined aquifer (i.e., the Theis solution), a leaky confined aquifer, and a leaky confined aquifer with delayed yield. The derivative curves have characteristic patterns and are more informative than the drawdown curves. The derivative of the Theis curve for a perfectly confined aquifer approaches an asymptote as the semi-logarithmic drawdown curve reaches a constant slope. The derivative curve of the leaky confined aquifer takes on a parabolic, horseshoe shape, as leakage causes the drawdown curve to flatten and the derivative to go to zero. The derivative curve for delayed yield initially follows the derivative curve of the leaky confined aquifer, then moves to follow that curve, creating a characteristic dip.

Figure 7 gives example curves for the cases of linear flow barrier and constant head boundaries (i.e., upwelling) that might be created by a fault. The amount of time for the effect to occur depends on the distance to the feature and the storage coefficient.

Figure 8 summarizes the shape of the derivative response for six commonly occurring situations. Spherical flow occurs, for example, when the well is partially penetrating. The circular boundary curve assumes a circular constant head boundary at a fixed distance from the well. The “skin effect” simulation shows how the derivative curve for an idealized confined aquifer is modified by non-ideal conditions in the well and gravel packs. The distance between the derivative and drawdown curves is a measure of the skin effect. The shape of the derivative curve is distinctive for each of the situations illustrated.

2.3.2 Test Analysis Methodology

The first step in test analysis and interpretation was to prepare a log-log diagnostic plot of head (i.e., water level) change versus pumping time (Figure 9) or, in the case of a recovery plot, shut-in time (Figure 10). In addition to the measured change in head, the logarithmic derivative of the drawdown and recovery data was also computed and plotted on these figures using a technique described by Horne (1995).

Based on the information in the preceding section, various flow regimes are evident from inspection of the log-log plots for the drawdown (Figure 9) and recovery (Figure 10) data in 10S. In this instance, the same basic inferences are drawn from either the drawdown or recovery plots.

The recovery data were selected for analysis of the pumping well because they are not affected by fluctuations in pumping rate, whereas the drawdown data are. The scatter in the drawdown derivative data on Figure 9 is clearly greater than the scatter on Figure 10.

There is some evidence of an initial unit slope between the first two data points on either figure, suggesting wellbore storage effects; however, these effects passed in less than a minute, and the data collection rate was insufficient to accurately show this flow regime. The zero slope derivative response data line in the recovery data from approximately 0.05 to 0.2 hours suggests that cylindrical radial flow is occurring during this time interval. The decline in the derivative data after 0.2 hour indicates the influence of a constant head boundary at some distance from the pumping well.

The next step in the analysis was to prepare a preliminary conceptual model for the aquifer system based on reviewing the diagnostic plot of the recovery data (Figure 10). Well test analysts generally begin with the simplest model possible. In this case, the disparate response of the two observation zones (Figure 5) indicates that at least two layers are present, while the falling derivative response on the diagnostic plots (Figures 9 and 10) indicates a constant head boundary. Accordingly, a model with two noncommunicating layers and a linear, constant head boundary was selected.

In analyzing the test, both the drawdown and recovery signals from 10S were considered, as were the responses of the two observation screens in 10P. More weight was given to the recovery response (Figure 10) than the drawdown response (Figure 9) for the reasons stated above. This was clearly the case in this test, as demonstrated by the greater scatter in the derivative response for the drawdown as compared to the recovery. Both the shallow and deep observation strings in 10P responded quickly to pumping at 10S. The shallow zone response was approximately eight times greater than the deep one. The spinner logs were not able to quantify the flow rate from the deeper screen in 10S, but the presence of mud in the pumping well, along with the observed head responses at the observation wells, indicates only a small percentage of the flow emanating from Zone 2. The lower flow rate and smaller head response in the deeper zone appear to be the result of skin damage caused by drilling mud or debris present at the time of the pump test.

In summary, factors that complicated the analysis of the 10S test and need to be addressed include the following:

- Uncertainty in the allocation of pump rates between the two zones.
- The high degree of skin damage in Zone 2.
- The presence of a constant head boundary near enough to Site 10 to influence the derivative response at the pumping well and both zones in the observation well.

In order to provide the most complete analysis of the test, consistent with field observations and observed head and derivative responses, the following analysis methodology was developed.

1. First, a value was assumed for the percentage of total pump rate coming from Zone 2 at 10S. Based on the limited head response in the deep observation well, it was estimated that 10 percent of the total pump rate during the test came from Zone 2; the remaining 90 percent was assumed to come from Zone 1.

2. Using the allocated rate for each layer, the observation well (i.e., 10P) response for each layer was matched using single layer models with constant head boundaries to estimate the transmissivity, storativity, and distance for each layer. The analysis of the drawdown and recovery head change and derivative response was accomplished using SAPHIR™, a well test analysis software program (Kappa Engineering, 2003). SAPHIR includes the standard methods of petroleum well test analysis, as well as hundreds of different models for the wellbore, different flow regimes, different types of boundaries, multiple layers, and other factors affecting flow. Except for the allocation of flow rates to each zone, skin effects at the pumping well have relatively small impact on the observation well responses. It was assumed that the distance to the constant head boundary was the same for each layer.
3. The pressure response of the pumping well was then analyzed, using a two-layer model with the aquifer properties determined in Step 2. This analysis, also using SAPHIR, led to a determination of the skin effect in each zone at the active well, for the assumed percentage of total pump rate distribution described in Step 1.
4. The total pump rate percentage was then varied and Steps 1 through 3 were repeated until a best match was achieved for the combined response of both wells at Site 10 (i.e., pumping well 10S and the two zones in observation well 10P). The best match was obtained when 95 percent of the flow was allocated to Zone 1 and 5 percent of the flow was allocated to Zone 2.

2.4 Observation Well Analysis Results

As previously noted, the observation piezometers at Site 10 were instrumented with MOSDAX pressure probes and dataloggers. The response of 10P to the pumping of 10S is shown on Figure 5. For the purposes of this report, it was assumed that the downhole distance between the wells was equal to the surface distance; this assumption does not materially affect the results of the analysis described below. Deviation surveys in 10S and 10P showed minimal deviation from vertical. The results presented in the following section are based on an analysis of the pump test drawdown and recovery data using SAPHIR.

2.4.1 10P Shallow Piezometer Analysis

Appendix A presents key data and a summary of the analysis for 10P Shallow. Simulated observation well data were compared to measured data on log-log, semilog, and Cartesian plots (Figures 11 through 13, respectively). The best match was obtained with a transmissivity of 650 square feet per day (ft^2/day) (Table 2). The computed interwell permeability between 10S and 10P Shallow was 4.2 darcy, based on the 55.6-ft sandpack for Zone 1. The pressure stabilization and declining derivative on the log-log plot indicates pressure support (constant head boundary) at a distance of approximately 150 ft from the wells (Figure 11).

In addition to determining permeability, an analysis of the observation well response also permits calculation of the storage coefficient, which in this case was 0.00063 foot per foot (ft/ft), indicative of a confined aquifer in Zone 1. The actual aquifer compressibility is not known, so it is not feasible to compute effective porosity from this value. It should be noted that the test was not long enough nor was there sufficient water volume produced for unconfined flow to occur.

The specific yield during unconfined flow conditions would lead to a substantially larger storage coefficient.

2.4.2 10P Deep Piezometer Analysis

Appendix A presents key data and a summary of the analysis for 10P Deep. Simulated observation well data were compared to measured data on log-log, semilog, and Cartesian plots (Figures 14 through 16, respectively). The best match was obtained with a transmissivity of 270 ft^2/day (Table 2). The computed interwell permeability between 10S and 10P deep was 0.9 darcy, based on the 104-ft sandpack for Zone 2 in 10S. The pressure stabilization and declining derivative on the log-log plot (Figure 14) indicates pressure support (i.e., a constant head boundary) at a distance of approximately 150 ft from the wells.

The storage coefficient was calculated as 0.00084 ft/ft, indicative of a confined aquifer in Zone 2. As in the case of 10P Shallow, it is not possible to compute effective porosity from this value. It should be noted that the test was not long enough nor was there sufficient water volume produced for unconfined flow to occur. The specific yield during unconfined flow conditions would lead to a substantially larger storage coefficient.

2.5 10S Pumping Well Analysis

After aquifer properties were determined from the single-layer analyses of the shallow and deep responses of the observation well, a SAPHIR analysis model was prepared for the pumping well using a two-layer system with a linear, constant-head boundary. The skin factor for each layer was then varied to determine a best fit of the modeled-to-observed responses, using nonlinear regression techniques. The term “skin factor” is used in the petroleum industry to account for near-wellbore pressure drops, and can be related to the concept of well efficiency in the field of groundwater hydrology for single-layer systems. The match of model versus observed results was examined on log-log, semilog, and Cartesian plots (Figures 10, 17, and 18, respectively). The match shown in these figures is considered to be acceptable.

The best match was obtained with skin factors of +0.9 in the shallow zone (i.e., Zone 1) and +50 in the deep zone (i.e., Zone 2). A skin factor of +0.9 corresponds to a computed well efficiency of approximately 90 percent, while a skin factor of +50 corresponds to a computed well efficiency of only approximately 12 percent.

The nearly flat derivative on the log-log plot of the actual recovery response between 0.08 and 0.50 hour indicates that flow is approximately radial during that time (Figure 10). The observed recovery data on the semilog plot follow a nearly straight line between 0.08 and 0.50 hour (Figure 17). A Cooper-Jacob analysis of this straight line resulted in a total transmissivity of 740 ft^2/day (Cooper and Jacob, 1946). This transmissivity is approximately 25 percent lower than the two-layer model results, which is consistent with the Cooper-Jacob analysis, not accounting for the high skin factor (i.e., low well efficiency) of the deeper zone.

The declining derivative on the log-log response plots (Figures 9 and 10) indicates the presence of a constant head boundary at some distance from the well. As in the observation well response, the indicated distance to the constant head boundary from Figure 10 is approximately 150 ft if the boundary is linear. The direction of the constant head boundary and its exact geometry (i.e., linear, arcuate, or other) cannot be determined from this test. The test was not long enough to evaluate the strength of the pressure support.

2.6 Results and Uncertainties

The 10S test analysis was complicated by many factors, including the presence of mud and debris in the well, a high skin effect in at least one of the layers, multiple layer effects, the need to estimate the percentage of flow from Zone 2, and the indicated presence of a constant head boundary. Given these complications, it is worthwhile to consider the reasons for preparing an analysis of this test, and the potential uncertainties and probable range of reliability of the results.

Many of these factors relate to the skin damage that was present in 10S in Zone 2 at the time of the pump test. Drilling mud or debris in the well and the aquifer near the well apparently caused this skin damage. Additional development activities were subsequently conducted at 10S in March 2002. Toward the end of this development, pumping at the same total flow rate from both zones as the pump test led to an observed drawdown increase in 10P Deep from approximately 1 to 5.5 ft, indicating success at establishing better communication with Zone 2. The greater drawdown observed at 10P Deep implies a much greater flow rate from Zone 2 after the completion of additional development activities.

Because of the change in observed drawdown after further development, the values herein for permeability and skin should be viewed as approximate as of the time of the test and may not be representative of current conditions. Given the effect of subsequent development activities, it is reasonable to question whether this test is suitable for analysis. In an ideal world, the test could be rerun to obtain better information post-development; however, even if that were done, it would still be important to analyze this pre-development test to assess the accuracy and repeatability of the results and compare the results pre- and post-development. Since 10S has not been retested, this test provides the only information currently available at this site.

The observed head changes and derivative responses are certainly large and smooth enough to permit analysis. The fundamental properties of the aquifer units, such as thickness and depth, were evaluated for this test, with similar levels of accuracy and quality control as those for other aquifer tests in EWDP wells. Also, test parameters and results, including pumping rates and pressures at the pumping and observation wells, were measured for this test with similar levels of accuracy and quality control as those for other tests. The key differences between this test and similar tests are the inadequate development of the well, especially Zone 2, and the need to estimate the percentage of flow coming from Zone 2.

It is important to note that a head response in an observation well zone is proportional to the pumping rate from that zone, not to the degree of damage at the pumping well. In other words, if Zone 2 were pumped in isolation at some specified rate (e.g., 5 gpm) before development of 10S, a certain head change would be observed. If additional well development were then conducted and the zone retested at the same rate, the response at the observation well would be essentially the same as for the previous test. Thus, the increased drawdown in 10P Deep after additional development activities is a direct result of a higher pumping rate from Zone 2 after development.

The computed transmissivity is proportional to the pumping rate. Because transmissivity and storativity are computed together as a match to the observed wellhead changes, any increase in the computed transmissivity would lead to an equivalent percentage increase in the computed storage coefficient. The effects of transmissivity and storativity on the computed distance to the constant head boundary and the skin factors are non-linear, but any error in allocated rate would lead to changes in those match parameters as well.

In this case, the total pumping rate was allocated as 5 percent from Zone 2 and the remainder (i.e., 95 percent) from Zone 1. If the correct allocation was instead 10 percent from Zone 2, the allocated rate for Zone 2 would be twice as large and the computed transmissivity and storativity therefore twice as large. Under this assumption, the allocated rate for Zone 1 would be reduced from 95 to 90 percent of the total, leading to a reduction in computed transmissivity and storativity for Zone 1 of approximately 5 percent. Similarly, if the correct allocation was 2.5 percent from Zone 2, the allocated rate and computed transmissivity and storativity for Zone 2 would be half as large, and the corresponding allocated rate and computed transmissivity and storativity for Zone 1 would increase by approximately 2.5 percent.

Based on this analysis, the computed results should be more reliable for Zone 1 than for Zone 2. Compared to similar analyses done for other well tests, the computed transmissivity and storativity for Zone 1 should be of similar reliability, with a small additional uncertainty caused by uncertainties in the allocated rate of approximately ±5 percent. The computed transmissivity and storativity for Zone 2, on the other hand, should be considered approximate to within a factor of 2, either up or down.

3.0 CONCLUSIONS AND RECOMMENDATIONS

Total transmissivity at 10S was determined to be 920 ft^2/day, corresponding to an average permeability of 2.0 darcy over the 160 ft of productive thickness. No significant vertical head gradient was present. Both intervals contributed to production, although the deeper interval (i.e., Zone 2) had extremely low well efficiency. Subsequent development following this test appears to have corrected this problem. However, because of the change in observed drawdown at 10P Deep after further development of 10S, the values for permeability and skin in this report should be viewed as approximate values as of the time of the test and may not be representative of current conditions. The shallower interval had greater permeability (i.e., 4.2 darcy) than the deeper (i.e., 0.9 darcy), as shown in Table 2. The computed aquifer properties for Zone 2 should be considered approximate, within a factor of approximately 2, either up or down.

Communication was demonstrated between the individual screened intervals in 10S and each of the matching piezometer completions. The 10S results are consistent with the sum of the individual observation analysis results for permeability and storage coefficients.

The computed well efficiency of 10S was 90 percent for the shallow zone, but only 12 percent for the deeper zone. It is believed that the majority of the indicated formation damage in the deep zone is attributable to drilling mud present at the time of the test, which has since been removed by subsequent development activities.

The analysis indicated pressure support at a distance of approximately 150 ft from the wells. The source, strength and direction of the pressure support cannot be determined from these test data.

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FIGURES

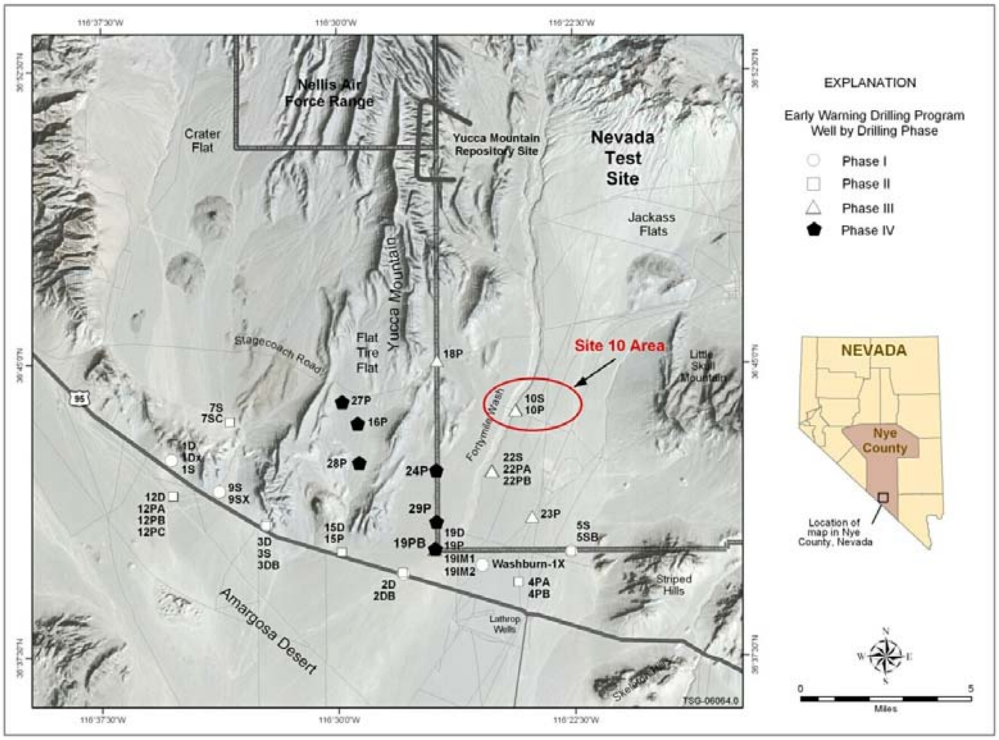


Figure 1
Location Map for Early Warning Drilling Program and Site 10

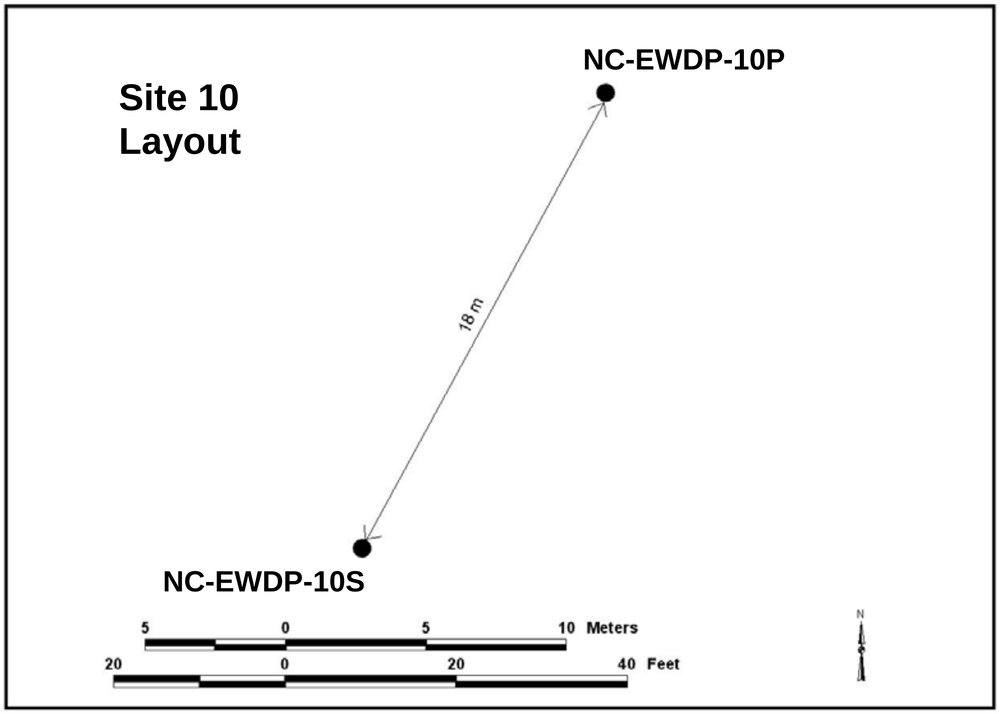
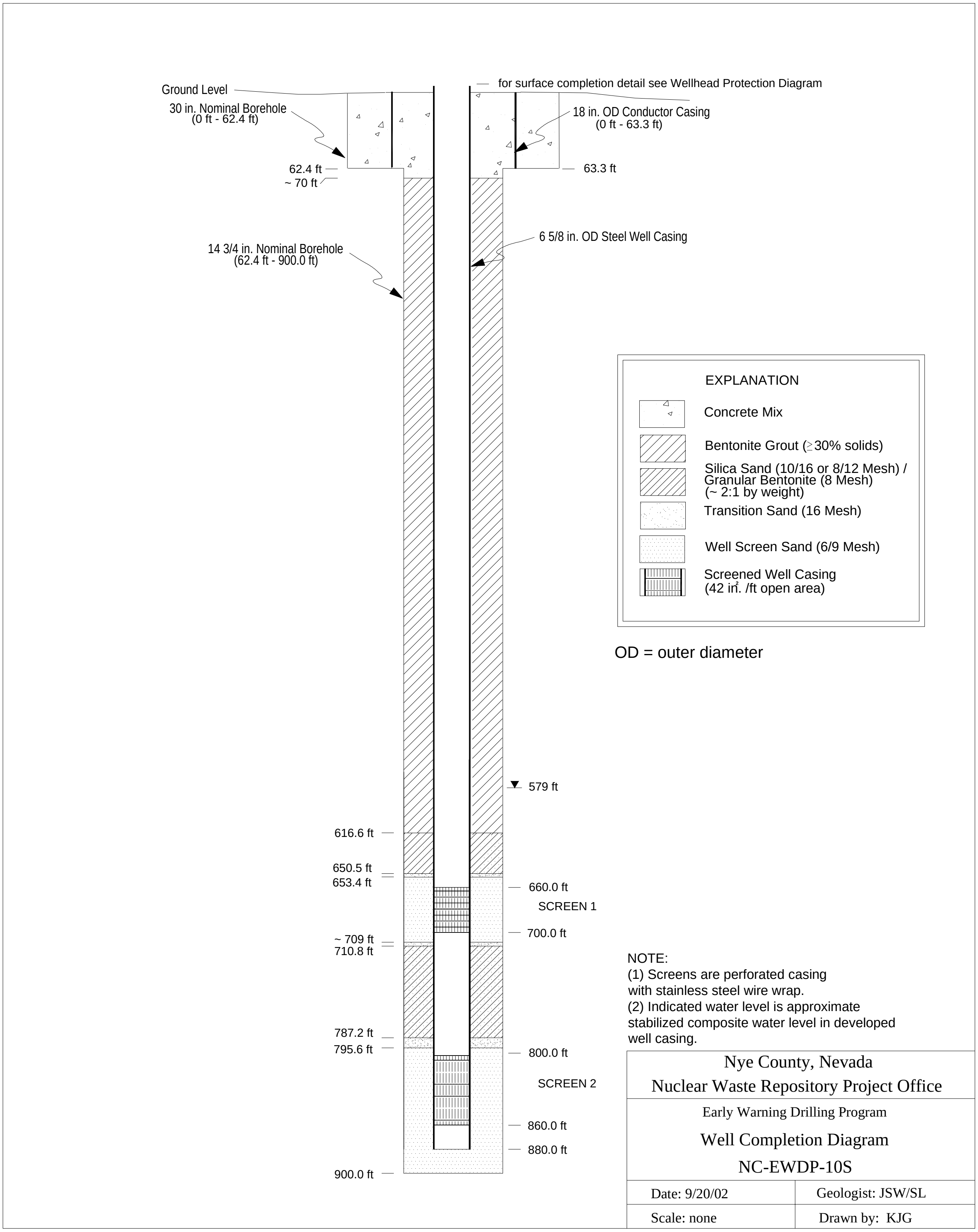


Figure 2
Layout for Site 10



NOTE:
(1) Screens are perforated casing with stainless steel wire wrap.
(2) Indicated water level is approximate stabilized composite water level in developed well casing.

Nye County, Nevada
Nuclear Waste Repository Project Office
Early Warning Drilling Program
Well Completion Diagram
NC-EWDP-10S

Date: 9/20/02	Geologist: JSW/SL
Scale: none	Drawn by: KJG

Figure 3
Pumping Well 10S Completion Diagram

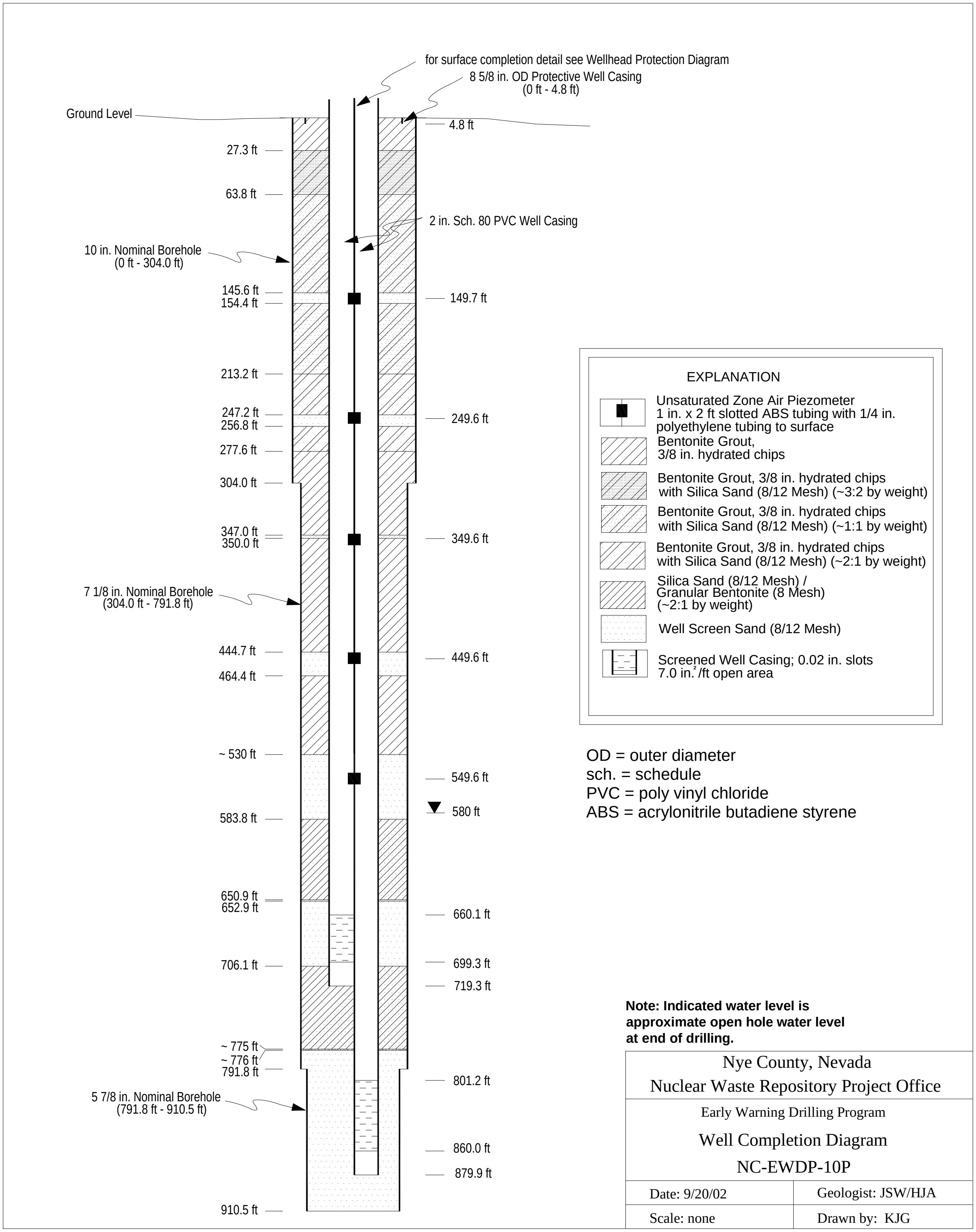


Figure 4
Piezometer 10P Completion Diagram

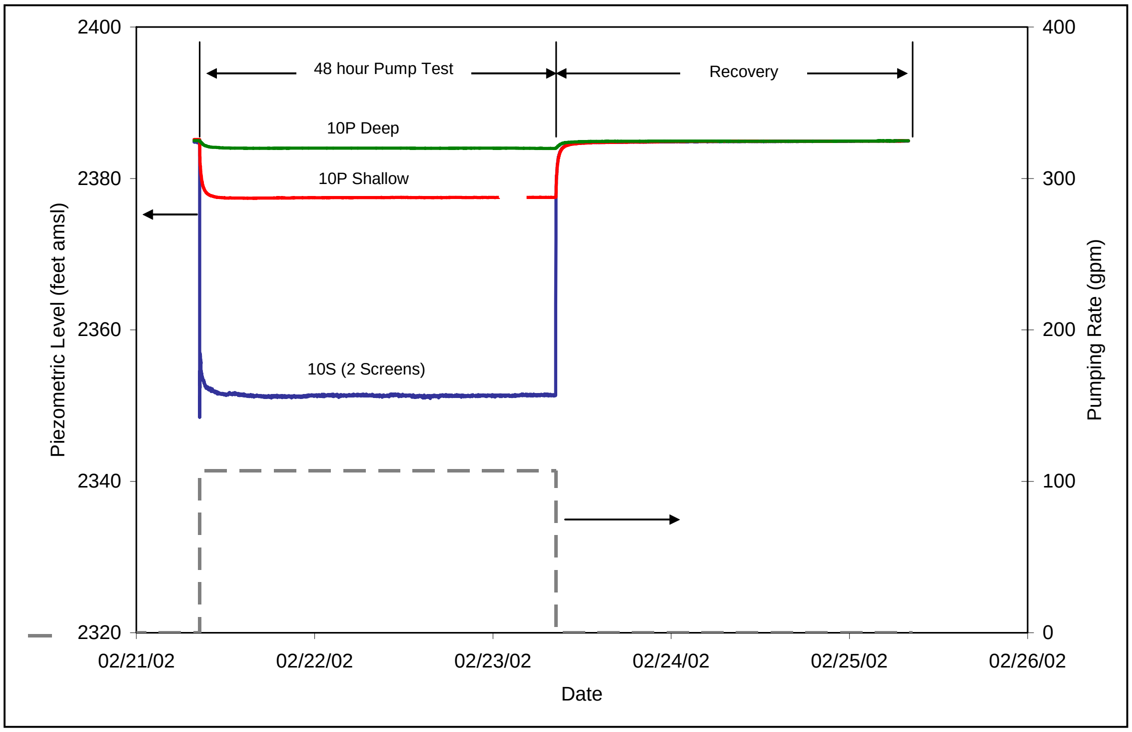


Figure 5
Observed Piezometric Levels and Pump Rate During 10S Pump Test and Recovery

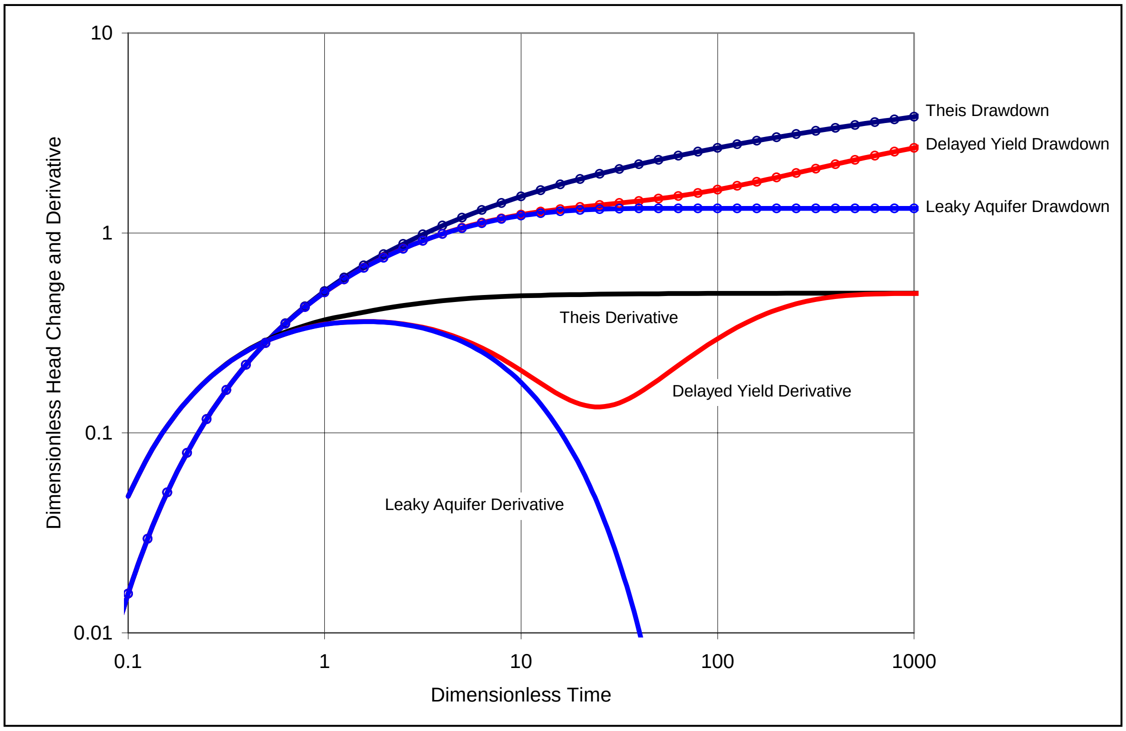


Figure 6
Example Curves for Confined, Leaky Confined, and Delayed Yield Aquifers

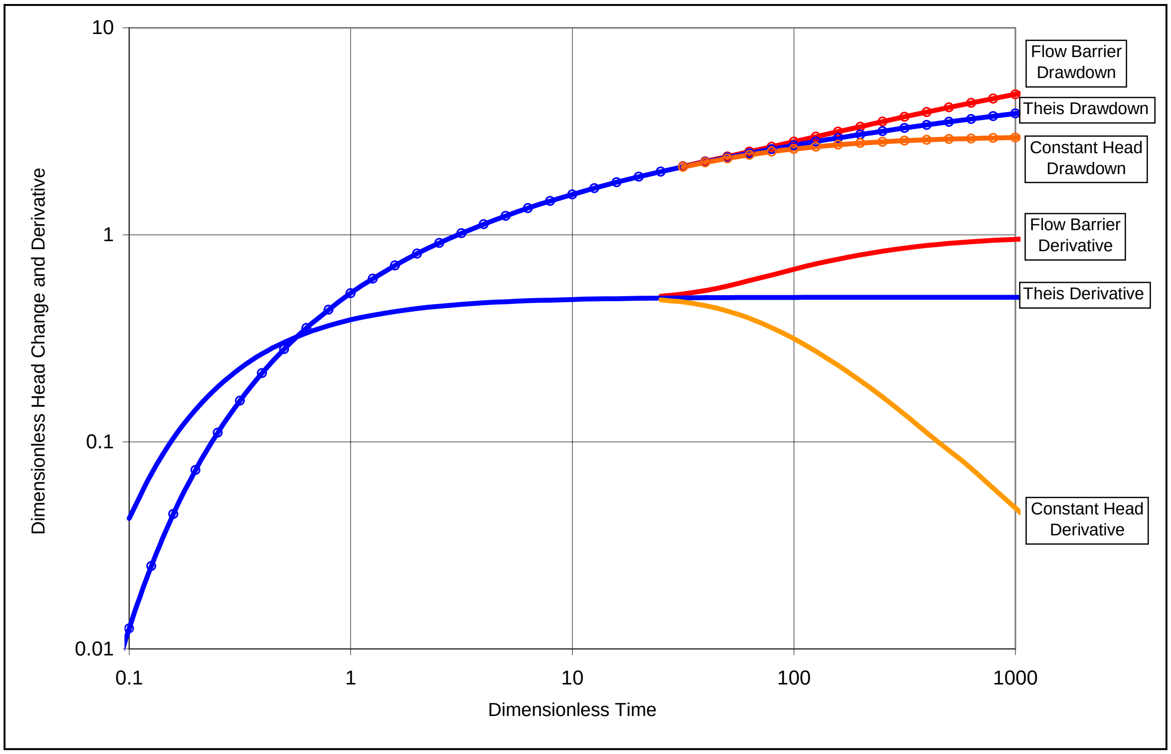


Figure 7
Example Curves for Aquifers with Linear Flow Barriers or Constant Head Boundaries

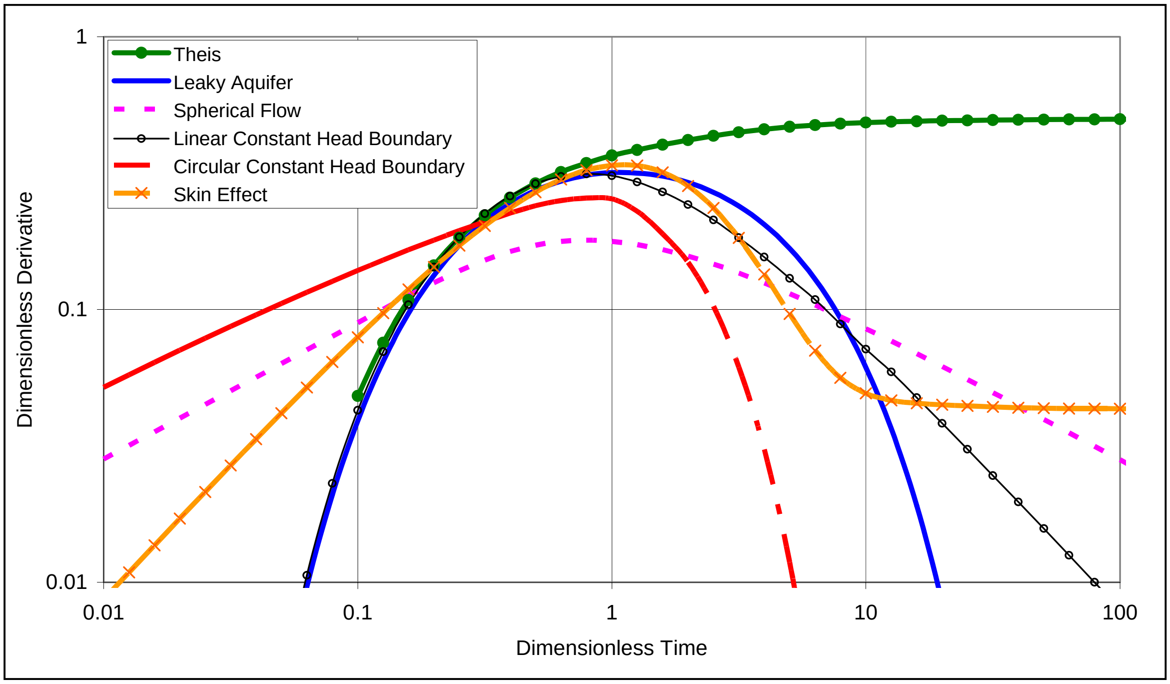


Figure 8
Derivative Results for Different Aquifer Types, Including Confined, Leaky Confined, Spherical Flow, Circular Constant Head Boundary, and Skin Effect

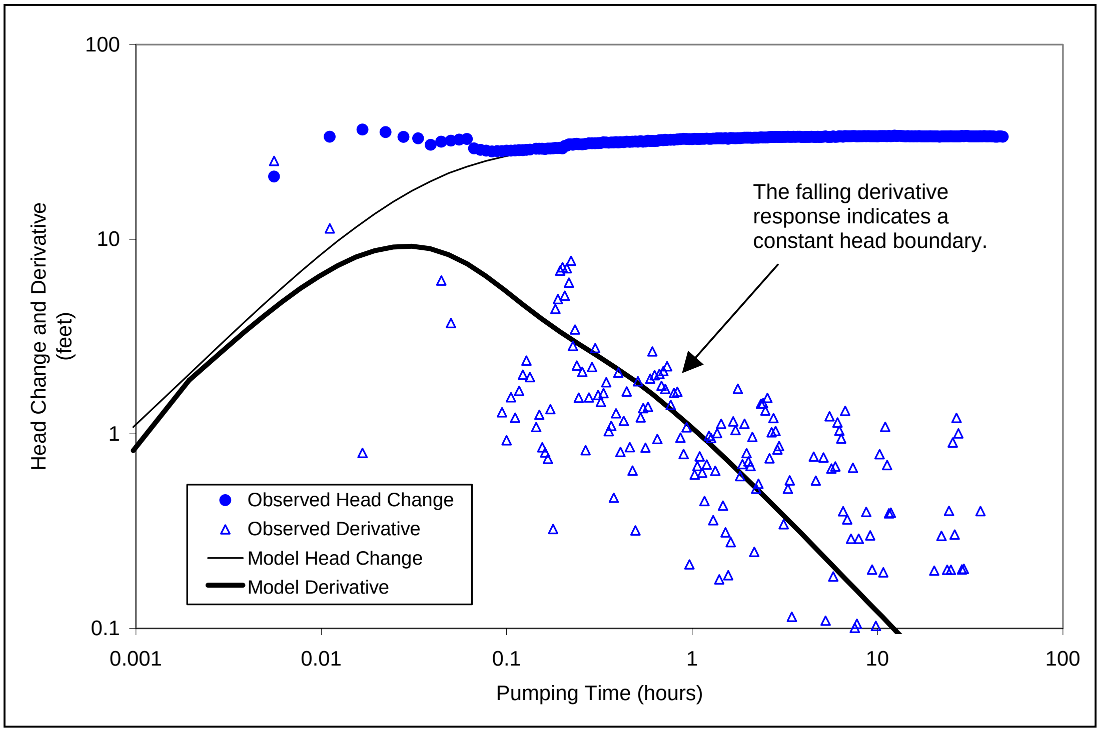


Figure 9
Log-Log Diagnostic Plot of 10S Drawdown Response

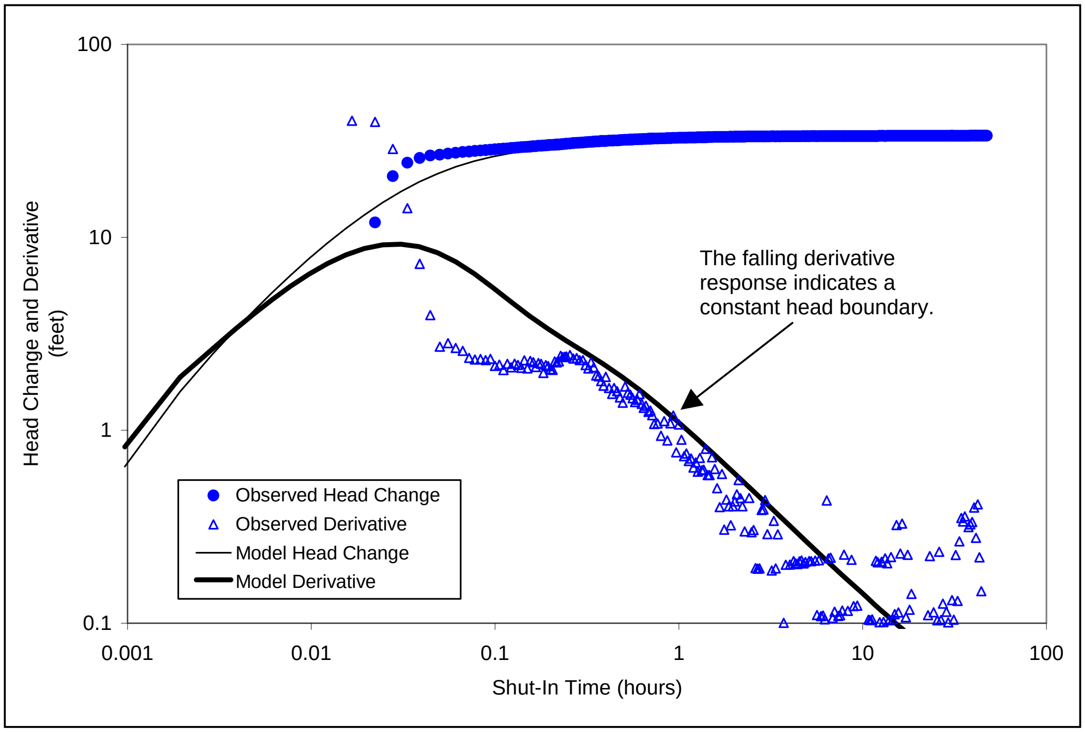


Figure 10
Log-Log Diagnostic Plot of 10S Recovery Response

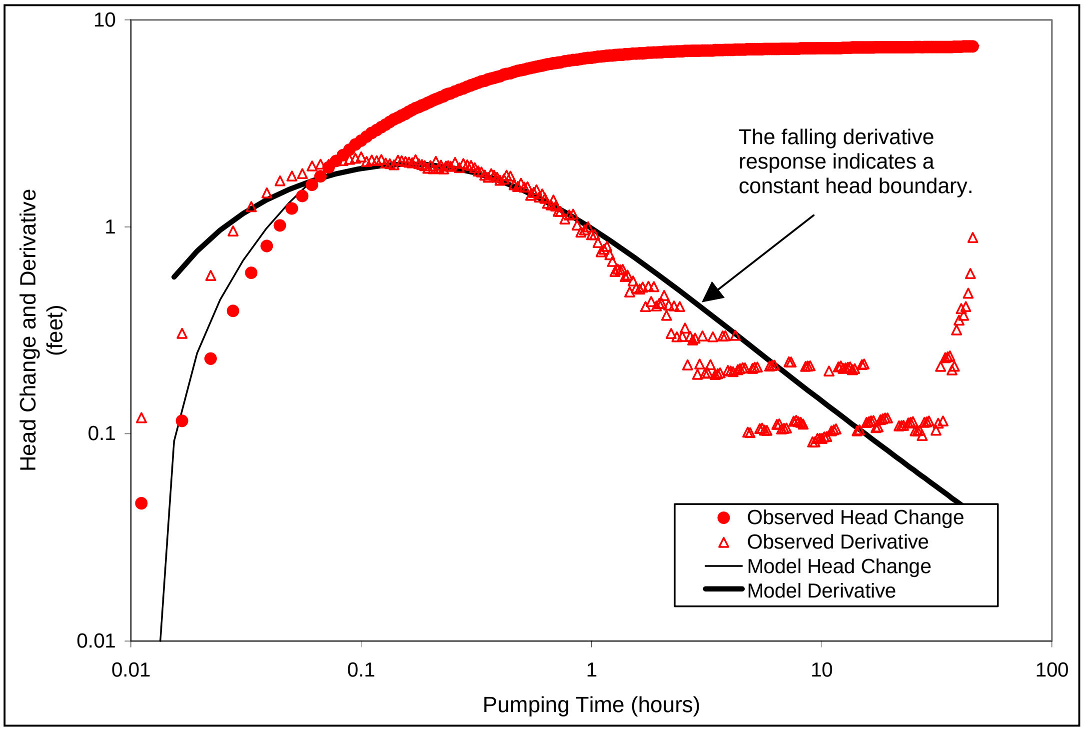


Figure 11
Log-Log Plot of 10P Shallow Piezometer Recovery Response to 10S Pumping

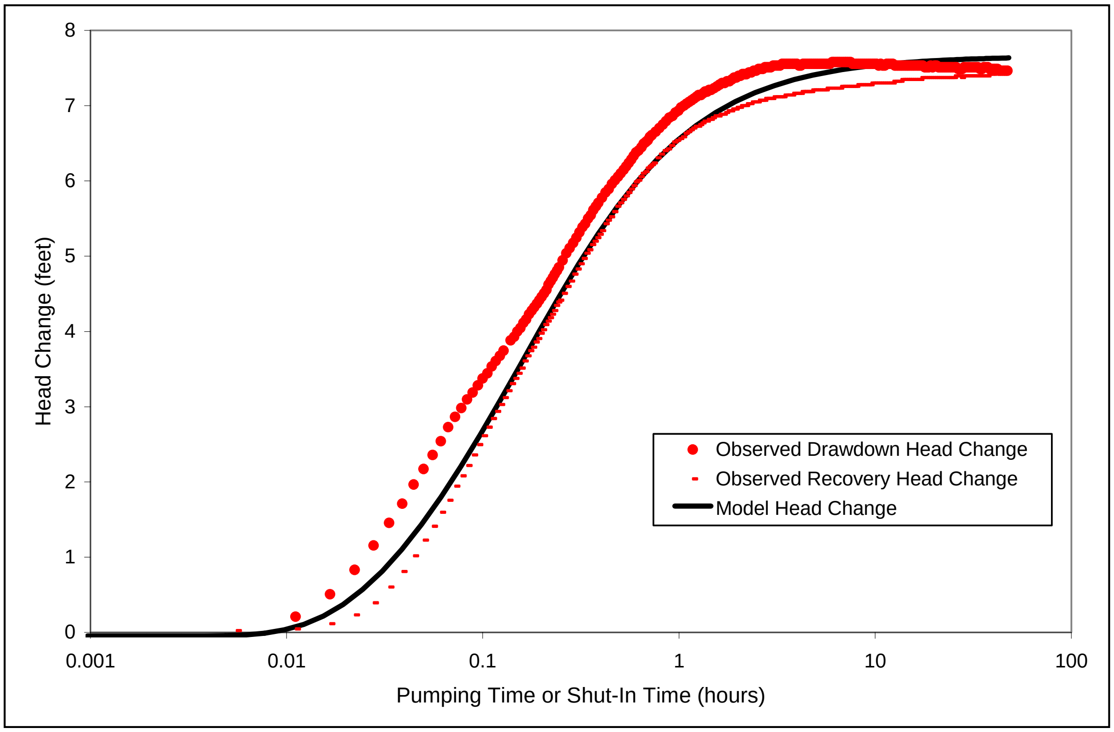


Figure 12
Semilog Plot of 10P Shallow Piezometer Recovery Response to 10S Pumping

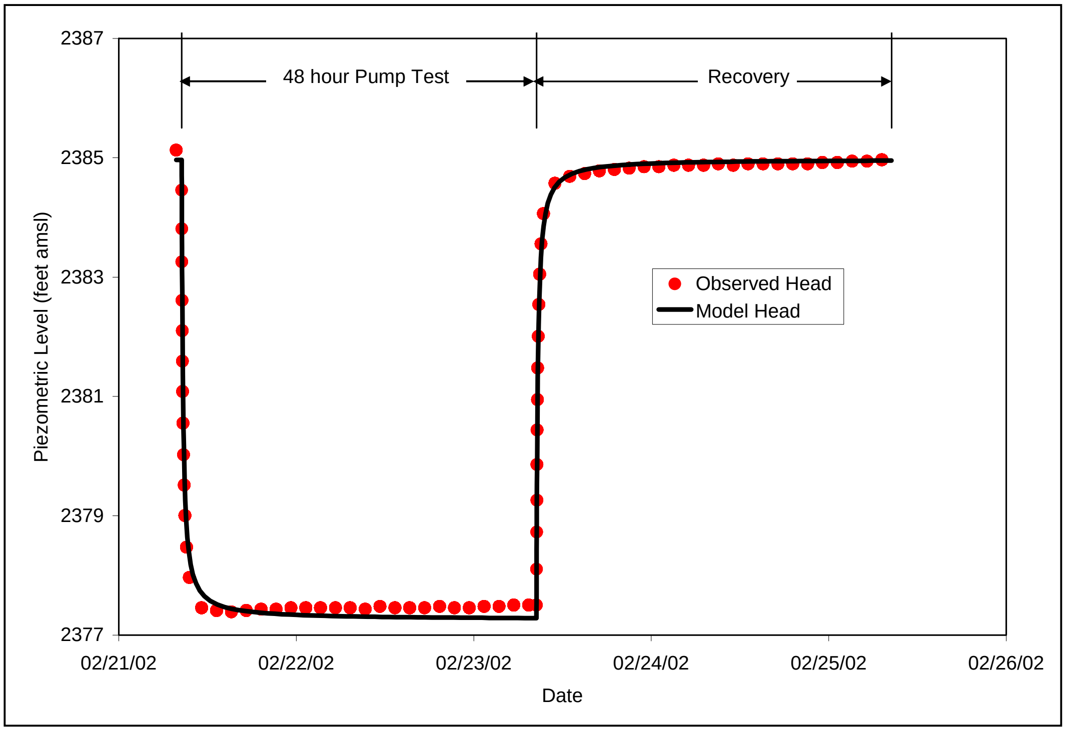


Figure 13
Cartesian Plot of 10P Shallow Piezometer Recovery Response to 10S Pumping

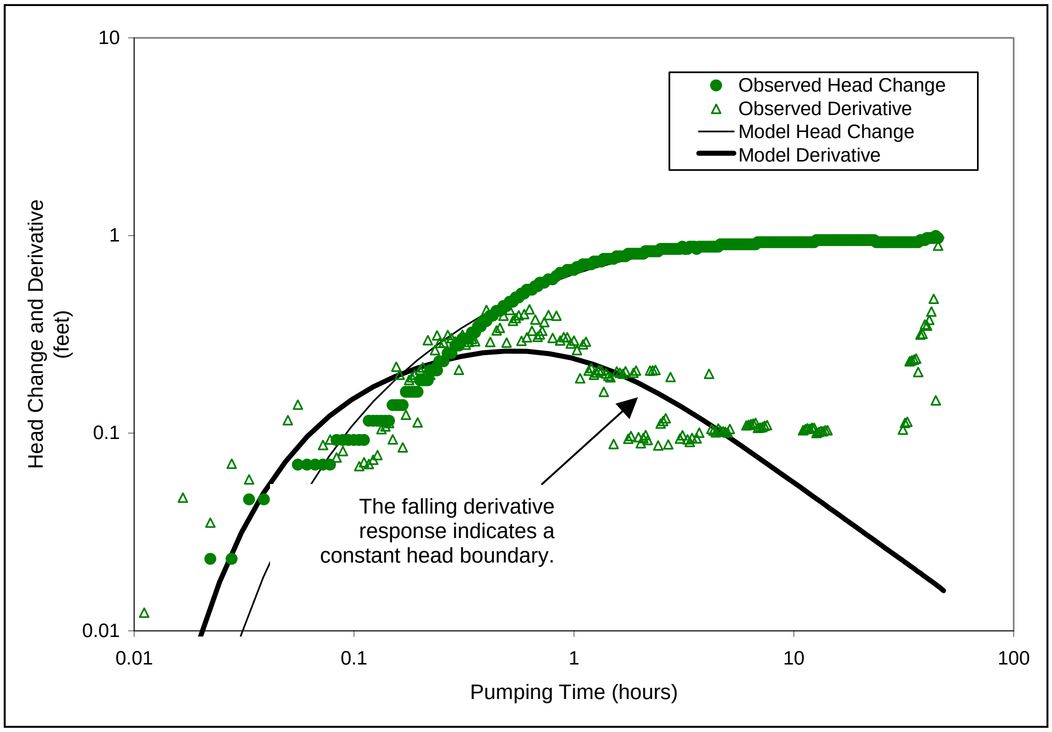


Figure 14
Log-Log Plot of 10P Deep Piezometer Recovery Response to 10S Pumping

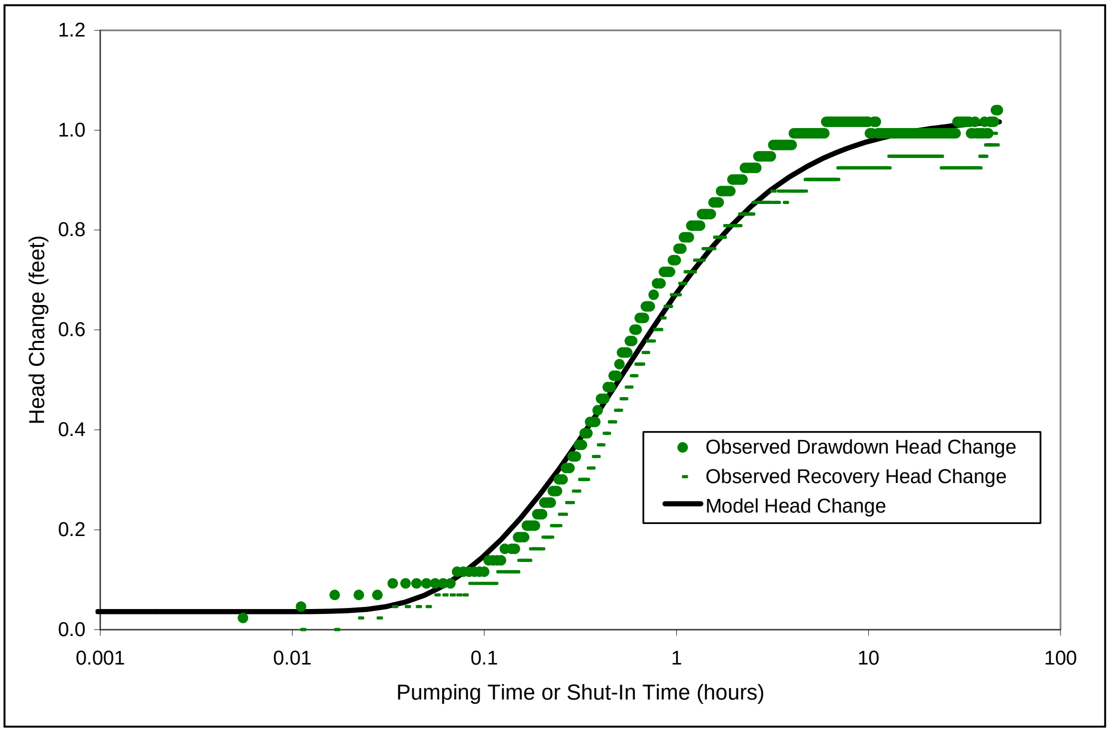


Figure 15
Semilog Plot of 10P Deep Piezometer Recovery Response to 10S Pumping

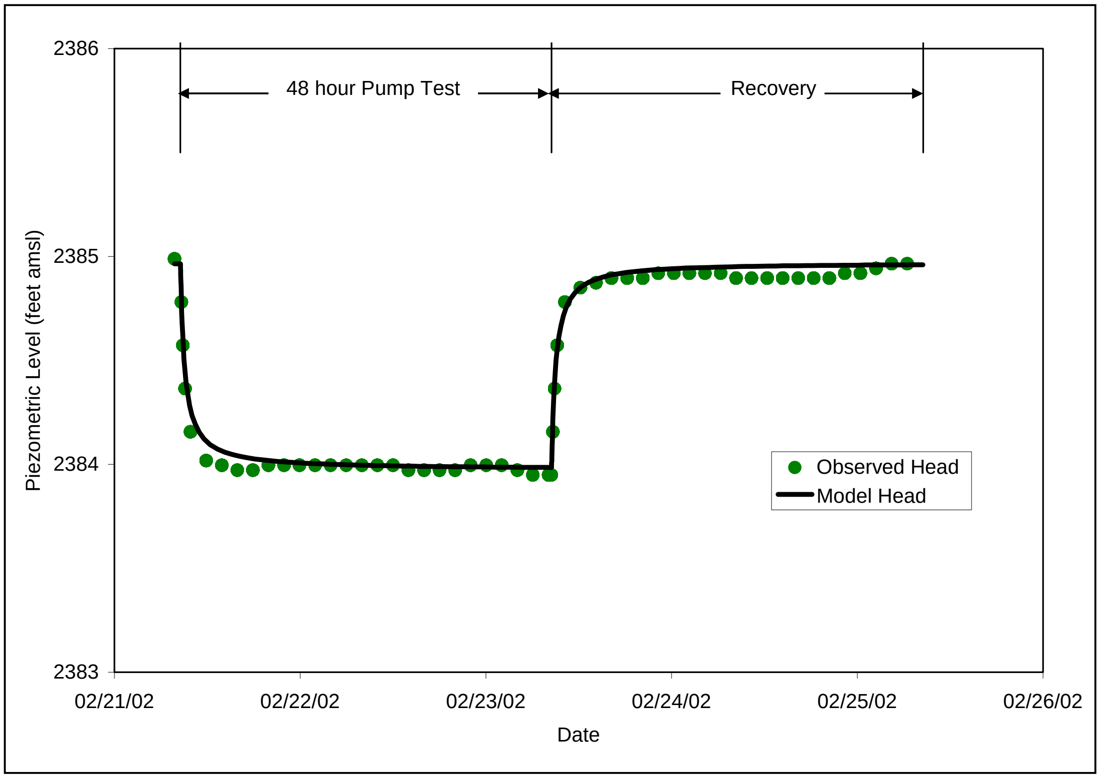


Figure 16
Cartesian Plot of 10P Deep Piezometer Recovery Response to 10S Pumping

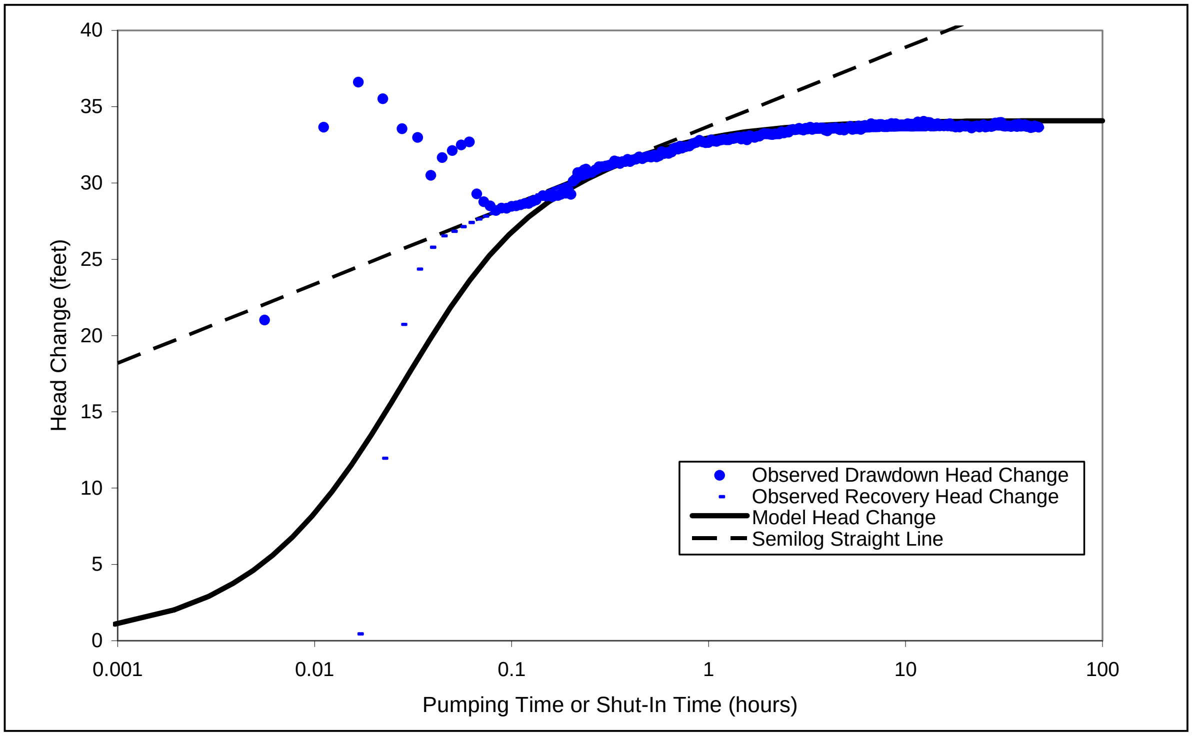


Figure 17
Semilog Plot Comparing Model Results to the Measured 10S Drawdown and Recovery Response

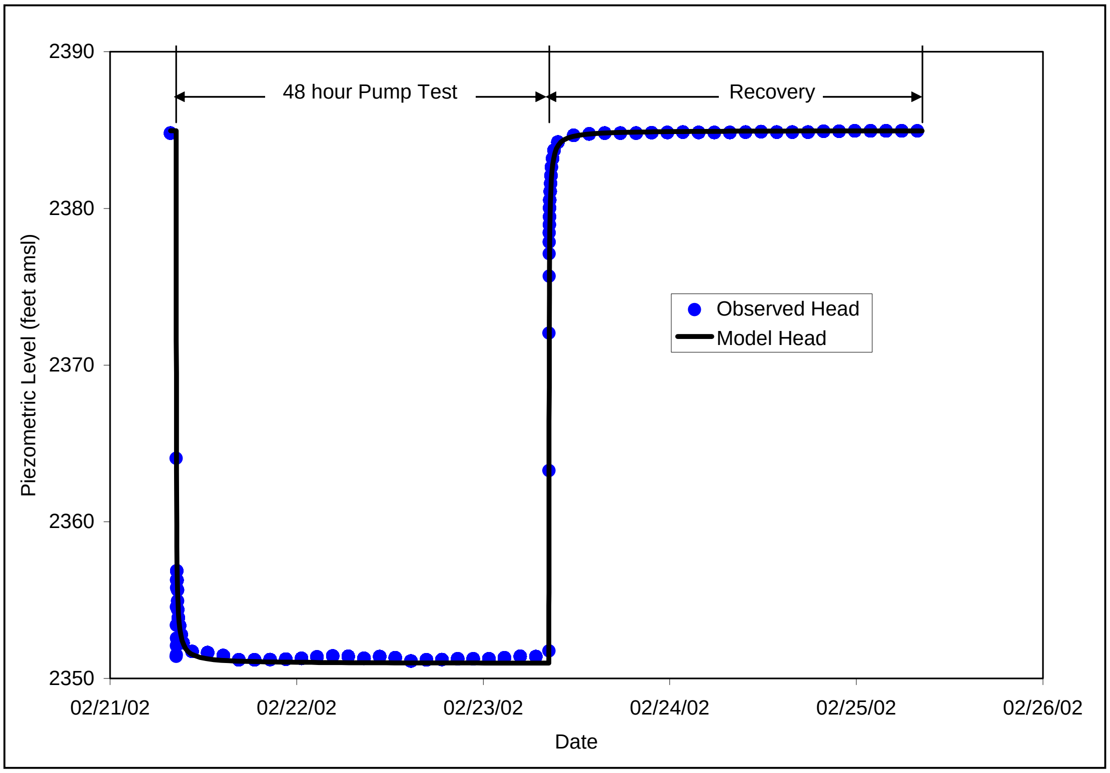


Figure 18
Cartesian Plot Comparing Model Results to the Measured 10S Drawdown and Recovery Response

TABLES

Table 1
Zone and Screen Depths in Site 10 Wells

Well Name	Well Zone	Sandpack Depth Interval (feet below ground surface [ft bgs])		Sandpack Thickness (ft)	Screen Depth Interval (ft bgs)		Screen Height (ft)
		From	To		From	To	
10S	1	653.4	~709	~55.6	660	700	40
	2	795.6	900.0	104.4	800	860	60
10P	1	652.9	706.1	53.2	660.1	699.3	39.2
	2	~776	910.5	134.5	801.2	860.0	58.8

Table 2
Summary of Pressure Analysis for Site 10 Pumping and Observation Wells[a]

Well Name	Well Zone	Thickness (ft)	Allocated Rate (gallons per minute)	Permeability (darcy)	Hydraulic Conductivity (ft/day)	Transmissivity (ft^2/day)	Storage Coefficient (ft/ft)
10S	1 and 2	160	107	2.0	5.8	920	----
10P Shallow	1	56[b]	102	4.2	12.0	650	0.00063
10P Deep	2	104[b]	5	0.9	2.6	270	0.00084

[a] Because of the change in observed drawdown after further development of 10S, the values for permeability and skin in this report should be viewed as approximate values as of the time of the test and may not be representative of the current conditions.
[b] The 10S thicknesses were used for analysis of response at 10P.

APPENDIX A
WELL TEST ANALYSIS QUALITY CONTROL CHECKLISTS

Well Test Analysis Quality Control Checklist for 10S

NYE COUNTY NUCLEAR WASTE REPOSITORY OFFICE

INDEPENDENT SCIENTIFIC INVESTIGATION PROGRAM, YUCCA MOUNTAIN, NEVADA

WELL TEST ANALYSIS QUALITY CONTROL CHECKLIST

Test Information

Borehole: NC-EWDP-10S
Interval Tested: Entire Wellbore, 2 Intervals 662'-860'
Test Date: February 21-25, 2002
Datum: 10S TOC, Probe @ 635.29 TOC
Test Type: 48-hr Pump Test
Observation Wells: NC-EWDP-10P (S & D)
Remarks: Stand alone, single well analysis for 10S Pump Test. No Spinner log.

Source of Data

Pressure File: 2250210S.wk1
Source: e-mail, R. Downing w/ Nye Co.
P Gauge: Westbay #2323 (10S), 250 psia
Units: psia & degrees C
Rate File: Hand Input
Source: Nye County Field Notebook
Flow Meter: Flow Meter Totalizer, Barrel Calibration
Units: GPM, converted to BPD

Assumptions

	Value	Units	Source	Comments
Height / Thickness	160	ft	Comp. Log	Estimate of gravel pack intervals
Porosity	30%	---	Estimated	Alluvium
Viscosity	0.9436	cp	Correlation	From Temperature Correlation
Wellbore Radius	0.615	ft	From bit size	Nominal Bit Size
Compressibility	7.20×10^{-5}	psi^{-1}	10P Match	Interference Model Match (wt. Avg)
Temperature	82	°F	Measured	Pumping Temperature
S - Storage Coef.	0.00147	ft/ft	Match	Interference Model Match (wt. Avg)

Plots and Analysis

Cartesian Plot Analysis: Yes
Length of Flow: 48 hrs
Steady State? Yes
Pseudo-Steady State? No
Remarks: Data analyzed were from the 48-hr pump test. No spinner log available.

Log-Log Plot Analysis: Yes
Flow Regimes Noted: (Circle Appropriate Types; Include Flow Regime Plot if Appropriate)

[✓ Wellbore Storage] ~~Bilinear~~ ~~Linear~~ [✓ Radial] ~~Spherical~~ [✓ Other]

Remarks: Drawdown data negatively influenced by surge when pump started and poor development. No indications of multiple head levels. Recovery log-log plot appears much "cleaner", and falling derivative indicates constant head boundary.

Analysis Procedures

Software Used: SAPHIR
File Name: 10S Active Final.ks3
Location: QEC Network
Software Used:
File Name:
Location:

Result Summary (Include Units)

T – Transmissivity: 920 ft^2/d
Initial Pressure: 37.0 psi, (2384.9' amsl)
Permeability: 2.0 Darcy
Final Flowing Pressure: 22.4 psi, (2351.8' amsl)
Skin: various
Extrapolated Pressure: 36.95 psi (2384.9' amsl)
Effective Flow Time: 48 hours
Radius of Investigation: n/a
Average Flow Rate: 107 gpm
Distance to Boundary: 150 ft
Total Flow Volume: 306,940 gal
Eff. Storativity for 0 Skin: n/a

Remarks

Several attempts were made in the days prior to the test to obtain a spinner survey. The presence of mud, Lost Circulation Material and other debris prevented an acceptable spinner log. Analysis was made with a two-layer model. Because of the change in observed drawdown after further development of 10S, the values for permeability and skin in this report should be viewed as approximate values as of the time of the test and may not be representative of the current conditions.

Analyzed by: Scott Stinson, Dave Cox
Analysis Date: 3/30/03

Well Test Analysis Quality Control Checklist for 10P Shallow

NYE COUNTY NUCLEAR WASTE REPOSITORY OFFICE

INDEPENDENT SCIENTIFIC INVESTIGATION PROGRAM, YUCCA MOUNTAIN, NEVADA

WELL TEST ANALYSIS QUALITY CONTROL CHECKLIST

Test Information

Borehole: NC-EWDP-10P Shallow
Interval Tested: Single Piezometer w/ Screen: 660'-699'
Test Date: February 21-25, 2002
Datum: 10P Top of PVC, Probe @ 2347.87' amsl
Test Type: 48-hr Pump Test
Observation Wells: NC-EWDP-10P (S & D)
Remarks: Stand alone, single well analysis for 10S Pump Test. No Spinner log.

Source of Data

Pressure File: 2250210S.wk1
Source: e-mail, R. Downing w/ Nye Co.
P Gauge: Westbay #2846 (10Ps), 30 psia
Units: psia & degrees C
Rate File: Hand Input
Source: Nye County Field Notebook
Flow Meter: Flow Meter Totalizer, Barrel Calibration
Units: GPM, converted to BPD

Assumptions

	Value	Units	Source	Comments
Height / Thickness	56	ft	10S Comp. Log	Estimate of gravel pack intervals
Porosity	30%	---	Estimated	Alluvium
Viscosity	0.9436	cp	Correlation	From Temperature Correlation
Wellbore Radius	0.615	ft	From bit size	Nominal Bit Size
Compressibility	9.05×10^{-5}	psi^{-1}	Match	Interference Model Match
Temperature	82	°F	Measured	Pumping Temperature
S - Storage Coef.	0.00063	ft/ft	Match	Interference Model Match (wt. Avg)

Plots and Analysis

Cartesian Plot Analysis: Yes
Length of Flow: 48 hrs
Steady State? Yes
Pseudo-Steady State? No
Remarks: Data analyzed were from the 48-hr pump test. No spinner log available.

Log-Log Plot Analysis: Yes
Flow Regimes Noted: (Circle Appropriate Types; Include Flow Regime Plot if Appropriate)

[✓ Wellbore Storage] ~~Bilinear~~ ~~Linear~~ [✓ Radial] ~~Spherical~~ [✓ Other]

Remarks: Drawdown data negatively influenced by surge when pump started and poor development. No indications of multiple head levels. Recovery log-log plot appears much "cleaner", and falling derivative indicates constant head boundary.

Analysis Procedures

Software Used: SAPHIR
File Name: 10P Shallow Final.ks3
Location: QEC Network
Software Used:
File Name:
Location:

Result Summary (Include Units)

T – Transmissivity	650 ft^2/d	Initial Pressure:	36.95 psi (2384.9' amsl)
Permeability	4.2 Darcy	Final Flowing Pressure:	25.6 psi, (2376.5' amsl)
Skin	+0.9	Extrapolated Pressure:	36.95 psi (2384.9' amsl)
Effective Flow Time:	48 hours	Radius of Investigation:	n/a
Average Flow Rate:	102 gpm allocated	Distance to Boundary:	150 ft
Total Flow Volume:	292,597 gal alloc.	Eff. Storativity for 0 Skin	n/a

Remarks

Several attempts were made in the days prior to the test to obtain a spinner survey in 10S. The presence of mud, Lost Circulation Material and other debris prevented an acceptable spinner log. This analysis based on minimal skin for shallow layer, and matching skin to obtain observed heads. Because of the change in observed drawdown after further development of 10S, the values for permeability and skin in this report should be viewed as approximate values as of the time of the test and may not be representative of the current conditions.

Analyzed by: Scott Stinson, Dave Cox
Analysis Date: 3/30/03

Well Test Analysis Quality Control Checklist for 10P Deep

NYE COUNTY NUCLEAR WASTE REPOSITORY OFFICE

INDEPENDENT SCIENTIFIC INVESTIGATION PROGRAM, YUCCA MOUNTAIN, NEVADA

WELL TEST ANALYSIS QUALITY CONTROL CHECKLIST

Test Information

Borehole: NC-EWDP-10P Deep
Interval Tested: Single Piezometer w/ Screen: 801'-860'
Test Date: February 21-25, 2002
Datum: 10P Top of PVC, Probe @ 2347.02' amsl
Test Type: 48-hr Pump Test
Observation Wells: NC-EWDP-10P (S & D)
Remarks: Stand alone, single well analysis for 10S Pump Test. No Spinner log.

Source of Data

Pressure File: 2250210S.wk1
Source: e-mail, R. Downing w/ Nye Co.
P Gauge: Westbay #2844 (10Pd), 30 psia
Units: psia & degrees C
Rate File: Hand Input
Source: Nye County Field Notebook
Flow Meter: Flow Meter Totalizer, Barrel Calibration
Units: GPM, converted to BPD

Assumptions

	Value	Units	Source	Comments
Height / Thickness	104	ft	10S Comp. Log	Estimate of gravel pack intervals
Porosity	30%	---	Estimated	Alluvium
Viscosity	0.9436	cp	Correlation	From Temperature Correlation
Wellbore Radius	0.615	ft	From bit size	Nominal Bit Size
Compressibility	6.20×10^{-5}	psi^{-1}	Match	Interference Model Match
Temperature	82	°F	Measured	Pumping Temperature
S - Storage Coef.	0.00084	ft/ft	Match	Interference Model Match (wt. Avg)

Plots and Analysis

Cartesian Plot Analysis: Yes
Length of Flow: 48 hrs
Steady State? Yes
Pseudo-Steady State? No
Remarks: Data analyzed were from the 48-hr pump test. No spinner log available.

Log-Log Plot Analysis: Yes
Flow Regimes Noted: (Circle Appropriate Types; Include Flow Regime Plot if Appropriate)

[✓ Wellbore Storage] ~~Bilinear~~ ~~Linear~~ [✓ Radial] ~~Spherical~~ [✓ Other]

Remarks: Drawdown data negatively influenced by surge when pump started and poor development. No indications of multiple head levels. Recovery log-log plot appears much "cleaner", and falling derivative indicates constant head boundary.

Analysis Procedures

Software Used: SAPHIR
File Name: 10P Deep Final.ks3
Location: QEC Network
Software Used:
File Name:
Location:

Result Summary (Include Units)

T – Transmissivity: 270 ft^2/d
Permeability: 0.9 Darcy
Skin: +50
Effective Flow Time: 48 hours
Average Flow Rate: 5 gpm allocated
Total Flow Volume: 14,343 gal allocated
Initial Pressure: 29.2 psia, (2383.4' amsl)
Final Flowing Pressure: 28.8 psia, (2383.0' amsl)
Extrapolated Pressure: 29.2 psia, (2383.4' amsl)
Radius of Investigation: n/a
Distance to Boundary: 150 ft
Eff. Storativity for 0 Skin: n/a

Remarks

Several attempts were made in the days prior to the test to obtain a spinner survey in 10S. The presence of mud, Lost Circulation Material and other debris prevented an acceptable spinner log. This analysis based on high skin for deep layer, and matching skin to obtain observed heads. Because of the change in observed drawdown after further development of 10S, the values for permeability and skin in this report should be viewed as approximate values as of the time of the test and may not be representative of the current conditions.

Analyzed by: Scott Stinson, Dave Cox
Analysis Date: 3/30/03