Analysis of Pump-Spinner Test and 48-Hour Pump Test in Well NC-EWDP-7SC, Near Yucca Mountain, Nevada

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ACRONYMS AND ABBREVIATIONS

cps	counts per second
ft	feet
gal.	gallons
gpm	gallons per minute
hr.	hours
km	kilometers
L	liters
m	meters
mi.	miles
min.	minutes
psi	pounds per square inch
psia	pounds per square inch absolute

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1.0 INTRODUCTION

This report presents field data, analyses, and interpretation of spinner logging and pump testing conducted in late March 2001 in well NC-EWDP-7SC. This well is located approximately 2 mi. (3.2 km) north of Highway 95, approximately 10 mi. (16 km) northwest of Lathrop Wells. It is completed with four screened intervals from 80 to 450 ft (24.4 to 137.2 m) (Figure 1) in alluvium, nonwelded ashfall tuff, and tertiary valley-fill sediments. Nearby offset well NC-EWDP-7S, which serves as an observation well during pump testing, is completed in the shallow paleospring deposits, with a single screen from 28 to 40 ft (8.5 to 12.2 m) (Figure 2). On the ground surface, well NC-EWDP-7SC is located 28 ft (8.5 m) from well NC-EWDP-7S.

2.0 SPINNER LOGGING AND PUMP TESTING

From March 26 to 27, 2001, a series of spinner logging runs was conducted in well NC-EWDP-7SC. The spinner logs were run prior to pumping to quantify flow rates between screens under non-pumping conditions (crossflow), and again while pumping to evaluate zonal contributions under pumping conditions. On March 28, 2001, following the pump-spinner tests, the spinner logging tool was removed from the well and a 48-hr. pump test was performed to determine aquifer properties, such as permeability and well efficiency. During the NC-EWDP-7SC pump test and recovery, water level responses were monitored both in the pumping well and in the adjacent observation well with MOSDAX™ pressure sensors to evaluate inter-well communication.

Non-pumping water levels measured in the upper two screens in well NC-EWDP-7SC prior to these tests were approximately equal and were significantly higher than those in the two lower screens (NWRPO, 2001a). More specifically, Screens #3 and #4 exhibited non-pumping water levels approximately 25 ft (7.6 m) and 101 ft (30.8 m) lower, respectively, than Screens #1 and #2. The higher standing water levels in Screens #1 and #2 are not thought to be related to perched water zones. Instead, it is hypothesized that upward flow along a major fault located approximately 1,500 ft (about 460 m) southeast of the well is preferentially focused into the higher permeability upper sediments monitored by Screens #1 and #2, with much less flow into the lower permeability sediments connected to Screens #3 and #4. The significant head differences between Screens #1 and #2, versus Screens #3 and #4, indicate there is insufficient vertical permeability in the sediments between the various layers for equilibration to a common potentiometric elevation.

2.1 SPINNER LOGS

2.1.1 Spinner Log Fundamentals

A spinner log is a tool designed to measure fluid velocity at various depths in a well. Spinners are relatively simple tools, consisting of a centralized logging tool with an impeller mounted on the bottom. The tool counts the number of rotations of the impeller using an optical or magnetic sensor. The counts are expressed as counts per second (cps). The counts per second are a function of the fluid velocity, the speed of the logging tool in the well, and the size and shape of the impeller. Because the logging tool only counts impeller rotations, a single stationary reading cannot distinguish between upward or downward flow, but only that flow is occurring. The raw log readings were normalized for logging speed differences and were averaged over intervals of approximately 4.5 ft (1.4 m) for analysis.

A two-pass technique involving both down and up logging runs at the same speed (Figure 3) was used to reduce potential errors due to borehole size changes, tool idiosyncrasies, and other factors. As the upward fluid velocity increases at any point in the wellbore, the counts on the down run will increase, while the counts on the up run will decrease, causing the two curves to diverge. To compensate for slight differences in responses, it is also desirable to record measurements in a section of the borehole where no flow is occurring. The baseline for the runs is then adjusted slightly until the two runs yield the same count rate across blank pipe with no fluid movement. In well NC-EWDP-7SC, this was done between 300 and 330 ft (91.4 and 100.6 m) on the March 26, 2001, pump-spinner log. The net count rate was determined as half the difference in counts per second between the up and down logging runs.

The logging tool used in tests described herein appeared to have a problem with low spinner count rates. This problem may have been caused by a faulty impeller or debris in the bearings. In cases where low count rates were observed (usually on the up logging run), the net count rate was determined solely from the change in readings on the down logging run. The fluid velocity was then computed from the spinner calibration correlation between counts per second and fluid velocity, using a velocity correction factor of 0.83 to adjust the spinner calibration measurements to field conditions (Schlumberger Limited, 1973).

The spinner tool is sensitive to fluid type, temperature, turbulence, borehole diameter, borehole size changes, and many other factors. For this reason, the spinner measurements are commonly correlated to measured flow rates in each well. Ideally, if the pump is set above all the screens, the relation between the measured counts per second and the total flow can be determined in the field. In the case of well NC-EWDP-7SC, however, Screen #1 was located so close to the standing water level in the well that the minimal drawdown associated with a low pump rate would reduce the water level below the top of Screen #1. The fluid velocity associated with such a low pump rate would not be high enough to provide accurate calibration for the spinner. Accordingly, the flow rate above the highest spinner readings while pumping was determined from the difference between the pumping rate and the flow produced from underlying screens. A detailed example of this calculation is presented in the NC-EWDP-19D report (NWRPO, 2001b).

2.1.2 Description of Spinner Logging

On March 26, 2001, prior to pump placement and pumping, a static (non-pumping) spinner log was run at a logging speed of 20 ft/min. (6.1 m/min.) in well NC-EWDP-7SC. No quantifiable crossflow was observed on this log, even though Screens #3 and #4 have significantly lower head levels than the upper two screens. Because crossflow was not observed, graphical presentations of the static spinner logging data are not included in this report.

Following the static spinner log, with the spinner logging tool already in the hole, the well was equipped with a Nye County submersible pump. The bottom of the pump was set 75 ft (22.9 m) below ground level, or approximately 5 ft (1.5 m) above the top of Screen #1. Although this configuration allowed Screen #1 to be logged, the drawdown achievable with such a shallow pump depth was small (Figure 4). While pumping at approximately 25 gpm (94.6 L/min.), the spinner log was run at a logging speed of 20 ft/min. (6.1 m/min.). The results of this log are presented in Figure 3. Stationary readings were also taken between screens, but the low fluid velocity precluded their use as a quality check.

On March 27, 2001, the pump was lowered to a depth of 159 ft (48.5 m), which is 21 ft (6.4 m) above the top of Screen #2. The pump was started with an initial rate of 150 gpm (567.8 L/min.) and maintained for 19 min. During the brief high rate pumping period, the water level in the well was drawn down below the standing water level for Screen #4 (Figure 4), and it is therefore likely that Screen #4 produced water during this brief time period.

To prevent excessive drawdown in the well, the pumping rate was reduced after 19 min. to a lower sustainable pumping rate between 34 and 39 gpm (128.7 and 147.6 L/min.). A spinner log was then run at a logging speed of 20 ft/min. (6.1 m/min.). Logging results are shown in Figure 5. Following the spinner logging, the pump and logging tools were removed from the well.

2.1.3 Qualitative Spinner Log Interpretation

Numerous factors affect the spinner log readings and interpretations, including turbulence, slight variations in logging speeds, temperature, viscosity, and debris. With these factors in mind, several features of the pump spinner logs shown in Figures 3 and 5 can be qualitatively interpreted.

- The slope of the interpretation line or the rate in which the curves diverge provides a relative indication of permeability. The faster the change, the higher the permeability. For example, in Figure 5, the slope of the interpretation line for Screen #2 and the upper 25 ft (7.6 m) of Screen #3 suggests similar permeabilities. The slope of the spinner response also indicates the lower 75 ft (22.9 m) of Screen #3 appears to have much lower permeability. There is considerable error in these data, due to fluctuating heads during pumping and variability in the log response, so these results should be considered qualitative.

- Because of turbulence effects in the screened interval, the most accurate and stable readings are generally found immediately below the screened intervals in blank pipe. A good example of this is illustrated in both the up and down logs immediately below Screen #1 in Figure 3.

- The counts per second should be steady across blank intervals with no changes in pipe diameter or flow rate. This is best illustrated on the up log between Screens #1 and #2 in Figure 3.

- Low contrast between logging speeds and fluid velocity causes erratic or zero spinner log readings. This is illustrated on Figure 5, between the top of Screen #3 and the top of Screen #2 on the up logging run. The raw data show the logging tool fluctuating between 3 cps and 0 cps.

In addition, qualitative information can be obtained from the static spinner logs, even though minimal crossflow was observed between screens during the logging. The absence of crossflow during static spinner logging, even though the lower two screened intervals exhibited much lower piezometric heads than the upper two screened intervals, was interpreted as evidence that the lower screened intervals have a much lower permeability than the other intervals, and/or the development of the well was insufficient to remove drilling fluid filter cake. Several lines of evidence suggest that both low permeability and filter cake clogging were responsible for the lack of flow in static tests. This evidence includes qualitative permeability interpretations presented above for pump-spinner logs, interpretations presented in the following section regarding small flows induced by high pumping rates, and the well construction history, which documents the use/loss of large quantities of bentonite mud and polymer drilling fluids during the drilling and completion of well NC-EWDP-7SC.

2.1.4 Quantitative Pump-Spinner Log Analysis and Interpretation

The primary purpose of the pump-spinner logs was to allocate flow rates (and by inference transmissivity and permeability) from the combined test to the individual zones. This allocation is valid if the head differentials and the wellbore efficiency are similar in the different zones. Allocated flow rates from different zones, both in terms of gpm and percent total production, are presented in Figures 3 and 5 for the two pump-spinner tests.

The first pump-spinner log was conducted with the submersible pump set as high as possible in the wellbore above Screen #1. While this high setting allowed all four screens to be observed with the logging tool, it precluded obtaining sufficient drawdown to permit inflow into the well from Screens #3 and #4, which have lower heads than the upper screens. (Additional drawdown would have dried out Screen #1.) A relatively low pumping rate (approximately 25 gpm, or about 95 L/min.) was maintained during this test. Based on interpretation of the spinner logs in Figure 3, the allocation of the production was 10% to Screen #1 and 90% to Screen #2. Flow rates in gpm are also presented for Screens #1 and #2 in Figure 3.

The second pump-spinner log was run with the pump set deeper (near the top of Screen #2) to allow greater drawdown and higher production (34 to 39 gpm, or 129 to 148 L/min.). Based on interpretation of the spinner logs, Screens #1, #2, and #3 produced 10%, 50%, and 40%, respectively, of the total flow under these conditions (Figure 5). Screen #4 contributed very little, and only for a brief period, during this portion of the testing. The small contribution of Screen #4 during this test may in part be a result of the production and associated clean-up of the well screen during the initial high flow rate pumping (150 gpm, or 567.8 L/min.), conducted prior to this spinner log. Finally, it should be noted that the above results may contain significant error, because the head levels in the well changed significantly during the test.

In summary, the upper two screens exhibit the same piezometric head, which suggests that they are in direct communication. Moreover, the allocated productions per foot of screen for Screens #1 and #2 during the higher rate pump-spinner test were similar (17% of the flow coming from 25% of the screen thickness), suggesting that permeabilities of these intervals are similar.

Screen #3 produced water when the water level in the well was reduced below the non-pumping water level for this zone. The average permeability of sediments in this zone appears to be lower than found in Screens #1 and #2, although the permeability of the upper 25 ft (7.6 m) of Screen #3 appears to be similar to that of the upper zone. The sediments exposed in Screen #4 require a greater drawdown before production occurs. Because the head level in the wellbore was only less than the static head level in Screen #4 for a brief time, little is known about its productivity and permeability.

2.2 PUMP TEST WATER LEVEL ANALYSIS

2.2.1 Test Procedures and Description

A 48-hr. pump test was designed for well NC-EWDP-7SC to determine its transmissivity and well efficiency. Beginning March 27, 2001, the well was pumped at an average rate of 45 gpm (170.3 L/min.) for 47.5 hr. with the pump set just above Screen #2 at a depth of 159 ft (48.5 m). Total production during the test was 128,500 gal. (about 486,400 L) and the maximum drawdown in well NC-EWDP-7SC was 90 ft (27.4 m). The water level response to pumping was also monitored in offset well NC-EWDP-7S. Maximum drawdown in the observation well was 2.3 ft (0.70 m). Upon cessation of pumping, water levels were monitored during a 17.7-hr. recovery period. The MOSDAX™ pressure sensor in the NC-EWDP-7S observation well failed 12.5 hr. into the recovery.

The measured pumping rates and computed depth to water for the pump-spinner test and the 48-hr. pump test are shown in Figures 4 and 6. Pump rates were obtained using a 55 gal. (208.2 L) drum and a stopwatch. Readings were also taken using a Macrometer™ turbine flow meter. However, low flow rates precluded obtaining accurate readings from the turbine meter. The depth to water was determined from pressures recorded by a MOSDAX™ pressure sensor placed above the pump. Barometric pressure was also recorded by a MOSDAX™ pressure sensor, and a nominal water density of 0.43275 psi/ft was used to convert psia to water depth.

Analysis of the pumping portion of the test was complicated by the presence of step increases in drawdown (Figure 6). These step increases appear to be related to settling in the gravel pack around the well casing. A review of the drilling and completion records for well NC-EWDP-7SC indicates the borehole was severely washed out and required a considerable amount of pea gravel to fill the annulus between the casing and the borehole. Two significant washouts requiring pea gravel are shown on the well completion diagram (Figure 1). The uppermost washout was located immediately below the conductor pipe from 76 to 59 ft (23.2 to 18.0 m). The interval from 263 to 235 ft (80.2 to 71.6 m) also required large volumes of pea gravel.

Further evidence that these drawdown step increases are related to wellbore phenomena, rather than aquifer properties, is provided by comparison to the observed drawdown in the observation well as these steps occurred in the pumping well. The head in the observation well decreased until 12 a.m. on March 29, 2001, and then increased slightly (Figure 7). Over the same period, the head in the pumping well dropped, in some cases very abruptly. Both responses can be explained as a reduction in flow from the upper screens, rather than an increase in drawdown that would be expected if there were a head change in the actual aquifer sediments.

The step changes in drawdown during the pumping portion of the test prevented meaningful analysis of the pumping data. Accordingly, the recovery data are considered to be more reliable for analysis of well NC-EWDP-7SC. Well Test Analysis Quality Control Checklists for wells NC-EWDP-7SC and -7S are included as Attachment 1. These checklists document the analysis procedures used and the results obtained.

2.2.2 Pumping Well Recovery Analysis

After obtaining the test data and verifying quality control, the first step in the test analysis and interpretation procedure was to prepare a log-log diagnostic plot of head change versus pumping time (Figure 8). In addition to the measured response, the logarithmic derivative of the drawdown was also computed and plotted using a technique described by Horne (1997). This type of plot provides important information regarding flow regimes, including, for example:

- An initial unit slope (+1 slope) (usually within the first few seconds of pumping) on the drawdown and the derivative indicates wellbore storage.

- A later flat line (0 slope) in the derivative response indicates radial cylindrical flow. The distance between the drawdown curve and the derivative curve is a measure of wellbore efficiency or skin effect.

- Multiple stable flat regions can be caused by flow barriers or multiple layers.

- A positive half slope (+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 (-½ slope) on the derivative response indicates spherical or hemispherical flow.

- A declining derivative response with increasing distance between the derivative and the differential head curve is indicative of improving permeability or increased thickness at greater distance from the well.

Several different flow regimes are evident from inspection of the log-log plot (Figure 8) for well NC-EWDP-7SC. The effects of wellbore storage and well efficiency dominated the very early time response, up to about 0.02 hr. The head then rose in a fairly steady fashion. The head change did flatten briefly as the water level in the wellbore increased above the standing water level for Screen #3. In the derivative, this is seen as a rapid decline followed by a sharp increase, before once again declining. The derivative and the change in head curve diverge more at later times, after about 1 hr., which appears to be the result of greater permeability at some distance from the well.

2.2.3 Model Analysis

The next step in the analysis was to prepare a test interpretation based on a conceptual model identified from reviewing the diagnostic plot (Figure 8) and the well history. Well test analysts generally begin an analysis with the simplest model that accounts for the observed behavior. In this case, that was a radial composite, two-layer model. The upper two screens were combined into a single zone and the third screen was modeled by itself. The influence of Screen #4 was assumed to be negligible, based on the pump-spinner test and the spinner logging results. The drawdown and recovery head changes and derivative response were analyzed using the SAPHIR™ computer-assisted well test analysis program (Kappa Engineering, 1999). SAPHIR™ includes the standard methods of 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. After a preliminary interpretation was selected, the test parameters were varied to determine a "best fit" using nonlinear regression techniques. The match results were examined on log-log (Figure 8), semilog (Figure 9), and Cartesian plots (Figure 10).

The declining derivative response in Figure 8 is interpreted as a damaged (clogged) area around the wellbore with improving transmissivity away from the wellbore. The well construction history suggests the likelihood of such damage. Large amounts of polymer and bentonite gel mud were lost while attempting to drill and complete this well. This damaged region was modeled as a cylindrical area of reduced transmissivity within an infinite system. The radius of reduced transmissivity was modeled as 11 ft (3.4 m) in the upper screens and 15 ft (4.6 m) in Screen #3. The best match was obtained with inner region transmissivities of 39.4 ft^2/day (3.7 m^2/day) for the 197 ft (60 m) of saturated interval with Screens #1 and #2, and 8.0 ft^2/day (0.7 m^2/day) for the 116 ft (35.4 m) of saturated interval in Screen #3. The transmissivity of the outer region, beyond 11 ft (3.4 m) in the upper screens and 15 ft (4.6 m) in Screen #3, was matched with an approximate 40-fold increase. The corresponding transmissivity away from the borehole was 1,620 ft^2/day (151 m^2/day) for Screens #1 and #2, and 329 ft^2/day (30.6 m^2/day) for Screen #3. Because most of the head drop occurred in the inner, low permeability region near the well, the permeability of the outer region was not uniquely determined from the matching. The outer region transmissivity was therefore selected, based on the interference response at well NC-EWDP-7SC (Section 2.3). The skin factors for the two model intervals were –0.71 and 0, respectively. The term "skin factor" is used in the petroleum industry to account for near-wellbore pressure drops, and is related to the concept of well efficiency in the groundwater industry. It is not feasible to prepare a direct conversion between the two terms in this case because of the multiple layers involved.

Using the match parameters for the two-layer, radial composite model, a very good match of the head change and derivative response during the recovery period was achieved (Figure 8). A good match was also obtained on the semilog plot (Figure 9). The influence of multiple layers and higher permeability in the outer region caused the head change to continuously decrease, so that it was not possible to select a suitable straight line for a Cooper-Jacob analysis (Cooper and Jacob, 1946). The Cartesian plot for the model recovery period also shows an excellent match (Figure 10).

2.3 OBSERVATION WELL RECOVERY ANALYSIS

As previously stated, nearby observation well NC-EWDP-7S was instrumented below the water table with a MOSDAX™ pressure sensor. Due to a shortage of available monitoring equipment, a sensor was used whose calibration had recently expired. However, it is possible to verify that the sensor was reading accurately by comparing the computed water levels in well

NC-EWDP-7S from the MOSDAX™ pressure sensor data with water levels that were recorded using a well sounder. The probe setting depth was determined from the initial amount of submergence below the measured water table. The sounder data and the water levels computed from the MOSDAX™ measurements are nearly identical, with a maximum observed error of ±0.08 ft (±0.02 m) (Figure 11). The slight error in readings probably resulted from measurement problems going from the small inner borehole in well NC-EWDP-7S to the larger surface casing used as the datum. Because of the excellent correlation between the two methods, and the greater data frequency available with the MOSDAX™ readings, the MOSDAX™ data were used for analysis.

The interference response at well NC-EWDP-7S as a result of pumping well NC-EWDP-7SC provided a useful data set for analysis (Figure 7). The head changes and derivative response during recovery were analyzed using the SAPHIR™ computer-assisted well test analysis program (Kappa Engineering, 1999). Simulated recovery data were compared to measured recovery data on log-log (Figure 12), semilog (Figure 13), and Cartesian plots (Figure 14). The best match was obtained with a transmissivity of 1,950 ft^2/day (181 m^2/day). The computed inter-well permeability between NC-EWDP-7SC and -7S was 2.2 darcy (2.2 x 10^{-12} m^2), based on the 313 ft (95.4 m) of saturated interval associated with Screens #1, #2, and #3.

In addition to determining the permeability, interference testing also permits calculation of the storage coefficient, which in this case was 0.059 ft/ft (0.059 m/m). The storage coefficient is large enough to indicate that the system is acting as an unconfined aquifer, rather than as a confined aquifer, which generally exhibits a much lower storage coefficient.

3.0 CONCLUSIONS

Spinner logs run under static (non-pumping) conditions in well NC-EWDP-7SC were used to measure natural crossflow between screens. The absence of significant crossflow, even though there are significant head differences between zones, is attributed to insufficient well development and the low permeability of sediments monitored by the deeper well screens. Additional spinner logs were run to evaluate individual zonal contributions while pumping. Screen #2 contributed the greatest flow (17 gpm, or 64.3 L/min.), followed by Screen #3 (14 gpm, or 53 L/min.), and Screen #1 (3 gpm, or 11.4 L/min.). No flow was observed from Screen #4.

A 48-hr. pump test was conducted to determine aquifer properties near well NC-EWDP-7SC. Analysis of the pump well test data indicated the presence of a severely damaged zone in the immediate vicinity of the well, which is consistent with the operations history indicating large amounts of polymer and bentonite gel mud were lost while attempting to drill and complete this well. The test was analyzed using two layers that communicated only at well NC-EWDP-7SC. Each layer was analyzed using a radial composite model consisting of an inner zone with reduced permeability, and an outer zone with higher permeability. The best fit transmissivities of the inner zone were 39.4 ft^2/day (3.7 m^2/day) for the first layer corresponding to Screens #1 and #2, and 8.0 ft^2/day (0.7 m^2/day) for the layer corresponding to Screen #3. The transmissivities for the layers in the outer, more permeable zone away from the borehole could not be uniquely determined from a single well test.

However, a unique estimate was obtained from analysis of the interference response from observation well NC-EWDP-7S. The best match obtained for the recovery head data was with a transmissivity of 1,950 ft^2/day (181 m^2/day). This corresponds to a permeability of 2.2 darcy (2.2 x 10^{-12} m^2) using the total 313 ft (95.4 m) saturated interval thickness. The interference response also indicates that the system is acting unconfined.

The general test methodology and logging equipment are applicable for use on future wells. Care should be applied when attempting to test wells with significant head differentials or limited room for logging tools between the water table and the completion screens.

4.0 REFERENCES

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Schlumberger Limited. 1973. *Production Log Interpretation*. p. 3. Houston, Texas: Schlumberger Limited.

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FIGURES

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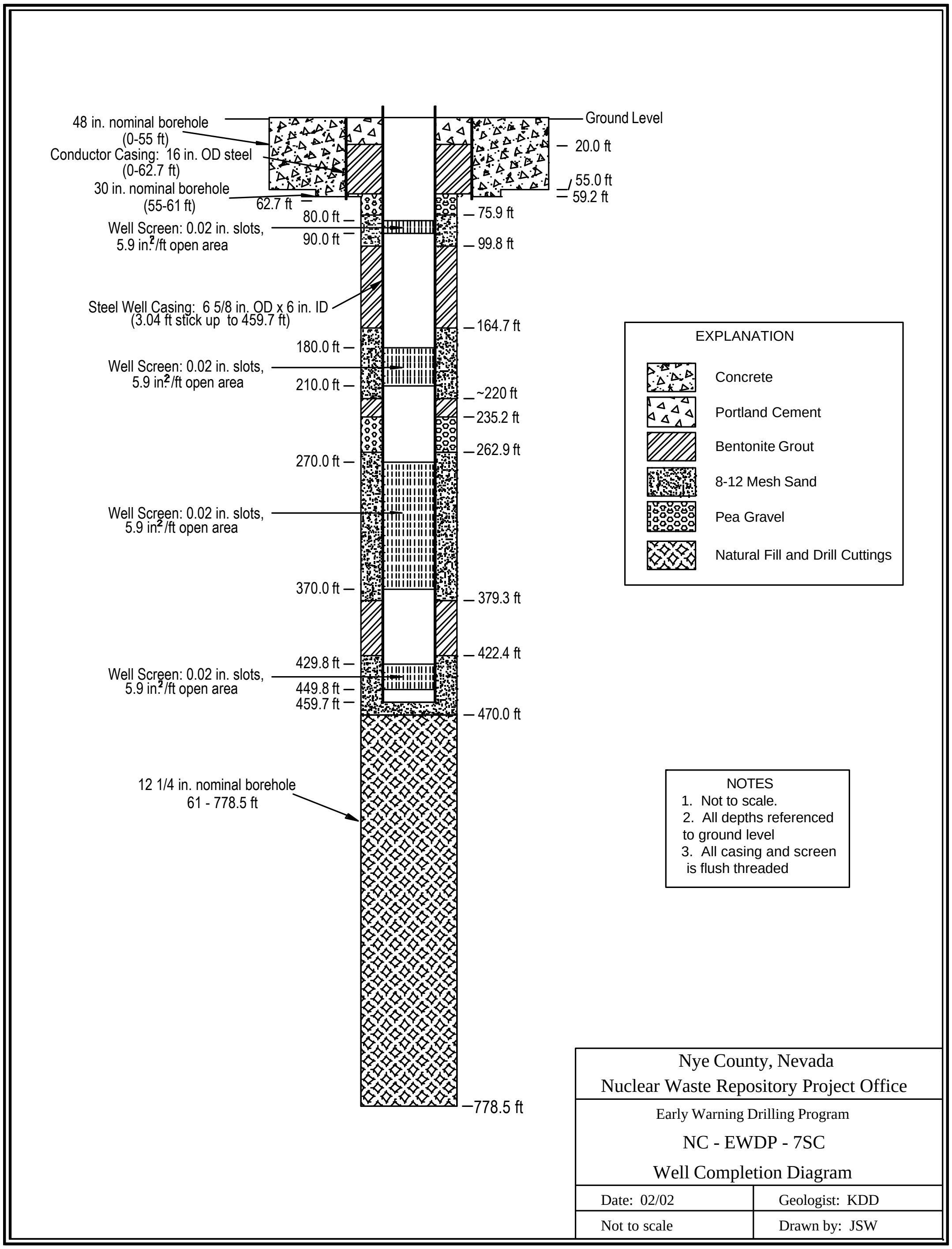
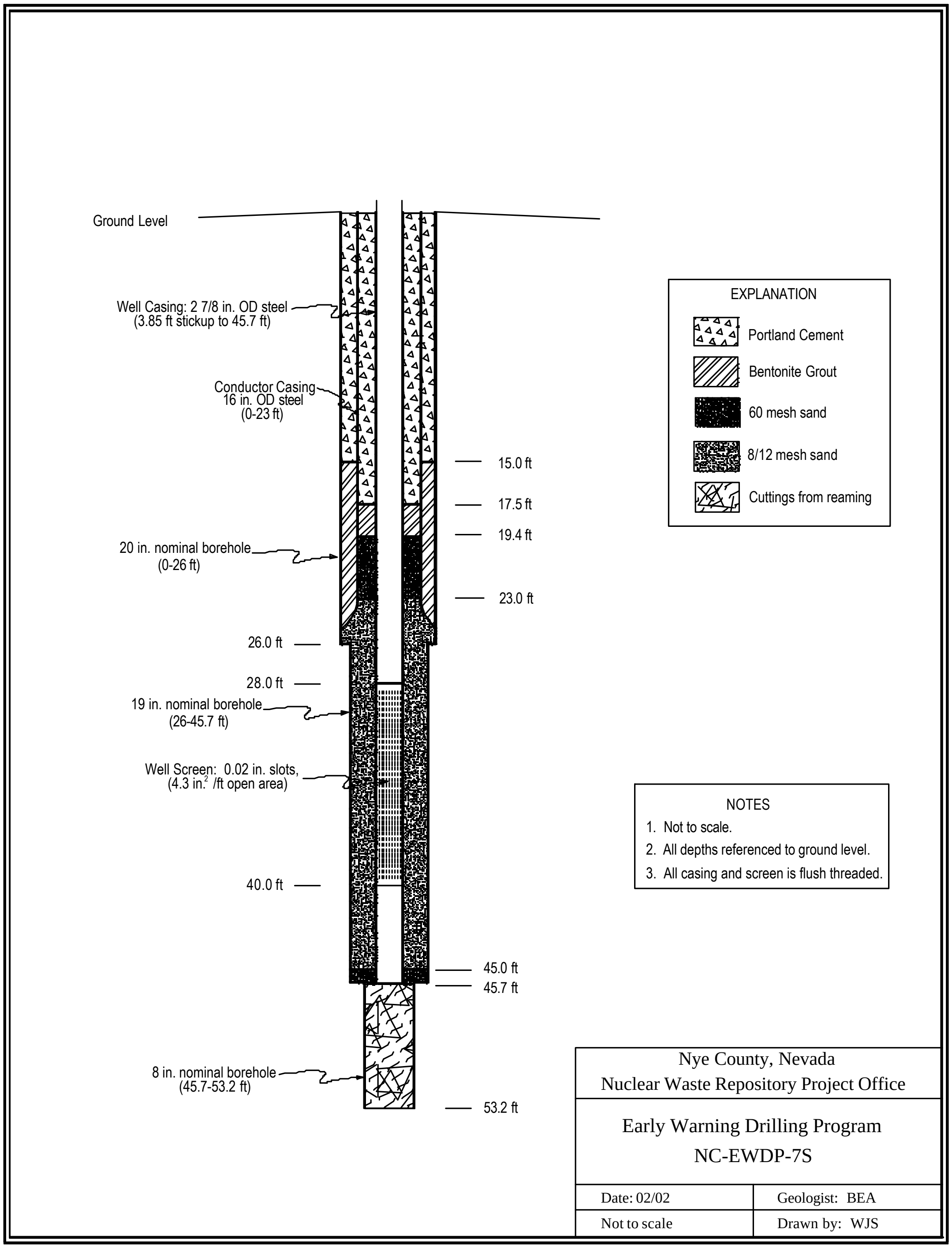


NOTE: OD = outer diameter; ID = inner diameter

Figure 1
Completion Diagram for Well NC-EWDP-7SC



NOTE: OD = outer diameter

Figure 2
Completion Diagram for Well NC-EWDP-7S

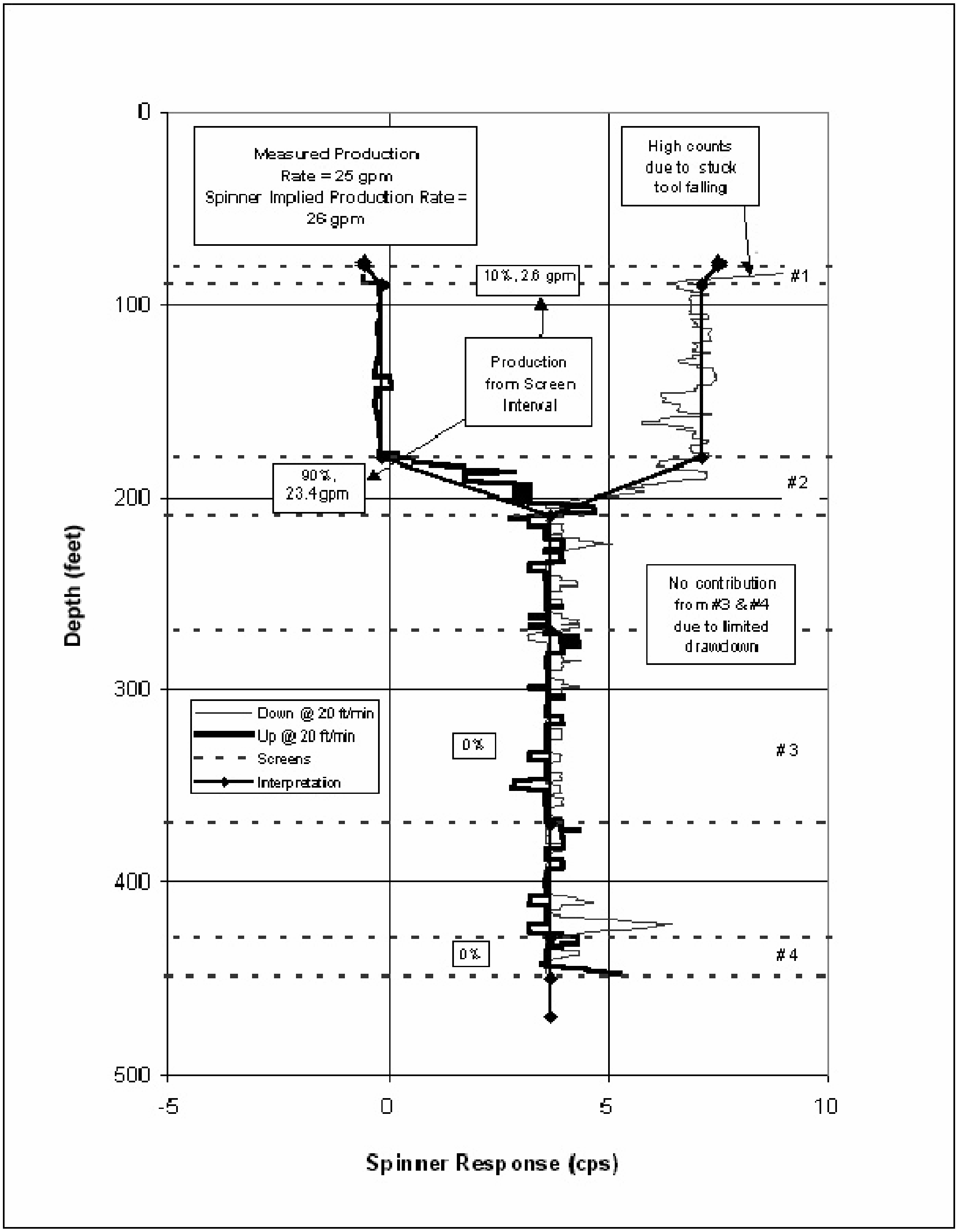


Figure 3
Spinner Log #1 for Well NC-EWDP-7SC, March 26, 2001

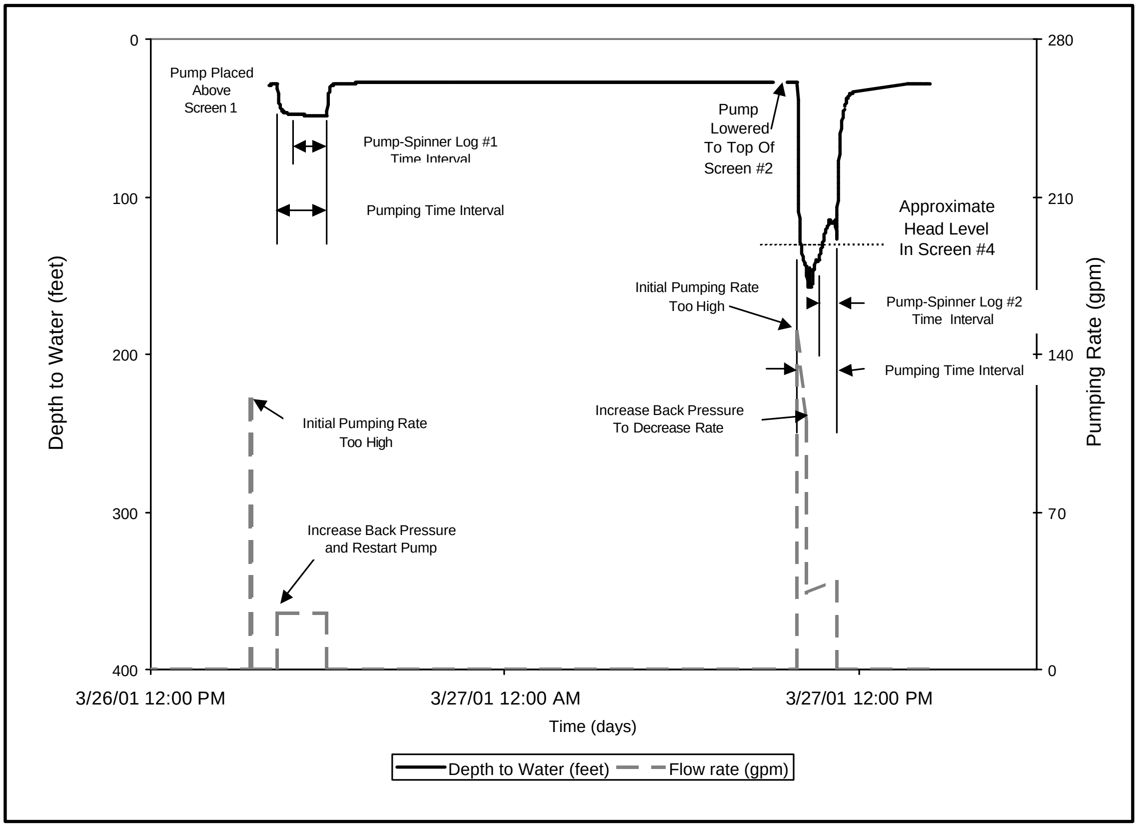


Figure 4
Measured Pumping Rates and Depth to Water for the Pump-Spinner Tests in Well NC-EWDP-7SC

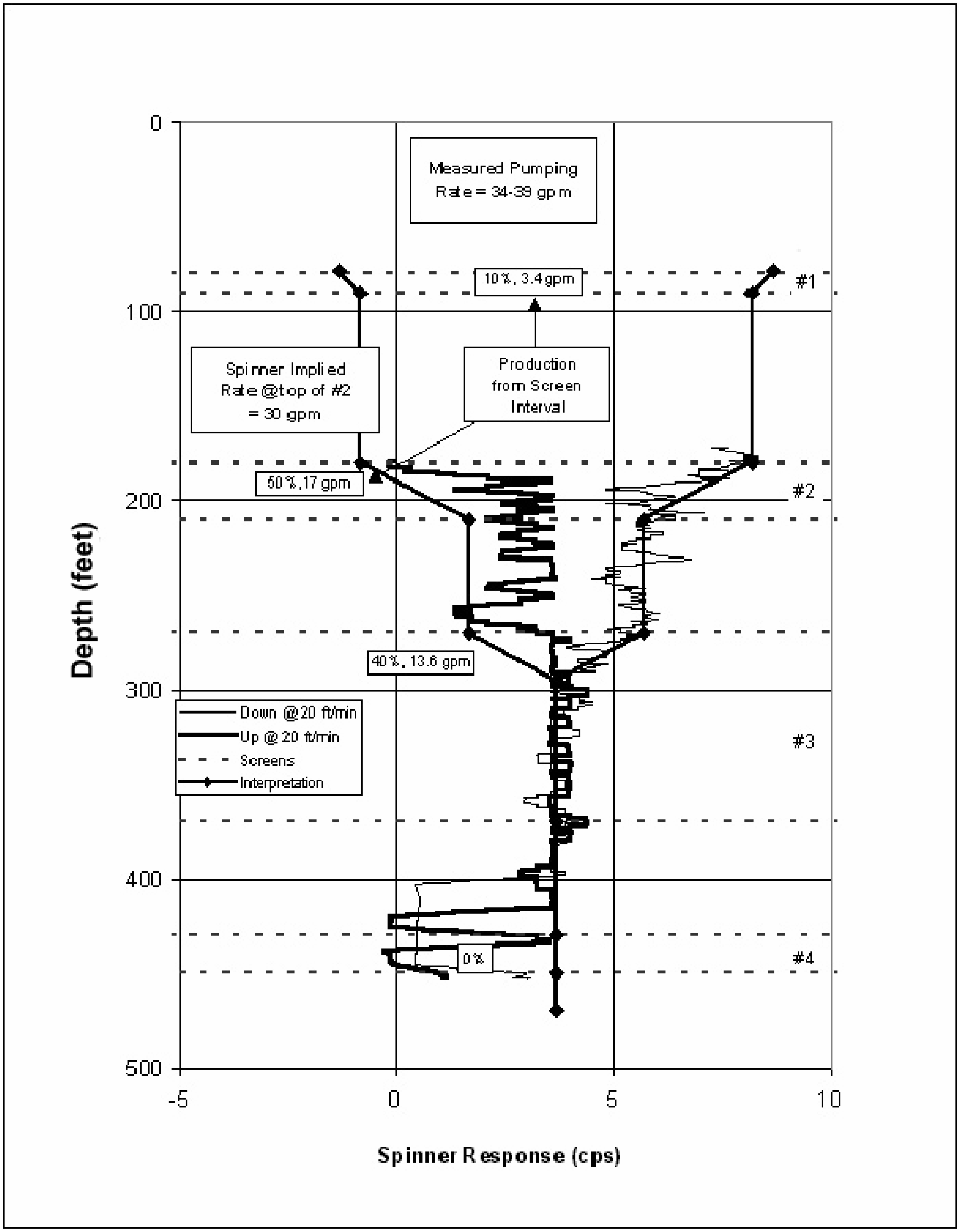


Figure 5
Spinner Log #2 for Well NC-EWDP-7SC, March 27, 2001

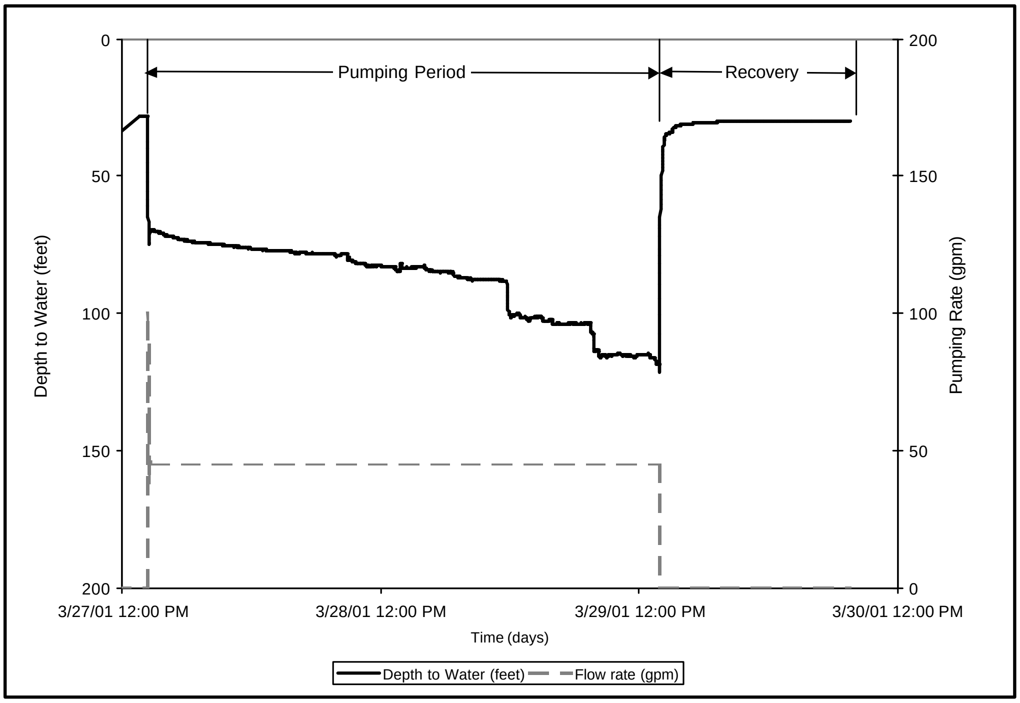


Figure 6
Measured Pumping Rates and Depth to Water for the 48-Hour Pump Test in Well NC-EWDP-7SC

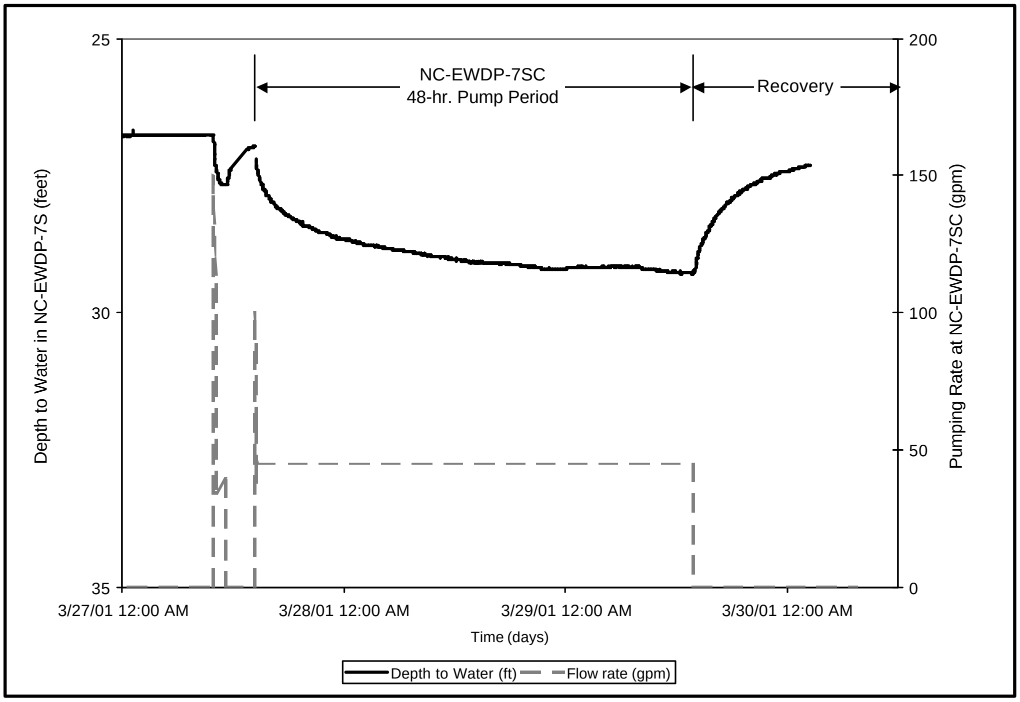


Figure 7
Measured Depths to Water at Well NC-EWDP-7S and Pumping Rates in Well NC-EWDP-7SC Before, During, and After the 48-Hour Pump Test

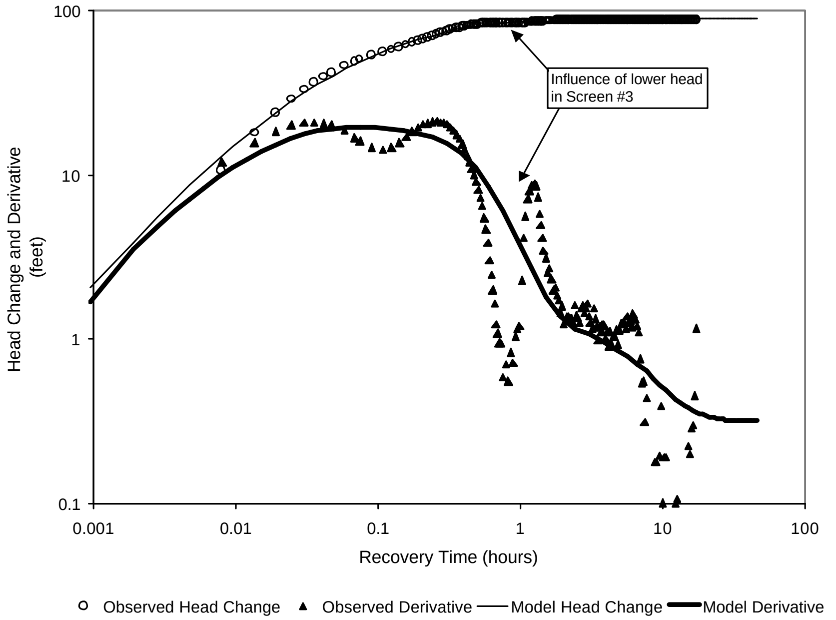


Figure 8
Log-Log Diagnostic Plot Comparing Model Results to the Measured Recovery Response in Well NC-EWDP-7SC

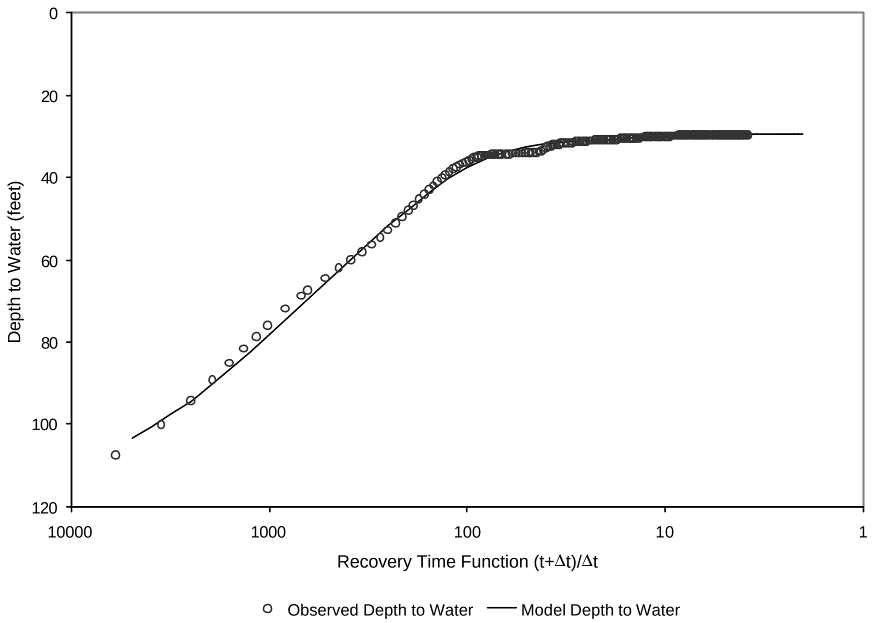


Figure 9
Semilog Plot Comparing Model Results to the Measured Recovery Response in Well NC-EWDP-7SC

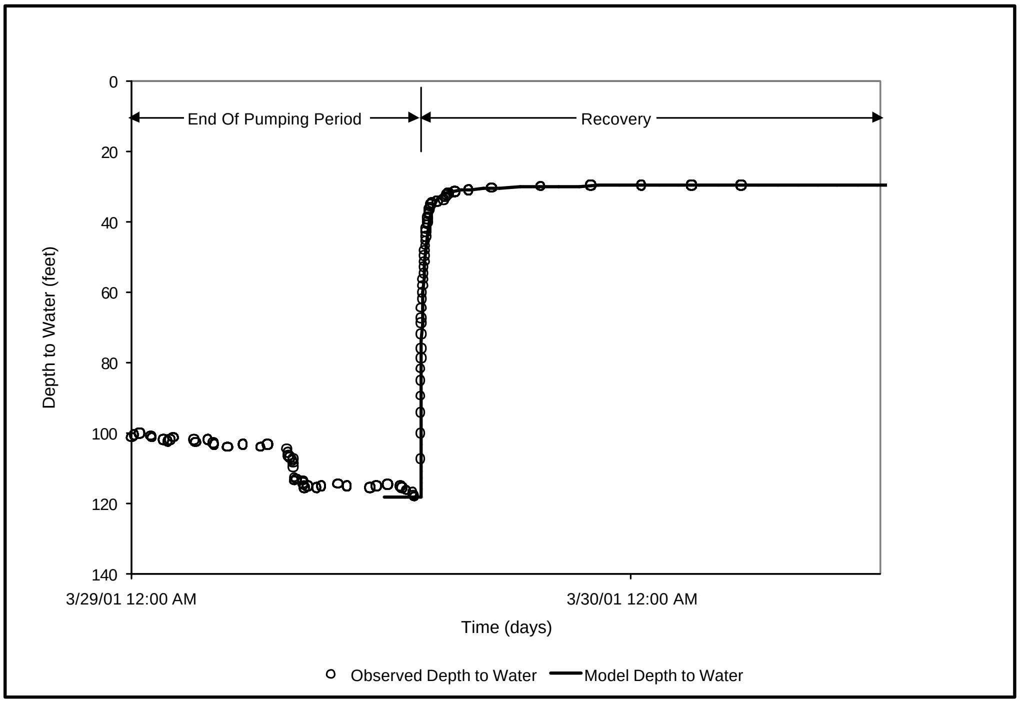


Figure 10
Cartesian Plot Comparing Model Results to the Measured Recovery Response in Well NC-EWDP-7SC

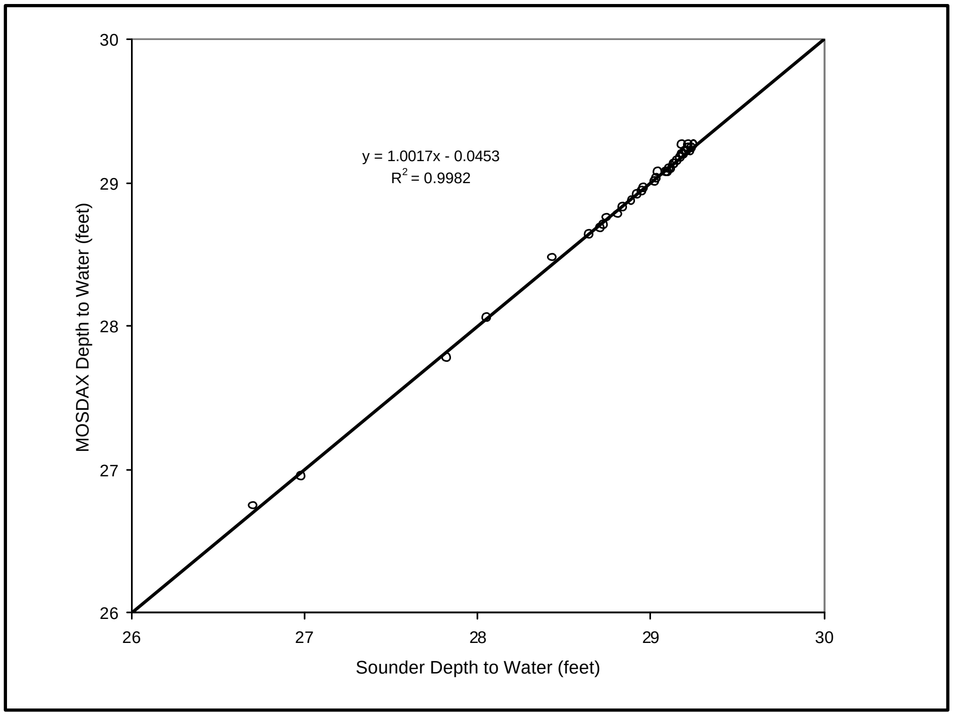


Figure 11
Measured Depth to Water at Well NC-EWDP-7S Using a MOSDAX^{TM} Pressure Sensor and a Well Sounder

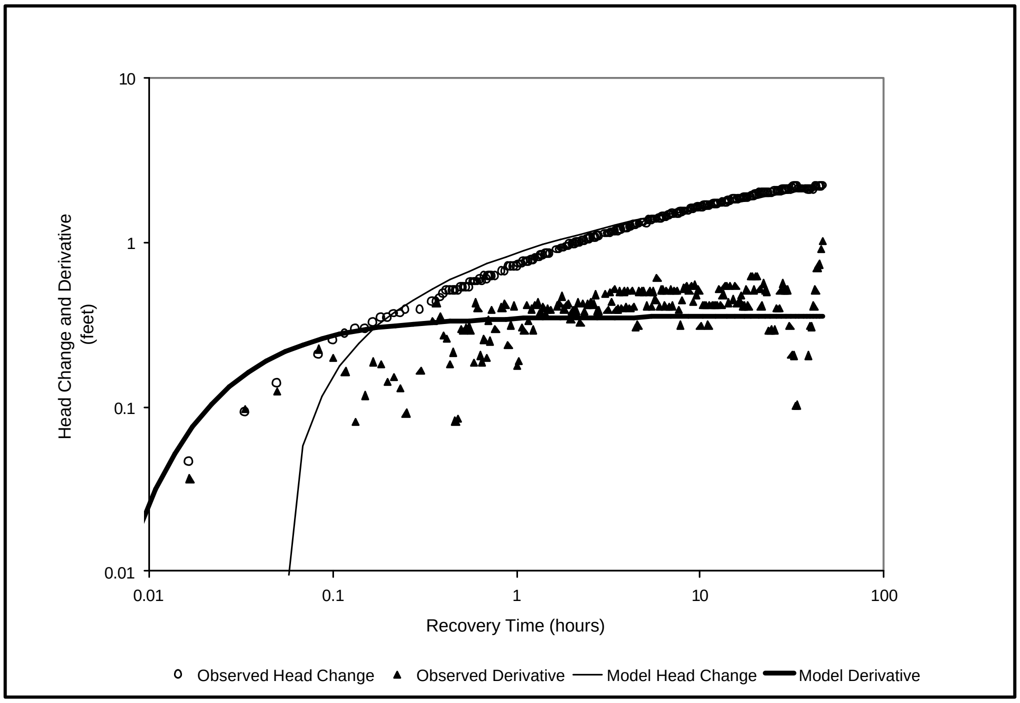


Figure 12
Log-Log Diagnostic Plot Comparing Model Results to the Measured Interference Response in Well NC-EWDP-7S

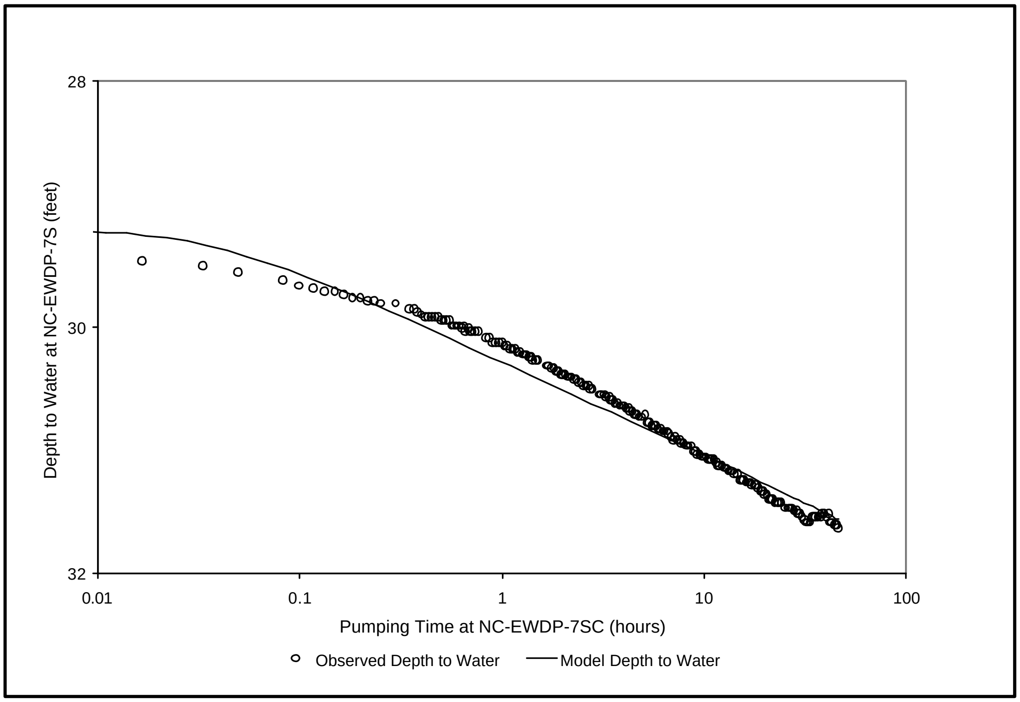


Figure 13
Semilog Plot Comparing Model Results to the Measured Interference Response in Well NC-EWDP-7S

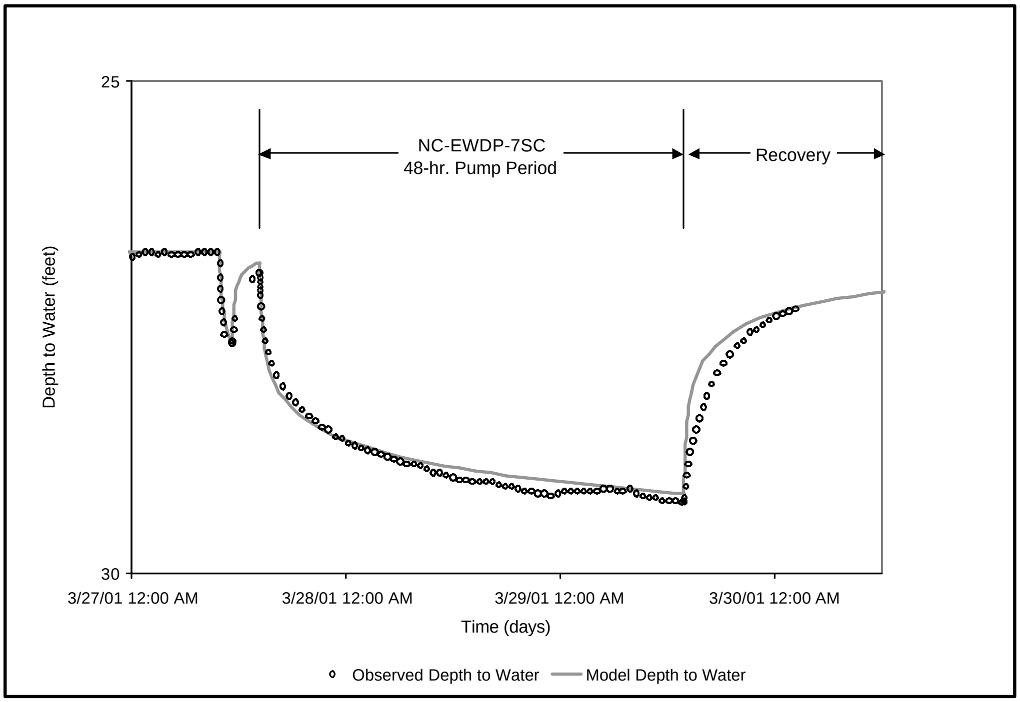


Figure 14
Cartesian Plot Comparing Model Results to the Measured Interference Response in Well NC-EWDP-7S

ATTACHMENT 1
WELL TEST ANALYSIS QUALITY CONTROL CHECKLISTS

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Attachment 1A

NYE COUNTY NUCLEAR WASTE REPOSITORY OFFICE

INDEPENDENT SCIENTIFIC INVESTIGATION
YUCCA MOUNTAIN, NEVADA

WELL TEST ANALYSIS QUALITY CONTROL CHECKLIST

Test Information

Borehole: NC-EWDP-**7SC**
Interval Tested: Entire wellbore, 4 intervals 80'-450'
Test Date: March 26-30, 2001
Datum: 3.04' above GL for Sounder, Probe @ 154.25' GL
Test Type: 48 hr. Pump/Spinner Survey
Observation Well: NC-EWDP-7S
Remarks: Good response observed at 7S. 7SC sounder data questionable below 80'.

Source of Data

Pressure File: 7SC5.CSV
Source: e-mail, R. Downing w/ Nye Co.
Gauge Type: Westbay **#1815 (-7S)**, #2323 (-7SC)
Units: psia & degrees C
Rate File: Hand Input
Source: Nye County Field Notebook
Flow Meter Type: Bucket and Stopwatch
Units: GPM, converted to BPD

Assumptions

	Value	Units	Source	Comments
Height	313	ft	Logs	Water table to bottom of interval #3.
Porosity	25%		Estimate	Alluvium and spring deposits
Viscosity	0.98	cp	*Saphir*	Software value
Wellbore Radius	0.51	ft	est	Nominal bit size
Compressibility	3.29E-04	psi^{-1}	Calculated	Interference analysis with -7S
Temperature	68	deg F	Measured	Pump probe temperature
S -Storage Coefficient	0.059	ft/ft	Calculated	-7S Interference

Results

Cartesian Plot Analysis: (Report Figures 3 and 4)
Length of Flow: 47.5 hrs
Steady State? No
Pseudo-Steady State? No
Remarks: Drawdown was still increasing, evidence of "step" plugging of screens.

Log-Log Plot Analysis: (Report Figure 7)
Flow Regimes Noted: (Circle Appropriate Types; Include Flow Regime Plot if Appropriate)
[✓ **Wellbore Storage**] ~~Bilinear~~ ~~Linear~~ ~~Radial~~ ~~Spherical~~ [✓ **Other**]
Remarks: Response shows effect of multiple layers and pressures.

Analysis Procedures

Software Utilized: Kappa-Saphir
File Name: 7SC_active vary skin9.ks3
Location: QEC Network
Software Utilized: Fekete-Welltest
File Name: 7SC48hrb.fkt
Location: FLE Dell

Result Summary (Include Units)

T - Transmissivity: 1,950 ft^2/d
Initial Pressure: 69.3 psia (25.1' below ground level)
Permeability: 2.2 darcy
Final Flowing Pressure: 30.1 psia (115.2' below G.L.)
Skin: -1 to 0 (inner region w/ 1/40 outer k)
Extrapolated Pressure: N/A
Effective Flow Time: 47.5 hours
Radius of Investigation: N/A
Average Flow Rate: 45.1 gpm, 1546 bpd
Distance to Boundary: NA
Total Flow Volume: 128,500 gal, 3,060 bbls
Effective Storativity for Zero Skin: NA

Remarks:

Analysis indicates inner region damaged by drilling. Outer region and interwell region, displays good permeability (2-4 darcy). Spinners and subsequent Westbay zonal data confirms reverse gradient, highest head in #1 & #2, #3 is 25' lower and #4 is 101' lower (than #1). Spinner data of limited use due to limits on drawdown and pump setting depth.
Observation probe was past calibration lifespan. Data believed valid based on sounder.

Analyzed by: Scott H Stinson, P.E.
Analysis Date: 1/9/2002

Attachment 1A
Well Test Analysis Quality Control Checklist for Well NC-EWDP-7SC

Attachment 1B

NYE COUNTY NUCLEAR WASTE REPOSITORY OFFICE

INDEPENDENT SCIENTIFIC INVESTIGATION
YUCCA MOUNTAIN, NEVADA

WELL TEST ANALYSIS QUALITY CONTROL CHECKLIST

Test Information

Borehole: NC-EWDP-7**S**
Interval Tested: Screen 28'-40', Open hole 46'-53' (TD)
Test Date: March 26-30, 2001
Datum: 4.57' above GL for Sounder, Probe @ 38.3' GL
Test Type: 48 hr. Pump/Spinner Survey
Pumping: NC-EWDP-7SC
Remarks: **Observation well** during Pump/Spinner and 48 Hour Pump Test for EWDP 7SC

Source of Data

Pressure File: 7SC5.CSV
Source: e-mail, R. Downing w/ Nye Co.
Gauge Type: Westbay **#1815 (-7S)**, #2323 (-7SC)
Units: psia & degrees C
Rate File: Hand Input
Source: Nye County Field Notebook
Flow Meter Type: Bucket and Stopwatch
Units: GPM, converted to BPD

Assumptions

	Value	Units	Source	Comments
Height	313	ft	Logs	Water table to bottom of Interval #3 in &SC
Porosity	25%		Estimate	Alluvium and spring deposits
Viscosity	0.98	cp	*Saphir*	Software value
Wellbore Radius	0.51	ft	est	Nominal bit size
Compressibility	3.29E-04	psi $^{-1}$	Calculated	Interference analysis with -7S
Temperature	68	deg F	Measured	Pump probe temperature in 7SC
S -Storage Coefficient	0.059	ft/ft	Calculated	-7S Interference

Results

Cartesian Plot Analysis: (Report Figure 11)
Length of Flow: 47.5 hrs
Steady State? No
Pseudo-Steady State? No
Remarks: Evidence of "step" plugging of screens in 7SC. Decrease in observed drawdown in 7S.

Log-Log Plot Analysis: (Report Figure 12)
Flow Regimes Noted: (Circle Appropriate Types; Include Flow Regime Plot if Appropriate)
[✓ **Wellbore Storage**] ~~Bilinear~~ ~~Linear~~ [✓ Radial] ~~Spherical~~ Other
Remarks: Responds quickly to changes in 7SC, No multiple zone effects evident.

Analysis Procedures
Software Utilized: Kappa-Saphir File Name: 7S EI 010902.ks3 Location: QEC Network
Software Utilized: Fekete-Welltest File Name: 7S48hrobs2.fkt Location: FLE Dell

Result Summary (Include Units)
T - Transmissivity: 1,950 ft^2/d
Initial Pressure: 20.2 psia (22.4' below ground level)
Permeability: 2.2 darcy
Final Flowing Pressure: 19.15 psia (24.7' below G.L.)
Skin: N/A
Extrapolated Pressure: N/A
Effective Flow Time: 47.5 hours
Radius of Investigation: N/A
Average Flow Rate: 45.1 gpm, 1546 bpd
Distance to Boundary: NA
Total Flow Volume: 128,500 gal, 3,060 bbls
Effective Storativity for Zero Skin: N/A

Remarks:
At the surface, the 7SC and the 7S are 28' apart. At least 3 boreholes were drilled on the location.
Analysis provides good estimation of interwell properties in upper, unconfined interval.
Effect of pumping multiple, deeper, lower head intervals not evident on observation data.
Observation probe was past calibration lifespan. Data believed valid based on sounder.

Analyzed by: Scott H Stinson, P.E.
Analysis Date: 1/9/2002

Attachment 1B
Well Test Analysis Quality Control Checklist for Well NC-EWDP-7S