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# Analysis of Well ER-EC-8 Testing, Western Pahute Mesa-Oasis Valley FY 2000 Testing Program

Revision No.: 0

September 2002

Prepared for U.S. Department of Energy under Contract No. DE-AC08-97NV13052.

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IT CORPORATION
P.O. Box 93838
Las Vegas, Nevada 89193

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Approved by: Signature Approved Date: 9-13-02

Janet N. Wille, UGTA Project Manager
IT Corporation

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## *List of Acronyms and Abbreviations*

| | |
|---|---|
| A | Amps |
| bgs | Below ground surface |
| BN | Bechtel Nevada |
| C | Carbon |
| °C | Degrees Celsius |
| CAU | Corrective Action Unit |
| CD | Compact disc |
| Cl | Chlorine |
| D | Deuterium |
| DIC | Dissolved inorganic carbon |
| DO | Dissolved oxygen |
| DOE | U.S. Department of Energy |
| DOP | Detailed Operating Procedure |
| DRI | Desert Research Institute |
| EC | Electrical conductivity |
| ESP | Electrical Submersible Pump Systems |
| °F | Degrees Fahrenheit |
| ft | Foot (feet) |
| ft/d | Feet per day |
| $ft^2/d$ | Square feet per day |
| fpm | Feet per minute |
| FS | Full scale |
| FY | Fiscal year |
| gpm | Gallons per minute |
| He | Helium |
| hp | Horsepower |
| HSU | Hydrostratigraphic unit |
| $H_z$ | Hertz |
| id | Inside diameter |
| in. | Inch(es) |

## List of Acronyms and Abbreviations *(continued)*

| | |
|---|---|
| ITLV | IT Corporation, Las Vegas Office |
| K | Hydraulic conductivity |
| LANL | Los Alamos National Laboratory |
| LiBr | Lithium bromide |
| LLNL | Lawrence Livermore National Laboratory |
| m | Meter |
| mbar | Millibars |
| MDC | Minimum detectable concentration |
| mg/L | Milligram per liter |
| mL | Milliliter |
| NDEP | Nevada Division of Environmental Protection |
| NDWS | *Nevada Drinking Water Standards* |
| nm | Nanometer |
| NNSA/NV | U.S. Department of Energy, National Nuclear Security Administration Nevada Operations Office |
| NTU | Nephelometric turbidity units |
| O | Oxygen |
| od | Outside diameter |
| pCi/L | Picocuries per liter |
| pmc | Percent modern carbon |
| psi | Pound per square inch |
| psig | Pounds per square inch gauge |
| PXD | Pressure transducer |
| rev/sec | Revolution per second |
| SQP | Standard Quality Practice |
| SU | Standard Units |
| T | Transmissivity |
| TDH | Total dynamic head |
| TOC | Top of casing |
| UGTA | Underground Test Area |
| UNLV-HRC | University of Nevada, Las Vegas - Harry Reid Center |

| | |
|---|---|
| V | Volts |
| VSD | Variable speed drive |
| WDHTP | Well Development and Hydraulic Testing Plan |
| WPM-OV | Western Pahute Mesa-Oasis Valley |
| WRL | Wireline |
| μg/L | Micrograms per liter |
| μmhos/cm | Micromhos per centimeter |
| % Sat | Percent saturation |

# 1.0 Introduction

This report documents the analysis of the data collected for Well ER-EC-8 during the Western Pahute Mesa - Oasis Valley (WPM-OV) well development and testing program that was conducted during fiscal year (FY) 2000. The data collection for that program is documented in Appendix A, *Western Pahute Mesa-Oasis Valley, Well ER-EC-8 Data Report for Development and Hydraulic Testing*.

## 1.1 Well ER-EC-8

Well ER-EC-8 is one of eight groundwater wells that were tested as part of FY 2000 activities for the U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Operations Office (NNSA/NV), Underground Test Area (UGTA) Project. Figure 1-1 shows the location of the WPM-OV wells. Drilling and well construction information was obtained from a draft of the *Completion Report for Well ER-EC-8* (Townsend, 2000).

Hydraulic testing and groundwater sampling were conducted at Well ER-EC-8 to provide information on the hydraulic characteristics of hydrostratigraphic units (HSUs) and the chemistry of local groundwater. Well ER-EC-8 is constructed with three completion intervals which are isolated from each other by blank casing sections with annular seals. The completion intervals extend over substantial vertical distances and access different HSUs and/or lithologies. Figures illustrating the lithology are provided in Section 3.0. The testing and sampling activities were designed to assess the completion intervals individually.

## 1.2 WPM-OV Testing Program

The testing program included:

1. Discrete pressure measurements for each completion interval
2. Well development and step-drawdown tests
3. Flow logging at three pumping rates
4. Collection of discrete groundwater sample(s) with a downhole sampler
5. Constant-rate pumping test and subsequent recovery
6. Collection of composite groundwater characterization samples

7. Flow measurements and water quality parameter logging under natural gradient flow

### *1.3 Analysis Objectives and Goals*

The testing program was designed to provide information about the local hydrologic conditions and HSU hydraulic parameters for use in the Corrective Action Unit (CAU)-scale flow and transport model. In addition, groundwater quality information from samples collected was intended for use in geochemistry-based analyses of hydrologic conditions and groundwater flow as well as to detect the presence of any radionuclides. The primary objective for this analysis was to evaluate all of the data collected and to derive the maximum information about the hydrology. A secondary objective was to evaluate the functionality of the well design for use in future investigation and testing activities, and also evaluate this well for use in future monitoring.

General goals for the analysis were to determine the discrete head for each completion interval and the resultant vertical gradient profile, determine representative hydraulic parameter(s) for the formation(s) in each completion interval, and determine representative groundwater quality for the formation(s) in each completion interval. With regard to the well, specific goals included determination of the well hydraulics of the multiple completion interval design under both natural gradient and pumping conditions, and the effectiveness of development and testing methodologies.

Section 2.0 of this report discusses the analysis of the nonpumping natural-gradient well hydrology, and evaluates opportunities for deriving hydraulic parameters for the completion intervals. Section 3.0 discusses the well hydraulics during pumping and the flow logging results. Hydraulic parameters for the well in general and for the upper completion interval in particular are presented. This section is completed with comments on working with these deep, multiple completion wells. Section 4.0 discusses the groundwater samples that were collected and the analytical results, as well as how this information fits into the general geochemistry of the groundwater in the area. Finally, concerns pertinent to the future use of Well ER-EC-8 for monitoring are discussed.

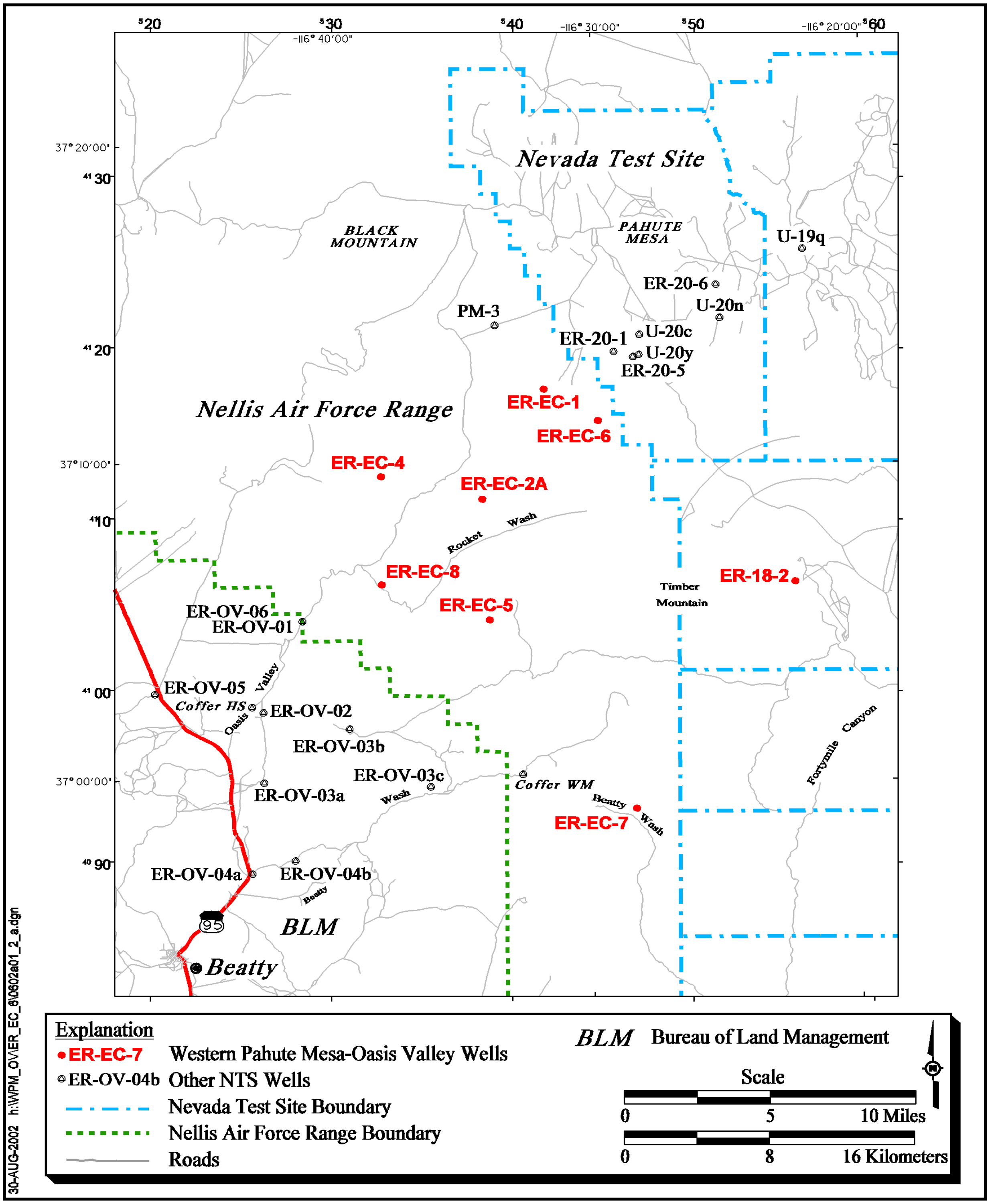



**Figure 1-1**
**Location Map for WPM-OV ER Wells**

# 2.0 Equilibrium Well Hydraulics

This section discusses many aspects of well hydraulics for Well ER-EC-8 in the equilibrium, nonpumping condition relating to the individual completion intervals. This material updates the initial analysis of the data in Appendix A, and further develops some of the concepts and concerns that were presented.

The well is constructed with three separate completion intervals. The longer intervals, the upper and the lower, are composed of alternating slotted casing and blank casing. At the top of the upper and for the middle completion interval there are two adjacent joints of slotted casing counted together as one screen. The completion intervals are isolated from each other outside the well casing by cement annular seals. Within each completion interval, the annulus is filled with continuous gravel pack extending above and below the screens. Downhole flow features are often discussed with reference to individual screens. The convention for referencing screens is by the consecutive number (e.g., first, second, third) of the screen from the top downward.

## 2.1 Composite Equilibrium Water Level

Table A.2-2 in Section A.2.0 of Appendix A presents all of the measurements of composite water level (depth-to-water) made during the testing program. The measurements reported in that table were very consistent, and there was no information collected during the testing program to indicate that these values are not representative.

## 2.2 Barometric Efficiency

The barometric efficiency of the well is used in the analyses of the hydraulic tests to refine the analysis and produce more accurate results. The importance of determining the correct value for barometric efficiency is somewhat dependent on the magnitude of the drawdown of the well during testing; the greater the drawdown, the less important the barometric correction. However, in circumstances requiring accurate knowledge of the status of a well relative to equilibrium with the natural state of the groundwater system, the refinement offered by correcting a water level monitoring record for barometric efficiency can be important. This is particularly important when making decisions based on a short or sparse record.

The analysis for the long-term monitoring yielded an efficiency of 64 percent. Figure 2-1 shows this PXD record corrected for barometric variation. The corrected record exhibits an upward trend in the water level and diurnal earth tide responses. The earth tides have a periodic variation in magnitude, with a cycle period of about 14 days, although this is not as clear as for other WPM-OV wells such as ER-EC-5 and ER-EC-7. The barometric efficiency was evaluated again at the end of development, and a value of 85 percent produced the best fit. This value was used to correct the constant-rate test data. The reason for the difference in apparent barometric efficiencies is not known. There is some inherent uncertainty in the analysis due to the other factors affecting the records. In any case, the difference does not significantly affect the aquifer analysis.

## 2.3 Completion-Interval Heads

Table 2-1 contains head values for the composite and individual completion intervals following equilibration of the different intervals to the isolation of the interval. Note that the measurements were made sequentially as equipment was installed, not simultaneously. The reported head differences may also include variations resulting from trends in head, barometric changes, and earth tides. Head values are presented rounded to the nearest 0.01 feet (ft) and pressure values are reported to the nearest 0.01 pounds per square inch (psi) as recorded by the instrumentation. The interpretation of these results and accuracy of the measurement process is discussed below.

**Table 2-1**
**Well ER-EC-8 Composite and Interval-Specific Head Measurements**

| Location in Well | Initial Equilibration: Head as Depth Below Ground Surface | | Change from Composite Head | End of Monitoring: Head as Depth Below Ground Surface | |
|---|---|---|---|---|---|
| | Feet | Meters | Feet | Feet | Meters |
| Composite Static WL (e-tape) | 322.87 | 98.41 | -- | N/A | N/A |
| Upper Interval (e-tape) | 322.86 | 98.41 | + 0.01 | 322.78 | 98.42 |
| Middle Interval (calculated) | 323.61 | 98.64 | - 0.74 | 323.36 | 98.56 |
| Lower Interval (calculated) | 323.80 | 98.69 | - 0.93 | 323.80 | 98.69 |

The depth to water was measured in the well before installing the bridge plugs and after each bridge plug was installed. The depth to water level for each measurement was the same except for an apparent 0.01 ft rise after the uppermost plug was installed. This difference is less than the accuracy of the measurement and may not represent an actual change. In any case, there was no substantial change as flow to lower completion intervals was blocked, indicating that there was no substantial drawdown in the well associated with downward flow under the natural gradient. The pressure in the lower interval immediately decreased 0.40 psi (0.93 ft of head) when the bridge plug between it and the middle interval was set. The pressure in the middle interval immediately decreased 0.32 psi (0.74 ft of head) when the bridge plug between it and the upper interval was set. At the end of the week of monitoring, the upper interval water level had risen about 0.08 ft, after correction for barometric changes. The middle interval head increased 0.25 ft above the initial adjustment. The pressure in the lower interval stayed the same as the initial adjusted pressure. The head difference between the upper interval and the lower interval was about 1 ft during the monitoring period.

The accuracy of the heads computed for the completion interval is a function of the accuracy of the water level measurements used for the reference heads and the accuracy of the measurement of head change. For the reference head and upper interval head measurements, the measurements were made with the same e-tape. E-tape measurements are made to a precision of 0.01 ft, which is the accuracy that to which the e-tapes are calibrated. E-tape measurements are generally repeatable within 0.10 ft or less per 1,000 ft between independent measurements.

The manufacturer's nominal specification for accuracy of the PXDs is 0.1 percent of the full-scale measurement. The PXD used in the middle interval, a 750 psi unit (SN# 21013), has a nominal accuracy of 0.75 psi (about 1.8 ft of head) and a resolution of 0.06 psi (0.14 ft of head). The calibration certificate supplied for this PXD indicates that the PXD had calibrated within about -0.35 psi (-0.81 ft of head) or less throughout the operational range. The calibration showed a maximum error of -0.35 psi (-0.81 ft of head) in the pressure and temperature range of the measurement. The PXD used in the lower interval, a 1,000 psi unit (SN# 21003), has a nominal accuracy of 1.00 psi equivalent to an absolute uncertainty of about 2.3 ft and a resolution of 0.08 psi (0.19 ft of head). The calibration certificate supplied for this PXD indicates that the PXD had calibrated within about 0.23 psi (-0.53 ft of head) or less throughout the operational range. The calibration showed a maximum error of -0.20 psi (-0.46 ft of head) in the pressure and temperature range of the measurement. There is no independent measure of the accuracy of the PXD calibrations at the time of the measurements at this level.

The potential error in the head difference between the composite water level and the lower completion interval head is the maximum error in the calibration, -0.46 ft, which is about half of the measured change of -0.93 ft. The potential error in the measurement of the head difference between the composite water level and the head in the middle interval is the sum of the maximum error in the calibration, -0.53 ft, and the e-tape measurement uncertainty 0.10 ft, totaling -0.63 ft which is slightly less than the measurement of -0.74 ft.

## 2.4 Variable Density/Viscosity of Water in the Wellbore

The measurements of pressure at various depths in the well indicate a variation in density of the water with depth that results in a nonlinear pressure-depth relationship. The variation in density is significant, and it is important to use the appropriate composite density when interpreting the bridge-plug pressure measurements to determine the head in a completion interval. The variation of temperature with depth is thought to be the primary factor in the density variation and can be shown to account for most of the variation. However, there may be other factors such as dissolved gasses and solids, suspended solids that vary with depth, and compressibility of the water. No information was collected that provides any understanding of these other factors, although it was noted during the development that there seemed to be a significant amount of entrained air in the produced water. The viscosity of the water also varies with temperature and perhaps other variables. Both the density and the viscosity variation may affect the flowmeter calibration and consistency of results.

Figure 2-2 shows the result of calculating the theoretical variation in density of water as a function of the temperature variation in the well. These calculations include the effect of compressibility. The temperature variation was derived from the posttesting ChemTool log, further discussed in Section 2.5.1. The pressures calculated from this exercise are within -0.35 to -0.57 percent of the measured pressure at the various depths of the bridge plug measurements. For the middle completion interval, the discrepancy in pressure between the PXD measurement and the calculated pressure is from -1.59 to -1.75 psi. As discussed in Section 2.3, the PXD used for the middle interval had a nominal accuracy of 0.75 psi, and a calibration accuracy of 0.16 psi. For the lower completion interval, the discrepancy was -3.02 to -3.08 psi. That PXD had a nominal accuracy of 1.00 psi and a calibration accuracy of 0.20 psi. These numbers indicate that much of the discrepancy is probably not a matter of the accuracy of the PXD. Part of the discrepancy is the uncertainty in accounting for the reference pressure of the PXDs, which is not known and was not recorded in the measurement process. However, the fairly consistent percent discrepancy also suggests that the discrepancy is a consistent factor of the water density. The remainder of the difference is probably due to the other factors mentioned that affect water density. The difference is negative, indicating that the actual density is less than the theoretical density, with the calculated specific gravity varying from 0.9943 to 0.9964. The discrepancy can be easily accounted for by dissolved gases.

## 2.5 Flow in the Well Under Natural Gradient

Measurement of flow in the well under the natural gradient can be used in conjunction with other information collected to calculate transmissivity (T) values for the individual completion intervals. There are two types of analyses that can be developed, a steady-state analysis using the measurement of the head differences between the completion intervals, and a transient analysis using the pressure adjustment that occurred when the bridge plugs were set. An additional use of the flow measurements is the calculation of the total amount of crossflow that had occurred between completion intervals prior to development. This information will be used in evaluation of the effectiveness of development for restoration of natural water quality. If crossflow is allowed to continue, the flow information will provide the basis for estimating future development/purging requirements for sampling the receiving intervals. Temperature logs run under nonpumping conditions also provide information on flow in the well, indicating locations of entry and exit of groundwater and direction of flow. The interpretation of the temperature logs is used in conjunction with the flow measurements to provide guidance for locating and interpreting discrete measurements.

### 2.5.1 Temperature Logs

Nonpumping temperature logs were run by Desert Research Institute (DRI) (ChemTool) prior to completion of the well, and then six days after the constant-rate test pumping ceased. These logs are shown in Figure 2-3 along with the DRI precompletion and postdevelopment thermal flow measurements, discussed in the next section. The temperature logs are similar in form and do not exhibit much temperature variation from top to bottom; however, the precompletion log is about 3 degrees Fahrenheit (°F) warmer. The difference may be related to cooling to natural temperature following drilling and/or calibration differences between the instrumentation. The posttesting temperatures are very similar to temperatures recorded by the PXDs used for the bridge plug measurements, and are probably close to equilibrium with the natural temperature regime and wellbore flow. The upper part of each log shows temperature increasing with depth that then reverses and becomes almost isothermal below. For the posttesting log, the reversal is about 200 ft above the uppermost completion interval. At this depth the temperature is 98.2°F, the maximum recorded in the well. The reason for the reversal is unclear since there are no features in the well associated with the inflection; this section of the well is blank casing cemented into the borehole. The precompletion temperature log also showed a similar inflection, but at about 400 ft depth. A variety of the geophysical logs run in the open borehole showed significant responses in this depth range, so the temperature inflection may be related to some feature in the formation. The constant temperature downward suggests downward flow of water, but there is no formation access in this depth interval in the completed well. The temperature profile from the upper completion interval downward also suggests flow in the well under the natural gradient, from the upper completion interval to the lower intervals.

### 2.5.2 Flow Measurements (Thermal Flowmeter)

Thermal flowmeter measurements (see Figure 2-3) were made during precompletion logging and following the testing. The precompletion measurements indicated slight upward flow in the upper part of the borehole, downward flow at an anomalous high rate in mid-depth (-64.33 gallons per minute [gpm]), and a reversal from slight downward to slight upward flow in the lower part of the borehole. These measurements probably do not accurately indicate natural gradient flow.

Flow in the completed well under natural head gradient (nonpumping, equilibrium conditions) was measured after recovery following the constant-rate test. The flow measurements were tabulated in Table A.2-9 in Appendix A. The measurements show downward flow of 0.82 gpm in the area of the upper two screens of the upper completion interval, but no flow below the second screen in the upper completion interval. Measurements between the upper completion interval and the middle interval did not detect flow. Downward flow of 0.47 gpm was found in the area of the middle completion interval, presumably going down to the lower completion interval. Based on the downward head gradient and the indications of downward flow from the temperature log, downward flow would be expected from the upper interval to the lower intervals. The thermal flowmeter measurements in the interval between the upper interval and the middle interval was very noisy and were interpreted as no flow, but this result is not definitive.

### *2.5.3 Derived Hydraulic Properties*

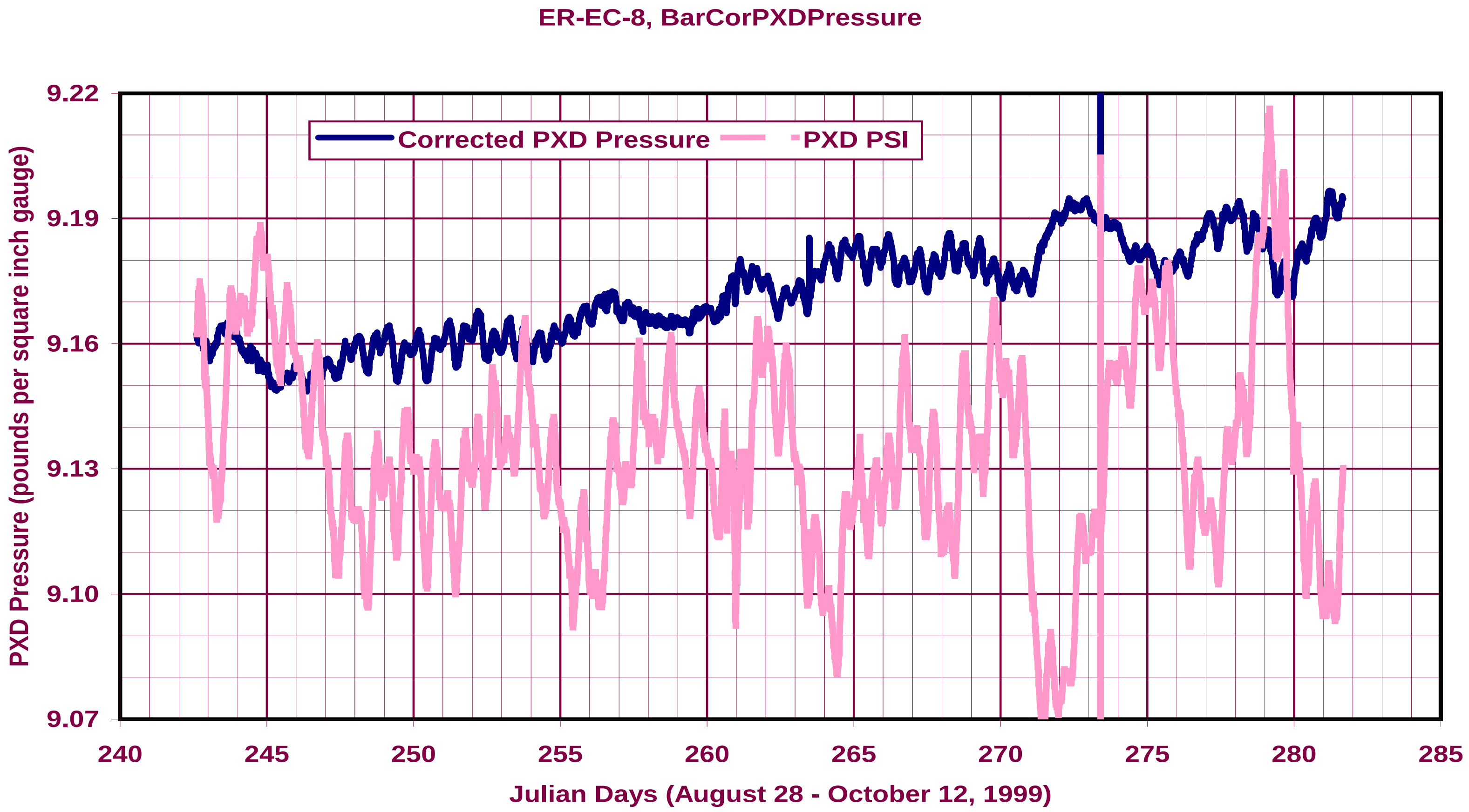
General estimates of the transmissivity of the completion intervals can be derived from information on the flow from and/or into the completion intervals and the hydraulic gradients associated with the flow. An estimate could be made using the empirical equation $T=2000Q/s_w$ (Driscoll, 1986), where Q is the flow rate in gpm and $s_w$ is the drawdown in feet. The head change data and the flow data both have substantial relative uncertainty, but can be used to derive general estimates. The data available for this well provide the basis for estimates of the transmissivity of the completion intervals. The head differences associated with flow to or from each interval are the changes in head of the isolated completion interval from the composite head, as presented in Table 2-1. The flows attributed to each interval are based on the thermal flowlog measurements. The upper interval appeared to produce 0.82 gpm, which may be a minimum value, and the lower interval appeared to receive 0.47 gpm. The difference, 0.35 gpm is assumed to be injected into the middle interval. The resultant transmissivity values are 29,900, 125.5, and 132.8 square feet per day ($ft^2/d$), respectively for the upper, middle, and lower intervals. These values would yield hydraulic conductivity (K) values, using the full thickness of the sand/gravel pack of the completion intervals, of 56.4, 1.0, and 0.4 feet per day (ft/d). These values can be compared to the K values determined from the flow logging for screens in the upper and lower intervals, presented in Table 3-7. The value calculated for the upper interval appears to be quite high, although probably within the same order of magnitude. This is attributable to the inability to measure the head change at the required level of accuracy as well as an ill-defined flow rate. The value calculated for the lower interval is very similar, which is probably due to the better relative accuracy of the applicable measurements.

These are only general estimates since the flows are not well defined and the head measurements have substantial inherent uncertainty. While these estimates are less specific and accurate than pumping test information, they can provide estimates of T and K values where better or more specific information is not available.

## *2.6 Pressure Equilibration Following Setting of Bridge Plugs*

The pressure equilibration records for each completion interval following setting the bridge plugs also have the potential for providing information on the transmissivity of the completion interval formation. For the upper completion interval, the recovery record could be analyzed if it could be captured with sufficient early-time data to define the recovery curve accurately. However, there was no measurable change in the water level.

Analysis of the pressure equilibration data for the lower completion interval can be conducted using a pressure fall-off model following cessation of injection (Earlougher, 1977). The record for the lower completion interval is shown in Figure A.3-3 of Appendix A. As mentioned in Section 2.3, the record shows rapid equilibration which did not provide an interpretable curve. Consequently the pressure fall-off analysis cannot be done.




psig - Pounds per square inch gauge
PXD - Pressure Transducer

**Figure 2-1**
**Barometric-Corrected Monitoring Record**

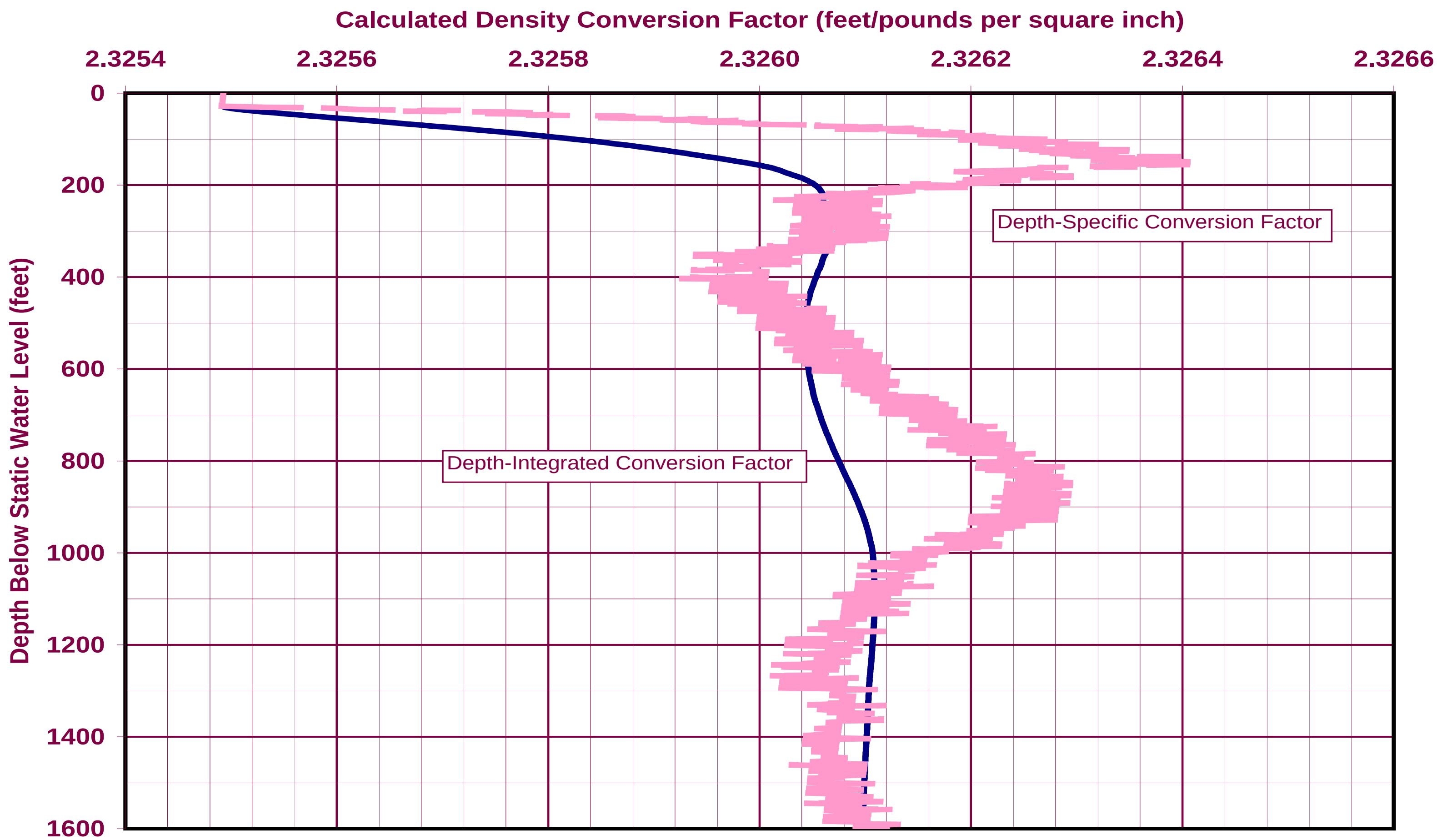



**Figure 2-2**
**Temperature-Dependent Density Variation**

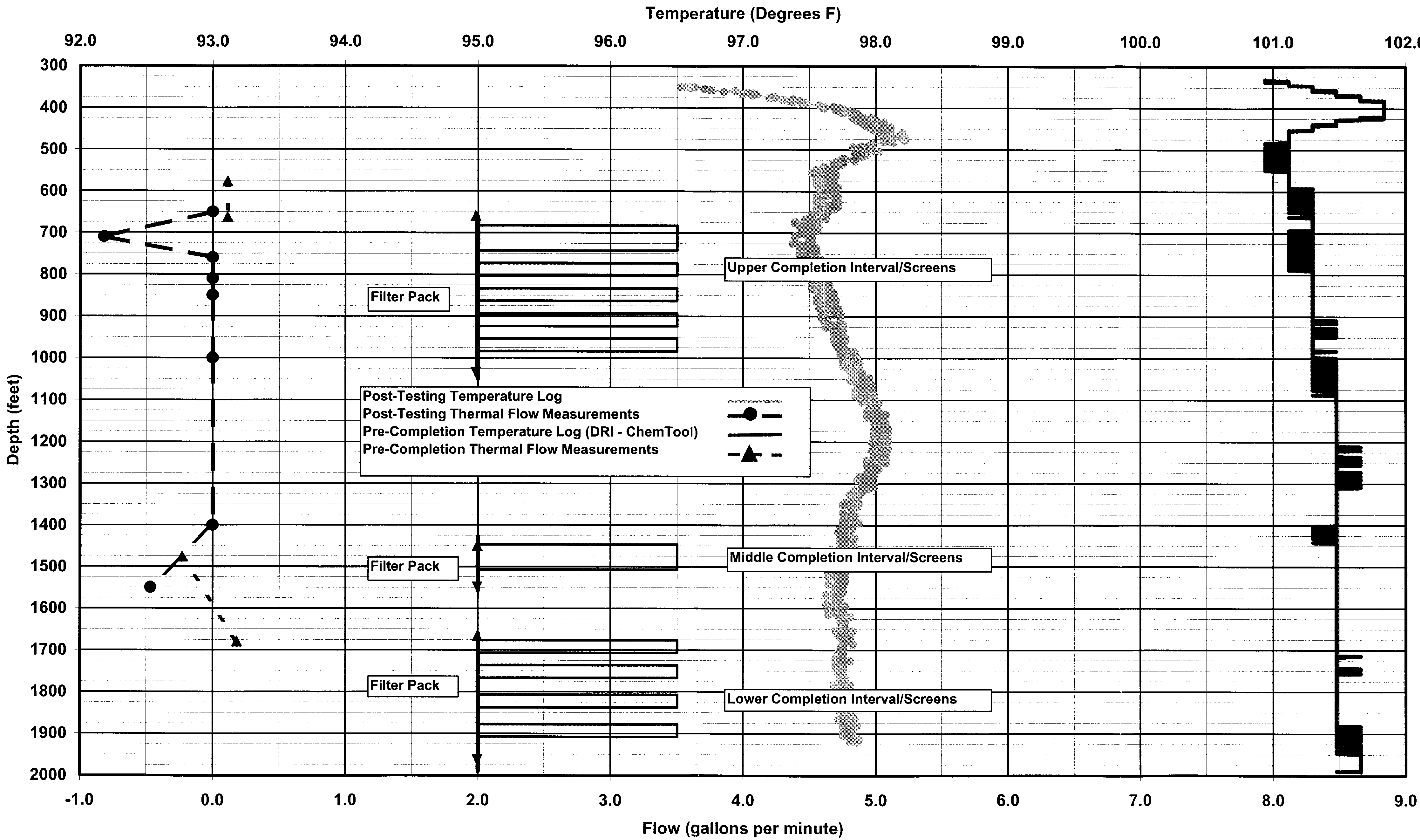



Figure 2-3
Nonpumping Temperature and Flow Logs

# 3.0 Pumping Well Hydraulics

The hydraulic testing of the well has been analyzed to provide both the transmissivity of the well and hydraulic conductivity of sections of the formation in the completion intervals. The hydraulic conductivity analysis is based on the flow logging conducted during pumping and a detailed analysis of the well losses.

## 3.1 Measured Discrete Production

One of the significant features of the WPM-OV testing program was the flow logging during pumping to identify the source(s) and distribution of water production in the well. This information will be used in interpreting the well hydraulics and water chemistry. These wells penetrate deeply through a variety of different formations and lithologies and have multiple completions, often in very different materials. Hydraulic testing and composite sampling provides information that is not specific to the differences in completion intervals, and interpretation of the data must often assume that, in general, the results pertain to all of the completion intervals.

Flow logging in conjunction with the testing and sampling allows the interpretation to be made specific to the origin of the produced water and the specific response of each completion interval, or even part of a completion interval. For example, as discussed later in this section, the flowmeter results show the production was very different between the completion intervals, even after accounting for the different lengths of the completion intervals. Consequently, the derived hydraulic conductivity is substantially greater for the upper interval, whereas, without the flow logging, all of the exposed formation would have been assigned one average value. The groundwater chemistry analyses can also be assigned more specifically to the depth and formation from which the samples actually came.

Figure 3-1 presents a composite picture of temperature and flow logs while pumping. The pumping case was characterized at the end of development and is presented with log erec8mov04 run at a nominal pumping rate of 177 gpm; but all of the logs show very similar results. Figure 3-2 and Figure 3-3 show the completion intervals and examples of the flow log for each of the three pumping rates that were used. These figures include depth, lithology, hole diameter, and well construction. Flow log erec8mov03 is presented for 66 gpm, erec8mov07 for 127 gpm, and erec8mov04 for 177 gpm.

The flowmeter logs typically show a small amount of inflow to the well from the lower completion interval (around 3.5 percent of the total production) with a very slight increase (around 0.4 percent) from the middle completion interval. Most of the production comes from the upper two screens of the upper completion interval. Increases in flow occur across the screens, with relatively steady flow in the blank casing between the screens and completion intervals.

### 3.1.1 Temperature Logs

Figure 3-1 shows the temperature log from the erec8mov04 flowlog. This log is typical of the temperature logs from all of the flowmeter runs. The temperature is relatively high in the uppermost part of the well considering the fairly shallow depth, and is almost isothermal to the bottom. The temperatures lower in the well are significantly less than would be expected. The temperatures in the pumping log are slightly less than were observed in the non-pumping log. Perhaps the temperatures in the lower completion intervals had been reduced by downward flow from the upper completion interval under the natural gradient. Although such flow was not measured, the evidence suggests it. Such flow would have occurred for the 11 months between well completion and the start of pumping. The net inflow versus production for the lower intervals is discussed in Section 4.2.3. At the time this temperature log was run, only a small fraction of the total inflow to the lower intervals would have been removed.

### 3.1.2 Impeller Flow Log Interpretation

During constant-rate pumping, the amount of flow in the well as a function of depth was recorded using a borehole flowmeter. The flowmeter is a spinner device provided by DRI, and was used in both a trolling and stationary mode. A total of nine logging runs were made at different logging speeds and different pumping rates. In addition, a series of nine stationary measurements were taken while the well was pumping and the meter held stationary at one depth. A summary of these different logging runs is presented in Table 3-1. The listed pumping rates have been updated based on tabulation of the flowmeter records to more accurately reflect the actual average pumping rates.

The flow logs provide a measure of the water production as a function of depth. This information, along with an estimate of the drawdown in each interval, can be used to calculate the hydraulic conductivity of each segment. This section describes the analysis of the flowmeter measurements in preparation for calculation of interval-specific hydraulic conductivity in Section 3.5.4.

The flowmeter impeller spins in response to water moving through the meter. The rate of revolution is related to water velocity and flow via an equation which accounts for pipe diameter and the trolling speed of the flowmeter. The coefficients of the equation relating the impeller response to the discharge are determined via calibration. In theory, the meter could be calibrated in the laboratory using the same pipe as the well and no further calibration would be necessary. In reality, the flowmeter response is influenced by a large number of factors specific to an individual well including temperature, pumping rate variation, hole condition, and sediment load. Therefore, it is advantageous to perform a calibration in the well to use for interpretation. For Well ER-EC-8, the calibration of the flowmeter response is determined using flowmeter data collected above the uppermost screen but below the crossover to the nominal 5.5-inch (in.) pipe. In this section of the well, the amount of water flowing upward to the pump should equal the discharge at the land surface. The flowmeter response is calibrated against the

**Table 3-1**
**Summary of Impeller Flow Logs**

| Run Number | Direction of Run | Line Speed (fpm) | Pumping Rate (gpm) | Run Start/Finish (ft bgs) |
|---|---|---|---|---|
| erec8mov01 | DOWN | 20 | 66 | 599 - 1,919 |
| erec8mov02 | UP | 40 | 66 | 1,919 - 599 |
| erec8mov03 | DOWN | 60 | 66 | 599 - 1,919 |
| erec8mov04 | DOWN | 20 | 177 | 599 - 1,919 |
| erec8mov05 | UP | 40 | 177 | 1,919 - 599 |
| erec8mov06 | DOWN | 60 | 177 | 599 - 1,919 |
| erec8mov07 | DOWN | 20 | 127 | 600 - 1,920 |
| erec8mov08 | UP | 40 | 127 | 1,920 - 599 |
| erec8mov09 | DOWN | 60 | 127 | 599 - 1,920 |
| erec8stat01 | Stationary | 0 | 66 | 1,600 |
| erec8stat02 | Stationary | 0 | 66 | 1,200 |
| erec8stat03 | Stationary | 0 | 66 | 660 |
| erec8stat04 | Stationary | 0 | 177 | 1,600 |
| erec8stat05 | Stationary | 0 | 177 | 1,200 |
| erec8stat06 | Stationary | 0 | 177 | 660 |
| erec8stat07 | Stationary | 0 | 127 | 1,600 |
| erec8stat08 | Stationary | 0 | 127 | 1,200 |
| erec8stat09 | Stationary | 0 | 127 | 660 |

fpm - Feet per minute
gpm - Gallons per minute
ft bgs - Feet below ground surface

measured surface discharge to provide the necessary coefficients to calculate the discharge at any depth in the well as a function of impeller response and logging speed.

### *3.1.3 Calibration of the Borehole Flowmeter in the Well*

The borehole flowmeter measures the velocity of water movement via an impeller that spins in response to water moving past it. Typically, the flowmeter is calibrated in the laboratory, under controlled conditions to establish a calibration between the impeller response and discharge. The calibration is specific to a certain size pipe and may be different if flow is moving upward or downward through the meter. Hufschmeid (1983) observed significant differences between the meter response to upward and downward flow and established separate calibration equations for those two conditions. Rehfeldt et al. (1989) also observed different flowmeter responses to upward and downward flow, but the differences were not significant enough to warrant separate calibration equations.

The borehole flowmeter was calibrated in the well to define a calibration equation specific to the well. This is necessary because the meter response may vary from well to well due to: (1) slight changes in the condition of the bearings that support the impeller; (2) differences in the physical characteristics of the fluid (density and viscosity) in the well that may vary from well to well due to temperature, dissolved gasses, or suspended solids content; (3) variations in the roughness or diameter of the well pipe; (4) slight variations in the position of the flowmeter relative to the center line of the well; and (5) variations in water flow in the well and the trolling speed of the flowmeter, which may vary among logging runs and affect the flowmeter response. To account for all these variations, the flowmeter is calibrated in the well. The calibration procedure and results are presented in this section.

#### *3.1.3.1 Calibration Procedure*

The flowmeter calibration procedure includes preparation of the calibration data and identification of the calibration equation and associated uncertainty.

The well is constructed with 60-ft of blank pipe above the uppermost screen. The pump is located above the blank section; therefore, the flow rate in the upper blank section should be the same as the discharge from the well. For each of the pumping rate and line speed combinations, the flowmeter response is recorded at 0.2-ft intervals along the length of the well including the blank section above the uppermost screen. To avoid end effects, the data observed from a 40-ft interval centered between the ends of the blank section are used to determine the calibration.

***Data Preparation***

Preparation of the flowmeter calibration data includes the following steps:

- Import the data into a spreadsheet and sort by depth
- Adjust the flow log depths
- Identify the blank intervals
- Extract the data above the top screen for use in the calibration

The flowmeter data, provided in ASCII format as a function of depth, are imported to Excel™. Some of the logging runs are made top to bottom, while others are bottom to top. To maintain consistency, each file is sorted to portray the data from top to bottom.

Differences in depth reporting equipment leads to errors in reported depths for the logging runs. An effort is made to correct logging depths to match the official well construction diagrams. Typically, this is performed by differentiating the log profile to identify locations where flow rates are changing rapidly. Such changes correspond to changes in the internal diameter of the well such as at the crossover, or to the boundaries of inflow. For simplification purposes, it was assumed that boundaries of inflow are located at the ends of the screens, which may not be correct in every case. However, considering the analysis method used, the impact of this assumption on the results would be negligible.

The flowmeter depths recorded for Well ER-EC-8 were adjusted to ensure that the flowmeter response corresponded to the well construction log. The top and bottom of blank and screened intervals were identified in the flowmeter logs by plotting the rate of change of flow rate versus depth, and recording the locations where flow rate was changing. These depths were compared with the top and bottom of pipe sections in the construction log. Then, the depth of the center of each section was calculated and compared between the two logs. The depth correction to match the flowmeter and construction logs was determined from the average difference in the center depth of blank and screened sections.

Figure 3-4 shows the differential flow log of the well corresponding to flow log erec8mov05, from depths 599.8 to 1,911.2 ft. This depth interval contains the blank casing above the first screen but below the crossover. Each peak on the curve shown in Figure 3-4 represents a change in flowmeter response, which corresponds to a transition from one type of interval to another. For example, the transition from the larger casing to the nominal 5.5-in. casing is clearly visible at a depth of 621 ft. The transition from the upper blank casing to the upper screen is also apparent at depths of 684.2 ft. Likewise, the transition from the upper screen to the second blank casing section is apparent at a depth of 741 ft. This process was performed for the top blank section and for the interval comprised of the upper screen and the lower blank casing section for each logging run. The depth of the midpoint for each of these intervals from the flow log was compared with the midpoint of the same interval from the construction diagram. A depth correction to match the flowmeter and construction logs was determined from the average differences in the center depth of the two intervals. The calculated depth correction was +0.28 ft. This process ensures that the appropriate depth intervals of the flow log are analyzed.

Following depth correction, a 40-ft long section of the borehole flow log data (impeller revolutions per second, line speed, and surface discharge) in the blank section above the uppermost screen were extracted from each of the six borehole flowmeter logging runs and from the three logging runs where the flowmeter was held stationary in the blank section while the well was pumped (stationary runs 3, 6, and 9).

***Calibration Equation and Uncertainty***

Identification of the calibration equation and associated uncertainty includes the following analyses:

1. Determination of a calibration equation that relates the borehole flow rate to the flowmeter response and the line speed

2. Estimation of uncertainty using the calibration equation to determine a lower detection limit for the flowmeter

A calibration equation was derived from the data described above in two steps. The first step consisted of a multiple linear regression on the calibration dataset using the flowmeter response rev/sec as the dependent variable and the line speed (fpm) and flow rate (gpm) as the independent variables. The second step consisted of expressing the flow rate as a function of the flowmeter response and the line speed by rearranging the equation used to regress the calibration data. The multiple linear regression approach in this work was chosen to provide a method by which the accuracy of the calibration could be quantified.

In this report, the equation used to regress the calibration data is of the form:

$$f = a + b_1\, Q + b_2 L_s \tag{3-1}$$

where:

| | | |
|---|---|---|
| f | = | Impeller frequency of revolution (rev/sec) |
| Q | = | Flow rate (gpm) |
| $L_s$ | = | Line speed (fpm) |
| a | = | Constant |
| $b_1$ and $b_2$ | = | Coefficients for the two independent variables |

This equation is solved by multiple linear regression of the flow log calibration data. The use of equation (3-1) is advantageous in the multiple linear regression because Q and $L_s$ are statistically independent which is desirable in regression analysis.

The equation expressing flow rate as a function of flowmeter response and line speed is then derived by rearranging equation (3-1) as follows:

$$Q = c + d_1\, f + d_2 L_s \tag{3-2}$$

where:

| | | |
|---|---|---|
| c | = | $-a/b_1$ |
| $d_1$ | = | $1/b_1$ |
| $d_2$ | = | $-b_2/b_1$ |

The primary advantage of the multiple regression approach is the ability to estimate the prediction error at any point in the response surface. For a given multiple regression on n data points where y is a variable that is dependent on k independent variables noted $x_i$, for i=1 to k, the confidence interval for a specific predicted value of y given specific values of the $x_i$ may be calculated using the following equation (Hayter, 1996):

$$\left(\hat{y}\big|_{x^*} - t_{\alpha/2,n-k-1}\,\mathrm{s.e.}(\hat{y}\big|_{x^*} + \varepsilon),\ \hat{y}\big|_{x^*} + t_{\alpha/2,n-k-1}\,\mathrm{s.e.}(\hat{y}\big|_{x^*} + \varepsilon)\right)$$

(3-3)

where the standard error, $\mathrm{s.e.}(\hat{y}\big|_{x^*} + \varepsilon)$, for the case of a single predicted value is given by:

$$\mathrm{s.e.}(\hat{y}\big|_{x^*} + \varepsilon) = \hat{\sigma}\sqrt{1 + x^{*\prime}(X'X)^{-1}x^*}$$

(3-4)

and

| | | |
|---|---|---|
| $\hat{\sigma}$ | = | Root mean sum of errors between the predicted and measured flow values |
| X | = | Matrix of entries that include the number of data points, sums of variables, sums of squared variables, and sums of cross terms |
| $x^*$ | = | Vector of independent variables with specific values 1, $x_1$*, $x_2$* where the confidence interval is to be estimated |
| $t_{\alpha/2,n-k-1}$ | = | Students' t-statistic at the α level of significance and n-k-1 degrees of freedom |
| n | = | Number of data points |
| k | = | Number of independent variables |

The prediction of a specific value of y given specific values of the independent variables is more uncertain than the mean y calculated by the regression equation. The prediction uncertainty is a function of how well the regression equation fits the data (the root mean sum of errors), the distance of the specific independent variable values from their means, and the number of data points which influences the value of the t-statistic and the X matrix.

Although equation (3-2) is not solved directly by multiple linear regression, it may be used to calculate downhole flow rates (Q) for each pair of measured flowmeter response and line speed of the calibration dataset. The standard error associated with equation (3-2) may then be calculated using the corresponding root mean sum of errors. The confidence interval for each predicted downhole flow rate is then calculated using equation (3-3). The confidence interval is important because it may be used to represent the bounding error on a given flowmeter measurement.

### 3.1.3.2 Calibration Results

The calibration dataset consisted of 2,706 data points. Each data point consists of discrete measurements of line speed (fpm) and flow rates (gpm) (as discharge measurement recorded at the land surface), and a corresponding measurement of flowmeter response (rev/sec).

Table 3-2 contains the values of the coefficients in equations (3-1) and (3-2), the regression model correlation coefficients, and the standard error, which is the root mean square of the predicted minus the observed discharge. In addition to the correlation coefficients and the equation coefficients, Table 3-2 contains the 95 percent confidence intervals for flow rates calculated using specific pairs of flowmeter response and line speed. The 95 percent confidence interval determined for specific pairs of flowmeter response and line speed that produced predicted discharge near zero provides an estimate of the measured discharge that is statistically indistinguishable from zero. As shown in Table 3-2, the confidence interval is less than 1.72 gpm. Measured flow rates less than 1.72 gpm are considered statistically indistinguishable from zero.

An argument against the flowmeter calibration approach described above is the concern that discharge measured at the land surface at a time, t, may not represent the instantaneous conditions recorded downhole by the flowmeter at that same time. To evaluate this source of uncertainty, a second approach could be used to derive a flowmeter calibration equation using the flow-logging data. In this method, the calibration dataset consists of values of the surface discharge, the line speed, and the flowmeter response averaged over the length of the blank section, or over time in the case of the stationary measurements and the surface discharge. The averaged-data approach is conceptually appealing because it eliminates the assumption of a direct link between a downhole response and surface discharge at the same instant in time. However, this approach has a major drawback, it greatly reduces the number of data points.

The averaged-data approach could not be used for Well ER-EC-8 because of the limited number of logging runs (9). After averaging along the section of blank casing used for flowmeter calibration, only nine data points corresponding to each of the logging runs would remain for use in the multiple regression. This number is too small to yield reliable results. This method was, however, used for Well ER-EC-1, the dataset was reduced to 14 sets of measurements which were used to derive a second calibration equation. The regression coefficients derived from the detailed and reduced datasets were nearly identical. The calculated flow rates using the coefficients from the two methods differed by less than 0.2 gpm over the entire range of values. The primary difference was that the confidence interval near the zero discharge prediction was narrower for the full dataset than when average values were used. Based on the case of Well ER-EC-1, it will be assumed that the time lag between the discharge measured at the land surface and the flow recorded by the flowmeter for Well ER-EC-8 has a negligible impact on the flowmeter calibration.

### 3.1.4 Calculation of Flow in the Well as a Function of Depth

Following calibration of the flowmeter, the flowmeter readings were converted to flow rates using the calibration equation (3-2) and the coefficients obtained using the full dataset (Table 3-2). For each moving flow log, each depth where a

**Table 3-2**
**Flowmeter Calibration Results Using all Data**
**Collected Above the Top Screen at Well ER-EC-8**

| **Equations 3-1 and 3-2 Solutions** | | |
|---|---|---|
| | **Equation 3-1** | **Equation 3-2** |
| Constant (a and c) | -0.0139 | 0.6276 |
| First dependent variable (b1 and d1) | 0.0221 | 45.1664 |
| Second dependent variable (b2 and d2) | -0.0217 | 0.9790 |
| Multiple R | 0.9999 | - |
| Sum of Squared Errors | 1.0126 | 2065.6367 |
| Standard Error | 0.0194 | 0.8742 |
| Number of Observations | 2706 | 2706 |

| **95 Percent Confidence Interval for Flow Rates Near Zero Based on Equation 3-2** | | | |
|---|---|---|---|
| **Flow Logging Run** | **Impeller Rate (rev/sec)** | **Line Speed (fpm)** | **Confidence Interval[a] (gpm)** |
| erec8mov01 | 0.493 | -22.01 | 1.72 |
| erec8mov02 | -0.908 | 41.258 | 1.72 |
| erec8mov03 | 1.37 | -63.027 | 1.72 |
| erec8mov04 | 0.477 | -21.649 | 1.72 |
| erec8mov05 | -0.873 | 41.094 | 1.72 |
| erec8mov06 | 1.393 | -64.597 | 1.72 |
| erec8mov07 | 0.489 | -21.626 | 1.72 |
| erec8mov08 | -0.904 | 41.157 | 1.72 |
| erec8mov09 | 1.39 | -64.388 | 1.72 |

Notes: Impeller rate and line speed values were taken from depths ranging between 1,900 and 1,910 ft below ground surface, corresponding to low flow rates measured for this well.

[a]Confidence interval is calculated using equation (3-3) and represents half of the full range of the uncertainty. This confidence interval was used to represent the error associated with low flow rate measurements.

flowmeter response and line speed were recorded, the values were inserted into equation (3-2), with the coefficient values provided in Table 3-2, and the flow rate in the well at that depth was calculated. This generated the flow log values used for later analysis.

### 3.1.5 Resolution Effects of Well Construction

The physical construction of the screens and the limited screen length within the completion interval defined by the gravel pack results in several limitations for resolving the origin of inflow from the aquifer. The slotting (3-in. slots, 18 per row) for each screen starts 2.5-ft on-center from the end of the casing joint, leaving 5-ft of unslotted casing between 25-ft lengths of closely spaced rows of slots (6-in. on-center). Also, the gravel pack extends a substantial distance beyond the ends of the screen. The drawdown imposed by pumping is distributed in some manner throughout the gravel pack and stresses the aquifer behind the blank casing. However, there is no way of accurately determining the distribution of inflow behind the blank casing. Some qualitative interpretation may be attempted by evaluating the increase in production at the edges of each screen on the flow logs and attributing some of that production to vertical flow from behind the blank casing, but this is very speculative. The hydraulics of vertical flow in the gravel pack and end effects for the screens are undefined. The main impact of this situation is the uncertainty in determining the appropriate thickness of the aquifer to use in calculations of hydraulic conductivity.

## 3.2 Well Losses

The drawdown observed in the well is comprised of aquifer drawdown and well losses resulting from the flow of water into the well and up to the pump. Aquifer drawdown can be observed directly in observation wells near a pumping well, but such wells were not available near Well ER-EC-8. The step-drawdown test analysis was used to determine the laminar and turbulent losses, and the laminar losses were attributed to aquifer drawdown. Flow losses inside the well were calculated independently, and subtracted from the turbulent losses to evaluate flow losses into the well. This breakdown of the total drawdown into its components provides better understanding of the hydraulics of water production and better estimates of aquifer properties. While there are some uncertainties in the accurate determination of the components of the drawdown, the calculated component values are better estimates of the actual values than the gross drawdown. This analysis provides more accurate results and reveals details of the hydraulics of production.

### 3.2.1 Step-Drawdown Test

The final step-drawdown test conducted prior to flow logging was analyzed according to the method of Jacob (Driscoll, 1986) using the Hantush-Bierschenk methodology (Kruseman and de Ridder, 1990). The assumptions and conditions for applying this analysis are: (1) the aquifer is confined, seemingly infinite in extent, homogeneous, isotropic, and of uniform thickness; (2) the initial piezometric surface is horizontal; (3) the well is fully penetrating and the well receives water through horizontal flow; (4) the well is pumped step-wise at increasing rates; (5) flow to the well is unsteady; and (6) non-linear well losses are appreciable and vary according to $Q^2$. While the assumptions and conditions about the aquifer and flow in the aquifer are not perfectly satisfied, it is believed that they were sufficiently satisfied during the step-drawdown test to provide a reasonable result. The test was conducted according to the required protocol.

The left side of Table 3-3 shows the basic data derived from the step-drawdown test, and Figure 3-5 shows the resultant graph of that data with the equation for the trendline. The coefficients of the trendline are substituted in the equation for losses, in the form of $s_w = BQ_n + CQ_n^2$ where $s_w$ is the total drawdown in the well, $Q_n$ is the net production rate, B is the linear loss coefficient, and C is the nonlinear loss coefficient. Evaluating this equation at the average production rate for the flow logging of 177 gpm gives a nonlinear component of about 9 ft**,** which is generally equated to turbulent losses in the well. The turbulent losses include flow losses from the aquifer into the wellbore (skin losses), entrance losses into the well casing through the screen slots, and flow losses up the casing to the pump. The linear component of the losses are generally considered to be the laminar losses of the flow in the aquifer. The predicted losses for all three flow logging pumping rates are tabulated in Table 3-3. It is recognized that this approach to determining total well losses for a single well test is not perfectly accurate, but it is believed to provide a reasonable estimate of the well losses. The results are used to estimate the aquifer drawdown, and this drawdown value is used to calculate hydraulic conductivity for each of the screens. This was particularly significant for this well because the calculated well losses are a large fraction (almost 60 percent) of the total drawdown.

**Table 3-3**
**Step-Drawdown Results and Application**

| Duration Days | Ave Pumping Rate - Q (gallons per minute) | Drawdown $s_w$ (feet) | $s_w/Q$ | Flow Logging Pumping Rate (gallons per minute) | Predicted $s_w$ (feet) | Laminar Losses (feet) | Turbulent Losses (feet) |
|---|---|---|---|---|---|---|---|
| 0.063 | 65.70 | 3.63 | 0.055 | 65.7 | 3.63 | 2.43 | 1.23 |
| 0.062 | 120.96 | 8.80 | 0.073 | 127.21 | 9.25 | 4.70 | 4.63 |
| 0.060 | 176.96 | 15.41 | 0.087 | 177.09 | 15.42 | 6.54 | 8.97 |

### *3.2.2 Flow Losses*

Flow losses inside the well casing were computed based on standard theory of flow in a pipe using the Darcy-Weisbach equation. Losses through the slotted sections were assigned friction factors double those of blank pipe (Roscoe Moss Company, 1990). Table 3-4 presents a tabulated profile of calculated friction losses showing the cumulative loss at various locations down the well from the pump intake. The flow rates attributed to each screen section of the well were the average of the inflows from the flow logs that were conducted at pumping rates of about 177.1 gpm. These losses are associated with the flow of water up the well, and are only affected by the flow rate at each point where the loss is tabulated.

**Table 3-4**
**Calculated Flow Losses**

| Location in Well | Flow at Location (gpm) | | | Cumulative Friction Loss Inside Casing (ft) | | | Incremental Flow Losses Into Casing Per Screen (ft) | | | Total Flow Losses at Center of Screen (ft) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Step 1 | Step 2 | Step 3 | Step 1 | Step 2 | Step 3 | Step 1 | Step 2 | Step 3 | Step 1 | Step 2 | Step 3 |
| Pump Intake | 65.7 | 127.2 | 177.1 | | | | | | | | | |
| Bottom of Pump Motor | 65.7 | 127.2 | 177.1 | 0.040 | 0.128 | 0.229 | | | | | | |
| Btm of 7 5/8-in. Casing - Top of Crossover | 65.7 | 127.2 | 177.1 | 0.055 | 0.177 | 0.318 | | | | | | |
| Crossover | 65.7 | 127.2 | 177.1 | 0.110 | 0.354 | 0.636 | | | | | | |
| Top of Screen 1 | 65.7 | 127.2 | 177.1 | 0.114 | 0.369 | 0.665 | 0.428 | 1.821 | 3.642 | 0.58 | 2.31 | 4.54 |
| Bottom of Screen 1 | 28.2 | 52.9 | 73.9 | 0.190 | 0.615 | 1.108 | | | | | | |
| Top of Screen 2 | 28.2 | 52.9 | 73.9 | 0.196 | 0.634 | 1.141 | 0.603 | 2.142 | 4.082 | 0.80 | 2.79 | 5.25 |
| Bottom of Screen 2 | 5.9 | 12.7 | 19.3 | 0.205 | 0.659 | 1.181 | | | | | | |
| Top of Screen 3 | 5.9 | 12.7 | 19.3 | 0.205 | 0.661 | 1.190 | 0.010 | 0.039 | 0.095 | 0.21 | 0.70 | 1.29 |
| Bottom of Screen 3 | 3.1 | 7.3 | 11.0 | 0.206 | 0.663 | 1.195 | | | | | | |
| Top of Screen 4 | 3.1 | 7.3 | 11.0 | 0.208 | 0.663 | 1.196 | 0.000 | 0.001 | 0.003 | 0.21 | 0.66 | 1.20 |
| Bottom of Screen 4 | 2.9 | 6.4 | 9.5 | 0.206 | 0.664 | 1.198 | | | | | | |
| Top of Screen 5 | 2.9 | 6.4 | 9.5 | 0.206 | 0.665 | 1.199 | 0.001 | 0.003 | 0.009 | 0.21 | 0.67 | 1.21 |
| Bottom of Screen 5 | 2.0 | 4.8 | 6.9 | 0.206 | 0.665 | 1.200 | | | | | | |
| Top of Screen 6 | 2.0 | 4.8 | 6.9 | 0.207 | 0.669 | 1.208 | 0.000 | 0.000 | 0.000 | 0.21 | 0.67 | 1.21 |
| Bottom of Screen 6 | 1.9 | 4.3 | 6.2 | 0.207 | 0.670 | 1.209 | | | | | | |
| Top of Screen 7 | 1.9 | 4.3 | 6.2 | 0.207 | 0.671 | 1.211 | 0.000 | 0.000 | 0.001 | 0.21 | 0.67 | 1.21 |
| Bottom of Screen 7 | 1.4 | 3.7 | 5.5 | 0.208 | 0.672 | 1.212 | | | | | | |
| Top of Screen 8 | 1.4 | 3.7 | 5.5 | 0.208 | 0.672 | 1.212 | 0.000 | 0.001 | 0.003 | 0.21 | 0.67 | 1.22 |
| Bottom of Screen 8 | 1.0 | 2.8 | 4.0 | 0.208 | 0.672 | 1.213 | | | | | | |
| Top of Screen 9 | 1.0 | 2.8 | 4.0 | 0.208 | 0.672 | 1.213 | 0.001 | 0.000 | 0.000 | 0.21 | 0.67 | 1.21 |
| Bottom of Screen 9 | 1.7 | 2.5 | 3.8 | 0.208 | 0.672 | 1.213 | | | | | | |
| Top of Screen 10 | 1.7 | 2.5 | 3.8 | 0.208 | 0.672 | 1.214 | 0.004 | 0.008 | 0.019 | 0.21 | 0.68 | 1.23 |
| Bottom of Screen 10 | 0 | 0 | 0 | | | | | | | | | |

Blank = Not applicable

The flow rates at each point of tabulation for the well screens should have been fairly stable since the well had been pumping for some time and the drawdown did not increase substantially during the period of logging. For the best applicability of flow logging data, flow logging should take place only after sufficient continuous pumping at each rate to achieve relatively stable drawdown.

For all three flow logging pumping rates, the component of turbulent losses for flow into the well casing were calculated by subtracting the flow losses inside the casing from the total turbulent losses tabulated in Table 3-3. The turbulent losses for flow into the well casing were then apportioned according to the flow through each screen by the square of the velocity.

This analysis was done using the flow logging pumping rates for use in the flow logging analysis. However, the constant-rate test pumping rate, 176.4 gpm, was very close to the 177.1 gpm flow logging rate, and the calculated flow losses would be very similar for the constant-rate test.

## *3.3 Head Distribution Under Pumping*

The column in Table 3-4 labeled Cumulative Friction Loss Inside Casing tabulates the loss of head down the well casing due to flow up the casing. These values can be subtracted from the total measured drawdown to calculate the head at each tabulation point down the casing. For example, during the flow log runs at 177.1 gpm, the drawdown in the well would have been approximately 15.5 ft. This estimate is based on the equation derived from the step-drawdown test. During flow logging, the PXD was removed to allow access downhole, and drawdown could not be measured directly. At this time, the drawdown in the casing at the top of the first screen would have been about 14.83 ft (15.50-0.67), and the drawdown at the top of the second screen would have been about 14.34 ft. The column labeled Total Flow Losses at Center of Screen provides the total calculated flow loss from the aquifer into the casing and up to the pump intake. Subtracting this value from the total drawdown gives the aquifer drawdown at the center of each screen. The average drawdown for the flow inside casing across the first screen would have been about 10.96 ft (15.50-4.54). The calculated total friction loss inside casing is 1.23 ft, a small part of the turbulent losses of 8.97 ft calculated from the equation derived from the step-drawdown data. The losses from flow through the slots (calculated as approximately 0.6 ft assuming they are 100 percent open) accounts for only a small fraction of the remaining losses. The greater part of the turbulent losses is attributed to borehole losses, either due to damaged borehole wall or clogged gravel pack/screen slots. These losses can be equated to the high well skin factor determined in the constant-rate test analysis discussed in Section 3.4.

The purpose of these computations is to estimate the actual aquifer drawdown at each pumping rate for each screen. The flow loss values will be used in the flow logging analysis to calculate the hydraulic conductivity attributed to the production from each screen. This analysis shows that almost 60 percent of the measured drawdown results from flow losses in the well, and that the actual formation drawdown is only about 40 percent of the measured drawdown.

## 3.4 Constant-Rate Test Analysis

The constant-rate test provides data for determining the overall transmissivity of the well. The constant-rate test was analyzed using the AQTESOLV® program (HydroSOLVE, Inc., 1996-2002). The features of the record are explained in Section A.3.4.2 of Appendix A. The average pumping rate for the test was 176.4 gpm.

The Moench model for dual porosity (1984 [HydroSOLVE, Inc., 1996-2002]) in a fractured aquifer was used to simulate the aquifer response. This model is consistent with the known geology, and produces an equivalent or better solution fit. The assumptions and conditions for this model are: (1) the aquifer is confined, seemingly infinite in extent, homogeneous, isotropic, and of uniform thickness; (2) the initial piezometric surface is horizontal; (3) the well is fully penetrating and the well receives water through horizontal flow; (4) the well is pumped step-wise at increasing rates; (5) flow to the well is unsteady; (6) non-linear well losses are appreciable and vary according to $Q^2$; (7) water is released from storage instantaneously; and (8) the aquifer is fractured and acts as a dual-porosity system consisting of low conductivity primary porosity blocks and high conductivity secondary porosity fractures. While the assumptions and conditions about the aquifer and flow in the aquifer are not perfectly satisfied, it is believed that they were sufficiently satisfied during the step-drawdown test to provide a reasonable result. The assumption about the fracture nature of the formation is believed to be appropriate based on characterization of the formation during drilling.

This model has many parameters that interact and can produce a variety of solutions, especially without observation well data. In order to determine the most appropriate solution with respect to K (fracture hydraulic conductivity), values for K' (matrix hydraulic conductivity) and Ss and Ss' (fracture and matrix specific storage) were constrained as much as possible. Ranges of possible values for those parameters were determined based upon typical properties for the rock type. Specific storage values were based on typical porosity and compressibility values.

Figure 3-6 shows the type curve for a dual-porosity solution and the resultant parameter values using the extent of the gravel pack (878 ft) for the producing section of the upper completion interval for aquifer thickness. This solution yields a K of 2.93 ft/day with an associated T of 2,573 $ft^2$/d. Figure 3-7 shows a solution using the combined length of the producing screens (313.7 ft) rather than of the gravel pack for the aquifer thickness. This solution is very similar to the first solution, with a resultant K of 8.16 ft/day, yielding a T of 2,561 $ft^2$/d.

The difference in these two values for aquifer thickness represents the overall uncertainty in the length of formation producing water. Examination of the flow logs generally finds progressive increases in flow near the bottom and top of the slotted portion of the screens rather than sudden increases which might be expected as an indication of substantial production behind the blank casing. However, the flow distribution that would be observed across the screen if there was significant production coming vertically through the gravel pack has not been characterized in any calibrated fashion. Flow losses in the gravel pack have an effect on the applied distribution of drawdown to the formation. Very high localized production related to a fracture would result in a different situation from well-distributed production from porous media. The difference in the fracture hydraulic conductivities derived using the two different aquifer thicknesses will be used later in an analysis of the uncertainty in the derived hydraulic conductivities.

## 3.5 Interval Transmissivities/Conductivities

The flowmeter data provide a detailed assessment of the sections of the completion intervals producing water for determining the average hydraulic conductivity. In addition, the flowmeter data provide measurements to attribute varying production to the different screens. These data provide the basis for determining differences in hydraulic conductivity across different sections of the producing interval. This analysis will be used later in modeling flow in that aquifer.

### 3.5.1 The Borehole Flowmeter Method - Concept and Governing Equations

The borehole flowmeter measures the flow rate inside a well as a function of depth. When measurements are taken during pumping of the well, valuable information is obtained for interpreting the amount of water production coming from each screened interval of the geologic formation being tested. The basic concept and theory for interpreting borehole flowmeter logs is presented in Molz et al. (1989). Their work is based primarily on the previous work of Hufschmeid (1983) and Rehfeldt et al. (1989), who present detailed descriptions of the theory and application of the method.

Conceptually, as a well is pumped water enters the well along the screen length, and the amount of water flowing inside the well at any depth is a function of the water that has entered the well. In the typical case of a pump located above the well screen, the amount of water flowing in the well will vary from zero at the bottom of the well to the well production rate (Q) above the screened interval. The change in flow rate between any two depths in the well is the amount of water that has been produced from that interval of the well. If certain assumptions are made, this water production profile can be used to estimate the hydraulic conductivity of the aquifer as a function of depth.

After a period of time following the start of pumping, the flow to the well is assumed to be horizontal. Javandel and Witherspoon (1969) used a finite-element model to show that flow to a fully screened well in a confined layered aquifer eventually became horizontal and that the drawdown in each layer eventually follows the Theis solution. The work of Javandel and Witherspoon (1969) assumes a constant head boundary condition at the well which ignores the effects of head losses in the well, the screen, and the gravel pack. Nonetheless, the assumption of horizontal flow is necessary to derive an analytical solution to calculate depth-dependent hydraulic conductivity from the flow in the well.

For each vertical interval in the well, the Cooper and Jacob (1946) equation is assumed to govern the relationship between flow into the well and the aquifer parameters such that:

$$T_i = \frac{Q_i}{4\pi s_i} \ln\left[\frac{2.25 K_i b_i t}{r_w^2 S_i}\right] \tag{3-5}$$

where:

| | | |
|---|---|---|
| $K_i$ | = | Hydraulic conductivity of the interval |
| $b_i$ | = | Thickness of the interval |
| $T_i$ | = | Transmissivity of the interval and is defined by the product $K_i$*$b_i$ |
| $s_i$ | = | Drawdown in the aquifer for the interval |
| $Q_i$ | = | Amount of flow from the interval into the well as determined from the flowmeter measurements |
| $S_i$ | = | Storage coefficient for the interval |
| t | = | Time since pumping started |
| $r_w$ | = | Effective radius of the well |

In this form, the equation is difficult to use because the layer storage coefficient is unknown. Kabala (1994) proposed a double flowmeter method to simultaneously estimate $K_i$ and $S_i$, but later (Ruud and Kabala, 1996) suggested the double flowmeter method produces inaccurate storage values and should not be used. Hufschmeid (1983) and Rehfeldt et al. (1989) assumed that the layer storage coefficient could be defined as a portion of the full storage coefficient, weighted by the transmissivity of each layer.

$$S_i = S\frac{K_i b_i}{Kb} \tag{3-6}$$

where:

| | | |
|---|---|---|
| S | = | Storage coefficient of the entire aquifer |
| K | = | Average hydraulic conductivity of the aquifer |
| b | = | Total aquifer thickness |

This assumption amounts to a statement that the hydraulic diffusivity (T/S) of the aquifer is constant with depth. Substituting equation (3-6) into equation (3-5) leads to the equation for calculating the interval transmissivity as presented in Hufschmeid (1983) and Rehfeldt et al. (1989):

$$T_i = \frac{Q_i}{4\pi s_i} \ln\left[\frac{2.25Kbt}{r_w^2 S}\right] \qquad (3\text{-}7)$$

The terms within the natural logarithm of equation (3-7) are determined from the full well response and are not dependent on interval-specific values. Molz and Young (1993), Kabala (1994), and Ruud and Kabala (1996) question the constant hydraulic diffusivity assumption and suggest it is a source of significant interpretation errors. Molz et al. (1989) and Molz and Young (1993) suggest that one alternative approach is to simply rely on the work of Javandel and Witherspoon (1969), and define the interval transmissivity as a simple ratio of the interval flow such that:

$$K_i b_i = \frac{Q_i}{Q} Kb \qquad (3\text{-}8)$$

Molz and Young (1993) and Molz et al. (1989) fail to recognize that equation (3-8) can be obtained by dividing equation (3-7) by the Cooper-Jacob equation for the full aquifer thickness if one assumes, as did Javandel and Withspoon (1969), that the drawdown in the well (s) is the same as the layer drawdown ($s_i$). Therefore, equation (3-8) is merely a special case of equation (3-7) where the well losses are assumed to be zero. Molz et al. (1989) and Molz and Young (1993) do provide a second alternative approach based on the assumption that the specific storage is constant in the aquifer such that:

$$S_i = S\frac{b_i}{b} \qquad (3\text{-}9)$$

Substituting equation (3-9) into equation (3-5) leads to an equation for the interval transmissivity of the form:

$$T_i = \frac{Q_i}{4\pi s_i} \ln\left[\frac{2.25K_i bt}{r_w^2 S}\right] \qquad (3\text{-}10)$$

The only difference between equations (3-7) and (3-10) is the replacement of K with $K_i$ within the logarithmic term. It is not clear which, if either, storage assumption is correct. To account for uncertainty, hydraulic conductivities were calculated for each storage assumption using equation (3-8) (a special case of equation [3-7]) and equation (3-10).

### 3.5.2 Calculation Process to Determine Interval Hydraulic Conductivity Values

The steps for calculating the hydraulic conductivity of selected intervals in the well are presented in this section. The process begins with the determination of the average discharge for each screened section of well and ends with the calculation of the interval hydraulic conductivity. The steps are:

1. Selection of specific intervals in the well for which interval hydraulic conductivity is to be calculated.

2. Calculation of the interval hydraulic conductivity which is comprised of three main steps: (1) determine the average discharge for each blank section of well, then determine the total flow contributed by each section of well as the difference of flow in the blank sections above and below; (2) calculate the transmissivity of each screened section using the flowmeter derived flow and the drawdown in each section, corrected for well losses; and (3) determine the uncertainty in hydraulic conductivity values for each screen section resulting from uncertainty in drawdown and contributing thickness.

### 3.5.3 Selection of Depth Intervals to Calculate Hydraulic Conductivity

To determine the hydraulic conductivity of an interval, the interval must be defined by top and bottom depths so inflow to the well can be determined. Previous applications of the flowmeter method (Rehfeldt et al., 1989; Hufschmeid, 1983; and Molz et al., 1989) calculated hydraulic conductivity at small intervals within fully screened wells in unconfined aquifers. One criterion to determine the size of the interval is to assess the minimum interval necessary to ensure that a statistically significant amount of flow enters the well between one flowmeter measurement and the next. The confidence intervals determined from equation (3-2) suggest that the difference in discharge should be in excess of 2 gpm to be statistically significant. A criterion such as this would produce a variable interval depending on inflow, that might be as small as 0.2 ft or as large as 10 feet or more.

In partially-penetrating wells, or irregularly screened wells such as ER-EC-8, the horizontal flow assumption may not hold. Cassiani and Kabala (1998) examined flow to a partially-penetrating well in an anisotropic confined aquifer where wellbore storage and infinitesimal skin may be present. Their example showed the flux near the end of the well screen could be exaggerated more than several times compared with elsewhere along the screen. Previous work by Ruud and Kabala (1996, 1997b) also showed that the flux to partially penetrating wells in heterogeneous aquifers can be significantly nonuniform and is a function of the hydraulic conductivity contrast of the adjacent layers. Ruud and Kabala (1997a) also examined the flow to a well in a layered aquifer with a finite skin zone. For their examples, they showed that the horizontal flow assumption inherent in the flowmeter analysis was violated and led to incorrect estimates of interval hydraulic conductivity values. The errors associated with violation of the horizontal flow assumption increase as the layer size decreases (i.e., the smaller the measurement interval). Another factor that may lead to errors is the head loss associated with flow through the borehole flowmeter itself. Ruud et al. (1999) show that head loss caused by the flowmeter can force water to flow in the gravel pack outside the well and can lead to errors in measured flow.

For the WPM-OV wells where alternating screen and blank sections are present, the errors in estimated K values may be substantial if the analysis interval is too small. To avoid the need to quantify the potential errors for the WPM-OV wells, the decision was made to interpret the flowmeter response for each screened interval that produced statistically measurable flow. As stated before, Well ER-EC-8 has ten screened intervals. Each screened interval is composed of a slotted section of pipe with slots beginning about 2.5 feet from both ends. The approximate lengths of these intervals are either 25 or 55 ft. Hydraulic conductivity values averaged over these slotted intervals are expected to provide adequate vertical resolution for the CAU-scale and sub CAU-scale models.

### 3.5.4 Calculation of Hydraulic Conductivity of Each Interval

The transmissivity of each interval is calculated using equations (3-8) and (3-10) prior to determining the hydraulic conductivity. The data requirements and the procedure are described.

#### 3.5.4.1 Data Requirements

For a given pumping rate (Q), Equations (3-8) and (3-10) require a number of parameters to calculate interval transmissivities. These parameters include the following:

- Interval flow rates ($Q_i$)
- Term $r_w^2 S$ .
- Drawdowns (sw and $s_i$) at selected times (t)
- Formation transmissivity
- Interval transmissive thicknesses ($b_i$)

Descriptions of each of these parameters are provided in the following text.

***Interval Flow Rates ($Q_i$)***

The quantities of inflow from each interval may be calculated from the flow in the well measured in the blank casing sections above and below each screen. The average discharges through the blank sections were determined for the portions of pipe centered between the ends of the blank section. This corresponds to lengths of 20 to 40 ft. The average discharge values are tabulated in Table 3-5 for the blank sections and in Table 3-6 for the screens numbered one through ten, beginning with the uppermost intervals. Since flow rates were not recorded for the deepest blank casing section below the lower screen of Well ER-EC-8, they were assumed to equal zero for all flow logs.

Hydraulic conductivity will be calculated only for screens for which flow rates extracted from reliable flow logs exceed 1.72 gpm. As seen in Table 3-5 and Table 3-6 several flow rates observed in Well ER-EC-8 are unreliable or are statistically equal to zero (less than 1.72 gpm). For example, flow rates calculated using the erec8mov01 flow log are considered to be unreliable for all screened intervals, except the top three. Screens 4, 6, 7, and 8 produced flow rates less than 1.72 gpm for all moving flow logs. Although, the rate for Screen 4 for the first moving flow log (Table 3-6) is greater than 1.72 gpm, it is unreliable. Producing screened intervals are 1, 2, 3, 5, 9, and 10. The top three screened intervals of Well ER-EC-8 (1, 2, and 3) produced measurable flow (greater than 1.72 gpm) for all moving flow logs. Screen 5 produced measurable flow only at the highest pumping rate of 177 gpm (flow logging runs 4, 5, and 6). Screens 9 and 10 produced measurable flow at the higher pumping rates of 127 and 177 gpm for flow logging runs 4 through 7 and run 9.

***The Term*** $r_w^2 S$.

The product $r_w^2 S$ is required in equation (3-10) and may be estimated using the Cooper-Jacob equation and data from the constant-rate test.

The Cooper-Jacob (1946) equation for flow to a well can be rearranged to produce:

$$\frac{1}{r_w^2 S} = \frac{1}{2.25Tt} \exp\left[\frac{4\pi sT}{Q}\right] \tag{3-11}$$

where:

| | | |
|---|---|---|
| Q | = | Discharge from the well |
| T | = | Transmissivity |
| s | = | Drawdown in the aquifer at the effective radius of the well |
| S | = | Storage coefficient |
| t | = | Time the drawdown was measured |

Using equation (3-11) and known values of Q and T, it is possible to determine an approximate value of the product $r_w^2 S$ for any given time t.

Formation and Interval Drawdowns (s and $s_i$)

**Table 3-5**
**Average Flow Rates Through the Blank-Casing Sections in gpm During the Flow Logging Runs of Well ER-EC-8**

| Pumping Rate = 66 gpm | | | | |
|---|---|---|---|---|
| **Blank Number** | **mov01** | **mov02** | **mov03** | **Average**[a] |
| 1 | 65.81 | 65.64 | 65.75 | 65.70 |
| 2 | 27.84 | 28.51 | 27.81 | 28.16 |
| 3 | 6.74 | 4.89 | 6.97 | 5.93 |
| 4 | 4.10 | 2.25 | 3.99 | 3.12 |
| 5 | -18.57 | 1.86 | 3.95 | 2.91 |
| 6 | 1.11 | 0.73 | 3.33 | 2.03 |
| 7 | 2.57 | 0.65 | 3.20 | 1.92 |
| 8 | 2.35 | 0.62 | 2.26 | 1.44 |
| 9 | 1.31 | 0.19 | 1.89 | 1.04 |
| 10 | 1.33 | 1.12 | 2.30 | 1.71 |
| **Pumping Rate = 177 gpm** | | | | |
| **Blank Number** | **mov04** | **mov05** | **mov06** | **Average** |
| 1 | 176.75 | 177.47 | 177.03 | 177.09 |
| 2 | 73.60 | 73.54 | 74.45 | 73.86 |
| 3 | 18.89 | 18.60 | 20.44 | 19.31 |
| 4 | 10.82 | 10.17 | 11.99 | 10.99 |
| 5 | 9.31 | 8.55 | 10.48 | 9.45 |
| 6 | 6.95 | 5.45 | 8.35 | 6.92 |
| 7 | 6.52 | 4.75 | 7.33 | 6.20 |
| 8 | 6.00 | 4.34 | 6.22 | 5.52 |
| 9 | 4.28 | 2.59 | 5.17 | 4.01 |
| 10 | 3.83 | 2.62 | 4.83 | 3.76 |
| **Pumping Rate = 127 gpm** | | | | |
| **Blank Number** | **mov07** | **mov08** | **mov09** | **Average** |
| 1 | 127.70 | 127.05 | 126.89 | 127.21 |
| 2 | 52.77 | 52.90 | 53.12 | 52.93 |
| 3 | 12.84 | 11.83 | 13.49 | 12.72 |
| 4 | 7.50 | 6.19 | 8.15 | 7.28 |
| 5 | 7.00 | 5.06 | 7.17 | 6.41 |
| 6 | 5.33 | 3.16 | 5.99 | 4.83 |
| 7 | 4.84 | 2.37 | 5.54 | 4.25 |
| 8 | 4.48 | 2.17 | 4.39 | 3.68 |
| 9 | 3.68 | 1.29 | 3.43 | 2.80 |
| 10 | 3.43 | 0.76 | 3.27 | 2.49 |

[a]Average excludes erec8mov01 measurements.

**Table 3-6**
**Average Flow Rates Through the Screened Sections in gpm During the Flow Logging Runs of Well ER-EC-8**

| Pumping Rate = 66 gpm | | | | |
|---|---|---|---|---|
| **Screen Number** | **mov01** | **mov02** | **mov03** | **Average[a]** |
| 1 | 37.97 | 37.13 | 37.94 | 37.54 |
| 2 | 21.10 | 23.63 | 20.83 | 22.23 |
| 3 | 2.64 | 2.64 | 2.98 | 2.81 |
| 4 | 22.67 | 0.40 | 0.04 | 0.22 |
| 5 | -19.68 | 1.13 | 0.62 | 0.88 |
| 6 | -1.46 | 0.08 | 0.13 | 0.11 |
| 7 | 0.22 | 0.03 | 0.94 | 0.48 |
| 8 | 1.04 | 0.43 | 0.37 | 0.40 |
| 9 | 1.31 | 0.19 | 1.89 | 1.04 |
| 10 | 1.33 | 1.12 | 2.30 | 1.71 |
| **Pumping Rate = 177 gpm** | | | | |
| **Screen Number** | **mov04** | **mov05** | **mov06** | **Average** |
| 1 | 103.16 | 103.94 | 102.58 | 103.22 |
| 2 | 54.70 | 54.94 | 54.02 | 54.55 |
| 3 | 8.07 | 8.43 | 8.45 | 8.32 |
| 4 | 1.51 | 1.62 | 1.51 | 1.54 |
| 5 | 2.36 | 3.11 | 2.13 | 2.53 |
| 6 | 0.44 | 0.70 | 1.02 | 0.72 |
| 7 | 0.51 | 0.42 | 1.11 | 0.68 |
| 8 | 1.72 | 1.74 | 1.05 | 1.51 |
| 9 | 4.28 | 2.59 | 5.17 | 4.01 |
| 10 | 3.83 | 2.62 | 4.83 | 3.76 |
| **Pumping Rate = 127 gpm** | | | | |
| **Screen Number** | **mov07** | **mov08** | **mov09** | **Average** |
| 1 | 74.93 | 74.14 | 73.77 | 74.28 |
| 2 | 39.94 | 41.08 | 39.63 | 40.21 |
| 3 | 5.34 | 5.64 | 5.34 | 5.44 |
| 4 | 0.50 | 1.13 | 0.98 | 0.87 |
| 5 | 1.67 | 1.90 | 1.19 | 1.58 |
| 6 | 0.49 | 0.80 | 0.44 | 0.58 |
| 7 | 0.37 | 0.20 | 1.16 | 0.57 |
| 8 | 0.80 | 0.88 | 0.96 | 0.88 |
| 9 | 3.68 | 1.29 | 3.43 | 2.80 |
| 10 | 3.43 | 0.76 | 3.27 | 2.49 |

[a]Average excludes erec8mov01 measurements.

The formation drawdown is the drawdown observed at a given time t since pumping began at a given pumping rate Q, adjusted for well flow losses. Well flow losses were calculated using an average of the "Total Flow Losses at Center of Screen" presented in Table 3-4 weighted by the intervals' flow rates (Table 3-7). These weighted average well flow losses were substracted from the total drawdown to obtain an estimate of the formation drawdown for each pumping rate.

**Table 3-7**
**Calculation of Average Well Losses For Each Pumping Rate**
(Page 1 of 2)

| **Q = 66 gpm** | | | |
|---|---|---|---|
| **Screen** | **(1) Flow Rate into Well (gpm)** | **(2) Total Flow Losses at Center of Screen (ft)** | **(1) X (2)** |
| Screen 1 | 37.68 | 0.58 | 21.85 |
| Screen 2 | 21.85 | 0.8 | 17.48 |
| Screen 3 | 2.75 | 0.21 | 0.58 |
| Screen 4 | 7.70 | 0.21 | 1.62 |
| Screen 5 | -5.98 | 0.21 | -1.25 |
| Screen 6 | -0.42 | 0.21 | -0.09 |
| Screen 7 | 0.39 | 0.21 | 0.08 |
| Screen 8 | 0.61 | 0.21 | 0.13 |
| Screen 9 | 1.13 | 0.21 | 0.24 |
| Screen 10 | 1.58 | 0.21 | 0.33 |
| Total Flow | 67.32 | | |
| Weighted Average Flow Loss in the Well = 0.605 ft | | | |
| **Q = 127 gpm** | | | |
| Screen 1 | 74.28 | 2.31 | **171.59** |
| Screen 2 | 40.21 | 2.79 | **112.20** |
| Screen 3 | 5.44 | 0.7 | **3.81** |
| Screen 4 | 0.87 | 0.66 | **0.57** |
| Screen 5 | 1.58 | 0.67 | **1.06** |
| Screen 6 | 0.58 | 0.67 | **0.39** |
| Screen 7 | 0.57 | 0.67 | **0.39** |
| Screen 8 | 0.88 | 0.67 | **0.59** |
| Screen 9 | 2.80 | 0.67 | **1.88** |
| Screen 10 | 2.49 | 0.68 | **1.69** |
| Total Flow | 129.70 | | |
| Weighted Average Flow Loss in the Well = 2.268 ft | | | |

**Table 3-7**
**Calculation of Average Well Losses For Each Pumping Rate**
(Page 2 of 2)

| Screen | (1) Flow Rate into Well (gpm) | (2) Total Flow Losses at Center of Screen (ft) | (1) X (2) |
|---|---|---|---|
| **Q = 177 gpm** | | | |
| Screen 1 | 103.22 | 4.54 | 468.63 |
| Screen 2 | 54.55 | 5.26 | 286.95 |
| Screen 3 | 8.32 | 1.3 | 10.81 |
| Screen 4 | 1.54 | 1.22 | 1.88 |
| Screen 5 | 2.53 | 1.22 | 3.09 |
| Screen 6 | 0.72 | 1.23 | 0.88 |
| Screen 7 | 0.68 | 1.23 | 0.84 |
| Screen 8 | 1.51 | 1.23 | 1.85 |
| Screen 9 | 4.01 | 1.23 | 4.94 |
| Screen 10 | 3.76 | 1.25 | 4.70 |
| Total Flow | 180.84 | | |
| Weighted Average Flow Loss in the Well = 4.338 ft | | | |

To capture the range of uncertainty associated with drawdowns during the flow logging, two sets of time-drawdown pairs were used. The drawdowns in the well corresponding to a pumping rate of 176.4 gpm were obtained from the time-drawdown data recorded during the constant-rate test. Drawdowns in the well for the other two pumping rates were estimated using the Cooper-Jacob (1946) equation applied to the whole well. The well transmissivity value derived from the constant-rate test was used in these calculations. The drawdown in the well was calculated for the time period between 0.0417 and 0.2917 day. This period approximately corresponds to the time period during which the flow logs were conducted. The formation drawdown was calculated by substrating the weighted average flow loss in the well (shown in Table 3-7) from the well drawdown values described above.

The individual screen's formation drawdown ($s_i$) at the effective radius of the well are calculated as the drawdown in the well corrected for friction, entrance, and skin losses. These losses have been estimated previously and were presented in Table 3-4 and Table 3-7 as "Total Flow Losses at Center of Screen."

Transmissivity of the Formation

The transmissivity of the formation is the well transmissivity as calculated from the constant-rate test adjusted for well flow losses. An estimate of the formation transmissivity was then derived by multiplying the transmissivity derived from the constant-rate pumping test (Q=176 gpm) by the ratio of the formation drawdown to the well drawdown at t =0.2917 day. The well drawdown @ 0.2917 day is 14.44 ft. As shown in Table 3-7, the average well flow losses at 176 gpm are equal to 4.338 ft. The estimated formation losses are, therefore, equal to 10.10 ft. As a result, the ratio of the formation drawdown to the well drawdown is equal to 0.70. As reported earlier, the transmissivity derived from the constant-rate pumping test is equal to 2,573 ft2/d. The derived estimate of formation transmissivity is 3,678 $ft^2$/d.

***Individual Interval's Transmissive Thickness ($b_i$)***

The interval thickness is not precisely known because flow to the screen may be derived, in part, from behind the blank section of pipe above or below the screen. The minimum contributing thickness is assumed to be the length of screen (approximately 25 ft or 55 ft depending on the screen) and the maximum is assumed to be equal to the lengths of the filter packs (between 60 and 142 ft).

### *3.5.4.2 Procedure and Results*

For equation (3-10), the interval transmissivity is determined using an iterative approach. Equation (3-10) is solved iteratively by estimating $K_i$, then solving for $T_i$, dividing by $b_i$, and then substituting back into the equation. After 10 to 18 iterations, a value of $T_i$ is determined. The Term $r_w^2 S$ is calculated using the formation transmissivity and a pair of known time-drawdown pair. The hydraulic conductivity of each interval is the interval transmissivity from equations (3-8) and (3-10) divided by the interval thickness.

The interval hydraulic conductivities from equations (3-8) and (3-10) are given in Table 3-8 for each of the logging runs and each of the cases considered. Except for erecmov01, the sum of the individual interval transmissivities represent the transmissivity of the formation (well transmissivity derived from constant-rate test adjusted for flow losses) with a maximum error of about 15 percent.

## *3.5.5 Sources of Uncertainty*

Uncertainty in the interval hydraulic conductivity values comes from primarily two sources; uncertainty in the model and uncertainty in parameters. The model uncertainty is principally the result of violations of key model assumptions such as the applicability of the Cooper-Jacob equation describing horizontal flow to the well. As Ruud and Kabala (1997a and b), Cassiani and Kabala (1998), and Ruud et al. (1999) note, vertical flow may occur in the vicinity of the well due to heterogeneity, head losses, well skin effects, and partially penetrating screens. Each of these can lead to errors in the calculated interval hydraulic conductivity when using the horizontal flow assumption. Many of the errors due to small-scale vertical flow have been minimized in this work by integrating flowmeter responses over the length of each screened section. Other sources of model uncertainty include the assumed form of the interval storage coefficient. The impact of the latter assumptions are presented in Table 3-8.

**Table 3-8**
**Interval Hydraulic Conductivities Calculated from Flow Logging Data for Well ER-EC-8**
(Page 1 of 2)

| Logging Run | Screen | Interval Thickness = Length of Screen | | | | Interval Thickness = Filter Pack | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Interval Thickness (ft) | Hydraulic Conductivity (ft/d) | | | Interval Thickness (ft) | Hydraulic Conductivity (ft/d) | | |
| | | | (Equation 3-10) | | (Equation 3-8) | | (Equation 3-10) | | (Equation 3-8) |
| | | | $s_{t=0.0417\ d}$ [a] | $s_{t=0.2917\ d}$ [b] | - | | $s_{t=0.0417\ d}$ | $s_{t=0.2917\ d}$ | - |
| erec8mov1 | Screen 1 | 55.55 | 41.63 | 40.98 | 37.89 | 103.95 | 22.25 | 21.90 | 20.36 |
| erec8mov2 | Screen 1 | 55.55 | 40.65 | 40.03 | 37.06 | 103.95 | 21.72 | 21.39 | 19.92 |
| erec8mov3 | Screen 1 | 55.55 | 41.62 | 40.98 | 37.88 | 103.95 | 22.24 | 21.90 | 20.36 |
| erec8mov4 | Screen 1 | 55.55 | 43.02 | 42.93 | 38.40 | 103.95 | 22.99 | 22.94 | 20.64 |
| erec8mov5 | Screen 1 | 55.55 | 43.37 | 43.28 | 38.69 | 103.95 | 23.18 | 23.13 | 20.80 |
| erec8mov6 | Screen 1 | 55.55 | 42.76 | 42.68 | 38.19 | 103.95 | 22.85 | 22.81 | 20.53 |
| erec8mov7 | Screen 1 | 55.55 | 43.48 | 42.68 | 38.93 | 103.95 | 23.23 | 22.81 | 20.92 |
| erec8mov8 | Screen 1 | 55.55 | 42.97 | 42.19 | 38.51 | 103.95 | 22.96 | 22.55 | 20.70 |
| erec8mov9 | Screen 1 | 55.55 | 42.74 | 41.97 | 38.32 | 103.95 | 22.84 | 22.43 | 20.60 |
| erec8mov1 | Screen 2 | 25.35 | 55.49 | 53.78 | 46.13 | 60.25 | 23.35 | 22.63 | 19.52 |
| erec8mov2 | Screen 2 | 25.35 | 62.72 | 60.70 | 51.68 | 60.25 | 26.39 | 25.54 | 21.87 |
| erec8mov3 | Screen 2 | 25.35 | 54.77 | 53.08 | 45.58 | 60.25 | 23.04 | 22.34 | 19.29 |
| erec8mov4 | Screen 2 | 25.35 | 54.89 | 54.67 | 44.63 | 60.25 | 23.09 | 23.00 | 18.88 |
| erec8mov5 | Screen 2 | 25.35 | 55.14 | 54.92 | 44.82 | 60.25 | 23.20 | 23.11 | 18.97 |
| erec8mov6 | Screen 2 | 25.35 | 54.15 | 53.94 | 44.07 | 60.25 | 22.78 | 22.70 | 18.65 |
| erec8mov7 | Screen 2 | 25.35 | 55.85 | 53.92 | 45.47 | 60.25 | 23.50 | 22.69 | 19.24 |
| erec8mov8 | Screen 2 | 25.35 | 57.55 | 55.54 | 46.75 | 60.25 | 24.22 | 23.37 | 19.79 |
| erec8mov9 | Screen 2 | 25.35 | 55.37 | 53.46 | 45.11 | 60.25 | 23.30 | 22.49 | 19.09 |
| erec8mov1 | Screen 3 | 25.35 | 4.76 | 4.92 | 5.77 | 60.30 | 2.00 | 2.07 | 2.43 |
| erec8mov2 | Screen 3 | 25.35 | 4.76 | 4.92 | 5.77 | 60.30 | 2.00 | 2.07 | 2.42 |
| erec8mov3 | Screen 3 | 25.35 | 5.46 | 5.63 | 6.53 | 60.30 | 2.29 | 2.37 | 2.74 |
| erec8mov4 | Screen 3 | 25.35 | 4.70 | 4.73 | 6.59 | 60.30 | 1.98 | 1.99 | 2.77 |
| erec8mov5 | Screen 3 | 25.35 | 4.93 | 4.95 | 6.88 | 60.30 | 2.07 | 2.08 | 2.89 |
| erec8mov6 | Screen 3 | 25.35 | 4.94 | 4.97 | 6.89 | 60.30 | 2.08 | 2.09 | 2.90 |
| erec8mov7 | Screen 3 | 25.35 | 4.50 | 4.73 | 6.08 | 60.30 | 1.89 | 1.99 | 2.55 |
| erec8mov8 | Screen 3 | 25.35 | 4.78 | 5.02 | 6.42 | 60.30 | 2.01 | 2.11 | 2.70 |
| erec8mov9 | Screen 3 | 25.35 | 4.50 | 4.73 | 6.08 | 60.30 | 1.89 | 1.99 | 2.55 |
| erec8mov4 | Screen 5 | 25.35 | 1.22 | 1.23 | 1.93 | 111.50 | 0.28 | 0.28 | 0.44 |
| erec8mov5 | Screen 5 | 25.35 | 1.65 | 1.66 | 2.53 | 111.50 | 0.37 | 0.38 | 0.58 |
| erec8mov6 | Screen 5 | 25.35 | 1.09 | 1.10 | 1.74 | 111.50 | 0.25 | 0.25 | 0.39 |
| erec8mov4 | Screen 9 | 25.35 | 2.34 | 2.36 | 3.49 | 70.55 | 0.84 | 0.85 | 1.25 |
| erec8mov5 | Screen 9 | 25.35 | 1.35 | 1.36 | 2.12 | 70.55 | 0.49 | 0.49 | 0.76 |
| erec8mov6 | Screen 9 | 25.35 | 2.87 | 2.89 | 4.22 | 70.55 | 1.03 | 1.04 | 1.52 |
| erec8mov7 | Screen 9 | 25.35 | 2.98 | 3.15 | 4.19 | 70.55 | 1.07 | 1.13 | 1.51 |
| erec8mov8 | Screen 9 | 25.35 | 0.93 | 1.01 | 1.46 | 70.55 | 0.33 | 0.36 | 0.53 |
| erec8mov9 | Screen 9 | 25.35 | 2.76 | 2.92 | 3.91 | 70.55 | 0.99 | 1.05 | 1.40 |
| erec8mov4 | Screen 10 | 25.35 | 2.08 | 2.09 | 3.13 | 132.55 | 0.40 | 0.40 | 0.60 |
| erec8mov5 | Screen 10 | 25.35 | 1.37 | 1.38 | 2.13 | 132.55 | 0.26 | 0.26 | 0.41 |
| erec8mov6 | Screen 10 | 25.35 | 2.67 | 2.69 | 3.94 | 132.55 | 0.51 | 0.51 | 0.75 |

**Table 3-8**
**Interval Hydraulic Conductivities Calculated from Flow Logging Data for Well ER-EC-8**
(Page 2 of 2)

| Logging Run | Screen | Interval Thickness = Length of Screen | | | | Interval Thickness = Filter Pack | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Interval Thickness (ft) | Hydraulic Conductivity (ft/d) | | | Interval Thickness (ft) | Hydraulic Conductivity (ft/d) | | |
| | | | (Equation 3-10) | | (Equation 3-8) | | (Equation 3-10) | | (Equation 3-8) |
| | | | $s_{t=0.0417\,d}$ [a] | $s_{t=0.2917\,d}$ [b] | - | | $s_{t=0.0417\,d}$ | $s_{t=0.2917\,d}$ | - |
| erec8mov7 | Screen 10 | 25.35 | 2.76 | 2.93 | 3.91 | 132.55 | 0.53 | 0.56 | 0.75 |
| erec8mov9 | Screen 10 | 25.35 | 2.61 | 2.77 | 3.72 | 132.55 | 0.50 | 0.53 | 0.71 |

[a]Drawdown in the well 0.0417 days after pumping started
[b]Drawdown in the well 0.2917 days after pumping started

The parameter uncertainty comes from uncertainty in the flow rate, drawdown, and parameters within the logarithm of equation (3-10). The flow rate determined from the flowmeter and line speed measurements is accurate to within about plus or minus 1.72 gpm. This means that flow uncertainty is a small factor for the upper intervals which produced the most water, but could be a significant factor, up to perhaps 80 percent of the value for Screen 5. The drawdown in the aquifer is uncertain because it relies on corrections for well losses, both inside and outside the well. The well loss corrections are similar down the well, but the impact of the uncertainty will be larger for the lower screen which has a lower flow rate.

The parameters within the logarithmic term of equations (3-7) or (3-10) are another source of uncertainty. The time at which flowmeter measurements are taken relative to the total time of pumping will influence calculated hydraulic conductivity as will the estimate for the effective radius-storage coefficient product. As seen in equation (3-10), time is a parameter in this equation. If the time of measurement is long after pumping began, the change in drawdown and well hydraulic condition will be small both during the logging run and between logging runs. If one logging run is made too close to the start of pumping, it seems likely that parameters from that run could differ from later runs. Table 3-8 summarized the hydraulic conductivity for each interval for each logging run using a range of interval thickness and a range of drawdowns. As can be seen for a given screen, the differences between logging runs is quite small considering that the logging runs were made at different times after pumping began. Therefore, the time of measurement was not a significant source of error in the interpretation. This is consistent with the expectation that the effect of these parameters is not too large because the logarithm has the effect of moderating the impact.

Perhaps the single biggest source of uncertainty is the selection of the length of the contributing interval for each screen. As was noted earlier, the thickness could vary between 60 and 142 ft. This uncertainty in the contributing thickness produces an uncertainty in interval hydraulic conductivity that is about a factor of five for Well ER-EC-8.

In summary, the interval hydraulic conductivity values are uncertain, with greater uncertainty associated with the small hydraulic conductivity interval (lower screened intervals). The interval hydraulic conductivity values are probably no more accurate than about a factor of 2 to 5. This range is quite good when compared with the range of hydraulic conductivity values presented in the regional groundwater model report (DOE/NV, 1997), where values of hydraulic conductivity for volcanic units ranged over more than seven orders of magnitude.

## 3.6 Comments on the Testing Program and the Well Design

The pumping test in this multiple-completion well worked fairly well, yielding results for all three completion intervals. This is a different result from Wells ER-EC-1 and ER-EC-6 where results were limited to the upper completion intervals, but similar to results for Well ER-EC-7. A combination of factors allowed the hydraulics of the well operation to produce significant amounts of water from all three completion intervals. These factors include high-enough hydraulic conductivities in the lower completion intervals, not-too-dissimilar hydraulic conductivities of the two intervals, lack of substantial vertical gradient relative to the drawdown, and sufficient drawdown to observe responses above the noise level.

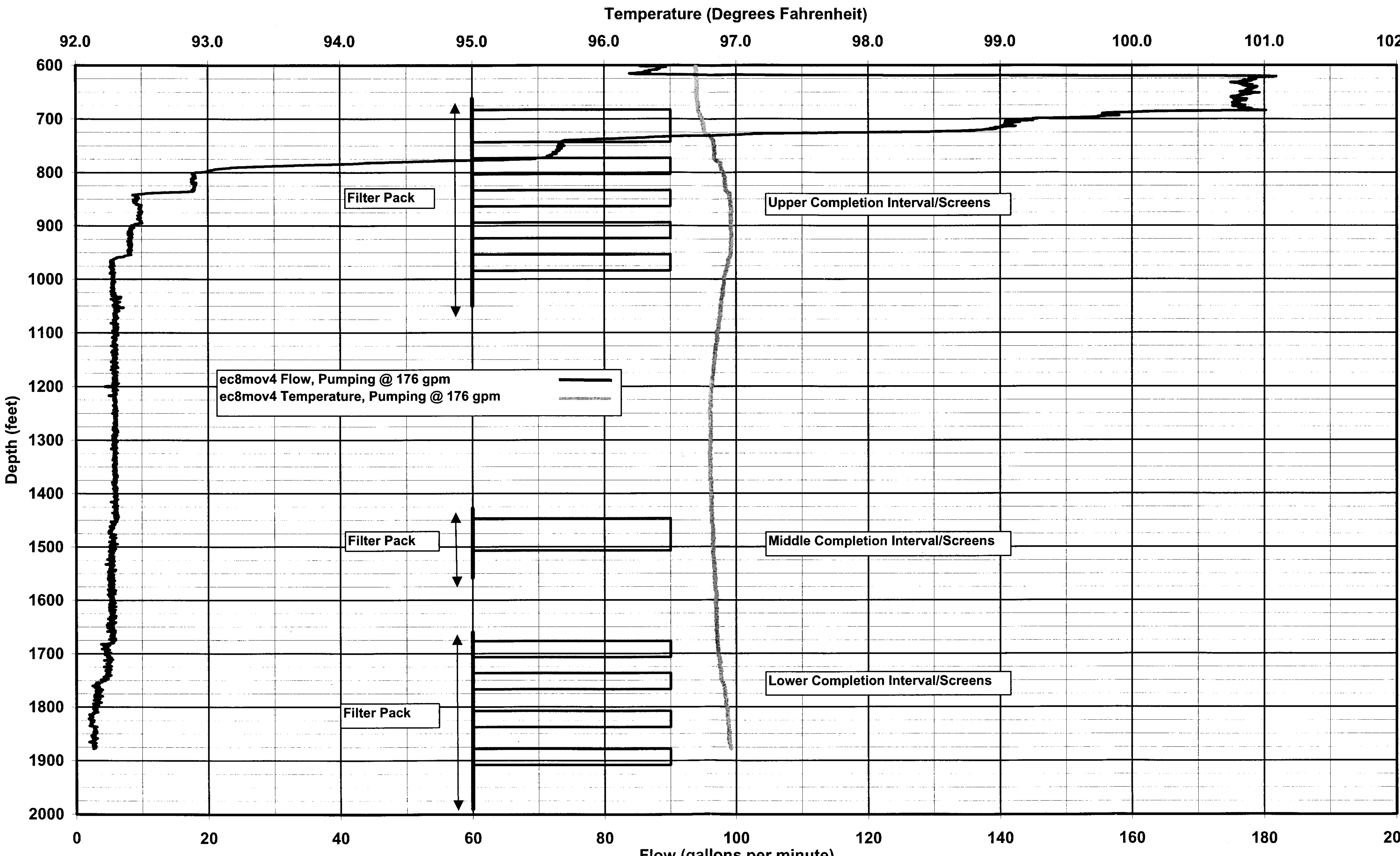





Figure 3-1
Pumping Temperature and Flow Logs

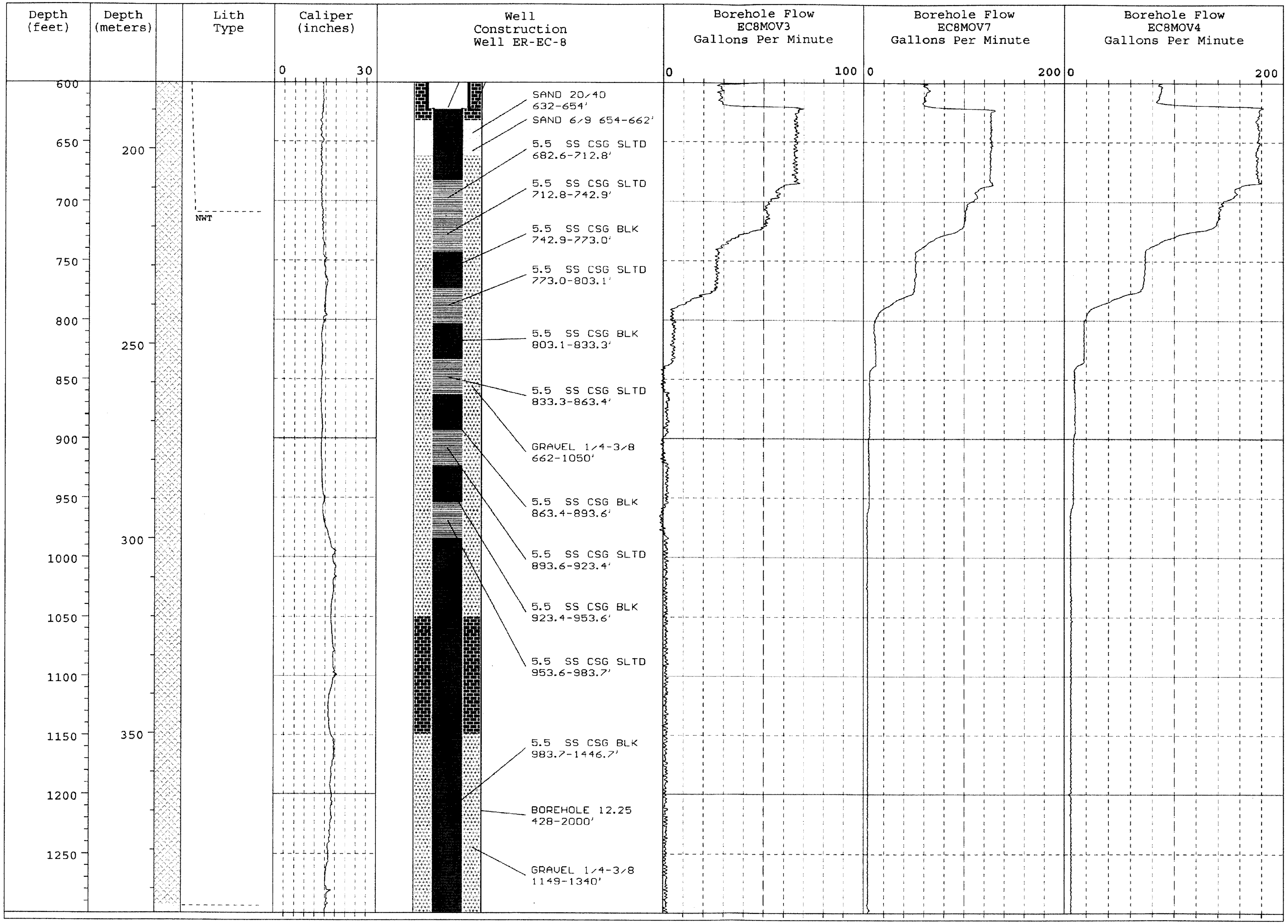



**Figure 3-2**
**Geology and Well Construction for the Upper Completion Interval**

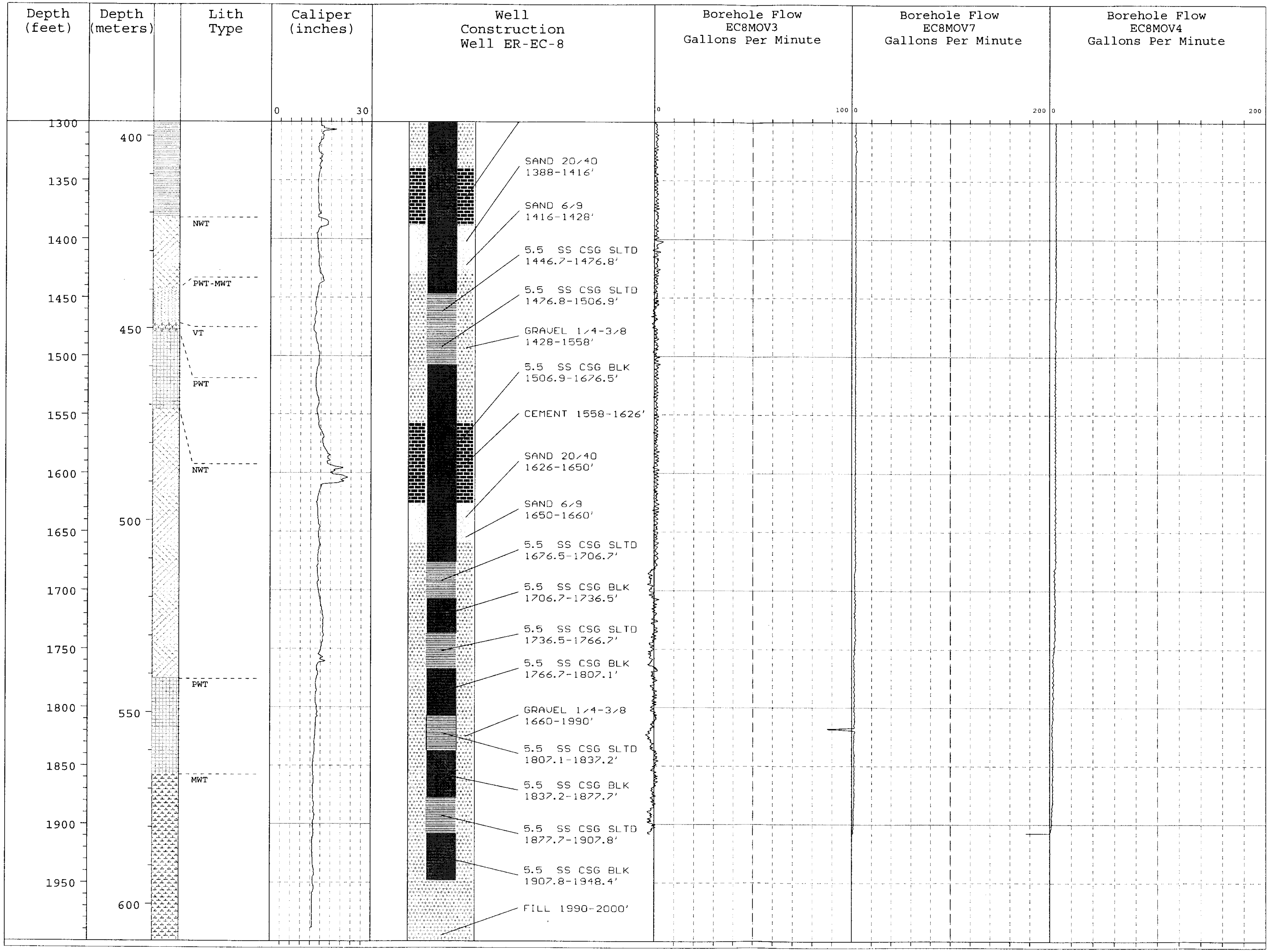



**Figure 3-3**
**Geology and Well Construction for the Middle and Lower Completion Intervals**

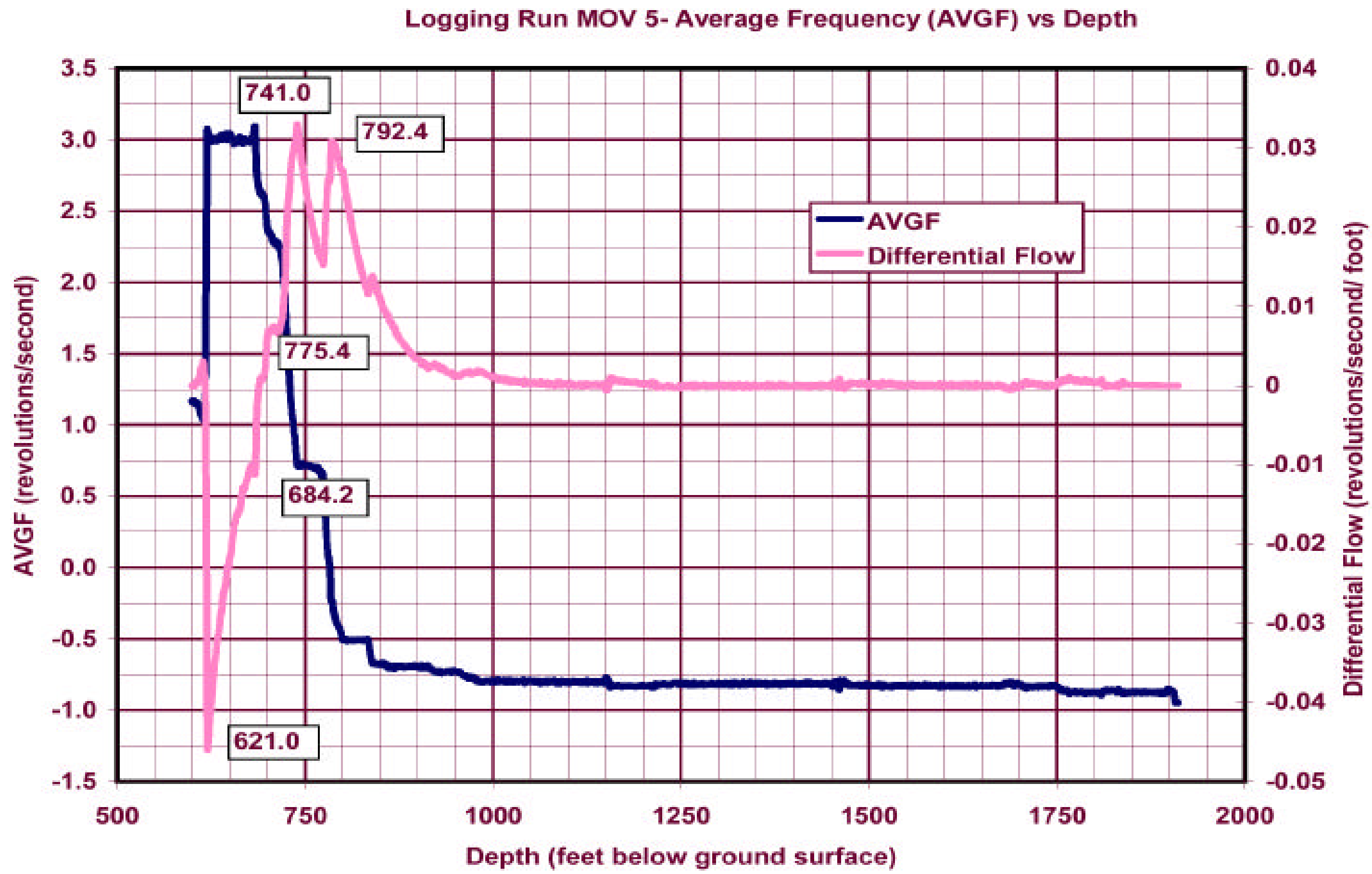



**Figure 3-4**
**Example of Differential Flow Log Superposed on Flow Log (Flow Log ec8mov05)**

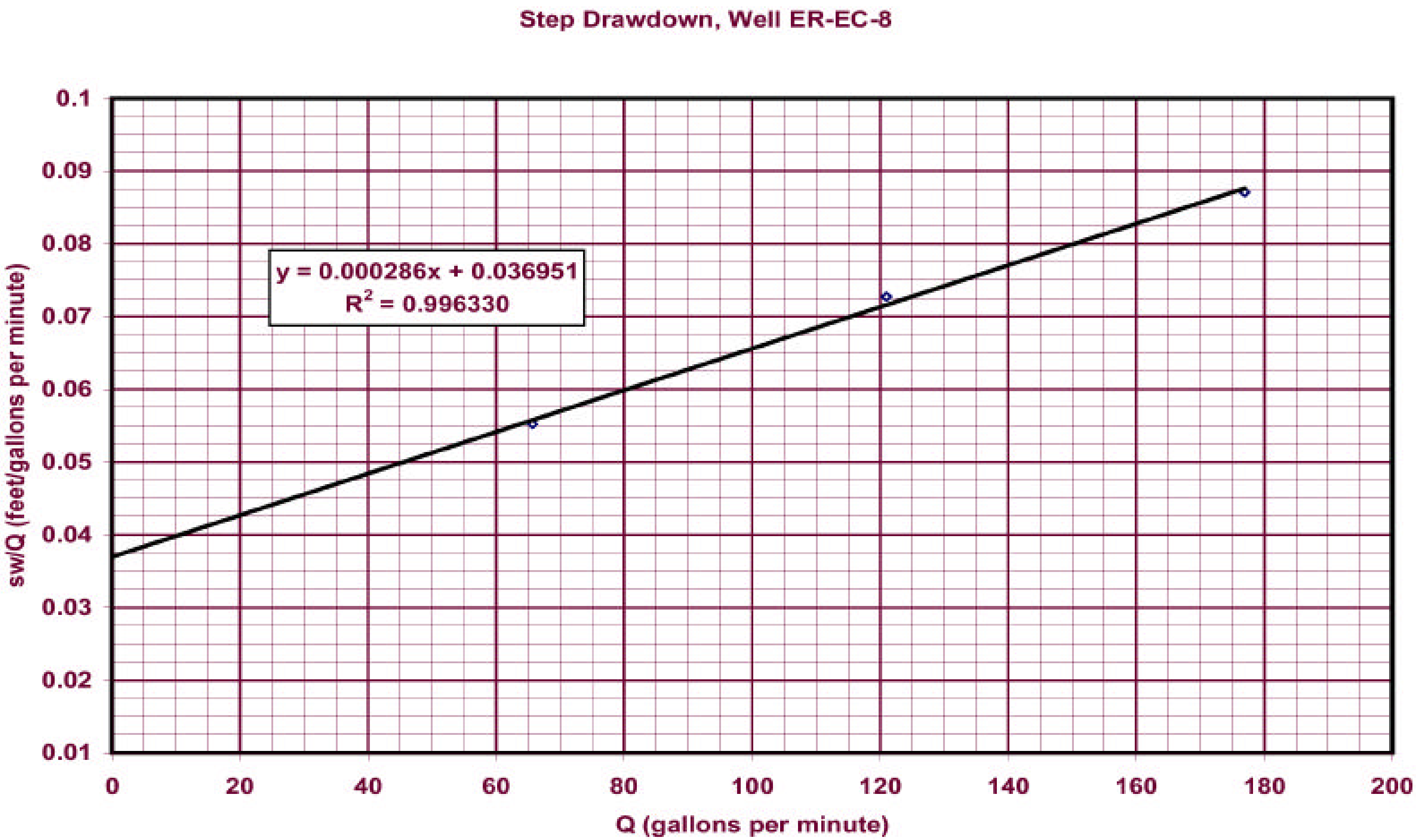



**Figure 3-5**
**Step-Drawdown Analysis**

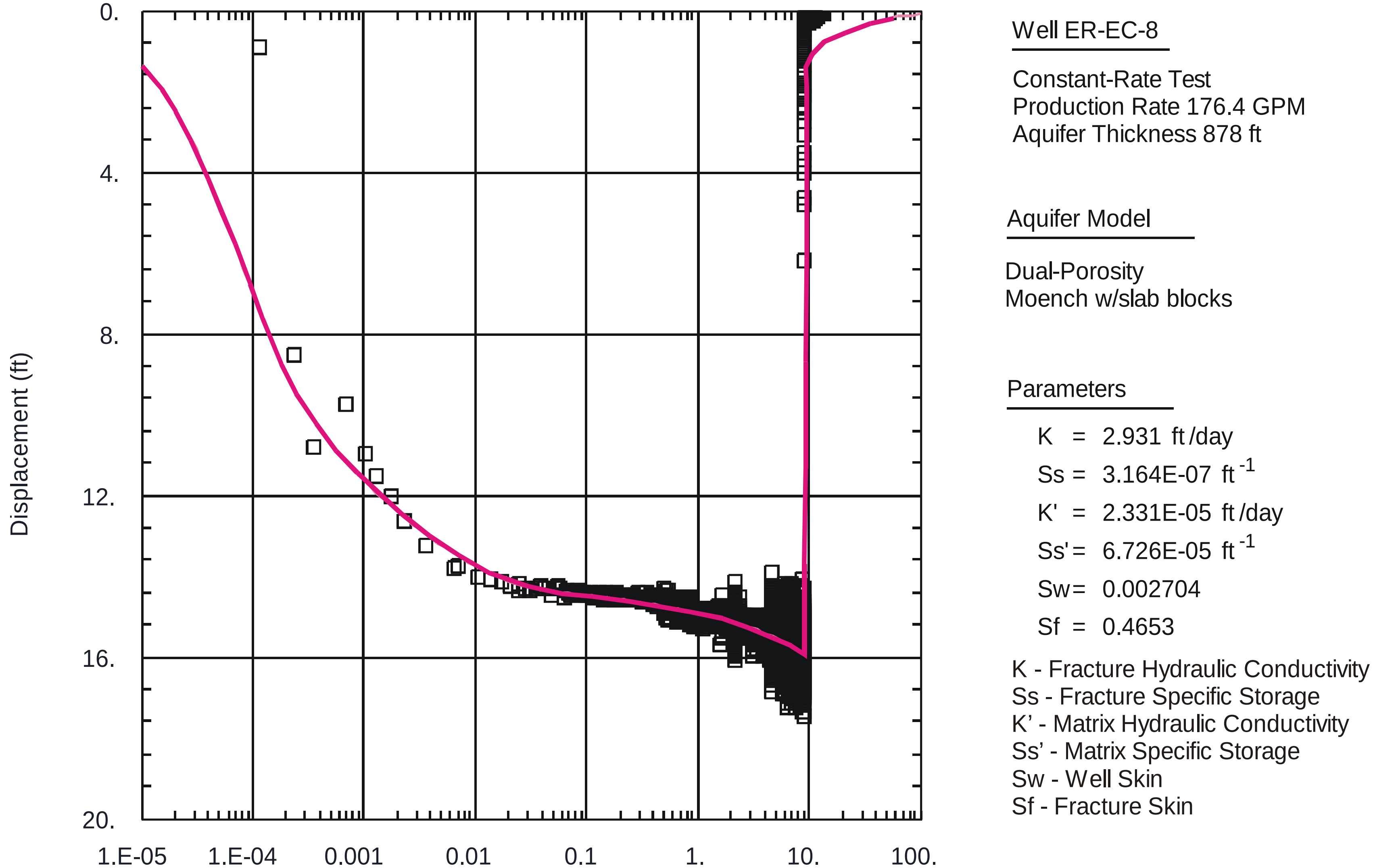
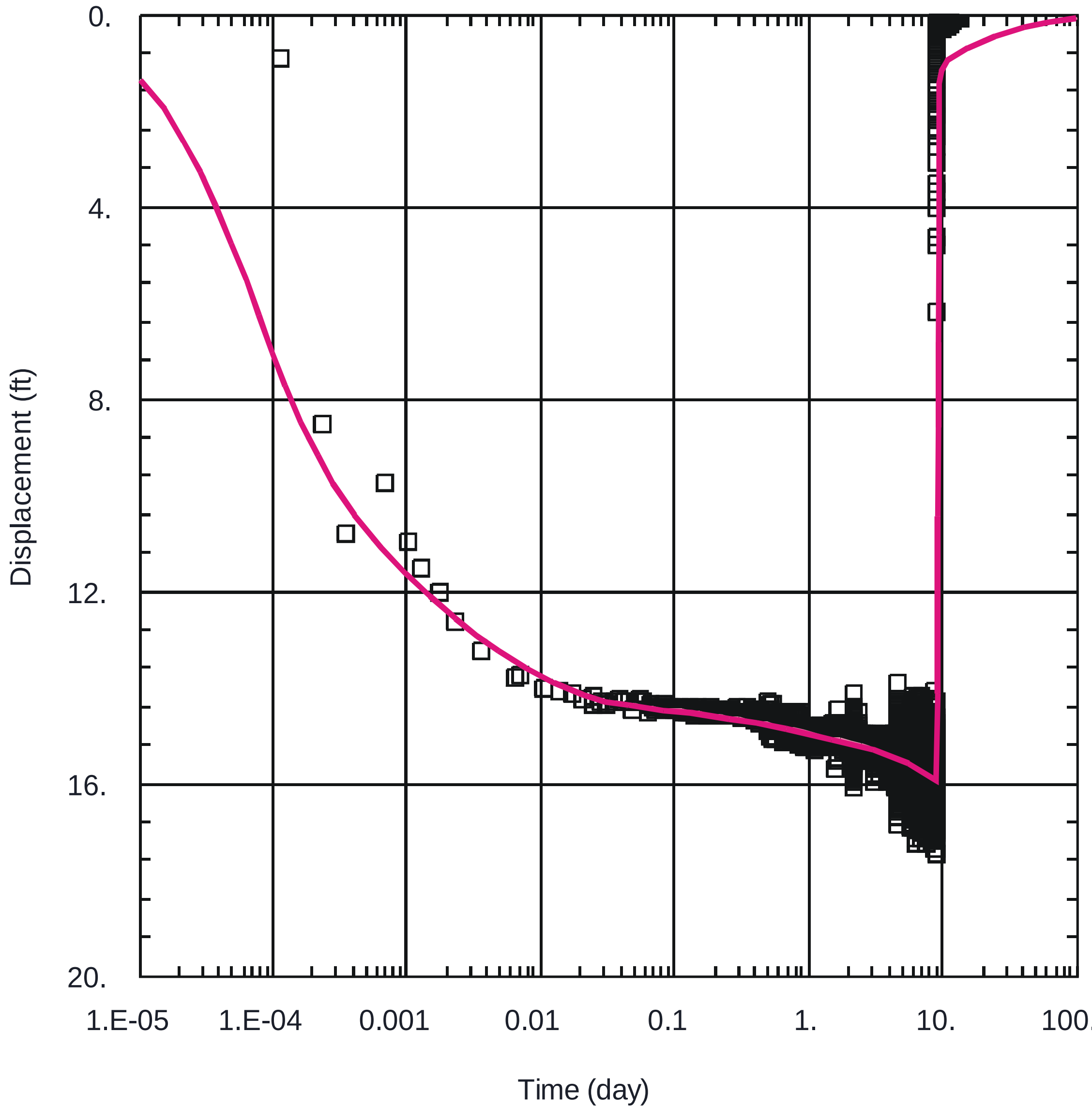



**Figure 3-6**
**Moench Analysis of the Constant-Rate Test**




Well ER-EC-8

Constant-Rate Test
Production Rate 176.4 GPM
Aquifer Thickness 313.7 ft

Aquifer Model

Dual-Porosity
Moench w/slab blocks

Parameters

K = 8.164 ft /day
Ss = 9.066E-07 $ft^{-1}$
K' = 6.206E-05 ft /day
Ss' = 0.0002059 $ft^{-1}$
Sw = 0.
Sf = 0.417

K - Fracture Hydraulic Conductivity
Ss - Fracture Specific Storage
K' - Matrix Hydraulic Conductivity
Ss' - Matrix Specific Storage
Sw - Well Skin
Sf - Fracture Skin

**Figure 3-7**
**Moench Analysis of the Constant-Rate Test - Alternate Aquifer Thickness**

# 4.0 Groundwater Chemistry

This section presents an evaluation of the analytical results for the groundwater characterization samples collected during well development and hydraulic testing activities at Well ER-EC-8. Two discrete bailer samples and one composite groundwater sample were collected at this site. The purpose of a discrete bailer sample is to target a particular depth interval for sampling under either static or pumping conditions, while the purpose of a composite sample is to obtain a sample that is as representative of as much of the open intervals as possible. The results from these groundwater characterization samples are used to examine the overall groundwater chemistry of the well and to compare this groundwater chemistry to that of other wells in the area. The groundwater chemistry results are also evaluated to establish whether Well ER-EC-8 was sufficiently developed to restore natural groundwater quality in the formation around the well.

## 4.1 Discussion of Groundwater Chemistry Sampling Results

The groundwater chemistry of Well ER-EC-8 will be discussed in this section and compared to the groundwater chemistry of other nearby wells.

### 4.1.1 ER-EC-8 Groundwater Characterization Sample Results

On June 28, 2000, two discrete bailer samples (#EC-8-062800-2 and #EC-8-062800-3) were obtained from two depths, 760 and 1,020 ft below ground surface (bgs), at pumping rates of approximately 66 and 177 gpm, respectively. The samples were obtained using a DRI logging truck and discrete bailer. On July 12, 2000, a composite groundwater characterization sample (#EC-8-071200-1) was collected from the wellhead sampling port directly into sample bottles. A constant production rate of about 176.4 gpm was maintained during the sampling event. This same pumping rate was used during the constant-rate test. At the time of composite sampling, approximately $3.8 \times 10^6$ gallons of groundwater had been pumped from the well during development and testing activities (Section A.2.10.2). The results from these three samples have been tabulated and are presented in Table ATT.3-1, Table ATT.3-2, Table ATT.3-3 in Attachment 3, Appendix A.

Examination of the Metals and Inorganics Sections in Table ATT.3-1, Attachment 3, Appendix A reveals that all three groundwater characterization samples have relatively similar analytical results. For example, it can be seen in the table that for each groundwater characterization sample sodium, calcium, and potassium are the predominate cations. The table also reveals that bicarbonate, sulfate, and chloride are the predominate anions for each groundwater characterization sample. Closer examination of Table ATT.3-1, Attachment 3, Appendix A reveals that not only do the groundwater characterization samples have the same major ions, but the actual concentrations of the major ions in all three characterization samples are extremely similar. For example, the sodium concentrations ranged from 110 to 120 milligrams per liter (mg/L) for each sample, while the calcium concentrations varied from 7.1 to 10 mg/L. The bicarbonate concentrations varied from an estimated 100 to 160 mg/L as CaCO3, while the sulfate concentrations varied from an estimated 81 to 82 mg/L. Table ATT.3-1, Attachment 3, Appendix A also reveals that all three groundwater characterization samples have roughly the same silicon concentrations and pH values that varied from 7.7 to an estimated 8.9. It can also be seen from the table that several of the analytes in each characterization sample were qualified in some form or another. For example, all results for samples whose analyses requires cooling to 4°C for the discrete bailer samples were qualified as estimated (J or UJ) because there was no documentation that the samples temperatures were kept at the appropriate temperature from the sample collection date to the their entry into refrigerated storage.

Inspection of the “Age and Migration Parameters” section of Table ATT.3-1, Attachment 3, Appendix A for the composite groundwater sample reveals several interesting things. For example, Lawrence Livermore National Laboratory (LLNL) (2001) states that the helium-3/helium-4 ($^{3}He/^{4}He$) ratio in Well ER-EC-8 groundwater ($R=1.74x10^{-6}$) is greater than the atmospheric ratio ($R_a=1.38x10^{-6}$), giving a $R/R_a$ value of 1.26. According to LLNL (2001), in the absence of tritium, elevated $R/R_a$ values are likely related to the transmission of deep fluids upward along faults in this region and have been observed in wells and springs within Oasis Valley. LLNL (2001) points out that Well ER-EC-8 is sited along an inferred north-northeast trending structural feature that is a likely source of the $^{3}He$ enrichment in Well ER-EC-8 groundwater. This may be related to the relatively high temperature observed at shallow depth in this well. It can also be seen from the table that Well ER-EC-8 has a $^{4}He$ concentration of $3.69x10^{12}$ atoms/milliliter (mL). LLNL (2001) states that this concentration is slightly elevated relative to the expected solubility of helium in groundwater recharge. This value yields a $^{4}He$ model age of approximately 2,000 years assuming a $^{4}He$ in-growth rate of $1.2x10^{9}$ atoms/year from the *in situ* α-decay of naturally occurring radioactive elements in the host rock (LLNL, 2001). However, further inspection of Table ATT.3-1, Attachment 3, Appendix A reveals that the carbon-14 ($^{14}C$) value of dissolved inorganic carbon (DIC) in Well ER-EC-8 groundwater is 8.7 percent modern, yielding an uncorrected $^{14}C$ age of 20,200 years. This value is substantially greater than the $^{4}He$ apparent age, and LLNL (2001) states that this implies that the DIC has reacted with $^{14}C$-absent carbonate minerals in the aquifer. It can also be seen from the table that the chlorine-36/chlorine ($^{36}Cl/Cl$) ratio for Well ER-EC-8 groundwater is $4.63x10^{-13}$. LLNL (2001) states that this value is consistent with natural environmental levels of $^{36}Cl$ in groundwater from this region.

Table ATT.3-2, Attachment 3, Appendix A presents the results of the colloid analyses for Well ER-EC-8. It can be seen from the table that both discrete bailer samples have relatively similar total colloid concentrations for colloids in the size range of 50 to 1,000 nanometers (nm). For example, the total colloid concentrations for the discrete bailer samples ranged from $9.03 \times 10^7$ particles/mL to $1.44 \times 10^8$ particles/mL. However, it can be seen from the table that discrete bailer sample #EC-8-062800-3 has the greatest colloid concentration for each particle size range. In addition, it can be seen from Table ATT.3-2, Attachment 3, Appendix A that the composite groundwater characterization sample had a total colloid concentration of $4.04 \times 10^7$ particles/mL, which is at least half the amount of the next highest total colloid concentration. Further inspection of the table for all three groundwater characterization samples reveals that the colloid concentrations for each sample decrease as the particle size increases. For the smaller sized ranges (up to approximately 150 nm), the colloid concentrations in each particle size range decrease at roughly the same rate for the two types of groundwater characterization samples. However, for the coarser size fractions (> 150 nm), the discrete bailer samples contain greater colloid concentrations relative to the composite sample.

While the three groundwater characterization samples have relatively similar analytical results, differences can be seen taking into account the uncertain nature of some of the data in Table ATT.3-1, Attachment 3, Appendix A. For example, one potential discrepancy between the three groundwater characterization samples can be seen in the oxidation-reduction sensitive parameters (iron and manganese). Table ATT.3-1, Attachment 3, Appendix A indicates that the concentrations of iron and manganese in the discrete bailer samples are at least an order of magnitude higher in the total analyses than in the dissolved analyses. This may indicate that iron and manganese are predominantly present in the total phase rather than the dissolved phase for the discrete bailer samples. However, further inspection of the table reveals that the total and dissolved concentrations of iron and manganese in the composite groundwater sample are similar discounting the fact that the analytes were not detected at the given minimum detectable limit. This implies that the analytes in the composite groundwater sample are predominantly present in the dissolved phase. This discrepancy between the two types of characterization samples can likely be attributed to some type of sampling artifact, and possibly related to the lesser development of the deeper completion intervals. For example, it is possible that the bailer sampling procedure could introduce a coarser sized fraction of colloids composed of iron and manganese oxides to the discrete samples. This would result in a greater concentration of those elements in the total analyses that would be filtered out in the dissolved analyses. In addition, Fetter (1988) points out that sampling processes can create colloids in groundwater that were not originally present, such as the precipitation of colloidal iron due to oxygenation of water. The observed differences in colloid concentrations at Well ER-EC-8 could be an indication that analyte concentrations in groundwater are impacted by the sampling method. Variations in colloid concentrations could potentially affect both total and "dissolved" concentrations, because filtering typically removes only particles greater than 0.45 micrometers (450 nm) in size from the "dissolved" samples.

In general, the geochemical compositions of all three groundwater characterization samples are typical for wells that penetrate volcanic rocks. These types of rocks tend to impart high concentrations of sodium and bicarbonate to groundwaters. Preliminary lithologic logs for the well indicated that the completion intervals for this well were within the nonwelded tuff of the Beatty Wash Formation, the welded Tuff of Buttonhook Wash, and the welded Ammonia Tanks tuff aquifer (DOE/NV, 2000).

### *4.1.2 Radionuclide Contaminants*

A radiological indicator parameter was detected in both of the discrete bailer samples for Well ER-EC-8 at activities that were above the minimum detectable activity. For example, it can be seen in the "Radiological Indicator Parameters" section of Table ATT.3-1, Attachment 3, Appendix A that plutonium-239 was present at an activity of 0.101 +/- 0.036 pCi/L in discrete bailer sample #EC-8-062800-2. It can also be seen from the table that plutonium-239 was detected in discrete bailer sample #EC-8-062800-3 at an activity of 0.066 +/- 0.03 pCi/L. This activity is less than the requested minimum detectable activity, but greater than the sample specific minimum detectable activity.

The detection of plutonium-239 activities in the discrete bailer samples from Well ER-EC-8 was unexpected because this radiological indicator had not previously been found in any of the other Pahute Mesa - Oasis Valley hydrogeologic investigation wells. To rule out the discrete bailer as a potential source of the plutonium-239 activities, the analytical results from the equipment rinsate sample (#EC-8-062800-1) were investigated. Equipment rinsate samples were collected from the final rinse solution from the equipment decontamination process to determine the effectiveness of the decontamination process. The analytical results from the rinsate sample revealed a plutonium-239 activity of 0.0013 +/- 0.0086 pCi/L. This value was qualified as a result that was not detected at the given minimum detectable activity. This implies that the discrete bailer was not the source of the plutonium-239 activity.

To further validate the original analytical results, two duplicate groundwater samples were sent to Los Alamos National Laboratory for analysis in July of 2001. Los Alamos National Laboratory reported that a blank sample was run before, between, and after the two duplicate samples to check for any possible contamination of the samples. They stated that all of the results for the blanks were non-detects (Los Alamos National Laboratory, 2001). Table 4-1 reveals the results of the Plutonium-238 and Plutonium-239 measurements. Los Alamos

**Table 4-1**
**Results of Plutonium Analysis for ER-EC-8 Discrete Bailer Samples**

| Isotope | Sample # | IT Sample # | Volume (L) | pCi/L +/- 2 sigma | MDA |
|---|---|---|---|---|---|
| Pu-239 | 000374 | EC-8-062800-2 | 0.440 | -0.0026 +/- 0.0009 | 0.0058 |
| Pu-239 | 000375 | EC-8-062800-3 | 0.380 | 0.0009 +/- 0.0090 | 0.0078 |
| Pu-238 | 000374 | EC-8-062800-2 | 0.440 | 0.0010 +/- 0.0054 | 0.0058 |
| Pu-238 | 000375 | EC-8-062800-3 | 0.380 | -0.0015 +/- 0.0015 | 0.0048 |

National Laboratory (2001) reported that all of the analytical results were considered non-detects as the detected activities are well below the minimum detectable activities and are overwhelmed by the associated error in most cases. They also state that the negative values are consistent with the statistical nature of radioactivity and are indicative of the fact that plutonium-238 and plutonium-239 were not present in the discrete bailer samples (Los Alamos National Laboratory, 2001).

In addition to reanalyzing the original discrete bailer samples, NNSA/NV is planning on resampling Well ER-EC-8 in fiscal year 2003. This will be done to further ensure that Pu isotopes are not present in Well ER-EC-8.

### *4.1.3 Comparison of ER-EC-8 Groundwater Chemistry to Surrounding Wells*

Table 4-2 presents groundwater chemistry data for Well ER-EC-8 and recently collected samples from wells and springs in close proximity to Well ER-EC-8. Shown in the table are the analytical results for selected metals, anionic constituents, field measurements, and several radiological parameters. The data in this table were used to construct the trilinear diagram shown in Figure 4-1. Trilinear diagrams contain three different plots of major-ion chemistry and are used to show the relative concentrations of the major ions in a groundwater sample. The triangular plots in Figure 4-1 show the relative concentrations of major cations and anions. The diamond-shaped plot in the center of the figure combines the information from the adjacent cation and anion triangles. The concentrations in all three plots are expressed in percent milliequivalents per liter and are used to illustrate various groundwater chemistry types, or hydrochemical facies, and the relationships that may exist between the types. Examination of the cation triangle in Figure 4-1 reveals that for Well ER-EC-8 and the surrounding sites the relative concentrations of the major cations fall within the sodium (or potassium) groundwater type. This can be ascertained from the figure because the relative concentrations of the major cations plot in the lower right corner of the cation triangle. This conclusion assumes that the qualified magnesium data used to construct the cation triangle are actually representative of the groundwater chemistry in the well. Further inspection of the anion triangle in Figure 4-1 reveals that Well ER-EC-8 and most of the wells and springs can be classified as having bicarbonate type water. This can be deduced from the figure because, for the most part, the relative concentrations of the major anions plot within the lower left corner of the anion triangle. Again, it must be assumed for Well ER-EC-8 that the estimated anion data for the discrete bailer samples are actually representative of the groundwater chemistry in the well. It can be seen from the anion triangle; however, that there are a number of sites whose relative anion concentrations do not fall within the bicarbonate type interval (e.g., ER-OV-03a2). These sites tend to plot within the center of the anion triangle. For these sites, there is no dominant anion type. It can also been seen from Figure 4-1 that the relative cation concentrations for all of the wells and springs tend to plot fairly close to each other along a straight line. The relative anion concentrations also tend to plot along a straight line in the anion triangle; however, there is a much greater spread among the anion concentrations. Regardless of the discrepancies between the cation and

**Table 4-2**
**Groundwater Chemistry Data for Well ER-EC-8 and Surrounding Sites**
**(1 of 2)**

| Analyte | ER-EC-8 | | | | | | Bailey Hot Springs Bath House 1 | Bailey Hot Springs Bath House 3 | Burrel Hot Spring | Campbell Spring | Coffer's Ranch | Coffer Ranch Spring | ER-OV-01 | ER-OV-02 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bailer at 760' bgs | | Bailer at 1020' bgs | | Wellhead Composite | | 11S/47E-16dcdb3 | 11S/47E-16dcd | 11S/47E-21 | 10S/47E-33a1 | Windmill Well | | | |
| | Total | Dissolved | Total | Dissolved | Total | Dissolved | | | | | | | | |
| *Metals (mg/L)* | | | | | | | | | | | | | | |
| Aluminum | B 0.073 | U 0.0047 | 0.5 | B 0.07 | U 0.077 | U 0.072 | 0.00329 | 0.00283 | | | 0.0009 | <0.00004 | 0.0512 | 0.003 |
| Arsenic | 0.013 | 0.01 | B 0.0082 | B 0.0085 | B 0.0081 | B 0.0071 | 0.0185 | 0.0201 | 0.0011 | | 0.00836 | 0.0064 | 0.003 | 0.003 |
| Barium | B 0.0045 | U 0.0031 | B 0.017 | B 0.0096 | UJ 0.00096 | UJ 0.0008 | 0.0187 | 0.0164 | 0.06 | | 0.00161 | 0.0098 | 0.0026 | 0.0039 |
| Cadmium | U 0.005 | U 0.005 | U 0.005 | U 0.005 | UJ 0.005 | UJ 0.005 | < 0.0000163 | 0.0000411 | < 0.005 | | 0.000019 | < 0.000016 | 0.001 | 0.001 |
| Calcium | 10 | 10 | 10 | 7.1 | 9.1 | 9.1 | 14.9 | 15.6 | 27.5 | 24 | 19.3 | 21.8 | 5.7 | 13.6 |
| Chromium | 0.032 | U 0.0018 | 0.016 | U 0.0037 | UJ 0.00056 | UJ 0.0004 | 0.00042 | 0.00039 | < 0.02 | | 0.00013 | 0.0008 | 0.0015 | 0.0015 |
| Iron | 3.4 | U 0.13 | 1.5 | U 0.13 | U 0.061 | U 0.054 | 0.0026 | | 0.06 | | 0.1933 | | 0.0036 | 0.0034 |
| Lead | U 0.003 | U 0.003 | U 0.003 | U 0.003 | U 0.003 | U 0.003 | 0.000031 | 0.000043 | < 0.02 | | 0.000274 | 0.000013 | 0.002 | 0.002 |
| Lithium | 0.16 | 0.17 | 0.15 | 0.15 | 0.16 | 0.16 | 0.235 | 0.24 | 0.251 | | 0.12 | 0.166 | 0.175 | 0.192 |
| Magnesium | U 0.48 | U 0.48 | U 0.5 | U 0.31 | U 0.39 | U 0.39 | 0.54 | 0.54 | 0.4 | 0.1 | 0.21 | 1.52 | 0.05 | 0.59 |
| Manganese | 0.055 | B 0.0051 | 0.025 | B 0.0034 | U 0.0015 | U 0.0014 | 0.0002 | 0.0001 | 0.02 | | 0.0082 | 0.00034 | 0.0005 | 0.001 |
| Potassium | 6.5 | 6.6 | 3.4 | 3.4 | 7.2 | 7.2 | 7.22 | 7.09 | 6 | | 0.91 | 9.54 | 6.56 | 5.41 |
| Selenium | U 0.005 | U 0.005 | U 0.005 | U 0.005 | U 0.005 | U 0.005 | 0.00032 | 0.00042 | < 0.001 | | 0.00053 | 0.00057 | 0.00082 | 0.00079 |
| Silicon | 23 | 23 | 24 | 22 | 23 | 23 | | | 62 | | | | | |
| Silver | U 0.01 | U 0.01 | U 0.01 | U 0.01 | U 0.01 | U 0.01 | < 0.00001 | 0.00003 | < 0.02 | | 0.00002 | < 0.00002 | 0.001 | 0.001 |
| Sodium | 120 | 120 | 120 | 120 | 110 | 120 | 146 | 157 | 151 | | 72.2 | 176 | 142 | 146 |
| Strontium | B 0.0056 | B 0.0048 | 0.031 | 0.024 | U 0.0024 | U 0.0028 | 0.117 | 0.115 | 0.05 | | 0.181 | 0.163 | 0.0047 | 0.0474 |
| Uranium | U 0.2 | U 0.2 | U 0.2 | U 0.2 | U 0.2 | U 0.2 | 0.00983 | 0.00863 | | | 0.00586 | 0.0154 | 0.0085 | 0.018319 |
| Mercury | UJ 0.0002 | UJ 0.0002 | UJ 0.0002 | UJ 0.0002 | UJ 0.0002 | UJ 0.0002 | | | < 0.0005 | | | | 0.0002 | 0.0002 |
| *Inorganics (mg/L)* | | | | | | | | | | | | | | |
| Chloride | J 49 | | J 46 | | 49 | | 40.4 | 40.4 | 44 | 65 | 7.6 | 65.8 | 44.4 | 49.2 |
| Fluoride | J 5.2 | | J 5 | | 5.4 | | 5.01 | 5.36 | 5.96 | 1.9 | 3.29 | 3.32 | 2.04 | 2.34 |
| Bromide | J 0.94 | | J 0.22 | | 0.2 | | 0.169 | 0.194 | | | 0.035 | 0.31 | 0.22 | 0.263 |
| Sulfate | J 81 | | J 81 | | 82 | | 117 | 113 | 121 | 14 | 31 | 110 | 82 | 86 |
| pH | J 8 | | J 8.9 | | 7.7 | | 7.75 | 7.72 | 7.89 | 8 | 8.43 | 7.13 | 8.54 | 8.29 |
| Total dissolved solids | J 430 | | J 410 | | 420 | | 416 | 463 | 542.3774 | 532 | 194 | 445 | 338 | 366 |
| Carbonate as CaCO3 | UJ 5 | | J 33 | | U 50 | | | | | | | | 1.7 | |
| Bicarbonate as CaCO3 | J 150 | | J 110 | | 160 | | 257 | 197.64 | 246 | 275 | 189 | 281.82 | 197 | 232 |
| *Age and Migration Parameters (pCi/L) - unless otherwise noted* | | | | | | | | | | | | | | |
| Carbon-13/12 (per mil) | N/A | | N/A | | -2.7 +/- 0.2 | | -3.53 | | | | -3.4 | | -1.43 | -2.17 |
| Carbon-14, Inorganic (pmc) | N/A | | N/A | | 8.7 +/- 0.1 | | 24.4 | | | | 9.6 | | 5 | 16.2 |
| Carbon-14, Inorganic age (years)* | N/A | | N/A | | 20,200 | | 11,660 | | | | 19350 | | 24,830 | 15,050 |
| Chlorine-36 | N/A | | N/A | | 8.81E-04 | | | | | | | | | |
| Helium-3/4, measured value (ratio) | N/A | | N/A | | 1.74E-06 | | | | | | | | | |
| Helium-3/4, relative to air (ratio) | N/A | | N/A | | 1.26 | | 1.73 | | | | 0.85 | | 1.13 | 1.51 |
| Oxygen-18/16 (per mil) | N/A | | N/A | | -15.0 +/- 0.2 | | -14.6 +/- 0.2 | | | | -14.2 +/- 0.2 | | -14.7 +/- 0.2 | -14.6 +/- 0.2 |
| Strontium-87/86 (ratio) | N/A | | N/A | | 0.708816 +/- 0.000017 | | 0.71172 | | | | 0.70922 | | 0.71058 | 0.71006 |
| Uranium-234/238 (ratio) | N/A | | N/A | | 0.000278 | | | | | | | | | |
| Hydrogen-2/1 (per mil) | N/A | | N/A | | -114 +/- 1.0 | | -110 +/- 1 | | | | -104 +/- 1 | | -112 +/- 1 | -112 +/- 1 |
| *Radiological Indicator Parameters-Level I (pCi/L)* | | | | | | | | | | | | | | |
| Tritium | U 0 +/- 150 | | U -20 +/- 150 | | U -180 +/- 160 | | < 1 | | | | 0.47 +/- 0.86 | | 3.33 +/- 0.90 | |
| Gross Alpha | 8.1 +/- 2.7 | | 7.7 +/- 2.7 | | U 3.6 +/- 2.5 | | | | | | | | 14.7 | 27.5 |
| Gross Beta | U 5.0 +/- 2.3 | | U 0.0 +/- 2.4 | | U 4.6 +/- 2.6 | | | | | | | | 11.8 | 10.1 |
| *Radiological Indicator Parameters-Level II (pCi/L)* | | | | | | | | | | | | | | |
| Carbon-14 | U -20 +/- 190 | | U -70 +/- 180 | | U -140 +/- 180 | | | | | | | | | |
| Strontium-90 | N/A | | N/A | | U -0.08 +/- 0.26 | | | | | | | | | |
| Plutonium-238 | U -0.005 +/- 0.012 | | U 0.003 +/- 0.011 | | U -0.005 +/- 0.012 | | | | | | | | | |
| Plutonium-239 | 0.101 +/- 0.036 | | LT 0.066 +/- 0.030 | | U -0.004 +/- 0.012 | | | | | | | | | |
| Iodine-129 | N/A | | N/A | | U -0.86 +/- 0.81 | | | | | | | | | |
| Technetium-99 | N/A | | N/A | | U 13.1 +/- 8.4 | | | | | | | | | |

B = Result less than the Practical Quantitation Limit but greater than or equal to the Instrument Detection Limit
J = Estimated value
N/A = Not Applicable for that sample
pmc = Percent modern carbon
U = Result not detected at the given minimum detectable limit or activity
mg/L = Milligrams per liter  μg/L = Micrograms per liter  pCi/L = Picocuries per liter
* = The carbon-14 age presented is not corrected for reactions along the flow path
LT = Result is less than requested minimum detectable concentration (MDC), but greater than sample-specific MDC

Table 4-2
Groundwater Chemistry Data for Well ER-EC-8 and Surrounding Sites
(2 of 2)

| Analyte | ER-OV-03a2 | ER-OV-03a3 | ER-OV-03c | ER-OV-04a | ER-OV-06a | Goss Spring | Goss Springs North | PM-3 | PM-3, 3019 ft | Rita Mullen Spring | Springdale Upper Well | Unnamed Spring | Ute Spring |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 11S/47E-10bcc | 11S/47E-10bad | | | 11S/47E-03cdb | 10S/47E-32adc | 10S/47E-33aab | 11S/47E-28dac |
| *Metals (mg/L)* | | | | | | | | | | | | | |
| Aluminum | 0.5011 | 0.0198 | 0.0113 | 0.0046 | 0.688 | < 0.06 | 0.0033 | 0.03 | < 0.01 | 0.0084 | 0.0017 | 0.012 | 0.0251 |
| Arsenic | 0.0224 | 0.004 | 0.0149 | 0.0146 | 0.0085 | 0.012111 | 0.00752 | | 0.004 | 0.00725 | 0.0137 | | |
| Barium | 0.0254 | 0.0079 | 0.0019 | 0.00222 | 0.0021 | 0.005 | 0.00497 | 0.004 | 0.002 | 0.00438 | 0.0211 | 0.025 | 0.0027 |
| Cadmium | 0.001 | 0.001 | 0.001 | 0.000016 | 0.001 | | < 0.0000163 | | < 0.001 | < 0.000016 | < 0.000016 | | |
| Calcium | 5.7 | 12.7 | 14.4 | 8.5 | 2.32 | 17.475 | 16.2 | 30.1 | 36 | 6.1 | 21.5 | 30 | 8.4 |
| Chromium | 0.0138 | 0.0013 | 0.001 | 0.00172 | 0.0016 | | 0.00132 | 0.01 | 0.002 | 0.00118 | 0.00141 | | |
| Iron | 0.0599 | 0.0045 | 0.0023 | 0.0026 | 0.0082 | < 0.02 | 0.0073 | 0.24 | 0.06 | 0.003 | 0.0036 | 0.018 | 0.4697 |
| Lead | 0.0046 | 0.002 | 0.002 | 0.000044 | 0.002 | < 0.001 | 0.000007 | | < 0.005 | 0.000012 | 0.000023 | | |
| Lithium | | 0.143 | 0.123 | 0.127 | 0.167 | 0.145 | 0.146 | 0.278 | | 0.147 | 0.097 | | 0.29 |
| Magnesium | 1.03 | 1.06 | 0.38 | 0.1 | 0.72 | 1.29 | 1.14 | 0.79 | 1.5 | 1.05 | 4.08 | 4.6 | |
| Manganese | | 0.0007 | 0.0005 | 0.0003 | 0.0024 | < 0.01 | 0.0001 | 0.014 | 0.014 | 0.0004 | 0.0001 | | |
| Potassium | 84.7 | 5.37 | 1.19 | 7.55 | 7.7 | 5.073 | 4.79 | 10.9 | 10 | 4.95 | 8.15 | 9 | 2.3 |
| Selenium | 0.004 | 0.00082 | 0.00041 | 0.00059 | 0.004 | < 0.01 | 0.0005 | | < 0.001 | 0.00049 | 0.00089 | | |
| Silicon | | | | | | 23.54 | | | 63 | | | | 38.5 |
| Silver | 0.001 | 0.001 | 0.001 | < 0.00001 | 0.001 | | < 0.00001 | | < 0.001 | < 0.00001 | < 0.00001 | | |
| Sodium | 331 | 124 | 81.9 | 101 | 141 | 116.49 | 104 | 140 | 130 | 103 | 130 | 169 | 249 |
| Strontium | 0.167 | 0.0755 | 0.102 | 0.0217 | 0.0105 | 0.09 | 0.0916 | | 0.081 | 0.0861 | 0.277 | 0.19 | 0.0902 |
| Uranium | 0.0098 | 0.00795 | 0.004187 | 0.00269 | 0.005237 | 0.0095 | 0.00923 | | | 0.00949 | 0.00266 | | |
| Mercury | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | | | | < 0.1 | | | | |
| *Inorganics (mg/L)* | | | | | | | | | | | | | |
| Chloride | 262 | 43.3 | 17.5 | 28.1 | 47.5 | 45 | 42.4 | 93.5 | 98 | 42.5 | 36 | 68 | 26.9 |
| Fluoride | | 2.14 | 4.55 | 2.8 | 3.07 | 2.79 | 2.45 | 2.5 | 2.4 | 2.45 | 2.07 | 4.4 | 3.8 |
| Bromide | | 0.228 | 0.066 | 0.145 | 0.224 | | 0.16 | | | 0.183 | 0.092 | | |
| Sulfate | 295 | 79 | 44 | 61 | 80.9 | 78.1 | 76 | 129 | 130 | 76 | 66 | 103 | 70.1 |
| pH | 9.08 | 8.5 | 8.38 | 8.57 | 8.4 | 7.73 | 8.35 | 8.73 | 7.9 | 8.2 | 7.84 | 7.8 | 8.9 |
| Total dissolved solids | 1100 | 320 | 218 | 257 | 426 | | 306 | 441 | 555.6241 | 311 | 358 | | 737 |
| Carbonate as CaCO3 | 41.6 | | | 2.2 | 3 | | | | | | | | |
| Bicarbonate as CaCO3 | 154 | 186 | 164 | 155 | 196 | 181 | 186 | 159 | 150 | 186 | 297 | 296 | 310.4 |
| *Age and Migration Parameters (pCi/L) - unless otherwise noted* | | | | | | | | | | | | | |
| Carbon-13/12 (per mil) | -4.7 | -2.35 | -2.9 | -2.86 | -1.8 | | -2.4 | | | -2.39 | -1.46 | -4.91 | -6.92 |
| Carbon-14, Inorganic (pmc) | 21 | 16.5 | 6.8 | 8 | 6 | 20.75 | 21.8 | | | 18.2 | 10.8 | | |
| Carbon-14, Inorganic age (years)* | 12,900 | 14,875 | 22,280 | 20,860 | 23,330 | | 12,600 | | | 14,090 | 18,440 | | |
| Chlorine-36 | | | | | | | | | | | | | |
| Helium-3/4, measured value (ratio) | | | | | | | | | | | | | |
| Helium-3/4, relative to air (ratio) | | | 0.88 | 0.88 | 1.16 | | 1.12 | | | | 1.1 | | |
| Oxygen-18/16 (per mil) | -14.5 +/- 0.2 | -14.6 +/- 0.2 | -14.7 +/- 0.2 | -14.7 +/- 0.2 | -14.7 +/- 0.2 | -14.7 | -14.7 +/- 0.2 | | | -14.7 +/- 0.2 | -13.9 +/- 0.2 | -14.02 | -14.14 |
| Strontium-87/86 (ratio) | 0.70809 | 0.71003 | 0.70924 | 0.71006 | 0.70932 | 0.7105 | 0.71039 | | | 0.71027 | 0.71026 | | |
| Uranium-234/238 (ratio) | | | | | | | | | | | | | |
| Hydrogen-2/1 (per mil) | -109 +/- 1 | -110 +/- 1 | -109 +/- 1 | -109 +/- 1 | -113 +/- 1 | -111.7 | -110 +/- 1 | | | -111 +/- 1 | -104 +/- 1 | -108 | -109 |
| *Radiological Indicator Parameters-Level I (pCi/L)* | | | | | | | | | | | | | |
| Tritium | | | | | 1.94 +/- 0.87 | | | 16 | | 1 | | | |
| Gross Alpha | 19.8 | 17.9 | 10.7 | 4.45 | 9.74 | | | | | | | | |
| Gross Beta | 58.9 | 8.8 | 3.45 | 5.71 | 7.46 | | | | | | | | |
| *Radiological Indicator Parameters-Level II (pCi/L)* | | | | | | | | | | | | | |
| Carbon-14 | | | | | | | | | | | | | |
| Strontium-90 | | | | | | | | | | | | | |
| Plutonium-238 | | | | | | | | | | | | | |
| Plutonium-239 | | | | | | | | | | | | | |
| Iodine-129 | | | | | | | | | | | | | |
| Technetium-99 | | | | | | | | | | | | | |

anion triangles, Figure 4-1 shows that the groundwater chemistry for Well ER-EC-8 is relatively similar to the surrounding wells and springs at least in terms of the major ionic constituents.

The groundwater chemistry data in Table 4-2 were also used to construct Figure 4-2. The figure shows the stable oxygen and hydrogen isotope compositions of groundwater for Well ER-EC-8 and for selected sites within twelve and a half miles of Well ER-EC-8. Also plotted on Figure 4-2 are the weighted averages of precipitation for various sites on Buckboard Mesa, Pahute Mesa, Rainier Mesa, and Yucca Mountain based on data from Ingraham et al. (1990) and Milne et al. (1987). As can be seen from the figure, the precipitation data, as expected, lie along the local and global meteoric water lines of Ingraham et al. (1990) and Craig (1961), respectively. However, it can be seen from the figure that there is some variability associated with the stable oxygen and hydrogen isotope compositions for Well ER-EC-8 and its nearby neighbors. For example, it can be seen that the delta oxygen-18 ($\delta^{18}O$) values vary from approximately -15 per mil to approximately -14 per mil, while the delta deuterium ($\delta D$) values vary from approximately -115 per mil to approximately -105 per mil. It can be seen from Figure 4-2 that the water from the wells and springs plots isotopically lighter than the precipitation averages suggesting little to no influence of modern atmospheric recharge. One possible explanation for the isotopically lighter groundwater of these wells and springs is that the recharge areas for the groundwater at those sites are located north of Pahute Mesa. Rose et al. (1998) report that the oxygen and hydrogen isotope composition of Pahute Mesa groundwater is similar to the composition of groundwater and alpine spring water in Central Nevada. An alternate explanation for the lighter isotopic signature is that the groundwater was recharged during cooler climatic conditions. Further inspection of the figure reveals that the isotopic signatures of some wells and springs plot well below the global and meteoric water lines. In general, data that fall below the meteoric water lines indicate that some form of secondary fractionation has occurred. This isotopic shift in the groundwater data for areas near Pahute Mesa has been ascribed to fractionation during evaporation of rainfall, sublimation of snowpack, or fractionation during infiltration (White and Chuma, 1987). Because the recent precipitation data plot along the meteoric water lines, it appears that fractionation during precipitation can be ruled out as causing the isotopic shift observed in the groundwater data. This tends to suggest that the isotopic shift in wells surrounding Well ER-EC-8 can likely be attributed to sublimation of snowpack or fractionation during infiltration.

## 4.2 Restoration of Natural Groundwater Quality

A primary purpose for well development was to restore the natural groundwater quality of the completion intervals so that any future groundwater samples taken from the well would accurately represent the water quality of the producing formations. The formations exposed in each completion interval had potentially been affected by drilling and completion operations as well as crossflow from other completion intervals occurring under the natural head gradient. Various aspects of the restoration of the natural groundwater quality will be discussed in this section.

### 4.2.1 Evaluation of Well Development

Water quality monitoring of the well discharge was conducted during pumping to provide information on water chemistry and to indicate when natural groundwater conditions predominate in the pumping discharge. The values of certain geochemical parameters (e.g., pH, turbidity, dissolved oxygen) were expected to decline and stabilize as development progressed, indicating restoration of natural groundwater quality as opposed to water affected by drilling and completion activities. The results from the water quality monitoring were presented in a Section A.2.9, Appendix A.

In particular, during drilling operations for Well ER-EC-8, the makeup water was tagged with a lithium bromide (LiBr) tracer to help determine such things as the water production during drilling. The makeup water was tagged with a LiBr concentration of approximately 20 mg/L to over 180 mg/L; Section A.2.6.1, Appendix A. The concentration of the tracer was increased as water production increased to keep the concentration in the produced water at measurable levels. The relatively high concentrations of lithium ($Li^+$) and bromide ions ($Br^-$) injected into the well bore provide a means to ascertain the effectiveness of well development in removing drilling induced water from the formation. After development, the groundwater characterization samples should only contain bromide concentrations representative of natural concentrations. High concentrations would indicate that the well is still not completely developed.

It can be seen in Table 4-2 that all three groundwater characterization samples had relatively low bromide concentrations. The discrete bailer samples had estimated bromide concentrations of 0.94 mg/L and 0.22 mg/L, while the composite groundwater characterization sample had a bromide concentration of 0.2 mg/L. It can also be seen from the table that the highest bromide concentration in the surroundings wells and springs was 0.31 mg/L for Coffer Ranch Spring. These bromide concentrations are at least an order of magnitude lower than the concentrations of bromide used during drilling and indicate that the well was sufficiently developed to restore groundwater quality to near its natural condition. This conclusion only pertains to the formations producing water during pumping.

### 4.2.2 Evaluation of Flow Between Completion Intervals

Well ER-EC-8 was drilled and completed in July 1999 with three discrete completion intervals. In order to determine flow in the well under ambient, static conditions, thermal flow logging was conducted. The results from the thermal flow logging were reported in the previous well development and testing data report, Section A.2.11 Appendix A, and are shown in Figure A.2-3. In general, the thermal flow logging indicated downward flow of 0.8 gpm in the uppermost screen of the upper completion interval (710 ft bgs), and downward flow of 0.4 gpm below the middle completion interval (1,550 ft bgs). However, as previously mentioned, the thermal flow logging measurements between the upper completion interval and the middle interval were not definitive. The bridge plug head measurements determined a downward gradient between the upper completion interval and the middle completion interval of 0.75 ft, and 0.19 ft between the middle interval and the lower interval. These head differences should produce downward flow given the demonstrated permeability of the lower intervals. A specific tabulation of groundwater flow between the completion intervals cannot be provided, but the information suggests that between 0.4 and 0.8 gpm flow downhole under the natural gradient. A greater amount may actually flow downward from the upper interval and leave the well in the middle interval.

### *4.2.3 Source Formation(s) of Groundwater Samples*

As has been discussed in Section 3.0, flow logging during pumping indicated that essentially all of the total production in the well originated from the upper completion interval (683 to 984 ft bgs). Specifically, the results from the stationary flow measurements indicated that between 96 and 100 percent of the total flow from the well originated from the upper completion interval (Section A.2.7.2, Appendix A) depending on the pumping rate. At the higher rate, at which the sampling was conducted, there is production from the lower intervals of about 7 gpm. Therefore, the discrete bailer characterization sample taken from 1,020 ft bgs should represent a combination of groundwater from both the middle and lower completion intervals. However, this assumes that the groundwater quality in the lower intervals was fully remediated. During the course of development and testing, approximately 3.8 million gallons of water were produced, of which less than 4 percent, about 150,000 gallons would have come from the middle and lower intervals. The time period between well completion and the start of pumping was 11 months. During this time the estimated natural flow down the well to the lower completion intervals was between 380,000 and 190,000 gallons using the two measured natural flow rates. This suggests that pumping for development and testing did not necessarily remove as much water as had entered the lower intervals from crossflow. Consequently, the water derived from the lower completion intervals probably did not represent the actual natural water quality of those intervals, but was some undefined composite of the upper interval with the natural water in the interval. This would be especially true of the discrete bailer samples which were collected before even half of the total volume of water was produced.

The preliminary lithologic and stratigraphic logs indicate that the upper completion interval is located within the nonwelded tuff of the Beatty Wash Formation. It can be concluded that the discrete bailer groundwater sample from 760 ft bgs is primarily derived from that formation. Preliminary lithologic and stratigraphic logs indicated that these two lower intervals were completed within the welded Tuff of Buttonhook Wash and the welded Ammonia Tanks Tuff. The deeper discrete bailer sample represents groundwater also from the nonwelded tuff of the Beatty Wash Formation, but composited to some extent with water from the lower formations. The composite groundwater characterization sample should represent, like the discrete bailer sample from 760 ft bgs, a combination of groundwater from all three completion intervals. However, for all practical purposes, the source formation for the composite groundwater characterization sample is the upper completion interval.

## 4.3 Representativeness of Water Chemistry Results

The analytical results from the groundwater characterization samples support the conclusions about the origin of the groundwater. There are no major geochemical differences between the two discrete bailer samples and the composite groundwater characterization sample. This is interpreted to mean that the composite groundwater characterization sample was indeed drawn from the same groundwater sources as the discrete characterization samples, especially the discrete bailer sample from 760 ft bgs. The major difference between the composite characterization sample and this discrete sample is that a large proportion of the production from the upper interval, almost 60 percent, occurred above the depth of the discrete sample. Any difference between the upper and lower portions of the upper completion interval could show up as a difference between these two samples.

In addition, since there was no significant evidence of residual contamination from drilling, it can be assumed that the samples are representative of the groundwater in the formation opposite the upper completion interval. No specific conclusions can be drawn about the water quality in the lower completion intervals. The lower completion intervals cannot be considered developed, and any samples taken below the upper completion interval are suspect.

## 4.4 Use of ER-EC-8 for Future Monitoring

As discussed in this section, the flow logging indicates that approximately 96 to 100 percent of the produced water originates from the upper completion interval at pumping rates of 177 gpm and below. The permanent sampling pump that was installed after testing has a maximum capacity of about 44 gpm, and sampling conducted with this pump should also produce water that primarily represents the water quality of the upper completion interval.

The direction of natural-gradient flow in the well is downwards, with measured flow rates of 0.8 to 0.4 gpm from the upper completion interval to lower completion interval. Consequently, the upper completion interval should not become contaminated with any foreign water between pumping episodes. However, the lower intervals will be flooded with water from the upper interval during the periods when the well is not being pumped since a bridge plug(s) was not installed in this well to prevent crossflow. Extended purging will be required to produce water from the lower intervals that actually represents water quality of the lower intervals if and when a method is employed that will produce substantial amounts from the lower intervals.

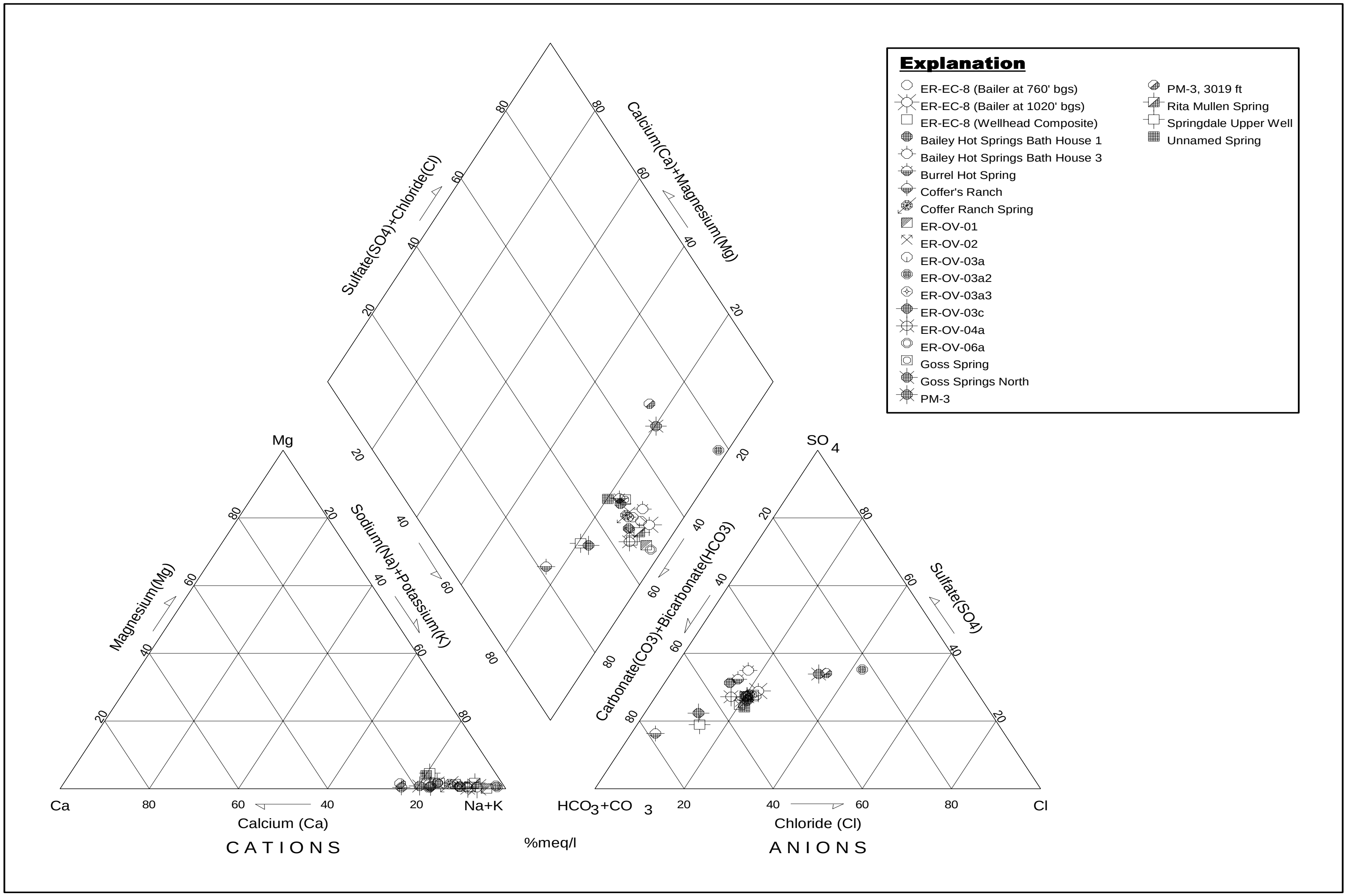



**Figure 4-1**
**Piper Diagram Showing Relative Major Ion Percentages**

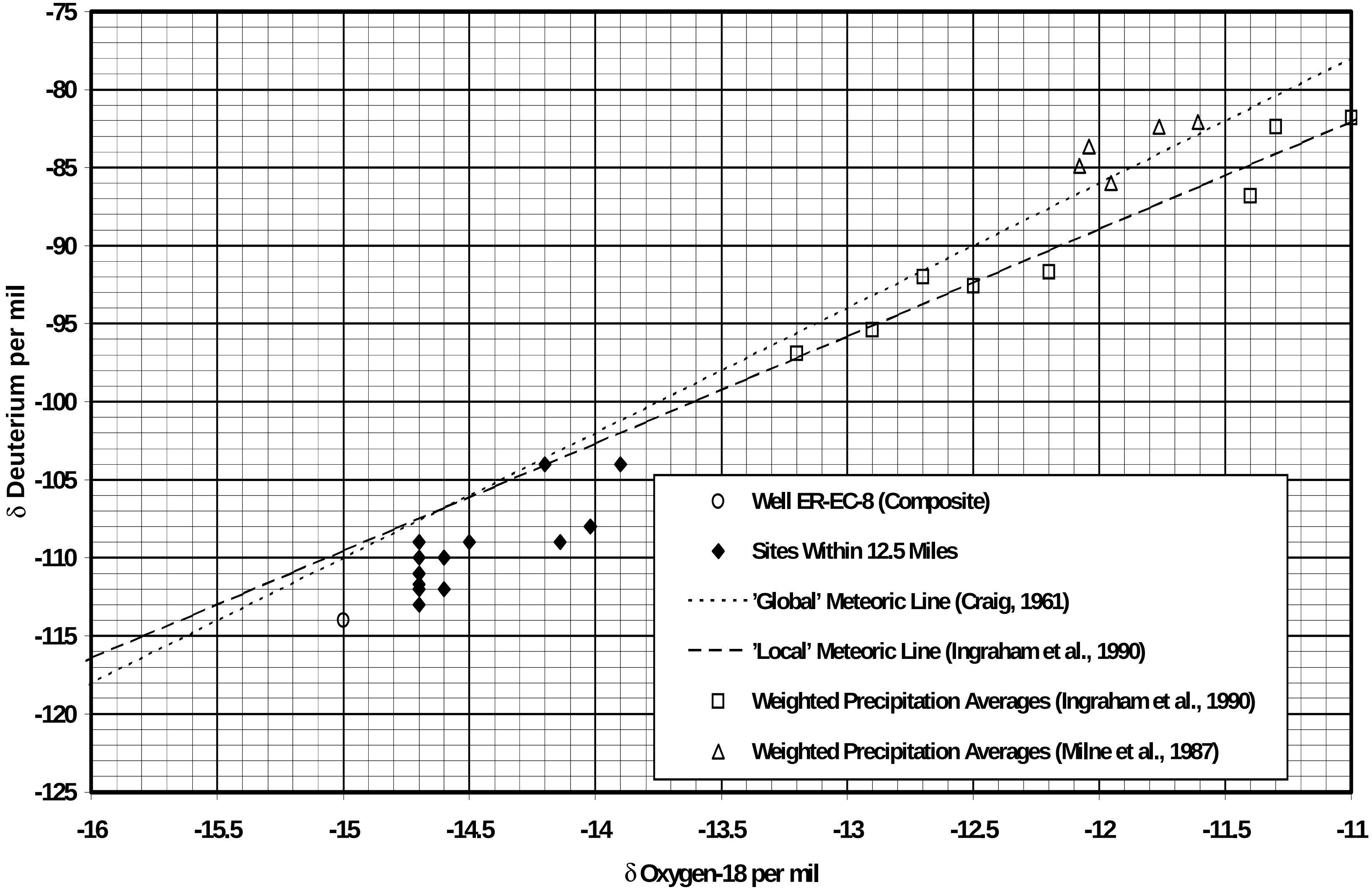



**Figure 4-2**
**Stable Isotope Composition of Groundwaters**

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# Appendix A

# Western Pahute Mesa-Oasis Valley Well ER-EC-8 Data Report for Development and Hydraulic Testing

# A.1.0 Introduction

Well ER-EC-8 is one of seven groundwater wells that were completed as part of FY 1999 activities for the NNSA/NV UGTA Project. Figure A.1-1 shows the location of the WPM-OV wells. Hydraulic testing and groundwater sampling were conducted at Well ER-EC-8 to provide information on the hydraulic characteristics of HSUs and the chemistry of local groundwater. Well ER-EC-8 is constructed with three completion intervals, intervals of slotted casing with gravel-pack, separated by blank casing sections with cement seals in the annular space. The three completion intervals are separated by distances of about 338 ft (upper to middle completion interval) and 68 ft (middle to lower completion interval). The upper interval is within the Beatty Wash Formation, and the middle and lower intervals are within the welded tuff aquifer of the Ammonia Tanks Tuff.

This document presents the data collected during well development and hydraulic testing for Well ER-EC-8 and the analytic results for groundwater samples taken during this testing.

The objectives of the development and testing program were:

1. Increase the hydraulic efficiency of the well.

2. Restore the natural groundwater quality.

3. Determine the hydraulic parameters of the formations penetrated.

4. Collect discrete samples from discrete locations and/or specific completion intervals to characterize spatial variability in downhole chemistry.

5. Collect groundwater characterization samples to evaluate composite chemistry.

Well ER-EC-8 was the sixth of the WPM-OV wells to be developed and tested. Activities began February 11, 2000, and were completed by July 20, 2000. A variety of testing activities were conducted including discrete head measurements for each completion interval, flow logging under ambient conditions and during pumping, a constant-rate pumping test, water quality parameter monitoring, and groundwater sampling of individual producing intervals and of the composite discharge.

### A.1.1 Well ER-EC-8 Specifications

The drilling and completion specifications of Well ER-EC-8 were obtained from a draft of the *Completion Report for Well ER-EC-8* (Townsend, 2000). This report also contains the lithologic and stratigraphic interpretation for this well. The schematic well construction is illustrated in various figures in this report which show logging information.

### A.1.2 Development and Testing Plan

Well development consisted of producing water from the well to clean out sediment and drilling-induced fluid to restore the natural productivity and the natural water quality of the formation(s) in the completion intervals. The well was hydraulically stressed and surged to the extent possible to promote the removal of lodged and trapped sediment. Water production was accompanied by both hydraulic response and water quality assessments to evaluate the status of development.

The testing program was structured to develop a complete assessment of the hydrology and groundwater quality accessed by the well completion. The elements of the testing can be found in *Well Development and Hydraulic Testing Plan for Western Pahute Mesa - Oasis Valley Wells* (WDHTP) (IT, 1999d) and associated technical change records.

The testing activities included: (1) discrete head measurements for each completion interval using bridge plugs equipped with pressure transducers and dataloggers for the lower intervals and a wireline-set pressure transducer for the uppermost interval; (2) flow logging during pumping to determine the extent of the open formation actually producing water and locations of discrete production along the borehole; (3) flow logging under ambient head conditions to determine circulation in the well under the natural gradient; (4) a constant-rate pumping test to determine hydraulic parameters for the formation(s); (5) discrete downhole sampling during pumping to capture samples that can be determined to represent specific formations or portions of formations; and (6) a composite groundwater characterization sample of water produced during pumping after the maximum possible development.

### A.1.3 Schedule

The generic schedule developed for the Well ER-EC-8 testing program was as follows:

1. Measurements of interval-specific hydraulic heads, including monitoring of equilibration after installation of last bridge plug (estimated 5 days).

2. Installation of well development and hydraulic testing equipment (estimated 2 days).

3. Well development, flow logging, and discrete sampling (estimated 7 days).

4. Water level recovery (estimated 5 days).

5. Constant-rate pumping test and groundwater characterization sampling (estimated 10 days).

6. Water level recovery (estimated 5 days).

7. Removal of downhole equipment and water level measurement (estimated 1 day).

8. Thermal flow logging (estimated 2 days).

9. Installation of dedicated sampling pump and possible groundwater characterization sampling (estimated 4 days).

A brief history of the testing program at Well ER-EC-8 is shown in Table A.1-1. In general, the work proceeded according to the planned schedule, but the work was spread over a greater time period than the generic schedule in order to coordinate with other activities. There were several delays related to generator problems and variable speed drive (VSD)/pump shutdown due to power cable failure.

**Table A.1-1**
**Brief History of Work Performed at Well ER-EC-8**

| Activity | Start Date | Finish Date | Duration (days) |
|---|---|---|---|
| Zone-specific head measurements (bridge plugs) | 2/11/2000 | 2/19/2000 | 9 |
| Site mobilization | 6/7/2000 | 6/12/2000 | 6 |
| Install testing pump, troubleshoot power cable problems and remove/reinstall pump twice. Check pump functionality. | 6/13/2000 | 6/21/2000 | 9 |
| Develop well and conduct step-drawdown testing | 6/21/2000 | 6/26/2000 | 6 |
| Conduct flow logging while pumping and discrete downhole sampling. Install check valve and shutdown pump. | 6/27/2000 | 6/28/2000 | 1 |
| Monitor for recovery and pretest conditions | 6/29/2000 | 7/3/2000 | 6 |
| Constant-rate test | 7/3/2000 | 7/12/2000 | 9 |
| Composite wellhead sampling | 7/12/2000 | 7/12/2000 | 1 |
| Monitor recovery | 7/12/2000 | 7/17/2000 | 5 |
| Remove access line and testing pump | 7/17/2000 | 7/18/2000 | 2 |
| Flow logging (thermal flowmeter) under ambient conditions | 7/18/2000 | 7/18/2000 | 1 |
| Install sampling pump and test for functionality | 7/19/2000 | 7/19/2000 | 1 |
| Demobilize from site | 7/20/2000 | 7/20/2000 | 1 |

## *A.1.4 Governing Documents*

Several documents govern the field activities presented in this document. The document describing the overall plan is the WDHTP (IT, 1999d). The implementation of the testing plan is covered in *Field Instruction for Western Pahute Mesa - Oasis Valley Well Development and Hydraulic Testing Operations*, (FI) (IT, 1999b), as modified by Technical Change No. 1, dated December 22, 1999. This document calls out a variety of Detailed Operating Procedures (DOPs) (IT, 1999a) and Standard Quality Practices (SQPs) (IT, 2000) specifying how certain activities are to be conducted. The work was carried out under the *Site-Specific Health and Safety Plan for Development, Testing, and Sampling of Clean Wells* (IT, 1999c), and two Technical Change Notices. Specifications for the handling and analysis of groundwater samples are listed in the *Underground Test Area Quality Assurance Project Plan* (DOE/NV, 1998).

## *A.1.5 Document Organization*

This data report is organized in the following manner:

- Section A.1.0: Introduction

- Section A.2.0: Summary of Development and Testing. This chapter presents mostly raw data in the form of charts and graphs. Methodologies for data collection are described, as well as any problems that were encountered. Data is presented under the following topics: water level measurements, interval-specific head measurements, pump installation, well development, flow logging during pumping, constant-rate pumping test, water quality monitoring, groundwater sampling, thermal-flow logging and ChemTool logging.

- Section A.3.0: Data Reduction and Review. This chapter further refines and reduces the data to present specific results that are derived from the program objectives. Information is presented on vertical gradients and borehole circulation, intervals of inflow into the well, the state of well development, reducing the data from the constant-rate test, changes in water quality parameters, and representativeness of groundwater samples.

- Section A.4.0: Environmental Compliance. This chapter records the results of the tritium and lead monitoring, fluid disposition and waste management.

- Section A.5.0: References.

- Attachment 1: Manufacturer Pump Specifications.

- Attachment 2: Water Quality Monitoring - Grab Sample Results. This appendix shows the field laboratory results for temperature, electrical conductivity (EC), pH, dissolved oxygen (DO), turbidity and bromide in relation to date/time and gallons pumped.

- Attachment 3: Water Quality Analyses - Composite Characterization Sample and Discrete Samples.
- Attachment 4: Fluid Management Plan Waiver for WPM-OV Wells.
- Attachment 5: Electronic Data Files Readme.txt This attachment contains the readme file text included with the electronic data files to explain the raw data files included on the accompanying compact disc (CD).

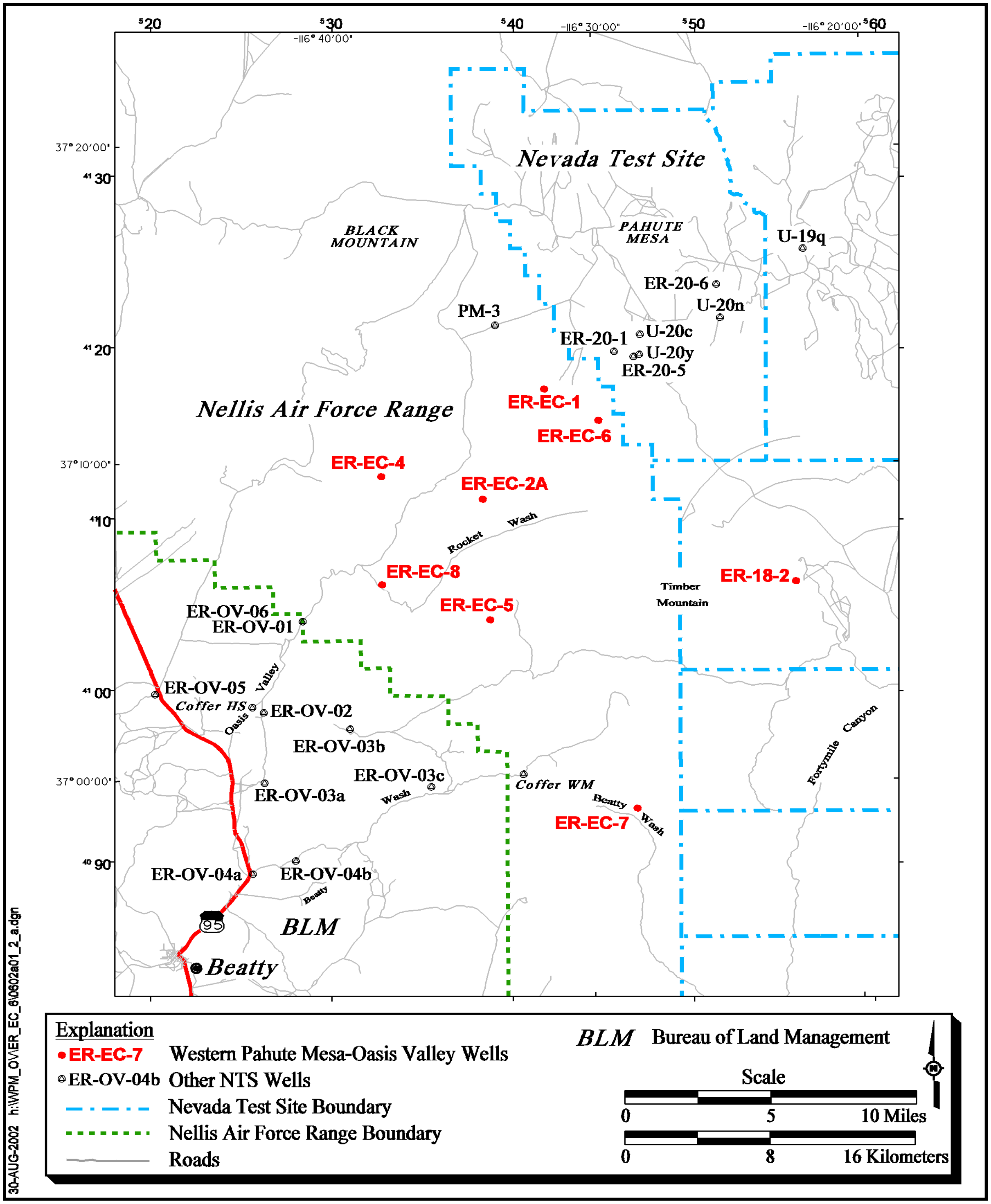



**Figure A.1-1**
**Area Location Map**

# A.2.0 Summary of Development and Testing

This section presents details of the well development and testing activities, the associated data collection activities, and summaries and depictions of the unprocessed data that were collected. The detailed history of Well ER-EC-8 development and testing is shown in Table A.2-1.

## A.2.1 Measurement Equipment

Following is a general description of the equipment used by IT Corporation, Las Vegas Office (ITLV) for measurements and monitoring during development and testing. Other equipment used for specific parts of the program are described in the appropriate section. Depth-to-water measurements were made with a metric Solinst e-tape equipped with a conductivity sensor. The PXDs were Design Analysis Associates' Model H-310 which are vented. The vent line is housed in an integral cable of sufficient length to allow installation of the PXD to its maximum working depth below the water surface. The cable was crossed over to a wireline above the water surface. The PXDs employ a silicon strain gauge element, and include downhole electronics to process the voltage and temperature measurements. Data is transmitted uphole digitally to a Campbell Scientific CR10X datalogger located on the surface using SDI 12 protocol. The rated accuracy of the PXDs are 0.02 percent full scale (FS). Barometric pressure was measured with a Vaisala Model PTA 427A barometer housed with the datalogger. All equipment was in calibration.

### A.2.1.1 Data Presentation

Most of the data were loaded into Excel® spreadsheets for processing and are presented with graphs directly from the spreadsheets. Due to the nature of the data and how the data were recorded in the datalogger program, certain conventions were used in presenting the data. Following are explanations of these conventions to aid in understanding the data presentations:

- The time scale presented for all monitoring is in Julian Days, as recorded by the datalogger. Julian Days are consecutively numbered days starting with January 1 for any year. This format maintains the correspondence of the presentation with the actual data, and presents time as a convenient continuous length scale for analysis purposes.

- The PXD data are presented as the pressure recorded by the datalogger so that it corresponds to the raw data in the data files. These data can be

**Table A.2-1**
**Detailed History of Development and Testing Activities**

| Date | Activities |
|---|---|
| 8/19/1999 | ITLV installs 0-15 psig PXD for predevelopment water level monitoring. |
| 10/8/1999 | ITLV removes PXD. |
| 2/11/2000 | Baker Hughes runs basket and gauge without problem. ITLV measures water level at 322.87 ft bgs. Baker Hughes runs Bridge plug/PXD is removed and pressure data downloaded. Data is checked for consistency, and found acceptable after allowing for temperature corrected density of the water in the well. |
| 2/14/2000 | ITLV measures water level at 322.87 ft bgs. Baker Hughes then installs lower bridge plug/PXD at 1,600 ft bgs. ITLV measures subsequent water level at 322.87 ft bgs. Baker Hughes then installs upper bridge plug/PXD at 1,365 ft bgs. ITLV measures subsequent water level at 322.86 ft bgs. ITLV then installs 0-15 psig PXD at 347 ft bgs. |
| 2/19/2000 | ITLV removes PXD and measures water level at 324.62 ft bgs. Baker Hughes removes upper and lower bridge plug/PXDs. |
| 6/7/2000 | Begin mobilization of drill rig to the site. |
| 6/12/2000 | Drill rig is set up. |
| 6/13/2000 | BN runs 2 3/8-in access line to a depth of 571.08 ft bgs. |
| 6/14/2000 | BN assembles, wires, and installs testing pump. Bottom of pump assembly is landed at 558.88 ft bgs, placing intake at 512.27 ft bgs. ITLV measures water level at 322.49 ft bgs, and installs PXD for hydraulic response monitoring. The back pressure system and discharge plumbing are installed. The pump is tested for functionality. The backpressure regulator must be adjusted for flow rates below 100 gpm to maintain 600 psi backpressure. The pump is run at 175 gpm overnight. |
| 6/15/2000 | The VSD shut the pump down at 23:30 the previous night. Checking determines that the power cable to the motor is going to ground. ITLV removes the PXD. BN removes the access line and pump from the well. Checks determine that the problem is with the cable. |
| 6/16/2000 | BN installs the access line to 571.08 ft bgs. BN installs the pump to 540.49 ft bgs. ITLV measures the water level at 322.52 ft bgs, and installs 0-30 psig PXD. Pump is started and a functionality test performed. At 17:33 the generator overheats and shuts down. Pump is restarted with backup generator, and pump is run at 180 gpm overnight. |
| 6/17/2000 | The VSD shut the pump down at 00:00 the previous night. Checking determines that the power cable to the motor is going to ground. ITLV removes the PXD and measures the water level at 322.60 ft bgs. |
| 6/19/2000 | BN removes pump. Motor lead is discolored and brass shavings are found in end cap of motor. |
| 6/20/2000 | Motor is flushed with oil and a #2 power cable is installed. BN installs pump to 540.29 ft bgs with intake at 494.66 ft bgs. |
| 6/21/2000 | ITLV measures water level at 322.70 ft bgs, and sets PXD. Pump is started. Pumping is discontinued while BN cuts power cable to eliminate excess cable on spool at surface. Pump restarted and pump is run overnight at 180 gpm. |
| 6/22/2000 | Pump runs all night. Pump is shut down to allow recovery before step-drawdown test. Conduct step-drawdown test. Pump overnight at 180 gpm. |
| 6/23/2000 | Power to flowmeter lost overnight so VSD raised pumping rate to high clamp (70 Hz), which also increased backpressure to 700 psig. Measure 70 Hz pumping rate at 196 gpm. Conduct functionality test. Conduct step-drawdown test. Pumping continues overnight at 180 gpm. |
| 6/24/2000 | Pump turned on and off for surging. Pump overnight. |
| 6/25/2000 | Conduct step-drawdown protocol. Pump overnight. |
| 6/26/2000 | Pump turned on and off for surging. Pump overnight. |
| 6/27/2000 | ITLV removes PXD. DRI conducts flow logging during pumping at 65 and 176 gpm. |
| 6/28/2000 | DRI completes flow logging at 127 gpm and collects downhole discrete samples. Samples collected at 760 ft bgs at 65 gpm, and at 1,020 ft bgs at 175 gpm. Pump is stopped and check valve is installed. Pump is started to fill tubing to test check valve. Check valve holds. |
| 6/29/2000 | ITLV measures water level at 322.06 ft bgs. ITLV then sets 0-30 psig PXD. Begin pretest monitoring. |
| 7/3-12/2000 | Constant-rate test, pumping at 176 gpm. |
| 7/12/2000 | Groundwater characterization sampling by ITLV, LLNL, DRI, and UNLV-HRC. Pump shut down at 12:30. |
| 7/12-17/2000 | Monitor recovery. |
| 7/13/2000 | ITLV begins to demobilize. |
| 7/17/2000 | ITLV removes PXD. DRI removes check valve. BN removes access line and begins to remove testing pump. |
| 7/18/2000 | BN finishes removing testing pump. DRI runs ChemTool, and collects Thermal Flow Log measurements at ten locations. |
| 7/19/2000 | BN installs permanent sampling pump and tests functionality. |
| 7/20/2000 | Demobilize equipment from site. |

BN - Bechtel Nevada
DRI - Desert Research Institute
ITLV - IT Corporation, Las Vegas Office
ft bgs - Feet below ground surface
in. - Inch(es)
PXD - Pressure transducer
UNLV-HRC - University of Nevada, Las Vegas - Harry Reid Center
Hz - Cycles per second (hertz)
gpm - Gallons per minute
VSD - Variable speed drive
psi - Pounds per square inch
psig - Pounds per square inch gauge
LLNL - Lawrence Livermore National Laboratory

processed to various forms of head, with or without barometric correction. The additional required data, which may be needed for further processing, is included in this report. Note that the data files contain a column in which the raw pressure measurement has been processed to a head measurement in terms of feet of water column above the PXD. The conversion was based on an approximate standard density for water, and was for field use in monitoring downhole conditions. In Section A.3.1, a well-specific value for the water density is derived and used for the processing of the drawdown response into head.

- Groundwater pressure measurements are reported as pounds per square inch gauge (psig) since the PXDs used for groundwater pressure monitoring were vented, not absolute. Pressure differences are reported as psi. Atmospheric pressure (i.e., barometric pressure) is reported as millibars (mbar); this is an absolute measurement.

- On graphs showing both PXD data and barometric data, the pressure scales for psi and mbar have been matched to show the changes in pressure proportionately. One psi is approximately equal to 69 mbar. For presentation convenience, the scales are not matched exactly, but are close enough so that the relative magnitude of the pressure changes is apparent. Complete electronic data files are included on an accompanying CD which allows the user to evaluate details of barometric changes and aquifer response as desired.

- The data on water density in this report are presented in terms of the derived conversion factor for pressure in psi converted to vertical height of water column in feet. This is actually the inverse of weight density expressed in mixed units (feet-square inches/pound or feet/pounds per square inch). This is a convenient form for use in calculations. Later in the text, the derived densities are discussed in terms of specific gravity.

- Note that various derived values for parameters presented in this report may differ from values previously reported in Morning Reports. These differences are the result of improved calculations. Changes in measured parameter values are the result of corrections based on checking and confirming values from multiple sources.

- The production rates given in the text, shown in figures, and recorded in the data files are the flowmeter readings. During well development, 1 to 3 gpm was diverted to the Hydrolab® before production rate measurement by the flowmeter. The specific flow to the Hydrolab® at any particular time is not known exactly.

### *A.2.2 Predevelopment Water Level Monitoring*

Following completion of Well ER-EC-8, the water level was monitored with a PXD and datalogger for a period of about five and one-half weeks to establish the equilibrium composite head for this well. Figure A.2-1 shows the results of this monitoring. An electronic copy of this data record can be found on the CD as file EC-8Water-LevelMon.xls. A readme text file is included in Attachment 5, which explains how the data may be accessed.

### A.2.3 Depth-to-Water Measurements

A series of depth-to-water measurements were made in Well ER-EC-8 as part of the various testing activities. Table A.2-2 presents all of the equilibrium, composite water level measurements made during the testing program. Measurements representing nonequilibrium or noncomposite water levels are presented in the appropriate section for the testing activity involved.

**Table A.2-2**
**Equilibrium, Composite Depth-to-Water Measurements**

| Date | Time | Depth-to-Water (bgs) | | Barometric Pressure (mbar) |
|---|---|---|---|---|
| | | Feet | Meters | |
| 8/19/1999 | 12:06 | 322.70 | 98.36 | -- |
| 10/8/1999 | 17:10 | 322.70 | 98.36 | 834.87 |
| 2/11/2000 | 10:02 | 322.87 | 98.41 | 866.86 |
| 2/14/2000 | 8:15 | 322.87 | 98.41 | 866.61 |
| 6/14/2000 | 17:16 | 322.49 | 98.29 | 868.57 |
| 6/16/2000 | 15:10 | 322.52 | 98.30 | 861.04 |
| 6/17/2000 | 10:25 | 322.60 | 98.33 | 865.83 |
| 6/21/2000 | 9:03 | 322.70 | 98.36 | 868.65 |
| 6/27/2000 | 8:37 | 323.04 | 98.46 | 869.02 |
| 6/29/2000 | 9:00 | 323.03 | 98.46 | 869.14 |
| 7/17/2000 | 9:11 | 322.78 | 98.38 | 869.45 |

bgs - Below ground surface
mbar - Millibars

### A.2.4 Interval-Specific Head Measurements

The representative hydraulic head of the individual completion intervals were measured to provide information on the vertical hydraulic gradients. This was accomplished by isolating the completion intervals from each other with bridge plugs and measuring the pressure or head in each interval. The bridge plugs contained pressure transducers and dataloggers to measure and record the pressure in the interval below the bridge plug. The head in the uppermost interval was monitored using a PXD installed on a wireline. After removal of the PXD, corresponding water levels were measured with an e-tape. The bridge plugs remained in their downhole stations for five days to monitor the pressure changes in the intervals.

### *A.2.4.1 Bridge Plug Installation and Removal*

The procedure for installing the bridge plugs included:

1. Run gauge and basket to below lower bridge plug set depth to verify that bridge plugs would fit through casing.

2. Measure the static water level to establish the reference head (head is assumed to be in equilibrium).

3. Run lower bridge plug to set-depth minus 50 ft and collect four or more pressure readings (bridge plug not set).

4. Lower bridge plug to set-depth plus 50 ft and collect four or more pressure readings (bridge plug not set).

5. Raise bridge plug to set-depth, collect four or more pressure readings, then set bridge plug to isolate lower completion interval. Monitor head change in lower interval with internal pressure transducer/datalogger.

6. Measure water level in well to determine head change after setting first plug and establish a new reference head elevation (treated as if stable).

7. Run upper bridge to set-depth minus 50 ft and collect four or more pressure readings.

8. Lower bridge plug to set-depth plus 50 ft and collect four or more pressure readings.

9. Raise bridge plug to set-depth, collect four or more pressure readings, then set bridge plug to isolate middle completion interval. Monitor head change in middle interval with internal pressure transducer/datalogger.

10. Measure water level in well to determine head change and establish a reference head elevation (treated as if stable).

11. Install PXD in uppermost interval and monitor head change in uppermost interval.

12. After five days, measure water level in upper interval with an e-tape, then remove equipment and download dataloggers.

This procedure provides in-well calibration of pressure versus head (i.e., density which is a function of the temperature profile) for use in interpreting the equilibrated head for each isolated interval. No problems were encountered in these operations.

### *A.2.4.2 Pressure/Head Measurements*

The bridge plug/PXD assemblies were supplied and installed by Baker Hughes Corporation on their own wireline. The PXDs were Sunada Model STC8064A with a rated measurement accuracy of 0.1 percent FS. PXDs with various pressure ranges were used to suit the depth of installation. Information was collected by a built-in datalogger recording on a time interval of 5 minutes following an initial 20-minute delay from the start of the datalogger. The datalogger time is in decimal hours. Since there was no data connection to the surface once the bridge plug was set, data could not be read or evaluated until the bridge plug was retrieved. The bridge plug/PXDs were left downhole for about five days, a length of time expected to be sufficient for equilibration to occur.

Table A.2-3 shows the interval-specific pressure and head measurements, including the calibration data. Graphs of the interval monitoring are included in Section A.3.0. Note that the corrected depths for the bridge plug are slightly different from the PXD set depths that had been specified, and listed in the Morning Reports. The set depths were located by keying off of casing collars, but there was a misunderstanding in the field about the direction of measurement, up versus down, from the collars. However, there was no problem using the measurements collected at the actual locations once the locations were verified. The location corrections are discussed in Section A.3.1.1. The datalogger files for the equilibration of the pressure transducers can be found on the enclosed CD, labeled as follows: EC8gradient.xls (upper interval), EREC8U.xls (middle interval), and EREC8L.xls (lower interval).

**Table A.2-3**
**Interval-Specific Head Measurements**

| Interval | Comment | Depth (ft bgs) | Depth (m bgs) | PXD Measurement (psig) |
|---|---|---|---|---|
| Upper | Final Head | 322.97 (e-tape) | 98.44 | -- |
| Middle | Reference Head - composite of upper two intervals | 322.87 (e-tape) | 98.41 | 447.30 |
| | Bridge Plug set depth minus 50 ft | 1,313.93 | 400.48 | 425.94 |
| | Bridge Plug set depth - post set | 1,363.95 | 415.73 | 447.14 |
| | Bridge Plug set depth plus 50 ft | 1,413.87 | 430.95 | 468.93 |
| Lower | Reference Head - composite of all three intervals | 322.87 (e-tape) | 98.41 | 549.58 |
| | Bridge Plug set depth minus 50 ft | 1,548.49 | 471.98 | 528.07 |
| | Bridge Plug set depth - post set | 1,598.50 | 487.22 | 549.25 |
| | Bridge Plug set depth plus 50 ft | 1,648.42 | 502.44 | 571.09 |

ft bgs - Feet below ground surface
m bgs - Meters below ground surface
psig - Pounds per square inch gauge

## A.2.5 Pump Installed for Development and Testing

A high-capacity pump was temporarily installed for well development and testing. This pump was later replaced with a lower capacity, dedicated pump for long-term sampling. The development and testing pump was the highest production-rate pump available that would physically fit into the well and still allow an access line to pass by. The access line was required to guide the flow logging and discrete sampling tools past the pump and into the completion intervals. The following sections discuss the details of pump installation and performance.

### A.2.5.1 Pump Installation

The pump installed for development and testing was a Centrilift 86-FC6000 (387 Series) electric submersible consisting of two tandem pump units (#01F82215 and #01F82216) with 43 stages each, and a 130 horsepower motor assembly (375 Series, 2 sections - #21D48009 and #21D48010). This pump was replaced on June 20, 2000, with a similar pump; two tandem pumps units (#01F-83184 and 01F-83185, seal (#31D-53113), and two motor sections (#21D-47849 and #21D-437843). Manufacturer's specifications for this pump are included in Attachment 1. Note that the pump units total 30.0 feet in length with the intake at the bottom of the lower pump unit. A seal section separates the pump units from the motor unit, which is located at the bottom of the assembly. The pump was installed on 2 7/8-in. Hydril® tubing. A model "R" seating nipple was placed just above the pump in the production tubing to allow future installation of a wireline-set check valve. The pump was operated without a check valve during development to allow the water in the production tubing to backflow into the well when the pump was shut down. This was intended to "surge" the well and aid in development. A check valve was installed prior to the constant-rate pumping test to prevent such backflow. The pump was removed from the well twice to deal with problems with the power cable. For the final installation, it was landed with the bottom of the motor at 540.29 ft bgs, which placed the pump intake at 494.66 ft bgs.

An Electra Speed 2250-VT VSD was used to regulate the production of the pump. To maintain a constant production rate for testing, the transmitter of the Foxboro 1.5-in. magnetic flowmeter was connected to the VSD in a feedback loop to supply the VSD with continuous flow rate information. The VSD automatically adjusts the frequency of the power supplied to the pump to maintain a constant production rate. The flowmeter record shows that this worked very well and a constant production rate could be maintained as drawdown progressed.

### A.2.5.2 Pump Performance

Pump performance is indicated by the records as shown in Table A.2-4. These production rates are in line with performance projections supplied by the manufacturer for this pump with similar pumping parameters. The pump was operated with an additional backpressure of 600 psig (nominal) imposed at the surface to meet the operational requirements of the pump. Note that the drawdown data provided for the various pumping rates is only a snapshot. For the drawdown data to be meaningful, it would need to be related to the amount of time of pumping at that rate and the water level from which the pumping started. Because this well exhibited an initial quick drawdown to a quasi-stable level, these values approximately represent characteristic drawdowns. This information indicates the range of drawdowns experienced during development and testing.

**Table A.2-4**
**Pump Performance**

| Date | Time | VSD Setting (Hz) | Production Rate (gpm) | Approximate Drawdown[a] (ft) |
|---|---|---|---|---|
| 6/14/2000 | 18:50 | 53 | 42.00 | 2.10 |
| 6/14/2000 | 19:00 | 58 | 111.55 | 9.51 |
| 6/14/2000 | 19:19 | 66 | 178.60 | 18.64 |
| 6/16/2000 | 16:56 | 55 | 63.25 | 4.35 |
| 6/16/2000 | 17:08 | 57.4 | 102.37 | 6.78 |
| 6/16/2000 | 17:22 | 60.3 | 140.41 | 11.59 |
| 6/16/2000 | 19:55 | 67.8 | 180.93 | 17.57 |
| 6/22/2000 | 07:20 | 66.1 | 181.64 | 17.64 |
| 6/22/2000 | 13:30 | 59.3 | 131.02 | 9.54 |
| 6/23/2000 | 08:00 | 67.4 | 181.31 | 16.96 |
| 6/23/2000 | 08:20 | 70 | 196.95 | 18.66 |
| 6/23/2000 | 08:30 | 65 | 172.14 | 15.32 |
| 6/23/2000 | 08:40 | 60 | 140.72 | 11.79 |
| 6/23/2000 | 08:50 | 55 | 60.89 | 4.42 |
| 6/25/2000 | 07:30 | 68.3 | 181.24 | 15.70 |
| 6/25/2000 | 10:15 | 55.4 | 65.68 | 3.65 |
| 6/25/2000 | 11:45 | 57.2 | 121.01 | 8.74 |
| 7/3/2000 | 10:45 | 66.2 | 176.39 | 13.93 |

Note: Significant figures reported as recorded from field documents.

[a] Drawdown derived from PXD pressure data using a density of 2.307 ft/psi.

Hz - Hertz, cycles per second
gpm - Gallons per minute
ft - Feet

The data in Table A.2-4 shows that there was an apparent small reduction in the well drawdown at the same production rates during the course of development. No significant changes were observed. Three flow rates were selected for the steps to be used in development activities: 65, 120, and 175 gpm. In practice there may be small variations in actual pumping rates that result from variables in current pumping conditions.

### *A.2.6 Development*

There were two objectives for well development, the physical improvement of the condition of the well completion and restoration of the natural water quality. The early development activities were primarily designed to improve the physical condition of the well completion. This involved removing drilling fluid and loose sediment remaining from drilling and well construction to maximize the hydraulic efficiency of the well screen, gravel pack, and the borehole walls. These improvements promote efficient and effective operation of the well and accurate measurement of the hydrologic properties. The development phase was primarily intended to accomplish hydraulic development in preparation for hydraulic testing.

Restoration of the natural water quality includes removal of all nonnative fluids introduced by the drilling and construction activities and reversal of any chemical changes that have occurred in the formation due to the presence of those fluids. This objective of development addresses the representativeness of water quality parameter measurements and chemical analyses of samples taken from the well. Another aspect of this objective was to remove nonnative water from completion intervals receiving water due to natural gradient flow from other intervals and reverse chemical changes that have occurred as a result. Since the well completion cross-connects intervals of different heads and hydraulic conductivities, such natural circulation was presumed to have been occurring since the well was drilled. Measurement of this circulation is addressed later under ambient flow logging with the thermal flowmeter. This issue would be important for the representativeness of discrete downhole samples that are intended to distinguish differences in water quality between completion intervals.

Restoration of natural groundwater quality is mostly a function of the total volume of water produced. Discrete sampling for groundwater characterization was scheduled at the end of the development stage, which provided the maximum development possible before downhole sampling without interfering with the constant-rate test. An evaluation of the status of development at the time of sampling is presented in Section A.3.6.

The history of the development phase for Well ER-EC-8 is shown in Table A.2-1. The generic plan allowed seven days for this phase, but additional time was required to sort out problems with the pump and to adjust the schedule to fit into the overall work scheme for UGTA field activities.

#### *A.2.6.1 Methodology and Evaluation*

The basic methodology for hydraulic development was to pump the well at the highest possible rates, and to periodically surge the well by stopping the pump to allow backflow of the water in the pump column. The parameters of the pumping operations, production rates, and drawdown responses were recorded continuously by a datalogger from the production flowmeter and a downhole PXD. During flow logging and discrete-interval sampling, the PXD had to be removed to allow access for the flow logging tool and the discrete bailer. Barometric pressure was also recorded in conjunction with PXD records.

Monitoring during development included hydraulic performance data and a variety of general water quality parameters intended to evaluate both the effectiveness of the development activities and the status of development. These parameters included drawdown associated with different production rates (to evaluate improvement in well efficiency), visual observation of sediment production and turbidity (to evaluate removal of sediment), and water quality parameters (temperature, pH, electrical conductivity [EC], turbidity, dissolved oxygen [DO], and bromide [Br] concentration) to evaluate restoration of natural water quality. With regard to the $Br^-$ concentration, the drilling fluid used during drilling was “tagged” with lithium bromide to have an initial concentration from about 20 mg/L to over 180 mg/L. The concentration was increased as water production increased to keep the concentration in the produced water at measurable levels. This methodology served to provide a measure of water production during drilling through reference to the dilution of the tracer, and later serves as a measure of development for evaluating the removal of residual drilling fluids from the formation.

### *A.2.6.2 Hydraulic Development Activities*

A PXD was installed in the access tube of the well to monitor the hydraulic response of the well during pumping. The PXD range must be sufficient to accommodate the change in pressure corresponding to the amount of drawdown produced by pumping at the maximum rate. It is also advantageous to use a PXD with the minimum range necessary to maximize accuracy. Information on the 0-30 psig PXD installation and calibration is presented in Table A.2-5.

The method of installing these PXDs does not provide a direct measurement of the total depth of the PXD. The uncertainty in the total measured depth is due to uncertainty in the hanging length of the PXD vent cable, which is difficult to measure accurately. Therefore, the installation depth is calculated from the depth-to-water and calibration measurements made during installation. The pressure reading of the PXD at the installation depth is multiplied by the water density conversion factor to give the depth below the static water level, which is then added to the measured depth-to-water level. The water density conversion factor is determined from the calibration measurements. Note that the Cal 1 PXD psig value was a measurement in air above the water surface, and is not used for the water density calculation.

The well was pumped for a total time of about six days prior to flow logging. During that time, development consisted mostly of pumping at high rates, periodically stopping the pump to surge the well with the backflow from the production tubing. Step drawdown protocol was used several times to assess well and pump performance. Water quality was monitored using both field laboratory grab sample testing and with an in-line Hydrolab® cell with instrumentation recorded by a datalogger.

**Table A.2-5**
**PXD Installation Prior to Well Development**

| | | | | | |
|---|---|---|---|---|---|
| Design Analysis H-310 PXD SN 2266, 0-30 psig | | | | | |
| Install Date: 6/21/2000 | | | | | |
| Installation Calibration Data: 6/21/2000 | | | | | |
| Static water level depth: 322.70 ft bgs | | | | | |
| Stations | Cal 1 | Cal 2 | Cal 3 | Cal 4 | Cal 5 |
| WRL/TOC[a] | 160.00 | 175.00 | 190.00 | 205.00 | 220.00 |
| PXD psig | -0.0004 | 3.7302 | 10.044 | 16.384 | 22.716 |
| Delta depth (ft): Cal5 - Cal2 | | | | | 45.00 |
| Delta psi: Cal5 - Cal2 | | | | | 18.9858 |
| Density ft of water column/psi: delta depth / delta psi (in ft/psi) | | | | | 2.3702 |
| Equivalent ft water: PXD psig (at Cal 5) x density of water (ft/psi) | | | | | 53.84 |
| Calculated PXD installation depth: static water level + equiv. ft water | | | | | 376.54 |

[a]Length of wireline (WRL) below top of casing (TOC); does not include the length of the PXD integral cable.

ft - Feet
ft bgs - Feet below ground surface
PXD - Pressure transducer
psi - Pounds per square inch
psig - Pounds per square inch gauge

### *A.2.6.2.1 Pumping Rates and Hydraulic Response*

Figure A.2-2 shows the datalogger record of the pumping rate and hydraulic response during the development phase. Figure A.2-3 shows the datalogger record of the hydraulic response and barometric pressure. An electronic file of these data can be found on the attached CD with the file name EC-8_AQTEST_WD.xls. The first five days of the data record (April 20 to 24) show no activity while the VSD was being repaired. The next several days (April 25 and 26) show the initial testing of the pump/VSD to determine the operating range of the pump (see Table A.2-4) and resultant drawdown. The pump was generally operated at a rate of about 180 gpm for the remainder of the development phase. This production rate was close to the maximum pumping rate. Maximum drawdown during pumping was on the order of 16 ft. The barometric record shows that the barometric pressure was proportionately constant relative to the PXD pressure. The stress that could be applied to the completions for development was limited by the production capacity of the pump.

Several factors should be kept in mind when evaluating the pumping and drawdown record from the development phase. First, the well was operated without a check valve. Consequently, a water column above the pump was not maintained after the pump was stopped. Whenever the pump was started, sufficient water had to be pumped to fill the tubing and surface hose before production would register at the flowmeter. This produces a lag time between the start of a drawdown response and the start of the flowmeter readings. This was not significant for this well because the depth to water is much less than the other WPM-OV wells. There is also a delay due to the startup procedure, which bypasses the initial production around the instrumentation to avoid affects of sediment on the instruments. The typical total delay for flowmeter readings is less than 2.6 minutes, as can be seen on Figure A.2-4.

Second, because there was little head on top of the pump at startup, the initial pumping rate was much higher than the rate when the final, stable total dynamic head (TDH) was reached. The pumping rate decreases as the TDH increased until the discharge system was filled and TDH stabilized. This phenomenon is not substantial for this well and is not very evident in Figure A.2-4, presumably because the depth to water is not very great. Dividing the volume of the discharge system by the time lag for production to reach the surface gives a production rate greater than the VSD setting would produce under stable pumping conditions. As a result of this situation, the rate of drawdown was initially greater until a stable pumping rate was reached. The installation of a check valve for the constant-rate test avoids these irregularities by maintaining the water column above the pump so that the stable TDH is developed very quickly as the system is pressurized.

For development the pump was normally started with the VSD operating in Mode 1. In this mode, the VSD is set to operate at a specific power frequency (Hz). The calibration of Hz versus gpm through the pumping range is determined during the functionality test. After the system is pressurized and a stable pumping rate is established, the VSD is switched to Mode 2. In this mode the VSD varies the Hz to maintain a specific gpm based on feedback from the flowmeter. Since the testing is run according to desired pumping rates, the objective is for consistency in the pumping rate between the two modes.

As mentioned earlier, to avoid problems from the initial production of sediment each time the pump is started during development, the initial production is bypassed around the flowmeter and Hydrolab®. Consequently, there is a delay before flow rate is registered and recorded. If the pump were to be turned on directly in Mode 2, the VSD would accelerate the pump until the flowmeter reading equals the pumping rate setting. However, since the feedback from the flowmeter is zero until production reaches the flowmeter, the VSD would initially accelerate to the upper clamp setting, usually set at the maximum pumping rate. This would result in correspondingly high pumping rates and drawdown until the flowmeter returned accurate pumping rate information. The VSD would then deaccelerate the pump and seek the gpm setting. This method of starting the pump was used previously, but was changed to the present approach because of the irregularity it introduced in the startup. For the constant-rate test, the check valve that is installed to maintain the water column precludes most of this problem since the flowmeter starts to measure the pumping rate very quickly.

An additional irregularity in the starting pumping rate is introduced by the back pressure system. The Bechtel Nevada (BN) protocol for starting the pump requires that the back pressure valve be initially open, and it is then closed to produce the required back pressure after the full flow is established. The additional back pressure causes a reduction in pumping rate, which is then compensated by the VSD in Mode 2. This procedure applies both to development and the constant-rate test. In Well ER-EC-8, the application of backpressure is proportionally a larger adjustment relative to the head buildup above the pump as the production tubing is filled compared to the other WPM-OV wells. This is due to the shallow depth to water; the combination of head from the lift to the surface, friction losses, and the backpressure has to achieve the minimum required TDH for the pump.

### *A.2.6.2.2 Surging and Step-Drawdown Protocol*

Figure A.2-2 shows each instance when the pump was stopped, and also the step-drawdown protocol that was conducted several times. Stopping the pump was intended to produce a surging effect in the well; however, this was not effective in Well ER-EC-8. Figure A.2-5 shows a representative instance of surging expanded to illustrate the detail. When the pump is stopped, the water in the production casing backflows through the pump into the well, raising the water level in the well. This is referred to as the “U-tube” effect. The water level in the well casing temporarily rises above the instantaneous head in the formation around the completion because the rate of backflow down the casing is faster than the rate the water is injected into the formation under the instantaneous head differential. This action produces a reverse head differential which “surges” the well. In this case, the reverse flow simply speeds the apparent recovery of the well. The surge rapidly dissipates, merging into the recovery curve. This effect was insubstantial in this well.

These starting and stopping effects are much subdued for the constant-rate test because a check valve is installed to prevent backflow into the well and maintain the water column in the production tubing. The initial condition upon startup is then a high proportion of the operating TDH, assuming the backpressure valve was not opened very much from its operating position.

For the step-drawdown protocol the pump was run for a certain period of time at each of three progressively higher rates, approximately 65, 120, and 175 gpm, producing drawdowns of 3.5, 8.4, and 15 feet. Drawdowns at the end of each pumping period could then be compared to evaluate the well performance and any improvement in hydraulic efficiency since the last time the protocol was run. Figure A.2-6 shows a representative close-up of the step-drawdown protocol. The same rates were used for flow logging. The performance of this well showed a small improvement during development.

### *A.2.6.2.3 Other Observations*

During development, visual observations were made of the water discharge, primarily whenever the pump was started, to monitor the amount of sediment produced. Logbook entries indicated that there was initially gray brown turbidity in the water for about a minute, and reduced to a yellow turbidity for several seconds each time the pump was started, after which the water cleared.

## A.2.7 Flow Logging During Pumping

Downhole flow logging (spinner tool) while pumping was conducted after the development phase. Data on the proportional in-flow of water from different completion intervals would be used for tuning the production rate used for the constant-rate test, and later in understanding the hydraulic and analytical data. It was expected that the different completion intervals would not respond uniformly to pumping due to the influence of vertical hydraulic gradients, differences in the hydraulic conductivity of the geologic units, and flow losses along the completion. This is of particular concern in wells such as ER-EC-8 that are completed across a great vertical range with multiple completion intervals in different formations. The flow logging directly measured the amount and location of incremental water production downhole.

### A.2.7.1 Methodology

The information on water production from each completion interval was collected at different pumping rates to evaluate the linearity of effects for use in later interpretation. The same target rates were used as for the step-drawdown protocol during development (65, 127, and 176 gpm) so that results could be directly compared with previous observations.

Flow logging (spinner tool) was conducted by the DRI on June 27 and 28, 2000. A complete program of flow logging was run, including both stationary measurements and trolling logs. A temperature log was also recorded in combination with the flow logging to help identify production patterns and specific production locations. Logging runs at three different speeds and in both directions were run to evaluate flow under all test conditions.

#### A.2.7.1.1 Equipment and Calibration

The DRI flow logging system consists of, from top to bottom (all Flexstak equipment): telemetry cartridge, a centralizer, a temperature tool, another centralizer, and a fullbore flowmeter. All logging tools and the data acquisition system are manufactured by Computalog. This tool string has a maximum diameter of 1 1/16-in., is temperature rated to 176 degrees Celsius (°C), and pressure rated to 17,000 psi. The fullbore flowmeter needs a minimum of 5-15 fpm flow to activate the impeller. This minimum flow past the impeller, known as the stall speed, can vary depending upon the condition of the flowmeter or the impeller.

The fullbore flowmeter has a collapsible impeller that opens to cover a much larger percentage of the casing cross section than a standard fixed-blade impeller. Centralizers are run in conjunction with the sensor tools to center the tool string in the wellbore. The temperature tool is run to provide gradient and differential temperature information with high resolution. In conjunction with information from the spinner tool, the temperature tool yields information useful in fluid flow analysis.

Calibration is completed by comparing the raw flowmeter readings of counts-per-second to known velocities. Low flow-rate calibration data are obtained from a DRI calibration facility which can produce 0 to 60 gpm flow through 5.5-in. casing. The flow logging tool calibration was also checked on site against the production flowmeter readings at the three pumping rates by measuring uphole velocities in the 5.5-in. casing above the uppermost screen.

### *A.2.7.1.2 Logging Methodology*

Nine trolling flow logs were run at three different line speeds from just above the top of the upper completion interval to the bottom of the lower completion interval. The runs were typically from about 600 to 1,920 ft bgs. The bottom of the well was tagged by DRI at 1,933.5 ft bgs. The logging runs were made in the following order: (1) a down run at 20 fpm, (2) an up run at 40 fpm, (3) a down run at 60 fpm, and (4) stationary flow measurements conducted while going up. This four-step sequence was repeated for each of three discharge rates, 65, 176, and 127 gpm. Stationary flow measurements (tool held motionless in the well) were taken above the upper completion interval (660 ft bgs), between the upper and the middle completion intervals (1,200 ft bgs), and between the middle and the lower completion intervals (1,600 ft bgs). Table A.2-6 lists the trolling flow logs that were run. Stationary measurements are listed in Table A.2-7.

**Table A.2-6**
**Listing of Trolling Flow Logs**

| Run Number | Date of Run | Direction of Run | Run Speed (fpm) | Surface Discharge (gpm) | Run Start/Finish (ft bgs) |
|---|---|---|---|---|---|
| erec8mov01 | 6/27/2000 | Down | 20 | 65 | 599 - 1,919 |
| erec8mov02 | 6/27/2000 | Up | 40 | | 1,919 - 599 |
| erec8mov03 | 6/27/2000 | Down | 60 | | 599 - 1,919 |
| erec8mov04 | 6/27/2000 | Down | 20 | 176 | 599 - 1,919 |
| erec8mov05 | 6/27/2000 | Up | 40 | | 1,919 - 599 |
| erec8mov06 | 6/27/2000 | Down | 60 | | 599 - 1,919 |
| erec8mov07 | 6/28/2000 | Down | 20 | 127 | 600 - 1,920 |
| erec8mov08 | 6/28/2000 | Up | 40 | | 1,920 - 599 |
| erec8mov09 | 6/28/2000 | Down | 60 | | 599 - 1,920 |

fpm - Feet per minute
gpm - Gallons per minute
ft bgs - Feet below ground surface

**Table A.2-7**
**Listing of Stationary Flow Measurements**

| Log Run | Location | Average Temperature (°F) | Pumping Rate (gpm) | Depth (ft bgs) | Average (gpm) |
|---|---|---|---|---|---|
| erec8sta01 | Between middle and lower intervals | 96.9 | 65 | 1,600 | 0 |
| erec8sta02 | Between upper and middle intervals | 96.9 | | 1,200 | 0 |
| erec8sta03 | Above upper intervals | 96.7 | | 660 | 66.0 |
| erec8sta04 | Between middle and lower intervals | 96.9 | 176 | 1,600 | 0.36 |
| erec8sta05 | Between upper and middle intervals | 96.8 | | 1,200 | 0 |
| erec8sta06 | Above upper intervals | 96.7 | | 660 | 176.8 |
| erec8sta07 | Between middle and lower intervals | 96.9 | 127 | 1,600 | 0 |
| erec8sta08 | Between upper and middle intervals | 96.9 | | 1,200 | 0 |
| erec8sta09 | Above upper intervals | 96.7 | | 660 | 126.9 |

gpm - Gallons per minute
ft bgs - Feet below ground surface
°F - Degrees Fahrenheit

## *A.2.7.2 Flow Logging Results*

The results of the trolling flow logs are presented in Figures A.2-7 through A.2-12. Figure A.2-7 and Figure A.2-8 show flow logs for two different trolling speeds (20 fpm downwards and 60 fpm downwards) at a well production rate of 65 gpm. Figure A.2-9 and Figure A.2-10 depict flow logs for the same two trolling speeds at a production rate of 176 gpm. Figure A.2-11 and Figure A.2-12 show the same two trolling speeds at a production rate of 127 gpm. The optimal logging speed/direction was downwards at 20 fpm, producing the least amount of noise and fluctuations. This configuration seemed to provide the most sensitivity with the least induced disturbance. Only six of the nine trolling log runs are shown in figures, showing the optimal logging runs (20 fpm downwards) for each pumping rate and the 60 fpm downwards runs to illustrate the range of results.

The trolling flow logs indicate that all or most of the production in the well originated from the upper completion interval (632 - 1,050 ft bgs). There is some uncertainty in interpreting the logs; the tabulation in Table A.2-7 gives the approximate production for each interval based on the stationary flow logs. The stationary flow measurements indicate that almost 100 percent of the total flow originated from the upper completion interval. A small amount of the production, less than one percent as indicated from the stationary flow logs, may have come from the lower interval. This was only observed at the highest production rate of 176 gpm.

The log run at 20 fpm at a 65 gpm production rate showed an anomalous flow loss in the lower section of the upper completion interval. This was the only log that showed this. Similar apparent flow losses were also observed in flow logs through the upper completion interval for Wells ER-EC-7 and ER-EC-5 at the slower line speeds. The distribution of production throughout the completion intervals has been tabulated and is discussed in more depth in Section A.3.3.2.

### *A.2.8 Constant-Rate Test*

A constant-rate pumping test was conducted following well development to collect hydraulic response data for determination of aquifer parameters. Prior to the test, the water level in the well was monitored to observe recovery to ambient head from development pumping and to establish baseline pretest conditions. Pumping for this test commenced on July 3, 2000, and continued for 9 days until July 12, 2000. In addition, pumping during the constant-rate test served to continue and complete the development process to restore natural water quality for sampling purposes. Following the pumping period, head recovery was monitored for five days until July 17, 2000.

#### *A.2.8.1 Methodology*

A continuous datalogger record was captured for barometric pressure and head pressure on the PXD in the well, extending from pretest monitoring through the recovery monitoring. During pumping, the discharge rate of produced water was also recorded continuously. The production rate of the pump was controlled using a feedback loop from the discharge flowmeter to ensure a consistent rate. In addition, water quality was monitored during the constant-rate test with field analyses of grab samples taken daily.

A pumping rate of 176 gpm was chosen for the test. This rate was near the maximum rate the pump was able to sustain and resulted in sufficient drawdown to produce a good record. Based on experience during the early part of development, PXD with a range of 0-30 psig was installed after flow logging for the pretest monitoring and constant-rate test. This provided an appropriate range of measurement for the maximum anticipated drawdown. Use of the lowest possible range maximizes the accuracy of the pressure measurements, which are proportional to the overall measurement range of the PXD.

The PXD was installed on June 29, 2000, at a calculated depth of 379.37 ft bgs based on the calibration. Table A.2-8 shows the calibration and PXD installation data for the constant-rate test.

#### *A.2.8.2 Hydraulic Data Collection*

Figure A.2-13 shows the datalogger record for the constant-rate test pumping period in terms of the pumping rate and the hydraulic response to pumping. Figure A.2-14 shows the head record for both the pumping period and the recovery period as well as the barometric pressure record. These graphs illustrate the datalogger record and major features of the respective activities. The average pumping rate was 176.4 gpm. The data file is EC-8_AQTEST_HT.xls on the

**Table A.2-8**
**PXD Installation Prior to Constant-Rate Test**

| | | | | | |
|---|---|---|---|---|---|
| Design Analysis H-310 PXD SN 2266, 0-30 psig | | | | | |
| Install Date: 6/29/2000 | | | | | |
| Installation Calibration Data: 6/29/2000 | | | | | |
| Static water level depth: 323.03 ft bgs | | | | | |
| Stations | Cal 1 | Cal 2 | Cal 3 | Cal 4 | Cal 5 |
| WRL/TOC[a] | 162.00 | 177.00 | 192.00 | 207.00 | 222.00 |
| PXD psig | -0.0078 | 4.7828 | 11.096 | 17.435 | 23.766 |
| Delta depth (ft): Cal5 - Cal2 | | | | | 45.00 |
| Delta psi: Cal5 - Cal2 | | | | | 18.9832 |
| Density ft of water column/psi: delta depth / delta psi (in ft/psi) | | | | | 2.3705 |
| Equivalent ft water: PXD psig (at Cal 5) x density of water (ft/psi) | | | | | 56.34 |
| Calculated PXD installation depth: static water level + equiv. ft water | | | | | 379.37 |

[a]Length of wireline (WRL) below top of casing (TOC); does not include the length of the PXD integral cable.

ft - Feet
bgs - Below ground surface
PXD - Pressure transducer
psi - Pounds per square inch
psig - Pounds per square inch gauge

accompanying CD. The data record was initially clean with only a small amount of noise in the drawdown PXD record. However, The PXD record became intermittently noisy in the fifth day of the test, and the noise became worse through the end of the test. The cause of the noise is not known; it is not believed to be an instrumentation problem. Rather, this may be the result of pumping fluctuations. Figure A.2-15 shows an expanded view of the PXD pressure and pumping rate records, and the noise in the PXD pressure record seems to correspond to greater instantaneous fluctuations in the pumping rate record. The reason for the pumping rate fluctuations is not known. Note that the barometric record in Figure A.2-14 has been scaled proportionate to the PXD record so that fluctuations are of proportional magnitude. The barometric record shows that the barometric pressure was proportionately constant relative to the PXD pressure changes.

## *A.2.9 Water Quality Monitoring*

Water quality monitoring of the well discharge was conducted during pumping to provide information on water chemistry and to indicate when natural groundwater conditions predominate in the pumping discharge. Certain parameters such as $Br^-$ ion concentration, pH, EC, turbidity, and DO were expected to decline as development progressed indicating natural groundwater quality as opposed to water affected by drilling and completion activities. Also, parameter values should stabilize after prolonged pumping and development as natural groundwater permeates the well environment. Rebound of parameter values at the beginning of each cycle of pumping was expected to decline toward the values observed toward the end of the previous cycle as development progressed.

The standard parameters that were monitored during development and testing of Well ER-EC-8 include the following: pH, EC, temperature, turbidity, DO and $Br^-$ ion. In addition, lead and tritium were sampled in compliance with the schedule in the Fluid Management Plan (including waivers) (DOE/NV, 1999). In-line monitoring data was collected continuously during development for all the standard parameters except bromide. Grab samples were obtained every two hours when possible and analyzed for all the water quality parameters.

Pumping for well development was initiated on June 14, 2000, but because of various problems with the pump, the official development did not begin until June 21, 2000, at 11:20. In-line monitoring began on June 14 with the operation of a Hydrolab® H20 Multiprobe. The Hydrolab® fed directly to the datalogger where data could be continuously accessed via a portable laptop computer. Grab sample monitoring was also initiated on June 14.

### *A.2.9.1 Grab Sample Monitoring*

Grab samples were obtained from a sample port located on the wellhead assembly. For the development phase, beginning June 21, grab samples were collected and analyzed every two hours, primarily during daylight hours, until 17:00 on June 28, 2000. For the constant-rate pumping test, three to six grab samples were obtained daily beginning on July 3 and ending on July 12, 2000.

Grab samples were analyzed using equipment and methodology contained in the DOP ITLV-UGTA-312, "Water Quality Monitoring"; DOP ITLV-UGTA-301, "Fluid Sample Collection"; and DOP ITLV-UGTA-101, "Monitoring and Documenting Well Site Activities." All instruments were calibrated according to DOP ITLV-UGTA-312 at the beginning of each 12-hour shift and a calibration check was completed at the end of each shift. The following instruments were used to analyze grab samples:

- YSI 58 (DO)
- YSI 3500 Multimeter (for pH, EC and temperature)
- HF Scientific DRT-15C Turbimeter (turbidity)
- Orion 290A (bromide)
- HACH DR100 Colorimeter Kit (lead)

The complete results of grab sample monitoring have been compiled and are presented in Attachment 2. The results have been related to the pumping rate, the total discharge, and the phase of development or testing. Additionally, two graphs have been derived showing water quality parameters versus total discharge in gallons. Figure A.2-16 shows EC, pH, and DO. Figure A.2-17 shows turbidity and $Br^-$ concentration.

As shown in Figure A.2-16, the pH remained fairly constant throughout the constant-rate test. EC and DO showed slightly more variations, but within the range of normal field laboratory error. Fluctuations mostly occurred during the development phase with all three parameters. At the end of the constant-rate test, EC leveled off at about 650 micromhos per centimeter (µmhos/cm), pH at about 8.0 and DO at about 5.0 mg/L.

Turbidity remained mostly below 1.0 nephelometric turbidity units (NTU) with only a few values over 3.0 NTU (Figure A.2-17). The highest measurement 10.1 NTU was measured from a bailer sample obtained from the lower completion interval. The bromide concentration fluctuated between 0.1 and 0.6 mg/L, which is within the uncertainty of the measurement. There were no long-term trends in turbidity or $Br^-$ concentration which indicate any continuing progress in development.

The temperature of the samples remained fairly constant, averaging 37.4°C and varying only four degrees between 35.1 and 39.1°C. A bailer sample from the lower completion interval produced a dubious temperature measurement of 32.6°C, probably due to the time lag for handling at the surface. All the other temperature measurement methods produced readings between 36.5°C and 38.5°C. Grab sample temperature results are not depicted graphically. Temperature differences can often fluctuate depending on ambient air temperature and the efficiency with which the temperature of the wellhead sample is measured. Downhole temperature values are discussed in Section A.2.11 where ChemTool logging results are presented. The results of lead and tritium monitoring are presented in Section A.4.0, Environmental Compliance.

### *A.2.9.2 In-Line Monitoring*

In-line monitoring was conducted using a Hydrolab® H2O Multiprobe. The Campbell Scientific datalogger recorded data at an interval of 10 minutes. The parameters temperature, EC, pH, turbidity and DO, were recorded continuously when the pump was running for well development between June 14, 2000, at 15:00 and June 26, 2000, at 17:40. The Hydrolab® was taken off-line during pump startups in order to prevent damage to delicate components. After about 5 minutes of pumping, the valve was opened to continue the in-line monitoring. The Hydrolab® was calibrated and maintenance was performed at the beginning of development on June 21 at 12:15, in accordance with DOP ITLV-UGTA-312. The DO was calibrated for percent saturation according to the DOP, but the readout was not switched to the mg\L mode as specified in the DOP. Consequently, the data are presented in their original condition which is percent saturation. A conversion formula (percent saturation to mg/L) has been obtained from the company that manufactures the Hydrolab® and this converted data is presented in Figure A.3-10. The conversion is temperature corrected, but not salinity corrected. The formula and conversion is contained in the file “Hydrolabcalc.xls” which is included on the accompanying CD. The Hydrolab® was not used during the constant-rate pumping test since any changes to the parameters were expected to be gradual.

Two figures have been derived from the in-line monitoring data. Figure A.2-18 shows EC and pH related to total discharge in gallons. Figure A.2-19 depicts the turbidity and DO (in percent saturation) over the same pumping period. The EC record in Figure A.2-18 shows early fluctuations between 475 and 675 µmhos/cm, with a leveling off at about 590 µmhos/cm. These results correlate well with the grab sample results over the same period. The pH record from in-line monitoring fluctuated between 7.85 and 8.35, which is not a great deal of variation considering the changes in pumping rate and stopping/starting during the development phase. This compares well with the fairly steady 8.0 average measured from the grab samples. In Figure A.2-19, the turbidity record shows a great deal of fluctuations at NTU levels much higher then the grab samples. This is probably the result of turbulence and bubbles of entrained air within the Hydrolab® multiprobe. The DO in the same figure shows that the percent saturation remained mostly above 85 percent. The dips can be correlated to stops/starts of the pump during development. Refer to Figure A.3-10 in Section A.3.5, which graphically illustrates this correlation (after conversion to mg/L). The temperature record (not shown) from the in-line monitoring averaged 38.5°C, which is about 1°C higher than the grab sample average. This is not unexpected since it takes additional time to process the grab samples. The in-line data are contained in the Excel® file “EC8Hydrolab.xls” on the accompanying CD.

## *A.2.10 Groundwater Sample Collection*

Two types of well samples were collected for characterization of the groundwater in Well ER-EC-8; downhole discrete bailer samples and composite samples from the wellhead.

### *A.2.10.1 Downhole Discrete Sampling*

There are two different purposes for the collection of discrete downhole samples. The first is to collect a sample at a particular depth, usually under nonpumping conditions, that represents the specific water quality at that depth or in the corresponding completion interval. The second purpose is to collect a sample that represents the composite water quality of all production below the depth of collection, and is taken while pumping. Discrete sampling is optimally performed after the well has been determined to meet the following criteria: (1) the maximum possible development has occurred for the interval in which the samples will be collected, and (2) a pumping rate can be maintained that will ensure a representative sample of the interval. The discrete sampling intervals were determined after initial well development and downhole flow and temperature logging.

On June 28, 2000, discrete samples were obtained from two depths, 760 and 1,020 ft bgs, at pumping rates of approximately 65 gpm and 175 gpm, respectively. The samples were obtained using a DRI logging truck, and discrete bailer. The bailer was decontaminated using the methodology in DOP ITLV-UGTA-500, “Small Sampling Equipment Decontamination,” and

SQP ITLV-0405, “Sampling Equipment Decontamination.” An equipment rinsate sample was collected from the decontaminated bailer prior to collection of the discrete samples. The samples were processed according to DOP ITLV-UGTA-302, “Fluid Sample Collection”; SQP ITLV-0402, “Chain of Custody”; and SQP ITLV-0403, “Sample Handling, Packaging, and Shipping.” Samples were immediately stored with ice and transported to a secure refrigerated storage. Samples were obtained for the following laboratories: Paragon, Los Alamos National Laboratory (LANL), UNLV-HRC, LLNL, and DRI.

The final, validated results of the June 28, 2000, discrete samples have been tabulated and are presented in Attachment 3. These results can be compared to the results of the discrete groundwater characterization sample taken during drilling (before well completion). That sample was obtained on July 23, 1999, from a depth of 800 ft bgs (DOE/NV, 2000).

### *A.2.10.2 Groundwater Composite Sample*

The purpose of this sample is to obtain a composite of as much of the well as possible. The composite groundwater characterization sample was collected at the end of the constant-rate pumping test from the sampling port at the wellhead. Since this sample is meant to represent a composite of the whole well, there are two criteria for the sample to be the most representative: (1) the sample should be obtained after pumping for the longest possible time, and (2) the pumping rate should be as great as possible in order for the component water production to include as many completion intervals as possible. From the results of the flow logging, the proportional composition of the composite sample was also determined. As discussed in Section A.2.7.2, the flow logging showed that 98-100 percent of the flow into the well originated in the upper completion interval (632 to 1,050 ft bgs) at a production rate of 176 gpm.

On July 12, 2000, a composite characterization sample was collected from the wellhead sampling port directly into sample bottles. A field duplicate sample was obtained concurrently. A constant production rate of 175 gpm was maintained during the sampling event, the same rate used during the constant-rate test. At the time of sampling, approximately 3,800,000 gallons of groundwater had been pumped from the well during development and testing activities. The samples were processed according to the same procedures used for the discrete sampling. Samples were immediately put on ice and transported to a secure refrigerated storage. Samples were collected for the following laboratories: Paragon, UNLV-HRC, LLNL, LANL, and DRI. The final, validated results of the July 12, 2000, composite sample have been tabulated and are presented in Attachment 3.

## *A.2.11 Thermal Flow Log and ChemTool Log*

Thermal flow logging was conducted at the very end of the development and testing program to determine flow in the well under ambient conditions. The resulting flow information may differ from that of the thermal flow logging conducted in the open borehole before well completion because it is specific to the completion intervals, and reflects remediation of conditions imposed by drilling. The ChemTool provides a depth log of temperature, pH, and EC. The thermal flow and ChemTool logging was conducted July 18, 2000, by DRI.

### *A.2.11.1 Methodology*

The thermal flow log is a stationary log that can measure vertical flow rates at very low velocities (less then 2 gpm). The flow profile along the well completion is constructed from multiple stationary flow measurements. The ChemTool log is a trolling log that collects data on parameter variation with depth.

### *A.2.11.2 Results*

The results of the ChemTool logging are presented in Figure A.2-20. The ChemTool log shows relatively constant EC from above the upper completion interval down to about 1,900 ft bgs, the bottom of the lower completion interval. The log is slightly noisy, but the values fluctuate within a narrow range of 720 to 730 µmhos/cm and trend to the high value with depth. The pH is also very stable from the upper section of the upper completion interval to the bottom of the well, ranging between 8.25 and 8.5, with the higher values below the middle completion interval. The temperature log shows consistent readings around 36.5°C from top to bottom, with only a small deviation between the upper and middle completion intervals.

The thermal flow log data was supplied by DRI and is presented in Table A.2-9. The data were collected under nonpumping conditions at 8 stations between 650 and 1,550 ft bgs. All stations indicated no flow except the stations at 710 ft bgs and 1,550, which had slight downward flows.

### *A.2.12 Sampling Pump Installation*

On July 19, 2000, a dedicated sampling pump was installed in Well ER-EC-8 by BN with the assistance of the Electrical Submersible Pump (ESP) Systems representative. The pump assembly was placed using 2 7/8-in. outside diameter (od) stainless steel pipe. The bottom of the pump assembly was landed at 646.69 ft bgs. A 2.33 ft stickup makes the entire string a length of 649.02 ft. The pump intake is at 626.76 ft bgs and the top of the pump assembly is at 620.19 ft bgs. The total length of the pump assembly, not including the crossover, is 26.5 ft. Note that the top of sediment was tagged at 1,933.5 ft bgs during flow logging. Table A.2-10 summarizes the details of the pump assembly components.

The pump string was landed to a 1-in. landing plate at the wellhead. Figure A.2-21 depicts the final wellhead configuration. A VSD was wired to the pump. On July 19, 2000, a functionality test was conducted on the pump after appropriate wellhead plumbing was attached to the pump string. The discharge was routed to the unlined Sump #1. At about 16:00, the pump was started at 60 Hz (~40 gpm) and discharge occurred at the surface 1 minute, 58 seconds later. The pump was run at six different VSD frequencies for about 40 minutes. The results of the functionality testing are shown is Table A.2-11. Approximately 1,400 gals were pumped during the functionality test. No problems were encountered.

**Table A.2-9**
**Thermal Flow Log Results**

| Station Depth (ft bgs) | Response (sec) | Flow Rate (gpm) | Velocity (fpm) |
|---|---|---|---|
| 650 | 19.10 +/- 10.000 | 0.000 +/- 0.000 | 0.000 +/- 0.000 |
| 710 | -1.64 +/- 0.268 | -0.819 +/- 0.134 | -0.803 +/- 0.131 |
| 760 | no flow interpretation, very noisy data | | |
| 810 | no flow interpretation, very noisy data | | |
| 1,000 | no flow interpretation, very noisy data | | |
| 1,400 | no flow interpretation, very noisy data | | |
| 1,550 | -2.18 +/- 0.572 | -0.467 +/- 0.122 | -0.457 +/- 0.120 |

ft bgs - Feet below ground surface
sec - Second
gpm - Gallons per minute

Internal diameter at all stations was 5.0 inches

Note: Positive values indicate upward flow; negative values indicate downward flow.

**Table A.2-10**
**Dedicated Sampling Pump Specifications for ER-EC-8**

| Pump Component | Type/Model | Serial Number | Other Information |
|---|---|---|---|
| ESP Pump | TD 800 | 2D8I15040 | 52 Stage |
| ESP Protector | TR3-STD | 3B8I07994 | Not Applicable |
| ESP Motor | TR3-UT/THD 13 | 1B8I06460 | 30 hp, 740 V, 30 A |

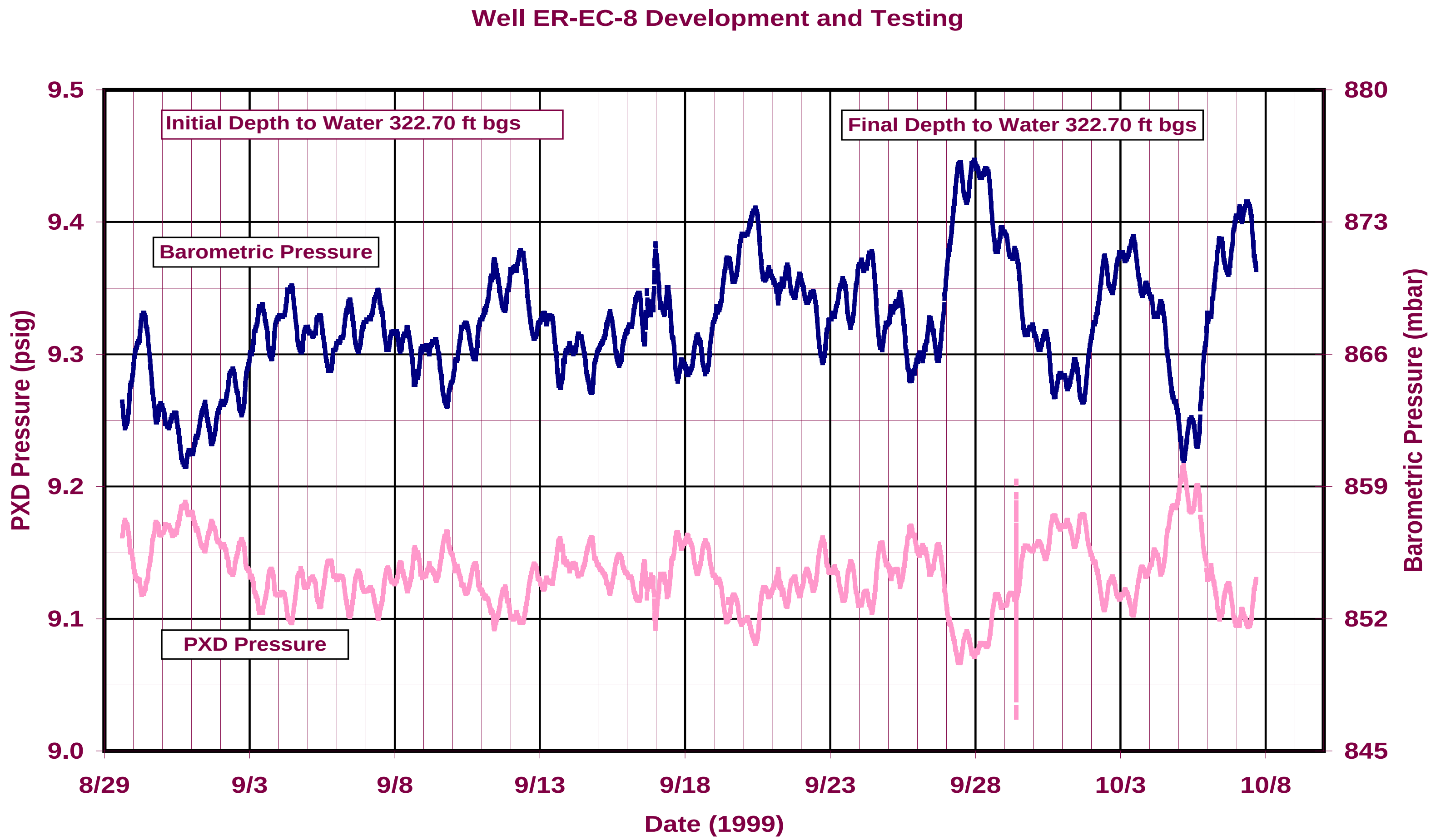
ESP - Electrical Submersible Pump Systems
hp - Horsepower
V - Volts
A - Amps

**Table A.2-11**
**Functionality Test Results for Dedicated Sampling Pump**

| Time | VSD Frequency (Hz) | Flow Rate Magnetic Flow Meter (gpm) | Downhole Amps | Downhole Voltage | Voltage to Ground |
|---|---|---|---|---|---|
| 16:05 | 60 | 40.0 | 25 | 635 | 287 |
| 16:13 | 55 | 35.8 | - - - | - - - | - - - |
| 16:16 | 50 | 32.0 | - - - | - - - | - - - |
| 16:19 | 45 | 27.8 | 18 | 482 | 215 |
| 16:27 | 65 | 43.3 | - - - | - - - | - - - |
| 16:30 | 70 | 46.9 | 30 | 735 | 332 |

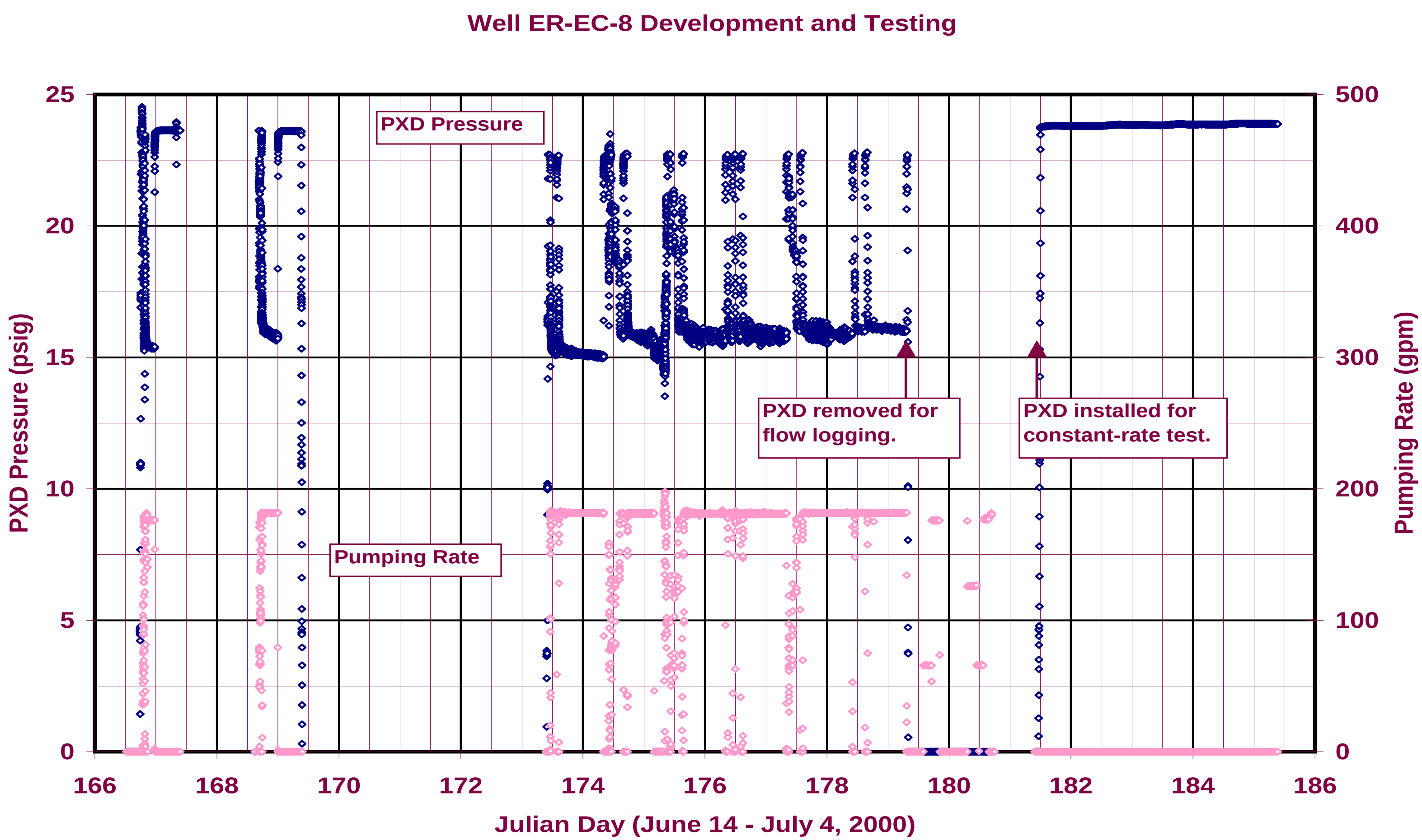
Note: Amps and voltage are mean values of three phases. Wellhead pressure remained at 0 pounds per square inch throughout testing.

Hz - Hertz (cycles)
gpm - Gallons per minute



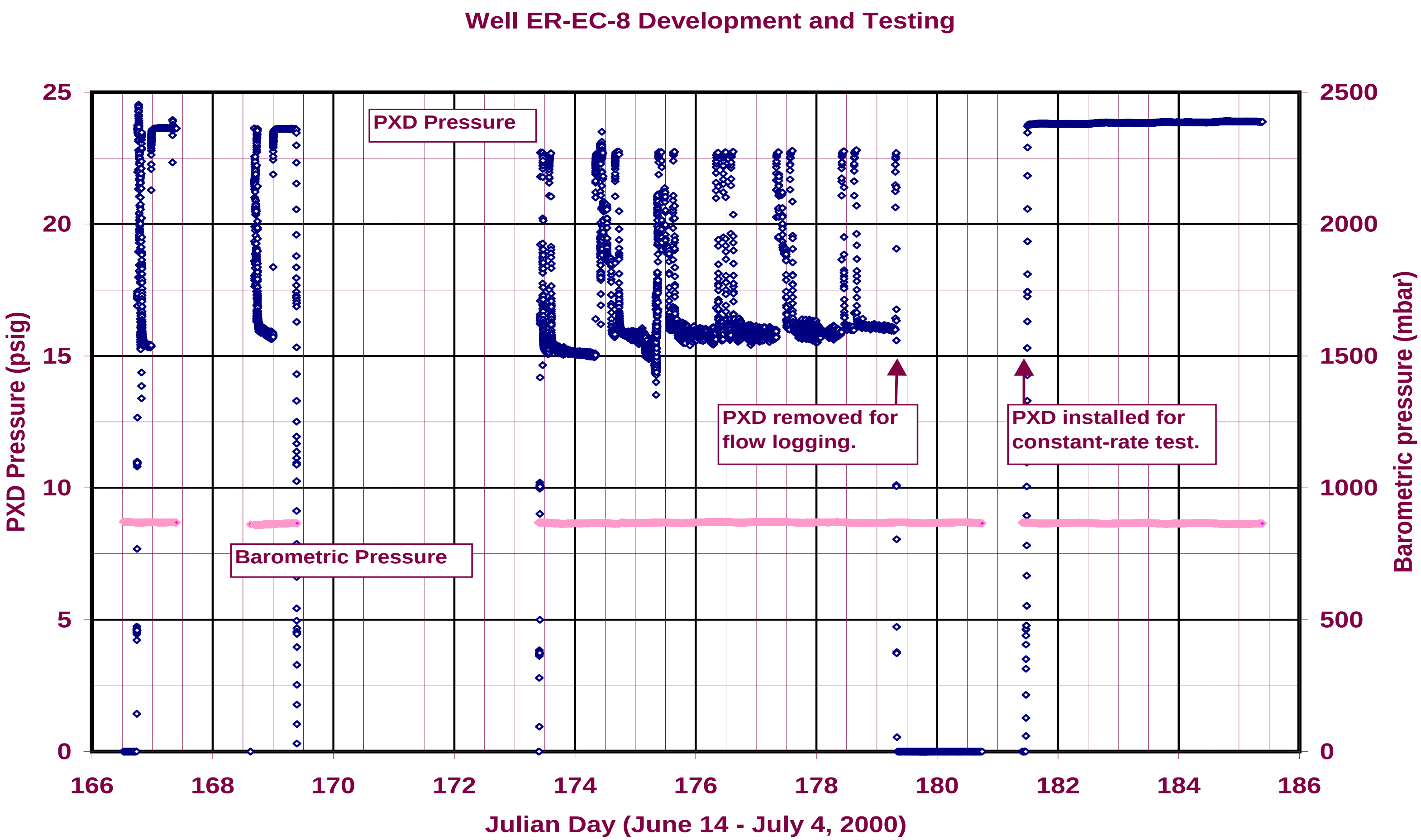

ft bgs - Feet below ground surface
mbar - Millibars
psig - Pounds per square inch gauge
PXD - Pressure transducer

**Figure A.2-1**
**Predevelopment Water Level Monitoring**



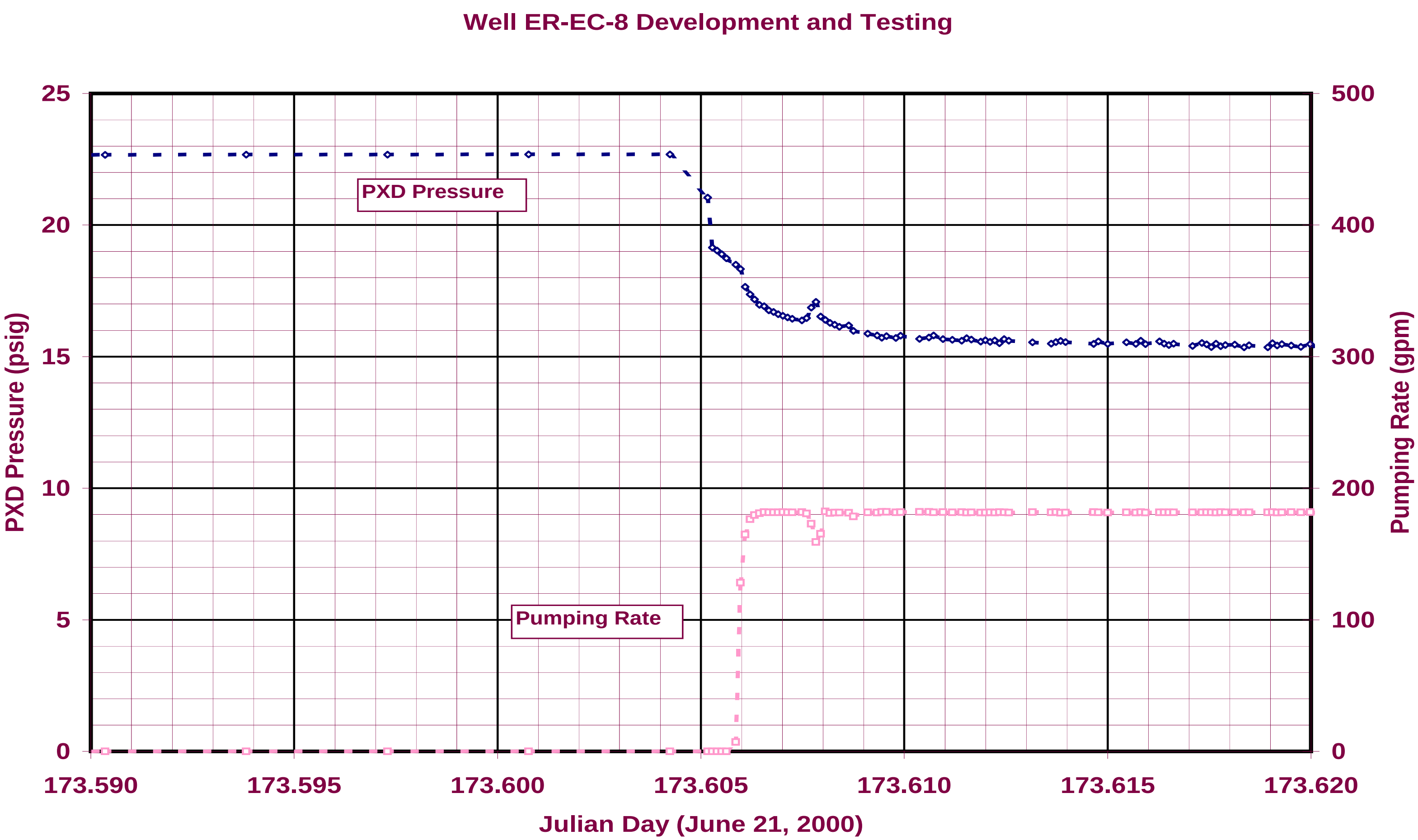

gpm - Gallons per minute
psig - Pounds per square inch gauge
PXD - Pressure transducer

**Figure A.2-2**
**Pumping Rate and Hydraulic Response During Development**



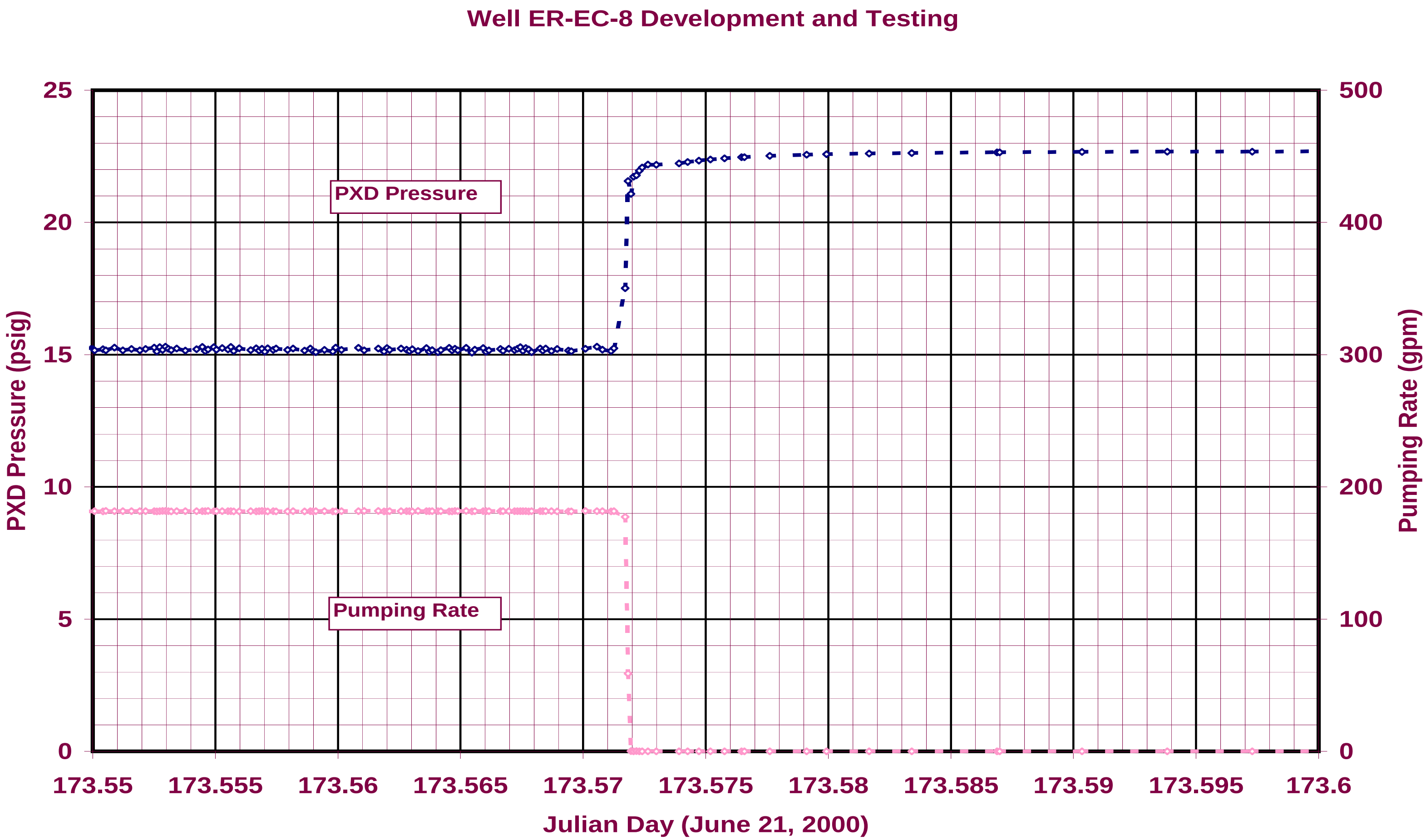

mbar - Millibars
psig - Pounds per square inch gauge
PXD - Pressure transducer

**Figure A.2-3**
**Hydraulic Response and Barometric Pressure During Development**



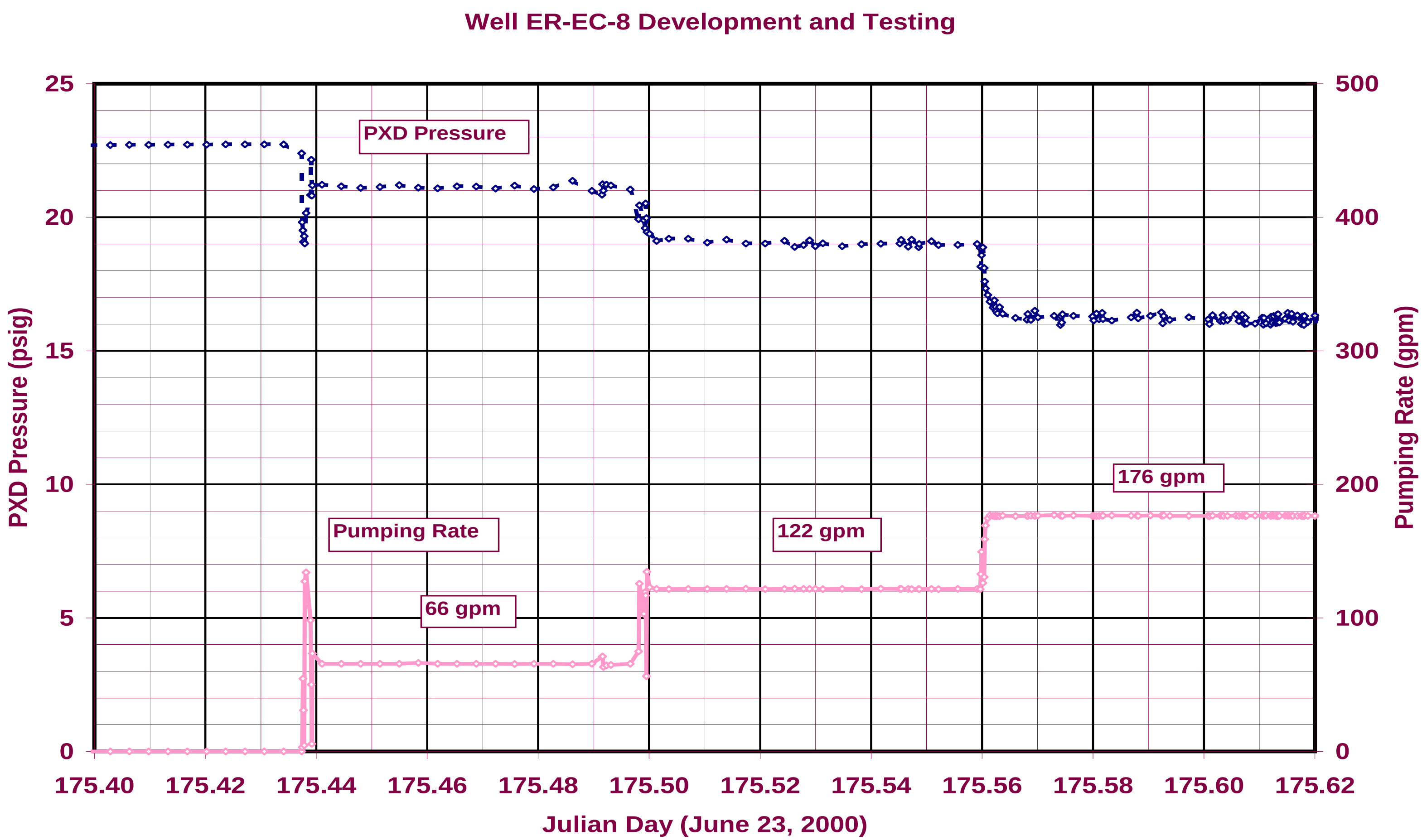

gpm - Gallons per minute
psig - Pounds per square inch gauge
PXD - Pressure transducer

**Figure A.2-4**
**Detail of Startup Effects**




gpm - Gallons per minute
psig - Pounds per square inch gauge
PXD - Pressure transducer

**Figure A.2-5**
**Detail of Surging Action**




gpm - Gallons per minute
psig - Pounds per square inch gauge
PXD - Pressure transducer

**Figure A.2-6**
**Detail of First Step-Drawdown**

| | | | |
|---|---|---|---|
| Well Name: ER-EC-8 | Western Pahute Mesa - Oasis Valley Drilling Program | | |
| Date: 6/28/2000 | Start Date: 6/27/2000 | Stop Date: 6/28/2000 | |
| Well Development and Hydraulic Testing | | Proj No: 799416.00020230 | |
| Log Run #: erec8mov01 | | Geol: J. Wurtz | |
| Logging Contractor: Desert Research Institute (DRI) | | Logging Method: Stressed Full-Bore Flowlog | |
| Flow logging at 20 feet/minute - Downward | | Surface Discharge: 65 gallons/minute | |

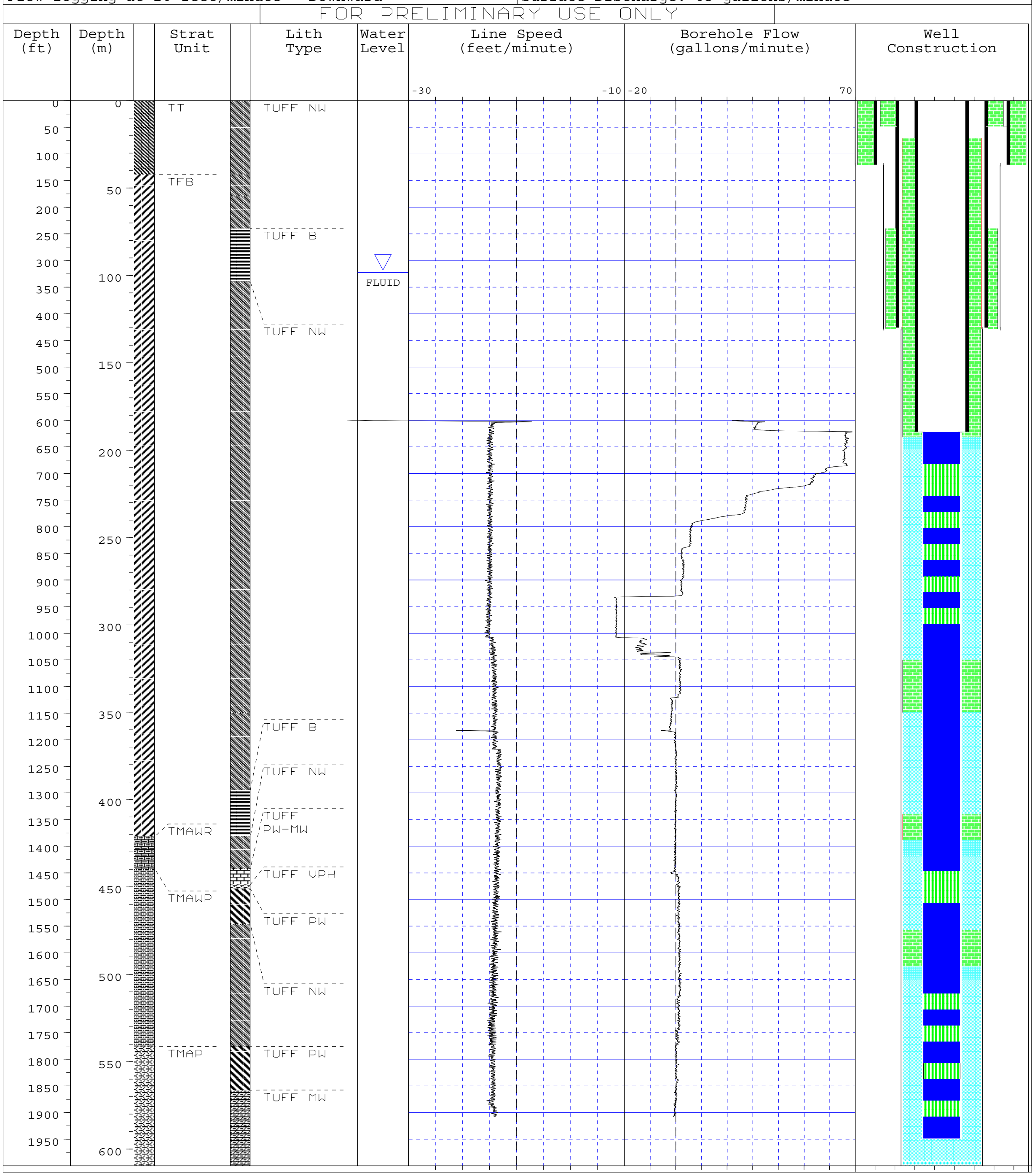



**Figure A.2-7**
**Flow Log at 65 gpm Production Rate and 20 fpm Downward Trolling Rate**

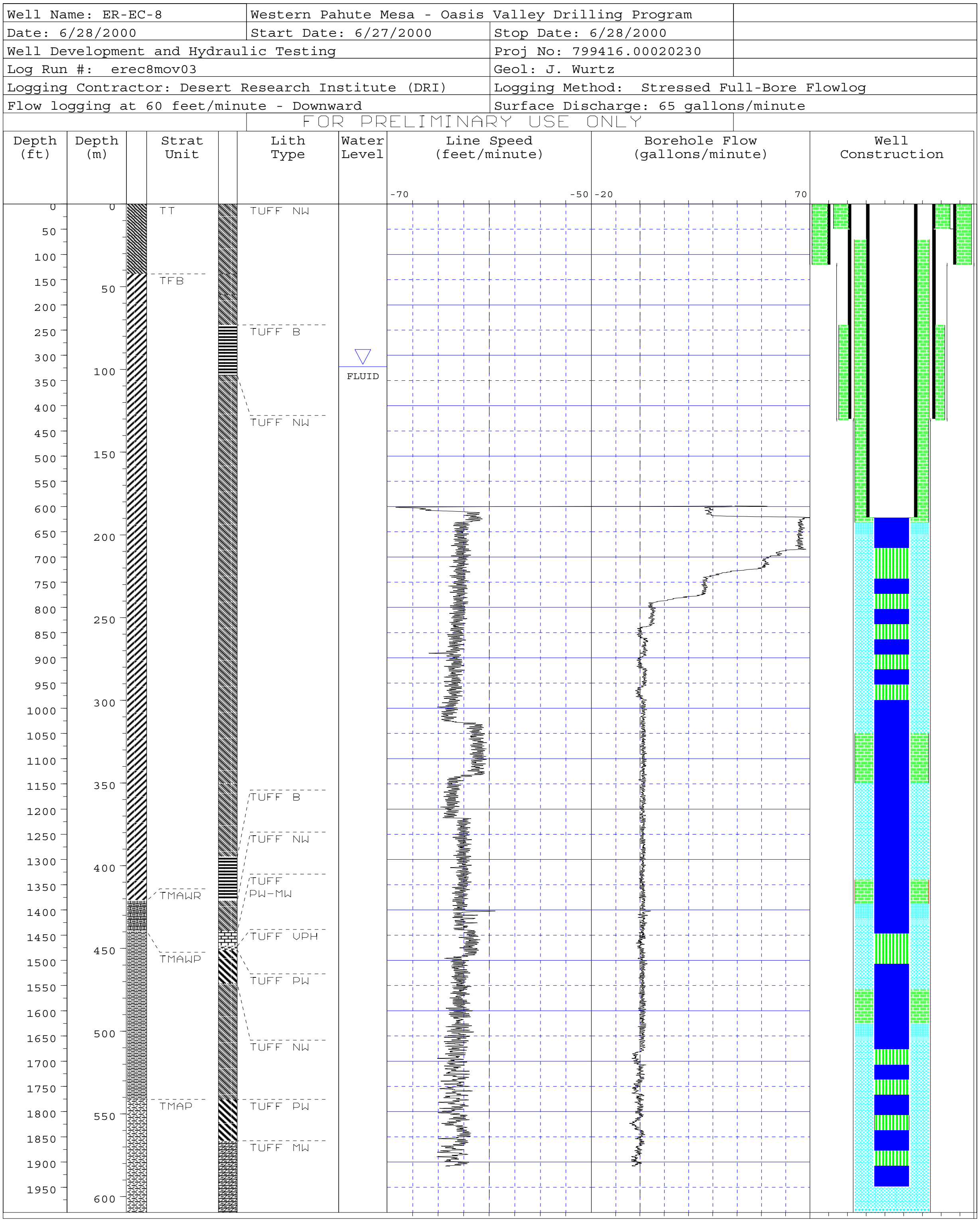



**Figure A.2-8**
**Flow Log at 65 gpm Production Rate and 60 fpm Downward Trolling Rate**

| | | | |
|---|---|---|---|
| Well Name: ER-EC-8 | Western Pahute Mesa - Oasis Valley Drilling Program | | |
| Date: 6/28/2000 | Start Date: 6/27/2000 | Stop Date: 6/28/2000 | |
| Well Development and Hydraulic Testing | | Proj No: 799416.00020230 | |
| Log Run #: erec8mov04 | | Geol: J. Wurtz | |
| Logging Contractor: Desert Research Institute (DRI) | | Logging Method: Stressed Full-Bore Flowlog | |
| Flow logging at 20 feet/minute - Downward | | Surface Discharge: 176 gallons/minute | |

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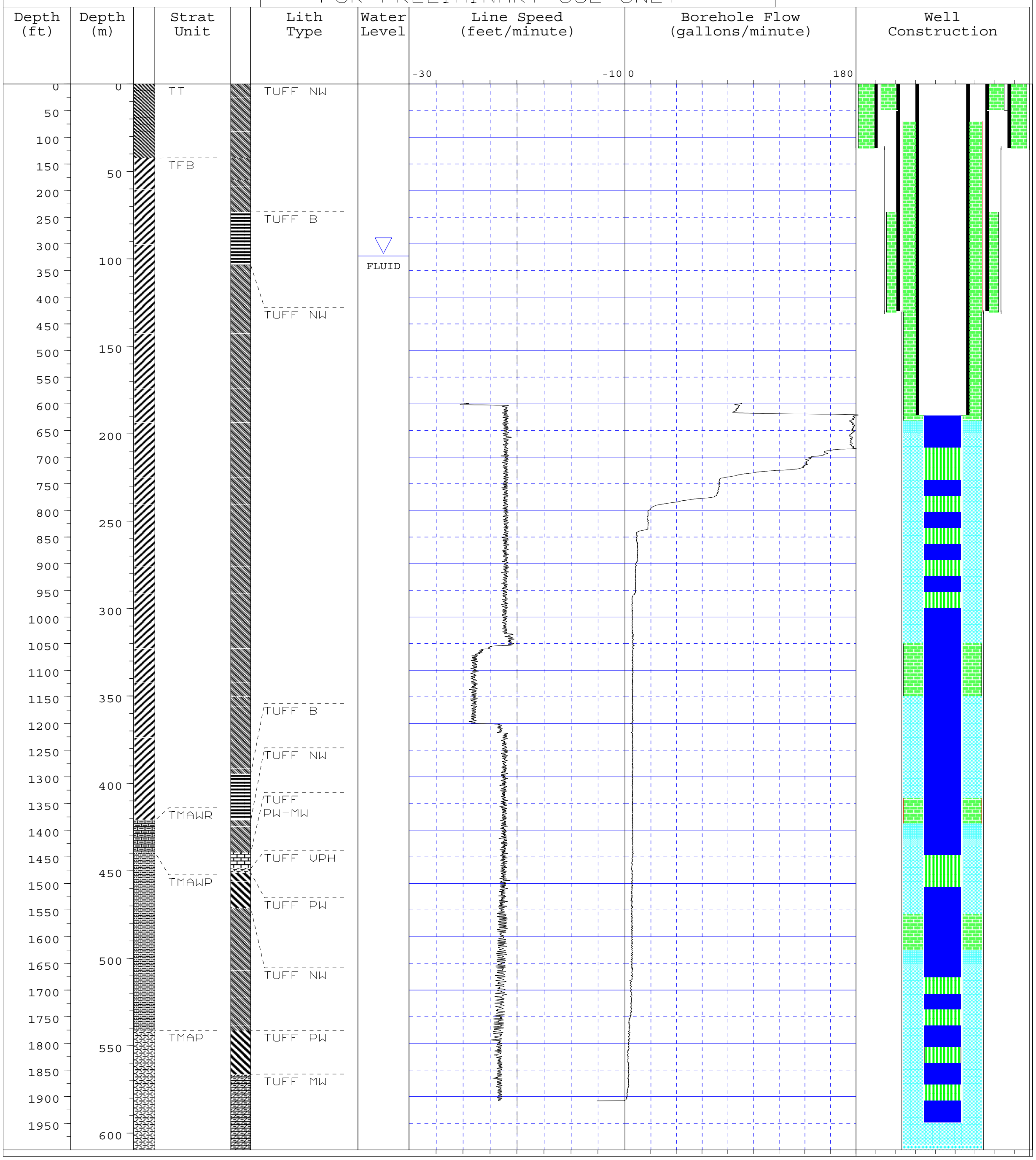



**Figure A.2-9**
**Flow Log at 176 gpm Production Rate and 20 fpm Downward Trolling Rate**

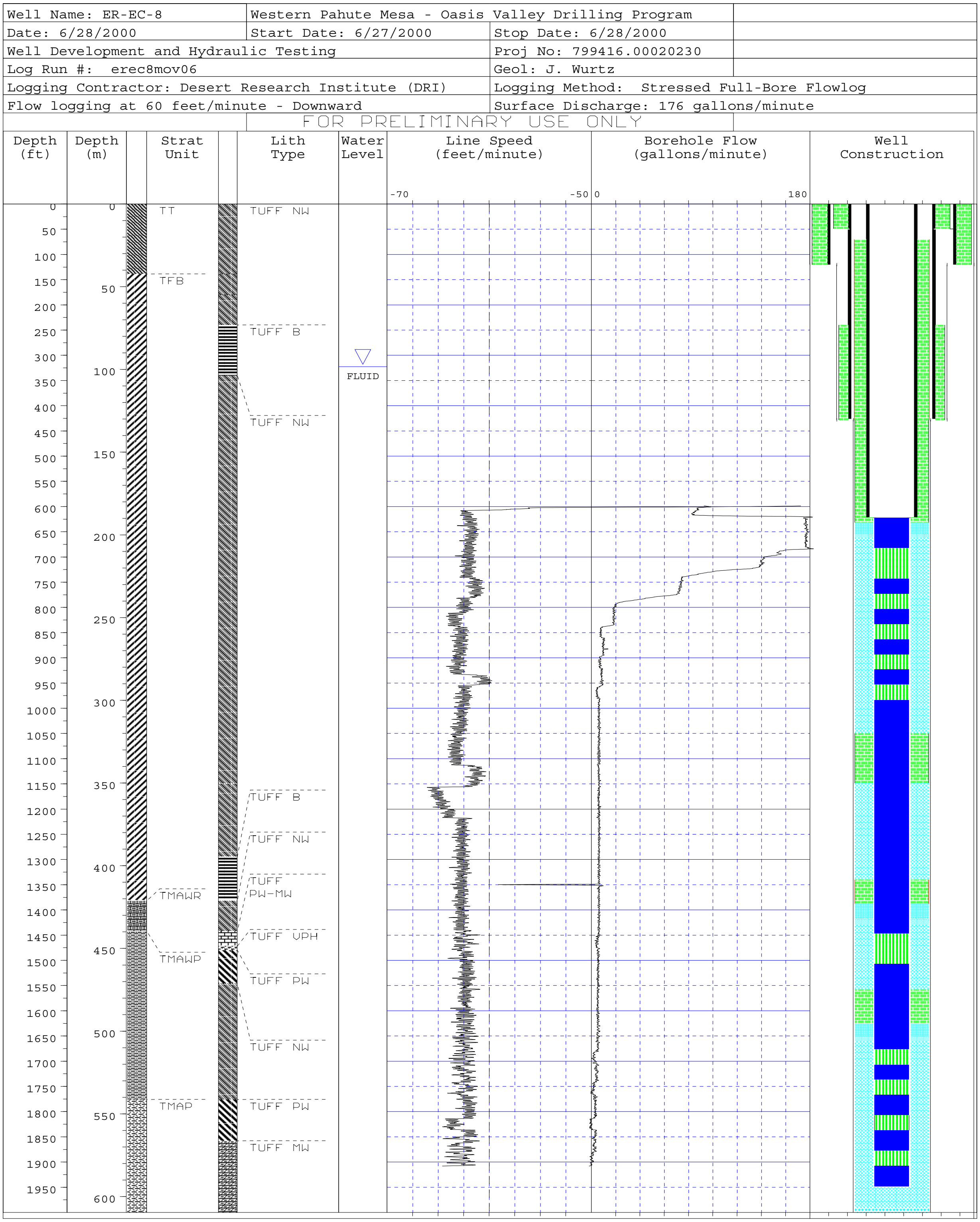



**Figure A.2-10**
**Flow Log at 176 gpm Production Rate and 60 fpm Downward Trolling Rate**

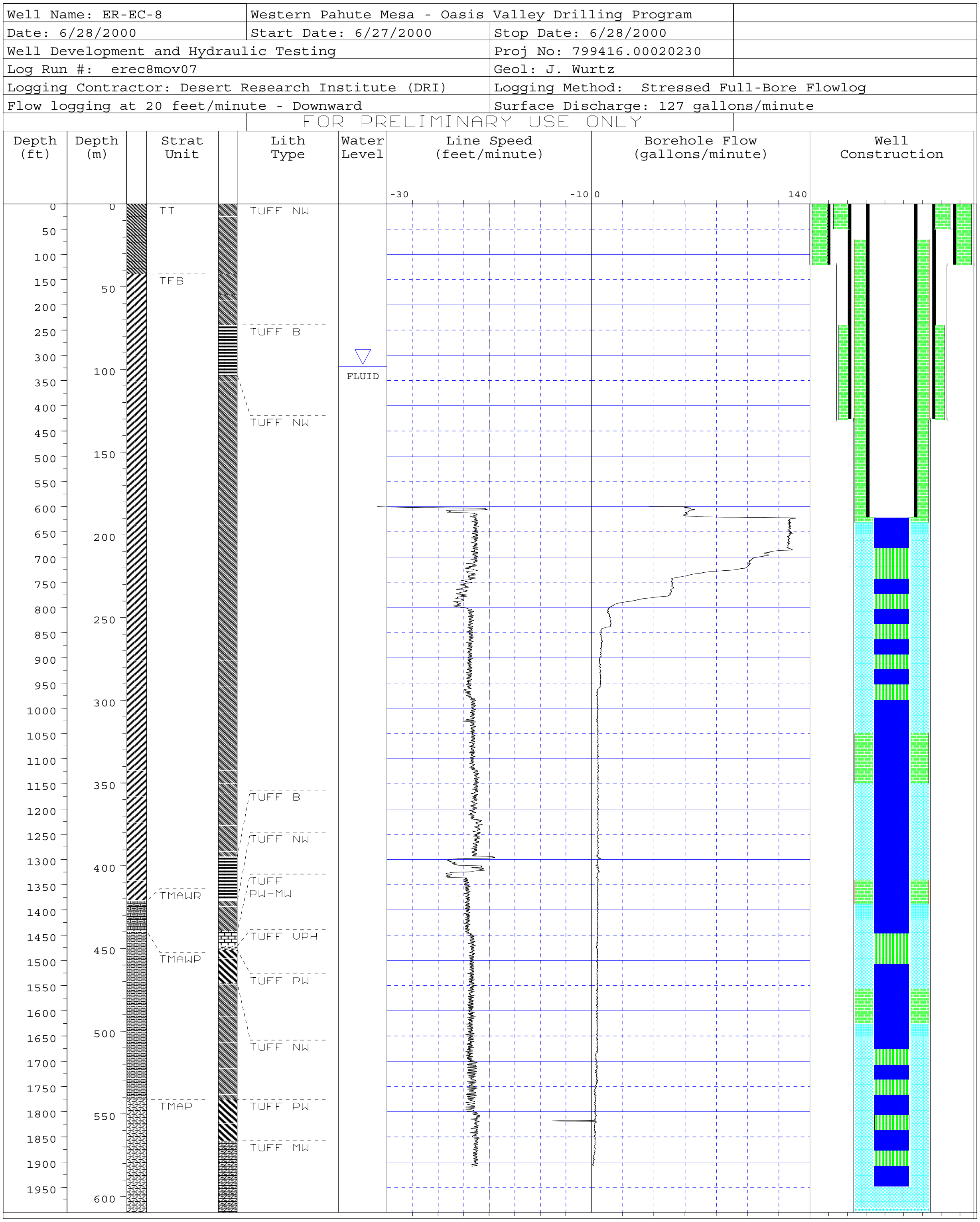



**Figure A.2-11**
**Flow Log at 127 gpm Production Rate and 20 fpm Downward Trolling Rate**

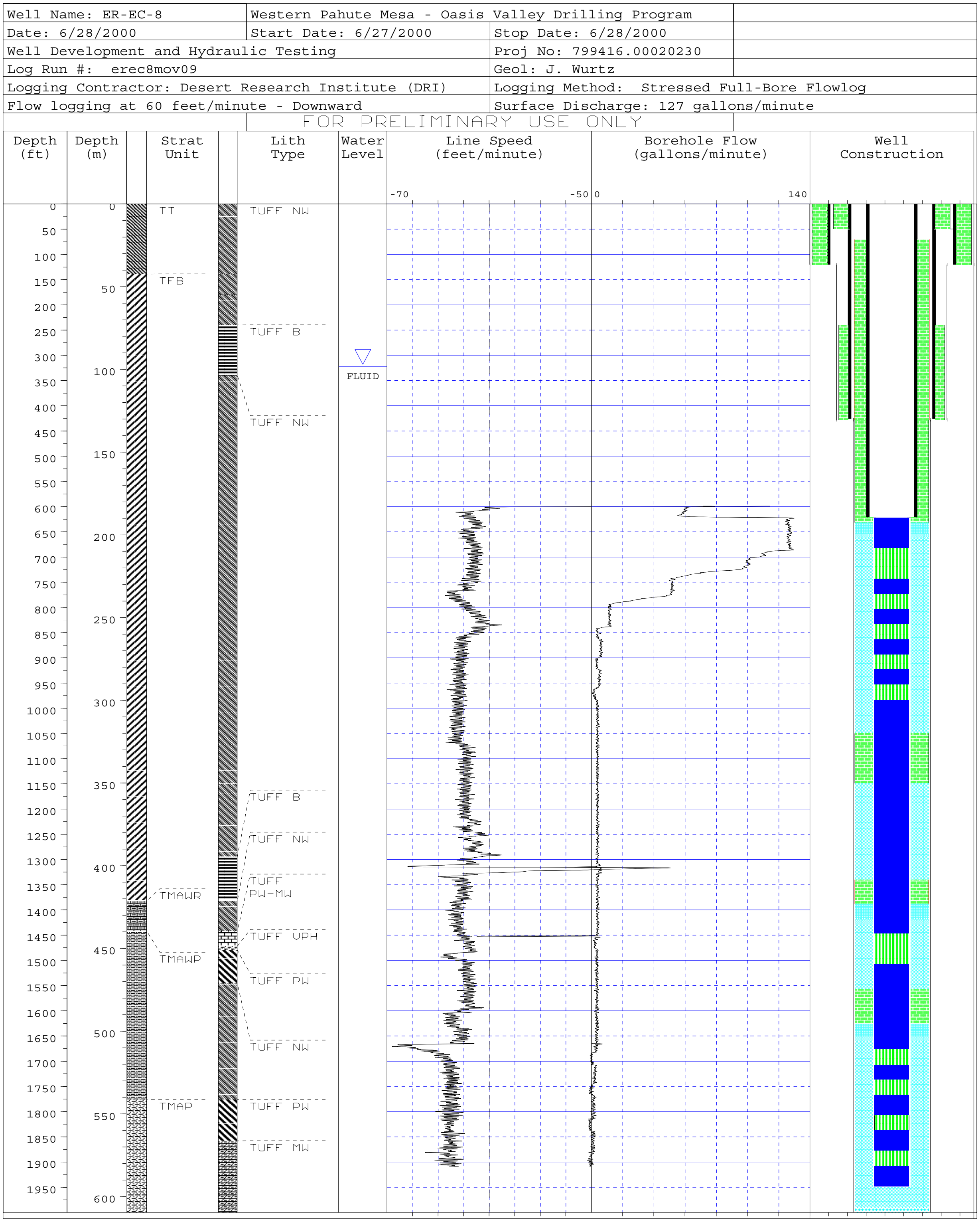
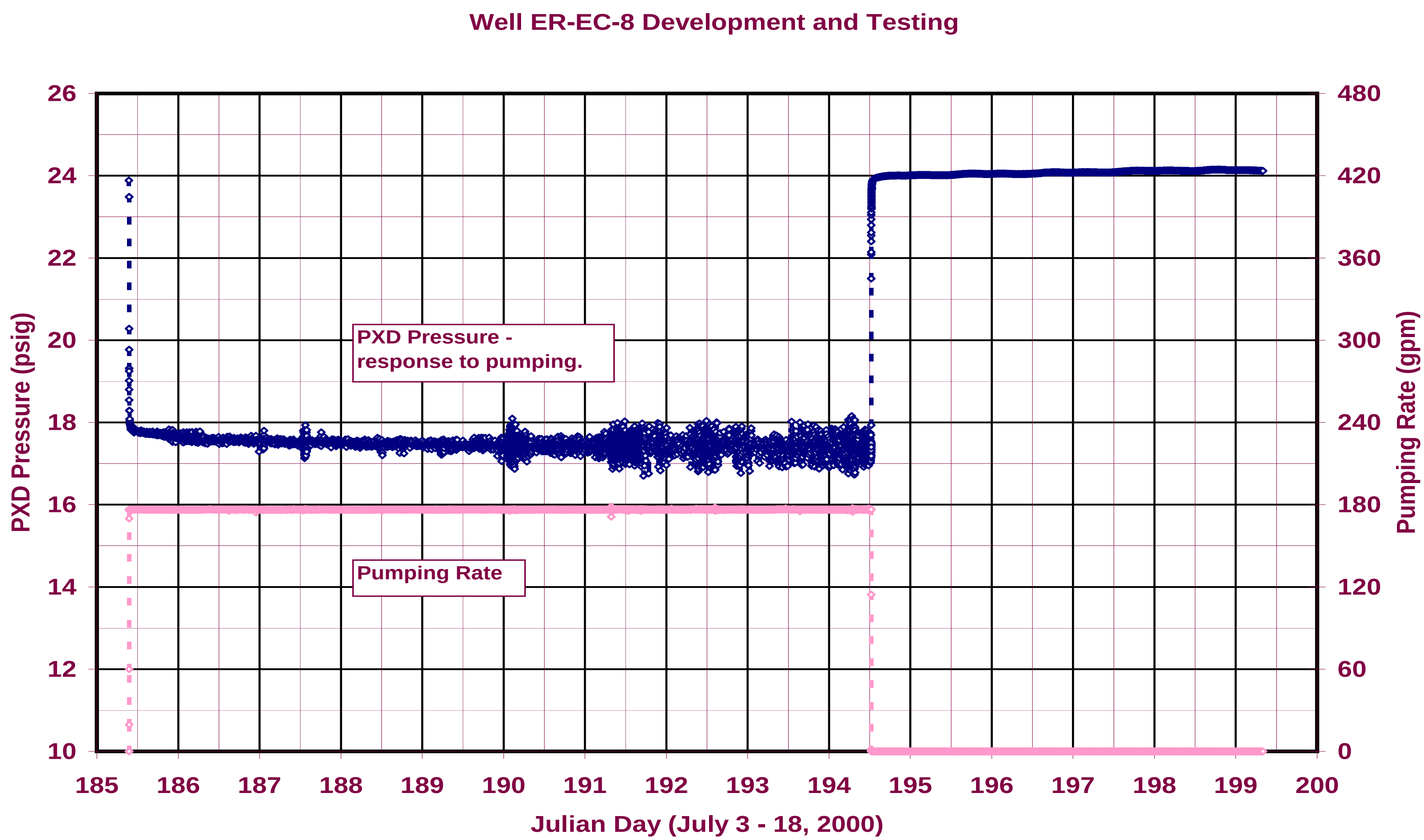
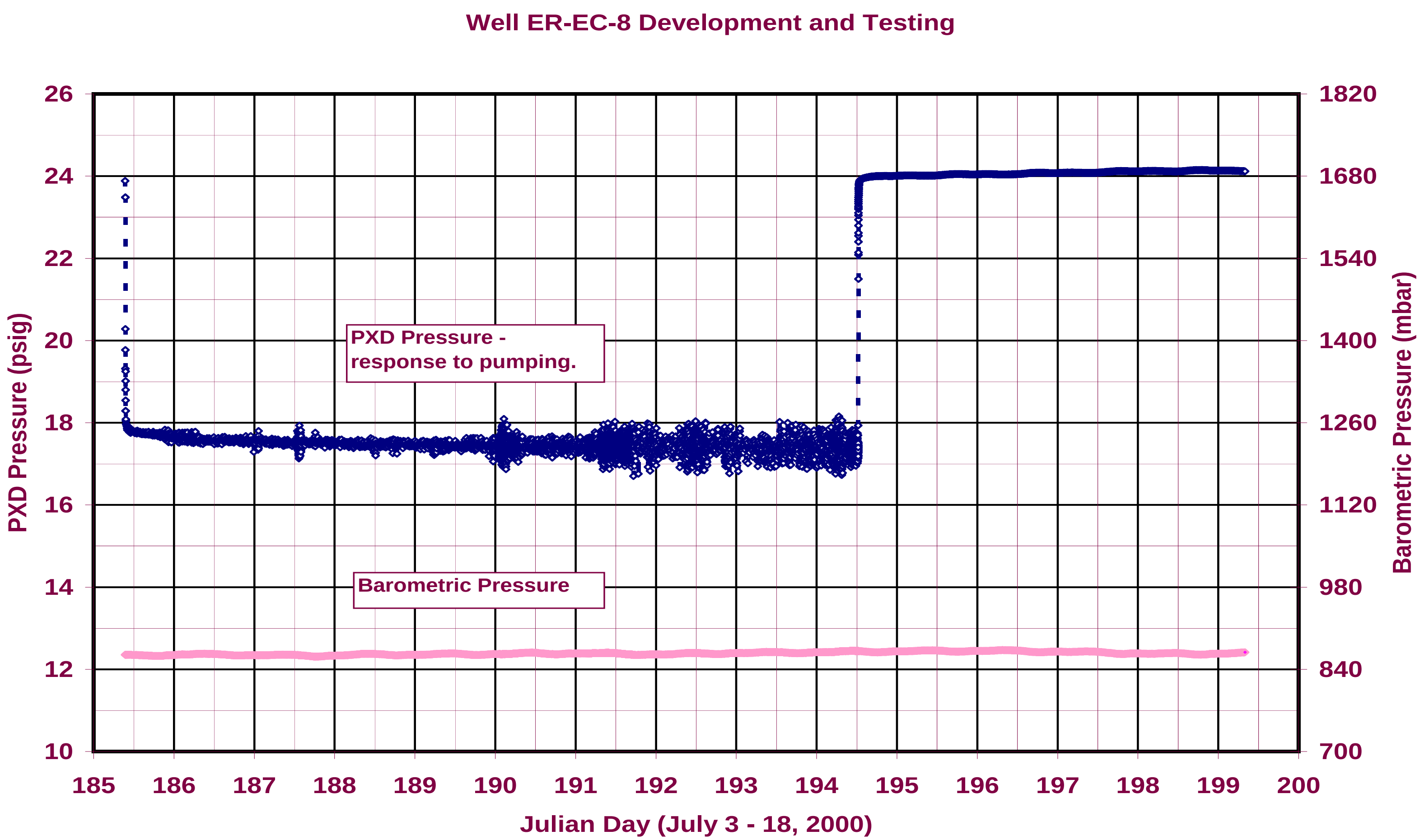



**Figure A.2-12**
**Flow Log at 127 gpm Production Rate and 60 fpm Downward Trolling Rate**



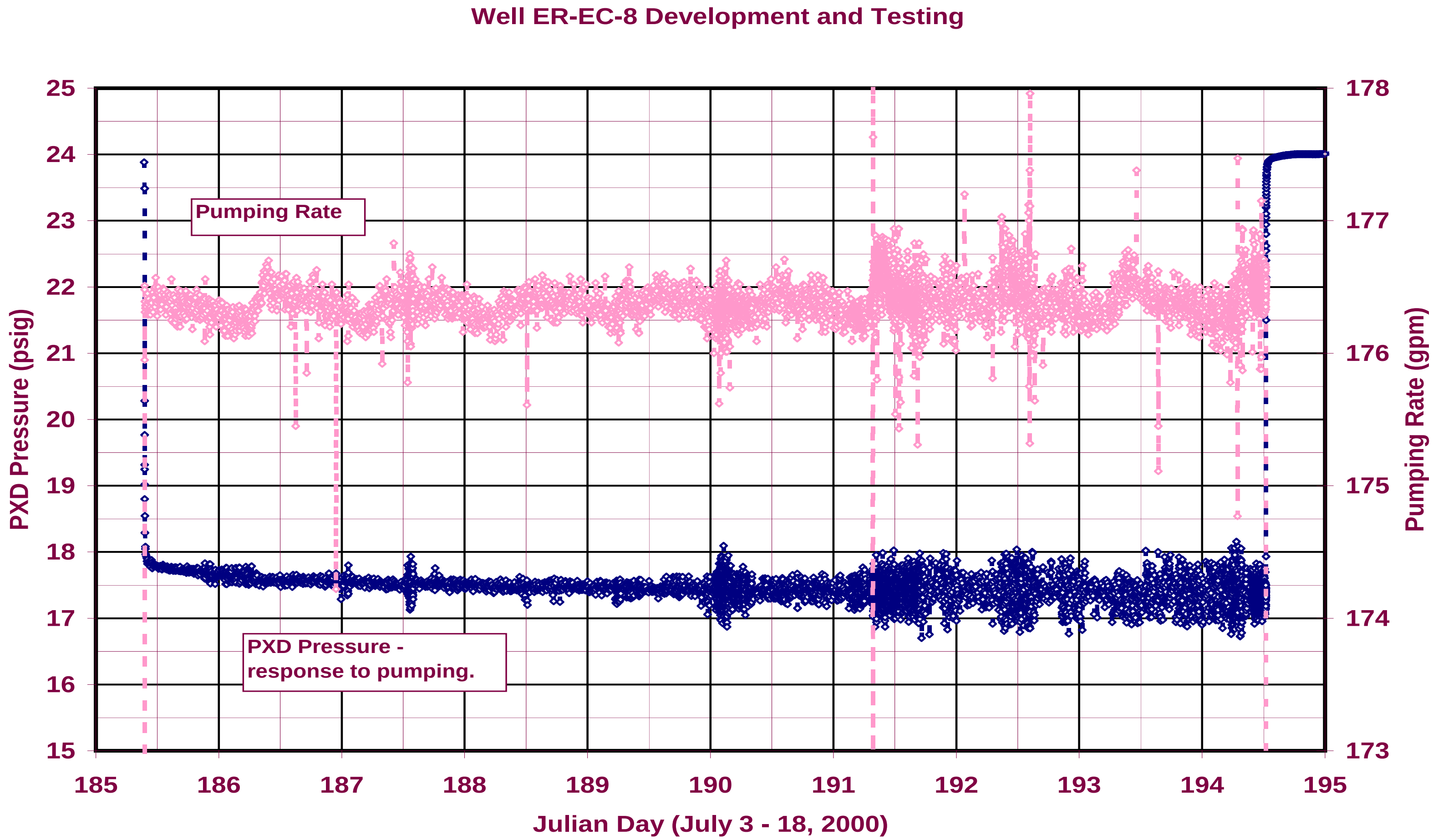

gpm - Gallons per minute
psig - Pounds per square inch gauge
PXD - Pressure transducer

**Figure A.2-13**
**Pumping Rate and Hydraulic Response During the Constant-Rate Test**



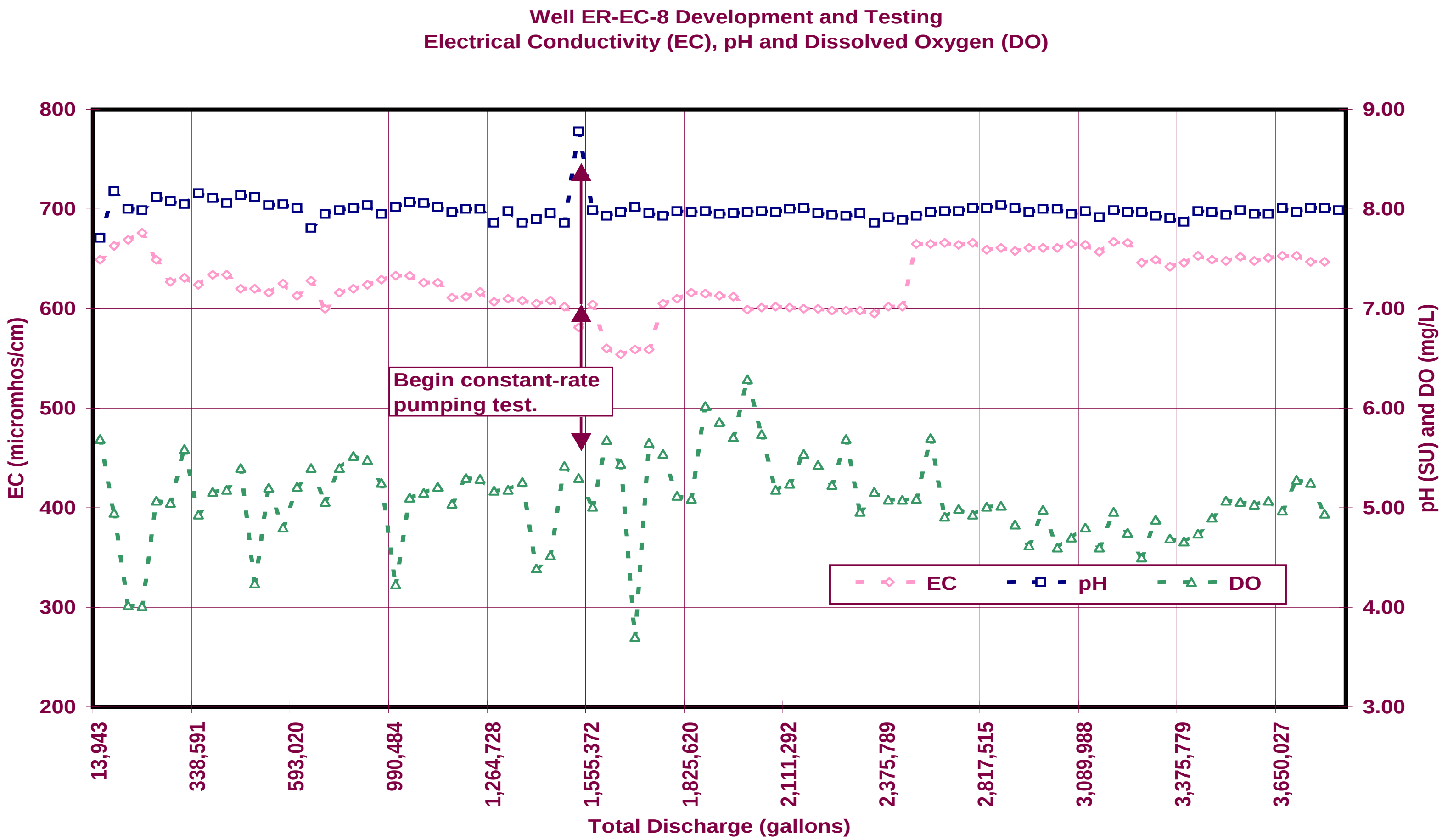

mbar - Millibars
psig - Pounds per square inch gauge
PXD - Pressure transducer

**Figure A.2-14**
**Hydraulic Response and Barometric Pressure During the Constant-Rate Test**



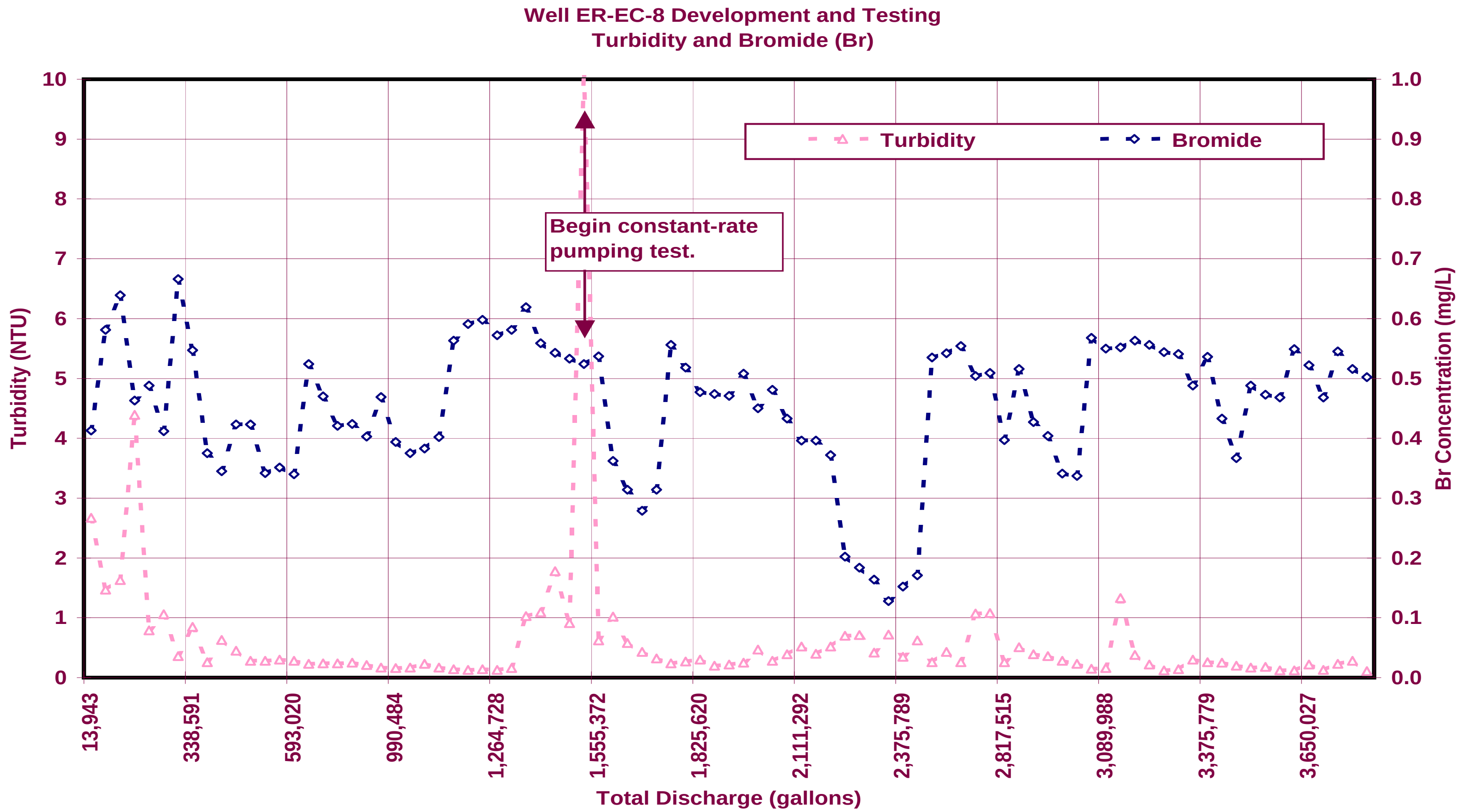

gpm - Gallons per minute
psig - Pounds per square inch gauge
PXD - Pressure transducer

**Figure A.2-15**
**Expanded View of PXD Pressure and Pumping-Rate Fluctuations**



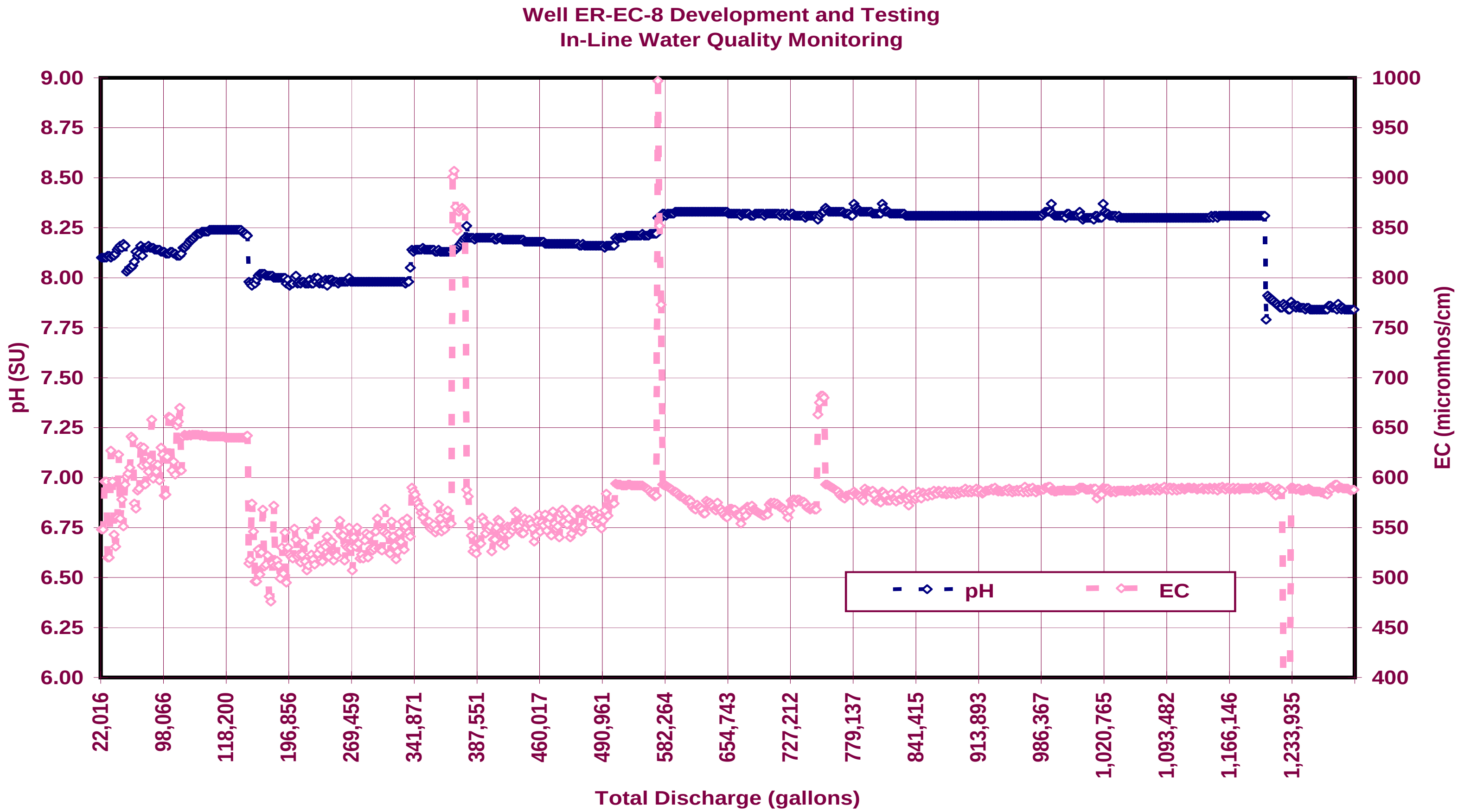

mg/L - Miligrams per liter
SU - Standard Units
cm - Centimeters

**Figure A.2-16**
**Grab Sample Monitoring for EC, pH, and DO**



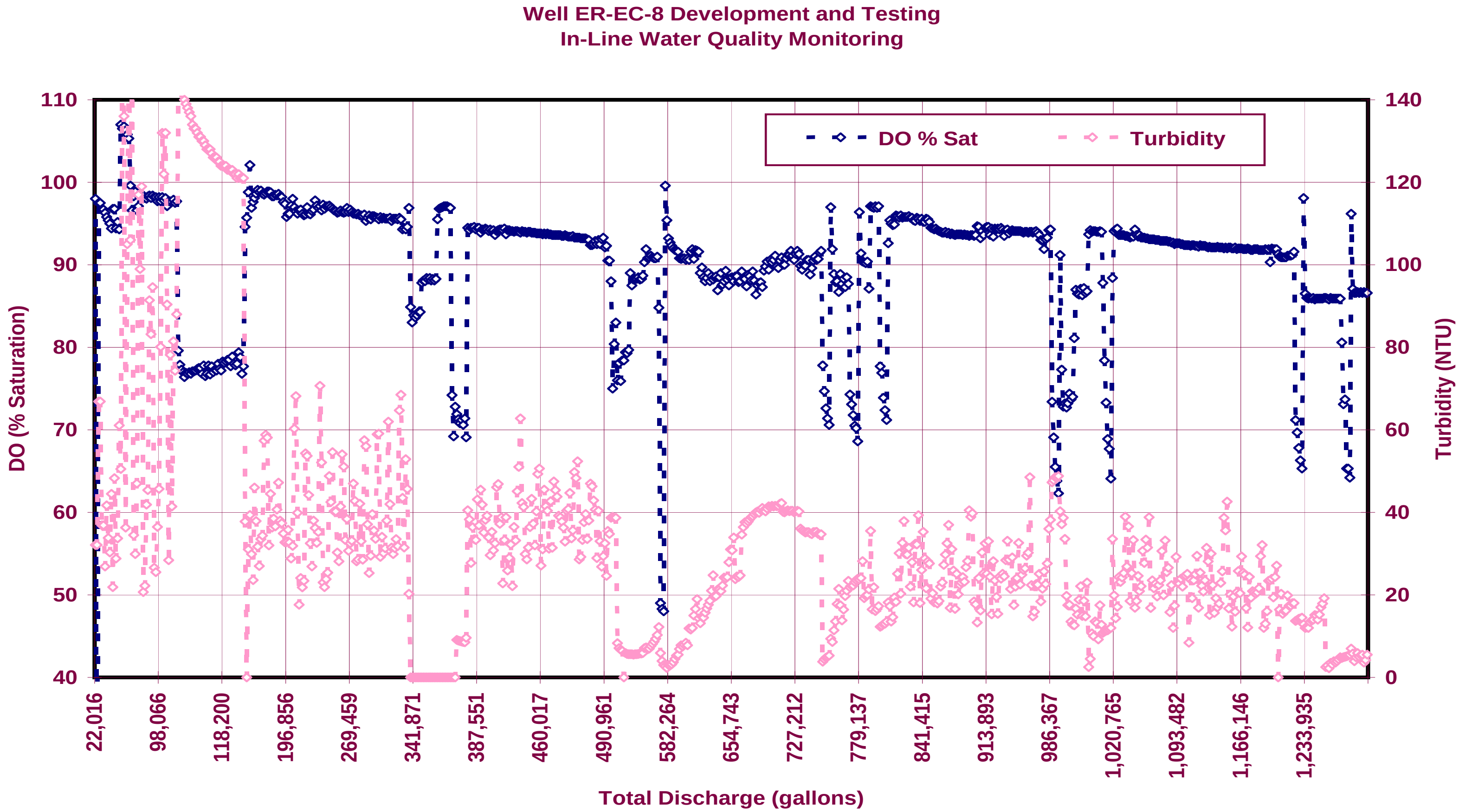

NTU - Nephelometric turbidity unit
mg/L - Milligrams per liter

**Figure A.2-17**
**Grab Sample Monitoring for Bromide and Turbidity**




EC - Electrical conductivity
cm - Centimeters
SU - Standard Units

**Figure A.2-18**
**In-Line Monitoring for EC and pH**




NTU - Nephelometric turbidity units
DO - Dissolved Oxygen
% Sat - Percent Saturation

**Figure A.2-19**
**In-Line Monitoring for Turbidity and Dissolved Oxygen**

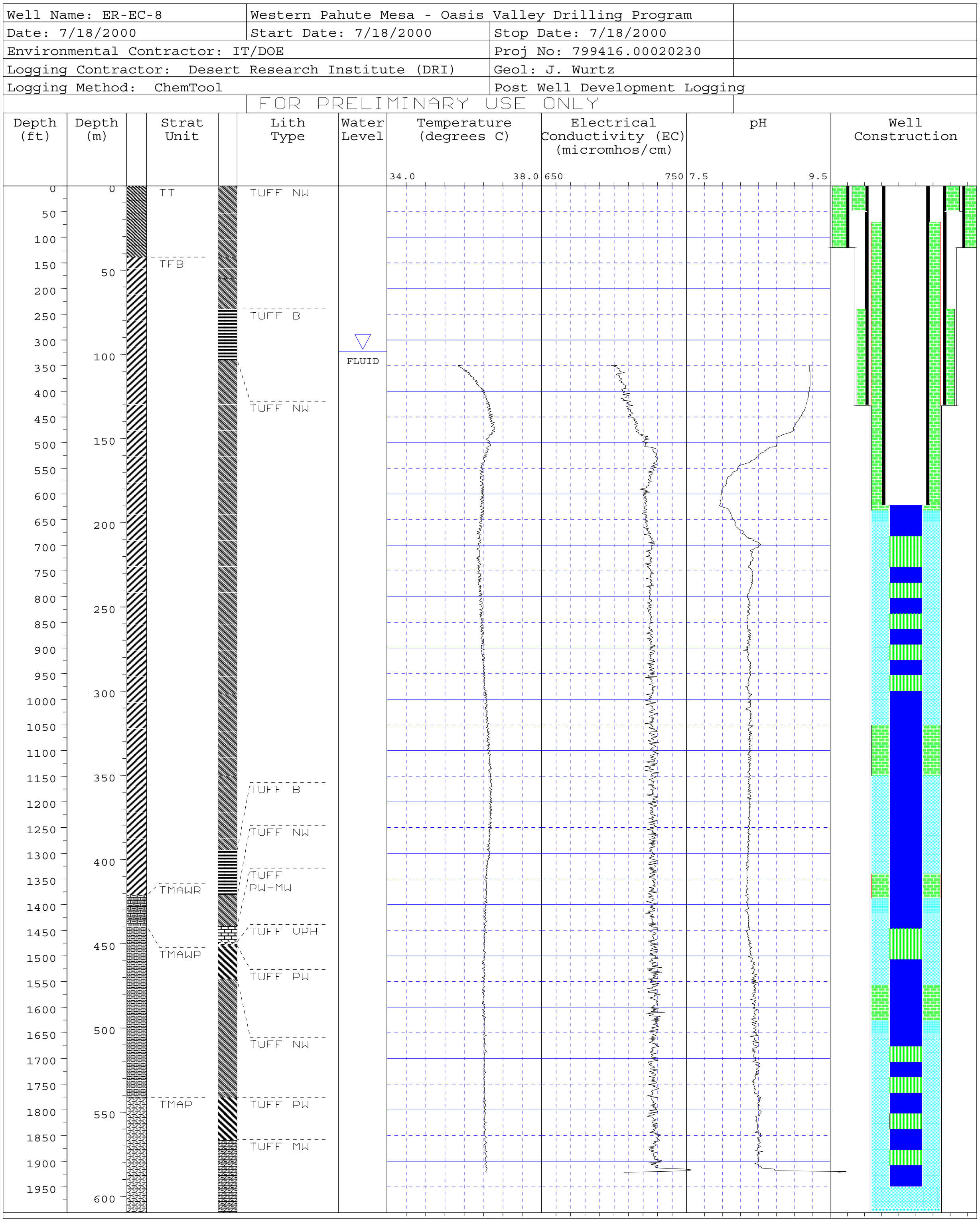



**Figure A.2-20**
**ChemTool Log**

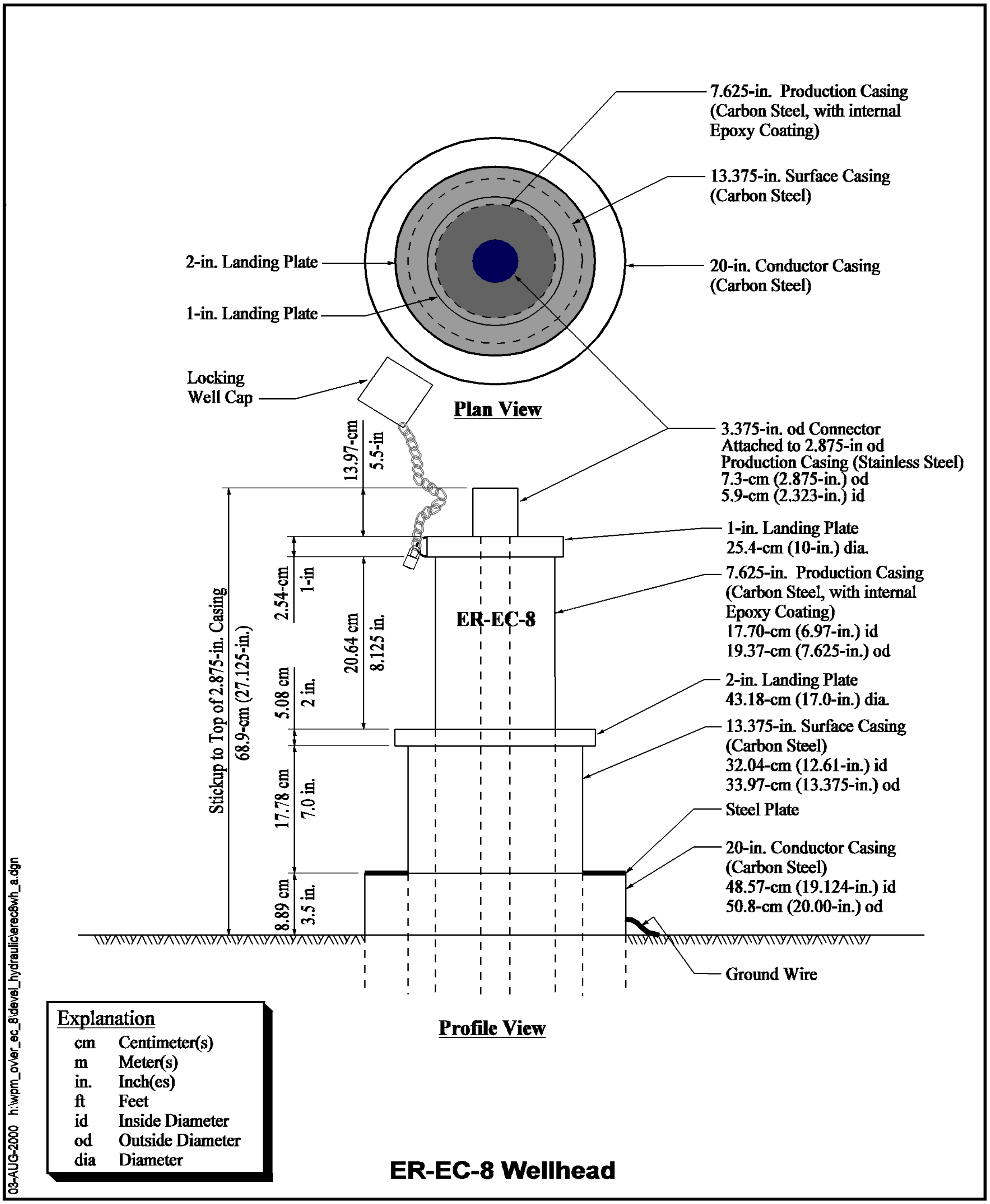



**Figure A.2-21**
**Wellhead Completion Diagram After Sampling Pump Installation**

# A.3.0 Data Reduction and Review

This section presents basic reduction and processing of data collected during the Well ER-EC-8 development and testing program. Data review and preliminary examination of the results are offered, clarifications of details are provided, and points of interest are noted. Any data interpretations in this section are preliminary and subject to change in future data analysis tasks.

## A.3.1 Vertical Gradient and Borehole Circulation

The ambient vertical gradient between completion intervals drives circulation of fluid in the wellbore. Bridge-plug head measurements provide independent measurements of the head in each of the completion intervals, and the thermal flow logging provides a direct measure of the resultant flow. The composite water level for the well is a transmissivity-weighted resultant head showing the effects of flow in the well.

### A.3.1.1 Methodology

The head for each of the lower intervals was calculated from the pressure change in the interval measured after the interval was isolated with a bridge plug. The head was computed by multiplying the pressure change by the composite density of the water in the well above the PXD, and adding that head to the elevation of the PXD. The composite density of the water in the well was computed by dividing the height of the water column above the PXD by the PXD pressure at the set depth measured before setting the bridge plug. Determining the composite density from the actual pressure of the water column was required to calibrate the head calculation to the average water density in the water column. Because of the high values of pressure, the calculation of equivalent head was very sensitive to density, which is not specifically known or otherwise measured. This is discussed further in Section A.3.1.4. This method also renders the calculation insensitive to wireline measurement errors.

The height of the water column was determined from the depth-to-water measurements (denoted as the reference head) taken after each bridge plug was set. This measurement accommodated any composite head adjustment that occurred due to isolating the lower interval(s). While there is a chance that the water level may not have completely stabilized, this measurement provides a better estimate of the height of the water column than the total well composite water level. The intervals were left to equilibrate for five days or more before the bridge plugs were removed. The PXD pressure was recorded at five-minute intervals during that time. The well-composite head and the head for the uppermost interval were determined with an e-tape measurement. Equilibration of the upper interval was verified by monitoring with a PXD set on a wireline.

### A.3.1.2 Data Reduction

Figure A.3-1 shows the PXD monitoring record for the upper interval. Since the upper interval was open to atmospheric pressure in the well, the head was affected by barometric pressure changes during the monitoring period. The graph of the upper interval monitoring shows the PXD pressure record and the barometric record for that period, and also a pressure record corrected for barometric change using a barometric efficiency of 0.55 calculated from the record. The method for calculating the barometric efficiency will be discussed in Section A.3.4.1 and Table A.3-7 shows the fitting of the barometric efficiency overlay. This barometric efficiency is specific to the upper interval and is somewhat different from that calculated for the entire well. This figure shows that there was a small upwards trend in the water level during the monitoring period. However, considering how productive the upper interval was during pumping, the upper interval probably equilibrated quickly and this trend probably represents a general trend in head.

Graphs of the bridge-plug monitoring records for the middle completion interval are presented in Figure A.3-2 and Figure A.3-3, and for the lower interval in Figure A.3-4 and Figure A.3-5. These records for the middle interval show that the pressure dropped immediately after the bridge plug was set, and then rose slowly for the remainder of the monitoring period. The lower interval pressure dropped immediately and then stayed constant. The initial drops are interpreted to be equilibration with formation pressure and the remainder of the record indicates trends in the head of each interval. Note the steadiness in the pressure readings for the calibration data points indicating the PXD temperatures were stable by the beginning of the record segments. The pressure adjustments in this well were small.

Figure A.3-3 and Figure A.3-5 show that the PXD pressure readings fluctuate a certain amount both above and below a central value representing limitations in the resolution of the instrumentation. The central values are used for calculations, and the heads at the end of the monitoring period were used as the representative values for each interval. Table A.3-1 shows interval-specific head information for Well ER-EC-8. The methodology for calculating the head for the middle and lower intervals depends upon the e-tape reference head measurement and the change in PXD pressure from before to after the bridge plug is set, and is insensitive to wireline errors for the PXD set depth. There has been no correction for friction losses due to gradient-driven circulation in the well.

The data indicate a downward hydraulic gradient: the head of the middle interval was 0.39 ft less than the head of the upper interval, and the head of the lower interval was 0.44 ft less than the head of the middle interval. The observed water level changes in the uppermost interval during the week of monitoring were substantially influenced by the changes in barometric pressure. The corrected upper interval head at the end of monitoring was almost the same as the initial head.

The following discussion on the potential error in these measurements indicates that these calculated head differences are less than the absolute accuracy of the individual measurements. Quoted accuracy for the PXDs is 0.1 percent of full scale. Treating the nominal accuracy as measurement uncertainty, the potential uncertainty for the middle interval pressure measurement is +/- 0.75 psi, and for the lower interval is +/- 1.0 psi. These uncertainties result in potential uncertainty in the head difference of +/-0.75 psi (approximately 1.8 ft) between the upper and upper-middle interval, and 1.75 psi (approximately 4 ft) between the middle and the lower interval. In addition, there is also some unquantified uncertainty in the e-tape measurements. The composite static water level measurement was used as the reference head for the lower interval, while the upper interval head was determined by a separate, direct measurement. Since two different e-tape measurements are used to determine the lower interval head and the upper interval head, the measurement uncertainty of e-tape measurements affects the calculated head difference between the upper and lower intervals. This uncertainty is probably in the range of one-tenth of a foot.

**Table A.3-1**
**ER-EC-8 Interval-Specific Heads**

| Measurement | Well Composite | Upper Interval | Middle Interval | Lower Interval |
|---|---|---|---|---|
| Head - Depth ft bgs | 322.87 | 322.97 | 323.36 | 323.80 |
| Determination Method | Direct Measurement Using E-Tape | Direct Measurement Using E-Tape | Calculated from Bridge Plug Data | Calculated from Bridge Plug Data |
| Change in Head ft | --- | -0.10 | -0.49 | -0.93 |
| Composite Water Density Conversion Factor ft/psi | --- | --- | 2.316 | 2.316 |
| Representative Pressure psig | --- | --- | 447.09 | 549.18 |
| Preset Pressure psig | --- | --- | 447.30 | 549.58 |
| Water Column Height ft | --- | --- | 1,041.08 | 1,275.63 |
| Reference Head ft | --- | --- | 322.87 | 322.87 |
| PXD Set Depth ft | --- | --- | 1,363.95 | 1,598.50 |
| PXD Serial Number | --- | --- | 21013 | 21003 |
| PXD Range psig | --- | --- | 0-750 | 0-1,000 |

bgs - Below ground surface
ft - Feet
psi - Pounds per square inch
psig - Pounds per square inch gauge
PXD - Pressure transducer

## A.3.1.3 Correction of Bridge Plug Set Depths

As mentioned in Section A.2.4, the bridge plug set depths have been corrected from the originally specified set depths. Table A.3-2 shows the specified and the corrected depths. These corrections were supplied by BN Geophysics personnel, who oversaw these measurements. The bridge plugs were located by placing them a specified distance from a reference casing collar that was located downhole based on the casing tallies from well construction. Corrections were required for the calibration error of the wireline measurement. The method employed to determine the calibration error correction was based on the error in the measured depth to the reference casing collar.

**Table A.3-2**
**Bridge Plug Set Depth Corrections**

| Location | Specified Depth (ft bgs) | Specified Depth (m bgs) | Corrected Depth (ft bgs) | Corrected Depth (m bgs) |
|---|---|---|---|---|
| Lower Interval Calibration at +50 ft | 1,650.00 | 502.92 | 1,648.42 | 502.44 |
| Lower Interval Calibration at -50 ft | 1,550.00 | 472.44 | 1,548.49 | 471.98 |
| Lower Interval Set Depth | 1,600.00 | 487.68 | 1,598.50 | 487.22 |
| Middle Interval Calibration at +50 ft | 1,415.00 | 431.29 | 1,413.87 | 430.95 |
| Middle Interval Calibration at -50 ft | 1,315.00 | 400.81 | 1,313.93 | 400.48 |
| Middle Interval Set Depth | 1,365.00 | 416.05 | 1,363.95 | 415.73 |

ft - Feet
bgs - Below ground surface
m - Meter(s)

The requirement for locating the bridge plugs was primarily to place them in the blank casing between completion intervals. They were nominally to be located halfway between completion intervals, and in the middle of a length of casing, between the casing joints. The actual set depths of the bridge plugs, although somewhat different from the specified depths, fulfilled those requirements.

## A.3.1.4 Composite Water Density

The calculated composite density conversion factors were 2.327 and 2.321 ft of water column/psi (0.992 and 0.995 in terms of specific gravity corrected for temperature), respectively, for the middle interval and the lower interval. The specific gravity values are based on calculations relative to values for standard temperature corrected weight density of water (Roberson and Crowe, 1975). These values seem reasonable considering they must accommodate effects of dissolved and entrained gases, suspended solids, and dissolved solids. The values also compare well with the conversion factor value of 2.328 ft of water column/psi (specific gravity 0.992) that was calculated from the PXD installation for predevelopment water level monitoring. The specific gravity values for the upper part of the well are slightly less. This may reasonably be expected because they apply to the upper part of the water column, which should have less suspended sediment and a greater proportion of entrained gas. A conversion factor value of 2.371 ft of water column/psi (specific gravity 0.974) was calculated from the PXD installation for monitoring drawdown for the constant-rate test, which was done after development.

#### A.3.1.5 Thermal Flow Logging

The thermal flow logging found downward flow of 0.8 gpm starting in the upper slotted joint of the upper completion interval (710 ft bgs), and 0.4 gpm downward flow below the middle completion (1,550 ft bgs). Measurements at other stations (760; 810; 850; 1,000; 1,400; and 1,700 ft bgs) found no flow. These results do not clearly indicate any flow from the upper completion interval downwards to the lower completion intervals. The 0.8 gpm downward flow found at 710 ft bgs appears to disappear within the same screen section in which it originates. There appears to be a flow of 0.4 gpm from the middle completion interval down into the lower completion interval. These results do not provide a definitive picture of natural circulation within this well. The corresponding vertical gradients are likewise uncertain. This information will probably not support any further analysis of the well hydraulics.

### A.3.2 Well Development

Well development actions appeared to have a small, progressive effect on improving the hydraulic efficiency of the well, see Figure A.2-2. The drawdown decreased a small amount each day after surging, based on the overnight pumping at the consistent rate of 180 gpm. Very little sediment was produced. A small improvement in specific capacity (drawdown divided by production rate) of the well during development was noted between step-drawdown tests on June 22 and June 25, 2000.

### A.3.3 Flow Logging During Pumping

The flow logging during pumping provided valuable information on the inflow of water to the well that was induced at the pumping rates used for development, testing, and sampling. This information will allow accurate analysis of the hydraulic response, perspective on the effectiveness of this type of well design for accessing the formations over large vertical distance, and representativeness of water samples taken.

#### A.3.3.1 Optimal Flow Logging Run

The optimal flow logging configuration during pumping is thought to be the downrun at 20 fpm. This configuration maximizes sensitivity of the logging to actual flow and minimizes the effects of trolling on the flow in the well. The logs from this configuration would be preferred for interpretation. However, other configurations are also run to supplement the data. The theory behind this conclusion is explained below.

The rotational response of the impeller is a function of two components, expressed as:

$$R_t = R_{ls} + R_v$$

where:

$R_t$ is the total rotation rate of the impeller at any depth

$R_{ls}$ is the rotation rate of the impeller due to linespeed

$R_v$ is the rotation rate of the impeller due to vertical flow

The greater the line speed, the more $R_{ls}$ contributes to the total response, thereby increasing error due to variable line speed, depth offset, and other related factors. Logs conducted at 20 fpm, which is well above the stall speed for the fullbore flowmeter, provide for relatively short logging runs (one to two hours), yet minimize the contribution of $R_{ls}$ and maximize the response to $R_v$. Additional runs are conducted at other line speeds in order to address the stall speed of the fullbore flowmeter. Every spinner tool has a minimum velocity required to initiate impeller movement and a slightly slower velocity at which the impeller will stall. There may be instances in any borehole where flow may be in the same direction and magnitude relative to the direction and line speed of the flowmeter. The impeller would be located in flow moving past the tool at rates below the stall-speed of the tool, despite substantial flow occurring within the well. Logging at different line speeds in different directions under identical conditions shifts the depths within the borehole where this is occurring so that the flow occurring in all depths of the borehole can be logged.

### *A.3.3.2 Intervals of Inflow*

Figures A.2-7 through A.2-12 showed the stressed flow logging for Well ER-EC-8. The trolling flow logging during pumping indicates that between 98-100 percent of the water produced came from the upper interval. This result was consistent between all of the logs at all three pumping rates. The uncertainty in the flow logging measurements makes the small amount of apparent production from lower intervals questionable. The results may show a slight increase in the small amount coming from the lower intervals at the two higher pumping rates.

The stationary flow measurements during pumping measured production from the lower completion intervals only at the highest pumping rate. Production was measured from the lowermost completion interval only at a fraction of a gpm. This rate is below the lower limit of the flow logging tool. This result essentially agrees with the results of the trolling flow logging, also leaving some uncertainty about very minor production from the lower intervals.

The bridge plug measurements determined very little vertical head gradient, and that gradient is a small fraction of the drawdown produced by pumping. This would suggest that most of the difference in production between the completion intervals can be attributed to different transmissivities of the formations in the intervals. Without any substantial flow, flow losses are negligible. This line of reasoning would attribute the greatest transmissivity to the upper interval. The situation may be clarified somewhat when the downhole hydraulics of the well are analyzed, incorporating the vertical gradient and potential friction losses for flow from the lower intervals.

### A.3.4 Constant-Rate Test

The drawdown and recovery data from the constant-rate pumping test have been processed to adjust for the influences of barometric pressure changes.

#### A.3.4.1 Barometric Efficiency

Barometric efficiency is a measure of the proportional response of the head (water level) in the well to a change in barometric pressure; when barometric pressure rises, the head will be depressed by some fractional amount. The efficiency of the response of the upper completion interval to barometric changes was determined from the monitoring record for the upper interval during the bridge plug measurement. The result was used to correct the upper interval monitoring record, as discussed in Section A.3.1.2. The barometric efficiency for the entire well (all three completion intervals) was first determined from the predevelopment water level monitoring record. This result was used to correct the predevelopment monitoring record, see Figure A.3-1, so that any trend in the water level would be evident. The barometric efficiency of the entire well was also determined for the record following development, just prior to the constant-rate test. This result was used for correction of the constant-rate test. The differences between the three different determinations of barometric efficiency are discussed below.

The method used for determining barometric efficiency was to overlay the barometric record onto the PXD pressure record and adjust it with a scaling factor and a trend rate until a best fit was obtained. In order to overlay the barometric record onto the PXD record, the barometric record had to be converted into psi, offset onto the PXD record, and reversed to match the sense of the response. The resultant factors are the barometric efficiency and a linear trend characterizing the PXD pressure record.

Figure A.3-6 shows the PXD pressure record for the predevelopment monitoring period with the barometric record adjusted for a best-fit overlay. The best-fit result was a barometric efficiency of 64 percent, with a trend of 0.00062 psi/day (about 0.0014 ft/d). This is somewhat different from the best-fit for the upper completion interval only, which was a barometric efficiency of 55 percent with a trend of 0.0018 psi/day (0.0042 ft/day). The overlay of the adjusted barometric record onto the PXD pressure record for the upper interval monitoring is shown in Figure A.3-7. Figure A.3-8 shows the overlay for the pretest monitoring record before the constant-rate test, yielding an efficiency of 85 percent with a trend representing recovery still occurring from development. The reason for the variation in barometric efficiency is not clear, but perhaps it is related to the development process and improvement in the connection of the well with the formation. The length of the records is also very different, and the fitting of both an efficiency and a trend on a short record may result in substantial uncertainty. Any changes resulting from development is probably dominated by the upper completion interval, which was the most productive.

#### *A.3.4.2 Drawdown Record*

Figure A.3-9 shows the resultant record for the constant-rate test and recovery period. The pressure drawdown record was converted to equivalent change in groundwater head using a conversion value for pressure to water head derived from the head measurement and pressure data collected when the PXD was removed after testing. This information is presented in Table A.2-8. The correction for barometric variation did not have a great effect on the drawdown curve because the magnitude of the drawdown was proportionally much greater.

### *A.3.5 Water Quality*

A variety of general water quality parameter information was collected, including grab samples taken during pumping, data collected using a Hydrolab® flow-through cell, and DRI ChemTool logs run both before well completion and after development activities. Comparisons can be made between the water quality parameters of the well water before well completion and after well development.

#### *A.3.5.1 Grab Sample and Hydrolab® Results*

Water quality parameter values measured for grab samples taken from produced water are shown in Attachment 2. During the course of pumping pH was generally very steady at about 8.0, as illustrated in Figure A.2-16. The Hydrolab® data is much more sensitive to small, short-term fluctuations, as shown in Figure A.3-10. This figure shows the change in pH versus the total gallons pumped during development and also the pumping rate versus total gallons pumped. This juxtaposition of parameters illustrates the relationship of the instantaneous pH value with the recent pumping history. Whenever the pumping is stopped and/or the pumping rate changed, the pH values responded with an adjustment. There is a rebound effect whenever pumping is stopped that appears to diminish with time. The grab sample EC values (Figure A.2-16) were consistently below 700 µmhos/cm, and initially became more consistent around 600 µmhos/cm with pumping. However, there was an apparent abrupt increase to 650-660 µmhos/cm almost halfway through the constant-rate test. The reason for this is not known, but the change in measured EC values may be due to variables in the measurement process. Figure A.3-10 also shows an inline sample DO to illustrate the similar effect pumping changes have on the measured values. The

DO has been converted from percent saturation to mg/L for consistency with grab sample results units.

In comparing grab sample results to Hydrolab® results it should be noted that all the Hydrolab® data was collected during development, when the water quality parameter values were much more erratic than during the constant-rate test. This is probably due both to incomplete development and constantly changing pumping conditions. The Hydrolab® pH values are very similar to the grab sample values, while the Hydrolab® EC values are somewhat lower. The DO values are also similar to grab sample results though slightly higher. In general, the Hydrolab® data may be judged as in agreement with the grab sample data, and shows the pattern of re-equilibration of parameter values to changes in pumping conditions.

### *A.3.5.2 Precompletion Versus Postdevelopment Water Quality*

The ChemTool log of downhole water quality parameters was run at the very end of the testing program, and gives another picture of the effectiveness of the development and testing activities on water quality restoration. The next three figures show the ChemTool logs that were run following drilling, but prior to well completion side-by-side with the logs that were run following well development and testing. Figure A.3-11 shows temperature logs, Figure A.3-12 shows the pH logs, and Figure A.3-13 shows EC logs. Included on these figures are lithologic information and well completion details.

The temperature log precompletion and postdevelopment show slight differences. The posttesting log is very similar in configuration, but approximately 2°C cooler. The inflection between the upper and middle completion intervals is also slightly greater. The parameters pH and EC generally give an indication of the representativeness of the water within the well relative to formation water. The postdevelopment pH log indicates that the water above the middle completion has pH between 8.25 and 8.5. This is higher than the precompletion pH log, which showed pH between 7.75 and 8.0. This contradicts the grab sample results which found pH consistently about 8. The calibrations of the different instruments were not checked against each other so these apparent differences may not be meaningful. Also, the conditions under which the measurements are made (e.g., surface/benchtop versus downhole) may produce results which are not directly comparable. Both the precompletion and postdevelopment logs show more variation in the pH below the middle completion interval.

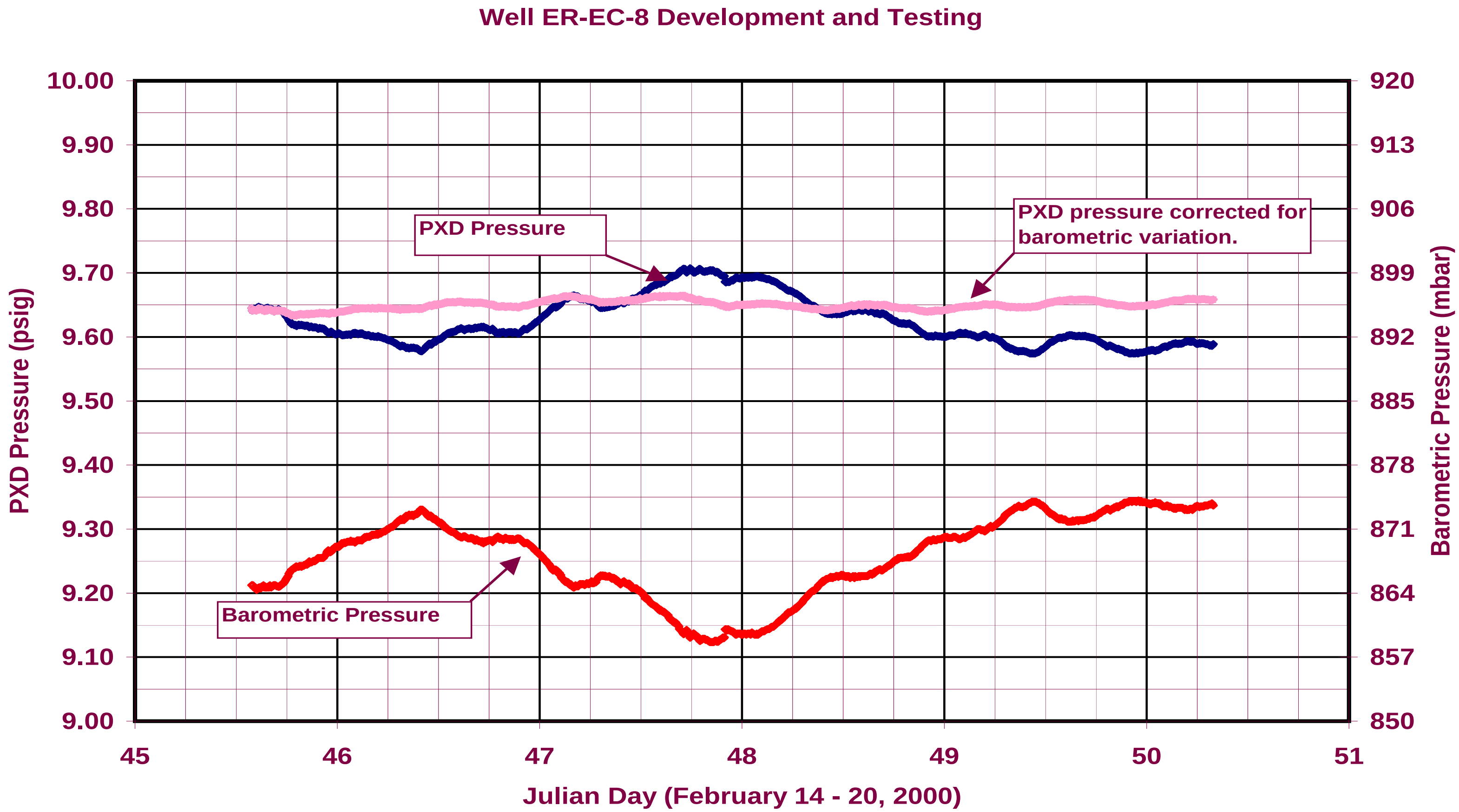
The EC log, in contrast to the pH log, indicates significantly higher EC values postdevelopment, consistently about 725 µmhos/cm versus 650 µmhos/cm precompletion. Also, the large deviation in the lower completion that was observed in the predevelopment log is no longer there. Both the pH and EC logs show general consistency throughout the depth of the well. The changes observed in the well below the middle completion interval suggests that the water quality has changed, either due to natural borehole circulation or pumping.

#### *A.3.5.3 Grab Sample Results Versus ChemTool Results*

The postdevelopment pH log seems anomalously high, and does not agree with the grab sample monitoring (Table ATT.2-1, Attachment 2, Appendix A), which generally indicated pH about 8. The EC values (720-730 μmhos/cm) also do not agree with the grab samples, which were generally around 650 μmhos/cm at the end of the constant-rate test. It is not expected that pH values or EC values would go up with time and development. Until the reason for differences between ChemTool log values and grab samples values is understood, any analysis using the values is suspect. This may primarily be a calibration problem or it may be related to differing environmental conditions between grab samples and downhole measurements.

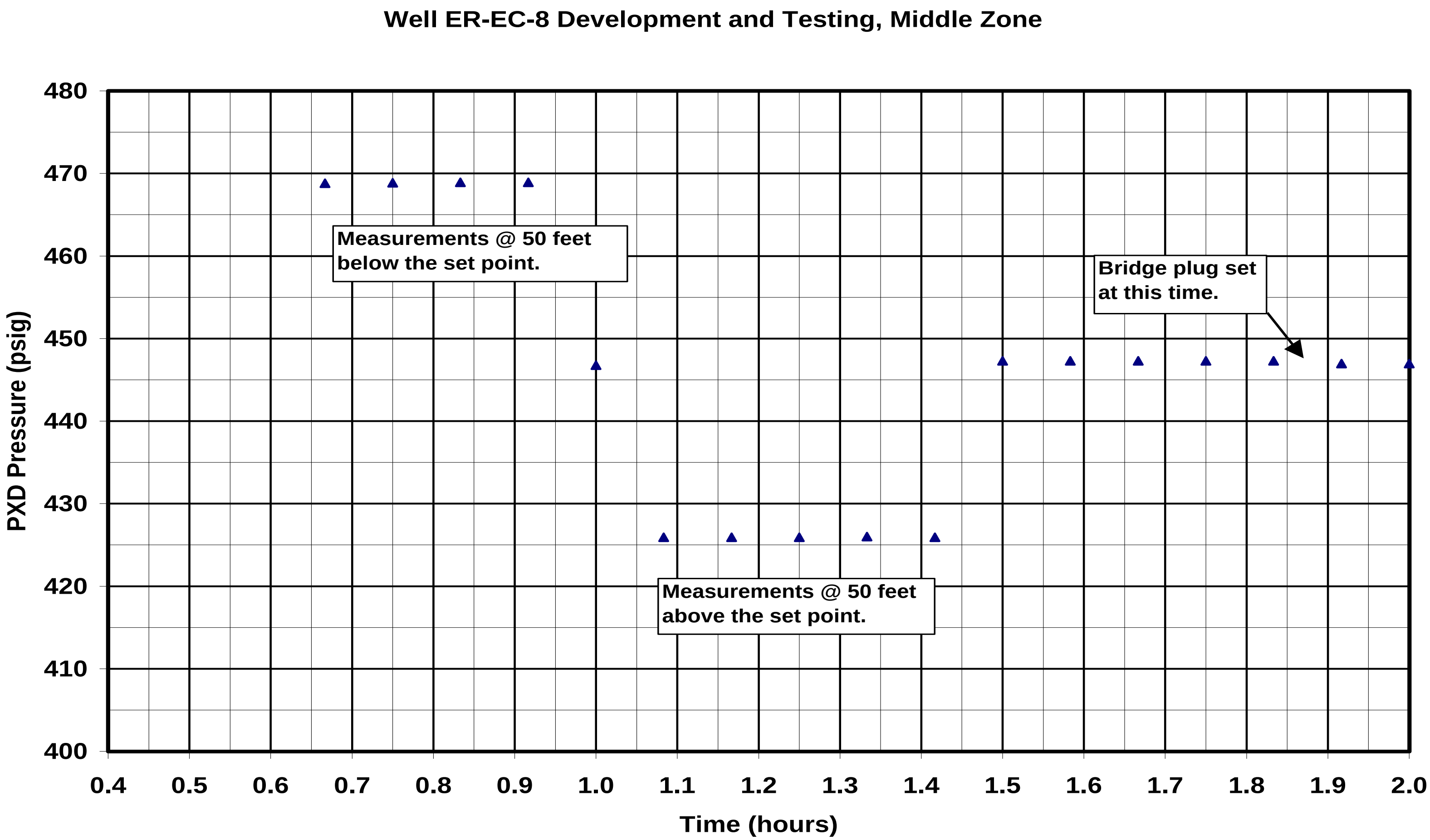
### *A.3.6 Representativeness of Hydraulic Data and Water Samples*

The results of water quality monitoring, development, hydraulic testing, and composite sampling can be considered to only represent the upper completion interval of this well. Since the upper completion interval appears to have the highest head and any natural flow in the well appears to be downward, the upper completion interval does not naturally receive water from any source. Therefore, this interval will probably maintain its individual character for future sampling. The discrete sample taken in the upper completion interval should represent that interval, similar to the composite groundwater characterization sample. It is not clear what the discrete sample taken below the uppermost completion interval may represent. The lower completion intervals cannot be considered developed, and any samples taken below the upper completion interval are suspect. They may, in fact, still be affected by drilling-induced fluids.



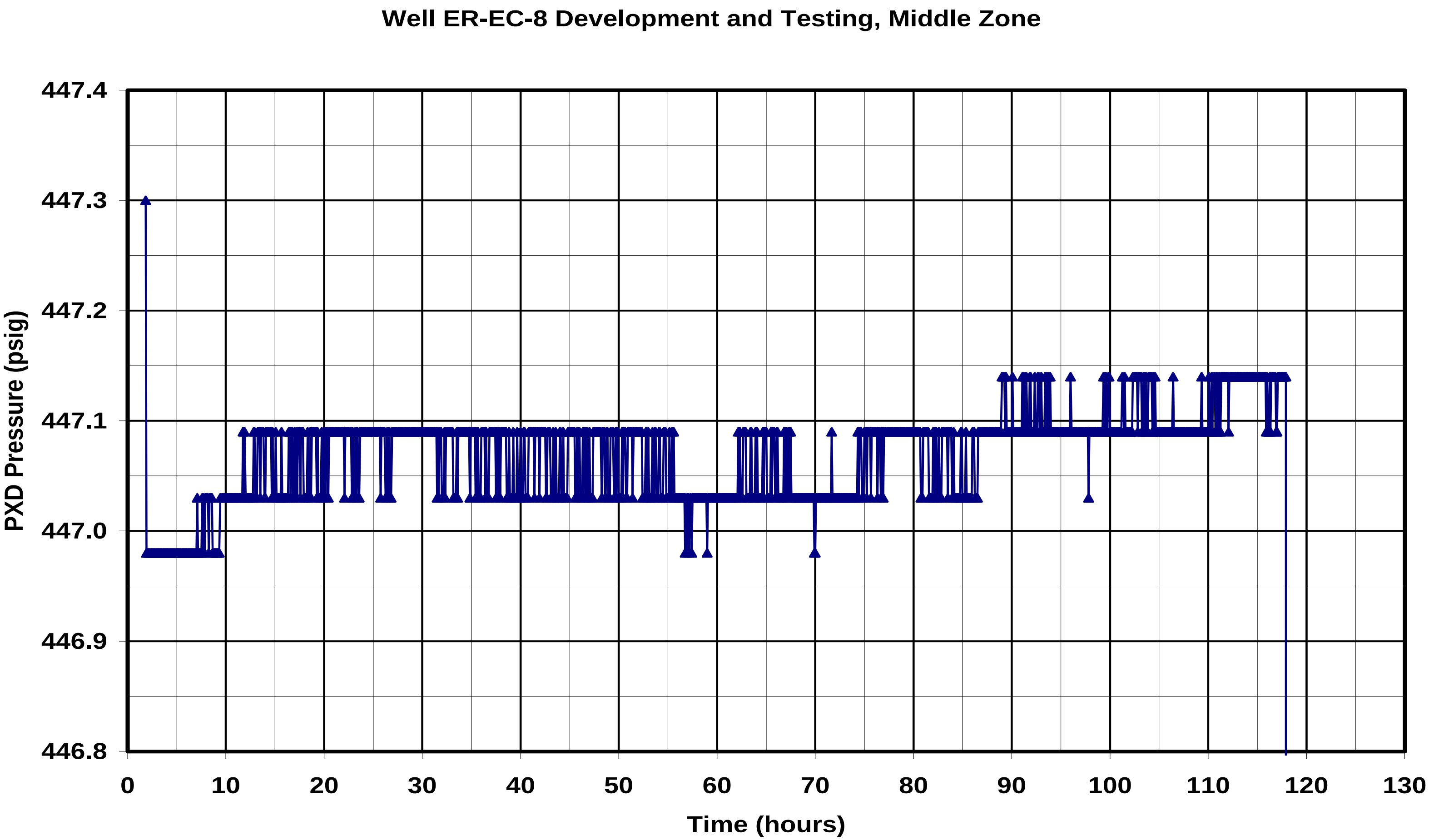

mbar - Millibars
psig - Pounds per square inch gauge
PXD - Pressure transducer

**Figure A.3-1**
**PXD Equilibration Record for the Upper Interval**



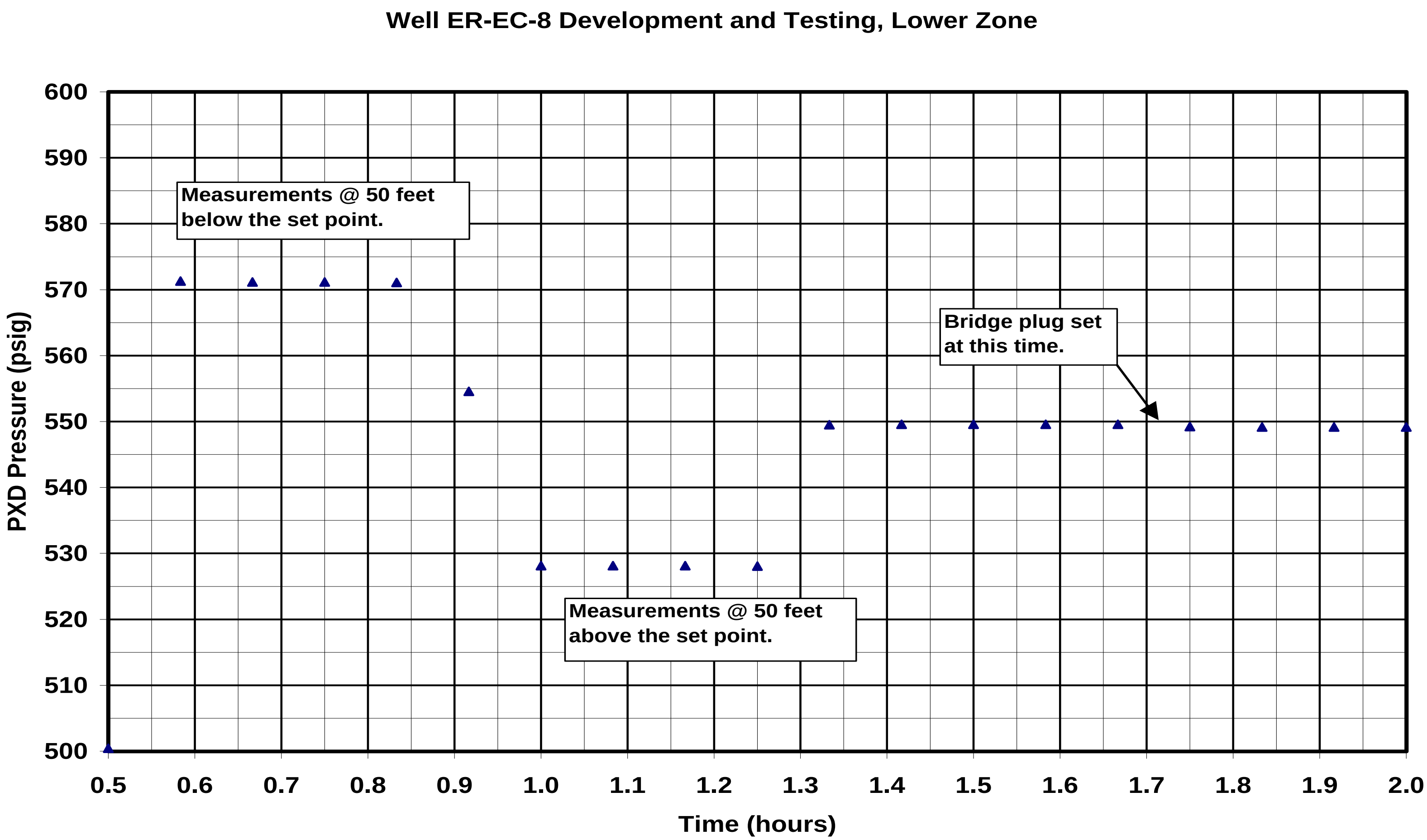

psig - Pounds per square inch gauge
PXD - Pressure transducer

**Figure A.3-2**
**Middle Interval Calibration and Bridge Plug Set**



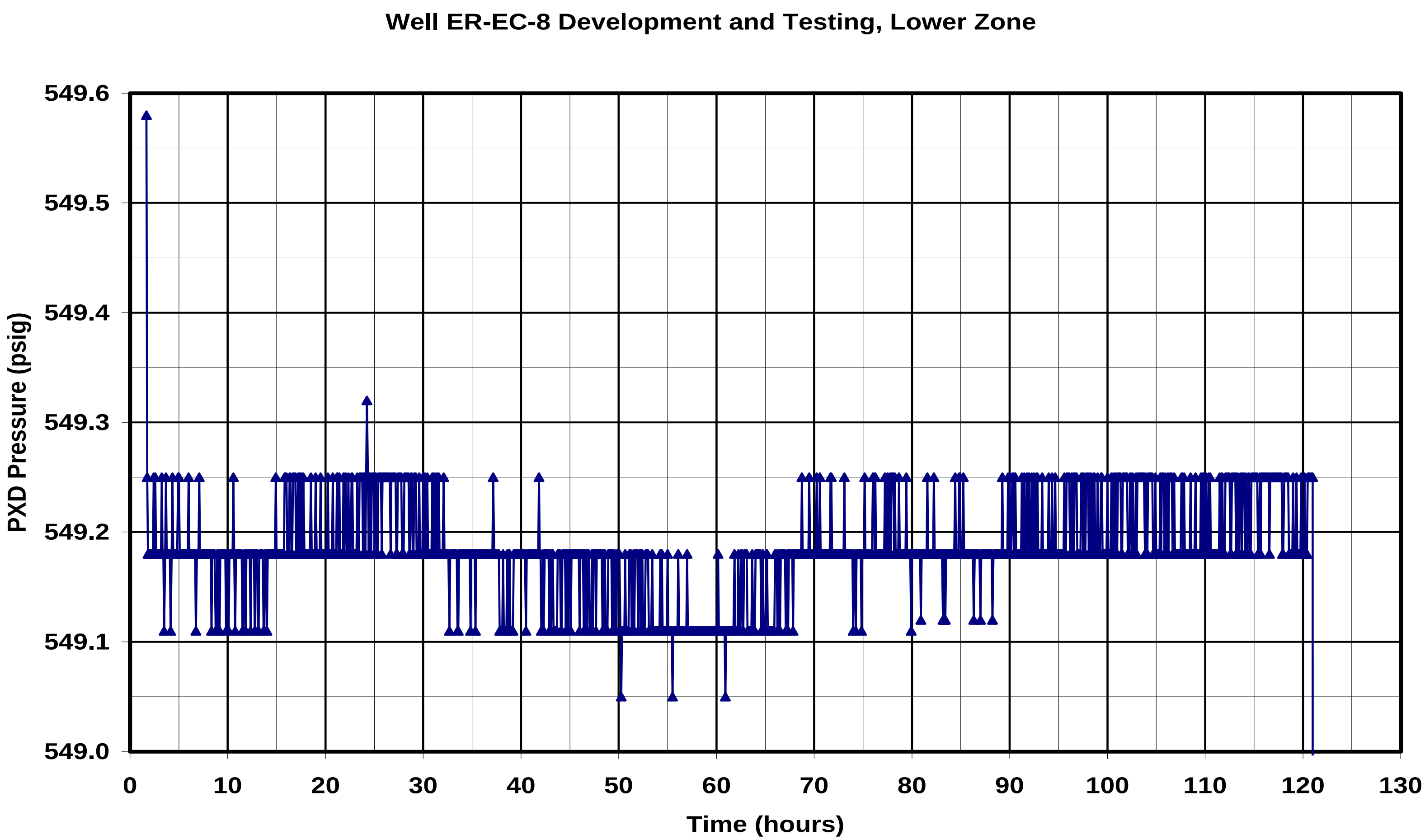

psig -Pounds per square inch gauge
PXD - Pressure transducer

**Figure A.3-3**
**Bridge Plug PXD Response for the Middle Interval**



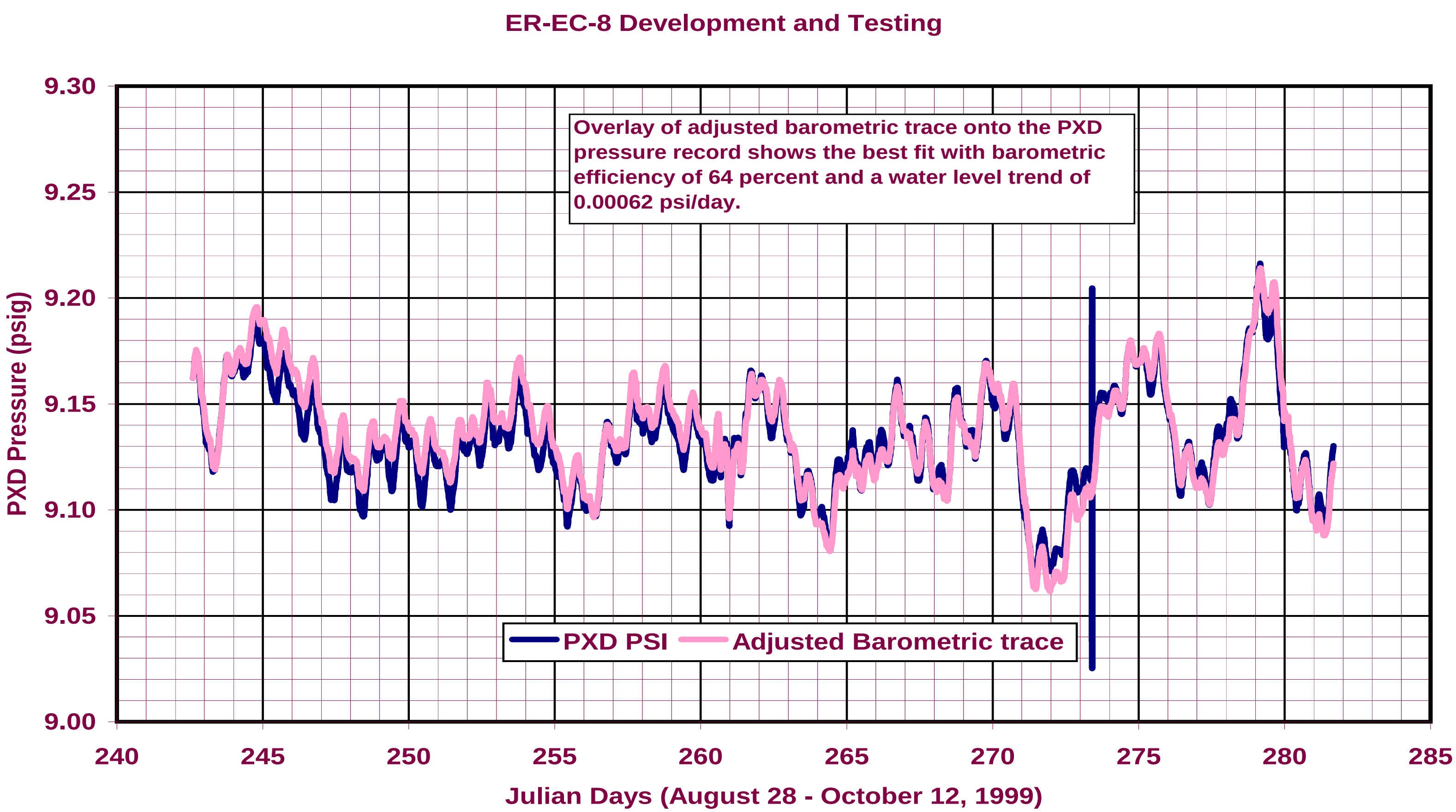

psig - Pounds per square inch gauge
PXD - Pressure transducer

**Figure A.3-4**
**Lower Interval Calibration and Bridge Plug Set**



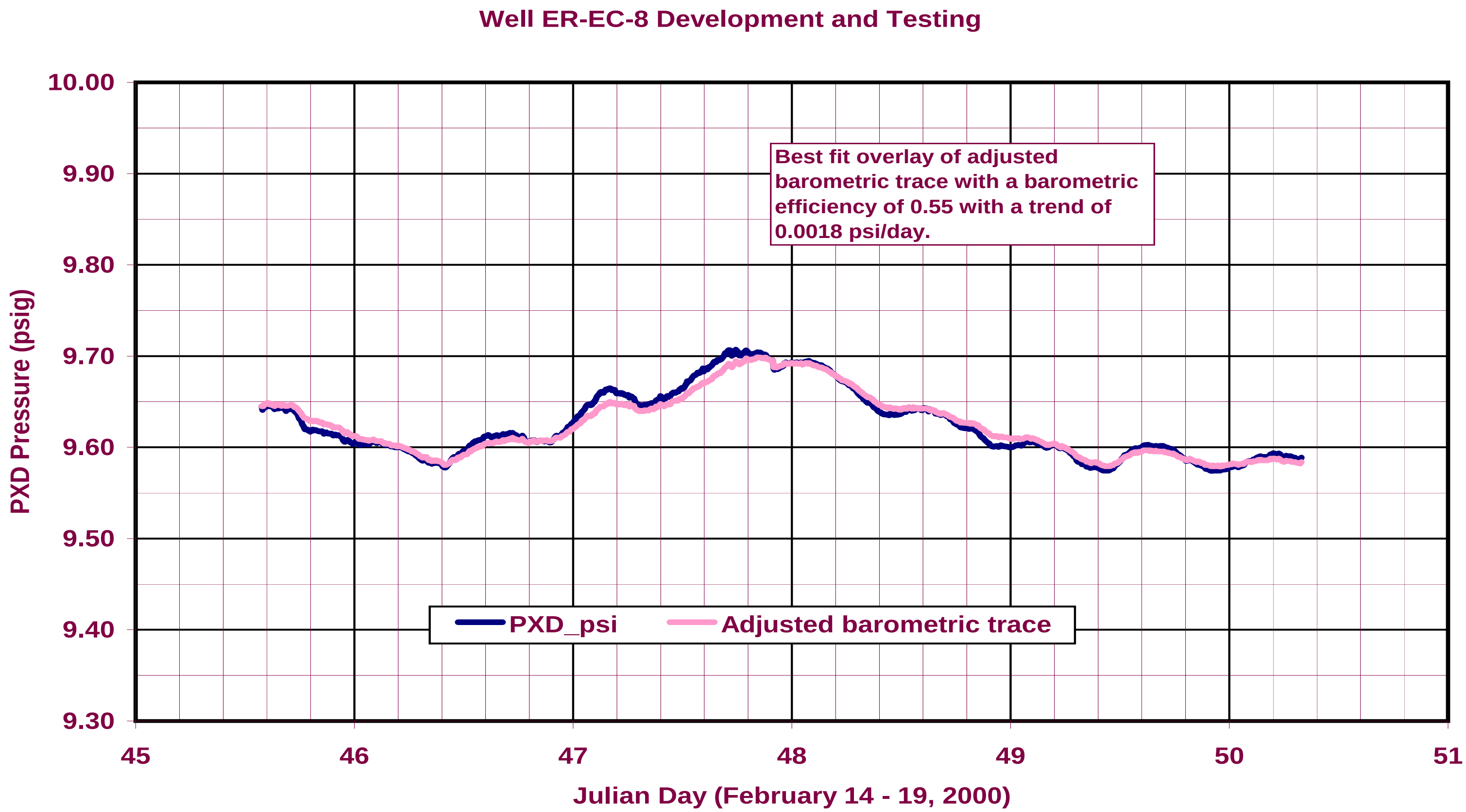

psig - Pounds per square inch gauge
PXD - Pressure transducer

**Figure A.3-5**
**Bridge Plug PXD Response for the Lower Interval**



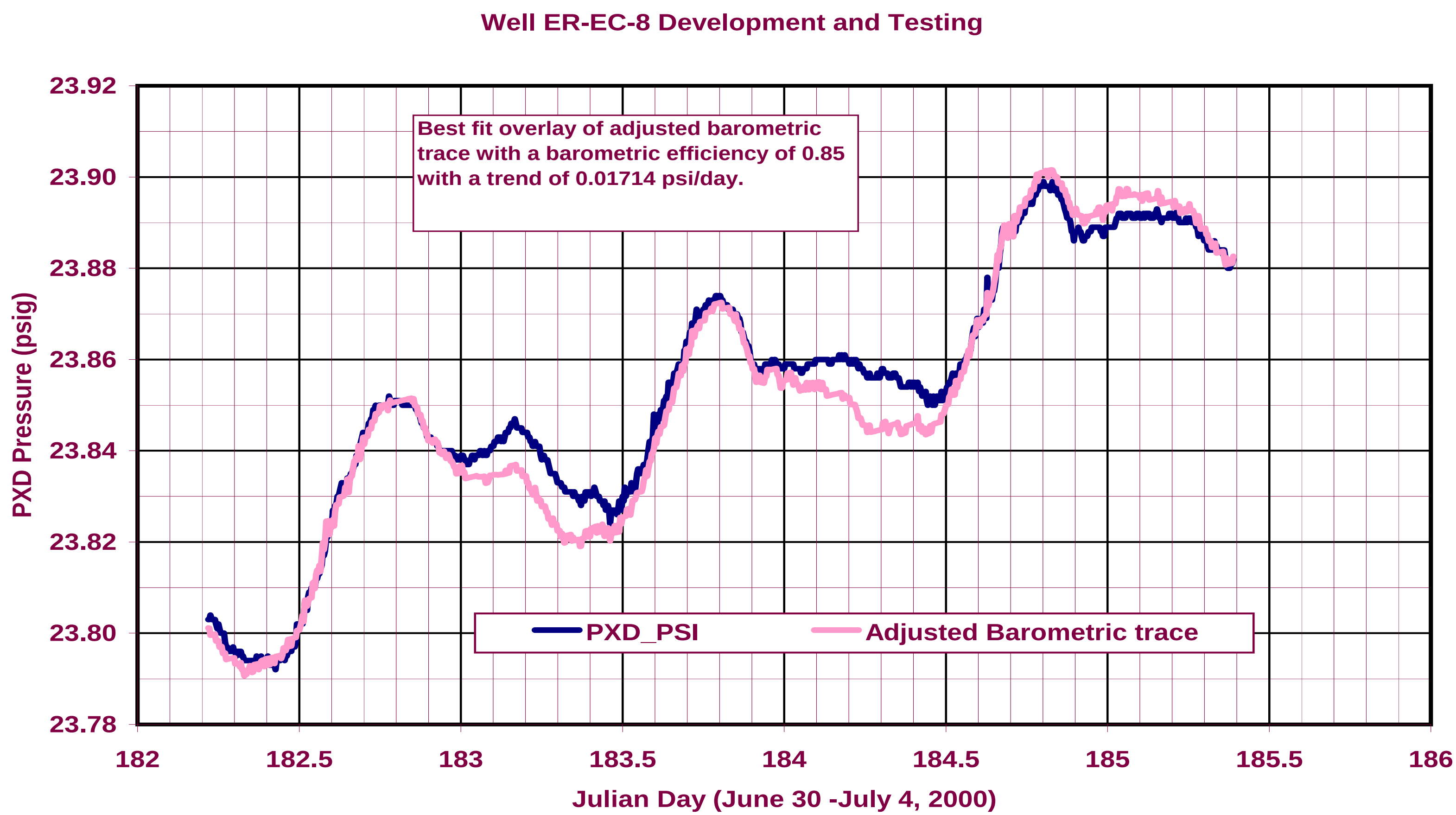

psi - Pounds per square inch
psig - Pounds per square inch gauge
PXD - Pressure transducer

**Figure A.3-6**
**Barometric Efficiency Overlay for Predevelopment Water Level Monitoring**



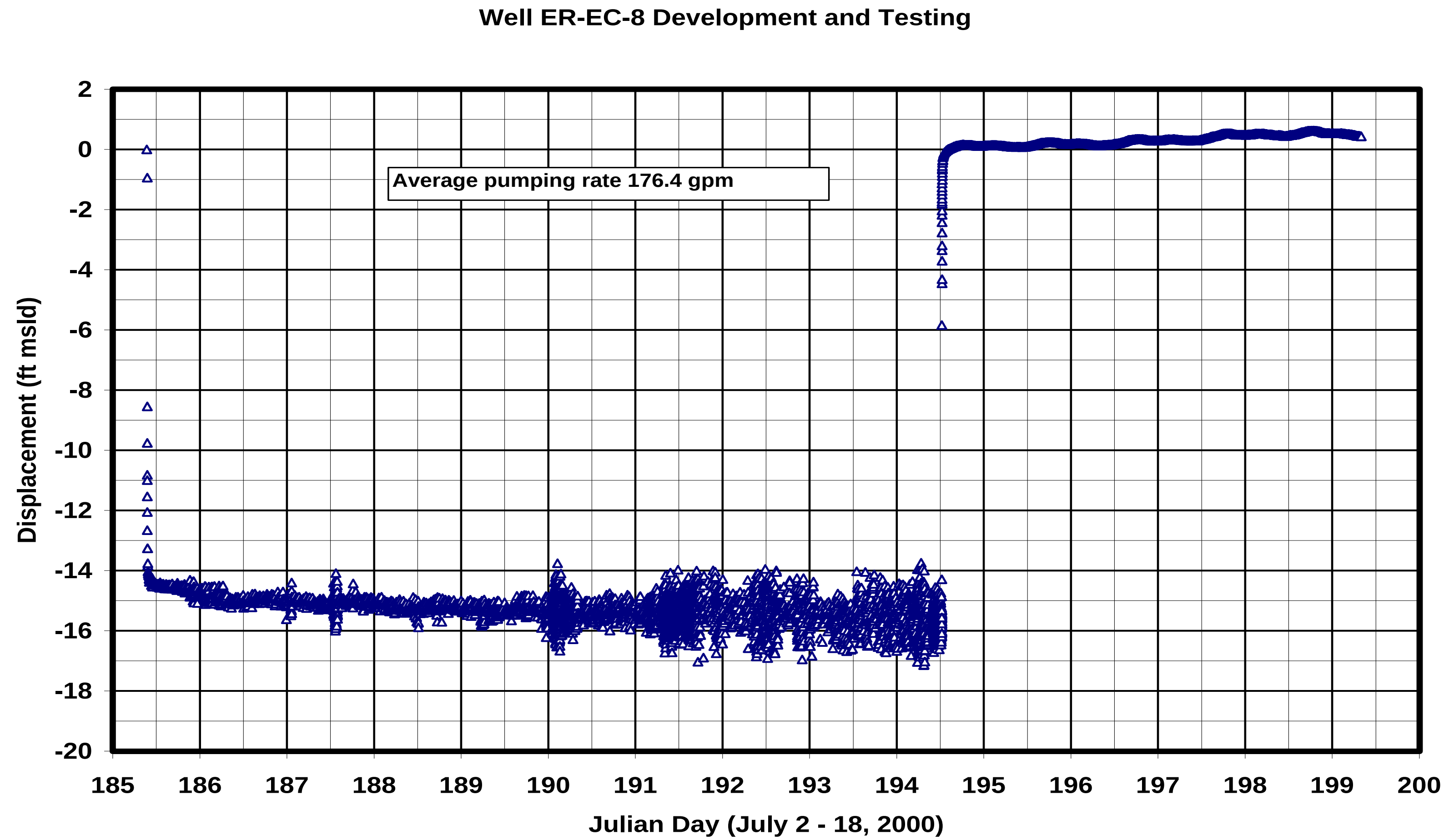

psi - Pounds per square inch
psig - Pounds per square inch gauge
PXD - Pressure transducer

**Figure A.3-7**
**Barometric Efficiency Overlay for Upper Interval Water Level Monitoring**



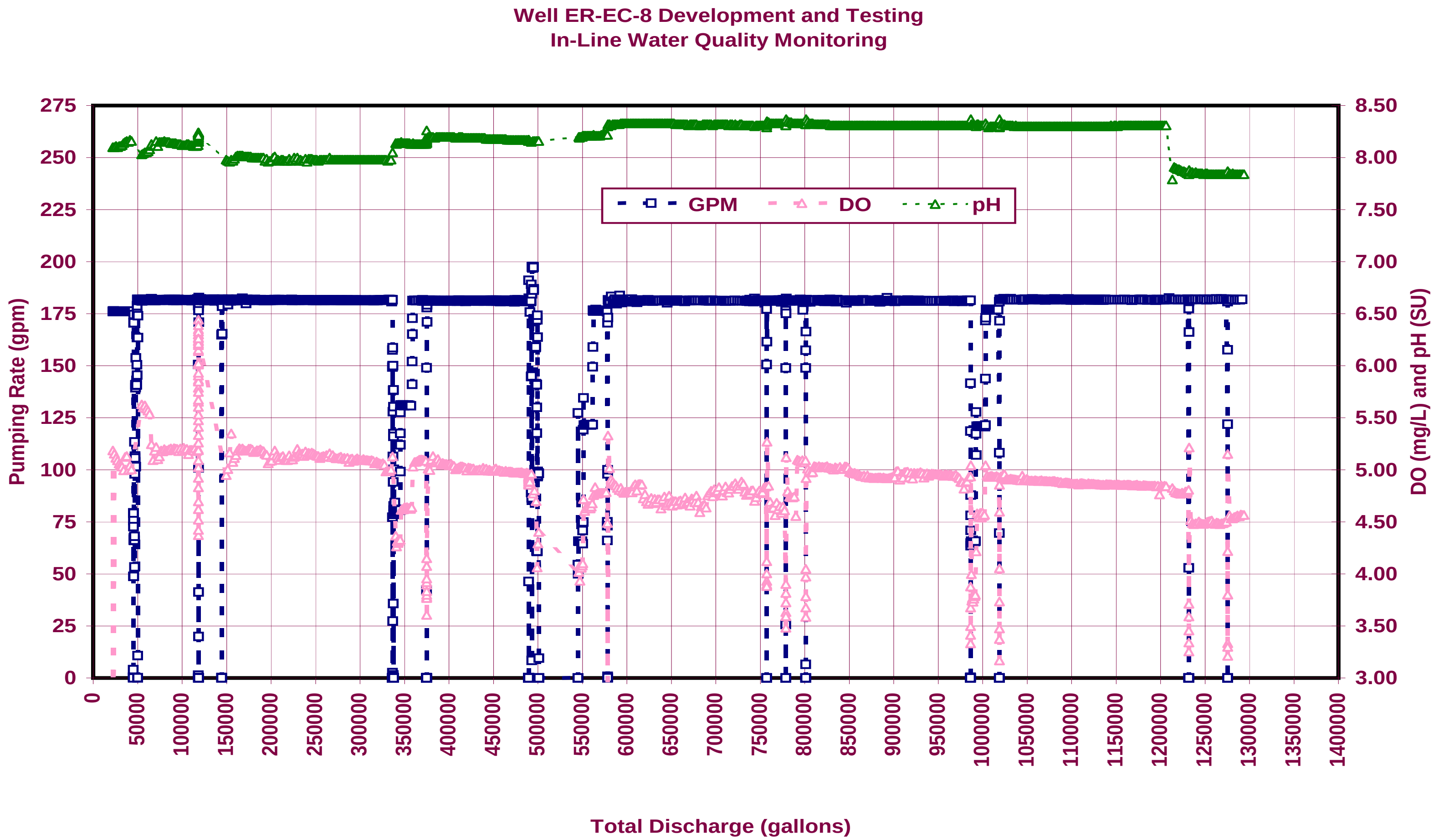

psig - Pounds per square inch gauge
PXD - Pressure transducer
psi - Pounds per square inch

**Figure A.3-8**
**Barometric Efficiency Overlay for the Constant-Rate Test**




ft msld - Feet above mean sea level datum
gpm - Gallons per minute

**Figure A.3-9**
**Constant-Rate Pumping Test with Barometric Correction**




DO - Dissolved Oxygen
gpm - Gallons per minute (from magnetic flowmeter)
mg/L - Milligrams per liter
SU - Standard Units

**Figure A.3-10**
**pH and DO Versus Pumping Rate**

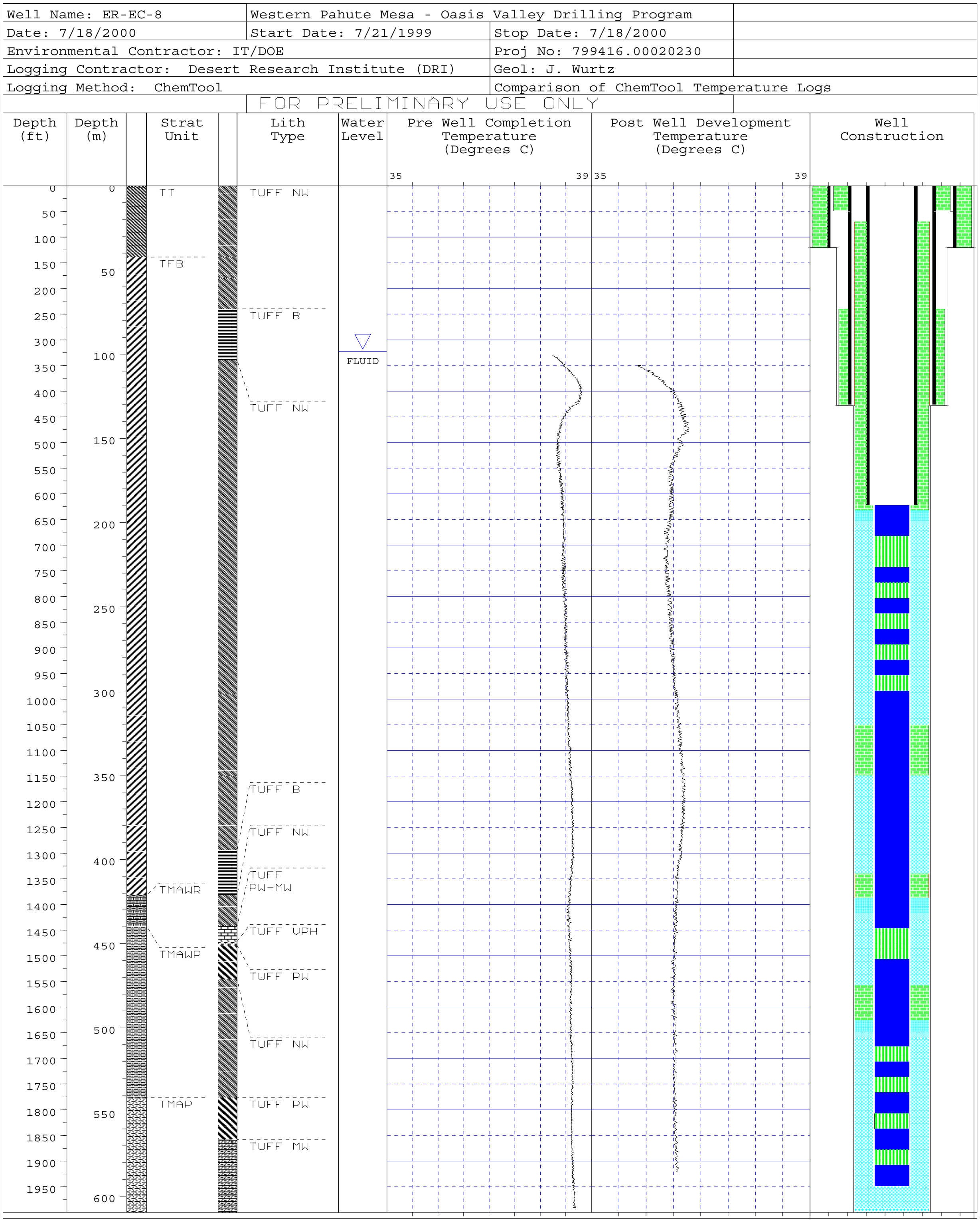



**Figure A.3-11**
**Temperature Log Prior to Completion Versus Postdevelopment**

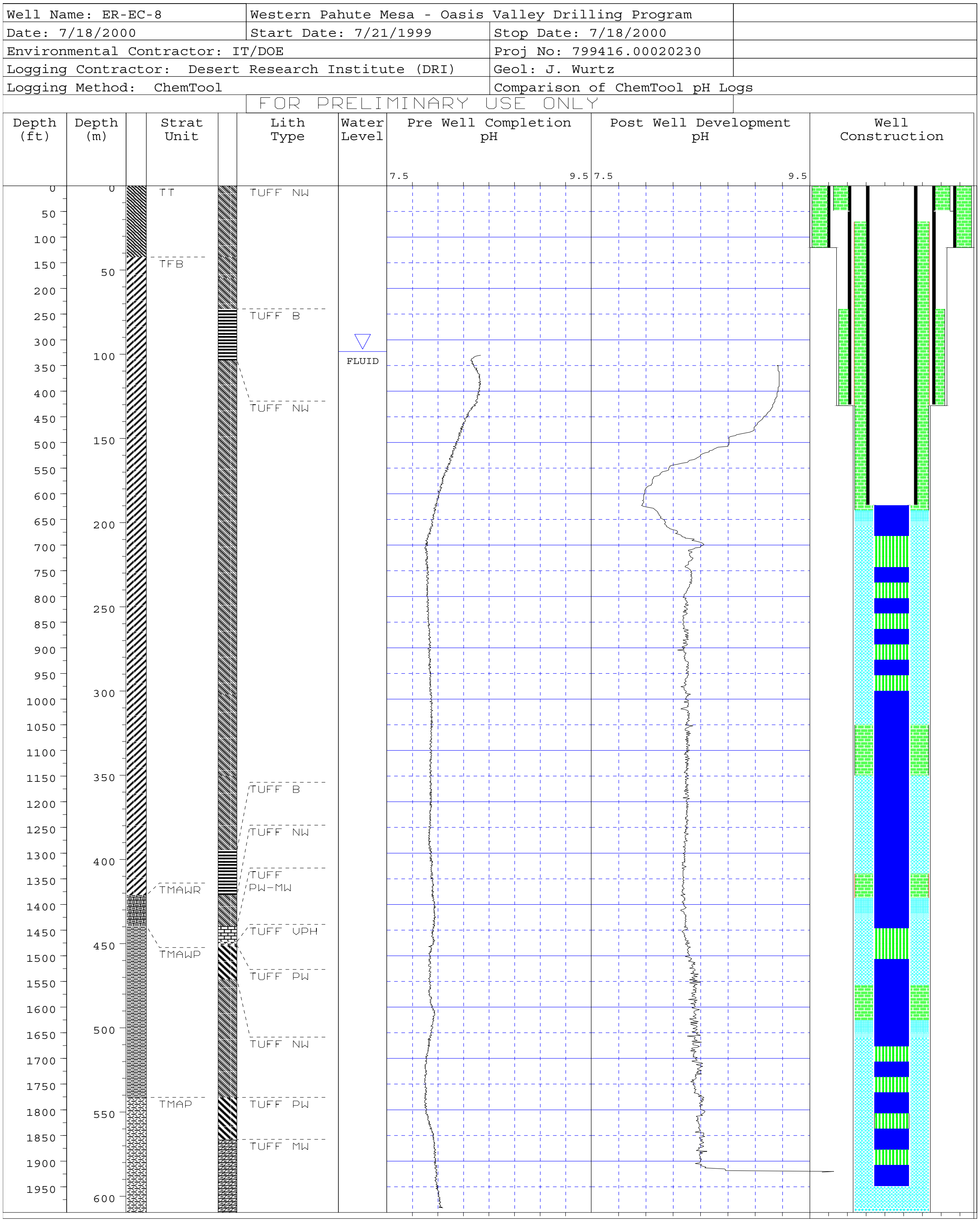
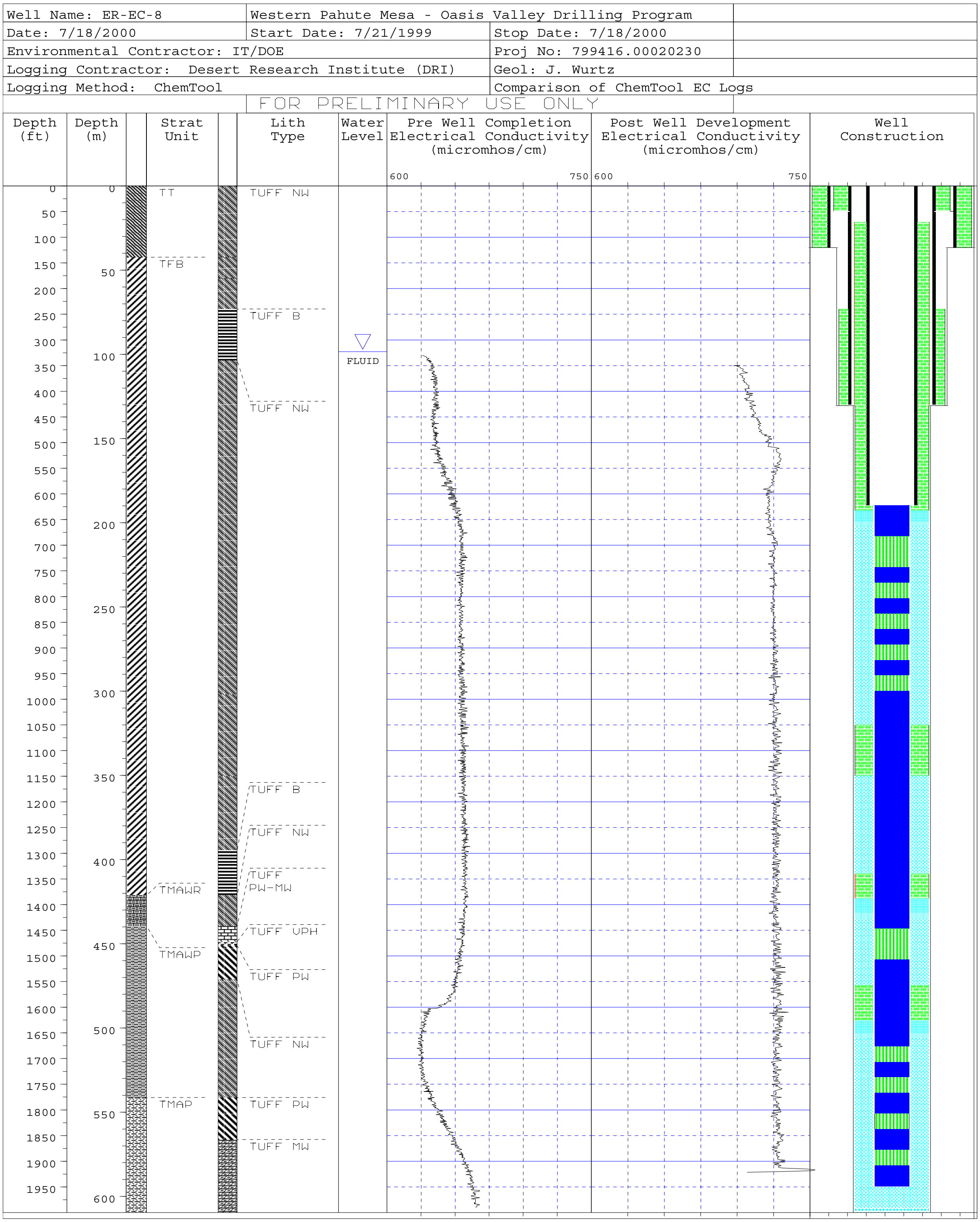



**Figure A.3-12**
**pH Log Prior to Completion Versus Postdevelopment**




## Figure A.3-13
## EC Log Prior to Completion Versus Postdevelopment

# A.4.0 Environmental Compliance

## A.4.1 Fluid Management

All fluids produced during well development and hydraulic testing activities were managed according to the *Fluid Management Plan for the Underground Test Area Subproject* (FMP) (DOE/NV, 1999) and associated state-approved waivers. In accordance with the FMP and the waivers, the fluids produced during drilling were monitored and tested for tritium and lead daily. Several samples of water were collected from the sumps and analyzed at a certified laboratory for total and dissolved metals, gross alpha/beta, and tritium. Based on this process knowledge, the Nevada Operations Office requested a waiver for the disposal of fluids produced during well development/hydraulic testing for Wells ER-EC-1, ER-EC-4, ER-EC-5, ER-EC-6, ER-EC-7, ER-EC-8, and ER-18-2. The Nevada Operations Office's proposal was to conduct activities at these well sites under far-field conditions with a reduced frequency of on-site monitoring. In October 1999, the Nevada Division of Environmental Protection (NDEP) granted the Nevada Operations Office a waiver to discharge fluids directly to the ground surface during well development (NDEP, 1999), testing, and sampling at the above wells. The waiver (provided in Attachment 4) was granted under the mandate that the following conditions were satisfied:

- The only fluids allowed to be discharged to the surface are waters from the wells.
- Fluids will be allowed to be discharged to the ground surface without prior notification to NDEP.
- Waters that are heavily laden with sediments need to be discharged to the unlined, noncontaminated basins to allow the sediments to settle out before being discharged to the land surface.
- One tritium and one lead sample from the fluid discharge will be collected every 24 hours for analysis.
- Additional sampling and testing for lead must be conducted at 1 hour, and then within 8 to 12 hours after the initial pumping begins at each location. If the field-testing results indicate nondetects for lead (less than 50 μg/L), then the sampling may be conducted every 24 hours. If the field testing indicates detectable quantities less then 75 μg/L (5 times the *Nevada Drinking Water Standards* [NDWS]), then sampling must occur every

12 hours until two consecutive nondetects occur. Sampling and testing may then resume on the 24-hour schedule.

- NDEP must be notified within 24 hours if any of the limits in the FMP are exceeded.

### A.4.1.1 Water Production and Disposition

At Well ER-EC-8, all fluids from the well development and testing were discharged into unlined Sump #1. Sump #2 was also unlined, but was not used during development and testing activities. Sump #1 serves as an infiltration basin and has an overflow pipe approximately 7.7 ft from the bottom. Discharge to the ground surface occurred after 516,700 gals had been pumped into Sump #1.

A total of approximately 3,872,700 gals of groundwater were pumped from Well ER-EC-8 during well development, hydraulic testing, and sampling activities. The total is composed of 1,555,400 gals during well development and 2,317,300 gals produced during constant-rate pumping. Table A.4-1 shows the Fluid Disposition Reporting Form for the testing program.

### A.4.1.2 Lead and Tritium Monitoring

Lead and tritium samples were collected daily according to the FMP and waivers. Lead analysis was conducted on site in the field laboratory using a HACH DR 100 Colorimeter according to DOP ITLV-UGTA-310, "Field Screening for Lead in Well Effluent." A tritium sample was collected daily at the sample port of the wellhead. The sample was kept in a locked storage until transported to the BN Site Monitoring Service at the Control Point in Area 6. The sample was analyzed using a liquid scintillation counter.

The NDWS were not exceeded at any time. The highest lead result was 2.0 μg/L and highest tritium activity was 513 picocuries per liter (pCi/L). The complete results of lead and tritium monitoring are presented in Table A.4-2.

### A.4.1.3 Fluid Management Plan Sampling

A fluid management sample was collected from the active unlined sump at the end of well development and testing activities to confirm on-site monitoring of well effluent. The sample was collected, along with an equipment rinsate sample, on July 12, 2000, and sent to Paragon. The FMP parameters of total and dissolved metals, gross alpha and beta, and tritium were requested for analysis. The laboratory results are presented in Table A.4-3 and compared to the NDWS.

**Table A.4-1**
**Fluid Disposition Reporting Form**

| | | | |
|---|---|---|---|
| **Site Identification:** | ER-EC-8 | **Report Date:** | August 16, 2000 |
| **Site Location:** | Nellis Air Force Range | **DOE/NV Subproject Manager:** | Bob Bangerter |
| **Site Coordinates:** | N 4,106,340.7; E 532,675.8 (UTM Zone 11, NAD 83, meters) | **IT Project Manager:** | Janet Wille |
| **Well Classification:** | ER | **IT Site Representative:** | Jeff Wurtz |
| **IT Project No.:** | 799416.00020230 | **IT Environmental Specialist:** | Patty Gallo/Mike Monahan |

| Well Construction Activity | Activity Duration | | #Ops. Days[a] | Well Depth (m) | Import Fluid (m³) | Sump #1 Volumes (m³) | | Sump #2 Volumes (m³) | | Volume of Infiltration Area (m³)[c] | Other[d] (m³) | Fluid Quality Objectives Met? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | From | To | | | | Solids[b] | Liquids | Solids | Liquids | Liquids | | |
| **Phase I:** Vadose-Zone Drilling | 7/15/99 | 7/15/99 | 1 | 98.5 | 1,430 | 14.4 | 10.8 | N/A | N/A | 10.8 | N/A | YES |
| **Phase I:** Saturated-Zone Drilling | 7/15/99 | 7/21/99 | 6 | 609.6 | 2,340 | 48.3 | 12,115 | 16 | 2,111 | 14,226 | N/A | YES |
| **Phase II:** Initial Well Development | 6/14/00 | 6/30/00 | 11 | 609.6 | N/A | N/A | 5,904 | N/A | N/A | 5,904 | N/A | YES |
| **Phase II:** Aquifer Testing | 7/03/00 | 7/12/00 | 10 | 609.6 | N/A | N/A | 8,754 | N/A | N/A | 8,683.7 | N/A | YES |
| **Phase II:** Final Development | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Cumulative Production Totals to Date:** | | | 28 | 609.6 | 3,770 | 62.7 | 26,773 | 16 | 2,111 | 28,824.5 | N/A | YES |

[a] Operational days refer to the number of days that fluids were produced during at least part (>3 hours) of one shift.
[b] Solids volume estimates include calculated added volume attributed to rock bulking factor.
[c] Ground surface discharge and infiltration within the unlined sumps.
[d] Other refers to fluid conveyance to other fluid management locations or facilities away from the well site, such as vacuum truck transport to another well site.

N/A = Not Applicable; m = Meters; m³ = Cubic meters;

Total Facility Capacities: Sump #1 (at height of 7.7 ft) = 1,201.3 m³ Sump #2(at height of 9.8 ft) = 1,932.9 m³

Infiltration Area (assuming very low/no infiltration) = N/A m³

Remaining Facility Capacity (Approximate) as of 7/19/00: Sump #1 = 1,131 m³ (94.1%) Sump #2 = 1,932.9 m³ (100%)

Current Average Tritium = 89.5 pCi/L

Notes:

IT Authorizing Signature/Date: [signature] 8-17-00

**Table A.4-2**
**Results of Tritium and Lead Monitoring at ER-EC-8**

| Sampling Date | Sample Number | Lead Results[1] | Tritium Results[2a] |
|---|---|---|---|
| | | µg/L | pCi/L |
| 6/14/2000 | ER-EC8-061400-01 | 1.0 | 0 |
| 6/16/2000 | ER-EC8-061600-01 | <1.0 | 0 |
| 6/21/2000 | EC-8-062100-1 | 2.0 | 380.7 |
| 6/22/2000 | EC-8-062200-1 | 2.0 | 0 |
| 6/23/2000 | EC-8-062300-1 | 1.0 | 0 |
| 6/24/2000 | EC-8-062400-1 | 1.0 | 0 |
| 6/25/2000 | EC-8-062500-1 | 1.0 | 0 |
| 6/26/2000 | EC-8-062600-1 | 1.0 | 513.0 |
| 6/27/2000 | EC-8-062700-1 | 1.0 | 0 |
| 6/28/2000 | EC-8-062800-1 | 1.0 | 0 |
| 7/3/2000 | EC-8-070300-1 | 1.2 | 0 |
| 7/4/2000 | EC-8-070400-1 | 1.8 | 0 |
| 7/5/2000 | EC-8-070500-1 | 0.8 | 0 |
| 7/6/2000 | EC-8-070600-1 | 0.9 | 0 |
| 7/7/2000 | EC-8-070700-1 | 1.0 | 167.4 |
| 7/8/2000 | EC-8-070800-1 | 1.5 | 184.3 |
| 7/9/2000 | EC-8-070900-1 | 1.0 | 141.6 |
| 7/10/2000 | EC-8-071000-1 | 1.0 | 276.2 |
| 7/11/2000 | EC-8-071100-1 | 1.0 | 126.0 |
| 7/12/2000 | EC-8-071200-1 | 1.0 | 0 |
| Nevada Drinking Water Standards: | | 15.0 | 20,000 |

1 - Lower detection limit 2 ppb.
2 - Lower detection limit 500 to 1,000 pCi/L, depending upon calibration.
[a]Analysis provided by Bechtel Nevada Site Monitoring Service at the CP in Area 6.

µg/L - Micrograms per liter
pCi/L - Picocuries per liter

## *A.4.2 Waste Management*

Wastes generated during well development and testing activities were managed in accordance with the *Underground Test Area Subproject Waste Management Plan* (DOE/NV, 1996); the *Waste Management Field Instructions for the Underground Test Area Subproject* (IT, 1997); SQP ITLV-0501, “Control of Hazardous Materials”; and SQP ITLV-0513, “Spill Management.” The following exceptions

**Table A.4-3**
**Analytical Results of Sump Fluid Management Plan Sample at Well ER-EC-8**

| Analyte | CRDL | Laboratory | NDWS | Results of Sump Composite Sample # EC-8-071200-3 (F) | |
|---|---|---|---|---|---|
| **Metals (mg/L)** | | | | | |
| | | | | **Total** | **Dissolved** |
| Arsenic | 0.01 | Paragon | 0.05 | 0.012 | B 0.0079 |
| Barium | 0.2 | Paragon | 2.0 | B 0.0019 | B 0.0006 |
| Cadmium | 0.005 | Paragon | 0.005 | U 0.005 | U 0.005 |
| Chromium | 0.01 | Paragon | 0.1 | B 0.00035 | B 0.00055 |
| Lead | 0.003 | Paragon | 0.015 | U 0.003 | U 0.003 |
| Selenium | 0.005 | Paragon | 0.05 | U 0.005 | U 0.005 |
| Silver | 0.01 | Paragon | 0.1 | U 0.01 | U 0.01 |
| Mercury | 0.0002 | Paragon | 0.002 | U 0.0002 | U 0.0002 |
| | | | | | |
| **Analyte** | **MDC** | **Laboratory** | **NDWS** | **Result** | **Error** |
| **Radiological Indicator Parameters-Level I (pCi/L)** | | | | | |
| Tritium | 270 | Paragon | 20,000 | U -90 | +/- 160 |
| Gross Alpha | 3.2 | Paragon | 15 | 9.4 | +/- 2.8 |
| Gross Beta | 4.0 | Paragon | 50 | 5.0 | +/- 2.6 |

B - Result was less than the CRDL, but greater than the instrument detection limit
U - Result not detected at the given minimum detectable limit or activity
CRDL - Contract-Required Detection Limit per Table 5-1, UGTA QAPP (DOE/NV, 1998)
MDC - Minimum Detectable Concentration, sample-specific
NDWS - *Nevada Drinking Water Standards*
mg/L - Milligrams per liter
pCi/L - Picocuries per liter

were added in the *Field Instructions for WPM-OV Well Development and Hydraulic Testing Operations* (IT, 1999b) because chemical and/or radiological contamination was not expected:

- Decontamination rinsate from laboratory and on-site equipment decontamination operations shall be disposed of with fluids in the on-site infiltration basin.

- All disposable sampling equipment and personal protective equipment shall be disposed of as sanitary waste and may be placed directly in on-site receptacles.

As a result of well development and testing activities, two types of waste were generated in addition to normal sanitary waste and decontamination water:

- Hydrocarbon: Two drums of hydrocarbon waste were produced containing stained absorbant pads (from pump oil, hydraulic fluid and diesel), soil, and debris.

- Hazardous Waste: Approximately 2 gallons of solid hazardous waste was generated from the installation of bridge plugs/packers. This material consists of combustion by-products. The waste was stored in a Satellite Accumulation Area at the ER-EC-8 well site. Monthly inspections were conducted of this area until the waste was transported off site for disposal.

Hydrocarbon and sanitary waste was disposed of by BN Waste Management after the well development operations at the Nellis Air Force Range were completed. The hazardous waste from each well site was removed and disposed of by Safety-Kleen Corporation.

# A.5.0 References

DOE/NV, see U.S. Department of Energy, Nevada Operations Office.

IT, see IT Corporation.

IT Corporation. 1997. *Waste Management Field Instructions for the Underground Test Area Subproject*. Las Vegas, NV.

IT Corporation. 1999a. *Detailed Operating Procedures Underground Test Area Operable Unit*. Las Vegas, NV.

IT Corporation. 1999b. *Field Instructions for Western Pahute Mesa - Oasis Valley Well Development and Hydraulic Testing Operations,* Rev. 0. Las Vegas, NV.

IT Corporation. 1999c. *Site-Specific Health and Safety Plan for Development, Testing and Sampling of Clean Wells*. Las Vegas, NV.

IT Corporation. 1999d. *Well Development and Hydraulic Testing Plan for Western Pahute Mesa - Oasis Valley Wells,* Rev. 0. Las Vegas, NV.

IT Corporation. 2000. *ITLV Standard Quality Practices Manual*, Vols. 1 and 2, March. Las Vegas, NV.

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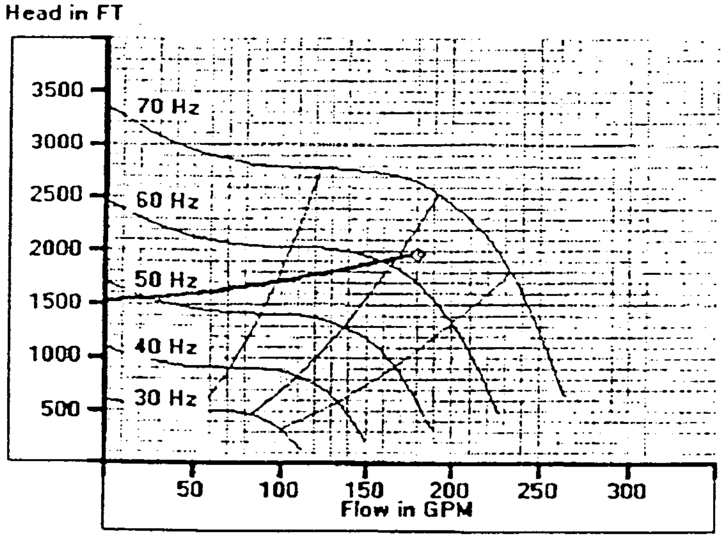
# Attachment 1

# Manufacturer's Pump Specifications

# High-Capacity Testing Pump

60-180 G.P.M. OPERATION
AT 500 FT PUMP SETTING DEPTH (600 PSI tubing pressure)

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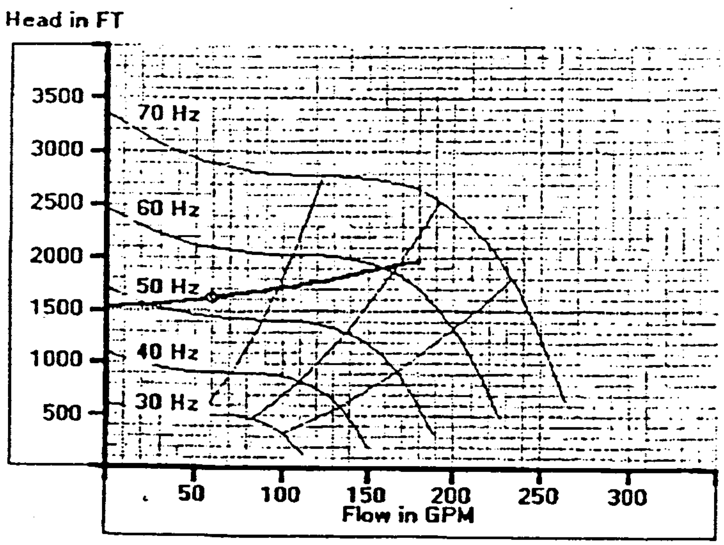


| | | | | | |
|---|---|---|---|---|---|
| Frequency | Hz | 50 | 55 | 60 | 65 |
| Flow at Stock Tank | GPM | 23.67 | 93 | 150 | 181 |
| Pump Intake Pressure | psi | 365 | 327 | 295 | 279 |
| Total Dynamic Head | FT | 1555 | 1702 | 1873 | 1980 |
| Fluid speed by motor | ft/sec | 0.284 | 1.115 | 1.804 | 2.166 |
| Motor Load | % | 34.19 | 56.27 | 78.79 | 93 |
| Motor Amps | A | 40.6 | 43.52 | 54.28 | 61.07 |
| Pump RPM | rpm | 2940 | 3224 | 3469 | 3719 |
| Surface KVA | kVA | 73.76 | 89.54 | 134 | 171 |

# BEST AVAILABLE COPY

**Centrilift - A Baker Hughes company**
(714) 893-8511 (800) 755-8976 (714) 892-9945 FAX (714) 397-0941 MOBILE
5421 Argosy Drive Huntington Beach, CA. 92649
Terry Fletcher- Sales Engineer E- Mail: Terry.Fletcher@Centrilift.com

October 10,1999

**Project:** Nevada Test Site
**Customer:** Bechtel Nevada
**Well:** Various
**Engineer:** Mr. Ken Ortego

**Pump:** 86-FC6000 [ 400Series]
**Seal:** DSFB3 [ 338Series]
**Motor:** DMF 130 HP 1490V 65 A [ 375Series]
**Cable:** #4 CPNR 3kV ,980ft
**Controller:** VSD 2250-VT 260kVA/ 480V/ 313A

60-180 GPM @ 500' pump setting depth, 53.1-65 Hz. operation (600 PSI tubing)
Slim-line design to accomodate production logging tools *NOTE: Motor ratings at 60Hz
7-5/8" casing internally coated for a drift of 6.83" i.d. * Note: Set VSD to 64.9 Hz

## Input Parameters:

**Fluid Properties:**
Oil Gravity = 20.0 °API
Water Cut = 100 %
SG water = 1.0 rel to H2O
SG gas = 0.8 rel to air
Sol GOR = 1.0 scf/STB
Prod GOR = 1.0 scf/STB
Bot Hole Temp = 120 °F
Surf Fluid Temp= 120 °F

**Gas Impurities:**
N2 = 0 %
H2S = 0 %
CO2 = 0 %

**Bubble Point Pressure**
Pb = 14.7psia

**Inflow Performance:**
Datum = 500ft
Perfs V. Depth = 2500ft
Datum Static P = 154psi
Test Flow = 6171BPD
Test Pressure = 64.94psi
PI = 63.05BPD/psi
IPR Method = Composite IPR

**Target:**
Pump Setting Depth (vertical) = 1000ft
Desired Flow = 6171BPD
Gas Sep Eff = 90%
Tbg Surf Press = 600psi
Csg Surf Press = 0psi

**Casing & Tubing:** Roughness = 0.0018 in

Casing ID (in) 6.969
Tubing ID (in) 2.441
Vertical Depth (ft) 3000
Measured Depth (ft) 3000

**Correlations PVT:**

**Dead Visc:** Beggs & Robinson
**Saturated Visc:** Beggs & Robinson
**UnderSaturated:** Vasquez & Beggs
**Gas Visc:** Lee

**Oil Compress:** Vasquez & Beggs
**Formation Vol:** Standings
**Z factor:** Hall & Yarborough
**Bubble Point P:** Standings

**Correlations Multiphase:**
**Tubing Flow:** Hagedorn & Brown
**Casing Flow:** Hagedorn & Brown

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5421 Argosy Drive Huntington Beach, CA. 92649
Terry Fletcher- Sales Engineer E- Mail: Terry.Fletcher@Centrilift.com

October 10,1999

## Operating Parameters / Selection:

**Design Point:**

| | | | |
|---|---|---|---|
| Desired flow (total) | = 6171 BPD | Frequency | = 64.9 Hz |
| % water | = 100.0 % | GOR into pump | = 1.0 scf/STB |
| % Gas into pump | = 0.0 %bs /0.0 % | TDH | = 1978 FT |

**Pump Selection:**

| | Intake | Discharge |
|---|---|---|
| Pressure | = 279 psi | 1125 psi |
| Flowrate | = 6252 BPD | 6237 BPD |
| Specific Gravity | = 0.987 rel-H2O | 0.989 rel-H2O |
| Viscosity | = 0.516Cp | 0.534Cp |

**Pump Selected:**
86 stages Type: FC6000 [ 400 Series]
Shaft HP at 64.9 Hz = 125 (33 %)
Required motor shaft HP at 60.0 Hz = 120

60-180 GPM @ 500' pump setting depth, 53.1-65 Hz. operation (600 PSI tubing)

**Seal Selection:**

Well angle at set depth = 0Deg from vertical
No sand present
Pump uses floater-type stages
Motor/Seal Oil type = CL4
Seal Selected : DSFB3 [ 338 Series]
Options : None

Oil temperature at thrust chamber = 194°F
Chamber Cap Used (Top to Bot)=
19% 21%
Thrust bearing load =52 %
Shaft load = 70 %

**Motor Selection:**

| | | | |
|---|---|---|---|
| Terminal Voltage | =1574.8 V | Fluid Speed | =2.158ft/s |
| Cable Current | =60.9 A | | |
| Load acc to N.P. | =92.3 % | Internal Temp | =161°F |
| Shaft Load | =48.6 % | Motor Selected: | DMF 130 HP 1490V 65 A [ 375Series] |
| | | Options : | None |

Slim-line design to accomodate production logging tools *NOTE: Motor ratings at 60Hz

**Cable Selection:**

| | | | |
|---|---|---|---|
| Surface Length | = 50.0ft | Wellhead Voltage | = 1609.4V |
| Tubing Length | = 980ft | Wellhead kVA | = 169.9kVA |
| MLE length | = 20.0ft | Voltage Drop | = 34.5V |
| Surface Temp | = 75°F | Cond Temp (main) | = 169°F |
| | | Temp Rating | = 205°F |

| Surface Cable | Main Cable | MLE Cable |
|---|---|---|
| #2 CTTF 3kV 50.0ft | #4 CPNR 3kV 980ft | #6 MLE-KLHTLP 5kV 20.0ft |

No comments

**Controller Selection:**

| | | | |
|---|---|---|---|
| Input kVA | = 134.7kVA | Voltage Input | = 480V |
| System kW | = 129.0kW | Max Well Head Volts | = 1609V |
| Max Ctrl Current | = 204.9A | Max Frequency | = 64.9Hz (7.40V/Hz) |
| Power Cost/kWH | = 0.05$/kW | Start Frequency | = 10.0Hz |
| Total Power Cost | = $4644/month | Step-up Trafo | = 3.361 ratio |
| | | Selected: VSD 2250-V | 260kVA/ 480V/ 313A |

NEMA 3 design (outdoor use)

— End of Report —

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5421 Argosy Drive Huntington Beach, CA. 92649
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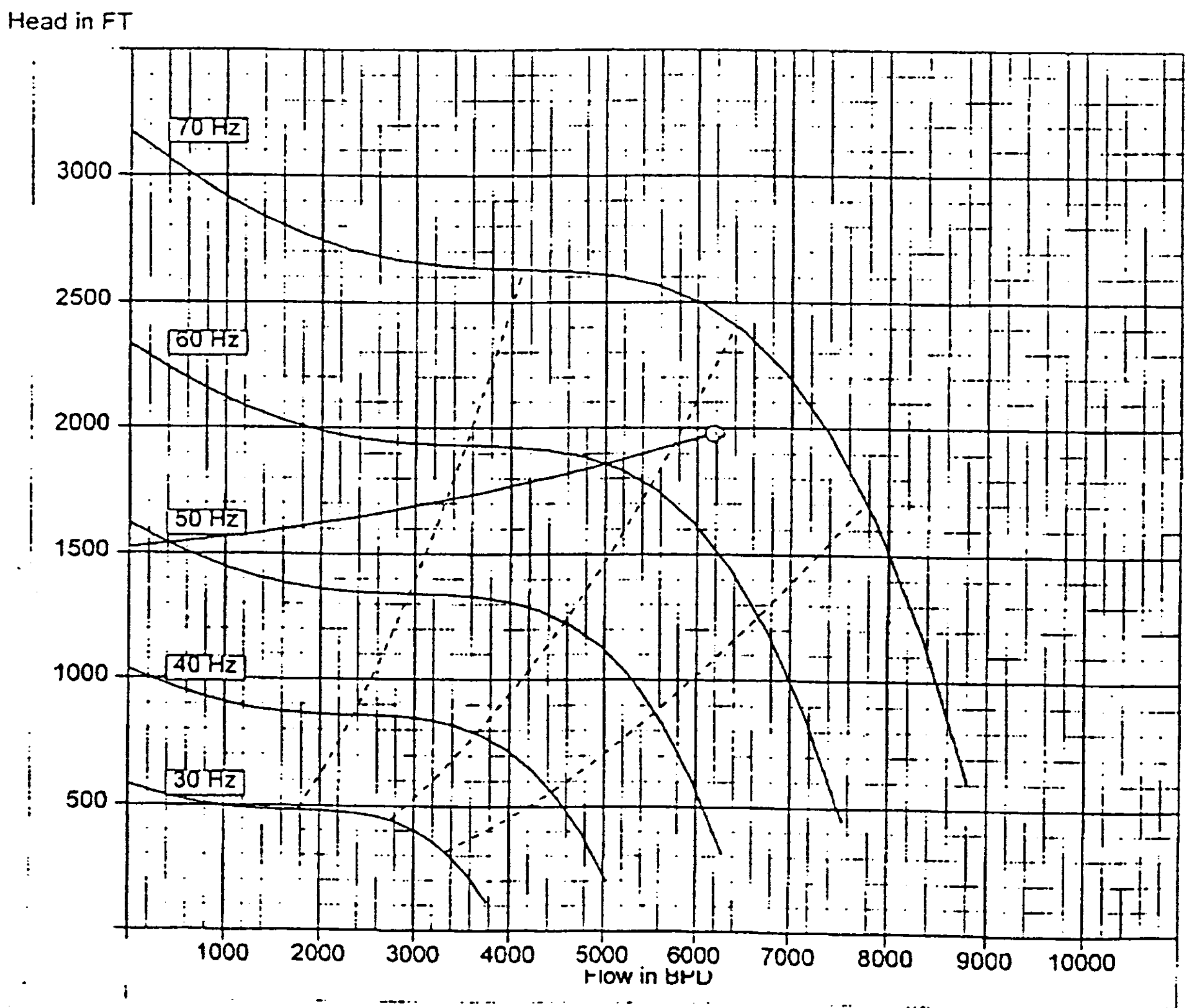
**Motor:** DMF 130 HP 1490V 65 A [ 375Series]
**Cable:** #4 CPNR 3kV ,980ft
**Controller:** VSD 2250-VT 260kVA/ 480V/ 313A

60-180 GPM @ 500' pump setting depth, 53.1-65 Hz. operation (600 PSI tubing)
Slim-line design to accomodate production logging tools *NOTE: Motor ratings at 60Hz
7-5/8" casing internally coated for a drift of 6.83" i.d. * Note: Set VSD to 64.9 Hz

**86-FC6000 Series: 400**

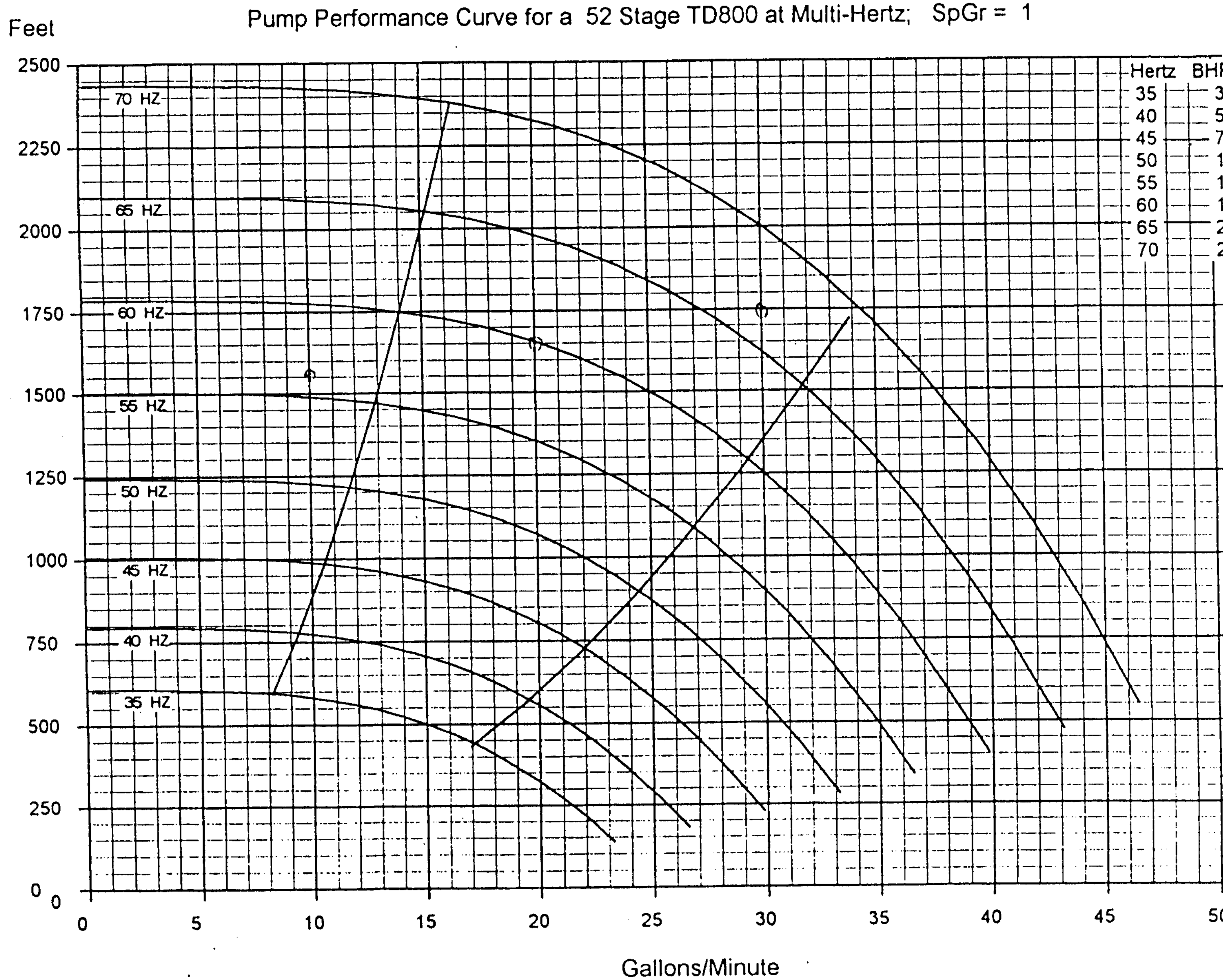


# Dedicated Sampling Pump

# Plot Program by Electric Submersible Pumps,Inc

4.00 ESP Pumps

Pump Performance Curve for a 52 Stage TD800 at Multi-Hertz; SpGr = 1




| Hertz | BHP | NPHP |
|---|---|---|
| 35 | 3.5 | 6 |
| 40 | 5.2 | 7.9 |
| 45 | 7.5 | 10 |
| 50 | 10.2 | 12.3 |
| 55 | 13.6 | 14.9 |
| 60 | 17.7 | 17.7 |
| 65 | 22.5 | 20.8 |
| 70 | 28.1 | 24.1 |

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Att-8

Attachment 1

Bechtel Nevada
Las Végas Nevada
Item Number 0002

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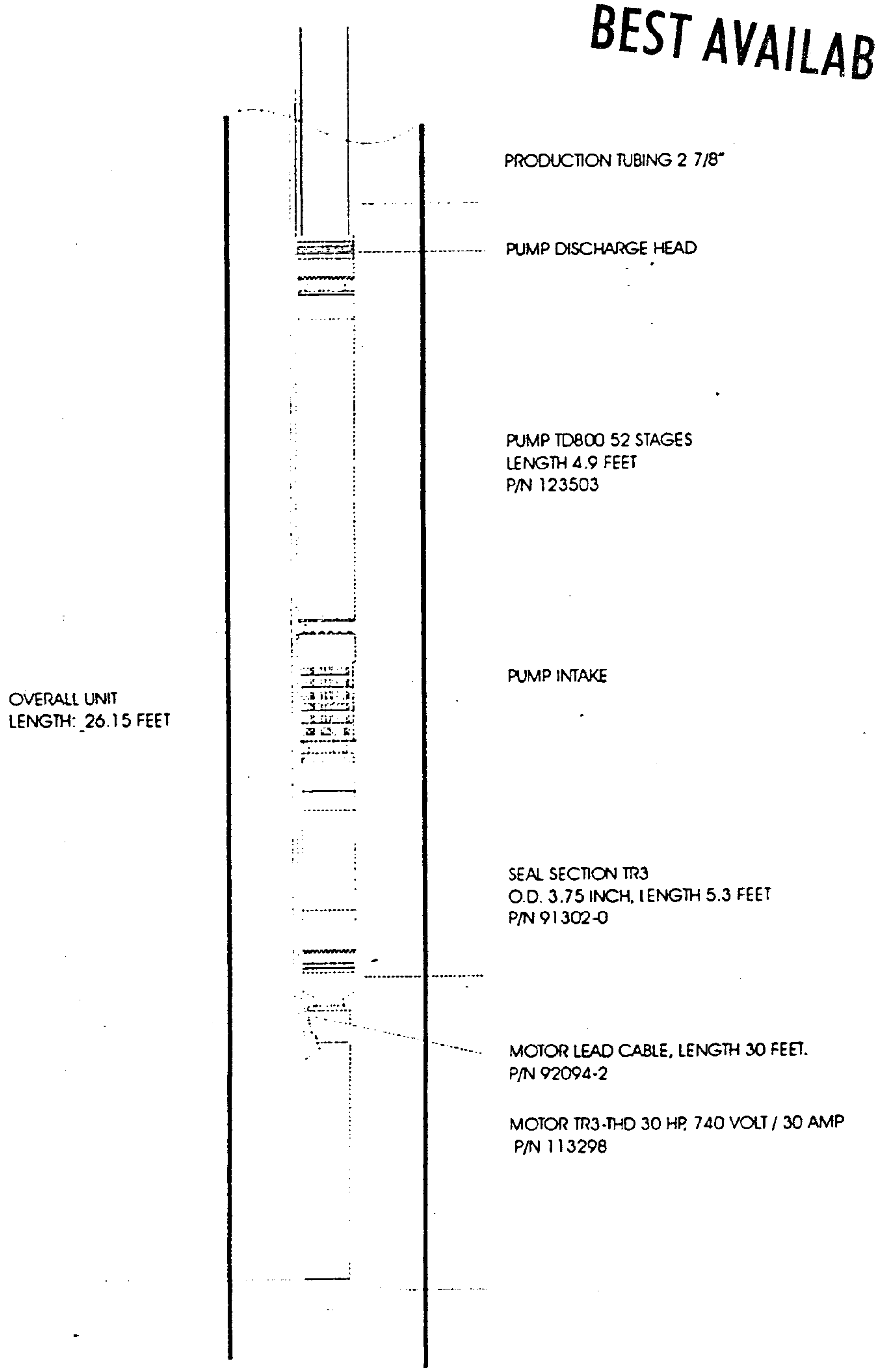

ESP

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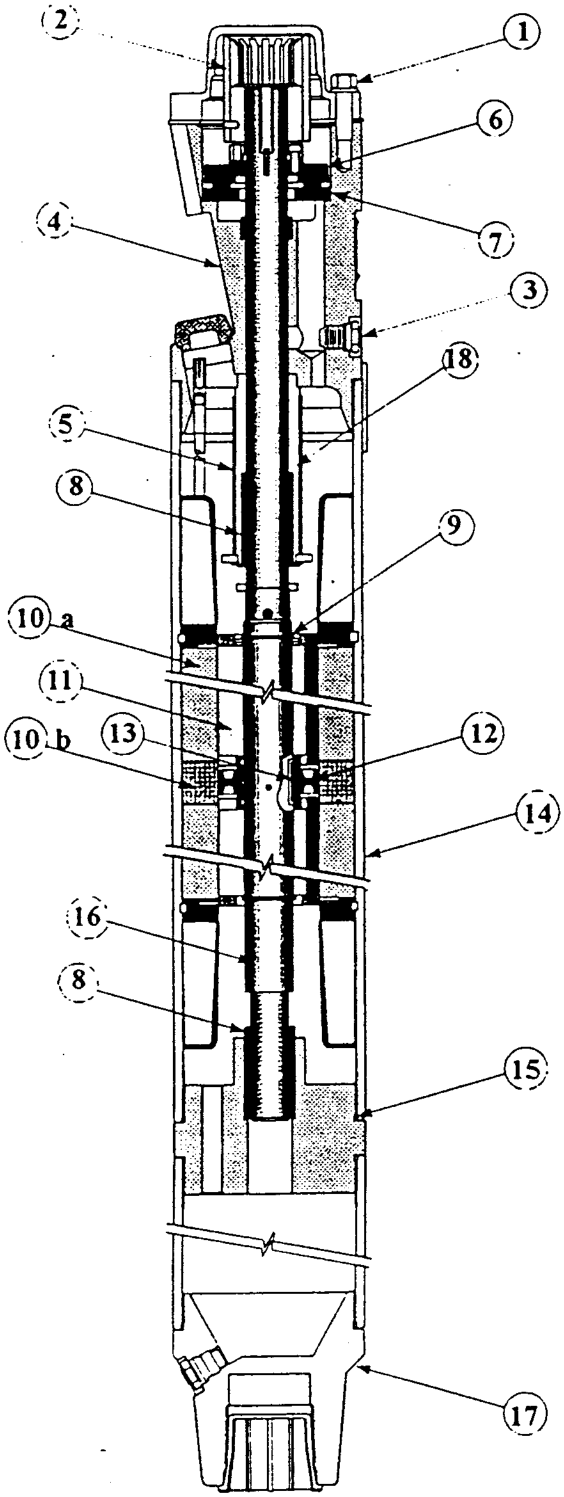
WOOD GROUP

# MOTOR, SINGLE 30HP, 740 V 30A




## PARTS LIST

| ITEM | DESCRIPTION / MATERIAL |
|---|---|
| 1 | Unit Bolts<br>Monel K500, UNS N05500 |
| 2 | Coupling<br>Steel 1042, ASTM 576 |
| 3 | Vent Plugs<br>Monel K500 |
| 4 | Head<br>Steel 1042, ASTM 576 |
| 5 | Lead Guard<br>Synthane |
| 6 | Thrust Runner<br>Steel, C1117 |
| 7 | Thrust Bearing<br>Bronze, SAE 660 MP-481 |
| 8 | Bushings<br>Bronze 660 |
| 9 | Snap Rings<br>Beryllium Copper |
| 10 | Stator Laminations<br>a)Steel<br>b)Bronze,Silicon |
| 11 | Rotor Laminations<br>Steel |
| 12 | Rotor Bearing<br>Nitralloy |
| 13 | Rotor BearingSleeve<br>Bronze 660 |
| 14 | Stator Housing<br>Steel 1026, ASTM A513 |
| 15 | "O" Rings<br>Viton |
| 16 | Shaft<br>Steel 4130, ASTM A513, ASTM A519, UNS G41300 |
| 17 | Base<br>Steel 1042, ASTM 576 |
| 18 | Guide Tube<br>Steel 1020, ASTM A513,A519, UNS G10200 |

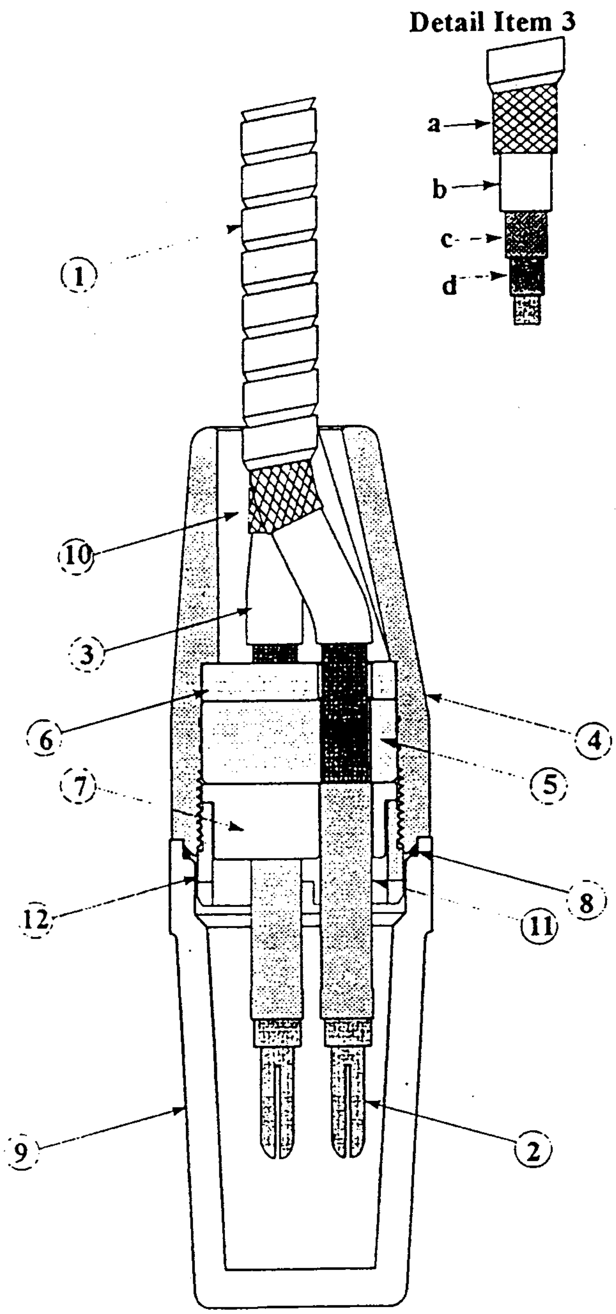
**O.D. - 3.75 INCH**
**LENGTH - 13.3FEET**
**WEIGHT -495 LBS**

materials\mtr,tr-sgl.cdr

QUALITY RUNS DEEP AT ESP

*New Release 15 May 1997*

# MLC, Tr3 KEOTB GALV.




## PARTS LIST

| ITEM | DESCRIPTION / MATERIAL |
|---|---|
| 1 | Cable, Flat<br>KEOTB Cable w/ Galv Armor |
| 2 | Terminal<br>Beryllium Copper MP1012 |
| 3 | Insulated Conductor<br>a) Nylon Braid<br>b) Lead Sheath<br>c) EPDM Insulation<br>d) Kapton Tape |
| 4 | Pothead Casting<br>Ni-Resist |
| 5 | Insulation Block<br>High Dielectric Hypalon |
| 6 | Wall, Upper<br>Epoxy Glass G10-11, MP1017-1018 |
| 7 | Wall, Lower<br>Aluminum 2014 |
| 8 | O-Ring<br>HSN 75 Duro |
| 9 | Shipping Cap<br>Ni-Resist |
| 10 | Filler<br>Epoxy, Thermoset |
| 11 | Tubing, Shrink<br>Teflon FEP |
| 12 | Nut, Compression<br>Steel 1042 ASTM 576 |

*materials\mlc.tr5-kelb-4kv.cdr*

QUALITY RUNS DEEP AT ESP

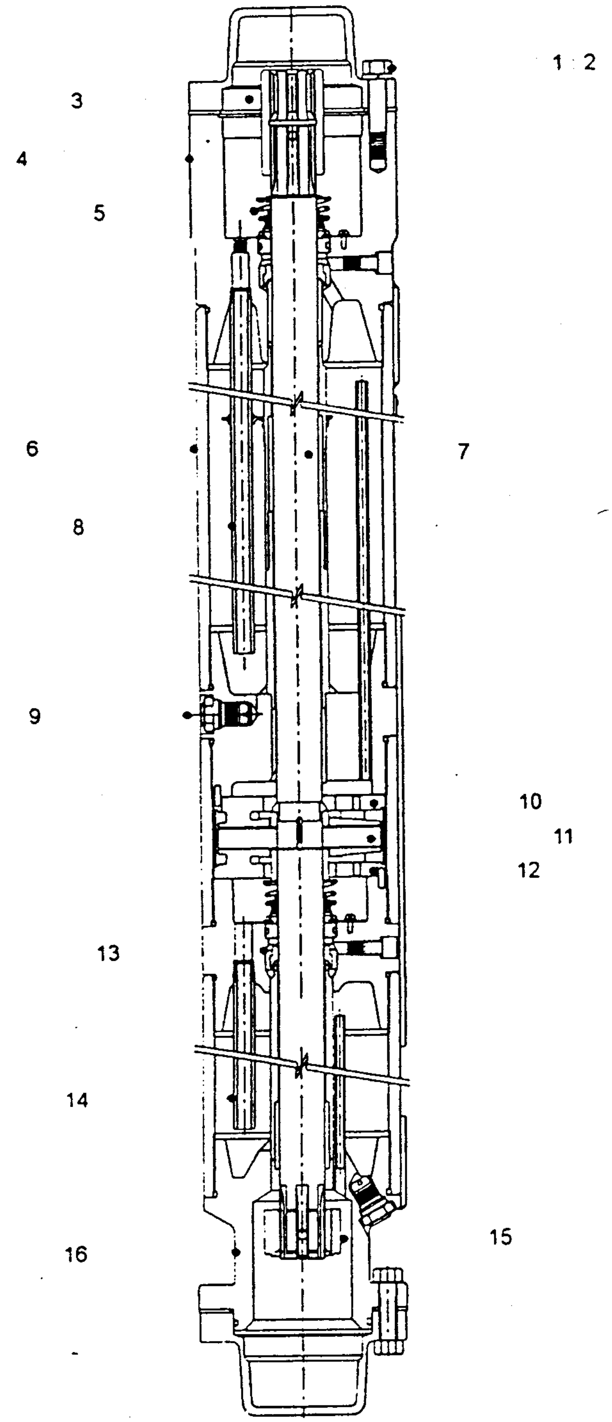
*New Release 27 May 1997*

ESP

**BEST AVAILABLE COPY**

# Standard Seal

WG WOOD GROUP




PARTS LIST

| ITEM | DESCRIPTION |
|---|---|
| 1 | Screw, Hex Head - Monel |
| 2 | Washer, Lock - Monel |
| 3 | Coupling - Monel |
| 4 | Head, Seal |
| 5 | Seal, Mechanical |
| 6 | Housing |
| 7 | Shaft |
| 8 | Breather Tube |
| 9 | Valve, Drain/Fill |
| 10 | Bearing, Up-Thrust |
| 11 | Runner, Thrust |
| 12 | Bearing, Down-Thrust |
| 13 | Water Shedder |
| 14 | Breather Tube |
| 15 | Coupling Adapter |
| 16 | Base |

TYPE TR3
3.75 O.D.
5.3 FT.
Shaft Dia. 1"
Shaft Nitronic 50
Weight 125 lbs.

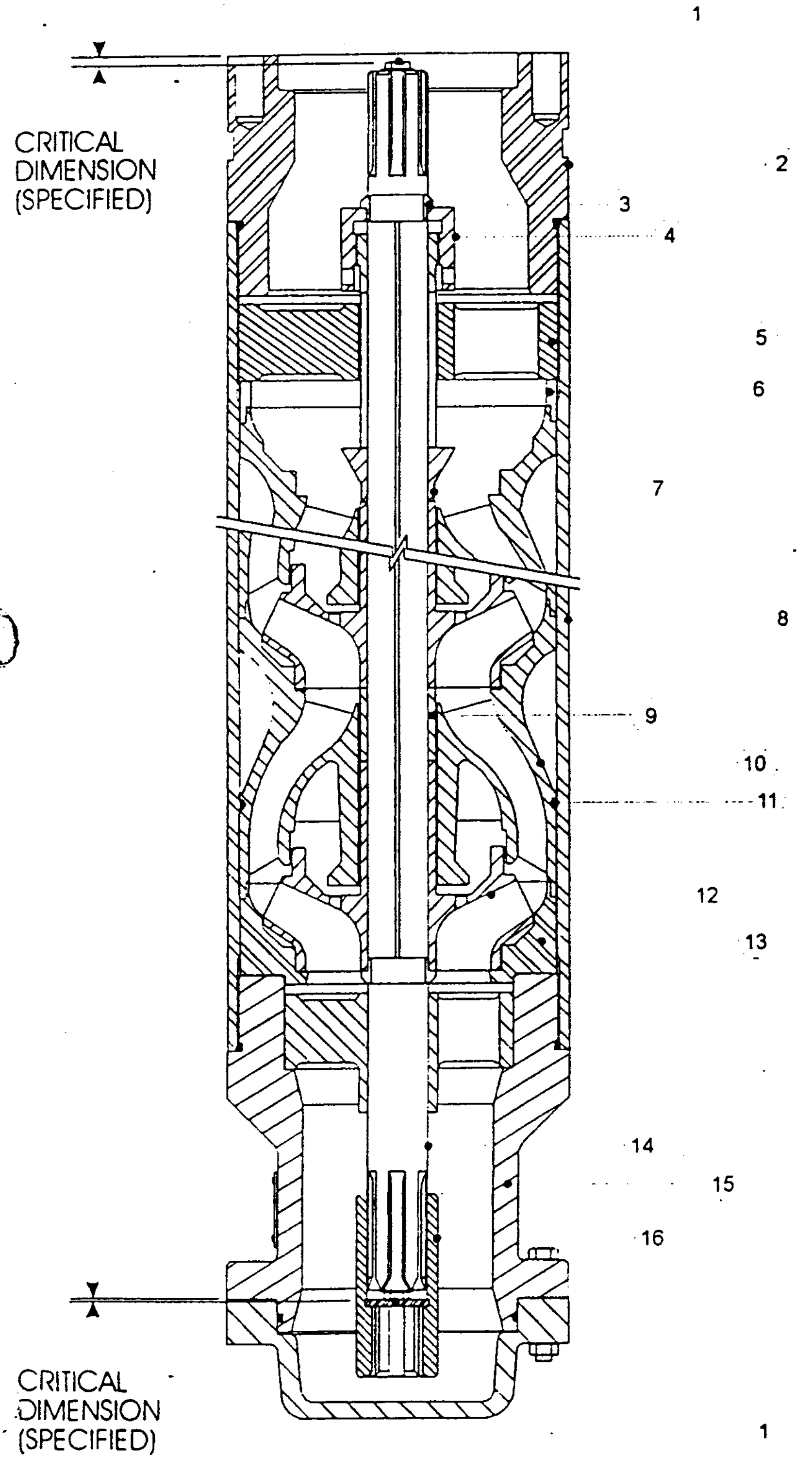
*tr-std.cdr*

ESP

# Standard Pump (Floater Stage Design)

BEST AVAILABLE COPY

WOOD GROUP




PARTS LIST

| ITEM | DESCRIPTION |
|---|---|
| 1 | Adj. Nuts & Shims |
| 2 | Head, TDM |
| 3 | Two Piece Ring |
| 4 | Compression Nut, Sleeve & Set Screw |
| 5 | Compression Bearing |
| 6 | Compression Tube |
| 7 | Fluid Director |
| 8 | Housing |
| 9 | Spacer - Impeller |
| 10 | Diffuser |
| 11 | O'Ring, Diffuser |
| 12 | Impeller |
| 13 | Lower Diffuser |
| 14 | Shaft |
| 15 | Base, TDM S/A |
| 16 | Coupling |

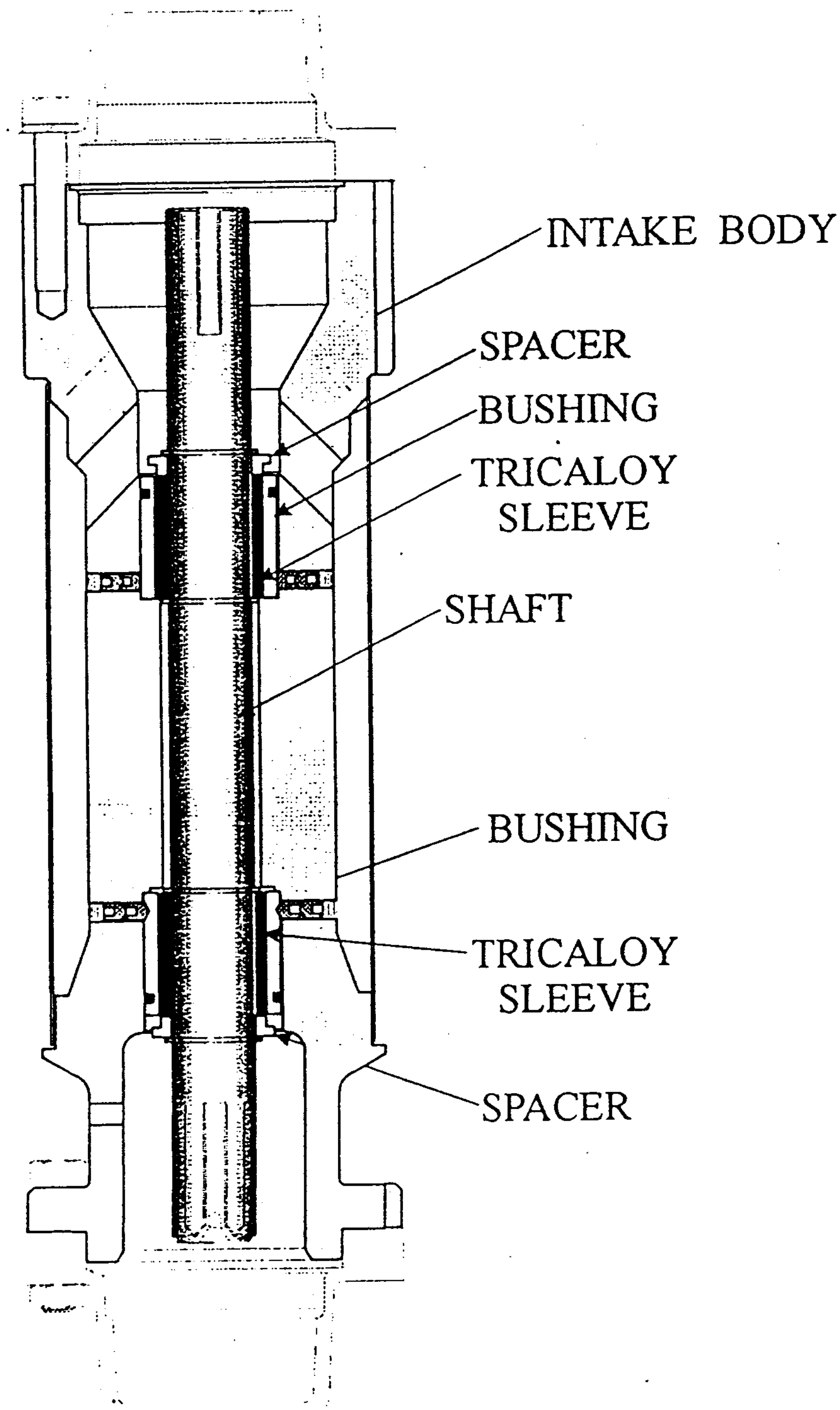
TD800
51STAGE
3.87O.D.
4.9 FT
2 3 /8 8RD DISCHARGE
BOLT ON INTAKE

cmp-mix.cdr

# 3.87 INTAKE






INTAKE BODY
SPACER
BUSHING
TRICALOY SLEEVE
SHAFT
BUSHING
TRICALOY SLEEVE
SPACER

# Attachment 2

# Water Quality Monitoring - Grab Sample Results

**Table ATT.2-1**
**Water Quality Monitoring - Grab Sample Results for Well ER-EC-8**
(Page 1 of 5)

| Date | Time hr:min. | Temperature ° C | EC µmhos/cm | pH SU | DO mg/L | Turbidity NTUs | Bromide mg/L | Pumping Rate gpm | Total Discharge gallons | Comments/Phase of Development or Testing |
|---|---|---|---|---|---|---|---|---|---|---|
| 06/14/2000 | 20:20 | 37.8 | 649 | 7.71 | 5.69 | 2.67 | 0.413 | 179.5 | 13,943 | Conduct pump functionality testing, begin development |
| 06/16/2000 | 18:20 | 38.3 | 663 | 8.18 | 4.95 | 1.47 | 0.581 | 181.5 | 50,771 | Pump off from 11:30 on 6/15/00 to 16:40 on 6/16/00, new functionality test |
| 06/21/2000 | 11:50 | 37.4 | 669 | 8.00 | 4.02 | 1.63 | 0.639 | 181.6 | 123,949 | Pump off from 24:00 on 6/17/00 to 11:21 on 6/21/00 for repairs |
| 06/21/2000 | 14:40 | 37.4 | 676 | 7.99 | 4.01 | 4.39 | 0.463 | 181.6 | 145,887 | Pump off from 13:45 to 14:30 to cut/splice cable; restart development on 14:32 |
| 06/21/2000 | 16:40 | 37.1 | 649 | 8.12 | 5.07 | 0.79 | 0.488 | 181.6 | 167,688 | |
| 06/21/2000 | 18:40 | 37.4 | 627 | 8.08 | 5.05 | 1.06 | 0.412 | 181.6 | 189,477 | |
| 06/22/2000 | 8:00 | 37.0 | 631 | 8.05 | 5.59 | 0.36 | 0.666 | 181.7 | 334,665 | Step-drawdown testing at 80, 130, and 180 gpm |
| 06/22/2000 | 11:20 | 38.0 | 624 | 8.16 | 4.93 | 0.85 | 0.547 | 80.7 | 338,591 | |
| 06/22/2000 | 13:20 | 36.7 | 634 | 8.11 | 5.16 | 0.26 | 0.375 | 131.1 | 350,093 | |
| 06/22/2000 | 15:20 | 36.7 | 634 | 8.06 | 5.18 | 0.63 | 0.345 | 181.3 | 368,466 | |
| 06/23/2000 | 9:00 | 39.0 | 620 | 8.14 | 5.40 | 0.45 | 0.423 | 96.5 | 499,850 | Flowmeter tripped off between 4:04 and 8:00; back-pressure adjusted from 700 to 600 psi; functionality test done; pump off from 9:15 to 10:30 |
| 06/23/2000 | 11:00 | 38.3 | 620 | 8.12 | 4.24 | 0.28 | 0.423 | 66.3 | 547,234 | |
| 06/23/2000 | 13:00 | 37.8 | 616 | 8.04 | 5.20 | 0.28 | 0.342 | 121.8 | 558,586 | |
| 06/23/2000 | 15:07 | 38.0 | 625 | 8.05 | 4.80 | 0.30 | 0.351 | 65.7 | 578,329 | |
| 06/23/2000 | 17:00 | 37.7 | 613 | 8.01 | 5.21 | 0.28 | 0.340 | 181.2 | 593,020 | Pump overnight at 180 gpm |

## Table ATT.2-1
## Water Quality Monitoring - Grab Sample Results for Well ER-EC-8
(Page 2 of 5)

| Date | Time hr:min. | Temperature °C | EC µmhos/cm | pH SU | DO mg/L | Turbidity NTUs | Bromide mg/L | Pumping Rate gpm | Total Discharge gallons | Comments/Phase of Development or Testing |
|---|---|---|---|---|---|---|---|---|---|---|
| 06/24/2000 | 8:08 | 37.7 | 628 | 7.81 | 5.40 | 0.23 | 0.524 | 96.4 | 757,251 | Surging well today |
| 06/24/2000 | 10:00 | 37.7 | 600 | 7.95 | 5.06 | 0.24 | 0.470 | 181.3 | 768,241 | Pump off from 8:00 to 9:00 |
| 06/24/2000 | 13:00 | 37.9 | 616 | 7.99 | 5.40 | 0.24 | 0.421 | 181.5 | 789,897 | Pump off from 11:00 to 12:00 |
| 06/24/2000 | 16:00 | 37.9 | 620 | 8.01 | 5.52 | 0.25 | 0.424 | 181.4 | 812,289 | Pump off from 14:00 to 15:00 |
| 06/24/2000 | 18:00 | 37.8 | 624 | 8.04 | 5.48 | 0.21 | 0.403 | 181.3 | 834,044 | Pump overnight at 180 gpm |
| 06/25/2000 | 8:00 | 37.9 | 629 | 7.95 | 5.25 | 0.17 | 0.469 | 181.1 | 986,246 | |
| 06/25/2000 | 10:00 | 38.7 | 633 | 8.02 | 4.23 | 0.16 | 0.394 | 66.2 | 990,484 | Pump off from 8:00 to 9:00 for surging; begin first step of step-drawdown |
| 06/25/2000 | 12:00 | 37.9 | 633 | 8.07 | 5.10 | 0.17 | 0.375 | 121.5 | 1,003,276 | Second step of step-drawdown |
| 06/25/2000 | 15:00 | 37.7 | 626 | 8.06 | 5.15 | 0.23 | 0.383 | 182.0 | 1,024,281 | Third step of step-drawdown |
| 06/25/2000 | 17:00 | 38.0 | 626 | 8.02 | 5.21 | 0.17 | 0.402 | 181.8 | 1,046,095 | Pump overnight at 180 gpm |
| 06/26/2000 | 8:00 | 37.2 | 611 | 7.97 | 5.04 | 0.14 | 0.563 | 182.5 | 1,209,633 | |
| 06/26/2000 | 10:00 | 37.8 | 612 | 8.00 | 5.30 | 0.13 | 0.591 | 181.2 | 1,231,446 | |
| 06/26/2000 | 12:00 | 37.2 | 617 | 8.00 | 5.29 | 0.14 | 0.598 | 181.7 | 1,242,906 | Pump off from 10:00 to 11:00 for surging |
| 06/26/2000 | 14:00 | 38.2 | 607 | 7.86 | 5.17 | 0.13 | 0.572 | 182.0 | 1,264,728 | |
| 06/26/2000 | 17:00 | 38.1 | 610 | 7.98 | 5.18 | 0.16 | 0.581 | 181.9 | 1,286,421 | Pump off from 15:00 to 16:00 for surging; pump overnight |
| 06/28/2000 | 8:00 | 37.7 | 608 | 7.86 | 5.26 | 1.03 | 0.619 | 125.9 | 1,495,970 | Flow logging by DRI starting on 6/27/00 and discreet bailer sampling |
| 06/28/2000 | 11:00 | 38.6 | 605 | 7.90 | 4.39 | 1.09 | 0.559 | 65.7 | 1,518,064 | |
| 06/28/2000 | 13:00 | 38.6 | 608 | 7.96 | 4.52 | 1.78 | 0.543 | 65.8 | 1,525,601 | |
| 06/28/2000 | 15:00 | 37.7 | 602 | 7.86 | 5.42 | 0.91 | 0.533 | 177.2 | 1,543,818 | |
| 06/28/2000 | 15:40 | 32.6 | 581 | 8.78 | - - - | 10.13 | 0.524 | 176.9 | 1,550,886 | Bailer sample from lower completion zone |

**Table ATT.2-1**
**Water Quality Monitoring - Grab Sample Results for Well ER-EC-8**
(Page 3 of 5)

| Date | Time hr:min. | Temperature °C | EC µmhos/cm | pH SU | DO mg/L | Turbidity NTUs | Bromide mg/L | Pumping Rate gpm | Total Discharge gallons | Comments/Phase of Development or Testing |
|---|---|---|---|---|---|---|---|---|---|---|
| 06/28/2000 | 17:00 | 38.1 | 604 | 7.99 | 5.30 | 0.62 | 0.537 | 180.8 | 1,555,372 | DRI installs check valve |
| 07/03/2000 | 10:00 | 36.5 | 560 | 7.93 | 5.01 | 1.02 | 0.362 | 176.3 | 1,561,136 | Begin Constant-rate pumping test at 9:30 |
| 07/03/2000 | 12:00 | 36.4 | 554 | 7.97 | 5.68 | 0.58 | 0.314 | 176.3 | 1,582,301 | |
| 07/03/2000 | 14:00 | 35.1 | 559 | 8.02 | 5.44 | 0.43 | 0.279 | 176.5 | 1,603,469 | |
| 07/03/2000 | 16:00 | 36.4 | 559 | 7.96 | 3.70 | 0.32 | 0.314 | 176.3 | 1,624,632 | |
| 07/04/2000 | 7:00 | 36.5 | 605 | 7.93 | 5.65 | 0.24 | 0.556 | 176.3 | 1,783,284 | |
| 07/04/2000 | 9:00 | 36.5 | 610 | 7.98 | 5.54 | 0.27 | 0.518 | 176.5 | 1,804,442 | |
| 07/04/2000 | 11:00 | 36.7 | 616 | 7.97 | 5.12 | 0.30 | 0.477 | 176.4 | 1,825,620 | |
| 07/04/2000 | 13:00 | 36.7 | 615 | 7.98 | 5.09 | 0.20 | 0.474 | 176.6 | 1,846,796 | |
| 07/04/2000 | 15:00 | 37.3 | 613 | 7.95 | 6.02 | 0.22 | 0.471 | 175.5 | 1,867,969 | |
| 07/04/2000 | 17:00 | 37.2 | 612 | 7.96 | 5.86 | 0.25 | 0.508 | 176.3 | 1,889,140 | |
| 07/05/2000 | 8:00 | 35.8 | 599 | 7.97 | 5.71 | 0.47 | 0.450 | 176.3 | 2,047,801 | |
| 07/05/2000 | 10:00 | 35.6 | 601 | 7.98 | 6.29 | 0.28 | 0.481 | 176.3 | 2,068,968 | |
| 07/05/2000 | 12:00 | 36.2 | 602 | 7.97 | 5.74 | 0.39 | 0.433 | 176.3 | 2,090,135 | |
| 07/05/2000 | 14:00 | 36.2 | 601 | 8.00 | 5.18 | 0.52 | 0.396 | 176.5 | 2,111,292 | |
| 07/05/2000 | 16:00 | 36.4 | 600 | 8.01 | 5.24 | 0.40 | 0.396 | 176.3 | 2,132,461 | |
| 07/05/2000 | 18:00 | 36.7 | 600 | 7.96 | 5.54 | 0.52 | 0.372 | 176.5 | 2,153,625 | |
| 07/06/2000 | 7:00 | 35.6 | 598 | 7.94 | 5.43 | 0.70 | 0.202 | 176.4 | 2,291,141 | |
| 07/06/2000 | 9:00 | 36.1 | 598 | 7.93 | 5.23 | 0.71 | 0.184 | 176.4 | 2,312,284 | |
| 07/06/2000 | 11:00 | 35.5 | 598 | 7.96 | 5.69 | 0.42 | 0.164 | 176.3 | 2,333,447 | |
| 07/06/2000 | 13:00 | 36.6 | 595 | 7.86 | 4.96 | 0.72 | 0.128 | 176.3 | 2,354,617 | |
| 07/06/2000 | 15:00 | 36.3 | 602 | 7.92 | 5.16 | 0.35 | 0.152 | 176.4 | 2,375,789 | |

## Table ATT.2-1
## Water Quality Monitoring - Grab Sample Results for Well ER-EC-8
(Page 4 of 5)

| Date | Time hr:min. | Temperature ° C | EC µmhos/cm | pH SU | DO mg/L | Turbidity NTUs | Bromide mg/L | Pumping Rate gpm | Total Discharge gallons | Comments/Phase of Development or Testing |
|---|---|---|---|---|---|---|---|---|---|---|
| 07/06/2000 | 17:00 | 36.4 | 602 | 7.89 | 5.08 | 0.62 | 0.171 | 176.4 | 2,396,960 | |
| 07/07/2000 | 9:35 | 37.3 | 665 | 7.93 | 5.08 | 0.26 | 0.535 | 176.3 | 2,572,415 | |
| 07/07/2000 | 11:00 | 37.5 | 665 | 7.97 | 5.09 | 0.43 | 0.542 | 176.3 | 2,587,405 | |
| 07/07/2000 | 13:30 | 37.7 | 666 | 7.98 | 5.70 | 0.26 | 0.554 | 176.5 | 2,613,849 | |
| 07/07/2000 | 15:30 | 37.7 | 664 | 7.98 | 4.91 | 1.07 | 0.504 | 176.4 | 2,635,024 | |
| 07/07/2000 | 17:30 | 37.8 | 666 | 8.01 | 4.99 | 1.08 | 0.509 | 176.4 | 2,656,193 | |
| 07/08/2000 | 8:45 | 37.5 | 659 | 8.01 | 4.93 | 0.26 | 0.397 | 176.2 | 2,817,515 | |
| 07/08/2000 | 10:00 | 37.5 | 661 | 8.04 | 5.01 | 0.51 | 0.516 | 176.4 | 2,830,741 | |
| 07/08/2000 | 12:00 | 37.7 | 658 | 8.01 | 5.02 | 0.39 | 0.427 | 176.4 | 2,851,906 | |
| 07/08/2000 | 14:00 | 37.9 | 661 | 7.97 | 4.83 | 0.36 | 0.404 | 176.6 | 2,873,079 | |
| 07/08/2000 | 16:00 | 37.8 | 661 | 8.00 | 4.62 | 0.28 | 0.341 | 176.4 | 2,894,253 | |
| 07/08/2000 | 17:00 | 37.8 | 661 | 8.00 | 4.98 | 0.23 | 0.337 | 176.4 | 2,904,821 | |
| 07/09/2000 | 8:30 | 37.8 | 665 | 7.95 | 4.60 | 0.15 | 0.568 | 176.3 | 3,068,795 | |
| 07/09/2000 | 10:30 | 38.1 | 664 | 7.98 | 4.70 | 0.16 | 0.550 | 176.5 | 3,089,988 | |
| 07/09/2000 | 12:34 | 37.7 | 657 | 7.92 | 4.80 | 1.33 | 0.552 | 176.4 | 3,111,852 | |
| 07/09/2000 | 14:30 | 38.2 | 667 | 7.99 | 4.60 | 0.38 | 0.563 | 176.6 | 3,132,318 | |
| 07/09/2000 | 16:30 | 38.1 | 666 | 7.97 | 4.96 | 0.22 | 0.556 | 176.6 | 3,153,484 | |
| 07/10/2000 | 7:32 | 38.4 | 646 | 7.97 | 4.75 | 0.12 | 0.544 | 176.3 | 3,312,230 | |
| 07/10/2000 | 9:30 | 38.6 | 649 | 7.93 | 4.50 | 0.14 | 0.541 | 176.7 | 3,333,414 | |
| 07/10/2000 | 11:30 | 38.1 | 642 | 7.91 | 4.88 | 0.30 | 0.488 | 176.5 | 3,354,603 | |
| 07/10/2000 | 13:30 | 38.0 | 646 | 7.87 | 4.69 | 0.26 | 0.536 | 176.6 | 3,375,779 | |
| 07/10/2000 | 15:34 | 38.3 | 653 | 7.98 | 4.66 | 0.25 | 0.433 | 176.2 | 3,397,799 | |

**Table ATT.2-1**
**Water Quality Monitoring - Grab Sample Results for Well ER-EC-8**
(Page 5 of 5)

| Date | Time hr:min. | Temperature ° C | EC µmhos/cm | pH SU | DO mg/L | Turbidity NTUs | Bromide mg/L | Pumping Rate gpm | Total Discharge gallons | Comments/Phase of Development or Testing |
|---|---|---|---|---|---|---|---|---|---|---|
| 07/10/2000 | 17:00 | 38.1 | 649 | 7.97 | 4.74 | 0.20 | 0.367 | 176.4 | 3,412,813 | |
| 07/11/2000 | 7:25 | 38.0 | 648 | 7.94 | 4.90 | 0.17 | 0.488 | 176.4 | 3,565,387 | |
| 07/11/2000 | 9:30 | 38.2 | 652 | 7.99 | 5.07 | 0.18 | 0.473 | 176.6 | 3,587,395 | |
| 07/11/2000 | 11:30 | 38.1 | 648 | 7.95 | 5.06 | 0.12 | 0.468 | 176.6 | 3,608,562 | |
| 07/11/2000 | 13:25 | 37.9 | 651 | 7.95 | 5.03 | 0.12 | 0.549 | 176.4 | 3,628,858 | |
| 07/11/2000 | 15:25 | 38.5 | 653 | 8.01 | 5.07 | 0.22 | 0.522 | 175.1 | 3,650,027 | |
| 07/11/2000 | 17:00 | 38.2 | 653 | 7.97 | 4.97 | 0.13 | 0.468 | 176.4 | 3,666,786 | |
| 07/12/2000 | 7:55 | 38.2 | 647 | 8.01 | 5.28 | 0.23 | 0.545 | 176.9 | 3,824,604 | ITLV, DRI, LLNL, and UNLV collect wellhead samples |
| 07/12/2000 | 9:40 | 37.9 | 647 | 8.01 | 5.25 | 0.28 | 0.516 | 176.5 | 3,843,141 | |
| 07/12/2000 | 11:35 | 38 | 647 | 7.99 | 4.94 | 0.11 | 0.502 | 177.2 | 3,863,441 | |

EC - Electrical Conductivity
DRI - Desert Research Institute
hr:min - Hour: minute
mg/L - Milligrams per liter
DO - Dissolved oxygen
NTUs - Nephelometric Turbidity Units
gpm - Gallons per minute
µmhos/cm - Micro mhos per centimeter
SU - Standard Units
in. - Inch(es)
ITLV - IT Corporation, Las Vegas Office
LLNL - Lawrence Livermore National Laboratory
UNLV - University of Nevada at Las Vegas

# Attachment 3

# Water Quality Analyses, Composite Characterization Sample and Discrete Samples

**Table ATT.3-1**
**Analytical Results of Groundwater Characterization Samples at Well ER-EC-8**
(Page 1 of 4)

| Analyte | CRDL | Laboratory | Results of Discrete Bailer Sample #EC-8-062800-2 | | Results of Discrete Bailer Sample #EC-8-062800-3 | | Results of Wellhead Composite Sample #EC-8-071200-1 | |
|---|---|---|---|---|---|---|---|---|
| **Metals (mg/L)** | | | | | | | | |
| | | | **Total** | **Dissolved** | **Total** | **Dissolved** | **Total** | **Dissolved** |
| Aluminum | 0.01 | Paragon | B 0.073 | U 0.0047 | 0.5 | B 0.07 | U 0.077 | U 0.072 |
| Arsenic | 0.01 | Paragon | 0.013 | 0.01 | B 0.0082 | B 0.0085 | B 0.0081 | B 0.0071 |
| Barium | 0.2 | Paragon | B 0.0045 | U 0.0031 | B 0.017 | B 0.0096 | UJ 0.00096 | UJ 0.0008 |
| Cadmium | 0.005 | Paragon | U 0.005 | U 0.005 | U 0.005 | U 0.005 | UJ 0.005 | UJ 0.005 |
| Calcium | 5 | Paragon | 10 | 10 | 10 | 7.1 | 9.1 | 9.1 |
| Chromium | 0.01 | Paragon | 0.032 | U 0.0018 | 0.016 | U 0.0037 | UJ 0.00056 | UJ 0.0004 |
| Iron | 0.04 | Paragon | 3.4 | U 0.13 | 1.5 | U 0.13 | U 0.061 | U 0.054 |
| Lead | 0.003 | Paragon | U 0.003 | U 0.003 | U 0.003 | U 0.003 | U 0.003 | U 0.003 |
| Lithium | 0.05 | Paragon | 0.16 | 0.17 | 0.15 | 0.15 | 0.16 | 0.16 |
| Magnesium | 5 | Paragon | U 0.48 | U 0.48 | U 0.5 | U 0.31 | U 0.39 | U 0.39 |
| Manganese | 0.015 | Paragon | 0.055 | B 0.0051 | 0.025 | B 0.0034 | U 0.0015 | U 0.0014 |
| Potassium | 5 | Paragon | 6.5 | 6.6 | 3.4 | 3.4 | 7.2 | 7.2 |
| Selenium | 0.005 | Paragon | U 0.005 | U 0.005 | U 0.005 | U 0.005 | U 0.005 | U 0.005 |
| Silicon | 0.1 | Paragon | 23 | 23 | 24 | 22 | 23 | 23 |
| Silver | 0.01 | Paragon | U 0.01 | U 0.01 | U 0.01 | U 0.01 | U 0.01 | U 0.01 |
| Sodium | 5 | Paragon | 120 | 120 | 120 | 120 | 110 | 120 |
| Strontium | 0.05 | Paragon | B 0.0056 | B 0.0048 | 0.031 | 0.024 | U 0.0024 | U 0.0028 |
| Uranium | 0.02 | Paragon | U 0.2 | U 0.2 | U 0.2 | U 0.2 | U 0.2 | U 0.2 |
| Mercury | 0.0002 | Paragon | UJ 0.0002 | UJ 0.0002 | UJ 0.0002 | UJ 0.0002 | UJ 0.0002 | UJ 0.0002 |

**Table ATT.3-1**
**Analytical Results of Groundwater Characterization Samples at Well ER-EC-8**
(Page 2 of 4)

| Analyte | CRDL | Laboratory | Results of Discrete Bailer Sample #EC-8-062800-2 | Results of Discrete Bailer Sample #EC-8-062800-3 | Results of Wellhead Composite Sample #EC-8-071200-1 |
|---|---|---|---|---|---|
| **Inorganics (mg/L) - unless otherwise noted** | | | | | |
| Chloride | 0.25 | Paragon | J 49 | J 46 | 49 |
| Fluoride | 0.25 | Paragon | J 5.2 | J 5 | 5.4 |
| Bromide | 0.25 | Paragon | J 0.94 | J 0.22 | 0.2 |
| Sulfate | 1 | Paragon | J 81 | J 81 | 82 |
| pH (pH units) | 0.1 | Paragon | J 8 | J 8.9 | 7.7 |
| Total Dissolved Solids | 10 | Paragon | J 430 | J 410 | 420 |
| Electrical Conductivity (micromhos/cm) | 0.1 | Paragon | J 650 | 630 | 633 |
| Carbonate as CaCO3 | 1 | Paragon | UJ 5 | J 33 | U 50 |
| Bicarbonate as CacCO3 | 1 | Paragon | J 150 | J 110 | 160 |
| **Organics (mg/L)** | | | | | |
| | **MDL** | **Laboratory** | **Result** | **Result** | **Result** |
| Total Organic Carbon | 1 | Paragon | UJ 1 | J 0.98 | U 1 |
| **Redox Parameters (mg/L)** | | | | | |
| Total Sulfide | 1 | Paragon | UJ 5 | UJ 5 | U 5 |
| **Age and Migration Parameters (pCi/L) - unless otherwise noted** | | | | | |
| **Analyte** | **MDC** | **Laboratory** | **Result** | **Result** | **Result** |
| Carbon-13/12 (per mil) | Not provided | DRI | N/A | N/A | -2.7 +/- 0.2 |
| C-14, Inorganic (pmc) | Not provided | LLNL | N/A | N/A | 8.7 +/- 0.1 |

**Table ATT.3-1**
**Analytical Results of Groundwater Characterization Samples at Well ER-EC-8**
(Page 3 of 4)

| Analyte | CRDL | Laboratory | Results of Discrete Bailer Sample #EC-8-062800-2 | Results of Discrete Bailer Sample #EC-8-062800-3 | Results of Wellhead Composite Sample #EC-8-071200-1 |
|---|---|---|---|---|---|
| **Age and Migration Parameters (pCi/L) - unless otherwise noted** | | | | | |
| **Analyte** | **MDC** | **Laboratory** | **Result** | **Result** | **Result** |
| C-14, Inorganic age (years)* | Not provided | LLNL | N/A | N/A | 20,200 |
| Chlorine-36 | Not provided | LLNL | N/A | N/A | 8.81E-04 |
| Cl-36/Cl (ratio) | Not provided | LLNL | N/A | N/A | 4.63E-13 |
| He-4 (atoms/mL) | Not provided | LLNL | N/A | N/A | 3.69E+12 |
| He-3/4, measured value (ratio) | Not provided | LLNL | N/A | N/A | 1.74E-06 |
| He-3/4, relative to air (ratio) | Not provided | LLNL | N/A | N/A | 1.26 |
| Oxygen-18/16 (per mil) | Not provided | DRI | N/A | N/A | -15.0 +/- 0.2 |
| Strontium-87/86 (ratio) | Not provided | LLNL | N/A | N/A | 0.708816 +/- 0.000017 |
| Uranium-234/238 (ratio) | Not provided | LLNL | N/A | N/A | 0.000278 |
| H-2/1 (per mil) | Not provided | DRI | N/A | N/A | -114 +/- 1.0 |
| Colloids | Not provided | LANL | See Table ATT.3-2 | | |
| **Radiological Indicator Parameters-Level I (pCi/L)** | | | | | |
| Gamma Spectroscopy:** | | | | | |
| Potassium-40 | 77, 160, 160 | Paragon | 264 +/- 83 | U 100 +/- 130 | U 130 +/- 130 |
| Tritium | 250, 250, 270 | Paragon | U 0 +/- 150 | U -20 +/- 150 | U -180 +/- 160 |
| Gross Alpha | 3.1, 3.1, 3.8 | Paragon | 8.1 +/- 2.7 | 7.7 +/- 2.7 | U 3.6 +/- 2.5 |
| Gross Beta | 3.6, 4.1, 4.1 | Paragon | U 5.0 +/- 2.3 | U 0.0 +/- 2.4 | U 4.6 +/- 2.6 |

**Table ATT.3-1**
**Analytical Results of Groundwater Characterization Samples at Well ER-EC-8**
(Page 4 of 4)

| Analyte | CRDL | Laboratory | Results of Discrete Bailer Sample #EC-8-062800-2 | Results of Discrete Bailer Sample #EC-8-062800-3 | Results of Wellhead Composite Sample #EC-8-071200-1 |
|---|---|---|---|---|---|
| **Radiological Indicator Parameters-Level II (pCi/L)** | | | | | |
| Carbon-14 | 310, 310, 310 | Paragon | U -20 +/- 190 | U -70 +/- 180 | U -140 +/- 180 |
| Strontium-90 | 0.44 | Paragon | N/A | N/A | U -0.08 +/- 0.26 |
| Plutonium-238 | 0.034, 0.026, 0.034 | Paragon | U -0.005 +/- 0.012 | U 0.003 +/- 0.011 | U -0.005 +/- 0.012 |
| Plutonium-239 | 0.0081, 0.0089, 0.04 | Paragon | 0.101 +/- 0.036 | LT 0.066 +/- 0.030 | U -0.004 +/- 0.012 |
| Iodine-129 | 1.4 | Paragon | N/A | N/A | U -0.86 +/- 0.81 |
| Technetium-99 | 13 | Paragon | N/A | N/A | U 13.1 +/- 8.4 |

U = Result not detected at the given minimum detectable limit or activity
J = Estimated value
B = Result less than the Practical Quantitation Limit but greater than or equal to the Instrument Detection Limit
CRDL = Contract-Required Detection Limit per Table 5-1, UGTA QAPP, 2/16/98
MDL = Method Detection Limit per Table 5-1, UGTA QAPP, 2/16/98
MDC = Minimum Detectable Concentration, sample-specific
LT = Result is less than requested MDC, but greater than sample-specific MDC
N/A = Not applicable for that sample
mg/L = Milligrams per liter µg/L = Micrograms per liter pCi/L = Picocuries per liter
micromhos/cm = Micromhos per centimeter
pmc = Percent modern carbon

* = The carbon-14 age presented is not corrected for reactions along the flow path.
** = All other gamma spectroscopy nuclides were non-detects.

**Table ATT.3-2**
**Colloid Analyses for Well ER-EC-8**
(Page 1 of 2)

| Analyte | Laboratory | Results of Discrete Bailer Sample #EC-8-062800-2 | Results of Discrete Bailer Sample #EC-8-062800-3 | Results of Wellhead Composite Sample #EC-8-071200-1 |
|---|---|---|---|---|
| Colloid Particle Size Range (in nanometer) | | Colloid Concentration (particles/mL) | Colloid Concentration (particles/mL) | Colloid Concentration (particles/mL) |
| | | | | |
| 50 - 60 | LANL | 1.963E+07 | 2.483E+07 | 8.593E+06 |
| 60 - 70 | LANL | 1.873E+07 | 2.353E+07 | 9.548E+06 |
| 70 - 80 | LANL | 1.723E+07 | 1.903E+07 | 7.487E+06 |
| 80 - 90 | LANL | 1.067E+07 | 1.404E+07 | 5.176E+06 |
| 90 - 100 | LANL | 7.062E+06 | 1.134E+07 | 3.266E+06 |
| 100 - 110 | LANL | 4.157E+06 | 1.069E+07 | 2.613E+06 |
| 110 - 120 | LANL | 3.205E+06 | 8.593E+06 | 1.658E+06 |
| 120 - 130 | LANL | 2.104E+06 | 4.446E+06 | 6.532E+05 |
| 130 - 140 | LANL | 1.803E+06 | 4.546E+06 | 6.532E+05 |
| 140 - 150 | LANL | 8.516E+05 | 4.496E+06 | 2.512E+05 |
| 150 - 160 | LANL | 8.012E+05 | 3.647E+06 | 2.512E+05 |
| 160 - 170 | LANL | 8.012E+05 | 3.297E+06 | 1.006E+05 |
| 170 - 180 | LANL | 7.012E+05 | 2.348E+06 | 1.006E+05 |
| 180 - 190 | LANL | 4.508E+05 | 2.348E+06 | 0.000E+00 |
| 190 - 200 | LANL | 4.008E+05 | 1.549E+06 | 0.000E+00 |
| 200 - 220 | LANL | 4.508E+05 | 1.349E+06 | 0.000E+00 |
| 220 - 240 | LANL | 2.152E+05 | 9.860E+05 | 2.060E+04 |
| 240 - 260 | LANL | 1.804E+05 | 6.976E+05 | 1.340E+04 |
| 260 - 280 | LANL | 9.720E+04 | 3.756E+05 | 3.600E+03 |
| 280 - 300 | LANL | 4.920E+04 | 2.188E+05 | 3.600E+03 |
| 300 - 400 | LANL | 1.464E+05 | 5.216E+05 | 4.800E+03 |
| 400 - 500 | LANL | 3.960E+04 | 1.196E+05 | 1.200E+03 |

**Table ATT.3-2**
**Colloid Analyses for Well ER-EC-8**
(Page 2 of 2)

| **Analyte** | **Laboratory** | **Results of Discrete Bailer Sample #EC-8-062800-2** | **Results of Discrete Bailer Sample #EC-8-062800-3** | **Results of Wellhead Composite Sample #EC-8-071200-1** |
|---|---|---|---|---|
| Colloid Particle Size Range (in nanometer) | | Colloid Concentration (particles/mL) | Colloid Concentration (particles/mL) | Colloid Concentration (particles/mL) |
| 500 - 600 | LANL | 5.640E+04 | 1.316E+05 | 3.600E+03 |
| 600 - 800 | LANL | 1.224E+05 | 2.776E+05 | 6.000E+03 |
| 800 - 1,000 | LANL | 6.720E+04 | 1.076E+05 | 1.200E+03 |
| >1,000 | LANL | 2.428E+05 | 3.112E+05 | 0.000E+00 |
| | | | | |
| Total Concentration, Particle Size Range, 50-1,000 nm | LANL | 9.03E+07 | 1.44E+08 | 4.04E+07 |

**Table ATT.3-3**
**Trace Element Results for Groundwater Characterization Samples**
(Page 1 of 2)

| Analyte | Detection Limit | Laboratory | Q | Results of Discrete Bailer Sample #EC-8-062800-2 | Q | Results of Discrete Bailer Sample #EC-8-062800-3 | UNIT |
|---|---|---|---|---|---|---|---|
| Ag, Dissolved | 0.16 | UNLV-HRC | < | 0.16 | < | 0.16 | µg/L |
| Al, Dissolved | 0.17 | UNLV-HRC | | 7.99 | | 72.7 | µg/L |
| As, Dissolved | 0.02 | UNLV-HRC | | 5.65 | | 7.33 | µg/L |
| Au, Dissolved | 0.030 | UNLV-HRC | < | 0.030 | | 0.051 | µg/L |
| Ba, Dissolved | 0.006 | UNLV-HRC | | 2.37 | | 8.98 | µg/L |
| Be, Dissolved | 0.018 | UNLV-HRC | < | 0.018 | | 0.022 | µg/L |
| Bi, Dissolved | 0.004 | UNLV-HRC | < | 0.004 | < | 0.004 | µg/L |
| Cd, Dissolved | 0.006 | UNLV-HRC | | 0.014 | | 0.014 | µg/L |
| Co, Dissolved | 0.006 | UNLV-HRC | | 0.017 | | 0.086 | µg/L |
| Cr, Dissolved | 0.012 | UNLV-HRC | | 1.16 | | 3.16 | µg/L |
| Cs, Dissolved | 0.003 | UNLV-HRC | | 0.473 | | 0.433 | µg/L |
| Cu, Dissolved | 0.011 | UNLV-HRC | | 0.802 | | 0.533 | µg/L |
| Ga, Dissolved | 6.3 | UNLV-HRC | | 54 | | 180 | ng/L |
| Ge, Dissolved | 0.006 | UNLV-HRC | | 1.69 | | 1.43 | µg/L |
| Hf, Dissolved | 0.015 | UNLV-HRC | < | 0.015 | < | 0.015 | µg/L |
| In, Dissolved | 0.004 | UNLV-HRC | < | 0.004 | < | 0.004 | µg/L |
| Ir, Dissolved | 8 | UNLV-HRC | < | 8 | < | 8 | ng/L |
| Li, Dissolved | 0.015 | UNLV-HRC | | 149 | | 127 | µg/L |
| Mn, Dissolved | 0.01 | UNLV-HRC | | 4.57 | | 2.46 | µg/L |
| Mo, Dissolved | 0.01 | UNLV-HRC | | 13.2 | | 13.5 | µg/L |
| Nb, Dissolved | 5.1 | UNLV-HRC | | 21 | | 24 | ng/L |
| Ni, Dissolved | 0.006 | UNLV-HRC | | 0.559 | | 0.388 | µg/L |
| Pb, Dissolved | 0.04 | UNLV-HRC | < | 0.04 | | 0.07 | µg/L |
| Pd, Dissolved | 0.021 | UNLV-HRC | < | 0.021 | | 0.022 | µg/L |
| Pt, Dissolved | 0.006 | UNLV-HRC | | 0.034 | | 0.167 | µg/L |
| Rb, Dissolved | 0.003 | UNLV-HRC | | 19.2 | | 10.5 | µg/L |
| Re, Dissolved | 0.004 | UNLV-HRC | | 0.004 | | 0.005 | µg/L |
| Rh, Dissolved | 0.004 | UNLV-HRC | < | 0.004 | < | 0.004 | µg/L |
| Ru, Dissolved | 0.005 | UNLV-HRC | | 0.006 | | 0.006 | µg/L |
| Sb, Dissolved | 0.004 | UNLV-HRC | | 4.11 | | 0.364 | µg/L |
| Se, Dissolved | 0.09 | UNLV-HRC | | 0.62 | | 0.66 | µg/L |

**Table ATT.3-3**
**Trace Element Results for Groundwater Characterization Samples**
(Page 2 of 2)

| Analyte | Detection Limit | Laboratory | Q | Results of Discrete Bailer Sample #EC-8-062800-2 | Q | Results of Discrete Bailer Sample #EC-8-062800-3 | UNIT |
|---|---|---|---|---|---|---|---|
| Sn, Dissolved | 0.004 | UNLV-HRC | | 0.047 | | 0.036 | µg/L |
| Sr, Dissolved | 0.01 | UNLV-HRC | | 4.12 | | 22.7 | µg/L |
| Ta, Dissolved | 0.009 | UNLV-HRC | | 0.025 | | 0.018 | µg/L |
| Te, Dissolved | 0.008 | UNLV-HRC | < | 0.008 | < | 0.008 | µg/L |
| Ti, Dissolved | 0.009 | UNLV-HRC | | 1.51 | | 3.34 | µg/L |
| Tl, Dissolved | 0.009 | UNLV-HRC | | 0.096 | | 0.080 | µg/L |
| U, Dissolved | 0.005 | UNLV-HRC | | 3.90 | | 3.62 | µg/L |
| V, Dissolved | 0.009 | UNLV-HRC | | 2.11 | | 5.19 | µg/L |
| W, Dissolved | 0.004 | UNLV-HRC | | 1.59 | | 2.04 | µg/L |
| Zn, Dissolved | 0.2 | UNLV-HRC | | 1.70 | | 50.5 | µg/L |
| Zr, Dissolved | 0.018 | UNLV-HRC | | 0.064 | | 0.130 | µg/L |

µg/L = Microgram per liter
ng/L = Nanogram per liter
< = Compound was analyzed for, but not detected above the reported sample quantitation limit. The detection limit (quantitation limit) is reported in the results field.
Q = Qualifier

# Attachment 4

# Fluid Management Plan Waiver for WPM-OV Wells

PETER G. MORROS, Director
ALLEN BIAGGI, Administrator
(775) 687-4670
TDD 687-4678
Administration
Water Pollution Control
Facsimile 687-5856
Mining Regulation and Reclamation
Facsimile 684-5259

STATE OF NEVADA
KENNY C. GUINN
Governor

Waste Management
Corrective Actions
Federal Facilities
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Water Quality Planning
Facsimile 687-6396

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
**DIVISION OF ENVIRONMENTAL PROTECTION**
333 W. Nye Lane, Room 138
Carson City, Nevada 89706-0851

October 19, 1999

Ms. Runore C. Wycoff, Director
Environmental Restoration Division
U.S. Department of Energy
Nevada Operations Office
P.O. Box 98593-8518
Las Vegas, Nevada 89193-8518

RE: U.S. Department of Energy's "Request For A Waiver From the Fluid Management Plan For Well Development At Wells ER-EC-1, ER-EC-4, ER-EC-5, ER-EC-6, ER-EC-7, ER-EC-8, and ER-18-2" (Oct. 5, 1999)

Dear Ms. Wycoff:

The Nevada Division of Environmental Protection (NDEP) has reviewed the U.S. Department of Energy's (DOE) request for a waiver to discharge fluids directly to the ground surface during the development, testing, and sampling of wells Wells ER-EC-1, ER-EC-4, ER-EC-5, ER-EC-6, ER-EC-7, ER-EC-8, and ER-18-2. NDEP hereby approves the requested waiver with the following conditions:

<u>Condition 1</u> - The only fluids allowed to be discharged to the surface are waters from the wells.

<u>Condition 2</u> - Any waters that are heavily laden with sediments need to be discharged to the unlined, non-contaminated basins in order to allow the sediments to settle out before being discharged to the land surface.

<u>Condition 3</u> - Additional sampling and testing for lead must be conducted at 1 hour and then within 8 to 12 hours after the initial pumping begins at each location. If the field testing results indicate non-detects for lead, then the sampling may be conducted every 24 hours. If the field testing indicates detectable quantities (if less then 5 times the

Runore C. Wycoff, Director
October 19, 1999
Page 2

SDWA standard) then sampling must occur every 12 hours until 2 consecutive nondetects occur. Sampling and testing may then resume on the 24 hour schedule.

Condition 4 - NDEP shall be notified within 24 hours should any of the limits set forth in the Fluid Management Plan be exceeded.

If you have questions regarding this matter please contact me at (775) 687-4670 (ext. 3039), or Clem Goewert at (702) 486-2865.

Sincerely,

Paul J. Liebendorfer, PE
Chief
Bureau of Federal Facilities

CC/SJ/CG/js

cc: L.F. Roos, IT, Las Vegas, NV
Patti Hall, DOE/ERD
Ken Hoar, DOE/ESHD
S.A. Hejazi, DOE/NV, Las Vegas, NV
Michael McKinnon, NDEP/LV

ERD (R)
ERD (RF)
EM (RF)
MGR (RF)

OCT 0 5 1999

Paul J. Liebendorfer, P.E., Chief
Department of Conservation and Natural Resources
Division of Environmental Protection
333 W. Nye Lane, Room 138
Carson City, NV 89706-0851

REQUEST FOR A FLUID MANAGEMENT PLAN WAIVER FOR WELL DEVELOPMENT AT WELLS: ER-EC-1, ER-EC-4, ER-EC-5, ER-EC-6, ER-EC-7, ER-EC-8, AND ER-18-2

The DOE Nevada Operations Office (DOE/NV) has completed drilling and well construction activities at seven wells as part of the Underground Test Area (UGTA) Pahute Mesa/Oasis Valley drilling program. Subsequent investigation activities planned for these wells include well development, hydraulic testing, and groundwater sampling. These activities will result in the production of substantial volumes of groundwater, which are subject to the conditions in the UGTA Fluid Management Plan (FMP) (July 1999). DOE/NV is requesting a waiver from the UGTA FMP (July 1999) to allow fluids produced during these activities to be discharged directly to the ground surface.

Enclosed for your information are the results for fluid management samples collected from the sumps and characterization samples collected by bailer from the boreholes upon completion of drilling activities. The enclosed data, coupled with the distance of the well locations from the nearest underground test, supports the premise that radiological and/or chemical contamination will not be encountered during subsequent investigation activities. Therefore, DOE/NV proposes to conduct activities at these well sites under far field conditions with a reduced frequency of on-site monitoring. The proposal includes the following elements:

- The on-site monitoring program will consist of collecting one tritium and one lead sample from the fluid discharge every 24 hours for analysis.
- Fluids will be allowed to discharge to ground surface without prior notification to the Nevada Division of Environmental Protection.
- All other conditions for far field wells, in the FMP, will be in effect.

This proposed strategy would be applicable only to well development, testing, and sampling activities at these well sites. These activities are scheduled to begin on October 18, 1999.

Paul J. Liebendorfer -2-

If you have any questions, please contact Robert M. Bangerter, of my staff, at (702) 295-7340.

Original Signed By:

Runore C. Wycoff

Runore C. Wycoff, Director
Environmental Restoration Division

ERD:RMB

cc w/encl:
M. D. McKinnon, NDEP, Las Vegas, NV

cc w/o encl:
S. R. Jaunarajs, NDEP, Carson City, NV
C. M. Case, NDEP, Carson City, NV
C. J. Goewert, NDEP, Las Vegas, NV
L. F. Roos, IT, Las Vegas, NV
K. A. Hoar, ESHD, DOE/NV, Las Vegas, NV
S. A. Hejazi, OCC, DOE/NV, Las Vegas, NV
P. L. Hall, EM, DOE/NV, Las Vegas, NV

# Attachment 5

# Electronic Data Files Readme.txt

***ER-EC-8 Development and Testing Data Report*:**

This README file identifies the included data files. Included with this report are 25 files containing data that were collected electronically during the development and testing program for Well ER-EC-8. The .xls data files were originally collected in ASCII format by datalogger, and the data have been imported into Microsoft EXCEL 97 with minimal changes. Files 3, 4, and 5 contain two sheets, a RAW DATA sheet and a PROCESSED DATA sheet. The PROCESSED DATA sheet references the Raw Data sheet and performs basic processing on the data. Please consult the data report for more information on the data. Also note additional qualifications on the contents of these files: The column marked "Head" is a processed result using a nominal density for water. This was calculated for reference during the testing and is not the final result. The density that was used in processing the data is discussed in the data report. File "EC8Hydrolab.xls" contains the Hydrolab® monitoring data collected during well development. The last file, "Hydrolabcalc.xls," contains the conversion calculations for converting percent saturation to mg/L for dissolved oxygen.

The files are:

1) EREC8L.xls
Bridge plug monitoring data for the lower interval.

2) EREC8U.xls
Bridge plug monitoring data for the upper middle interval.

3) EC-8gradient.xls
Monitoring data for the upper interval during the bridge plug measurements.

4) EC-8_AQTEST_WD.xls
Complete monitoring record of development.

5) EC-8_AQTEST_HT.xls
Complete monitoring record of testing.

6) ER-EC-8 Water Level Monitoring.xls
Pre-development monitoring record.

7) EC8Hydrolab.xls
Hydrolab monitoring data during development.

8.) DRIFileInfoGeneric.txt
DRI log head information.

9) erec8mov01, erec8mov02, erec8mov03, erec8mov04, erec8mov05, erec8mov06, erec8mov07, erec8mov08, and erec8mov09.txt - DRI flow logs.

10) erec8sta01, erec8sta02, erec8sta03, erec8sta04, erec8sta05, erec8sta06, erec8sta07, erec8sta08, and erec8sta09.txt - DRI static impeller tool flow measurements.

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