Petrotek

MOORE RANCH
5-SPOT HYDROLOGIC TEST REPORT
VOLUME I
TEST DESIGN, RESULTS AND ANALYSIS

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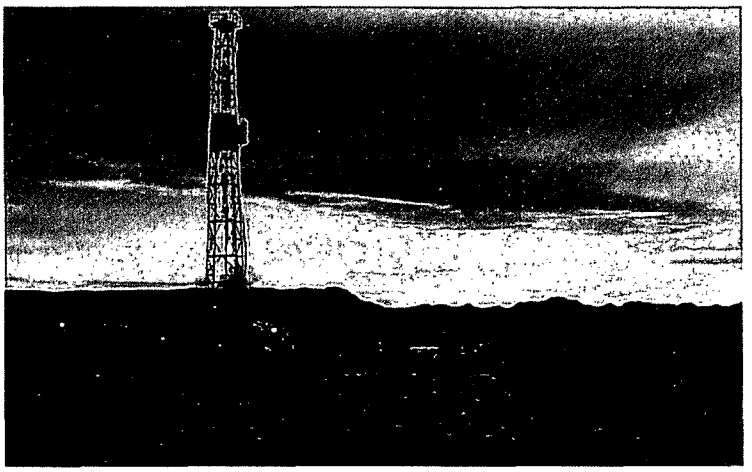

MOORE RANCH PROJECT

CAMPBELL COUNTY, WY

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Moore Ranch 5-Spot Hydrologic Test Report
Volume I –Test Design, Results and Analysis

Introduction

Uranium One has submitted an application to the U.S. Nuclear Regulatory Commission (NRC) for a Source Materials License (SML) to conduct in-situ recovery (ISR) of uranium at the Moore Ranch Project in Wyoming (Energy Metals, Inc. 2007). The target ore zone is designated as the 70 Sand. Aquifer conditions within the 70 Sand transition from confined to unconfined toward the southern portion of the site. The NRC responded to the SML application with a request for additional information (RAI) regarding the impacts that unconfined conditions will have on operation of the ISR project during production and restoration phases. To collect data that could be used to respond to the RAI, Uranium One conducted a well pattern scale hydrologic test within an area of the project where unsaturated conditions exist in the ore zone aquifer. Petrotek Engineering Corporation (Petrotek) assisted with the design and operation of the test and performed the analysis and evaluation of the test data. Results of the test were used to develop and calibrate a numerical groundwater flow model. The numerical model will be used to further address NRC comments regarding operational issues specific to ISR of uranium within an unconfined aquifer system. Results of the test and modeling will also support Uranium One in planning and operation of the ISR project. Reporting of the test description, results, analysis and modeling is included in two volumes. This report is Volume I, which summarizes the pump test design, layout, results and analysis. Volume II describes the development of the numerical model and summarizes the results of numerical simulations used to address NRC comments. Additional modeling will be performed to address wellfield scale issues related to production and aquifer restoration.

Purpose and Objectives

The 5-Spot Hydrologic Test was designed and implemented to address key issues related to ISR of uranium reserves at the Moore Ranch Project. Objectives of the 5-Spot Hydrologic Test included the following:

- Evaluate, in detail, the site-specific hydraulics associated with unconfined flow during typical ISR operations.
- Characterize pattern-scale aquifer properties within the production zone.
- Collect data that supports selection of input parameters for the development of site-specific numerical models.
- Develop data suitable to address NRC (and internal) concerns regarding production and restoration of an unconfined aquifer system.

Data derived from the 5-Spot Hydrologic Test were used to develop a numerical model that is representative of site-specific conditions (including the unconfined nature of the production zone aquifer). The numerical model was validated through comparison with measured field data. The calibrated and validated model was then used to demonstrate impacts of an unconfined system on mine design, excursion control, and restoration operations. Discussion of the model development, calibration and simulations is presented in Volume II of this technical memorandum.

Test Design and Layout

A phased approach for the 5-Spot Hydrologic Test was developed to assess aquifer characteristics of the 70 Sand on a well pattern scale and to evaluate the hydraulics associated with unconfined flow during typical ISR operations. The phases of the 5-Spot Hydrologic Test are described below.

- Installation of 5-Spot Well Pattern

  The location selected for the 5-Spot Test was within an area of Wellfield 2 where the ore zone (the 70 Sand) is present under unconfined aquifer conditions [Figure 5ST (1)]. The test layout included installation of a single 5-spot pattern with a centrally located recovery well (PMW1) surrounded by four injection wells (IMW1 through IMW4). Spacing between the recovery well and each of the injection wells was 71.5 feet. Four additional monitoring wells were placed at distances of 10 (MW16), 30 (MW18), 40 (MW17) and 70 (MW19) feet from the recovery well. Monitor well UMW5 is screened within the underlying aquifer (the 68 Sand) and was also included as an observation well for the testing. The location of the wells is shown on Figure 5ST (2). Well data for the recovery, injection and observation wells are presented in Table 5ST (1). Well boring logs are included in Attachment 5ST(1).

- Background Monitoring

  Background monitoring was conducted before and in between each of the following phases of the test to determine if any antecedent trends were present that would require adjustment of the data. Background monitoring included water level measurements in all wells and barometric pressure monitoring.

- Step Test

  A step test was conducted to determine an extraction rate for the 5-Spot ExtractionTest that would adequately stress the aquifer but not result in premature termination of the test because of excessive dewatering of the aquifer at the extraction well.

- Recovery Period
  The recovery period following the step test was included to allow water levels in the 70 Sand aquifer to return to static or near static conditions prior to commencing the extraction test.

- Extraction Test
  The initial test was to include only extraction from a single recovery well. This phase was designed to allow for accurate assessment of aquifer characteristics (transmissivity, hydraulic conductivity and specific yield) within the area of the 5-Spot Hydrologic Test using documented, widely accepted analytical methods, (Theis, Cooper-Jacobs, Neuman etc.).

- Recovery Period
  The recovery period following the extraction test was included to allow water levels in the 70 Sand aquifer to return to static or near static conditions prior to commencing the extraction/injection test.

- Extraction/Injection Test
  This phase of the test included extraction from the recovery well and injection of the recovered water into the four injection wells. This phase was designed to evaluate the change in water levels within the 5-spot well pattern under hydraulic conditions that are typical of ISR operations. The second phase of the test was modified after startup to include variable rates of injection into the injection wells, as described in the section on Extraction/Injection test results

Geology and Hydrogeology of the Test Area

Figures 5ST (3) and (4) show the top and bottom elevation of the 70 Sand hydrostratigraphic unit. The map of the top elevation of the 70 Sand indicates a dip to the northwest of approximately 0.02 ft/ft. The map of the bottom elevation of the unit indicates a slight rise to the northwest, resulting in a thinning of the 70 Sand in that direction. The 70 Sand ranges from 85 to 95 feet thick within the 5-spot well pattern [(Figure 5ST (5)]. The 70 Sand is overlain by a 30 to 40 foot thick confining unit. Figure 5ST (6) shows the electric logs for the recovery well (PMW1) and indicates the location of the 70 Sand, the ore zone and the screen interval.

The potentiometric surface prior to the beginning of the 5-Spot Hydrologic Test is shown on Figure 5ST (7). The potentiometric surface has a hydraulic gradient of 0.0026 to 0.0036 ft/ft toward the north. In the area of the test, the water level within the 70 Sand is approximately 20 feet below the top of the stratigraphic interval. Each of the wells were screened across ore-bearing and saturated portions of the 70 Sand, with the exception of UMW5 which was screened within the underlying 68 Sand. The upper portion of the 70 Sand is unsaturated at each

of the well locations, verifying that the aquifer is unconfined. Figure 5ST (8) is a cross section in the 5-spot pattern that illustrates the unconfined nature of the 70 sand. The cross section is oriented from northeast to southwest through injection well IMW3, recovery well PMW1 and injection well IMW2. The saturated thickness of the 70 Sand at the wells ranges from 67 to 75 feet.

Test Equipment and Instrumentation

The test was conducted with a 1.5 HP Grundfos electrical submersible pump in the recovery well (PMW1) powered by a portable diesel generator. The pump was set at a depth of 184 feet, approximately 4 feet above the bottom of the well screen and 31 feet above the bottom of the 70 Sand. The static water level in PMW1 prior to beginning the first phase of the testing was 142.3 feet below the top of casing, providing 41.7 feet of head above the pump.

Each of the recovery, injection and observation wells were outfitted with In-situ Level Troll transducers/data loggers. The pressure rating for the transducers was 30 psi for the recovery well and 15 psi for the injection and observation wells. The transducers were programmed to record depth to water at 10-minute intervals. Barometric pressure was monitored at the same frequency using a surface mounted Bara-Troll transducer.

For the Extraction Test, recovered water was discharged as surface flow approximately 500 feet from the recovery well (as allowed under temporary WDEQ permit). Flow was measured at the surface with two in-line totalizers.

During the Extraction/Injection Test, flow from the recovery well was routed to the injection wells through a manifold assembly with separate discharge lines for each injection well. An inline totalizer was installed in each discharge flow line.

Petrotek and Uranium One personnel installed the equipment prior to testing and verified the datalogger programming and equipment layout. Petrotek personnel assisted with the step test and initial startup of the extraction and recovery phases of the testing. Uranium One personnel provided daily downloads and transferred the data to Petrotek for review/QA/QC for the duration of the extraction and recovery tests.

5-Spot Test Results

Background Monitoring and Step Test

Background monitoring began in recovery well PMW1 on May 7, 2008 at 4:10 PM. Monitoring began on all of the remaining wells the following day just prior to startup of the step test.

The step test at PMW1 began on May 8 at 11:50 AM. The initial rate was 15.5 gpm for a period of 1 hour, followed by a rate of 19.6 gpm for 1 hour and 10

minutes and then 25.5 gpm for 1 hour [Figure 5ST (9)]. The maximum observed drawdown in the recovery well at the end of each step was 12.6, 16.6 and 21.1 feet, respectively. Based on the results of the step test, it was decided that a rate between 20 and 25 gpm would be sustainable for a long-term pump test.

Following the step test, background monitoring of water levels in all of the 5-Spot Hydrologic Test wells resumed until the beginning of the Extraction Test on May 12, 2008. Results of the background monitoring indicated no significant antecedent trends in water levels prior to the beginning of the Extraction Test [(Figure 5ST (10)].

Extraction Test

The Extraction Test began on May 12, 2008 at 10:40 AM. Recovery well PMW1 was the pumping well. The test was run for a period of 3 days, 10 hours and 52 minutes. The average rate during the test was 22.32 gpm, with minimal fluctuation during the test [Table 5ST(2)]. The test was terminated on May 16, 2008 at 9:32 AM.

The drawdown in the recovery well at the end of the test was 21.3 feet. The drawdown response of the recovery well is shown in Figure 5ST (10). Note that during the test, the water level dropped below the top of the well screen.

Drawdown was observed in the four injection wells (IMW1 through IMW4) and the four production zone monitoring wells (MW16 through MW19) during the Extraction Test. Maximum drawdown ranged from 6.9 feet at MW16 (the closest well to PMW1) to 3.7 feet at IMW4. The drawdown was similar at the four injection wells, ranging from 3.7 to 4.1 feet (IMW1) [Figure 5ST (11)]. The slightly greater drawdown at IMW1 can be attributed to the thinner saturated thickness at that well compared to the other locations. The relatively uniform drawdown at the injection wells, each located 71.5 feet from the extraction well, indicate a homogeneous, isotropic aquifer system, at least within the bounds of the 5-Spot Test. The water level response of the four injection wells during the Extraction test is shown on Figure 5ST (12). The response of the four monitor wells during the Extraction Test is shown on Figure 5ST (13). Based on the data from the Extraction Test, there does not appear to be a significant directional component to aquifer transmissivity. A hydrogeologic cross section that shows the water level response at the end of the Extraction Test is shown on Figure 5ST (14).

Barometric pressure was monitored prior to and throughout the Extraction Test. Barometric pressure began to rise just prior to the beginning of the Extraction Test and the increasing trend continued throughout the duration of the test. A barometric correction was applied to the water level data to evaluate if changes in barometric pressure during the test significantly impacted the results. The Manual Correction method was used to adjust the data based on barometric pressure fluctuations during the test. The Manual Correction method is described in detail in the Moore Ranch Hydrologic Testing Report (Petrotek 2007)

submitted as Appendix B of the Technical Report of the Application for Source Material License (EMC 2007). The Manual Correction method involves evaluating the data based on total head (i.e., the elevation of water in the well plus barometric pressure as feet of water), and normalizing the values to the initial barometric pressure at the start of each pump test. The results of the correction indicate that barometric changes accounted for approximately 0.46 to 0.50 ft of the drawdown observed in the injection and monitor wells. The drawdown within the 5-Spot Test area at the end of the Extraction Test with barometrically corrected data is shown in Figure 5ST (15).

The response of the underlying monitor well (UMW5) is shown in Figure 5ST (16). There appears to be a slight increase in depth to water that corresponds with the start of the pump test. However when a barometric correction is applied to the data from UMW5, the overall trend is a decrease in depth to water during the period of the extraction test [Figure 5ST (17)]. The barometrically corrected data indicate that the response in UMW5 is unrelated to pumping activities.

Monitoring at each of the injection and monitor wells continued after the end of the Extraction Test to observe the recovery of water levels and to continue background monitor prior to the Extraction/Injection Test.

Extraction Injection Test

Startup of the Extraction/Injection test began on May 21, 2008 at 2:00 PM. The Extraction/Injection Test included extraction from the recovery well and injection of the extracted water into the injection wells. The flow extracted from the recovery well was divided equally between the four injection wells. However, the initial attempt of the test was aborted (at 3:14 PM) when it became apparent that the injection wells could not accept the discharge water at the designed rates (5 gpm per injection well). Water discharged into the injection wells filled up the casing and discharged onto the surface.

After review and evaluation of the data, Uranium One and PEC determined that the injection wells required additional development. A rig was mobilized to the site on May 30, 2008 and the wells were developed using airlifting. Development activities were completed by June 2, 2008

Slug tests were performed on the injection wells to evaluate the effectiveness of the development efforts. Slug tests were conducted on May 29, 2008, before development of the wells, and again on June 3, 2008, after development was completed. Figure 5ST (18) illustrates the results of the before and after response of those wells to the development. In most cases, the apparent hydraulic conductivity of the aquifer in the vicinity of the wells increased by an order of magnitude. The completion rig was unable to get below the top of the screen in IMW2 during airlifting activities. The response curves shows that IMW2 did not "clean up" as well as the other injection wells and this became more apparent during the Extraction/Injection tests as described below. A summary of

the hydraulic conductivity calculated from the before and after development slug tests is presented in Table 5ST (3). The

Following development and slug test activities, the Extraction/Injection Test was restarted on June 5, 2008 at 1:36 PM. The extraction rate was 20.0 gpm. The first stage of the test included equal distribution of the extracted water to the four injection wells (5 gpm each). On June 7, 2008 at 3:08 PM (2.06 days from the test startup), two of the wells (IMW1 and IMW2) were shut in and the flow was allocated to the remaining wells (IMW3 and IMW4) at a rate of 10 gpm each. This second stage continued until June 8, 2008 at 3:06 PM. At that time, well IMW4 was shut in, the pump rate at PMW1 was increased to 20.5 gpm and all of the extracted water was discharged into injection well IMW3. This phase of the Extraction/Injection test ended on June 9, 2008 at 1:04 PM.

Table 5ST (4) summarizes the results of the Extraction/Injection Test at the end of each stage. The response of the injection wells was relatively consistent with the exception of well IMW2. During the first stage of the test, water levels rose in all injection wells from 2 to 4 feet except at well IMW2 where the increase was over 26 feet. As previously noted, during development of IMW2, the rig was unable to airlift the well below the top of the well screen. A hydrogeologic cross-section shows the change in water level that occurred by the end of the first stage of the test and illustrates the anomalous rise in water level at IMW2 [Figure CR 5ST (19)). The second stage of the Extraction/Injection test resulted in a rise in water levels at IMW3 and IMW4 of over 9 feet [Figure 5ST (20)]. The final stage of the test resulted in a rise of nearly 15 feet at IMW3, which is similar to the decline in water levels at the extraction well [Figure (5ST (21)]. Figure 5ST (22) shows the response of the recovery well (PMW1) and injection wells IMW1 and IMW3 throughout the Extraction/Injection Test. The response of monitor wells MW16, MW17 and MW18 during the test is shown on Figure 5ST (23). Within one hour after the end of the test, water levels had returned to within one foot of pre-test levels, even at the extraction well (PMW1).

5-Spot Test Analyses

Analytical Methods

The 5 Spot Extraction Test provided data suitable for detailed analysis of aquifer properties. Drawdown data collected from the recovery, injection and monitor wells were graphically analyzed to determine transmissivity and storativity/specific yield. The data collected from the test were analyzed using a variety of analytical methods including Theis (1935), Cooper-Jacob (1946), Neuman (1972) and Theis recovery (1935). Assumptions common to each of these methods, with the exception of confining conditions, which are not assumed for the Neuman method, are as follows

- The aquifer is confined and has apparent infinite extent;
- The aquifer is homogeneous and isotropic, and of uniform effective

thickness over the area influenced by pumping;

- The piezometric surface is horizontal prior to pumping;
- The well is pumped at a constant rate;
- The pumping well is fully penetrating; and,
- Well diameter is small, so well storage is negligible

These assumptions are reasonably satisfied, with the exception of confined conditions and fully penetrating wells. None of the recovery, injection or monitoring wells are fully penetrating.

The water table in an unconfined aquifer is equal to the elevation head. Transmissivity in an unconfined aquifer does not remain constant during a pump test. During a pump test, as the drawdown increases in a well, the available head in the well decreases, resulting in a decrease in transmissivity. In order to account for the decreased transmissivity during an aquifer test, a correction can be applied to the drawdown to approximate confined conditions. The correction proposed by Jacob (1944) is as follows:

$$s_{cor} = s - (s^2/2d)$$

where:

s_{cor} = corrected drawdown
s = measured drawdown
D = original saturated aquifer thickness

The Jacob correction allows for the use of the Theis, Cooper-Jacob, and Theis Recovery solutions for analysis of pumping test data for an unconfined aquifer (Waterloo Hydrogeologic Inc, 2002).

Because of the confirmed unconfined conditions present in the 70 Sand within the 5-Spot Hydrologic Test area, all drawdown data were corrected using the method described above for the Theis, Cooper-Jacob, and Theis Recovery solutions.

Also, as previously stated, barometric pressure changes influenced the response of the wells during the 5-Spot Hydrologic Test. Therefore, a barometric pressure correction was applied to all drawdown data prior to performing the analysis. The Manual Correction method, previously described, was applied to the data prior to analysis.

Analytical Results

The results of the analyses for the Extraction Test are summarized in Table 5ST (5). Curve matching plots for all of the 5-Spot Hydrologic Test wells for each of the methods used for analysis are included in Attachment 5ST(2). Results using the Theis method (corrected for unconfined conditions) provided the highest transmissivity values [ranging from 284 to 682 ft^2/d (2,125 to 5,100 gpd/ft)],

followed by results from the Cooper Jacob method [from 440 to 510 ft^2/d (3,290 to 3,850 gpd/ft)]. Results using the Theis recovery provided the lowest transmissivity values ranging from 180 to 253 ft^2/d (1,350 to 1,890 gpd/ft).

Visual observation of the curve fitting for the different methods indicates that the Neuman (delayed yield, unconfined conditions) method provided the best fit to the data [with a range of 272 to 395 ft^2/d (2,035 to 2,955 gpd/ft) and an average of 356 ft^2/d (2,660 gpd/ft)]. Many of the drawdown responses from the wells in the Extraction Test showed reasonable early and late time fit to the standard Theis curve but poor correlation during the middle portion of the test. The rate of drawdown in most of the wells showed a flattening in the middle of the test that is interpreted as the delayed yield response characteristic of an unconfined aquifer system. Because of the unconfined nature of the 70 Sand in the vicinity of the test, the Neuman delayed yield analysis method is considered the most appropriate. Analytical results using the Neuman method were typically only 60 to 70 percent of the value determined using the standard Theis method. The average transmissivity value calculated from all of the wells and all of the methods was 405 ft^2/d (3,030 gpd/ft).

Figure 5ST-24 is a comparison of transmissivity and hydraulic conductivity values calculated for each 5-Spot Hydrologic Test well using the different analytical solutions (Theis, Cooper-Jacobs, Neuman and Theis recovery). The variability in transmissivity between wells for a specific solution method is generally less than the variability exhibited between different analytical methods. As previously noted, the best visual fit to the analytical solution curves, is with the Neuman solution. Based on the results of the analyses, the transmissivity values calculated using Neuman are considered the most representative of site conditions.

The hydraulic conductivity was determined by dividing the transmissivity by the saturated thickness of the aquifer. The saturated thickness within the 5-Spot Hydrologic Test area was approximately 72 feet. The hydraulic conductivity calculated from the average transmissivity from all analytical methods is 5.6 ft/d, with a range of 2.5 to 9.5 feet. The hydraulic conductivity calculated from the average transmissivity from the Neuman method is 5.0 ft/d.

Specific yield was calculated for the aquifer based on the Neuman solutions. The range of values was 0.011 to 0.039. Storativity was not calculated from the test results because of the unconfined nature of the aquifer

Water level stability data collected during the pre-test and post-test periods along with barometric pressure were used to assess the background trends. No significant recharge or trend corrections were warranted for any of the wells other than the barometric pressure corrections previously described.

Discussion and Summary

Uranium One and Petrotek conducted a hydrologic test to evaluate hydraulics associated with unconfined flow during typical ISR operations and to characterize pattern-scale aquifer properties within the production zone. A 5-Spot Hydrologic Test was designed to address NRC concerns regarding ISR operations in an unconfined aquifer system. A 5-spot well pattern was installed within an area of Wellfield 2 where unconfined conditions are prevalent. The 5-spot well pattern included a centrally located recovery well and four injection wells. Four additional production zone monitor wells and one underlying aquifer monitor well were also installed in the 5 Spot Hydrologic Test area.

The initial phase of the test included only extraction from the recovery well. Data from the Extraction Test allowed detailed analysis and characterization of production zone aquifer properties. The second phase of the test included injection of water extracted from the recovery well. Data from the Extraction/Injection Test provided information regarding response of the unconfined aquifer to anticipated ISR production rates for the Moore Ranch Uranium Project.

Results of the Extraction Test indicate that, within the 5-Spot Hydrogeologic Test area, the production zone aquifer is relatively homogeneous and isotropic. The Extraction Test was run for 4 days at a rate of 22.33 gpm. Drawdown in the recovery well at the end of the Extraction Test was 20.9 feet, approximately 29 percent of the available head (72 feet) in the aquifer. At a distance of 10 feet from the recovery well, drawdown was 6.4 feet, less than 10 percent of the available head in the production zone aquifer. Drawdown at the injection wells was between 3.1 and 3.7 feet.

Data from the Extraction test were analyzed using several solution methods including Theis, Cooper-Jacobs, Neuman and Theis Recovery. The variability in transmissivity determined using a single analytical solution was generally small. However, there was larger variability in transmissivity between different solution methods. The Neuman solution provided the best visual match to the data, as this method is specifically developed to evaluate unconfined aquifer conditions. The response in most of the 5-Spot Hydrologic Test wells during the Extraction test showed a period of flattening during the middle of the test, interpreted as the delayed yield typical of an unconfined aquifer. The overall range of transmissivity, using all of the analytical solutions was from 180 to 682 ft^2/d. The range of transmissivity using only the Neuman method was from 272 to 395 ft^2/d with an average of 356 ft^2/d. Hydraulic conductivity values using all methods ranged from 2.5 to 9.5 ft/d, and from 4.5 to 5.7 ft/d for only the Neuman solution. Specific yield calculated using the Neuman method ranged from 0.011 to 0.039.

Results of the Extraction/Injection Test indicate that the production zone aquifer can sustain recovery and injection rates that are anticipated during production. A single injection was able to receive 20 gpm during the last stage of the test. Dewatering of the aquifer within a 5-Spot Pattern during typical ISR operating rates will generally be limited to a localized area around the recovery well. The rapid recovery to near pre test levels within an hour following termination of the test (which ran for a period of 4 days) indicates the aquifer has adequate transmissivity and areal extent to support ISR operations. Injection of lixiviant into the aquifer during production will prevent large scale dewatering of the 70 Sand. Similarly, reinjection of treated water during restoration activities will resaturate the upper portion of the 70 Sand in the vicinity of recovery wells that may be dewatered during production.

Results of the 5-Spot Hydrologic Test provided detailed site-specific aquifer characterization that will be utilized in the development, calibration and validation of a numerical model. The numerical model will used to simulate the hydraulic response of the aquifer during production and restoration operations. Discussion of the model development, calibration and simulation is presented in Volume II of this report.

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Table 5ST (5) Extraction Test Analytical Results, 5 Spot Hydrologic Test, Moore Ranch Uranium Project, Wyoming

	Theis		Cooper-Jacob		Theis Recovery		Neuman			Average All Methods	
	T	K	T	K	T	K	T	K	Sy	T	K
Well ID	(ft^2/d)	(ft/d)	(ft^2/d)	(ft/d)	(ft^2/d)	(ft/d)	(ft^2/d)	(ft/d)		(ft^2/d)	(ft/d)
IMW1	634	8.81	461	6.40	253	3.51	359	4.99	0.012	427	5.93
IMW2	667	9.26	510	7.08	253	3.51	395	5.49	0.014	456	6.34
IMW3	659	9.15	475	6.60	221	3.07	395	5.49	0.015	438	6.08
IMW4	682	9.47	447	6.21	251	3.49	342	4.75	0.027	431	5.98
MW16	284	3.94	471	6.54	180	2.50	272	3.78	0.015	302	4.19
MW17	622	8.64	457	6.35	228	3.17	381	5.29	0.011	422	5.86
MW18	369	5.13	489	6.79	246	3.42	388	5.39	0.039	373	5.18
MW19	581	8.07	440	6.11	239	3.32	319	4.43	0.024	395	5.48
PW1	-	-	-	-	237	3.29	-	-		237	3.29
Average	562	7.81	469	6.51	234	3.25	356	4.95	0.020	405	5.63
Maximum	682	9.47	510	7.08	253	3.51	395	5.49	0.039	-	-
Minimum	284	3.94	440	6.11	180	2.50	272	3.78	0.011	-	-
Std dev	150.5	2.1	22.8	0.3	23.2	0.3	43.6	0.6	0.010	-	-

T - Transmissivity
K - Hydraulic Conductivity
Sy - Specific Yield

Table 5ST (6) Calibration Targets, Residuals and Statistics, 5-Spot Extraction Test Simulation

Well ID	Simulation Time (days	Observed Drawdown (ft)	Computed Drawdown (ft)	Residual (ft)
IMW-1	0.5	2.04	1.33	0.71
	1	2.53	2.04	0.49
	2	3.05	2.82	0.23
	3	3.37	3.30	0.07
	4	3.60	3.32	0.28
IMW-2	0.5	1.81	1.31	0.50
	1	2.27	2.01	0.26
	2	2.75	2.78	-0.03
	3	3.06	3.26	-0.20
	4	3.29	3.28	0.01
IMW-3	0.5	1.70	1.32	0.38
	1	2.19	2.03	0.16
	2	2.71	2.81	-0.10
	3	3.04	3.29	-0.25
	4	3.30	3.31	-0.01
IMW-4	0.5	1.55	1.31	0.24
	1	2.04	2.01	0.03
	2	2.59	2.78	-0.19
	3	2.92	3.25	-0.33
	4	3.16	3.27	-0.11
MW-16	0.5	4.82	6.03	-1.21
	1	5.30	6.93	-1.63
	2	5.86	7.83	-1.97
	3	6.19	8.37	-2.18
	4	6.43	8.40	-1.97
MW-17	0.5	2.92	2.57	0.35
	1	3.43	3.38	0.05
	2	3.98	4.22	-0.24
	3	4.28	4.73	-0.45
	4	4.53	4.75	-0.22
MW-18	0.5	3.44	3.22	0.22
	1	3.93	4.06	-0.13
	2	4.44	4.91	-0.47
	3	4.78	5.42	-0.64
	4	5.00	5.44	-0.44
MW-19	0.5	1.76	1.35	0.41
	1	2.24	2.07	0.17
	2	2.78	2.84	-0.06
	3	3.12	3.32	-0.20
	4	3.38	3.34	0.04
PMW-1	0.5	18.90	17.08	1.82
	1	19.46	18.16	1.30
	2	20.00	19.25	0.75
	3	20.47	19.91	0.56
	4	20.79	19.94	0.85

Residual = Observed - Simulated
A positive residual indicates the model underpredicted drawdown
A negative residual indicates the model overpredicted drawdown

Calibration Statistics	
Residual Mean	-0.07
Res. Std. Dev.	0.76
Sum of Squares	26.49
Abs. Res. Mean	0.51
Min. Residual	-2.18
Max. Residual	1.82
Range	19.24
Std/Range	0.040

5ST (7) Comparison of Calibration Statistics, 5 Spot Extraction Test Simulations

Simulation ID	k	Sy	RSS Total	RM Total	ARM Total	RSD Total	RSS End	RM End	ARM End	RSD End
	(ft/d)		(ft2)	(ft)	(ft)	(ft)	(ft2)	(ft)	(ft)	(ft)
MR5STMs082408_K3S0025	3.0	0.0025	1650.0	-5.44	5.44	2.67	375.0	-5.85	5.86	2.71
MR5STMs082408_K3S025	3.0	0.025	318.0	-1.67	1.76	2.07	93.5	-2.40	2.40	2.15
MR5STMs082408_K3S03	3.0	0.03	268.0	-1.38	1.56	2.01	80.2	-2.11	2.11	2.11
MR5STMs082408_K3S035	3.0	0.035	232.0	-1.14	1.42	1.96	70.1	-1.87	1.87	2.07
MR5STMs082408_K3S04	3.0	0.04	206.0	-0.94	1.33	1.92	62.3	-1.66	1.66	2.04
MR5STMs082408_K3S045	3.0	0.045	184.0	-0.75	1.27	1.88	54.9	-1.44	1.46	2.00
MR5STMs082408_K3S05	3.0	0.05	169.0	-0.59	1.24	1.84	49.9	-1.28	1.33	1.98
MR5STMs082408_K3S06	3.0	0.06	147.0	-0.32	1.27	1.78	42.2	-0.99	1.27	1.93
MR5STMs082408_K3S08	3.0	0.08	126.0	0.10	1.34	1.67	33.1	-0.51	1.27	1.85
MR5STMs082408_K3S10	3.0	0.1	120.0	0.40	1.42	1.58	28.8	-0.15	1.34	1.78
MR5STMs082408_K35S01	3.5	0.01	243.0	-2.02	2.02	1.15	58.3	-2.28	2.28	1.12
MR5STMs082408_K35S015	3.5	0.015	147.0	-1.44	1.45	1.09	36.6	-1.71	1.71	1.07
MR5STMs082408_K35S02	3.5	0.02	103.0	-1.08	1.12	1.06	29.5	-1.48	1.48	1.04
MR5STMs082408_K35S025	3.5	0.025	74.3	-0.77	0.89	1.03	21.8	-1.18	1.18	1.01
MR5STMs082408_K35S03	3.5	0.03	57.9	-0.54	0.77	1.00	17.6	-0.98	0.98	0.99
MR5STMs082408_K35S035	3.5	0.035	47.4	-0.33	0.70	0.97	13.9	-0.77	0.80	0.97
MR5STMs082408_K35S04	3.5	0.04	41.6	-0.15	0.68	0.95	11.4	-0.59	0.68	0.96
MR5STMs082408_K35S045	3.5	0.045	38.6	0.01	0.71	0.93	9.5	-0.42	0.66	0.92
MR5STMs082408_K35S05	3.5	0.05	38.0	0.14	0.75	0.91	8.6	-0.30	0.67	0.93
MR5STMs082408_K35S06	3.5	0.06	40.6	0.44	0.86	0.84	7.6	0.30	0.83	0.87
MR5STMs082408_K35S1	3.5	0.1	74.9	1.06	1.21	0.74	14.4	0.99	1.20	0.79
MR5STMs082408_K4S0025	4.0	0.0025	309.0	-2.52	2.52	0.73	49.8	-2.24	2.24	0.70
MR5STMs082408_K4S005	4.0	0.005	169.0	-1.79	1.79	0.73	27.0	-1.58	1.58	0.70
MR5STMs082408_K4S01	4.0	0.01	87.1	-1.17	1.19	0.76	18.4	-1.25	1.25	0.70
MR5STMs082408_K4S015	4.0	0.015	46.4	-0.67	0.76	0.76	9.8	-0.76	0.78	0.71
MR5STMs082408_K4S02	4.0	0.02	30.9	-0.33	0.56	0.76	6.2	-0.43	0.55	0.71
MR5STMs082408_K4S025	**4.0**	**0.025**	**26.5**	**-0.07**	**0.51**	**0.76**	**4.9**	**-0.17**	**0.44**	**0.72**
MR5STMs082408_K4S03	**4.0**	**0.03**	**27.3**	**0.14**	**0.55**	**0.77**	**4.7**	**0.04**	**0.48**	**0.72**
MR5STMs082408_K4S035	4.0	0.035	31.1	0.32	0.70	0.77	5.2	0.22	0.57	0.73
MR5STMs082408_K4S04	4.0	0.04	36.9	0.48	0.74	0.77	6.3	0.40	0.70	0.73
MR5STMs082408_K45S0025	4.5	0.0025	144.0	-1.47	1.67	1.02	17.6	-0.98	1.31	1.00
MR5STMs082408_K45S005	4.5	0.005	97.1	-1.06	1.38	1.01	14.8	-0.79	1.17	1.01
MR5STMs082408_K45S01	4.5	0.01	56.6	-0.38	0.88	1.06	10.1	-0.15	0.71	1.05
MR5STMs082408_K45S015	4.5	0.015	52.0	0.08	0.69	1.07	10.1	-0.04	0.65	1.06
MR5STMs082408_K45S02	4.5	0.02	55.9	0.23	0.62	1.09	11.0	0.26	0.58	1.08
MR5STMs082408_K45S025	4.5	0.025	64.6	0.46	0.69	1.11	12.9	0.49	0.73	1.09
MR5STMs082408_K45S03	4.5	0.03	75.0	0.64	0.83	1.12	15.1	0.68	0.87	1.10
MR5STMs082408_K45S035	4.5	0.035	86.2	0.80	0.95	1.13	17.3	0.83	0.98	1.11
MR5STMs082408_K45S04	4.5	0.04	97.2	0.93	1.04	1.14	19.4	0.95	1.07	1.12
MR5STMs082408_K5S001	5.0	0.001	146.0	-1.03	1.64	1.48	19.4	-0.34	1.14	1.43
MR5STMs082408_K5S0025	5.0	0.0025	119.0	-0.72	1.42	1.46	18.8	-0.14	0.99	1.44
'MR5STMs082408_K5S005	5.0	0.005	101.0	-0.44	1.21	1.41	18.8	0.07	0.94	1.45
'MR5STMs082408_K5S010	5.0	0.01	98.7	0.17	0.80	1.47	21.9	0.48	0.69	1.48
'MR5STMs082408_K5S015	5.0	0.015	107.0	0.42	0.71	1.48	22.8	0.57	0.74	1.49
'MR5STMs082408_K5S02	5.0	0.02	122.0	0.68	0.82	1.50	26.4	0.82	0.94	1.50
MR5STMs082408_K5S025	5.0	0.025	138.0	0.89	0.98	1.51	30.0	1.02	1.09	1.52
MR5STMs082408_K5S03	5.0	0.03	155.0	1.05	1.10	1.53	33.5	1.18	1.21	1.53
MR5STMs082408_K6S0005	6.0	0.0005	216.0	0.28	1.21	2.17	50.3	1.00	1.01	2.15
MR5STMs082408_K6S001	6.0	0.001	216.0	0.27	1.21	2.17	50.2	0.99	1.00	2.15
MR5STMs082408_K6S0025	6.0	0.0025	221.0	0.46	1.15	2.17	53.2	1.13	1.13	2.15
MR5STMs082408_K6S005	6.0	0.005	237.0	0.75	1.13	2.17	59.2	1.37	1.37	2.17
MR5STMs082408_K6S01	6.0	0.01	248.0	0.95	1.03	2.15	59.1	1.37	1.37	2.17
MR5STMs082408_K6S015	6.0	0.015	285.0	1.28	1.28	2.17	69.0	1.70	1.70	2.19
MR5STMs082408_K6S02	6.0	0.02	312.0	1.48	1.48	2.18	75.3	1.88	1.88	2.20
MR5STMs082408_K6S025	6.0	0.025	339.0	1.65	1.65	2.19	82.3	2.07	2.07	2.21

k - hydraulic conductivity **Values in bold indicate simulations with calibration statistics that "best fit" observed data**
Sy - specific yield
RSS Total- residual sum of squares for all calibration targets
RM-Total - residual mean of calibration targets for all calibration targets
ARM-Total - absolute residual mean of calibration targets for all calibration targets
RSD Total - Standard deviation of the residuals for all calibration targets
RSS End- residual sum of squares for calibration targets at end of simulation
RM-End - residual mean of calibration targets at end of simulation
ARM-end - absolute residual mean of calibration targets at end of simulation
RSD End - Standard deviation of the residuals for calibration targets at end of simulation

Table MR5ST (8) Calibration Simulation Results-Hydraulic Conductivity vs Specific Yield

Residual Sum of Squares for Calibration Simulations, All Simulation Targets

		Hydraulic Conductivity (ft/d)					
		3.0	3.5	4.0	4.5	5.0	6.0
Specific Yield	0.0005						216.0
	0.001					146	**216**
	0.0025			309	144	119	221
	0.005			169	97.1	101	237
	0.01		243	87.1	56.6	**98.7**	248
	0.015		147	46.4	**52**	107	285
	0.02		103	30.9	55.9	122	312
	0.025	318	74.3	**26.5**	64.6	138	339
	0.03	268	57.9	27.3	75	155	
	0.035	232	47.4	31.1	86.2		
	0.04	206	41.6	36.9	97.2		
	0.045	184	38.6				
	0.05	169	**38**				
	0.06	147	40.6				
	0.08	126					
	0.1	**120**	74.9				

Residual Sum of Squares for Calibration Simulations, End of Simulation Targets

		Hydraulic Conductivity (ft/d)					
		3.0	3.5	4.0	4.5	5.0	6.0
Specific Yield	0.0005						50.3
	0.001					19.4	**50.2**
	0.0025			49.8	17.6	**18.8**	53.2
	0.005			27.0	14.8	**18.8**	59.2
	0.01		58.3	18.4	**10.1**	21.9	59.1
	0.015		36.6	9.8	**10.1**	22.8	69.0
	0.02		29.5	6.2	11.0	26.4	75.3
	0.025	93.5	21.8	4.9	12.9	30.0	82.3
	0.03	80.2	17.6	**4.7**	15.1	33.5	
	0.035	70.1	13.9	5.2	17.3		
	0.04	62.3	11.4	6.3	19.4		
	0.045	54.9	9.5				
	0.05	49.9	8.6				
	0.06	42.2	**7.6**				
	0.08	33.1					
	0.1	**28.2**	14.4				

Values in Bold indicate lowest RSS ("best fit") for that simulated hydraulic conductivity

Table 5ST(9) Summary of Input Parameters for the Calibration Simulation

Model Input	Number or Value	Units
Dimensions		
South to North	1980	feet
West to East	1980	feet
Model Origin (from bottom LH corner)		
Easting	320,730.00	feet
Northing	1,056,718.00	feet
Layers		
Number	1	-
Cells		
Number	421,201	-
Minimum size	1' x 1'	feet
Maximum size	5' x 5'	feet
Elevation		
Top Elevation (south end)	5218	feet; AMSL
Bottom Elevation (south end)	5130	feet; AMSL
Top Elevation (north end)	5196	feet; AMSL
Bottom Elevation (north end)	5093	feet; AMSL
Boundaries		
General Head - South Side	5195.15	feet; AMSL
General Head - North Side	5188.75	feet; AMSL
No Flow - East and West Sides	-	-
Recharge		
Rate	0.0	ft/d
Wells		
Number	1	-
Rate	4296.89	ft3/d
Parameter		
Hydraulic Conductivity	4.0	ft/d
Specific Yield	0.25	unitless
Formation Storativity	0.0005	unitless
Porosity	15	percent

Table 5ST (10) Verification Targets and Residuals, 5-Spot Extraction/Injection Test Simulation

Well ID	Simulation Time (days	Observed Drawdown (ft)	Computed Drawdown (ft)	Residual (ft)
IMW-1	2.06	-2.37	-2.77	0.40
	3.06	0.85	0.31	0.54
	3.98	0.76	0.66	0.10
IMW-2	2.06	NU	NA	NA
	3.06	0.62	0.31	0.31
	3.98	0.87	1.17	-0.30
IMW-3	2.06	-2.27	-2.76	0.49
	3.06	-9.48	-5.57	-3.91
	3.98	-14.91	-11.97	-2.94
IMW-4	2.06	-3.79	-2.68	-1.11
	3.06	-9.29	-5.41	-3.88
	3.98	0.30	0.62	-0.32
MW-16	2.06	2.56	3.73	-1.17
	3.06	2.08	3.90	-1.82
	3.98	2.28	4.03	-1.75
MW-17	2.06	0.98	0.68	0.30
	3.06	0.06	0.51	-0.45
	3.98	-0.22	-0.53	0.31
MW-18	2.06	1.31	1.32	-0.01
	3.06	0.85	1.29	-0.44
	3.98	0.91	1.24	-0.33
MW-19	2.06	-0.30	-0.35	0.05
	3.06	-2.50	-0.89	-1.61
	3.98	-3.57	-2.84	-0.73
PMW-1	2.06	14.96	13.18	1.78
	3.06	13.36	13.45	-0.09
	3.98	16.33	14.15	2.18

NU -observed value of 25.94 ft not used in calibration
NA - Not applicable
Residual = Observed - Simulated

5ST (11) Drawdown versus Distance at Simulated Pumping Rates, Hydrologic Test Design

Distance from Extraction Well	400 ft			500 ft			600 ft			700 ft		
	20 gpm	30 gpm	40 gpm	20 gpm	30 gpm	40 gpm	20 gpm	30 gpm	40 gpm	20 gpm	30 gpm	40 gpm
Time of Test	Drawdown (ft)			Drawdown (ft)			Drawdown (ft)			Drawdown (ft)		
1 day	0.11	0.17	0.23	0.03	0.05	0.07	0.01	0.01	0.02	0.00	0.00	0.00
2 days	0.35	0.54	0.72	0.17	0.27	0.35	0.08	0.12	0.16	0.03	0.05	0.07
3 days	0.56	0.89	1.17	0.32	0.51	0.67	0.18	0.28	0.38	0.10	0.15	0.20
4 days	0.75	1.18	1.53	0.47	0.73	0.96	0.29	0.45	0.59	0.17	0.27	0.35
5 days	0.90	1.43	1.80	0.59	0.93	1.19	0.38	0.60	0.77	0.24	0.38	0.49
6 days	0.90	1.52	1.82	0.59	1.01	1.20	0.38	0.67	0.79	0.24	0.43	0.50
7 days	0.90	1.52	1.83	0.59	1.01	1.21	0.38	0.67	0.79	0.24	0.43	0.50
8 days	0.90	1.53	1.86	0.59	1.02	1.23	0.38	0.67	0.81	0.24	0.43	0.52

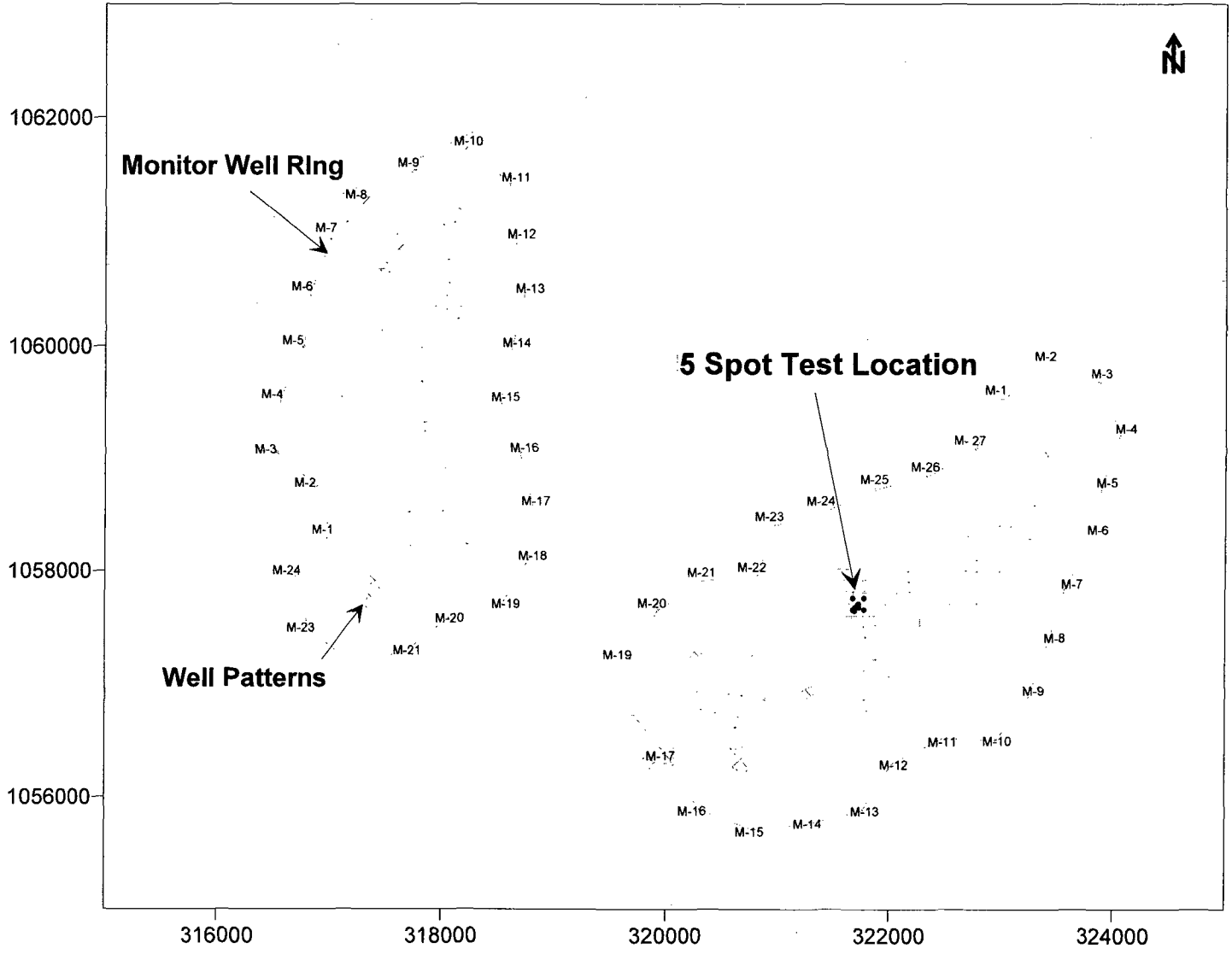

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Figure 5ST(1). 5 Spot Test Location
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST-1.srf Date: 08/08/08

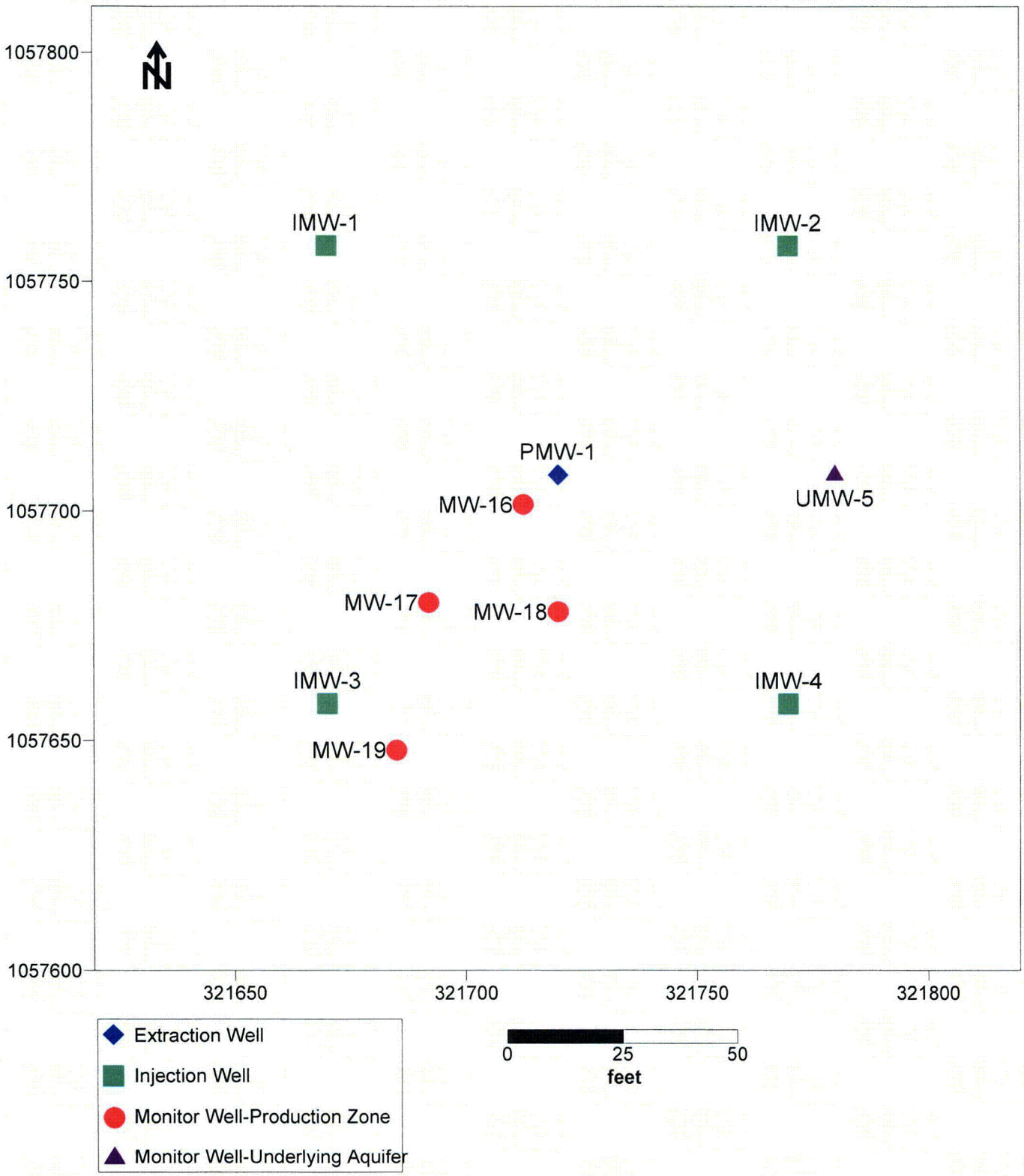

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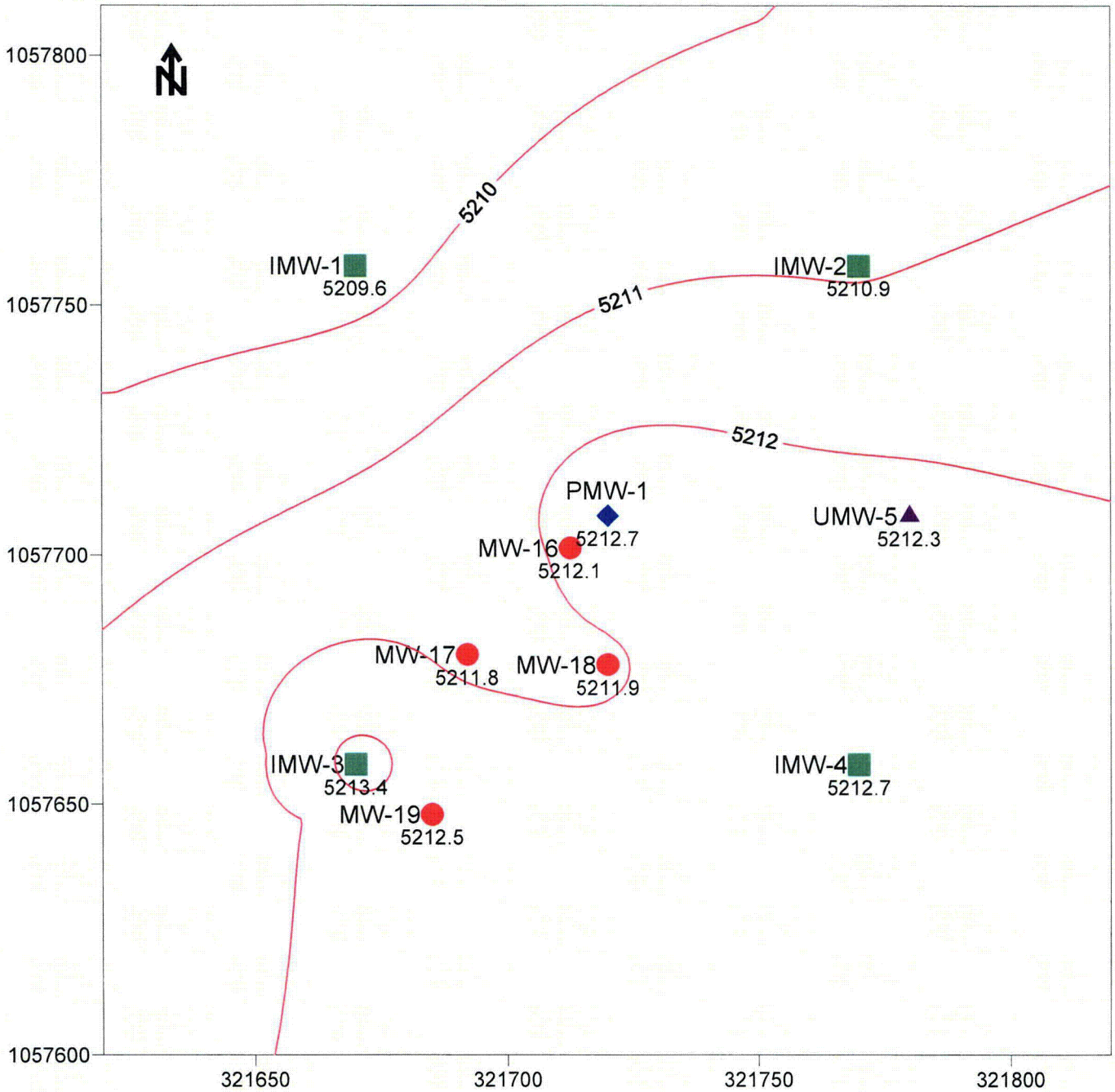
Figure 5ST(2). 5 Spot Test Layout
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST-2t.srf Date: 08/08/08



Extraction Well

Injection Well

Monitor Well-Production Zone

Monitor Well-Underlying Aquifer

IMW3 Well Identification
5213.4 Top of 70 Sand Elevation (ft amsl)

0 25 50
feet

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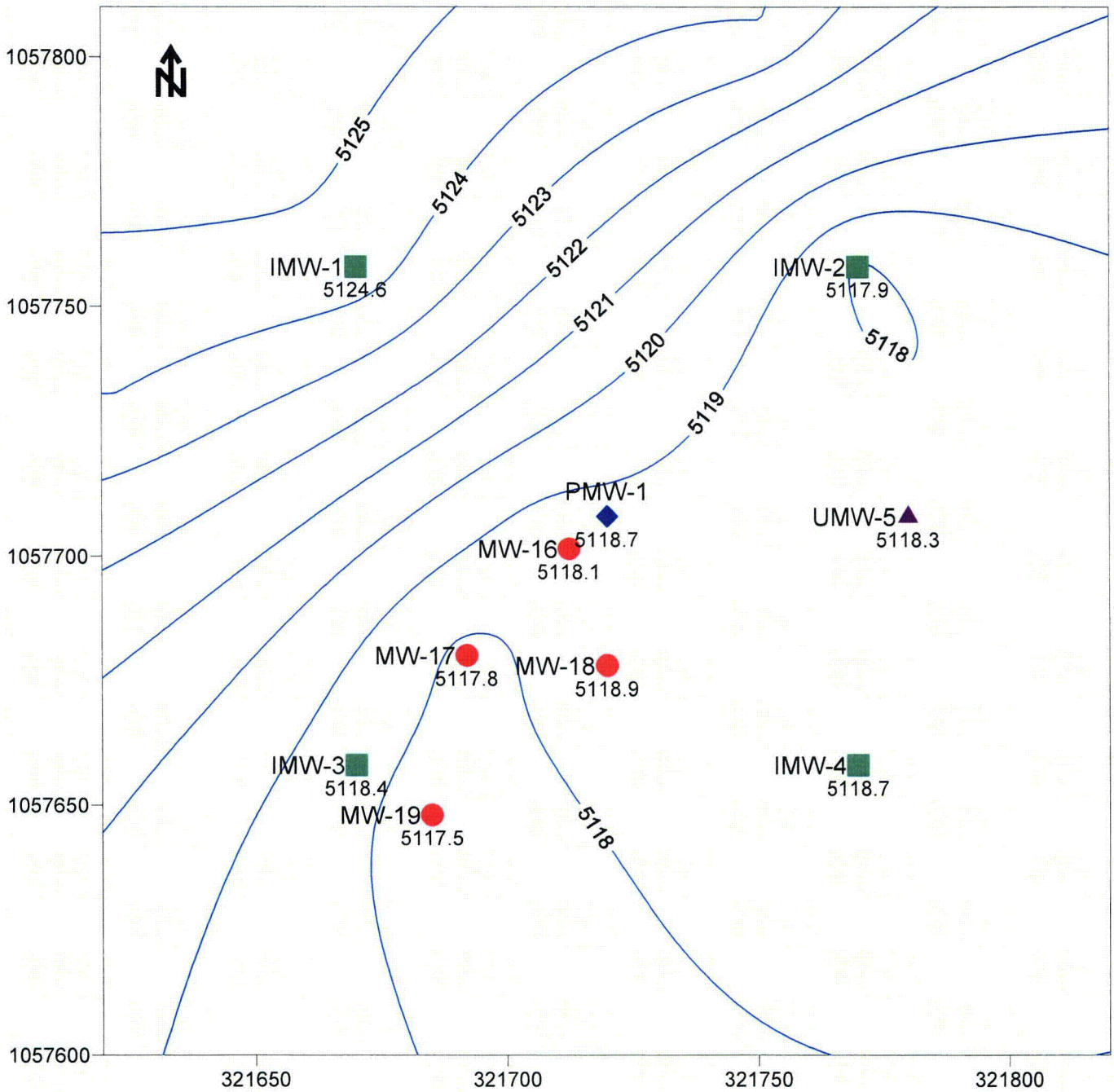
Figure 5ST(3). Top Elevation - 70 Sand - 5 Spot Test
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST3.srf Date: 08/08/08



Extraction Well

Injection Well

Monitor Well-Production Zone

Monitor Well-Underlying Aquifer

IMW3 Well Identification
5218.4 Bottom of 70 Sand Elevation (ft amsl)

0 25 50
feet

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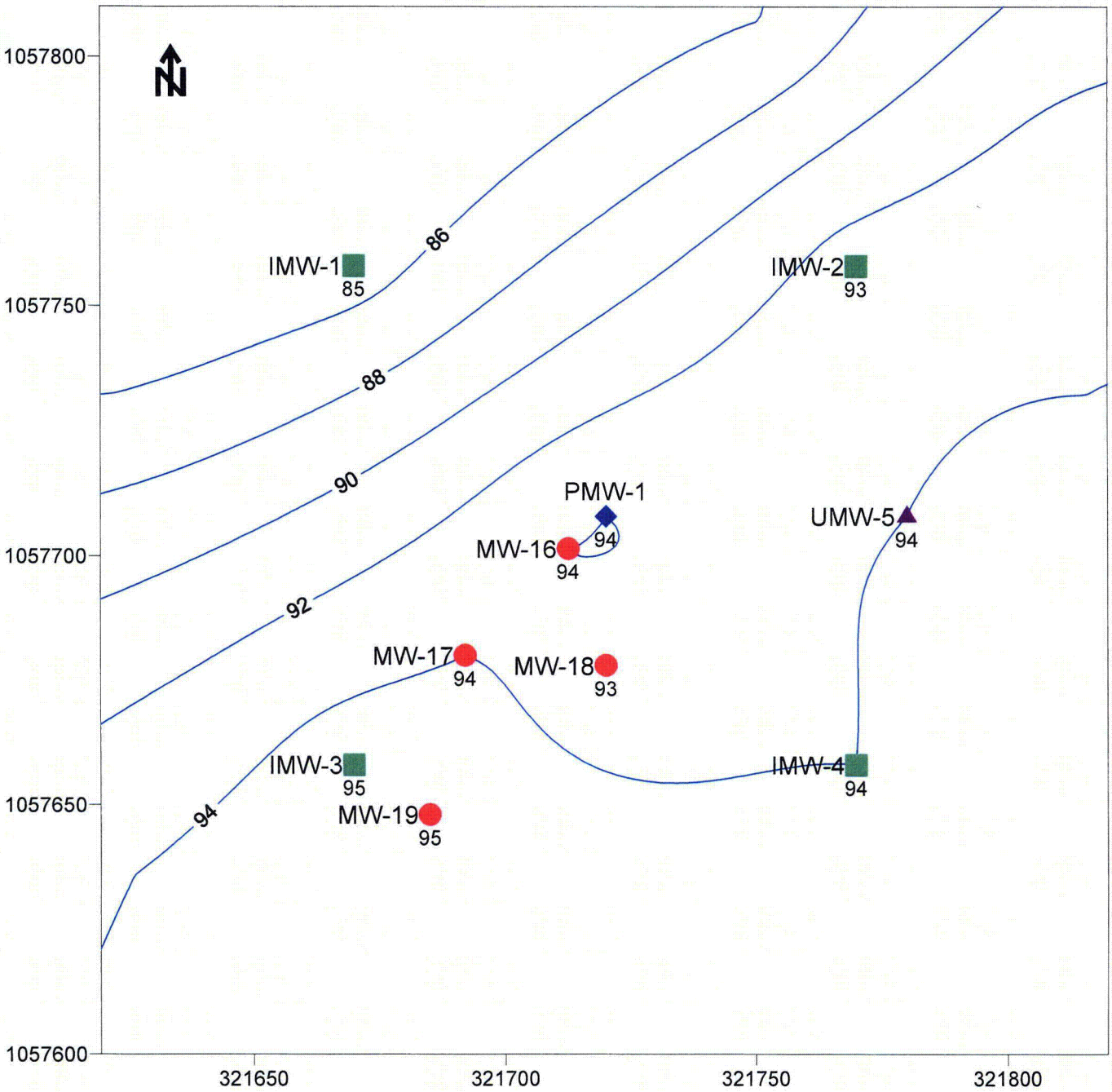
Figure 5ST(4). Bottom Elevation - 70 Sand - 5 Spot Test
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST4.srf Date: 08/08/08



Extraction Well

Injection Well

Monitor Well-Production Zone

Monitor Well-Underlying Aquifer

IMW3 Well Identification
96 70 Sand Thickness (ft)

0 25 50
feet

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Littleton, CO 80127-4239

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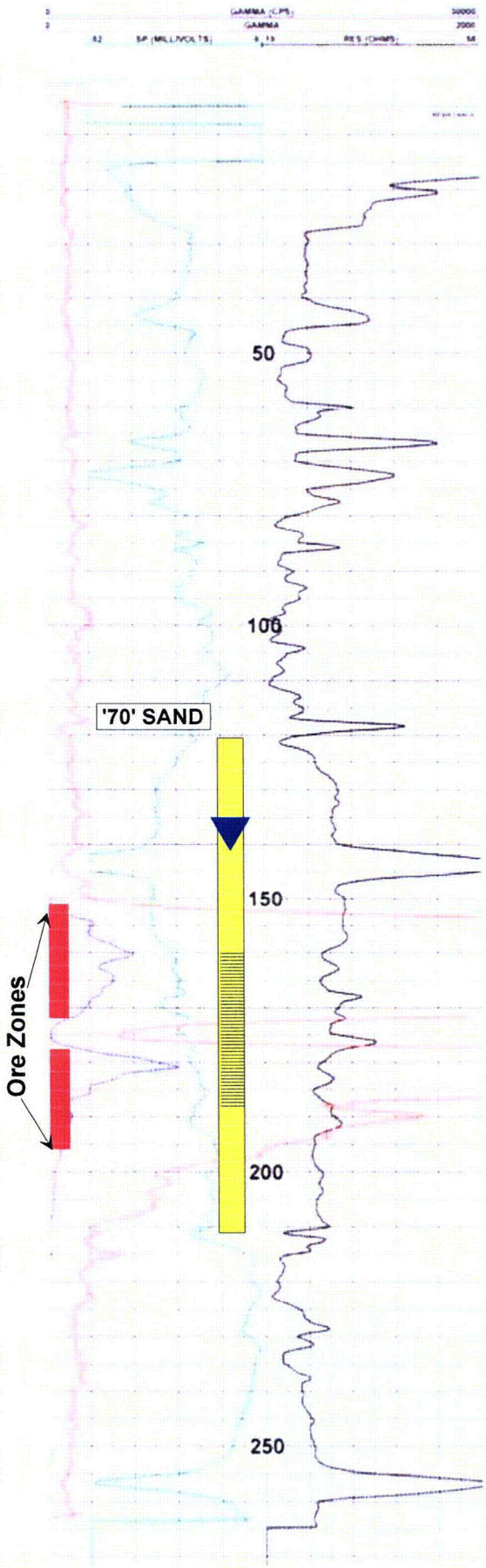
Figure 5ST(5). Thickness - 70 Sand - 5 Spot Test
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST5.srf Date: 08/08/08



Initial Depth to Water
142.4 feet on 5/7/08

70 Sand Interval
121' to 212' bgs

Screen Interval
160' to 188' bgs

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Figure 5ST(6). Recovery Well PMW1 -Electric Logs
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST-6.srf Date: 08/08/08

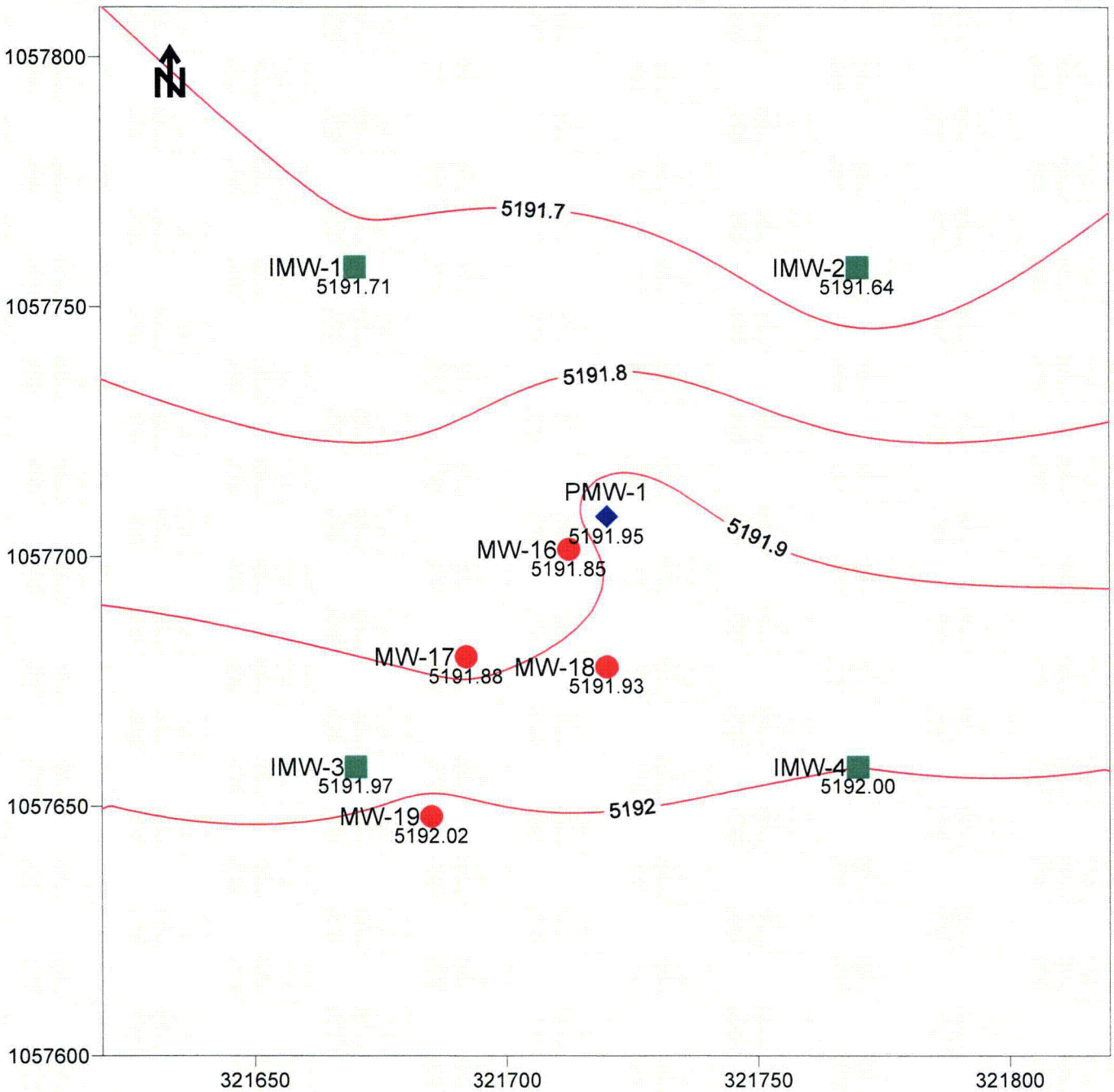

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Figure 5ST(7). Potentiometric Surface 70 Sand Prior to 5 Spot Test (5/7/08)
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST7.srf Date: 08/08/08

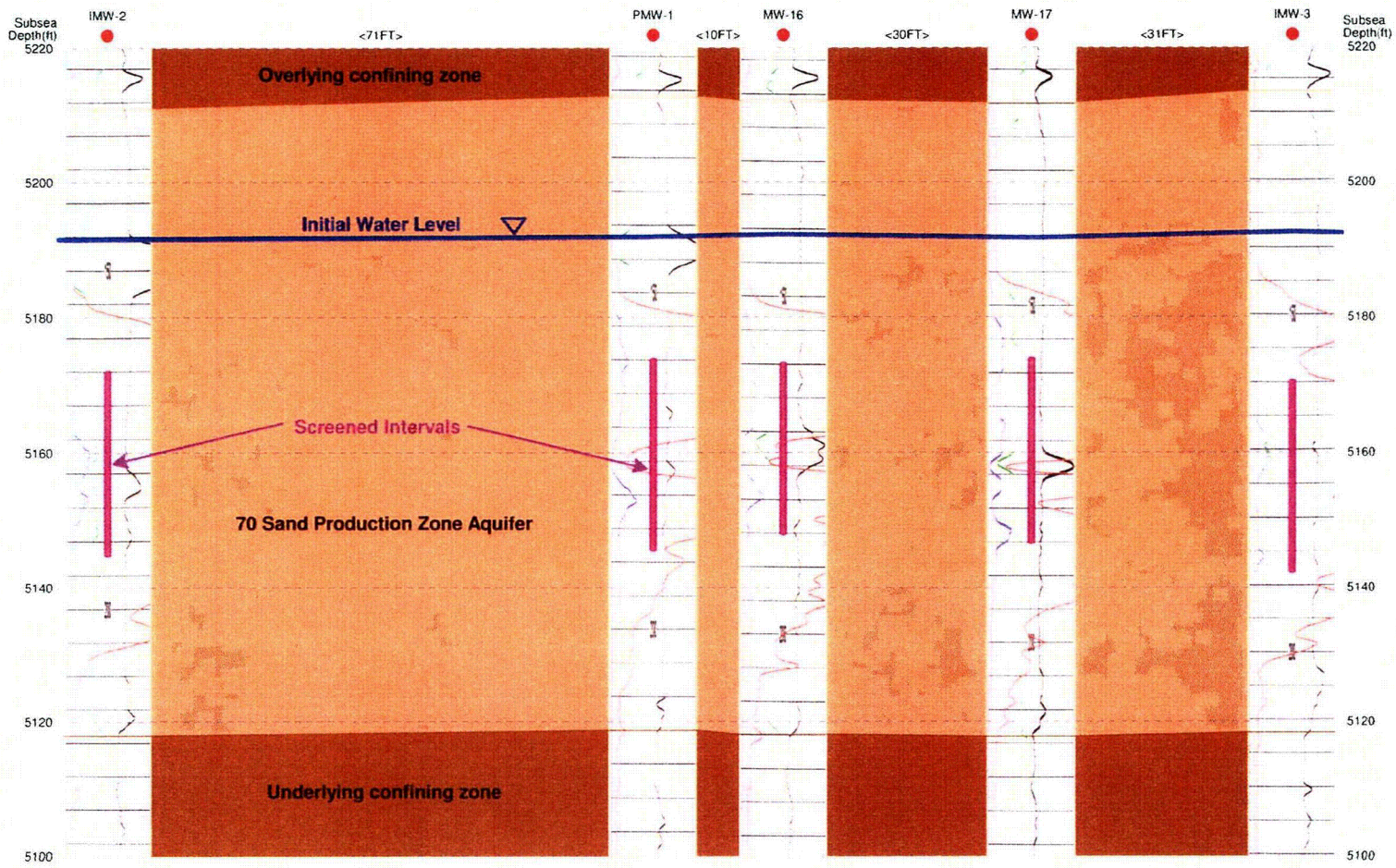

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Figure 5ST(8)
Hydrogeologic Cross Section
5-Spot Test, Initial Conditions

Project: 312-16	Date: August 2008	
File: 5ST(8).dwg	By: KRS	Checked: EPL

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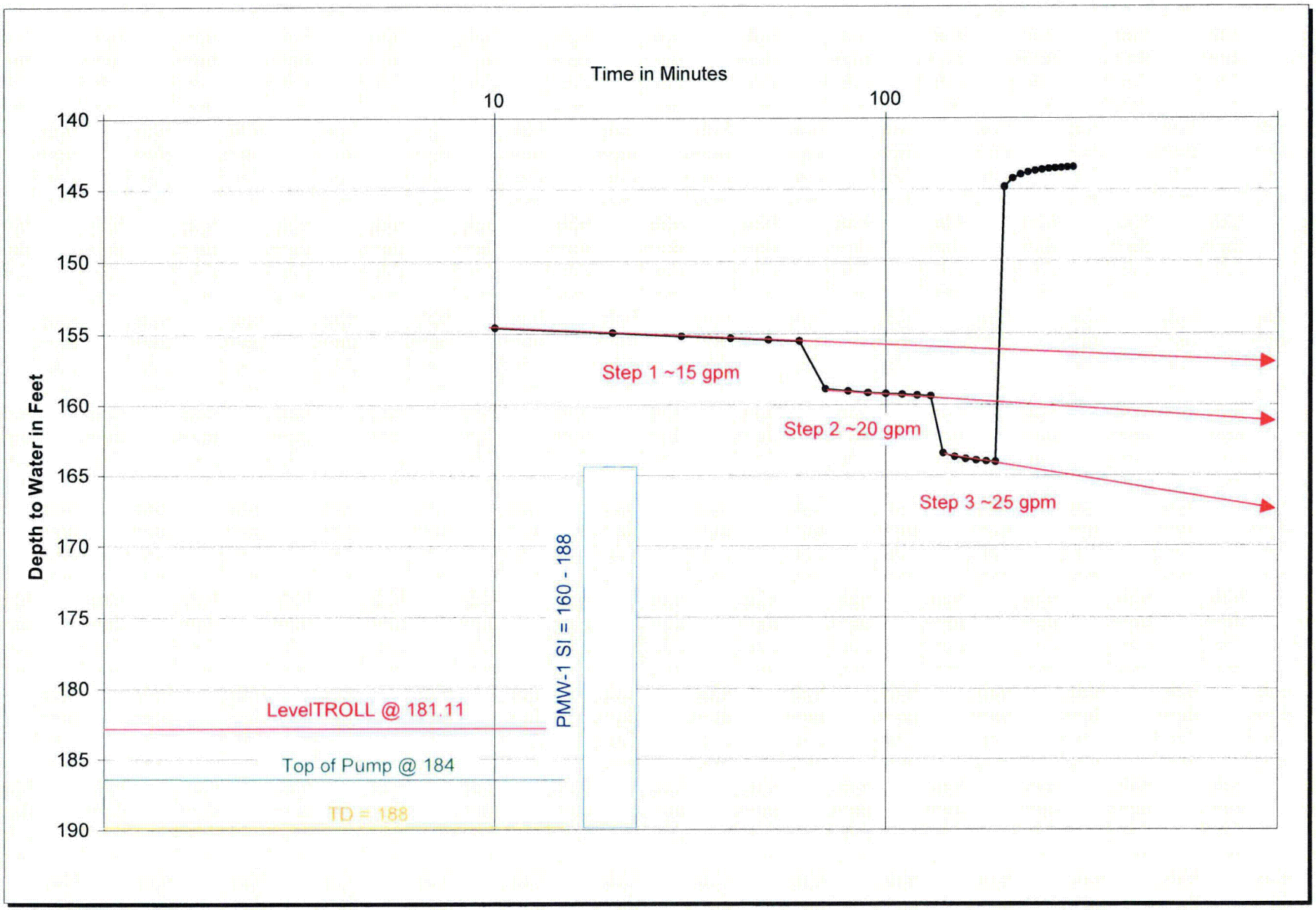

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Figure 5ST(9). Result of Step Test - PMW1
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST-9.srf Date: 08/08/08

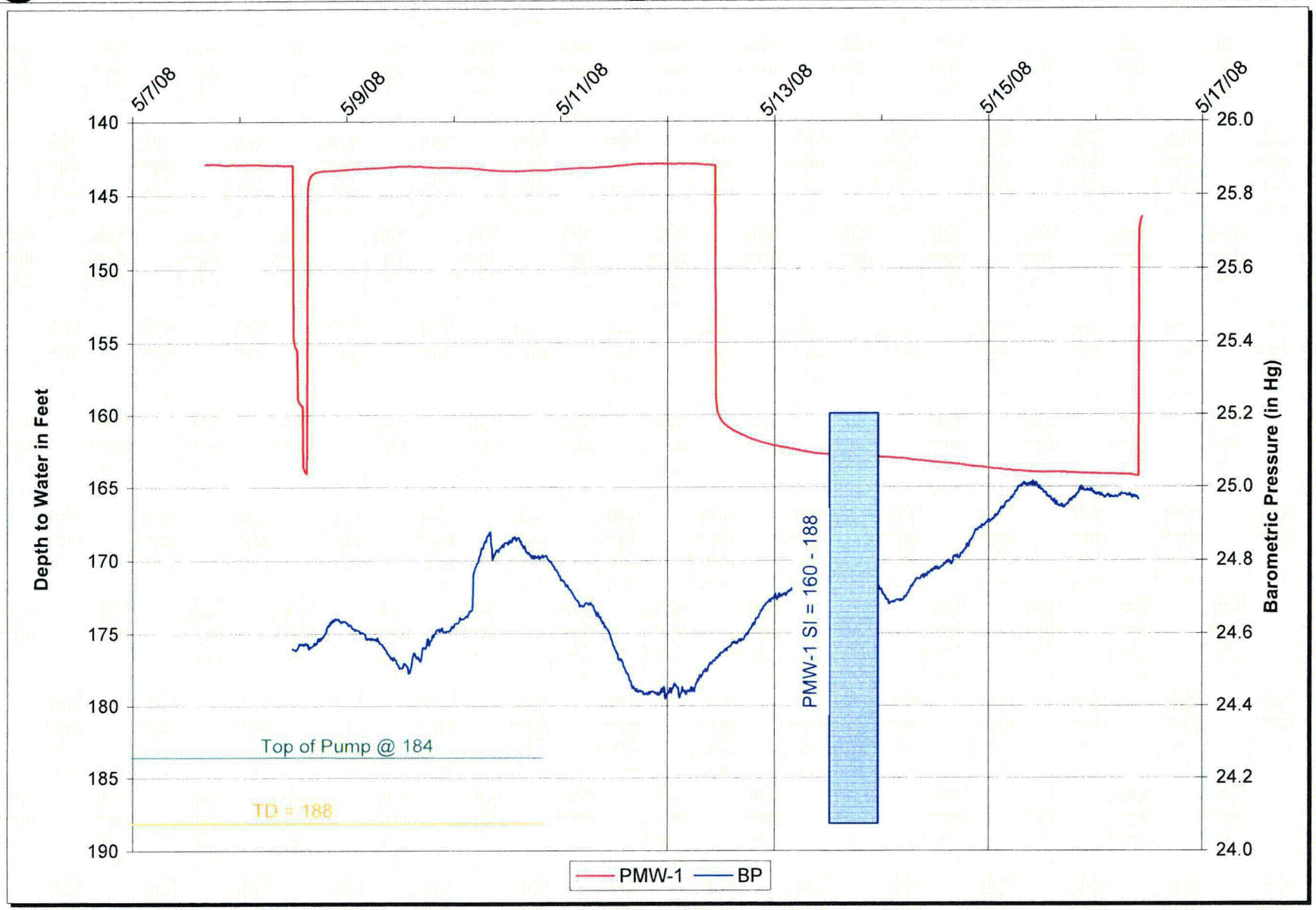

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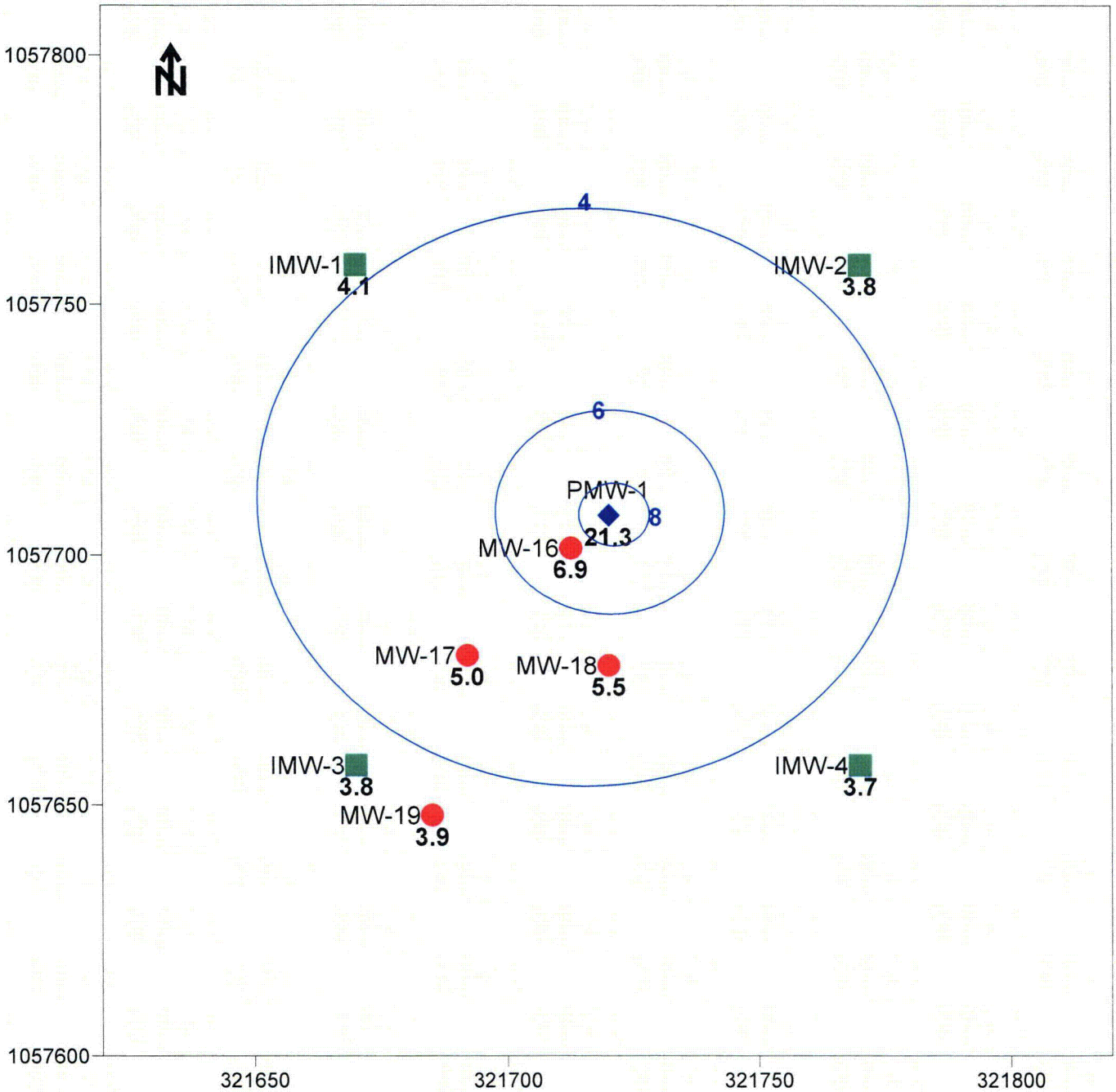
Figure 5ST(10). Extraction Test Response - PMW1
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST-10.srf Date: 08/08/08



Extraction Well

Injection Well

Monitor Well-Production Zone

IMW3 Well Identification
3.8 Drawdown at End of Extraction Test (ft)

0 25 50
feet

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Figure 5ST(11). Drawdown-End of Extraction Test
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST11.srf Date: 08/08/08

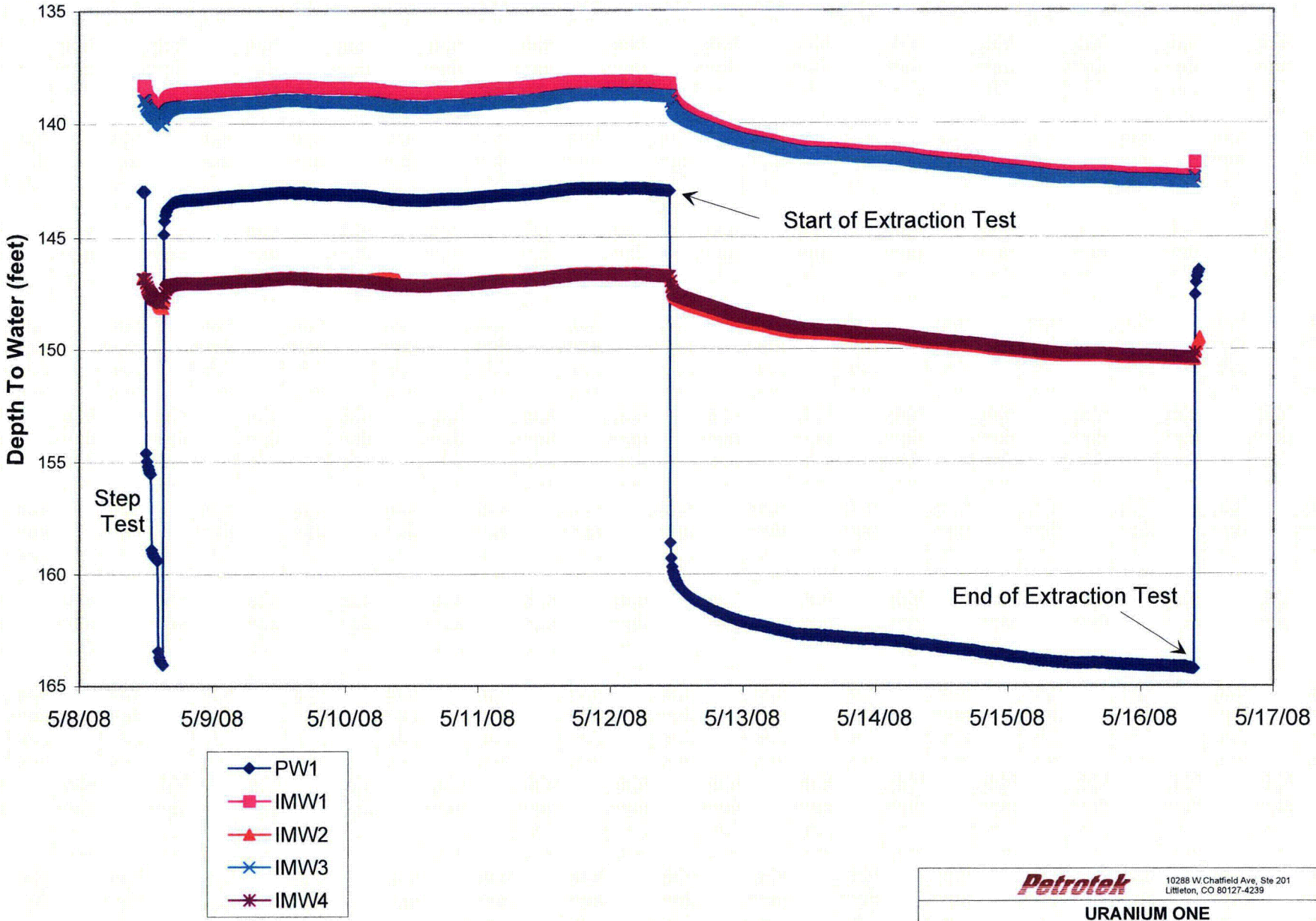

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Figure 5ST(12). Extraction Test Results at Injection Wells Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST-12.srf Date: 08/08/08

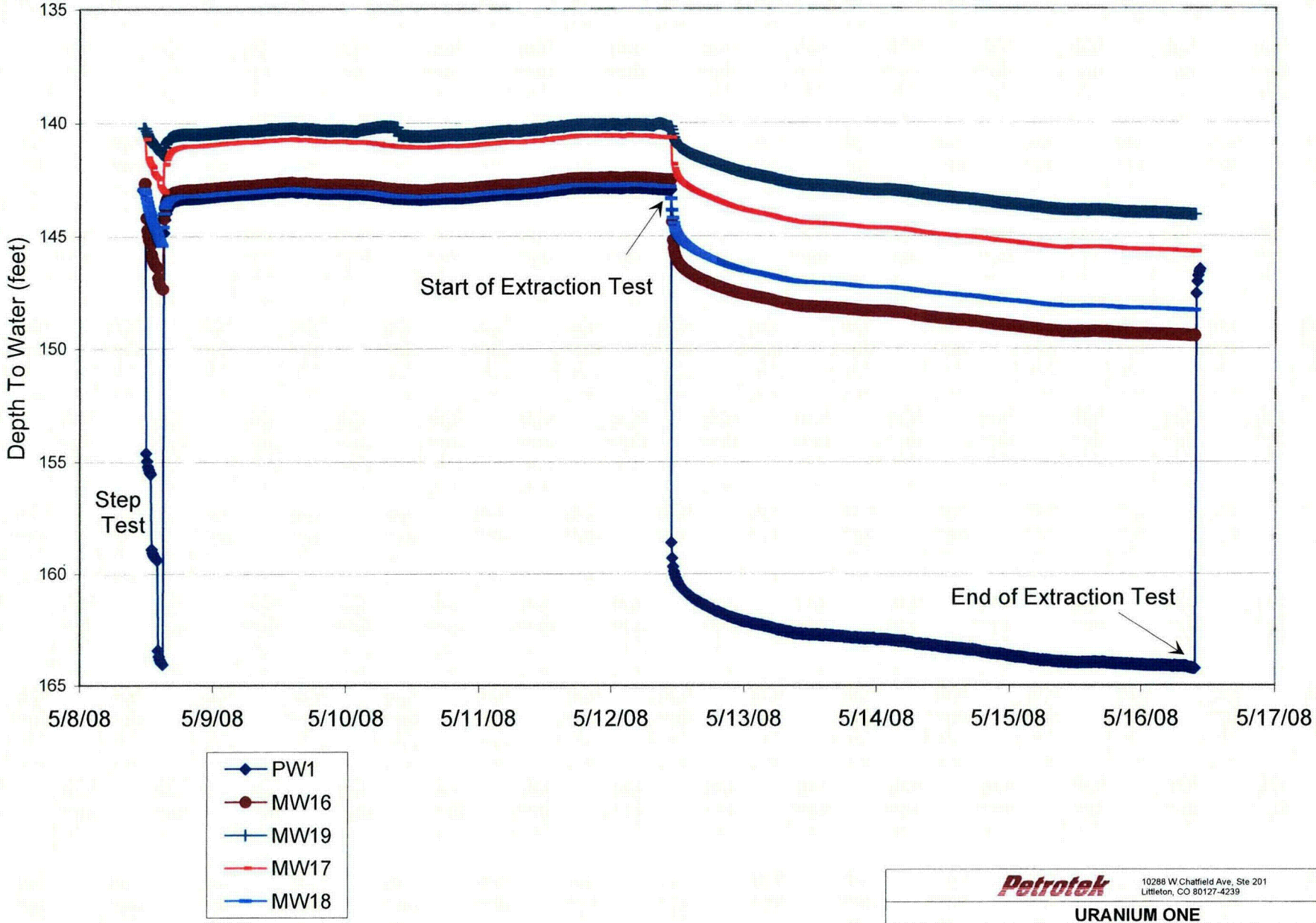

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Figure 5ST(13). Exxtraction Test Results at 70 Sand Monitor Wells Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST-13.srf Date: 08/08/08

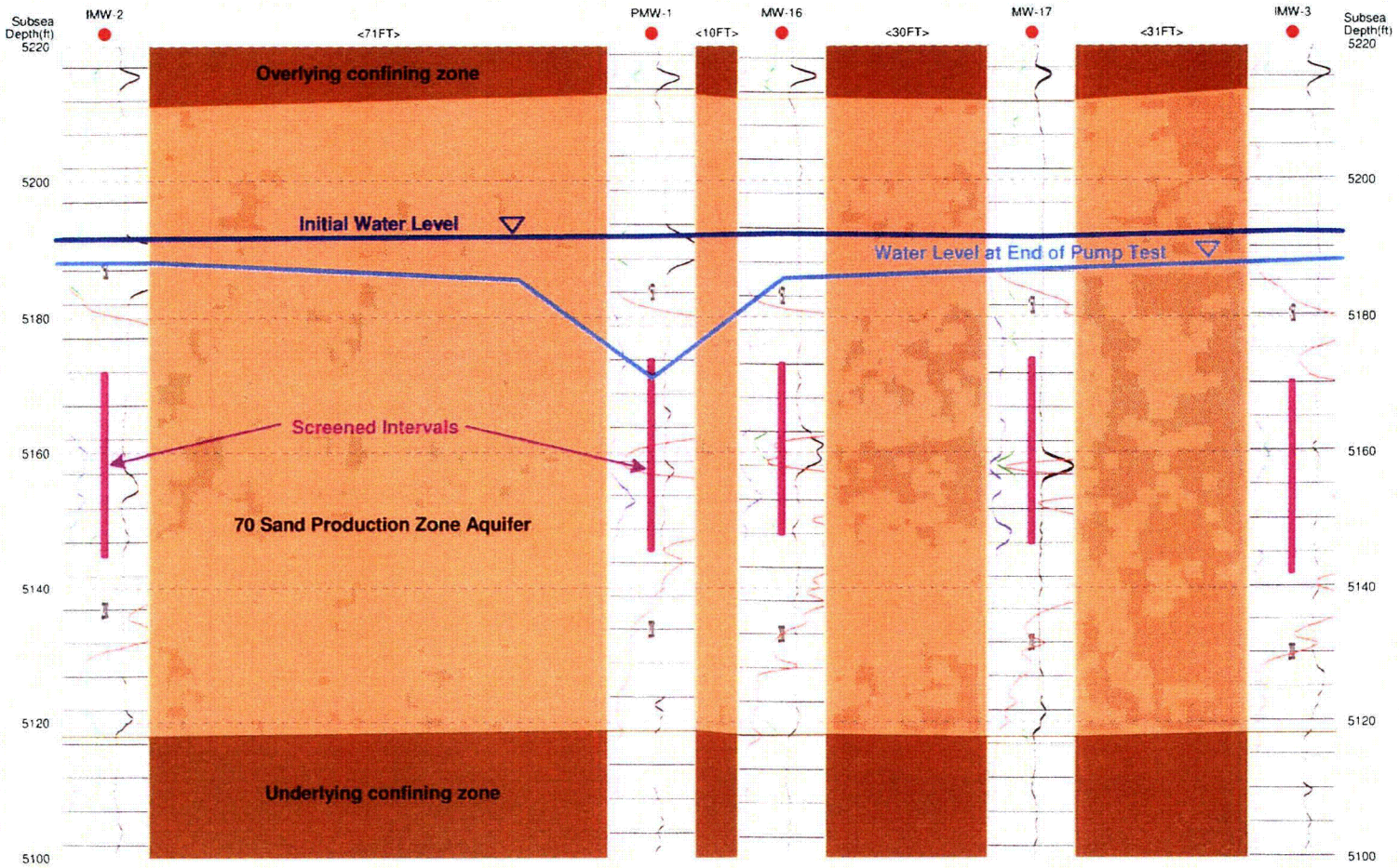

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Figure 5ST(14)
Hydrogeologic Cross Section
End of Extraction Test

Project: 312-16	Date: August 2008	
File: 5ST(14).dwg	By: KRS	Checked: EPL

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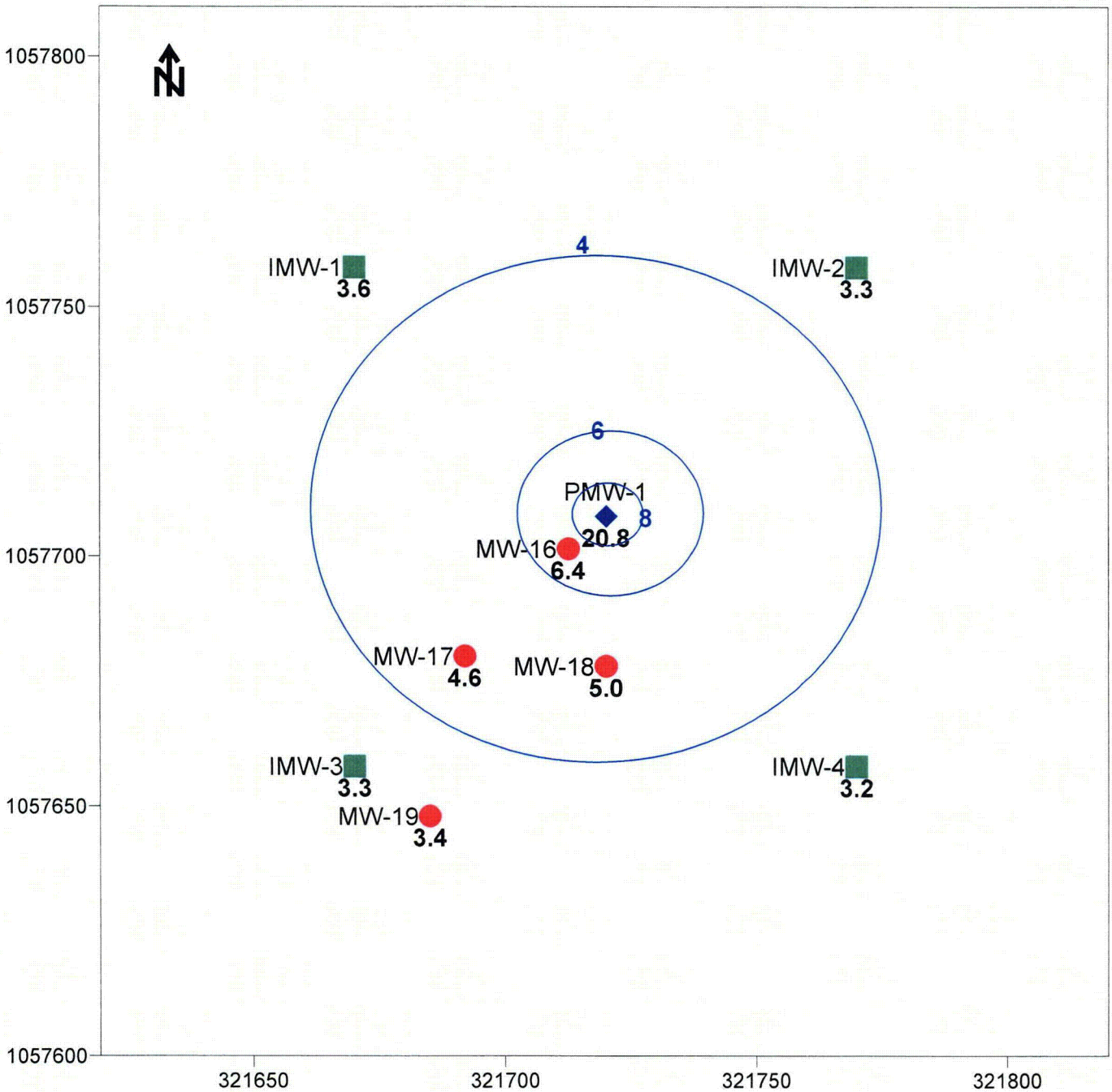

Extraction Well

Injection Well

Monitor Well-Production Zone

IMW3 Well Identification
3.8 Barometrically Corrected Drawdown at End of Extraction Test (ft)

0 25 50
feet

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Figure 5ST(15). Barometrically Corrected Drawdown End of Extraction Test Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST15.srf Date: 08/08/08

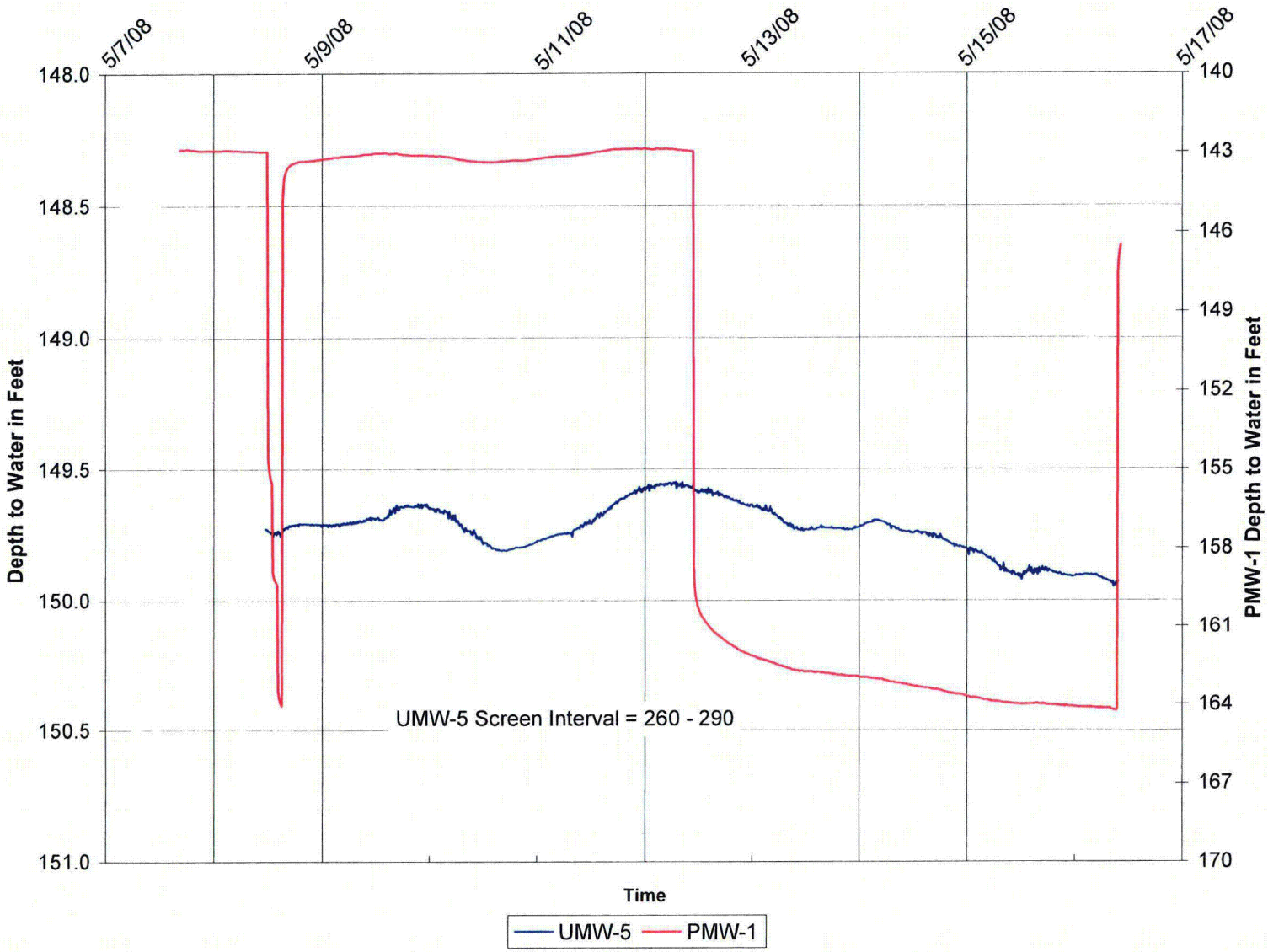

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Figure 5ST(16). Extraction Test Response - UMW5
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST-16.srf Date: 08/08/08

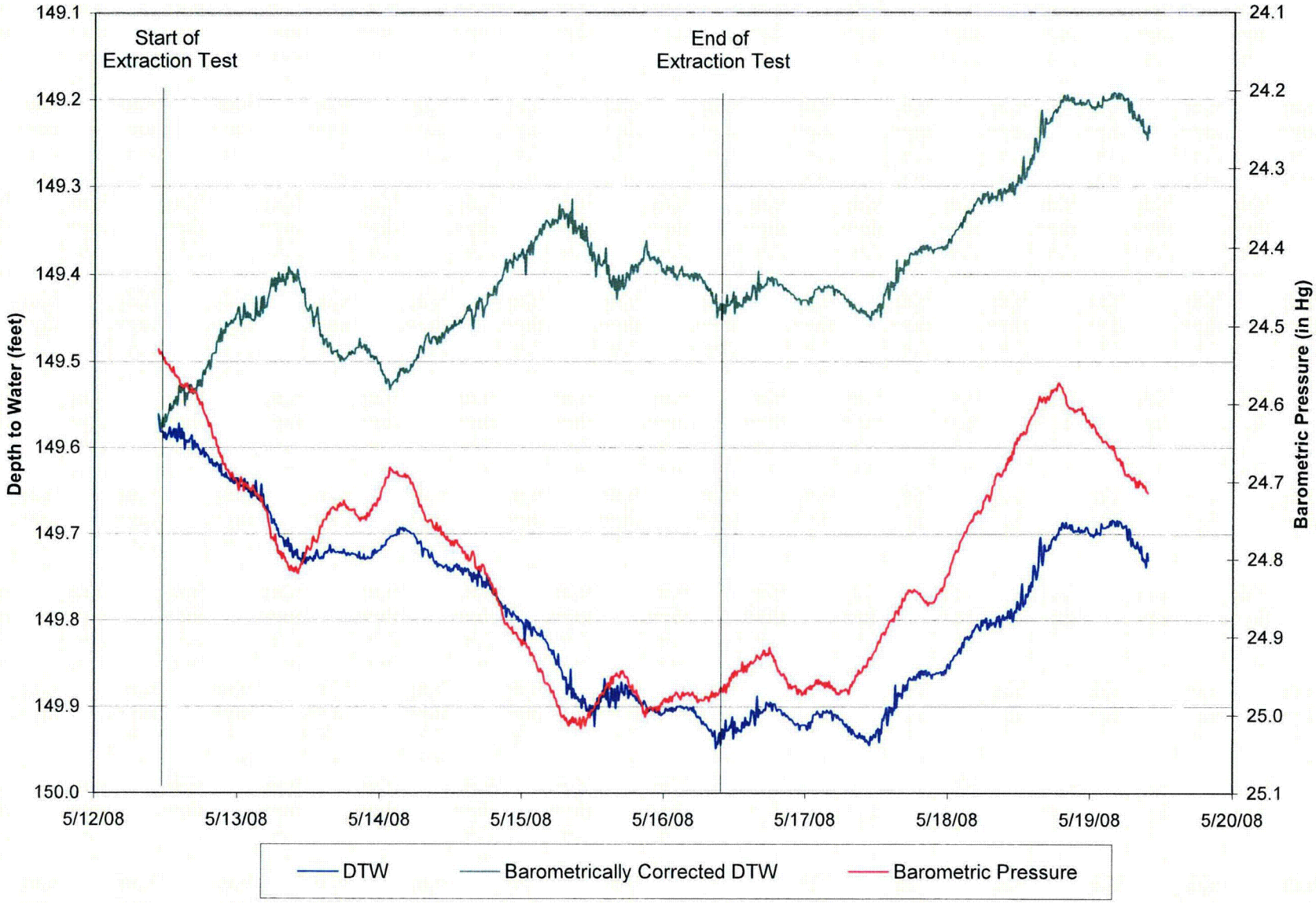

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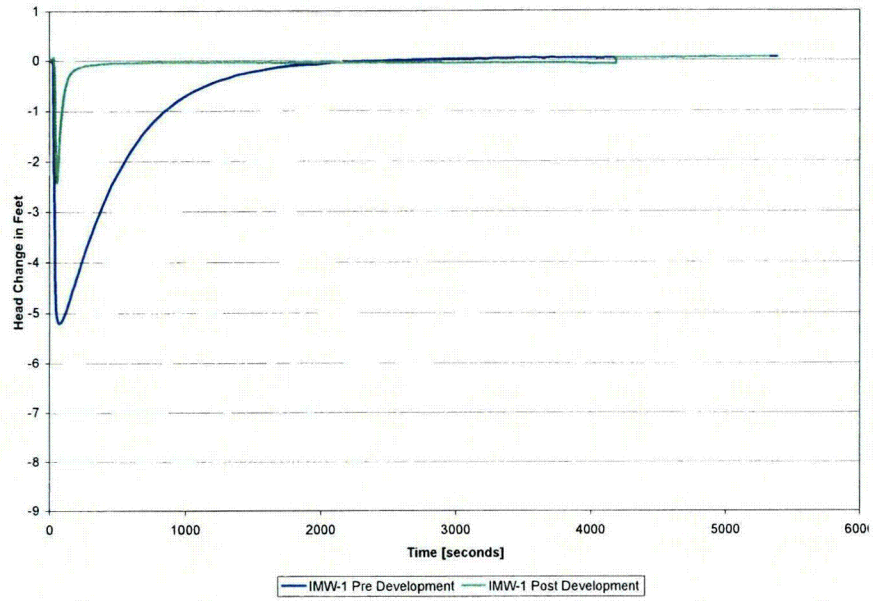
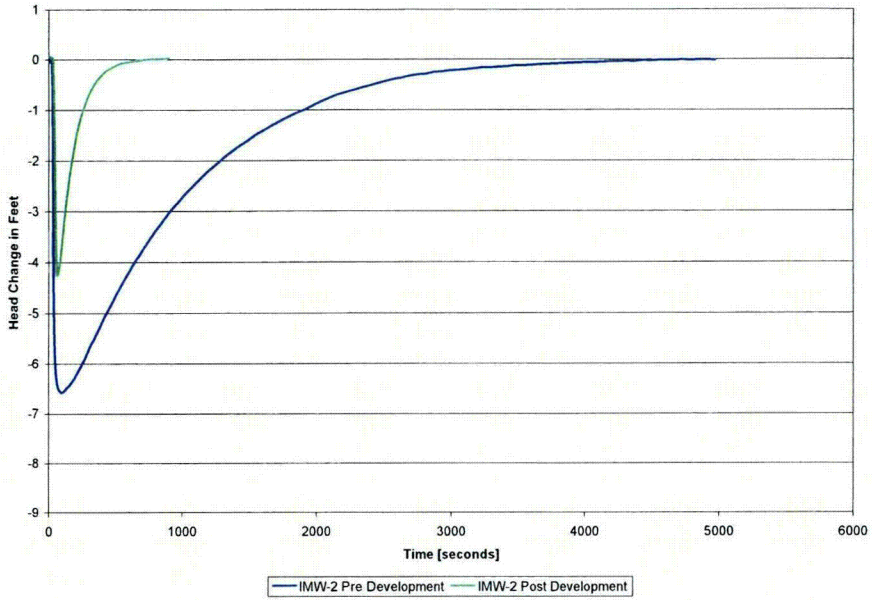
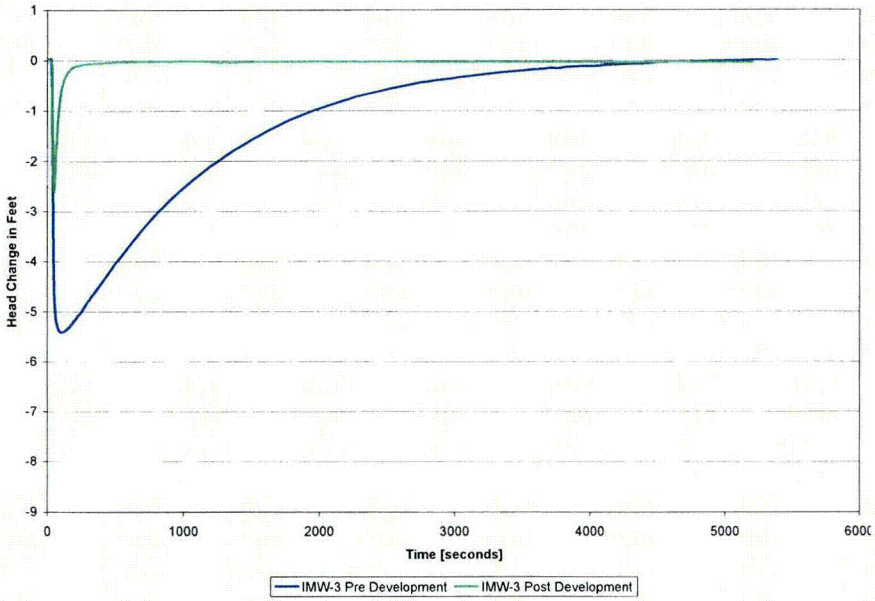
Figure 5ST(17). Barometrically Corrected Depth to Water- UMW5
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST-17.srf Date: 08/08/08







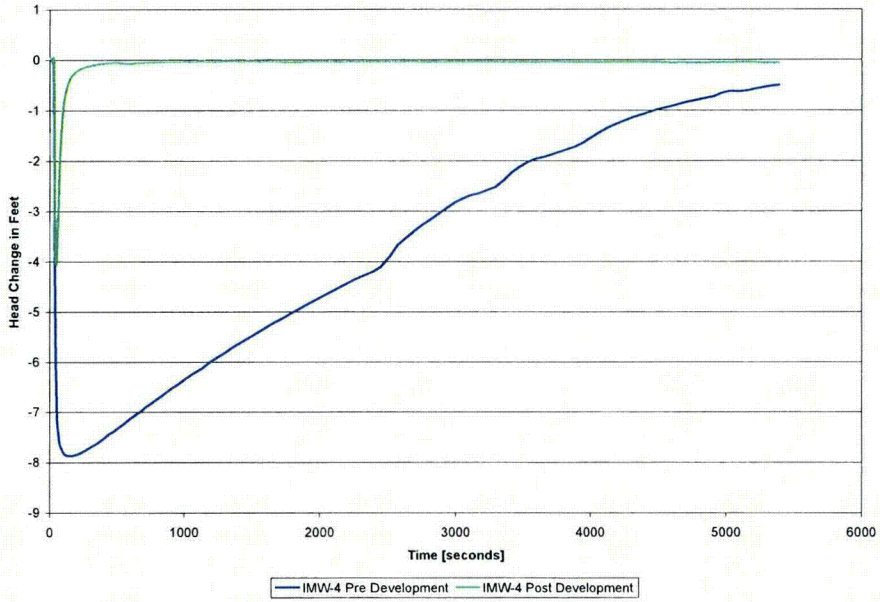


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Figure 5ST(18). Pre and Post Development Slug Test Results
Injection Wells
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST-18.srf Date: 08/08/08

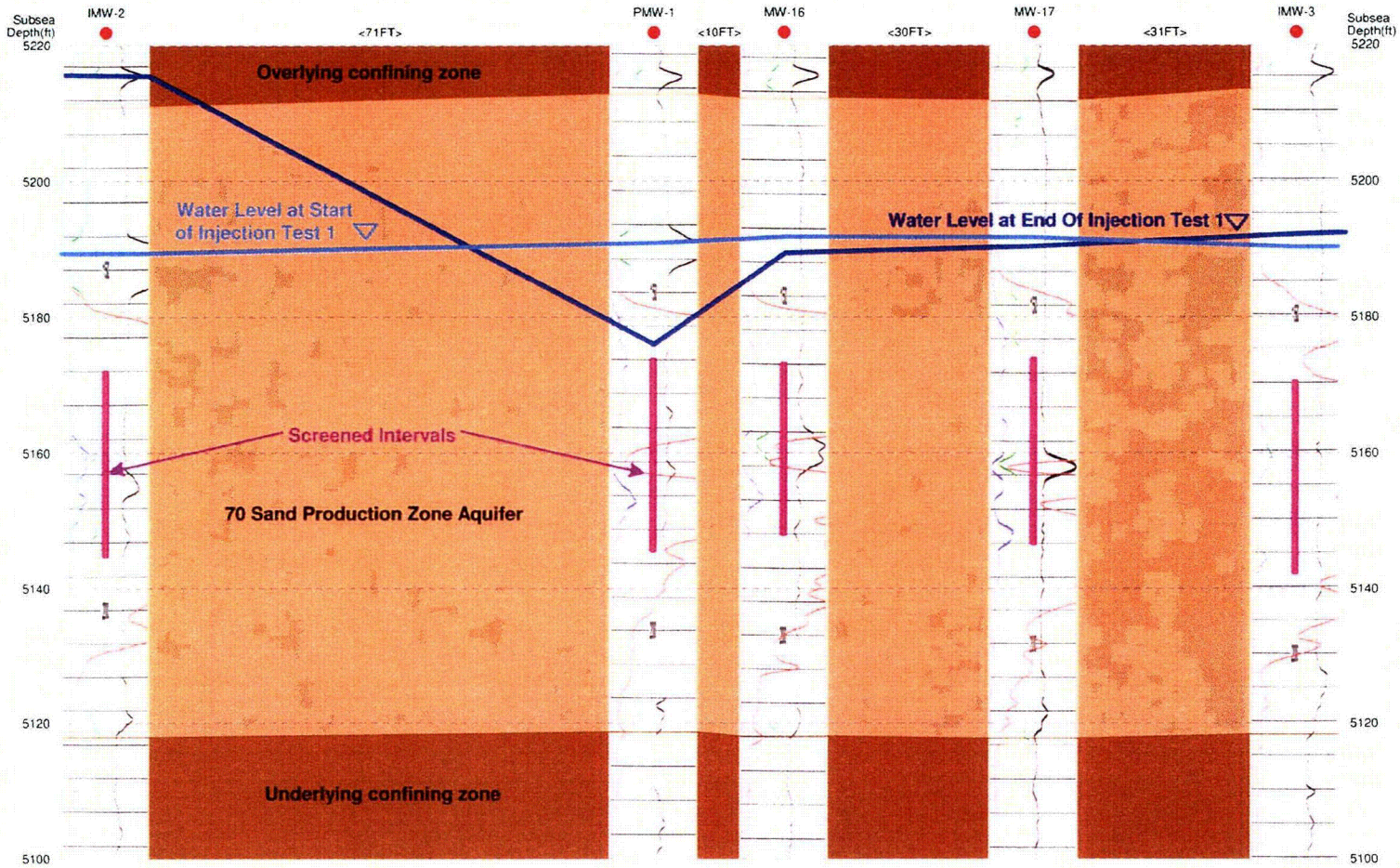

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Figure 5ST(19)
Hydrogeologic Cross Section
First Stage, Extraction/Injection Test

Project: 312-16	Date: August 2008	
File: 5ST(19).dwg	By: KRS	Checked: EPL

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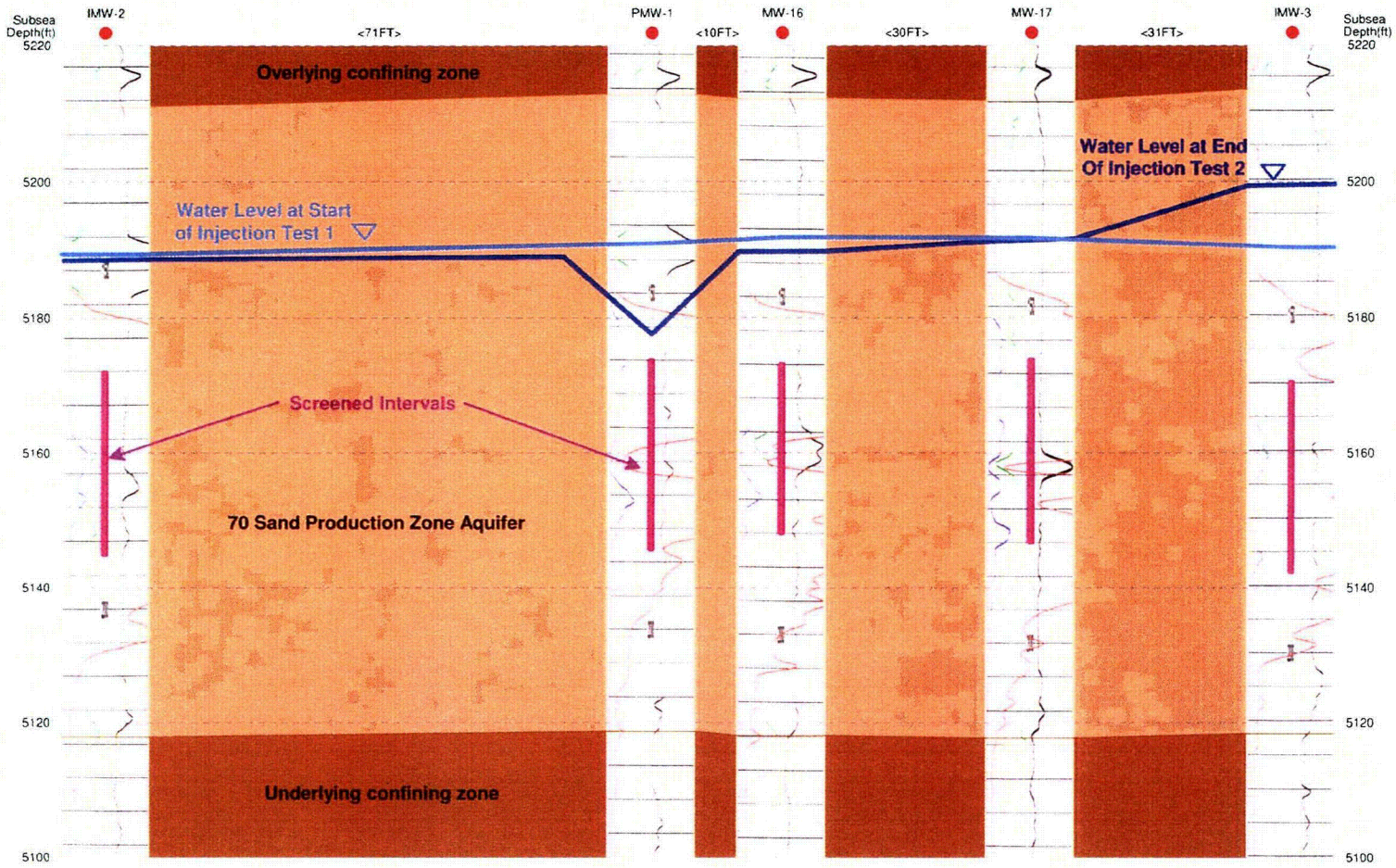

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Figure 5ST(20)
Hydrogeologic Cross Section
Second Stage, Extraction/Injection Test

Project: 312-16	Date: August 2008	
File: 5ST(20).dwg	By: KRS	Checked: EPL

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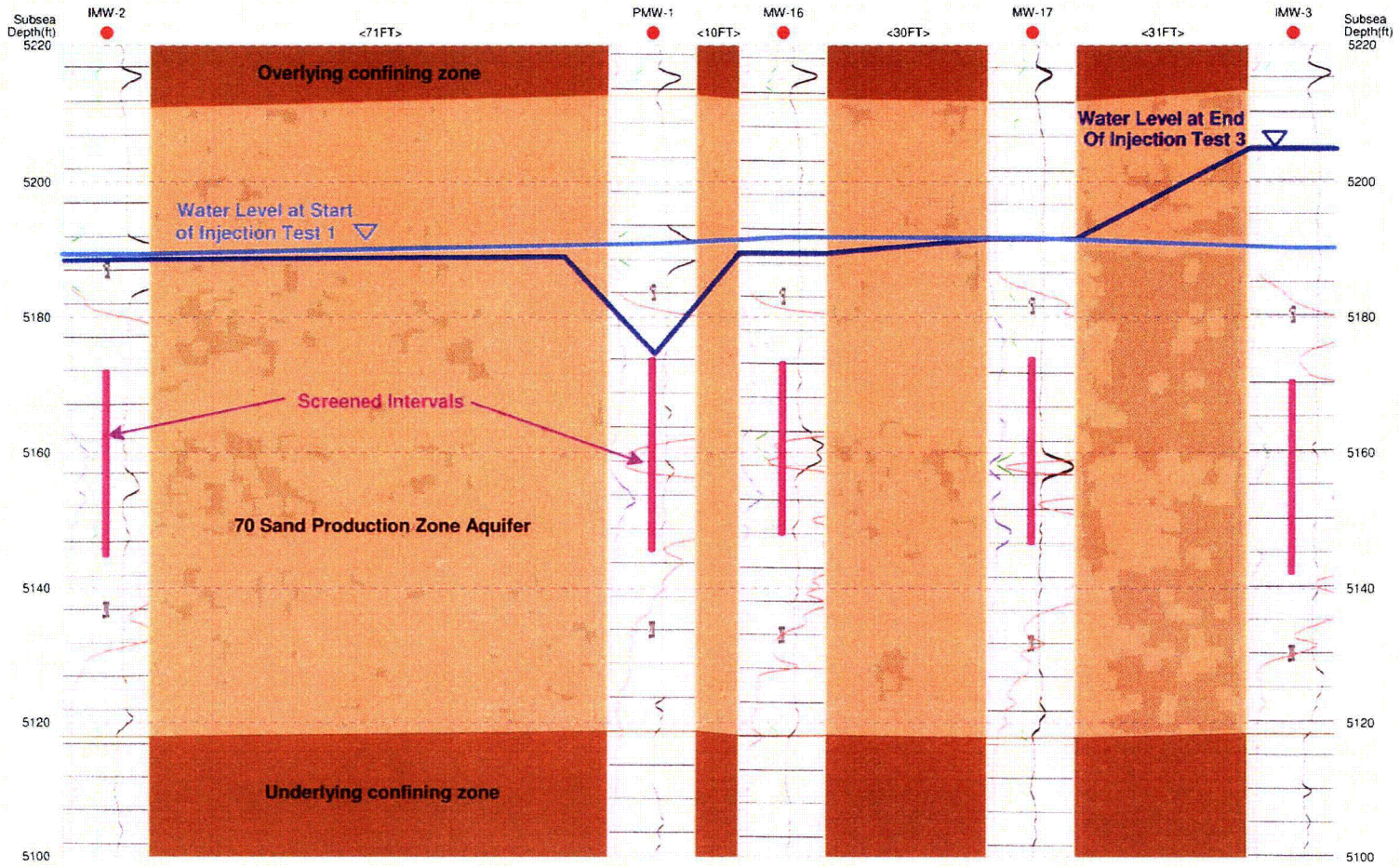

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Figure 5ST(21)
Hydrogeologic Cross Section
Third Stage, Extraction/Injection Test

Project: 312-16	Date: August 2008	
File: 5ST(21).dwg	By: KRS	Checked: EPL

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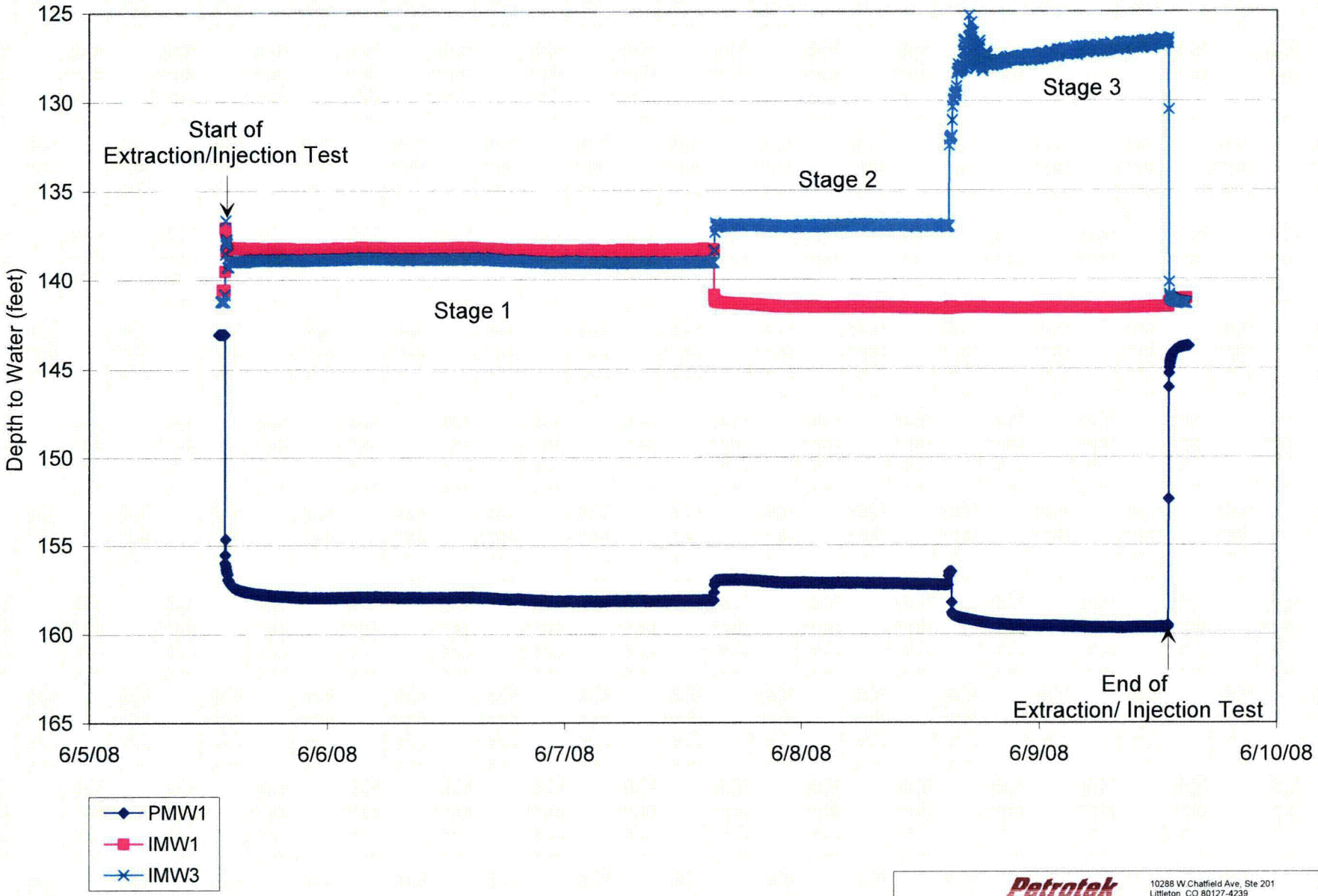

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Figure 5ST(22). Extraction/InjectionTest Response Injection Wells IMW1 and IMW3, Recovery Well PMW1 Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST-22.srf Date: 08/08/08

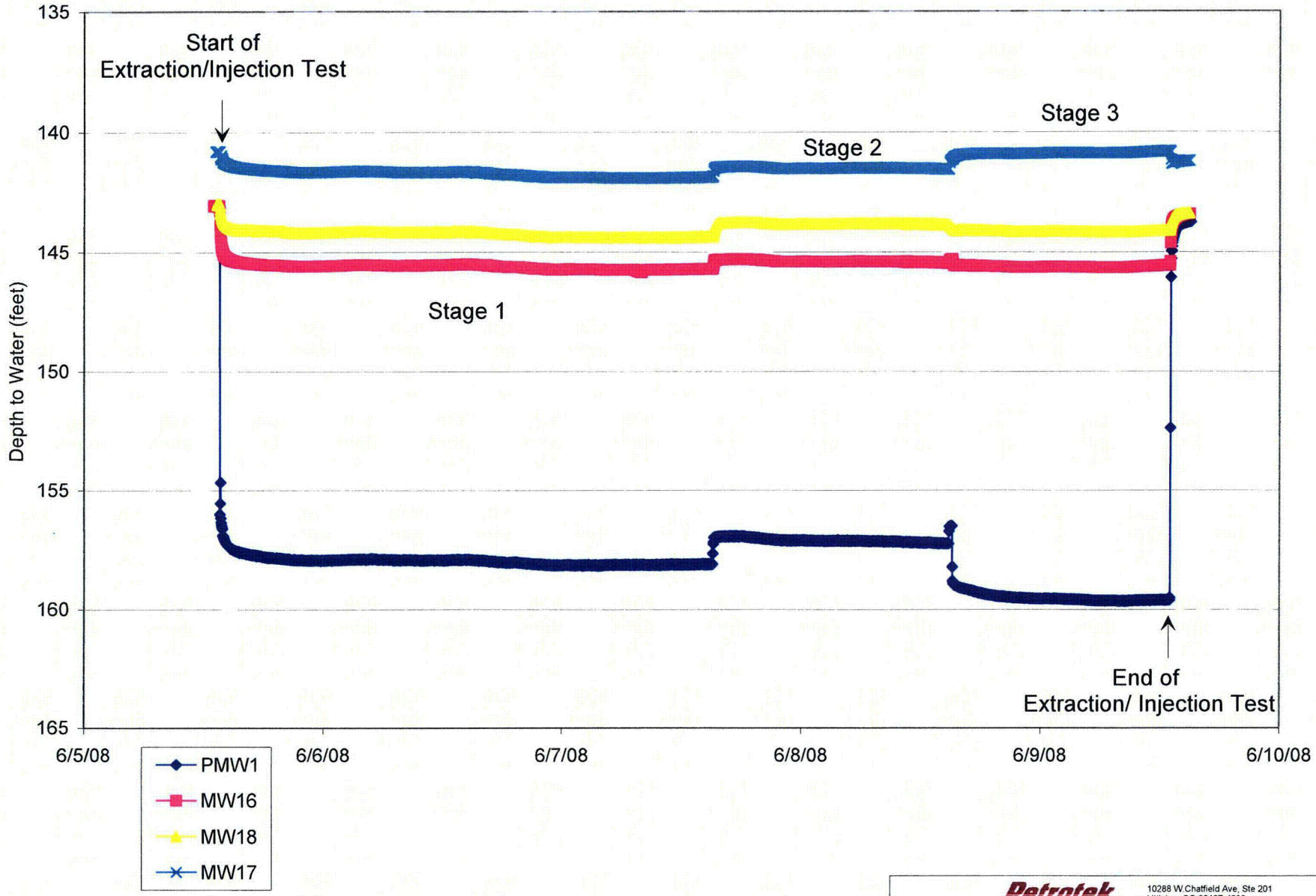

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Figure 5ST(23). Extraction/InjectionTest Response Monitor Wells MW16, MW17 and MW18 Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST-23.srf Date: 08/08/08

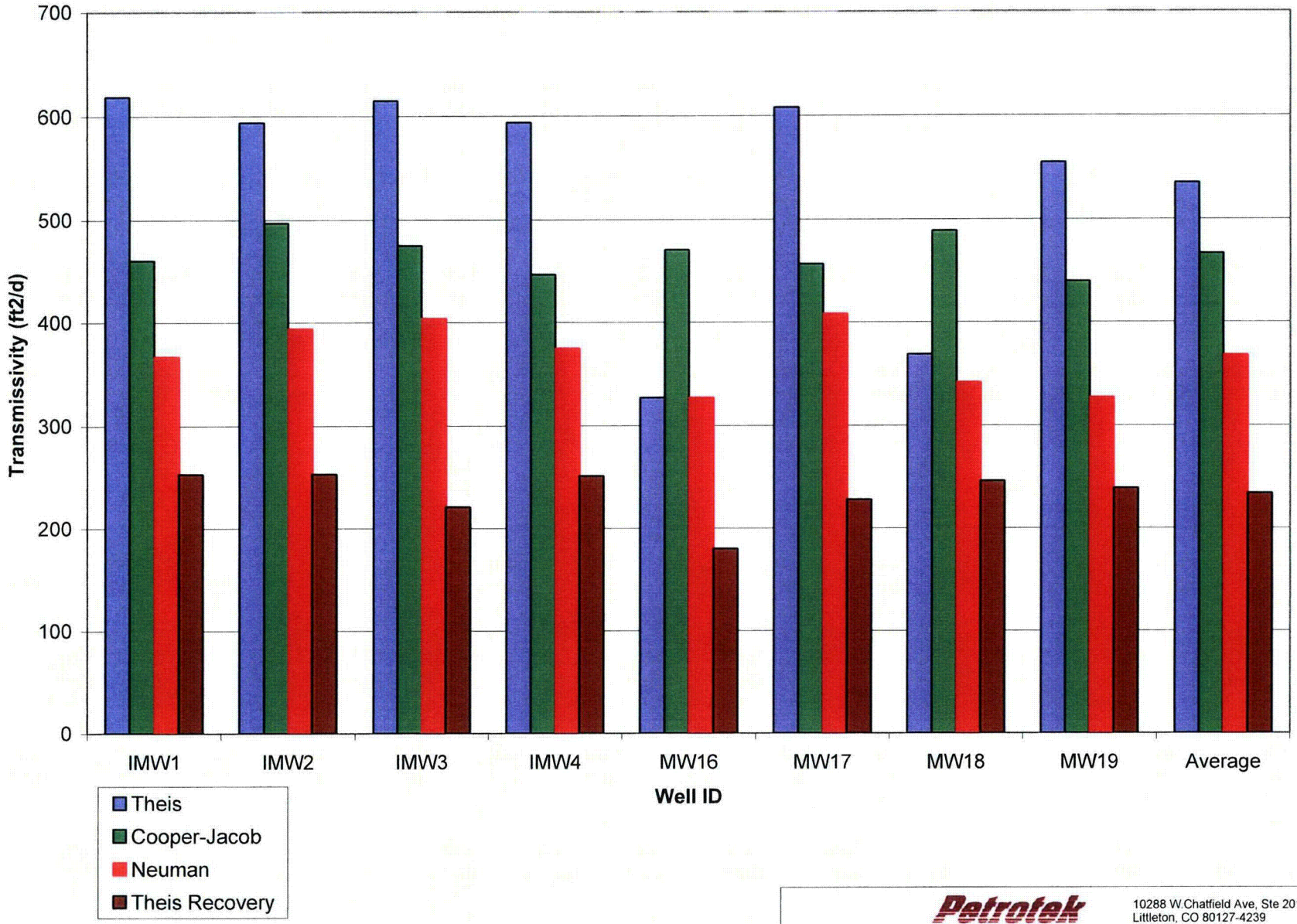

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Figure 5ST(24). Transmissivity - 5-Spot Extraction Test
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST-24.srf Date: 08/08/08

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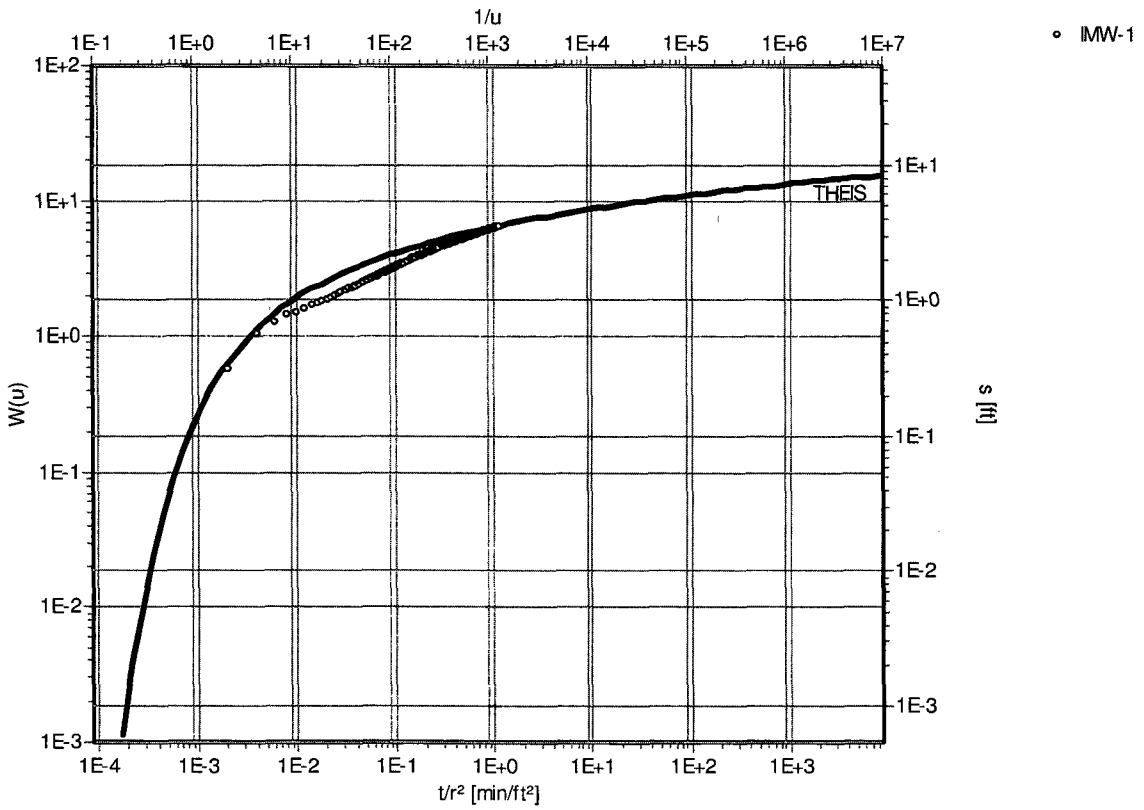
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas

5 Spot Pump Test Barometric Correction [Theis]



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Theis**

Analysis Results:	Transmissivity:	6.34E+2 [ft²/d]	Conductivity:	8.80E+0 [ft/d]

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/28/2008

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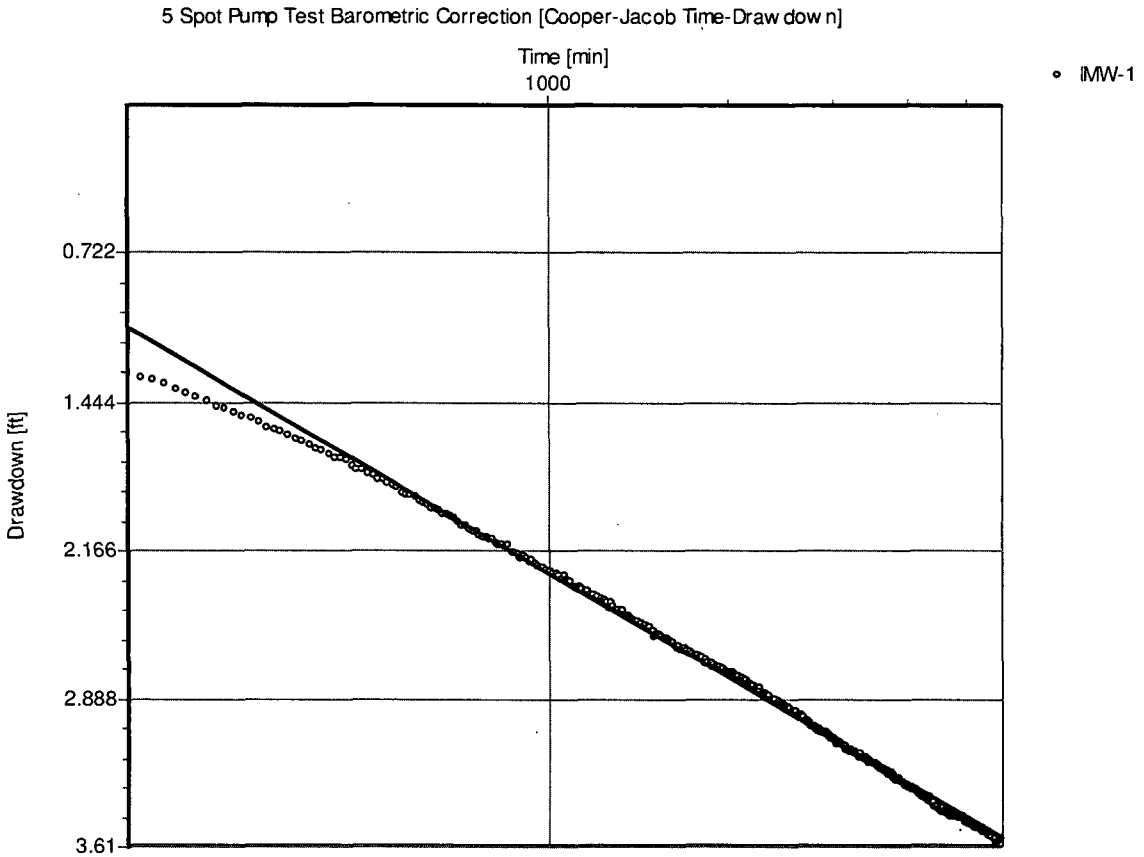
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Cooper-Jacob Time-Drawdown**

Analysis Results:	Transmissivity:	4.61E+2 [ft²/d]	Conductivity:	6.41E+0 [ft/d]

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Confined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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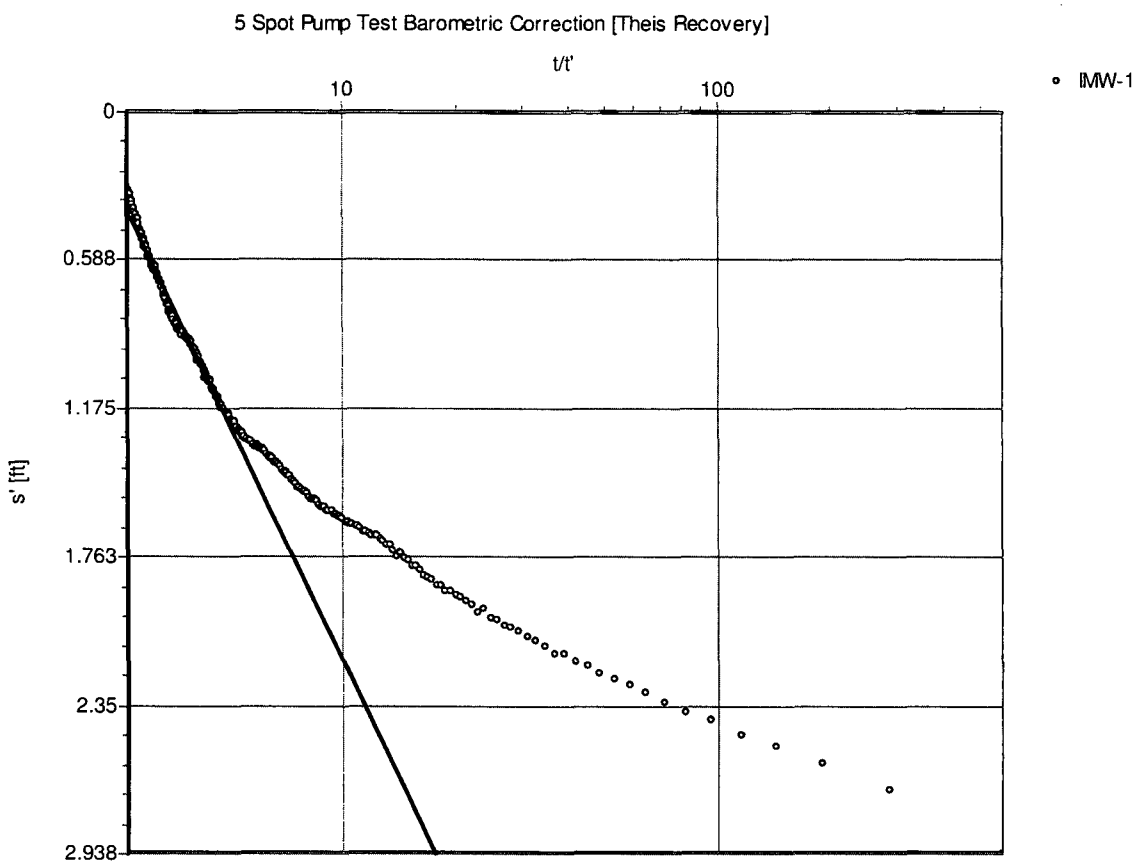
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Theis Recovery**

Analysis Results:	Transmissivity:	2.53E+2 [ft²/d]	Conductivity:	3.51E+0 [ft/d]

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		
	Pumping Time	5700 [min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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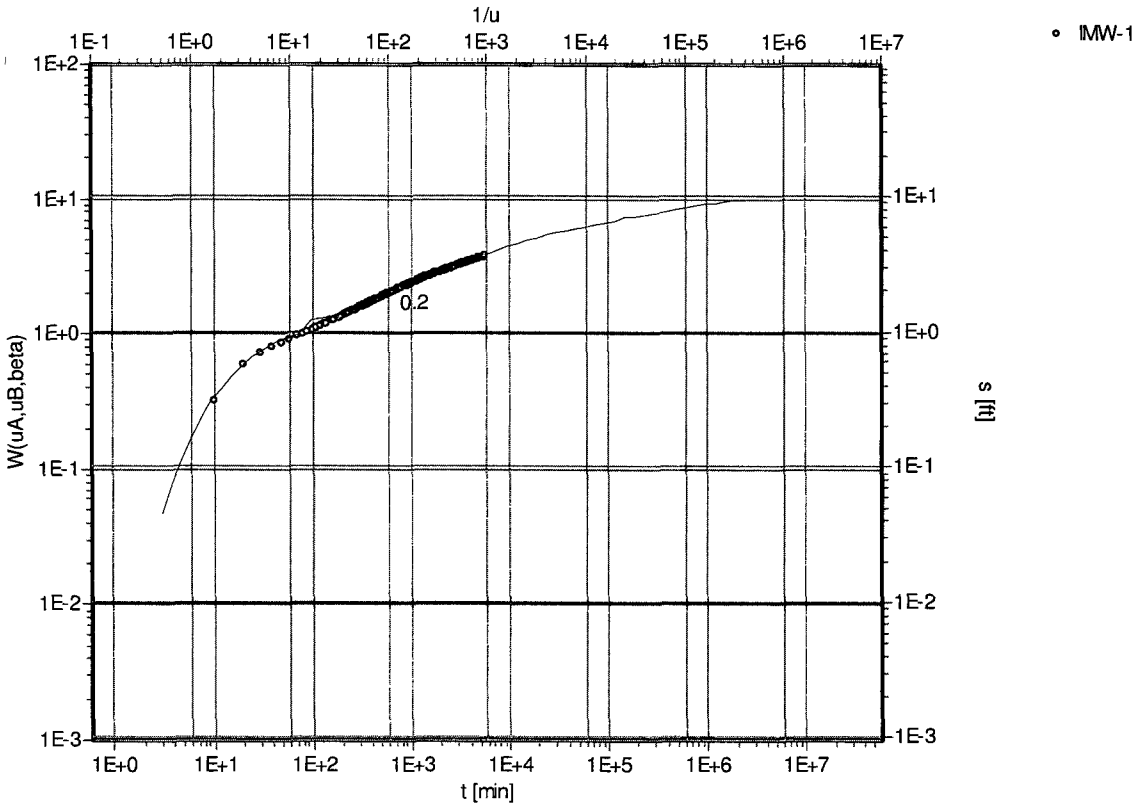
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas

5 Spot ExtractionTest -Barometric Correction Applied [Neuman]



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Neuman**

Analysis Results:	Transmissivity:	3.59E+2 [ft²/d]	Conductivity:	4.99E+0 [ft/d]
	Storativity:	1.20E-3	Specific Yield:	1.20E-2

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Beta:	0.2
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		
	LOG(Sy/S):	1		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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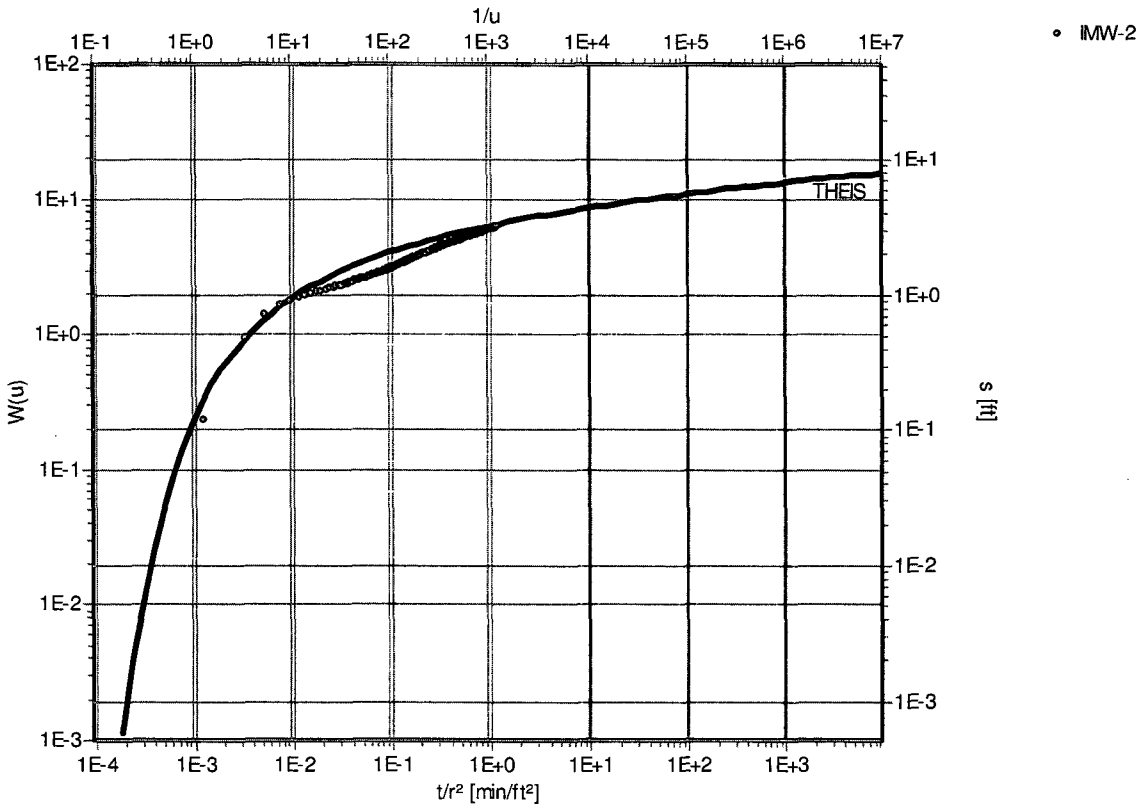
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas

5 Spot Pump Test Barometric Correction [Theis]



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Theis**

Analysis Results:	Transmissivity:	6.67E+2 [ft²/d]	Conductivity:	9.26E+0 [ft/d]

Test parameters:				
	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/28/2008

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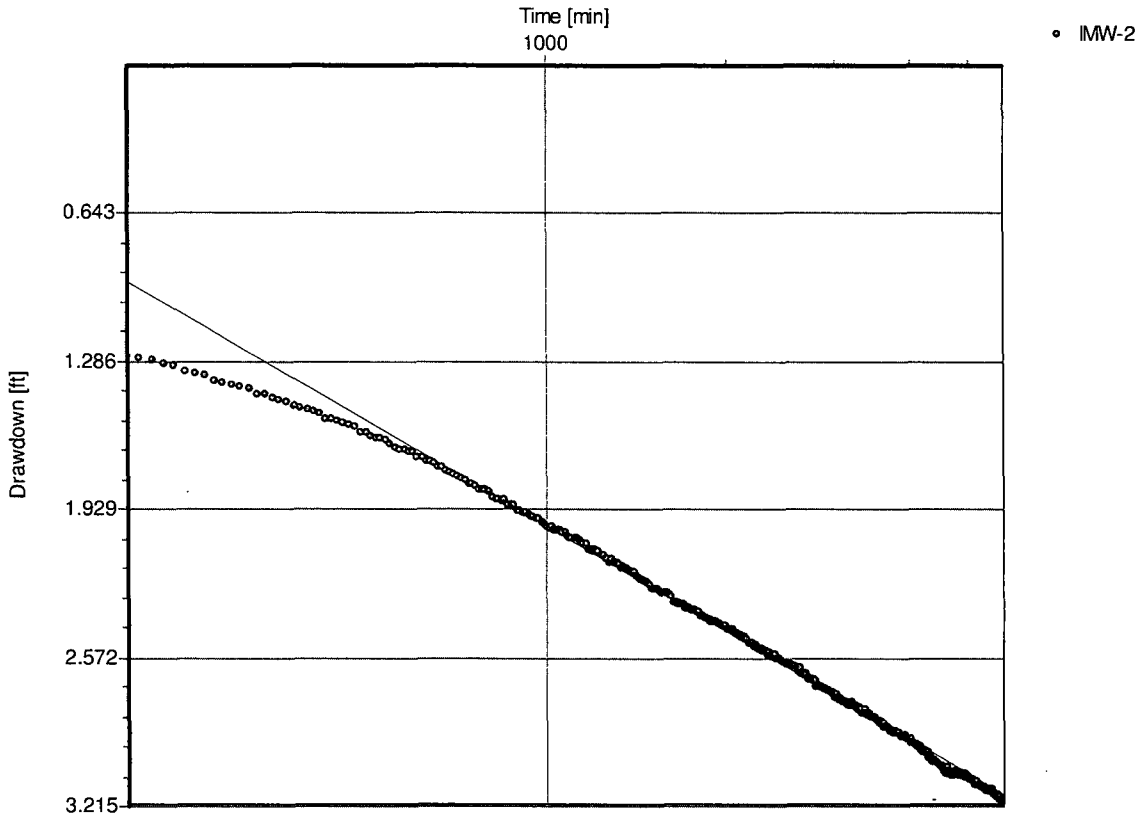
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas

5 Spot Pump Test Barometric Correction [Cooper-Jacob Time-Draw dow n]



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Cooper-Jacob Time-Drawdown**

Analysis Results:	Transmissivity:	5.10E+2 [ft²/d]	Conductivity:	7.08E+0 [ft/d]

Test parameters:				
	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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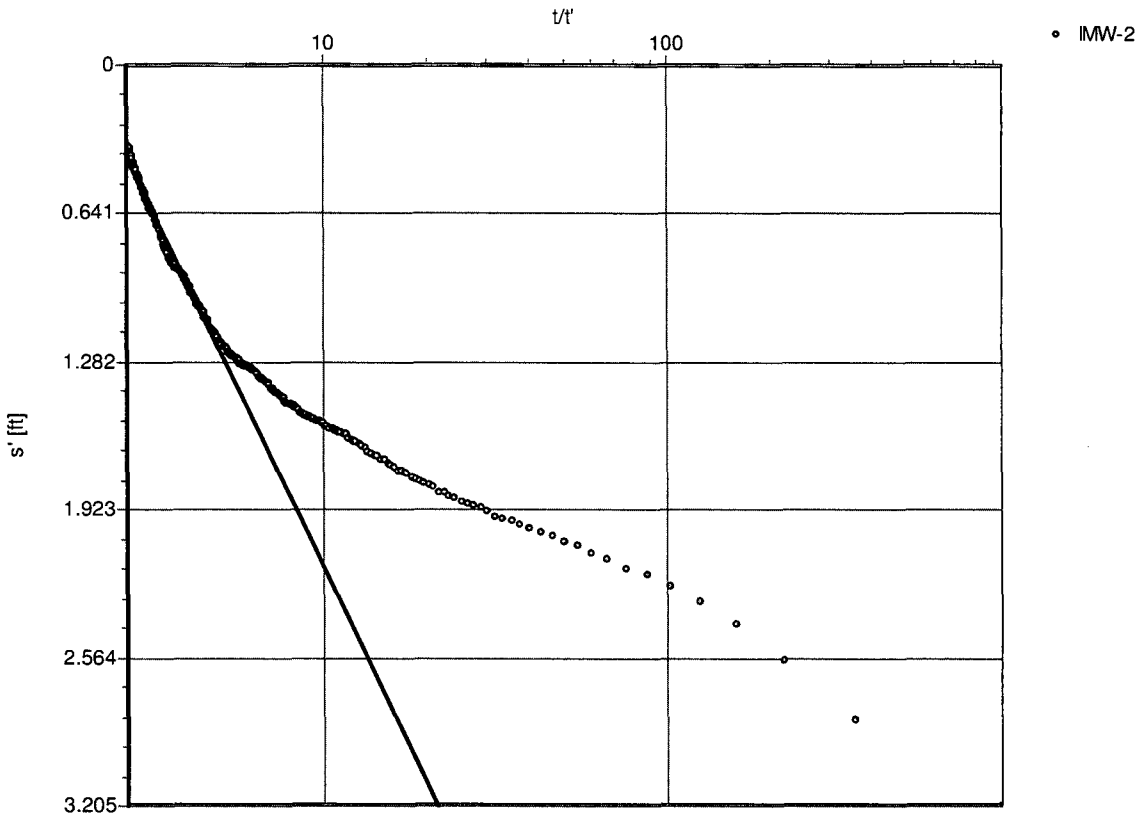
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas

5 Spot Pump Test Barometric Correction [Theis Recovery]



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Theis Recovery**

Analysis Results:	Transmissivity:	2.53E+2 [ft²/d]	Conductivity:	3.51E+0 [ft/d]

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		
	Pumping Time	5700 [min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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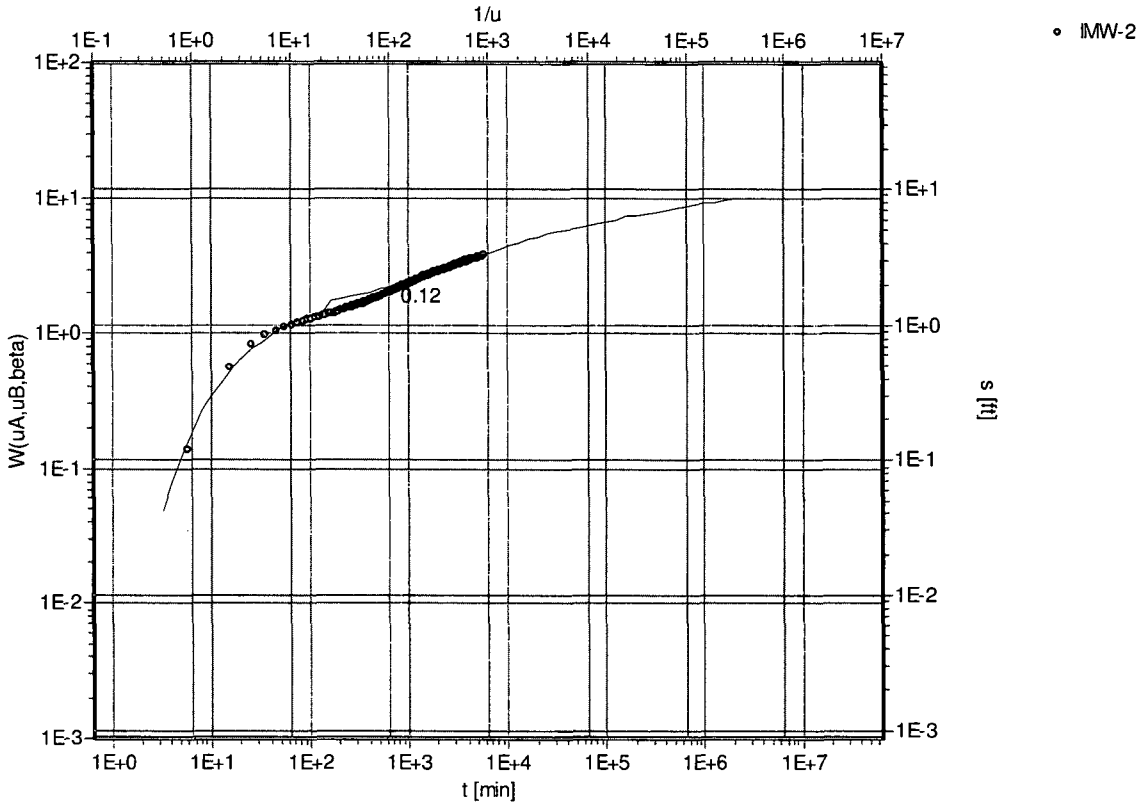
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas

5 Spot Pump Test Barometric Correction [Neuman]



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Neuman**

Analysis Results:	Transmissivity:	3.95E+2 [ft²/d]	Conductivity:	5.49E+0 [ft/d]
	Storativity:	1.43E-3	Specific Yield:	1.43E-2

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Beta:	0.12
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		
	LOG(Sy/S):	1		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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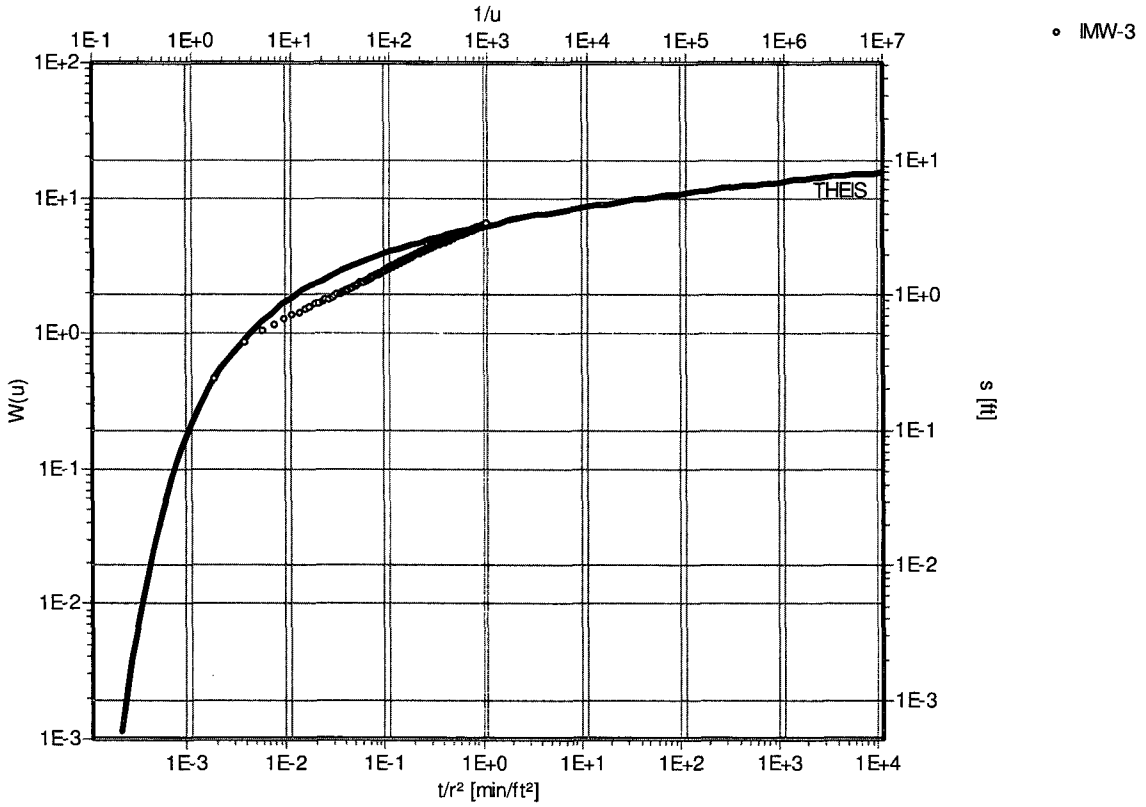
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas

5 Spot Pump Test Barometric Correction [Theis]



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Theis**

Analysis Results:	Transmissivity:	6.59E+2 [ft²/d]	Conductivity:	9.15E+0 [ft/d]
	Storativity:	2.08E-3		
Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Confined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/28/2008

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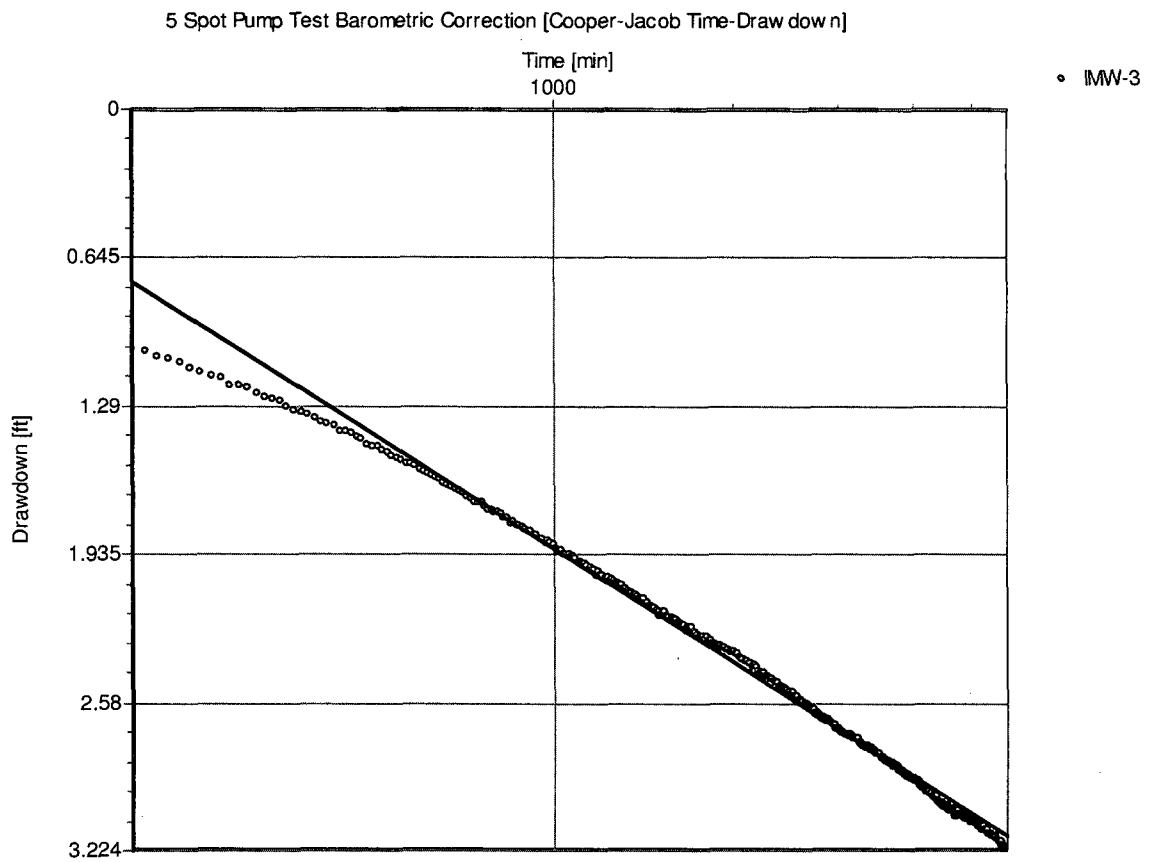
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Cooper-Jacob Time-Drawdown**

Analysis Results:	Transmissivity:	4.75E+2 [ft²/d]	Conductivity:	6.59E+0 [ft/d]

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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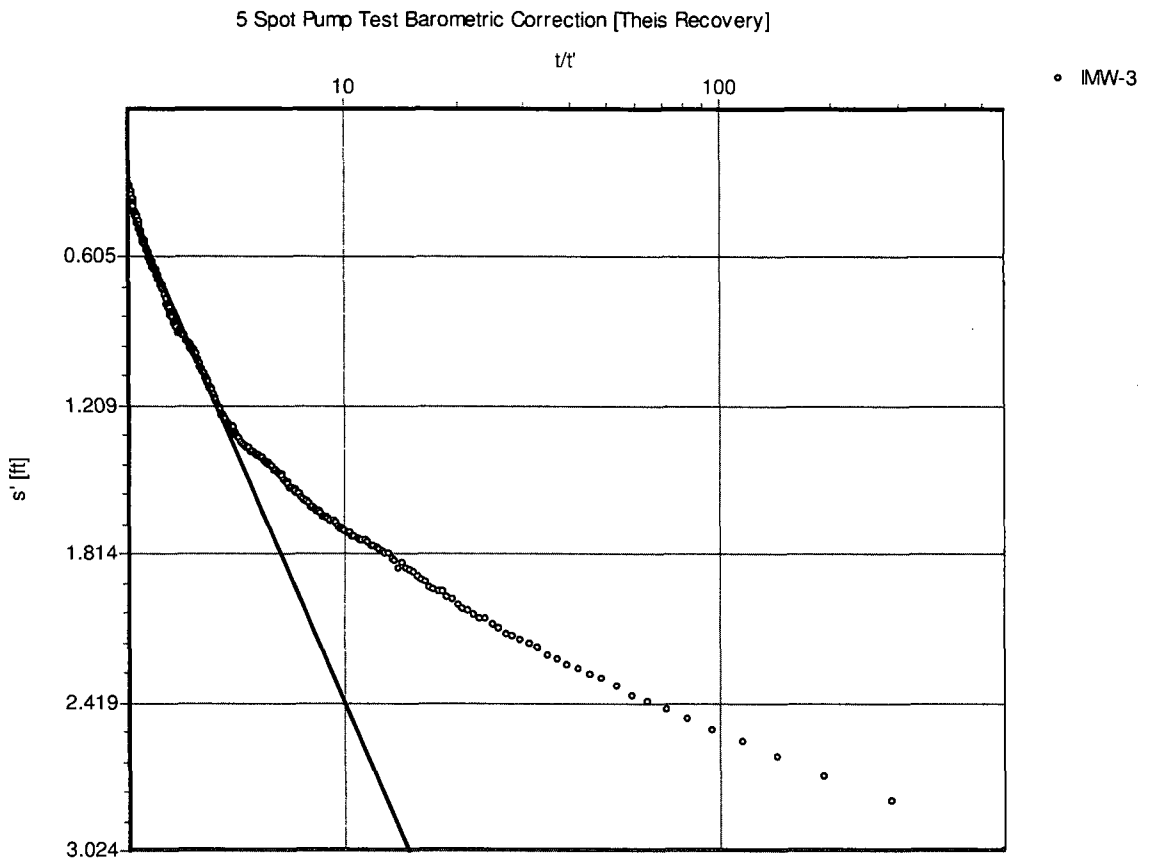
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Theis Recovery**

Analysis Results:	Transmissivity:	2.21E+2 [ft²/d]	Conductivity:	3.06E+0 [ft/d]

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		
	Pumping Time	5700 [min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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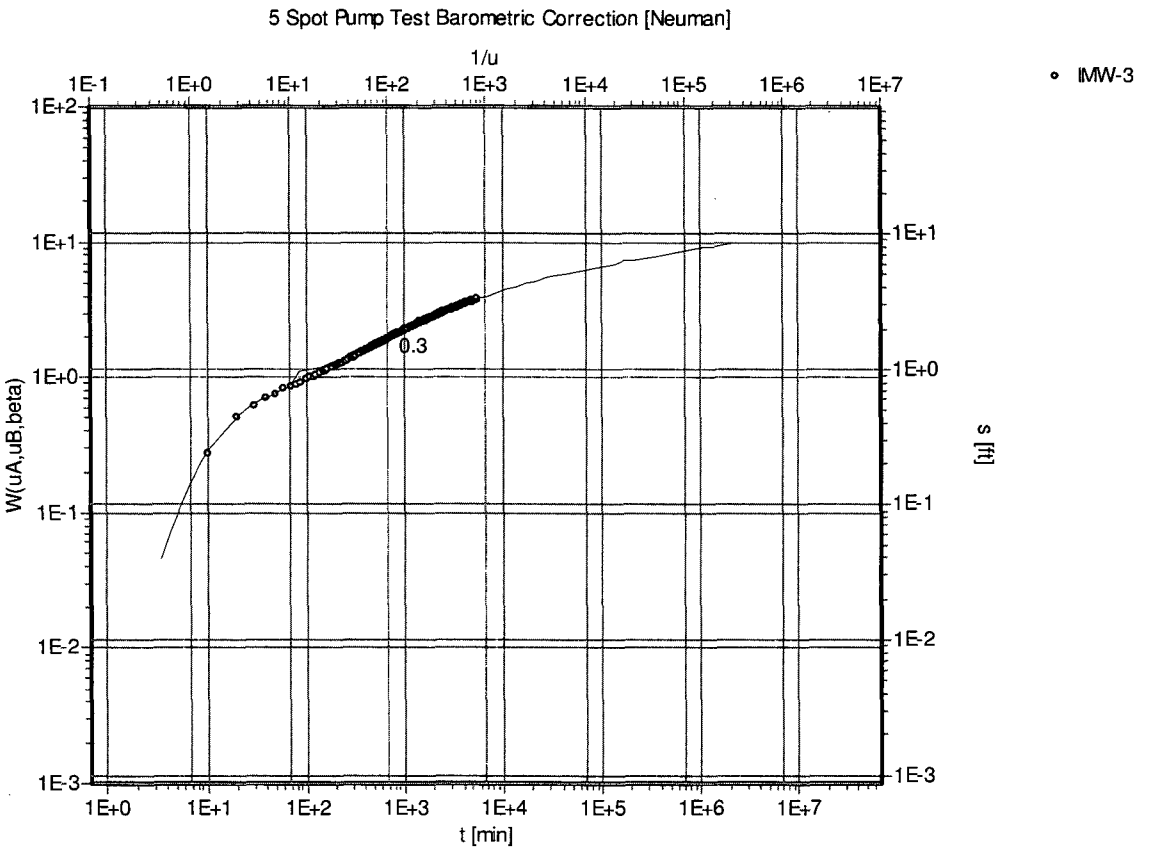
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Neuman**

Analysis Results:	Transmissivity:	3.95E+2 [ft²/d]	Conductivity:	5.48E+0 [ft/d]
	Storativity:	1.49E-3	Specific Yield:	1.49E-2

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Beta:	0.3
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		
	LOG(Sy/S):	1		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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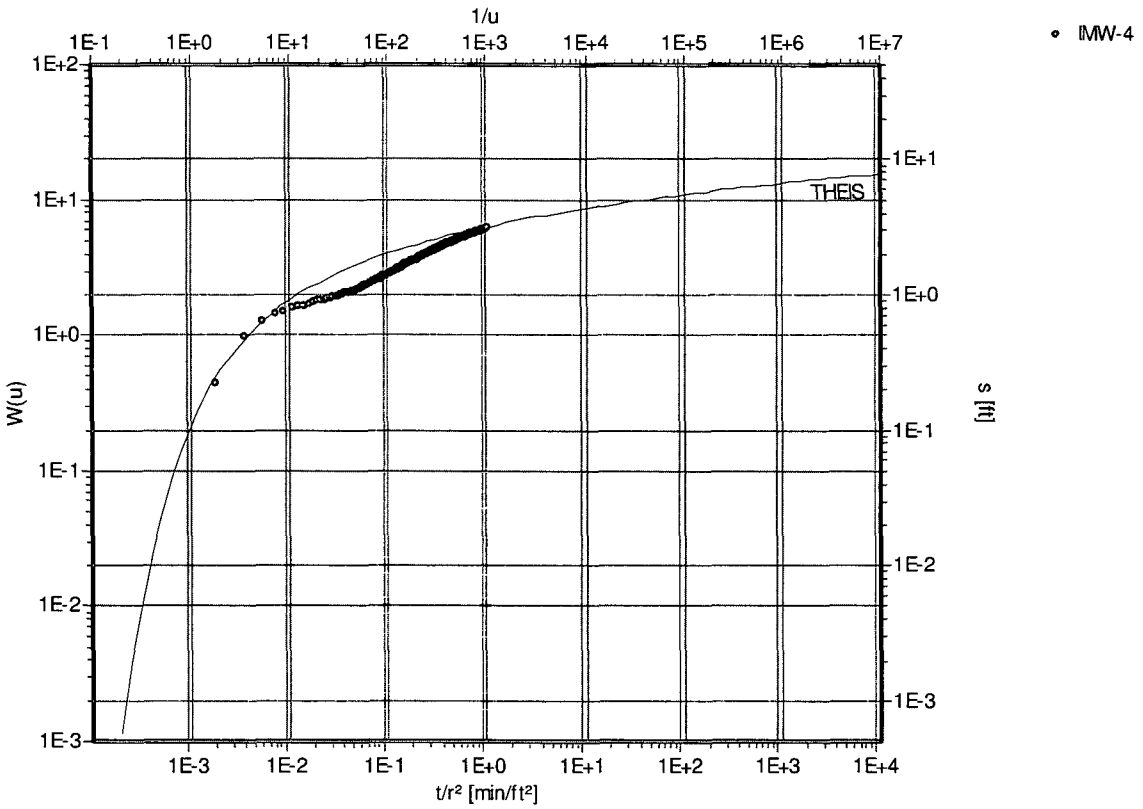
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas

5 Spot Pump Test Barometric Correction [Theis]



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Theis**

Analysis Results:	Transmissivity:	6.82E+2 [ft²/d]	Conductivity:	9.48E+0 [ft/d]

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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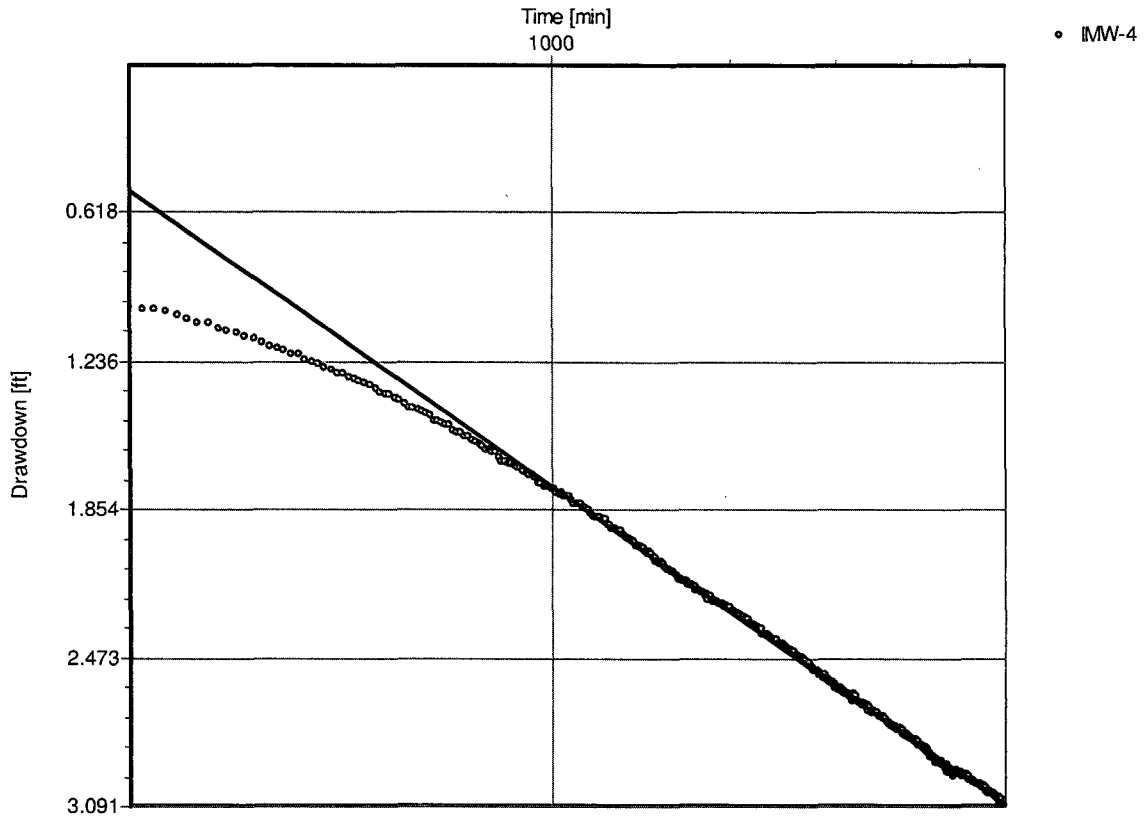
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas

5 Spot Pump Test Barometric Correction [Cooper-Jacob Time-Draw dow n]



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Cooper-Jacob Time-Drawdown**

Analysis Results:	Transmissivity:	4.47E+2 [ft²/d]	Conductivity:	6.21E+0 [ft/d]

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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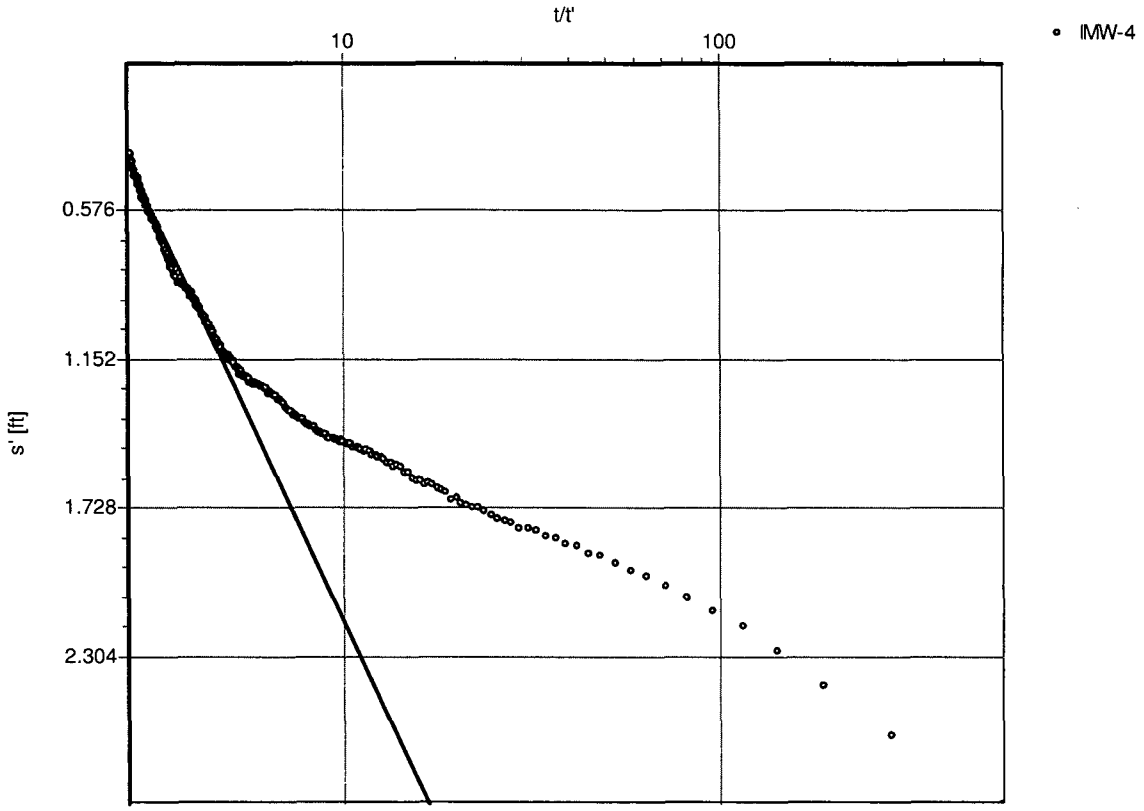
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas

5 Spot Pump Test Barometric Correction [Theis Recovery]



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Theis Recovery**

Analysis Results:	Transmissivity:	2.51E+2 [ft²/d]	Conductivity:	3.49E+0 [ft/d]

Test parameters:				
	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		
	Pumping Time	5700 [min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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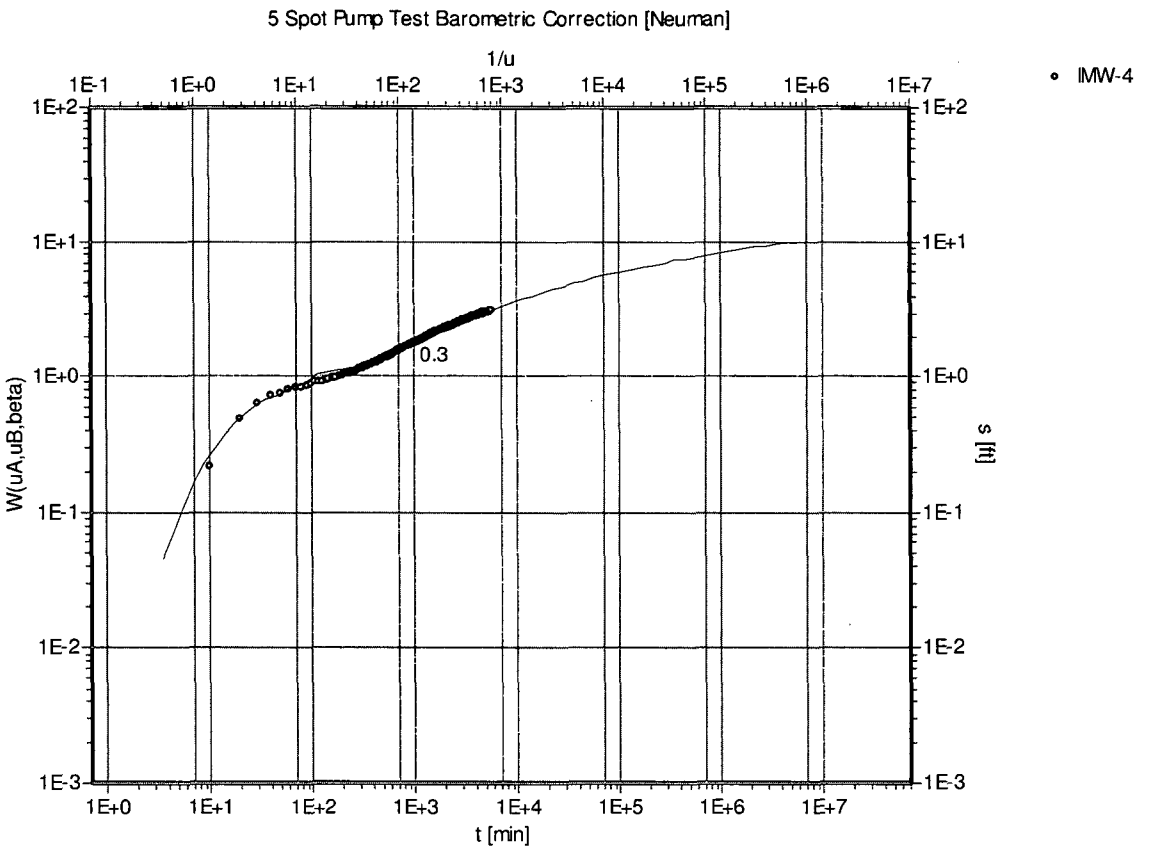
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Neuman**

Analysis Results:	Transmissivity:	3.42E+2 [ft²/d]	Conductivity:	4.75E+0 [ft/d]
	Storativity:	1.33E-3	Specific Yield:	2.66E-2

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Beta:	0.3
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		
	LOG(Sy/S):	1.3		

Comments:

Evaluated by: EPL

Evaluation Date: 5/28/2008

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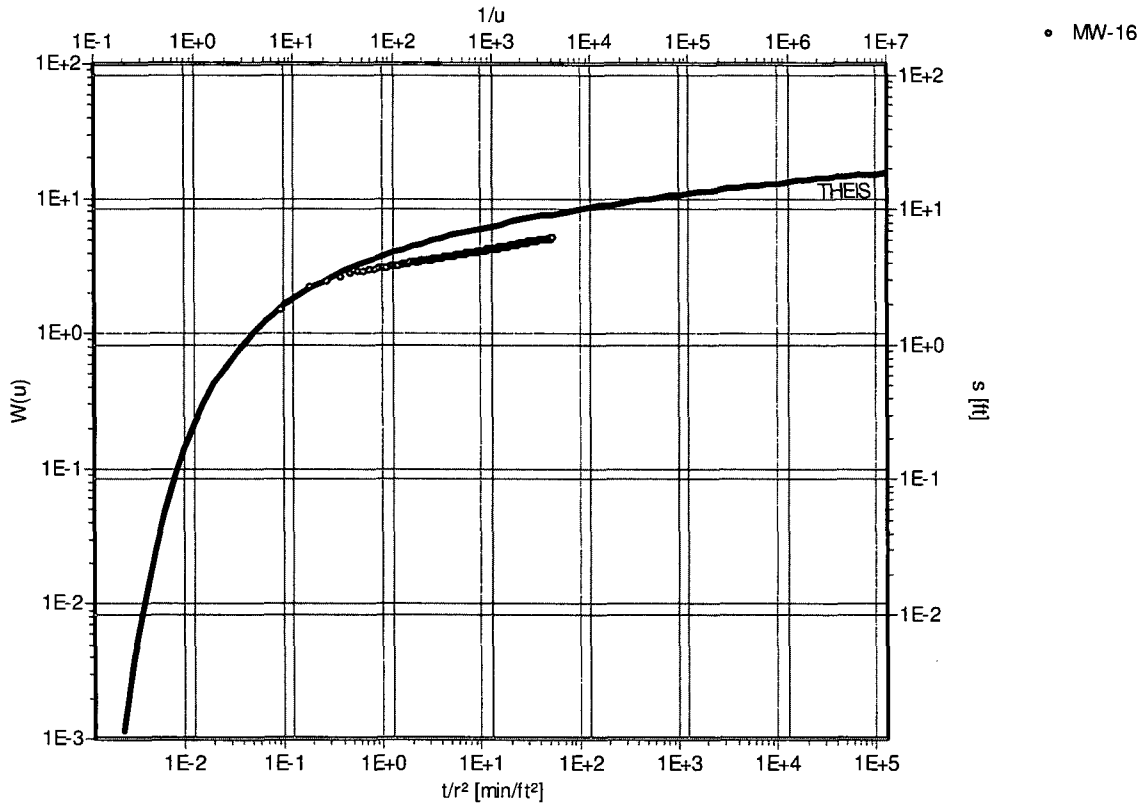
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas

5 Spot Extraction Test-Barometrically Corrected Draw dow n [Theis]



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Theis**

Analysis Results:	Transmissivity:	2.84E+2 [ft²/d]	Conductivity:	3.95E+0 [ft/d]

Test parameters:				
	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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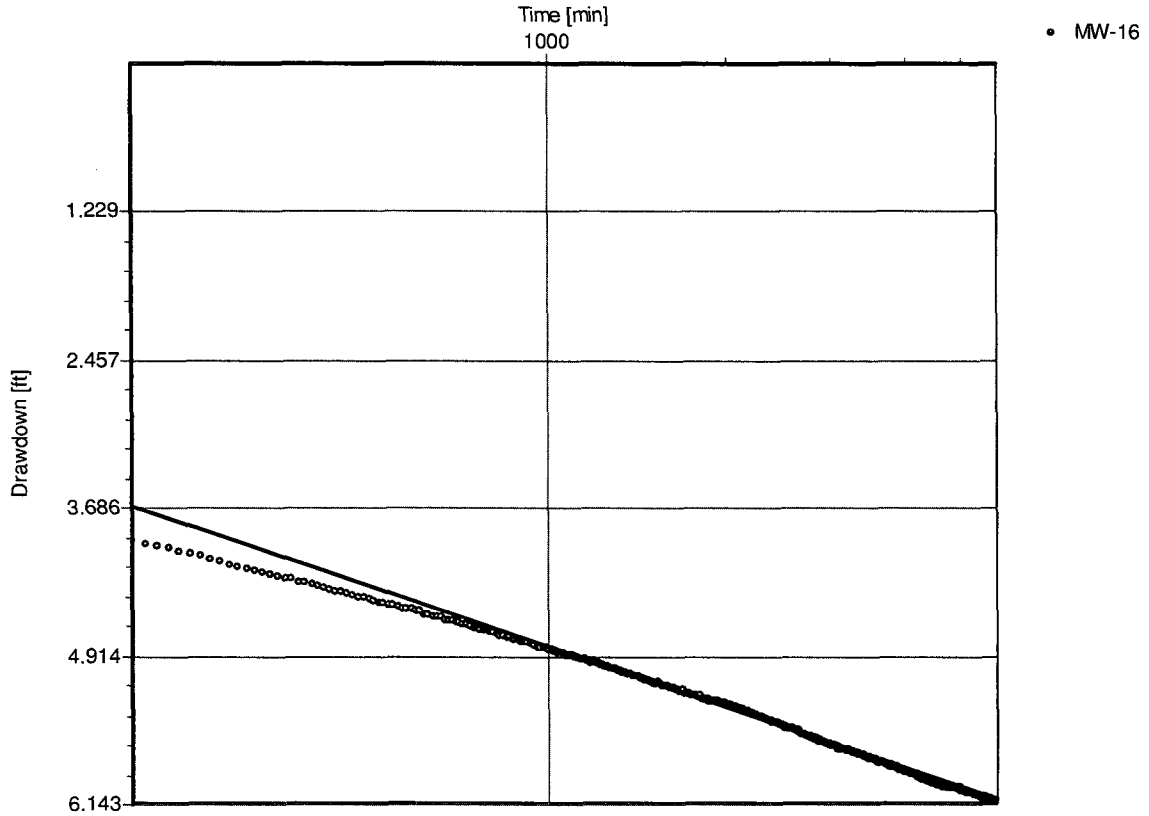
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas

5 Spot Pump Test Barometric Correction [Cooper-Jacob Time-Draw dow n]



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Cooper-Jacob Time-Drawdown**

Analysis Results:	Transmissivity:	4.71E+2 [ft²/d]	Conductivity:	6.54E+0 [ft/d]

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

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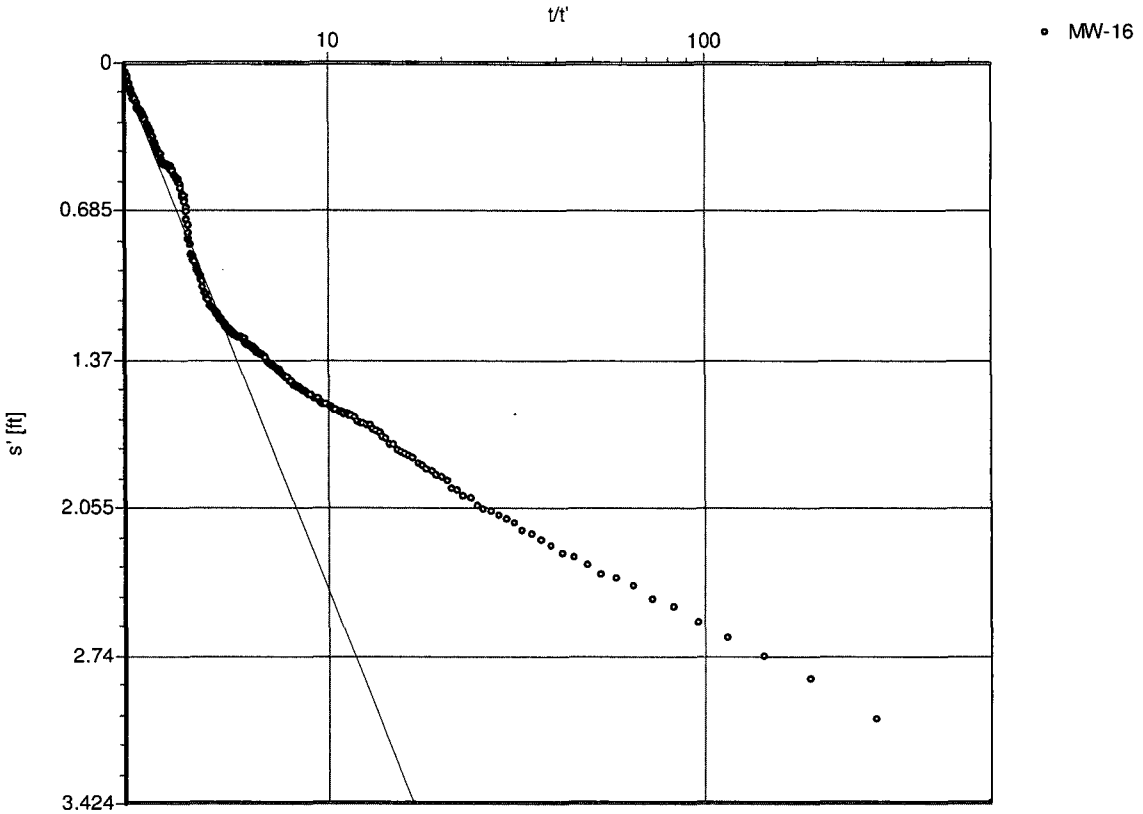
5 Spot Pump Test Barometric Correction [Theis Recovery]



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Theis Recovery**

Analysis Results:	Transmissivity:	1.80E+2 [ft²/d]	Conductivity:	2.50E+0 [ft/d]

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		
	Pumping Time	5700 [min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

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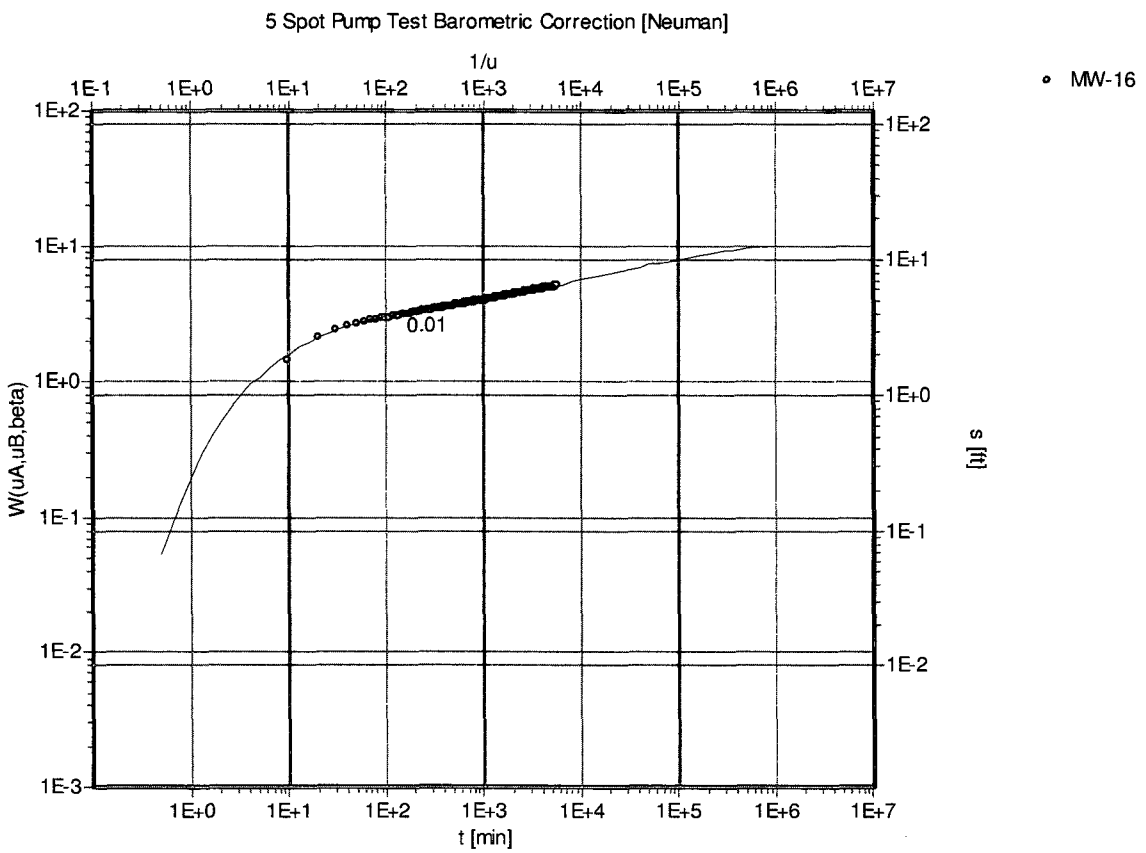

Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Neuman**

Analysis Results:	Transmissivity:	2.72E+2 [ft²/d]	Conductivity:	3.77E+0 [ft/d]
	Storativity:	7.33E-3	Specific Yield:	1.46E-1

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Beta:	0.01
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		
	LOG(Sy/S):	1.3		

Comments:

Evaluated by: EPL

Evaluation Date: 5/28/2008

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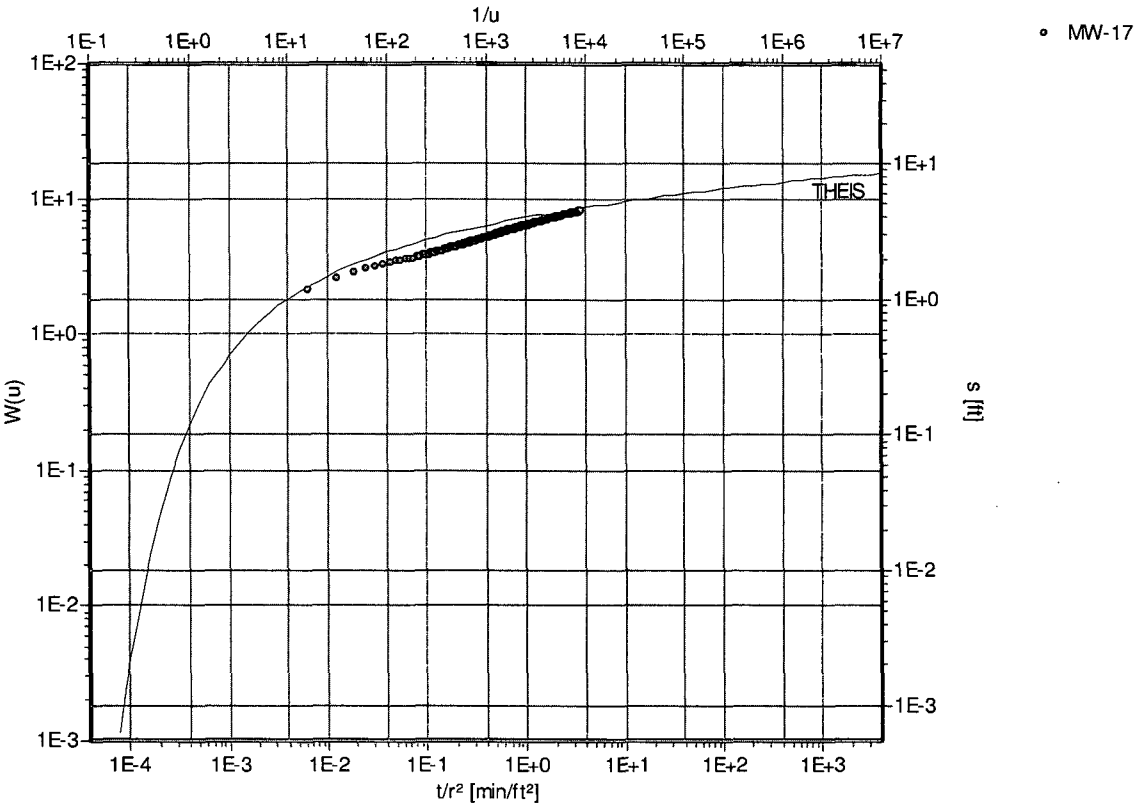
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas

5 Spot Pump Test Barometric Correction [Theis]



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Theis**

Analysis Results:	Transmissivity:	6.22E+2 [ft²/d]	Conductivity:	8.64E+0 [ft/d]

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

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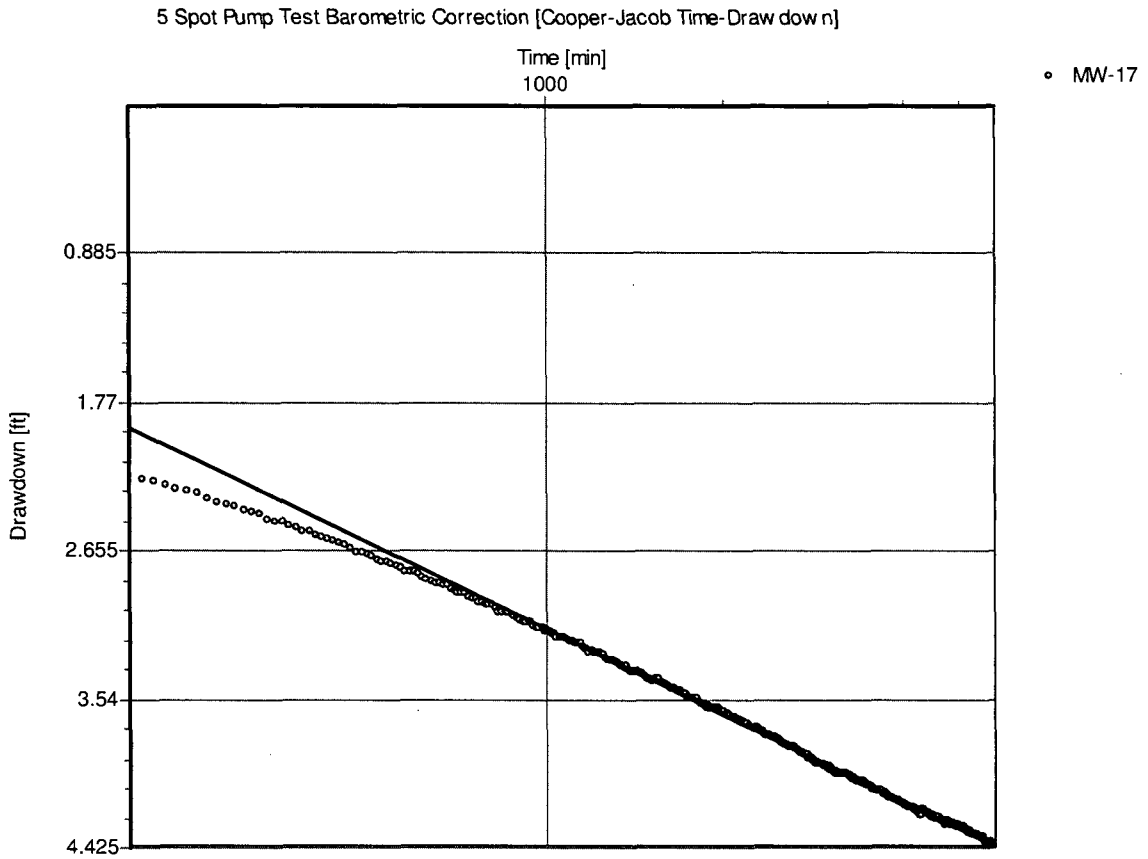

Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Cooper-Jacob Time-Drawdown**

Analysis Results:	Transmissivity:	4.57E+2 [ft²/d]	Conductivity:	6.35E+0 [ft/d]

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

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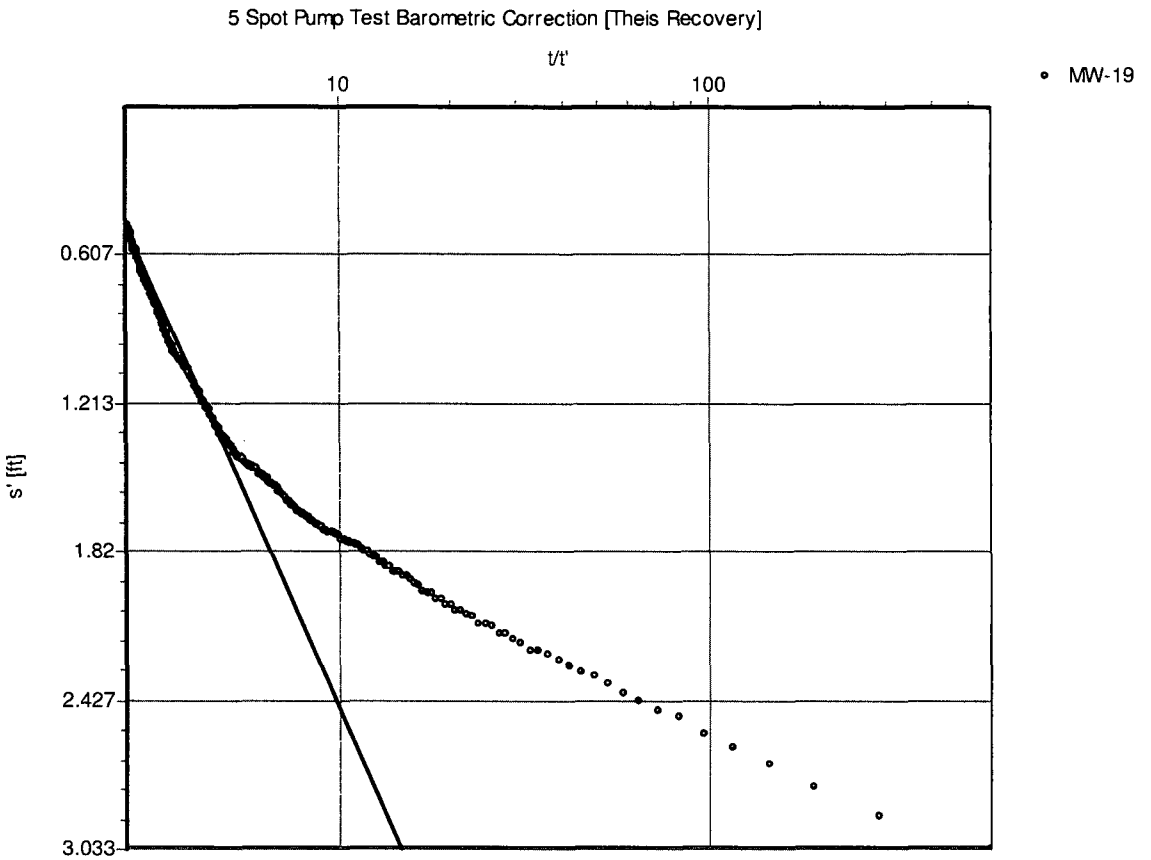

Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Theis Recovery**

Analysis Results:	Transmissivity:	2.28E+2 [ft²/d]	Conductivity:	3.17E+0 [ft/d]

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		
	Pumping Time	5700 [min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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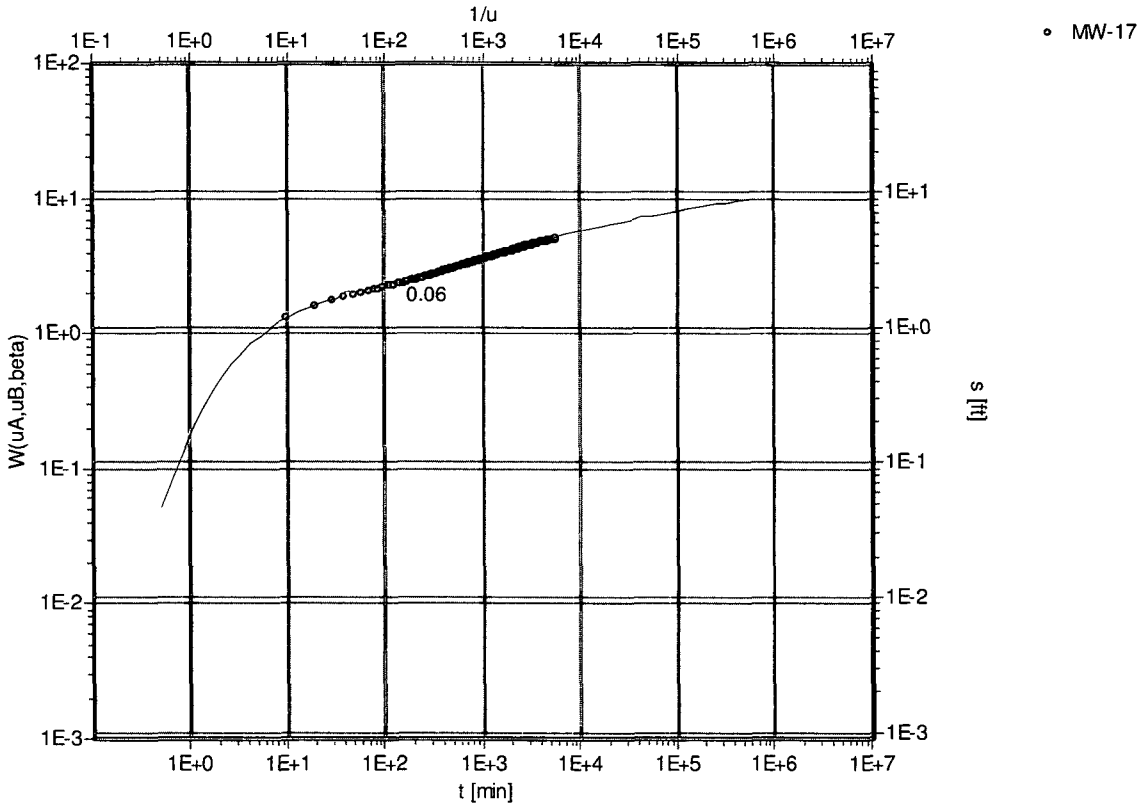
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas

5 Spot Pump Test Barometric Correction [Neuman]



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Neuman**

Analysis Results:	Transmissivity:	3.81E+2 [ft²/d]	Conductivity:	5.29E+0 [ft/d]
	Storativity:	6.95E-4	Specific Yield:	1.10E-2

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Beta:	0.06
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		
	LOG(Sy/S):	1.2		

Comments:

Evaluated by: EPL

Evaluation Date: 5/28/2008

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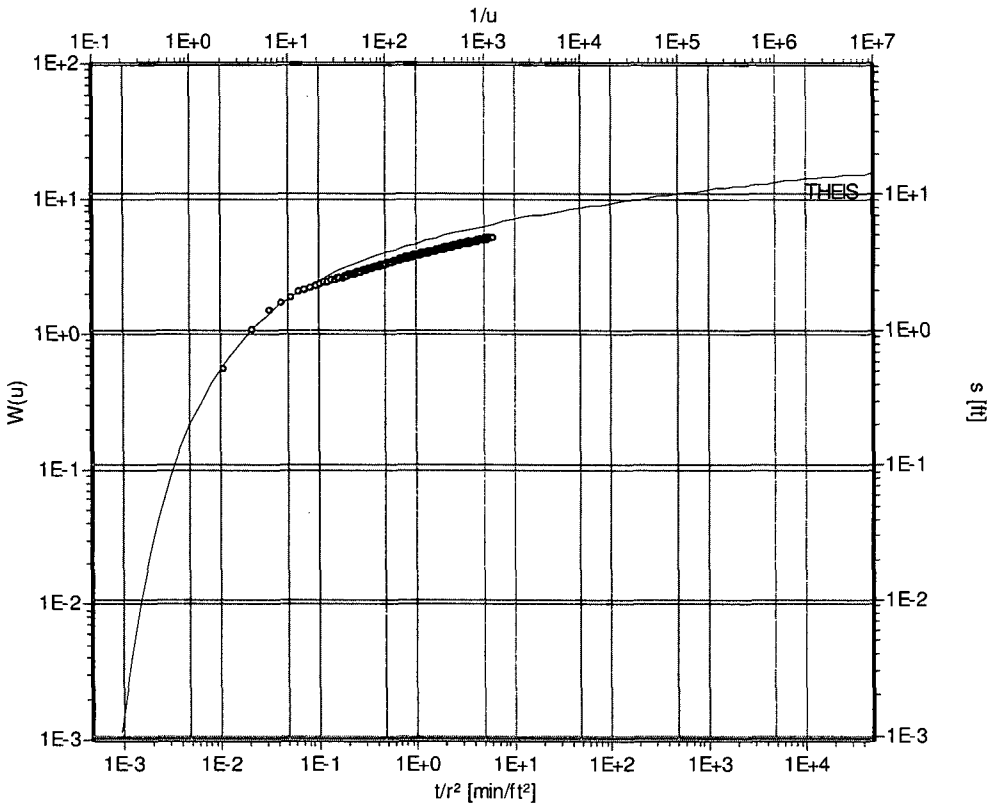
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas

5 Spot Pump Test Barometric Correction [Theis]



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Theis**

Analysis Results:	Transmissivity:	3.69E+2 [ft²/d]	Conductivity:	5.13E+0 [ft/d]

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

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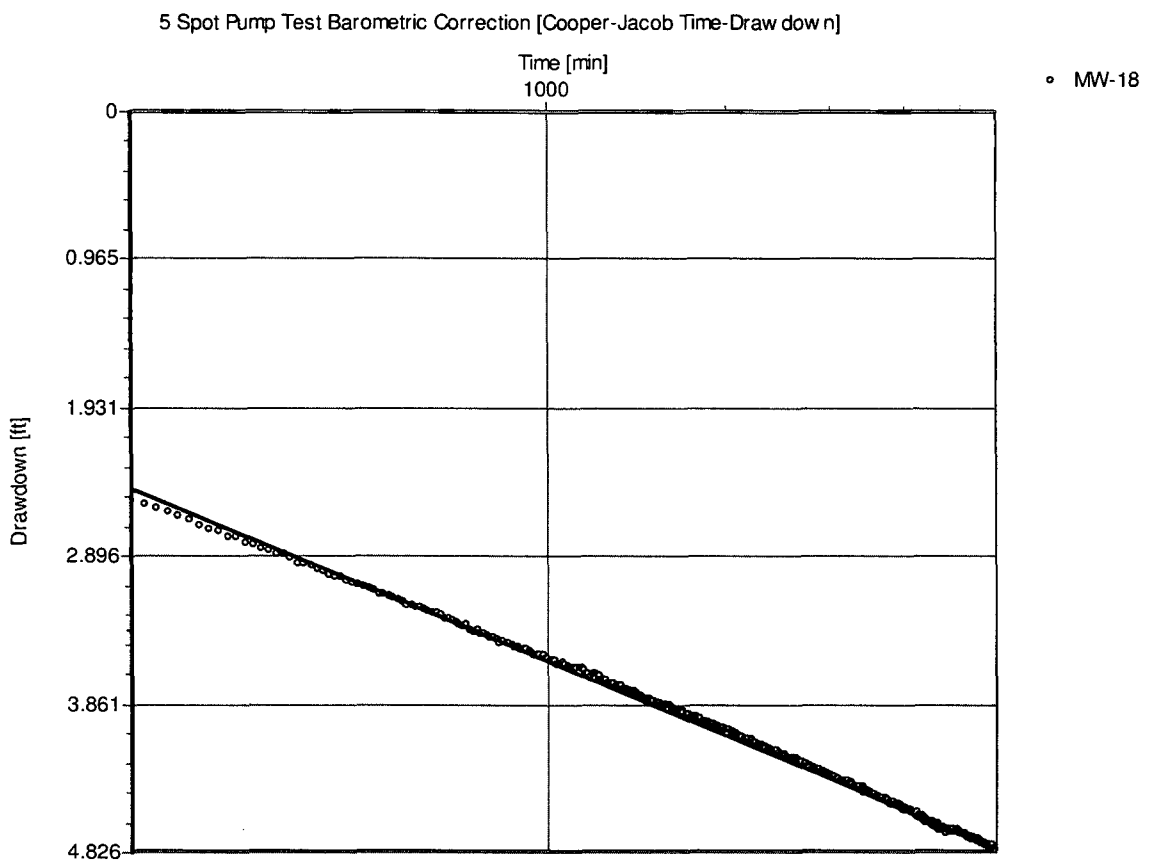

Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Cooper-Jacob Time-Drawdown**

Analysis Results:	Transmissivity:	4.89E+2 [ft²/d]	Conductivity:	6.79E+0 [ft/d]

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

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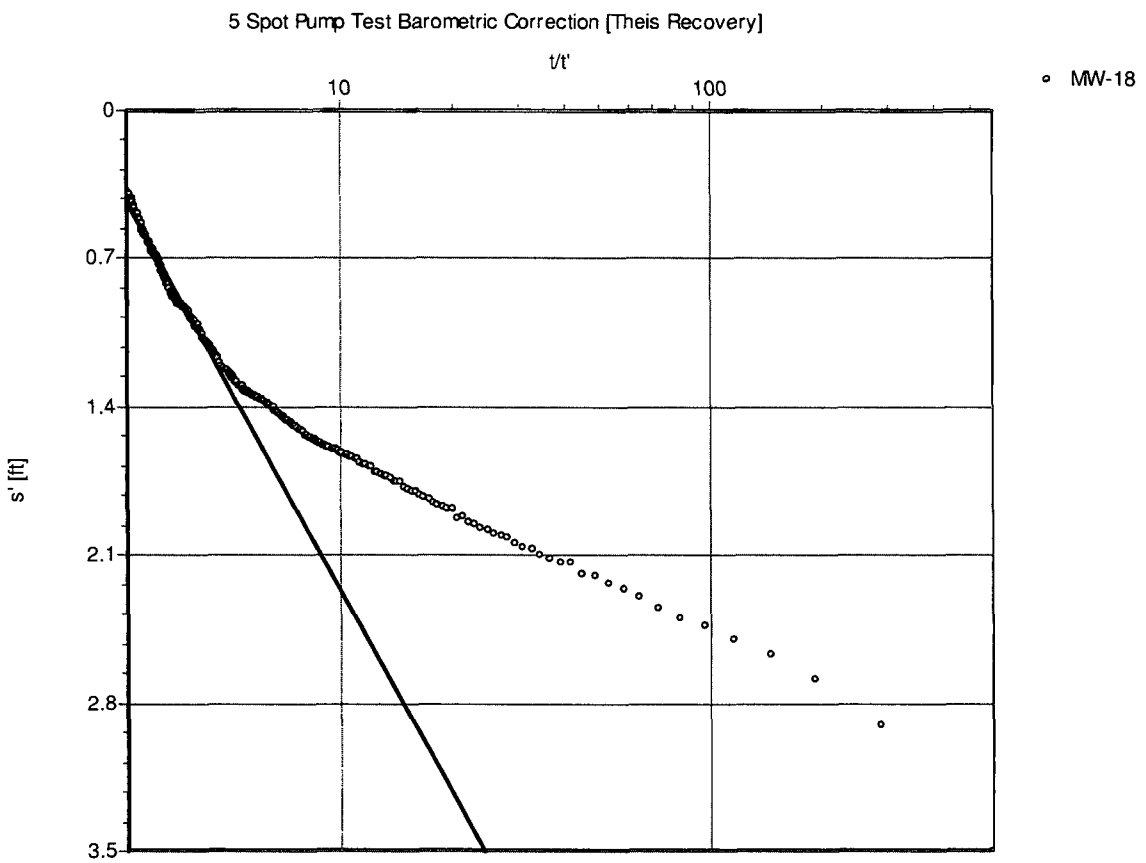

Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Theis Recovery**

Analysis Results:	Transmissivity:	2.46E+2 [ft²/d]	Conductivity:	3.41E+0 [ft/d]

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		
	Pumping Time	5700 [min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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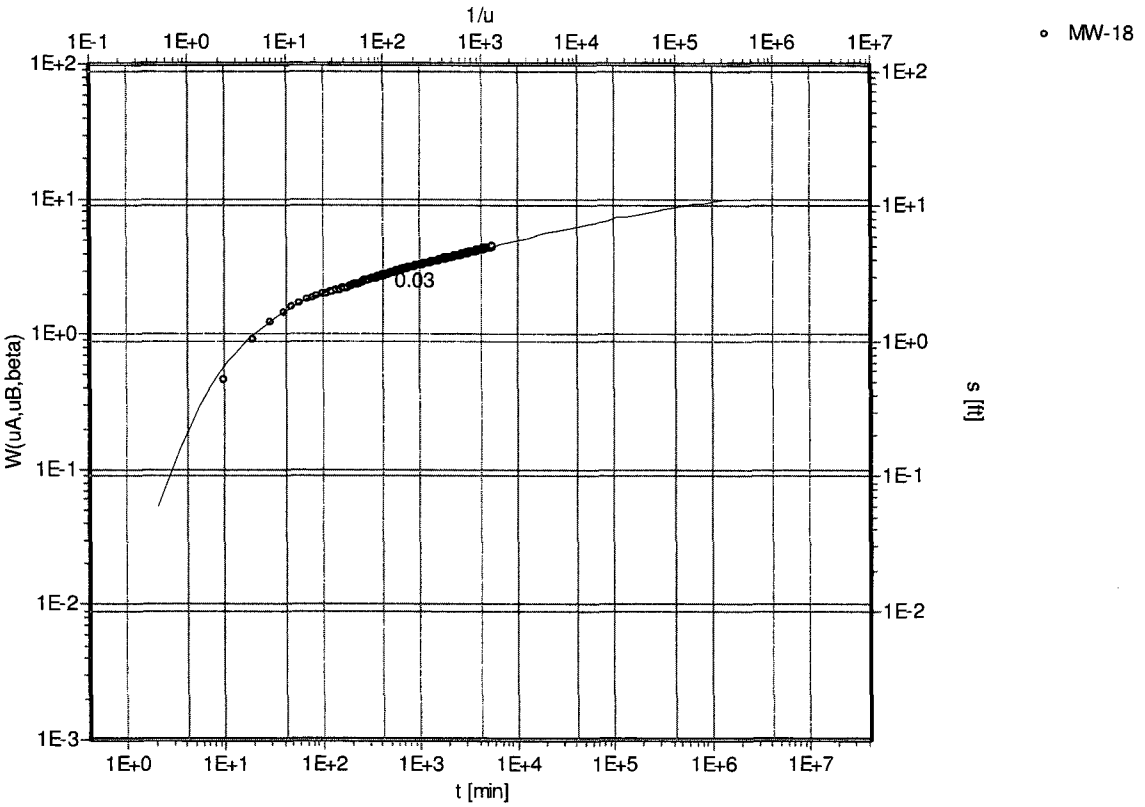
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas

5 Spot Pump Test Barometric Correction [Neuman]



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Neuman**

Analysis Results:	Transmissivity:	3.05E+2 [ft²/d]	Conductivity:	4.23E+0 [ft/d]
	Storativity:	3.88E-3	Specific Yield:	3.88E-2

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Beta:	0.03
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		
	LOG(Sy/S):	1		

Comments:

Evaluated by: EPL

Evaluation Date: 5/28/2008

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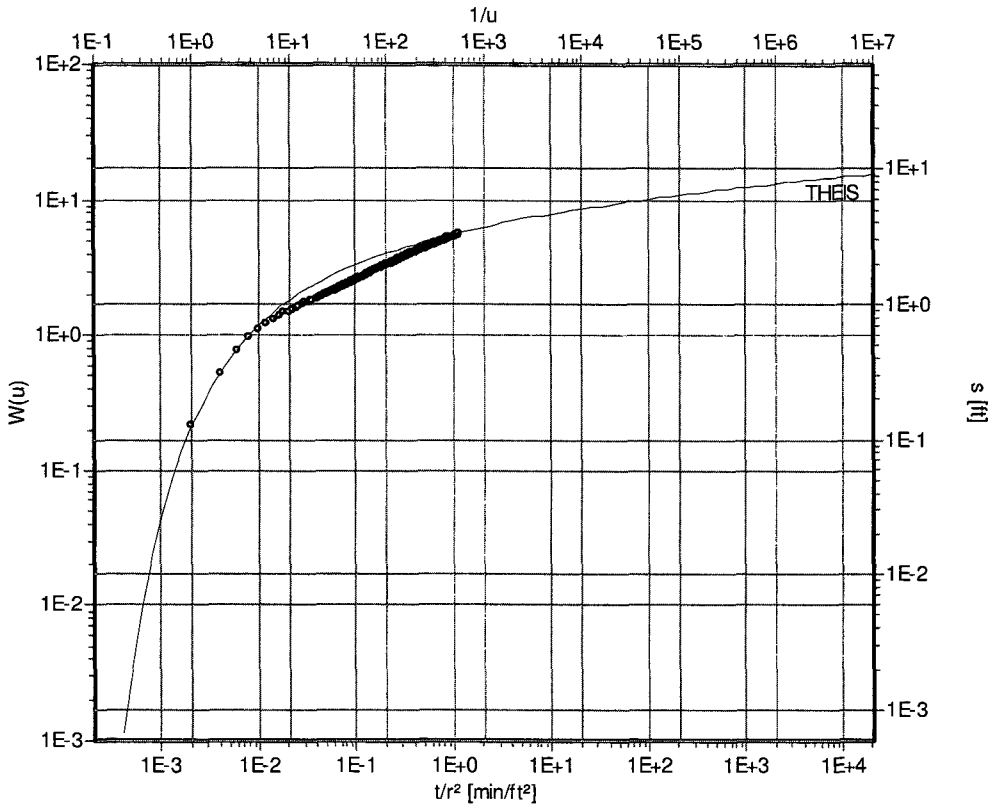
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas

5 Spot Pump Test Barometric Correction [Theis]



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Theis**

Analysis Results:	Transmissivity:	5.81E+2 [ft²/d]	Conductivity:	8.06E+0 [ft/d]

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

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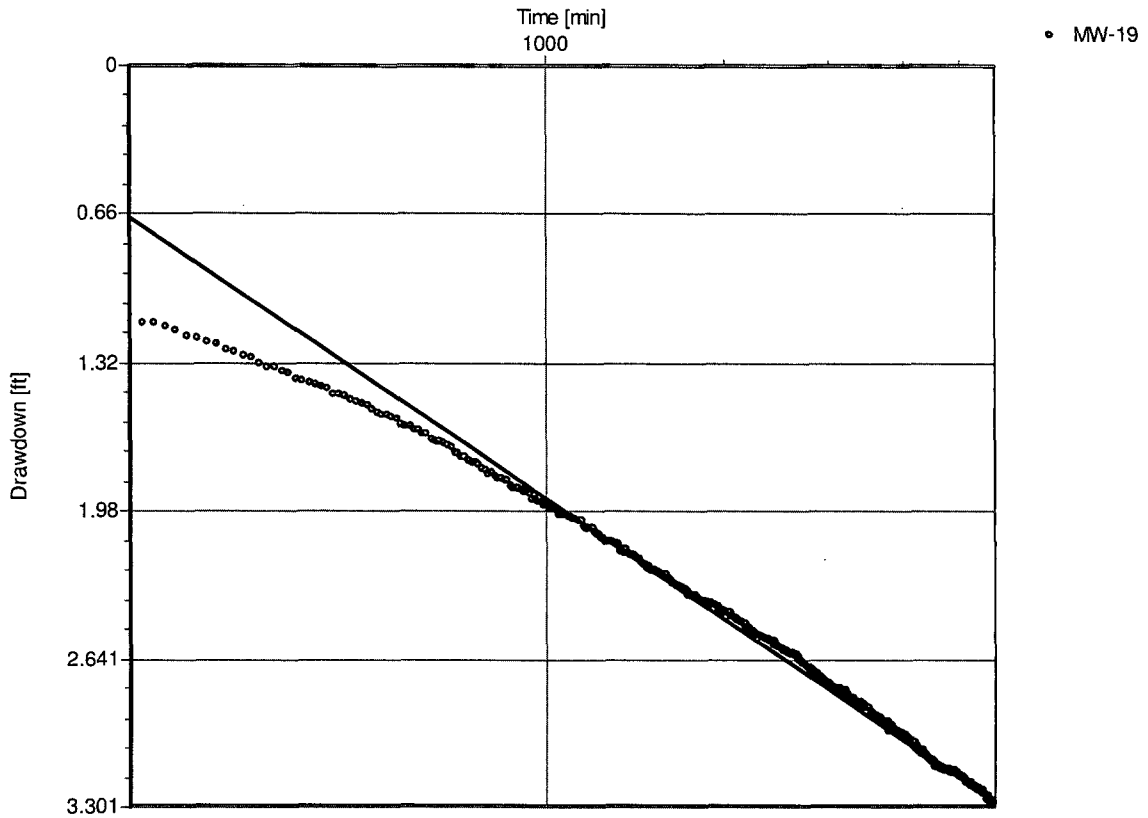
Client: Uranium One, Americas

5 Spot Pump Test Barometric Correction [Cooper-Jacob Time-Draw dow n]



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Cooper-Jacob Time-Drawdown**

Analysis Results:	Transmissivity:	4.40E+2 [ft²/d]	Conductivity:	6.11E+0 [ft/d]

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

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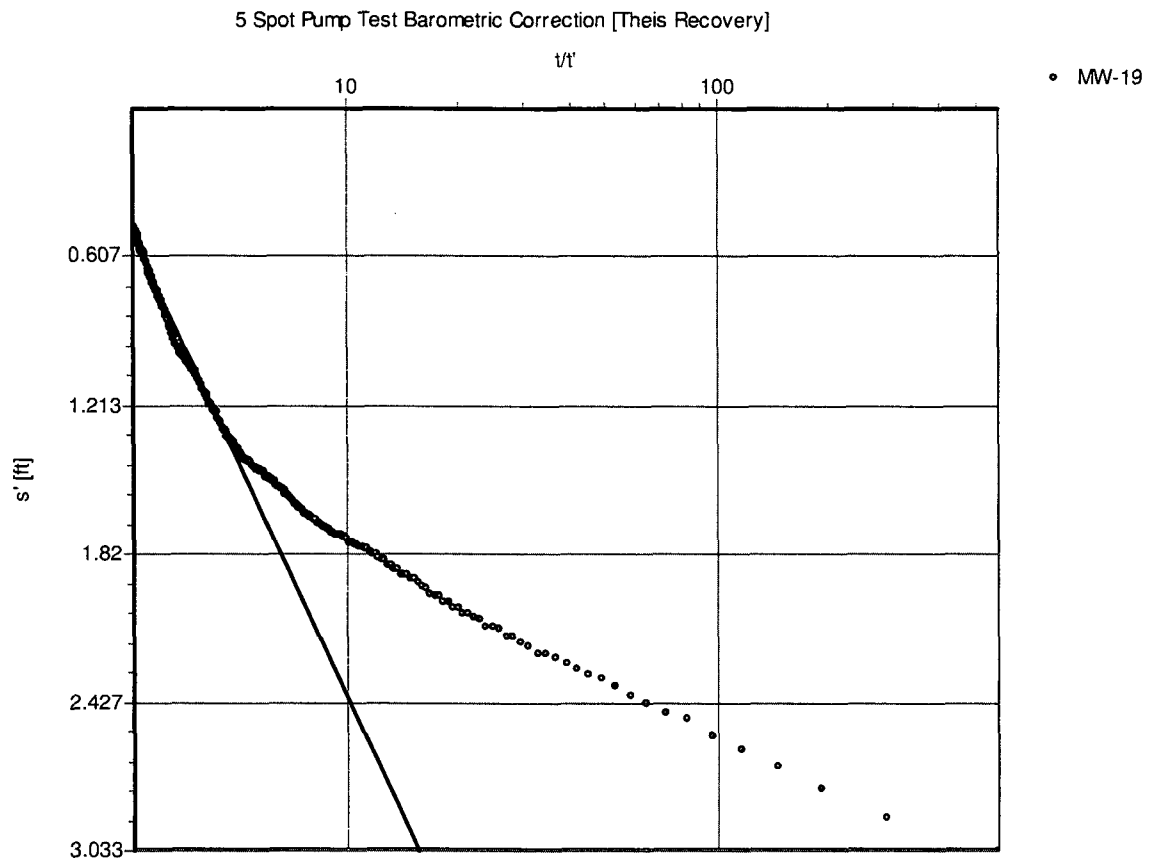
Client: Uranium One, Americas



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Theis Recovery**

Analysis Results:	Transmissivity:	2.39E+2 [ft²/d]	Conductivity:	3.33E+0 [ft/d]

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		
	Pumping Time	5700 [min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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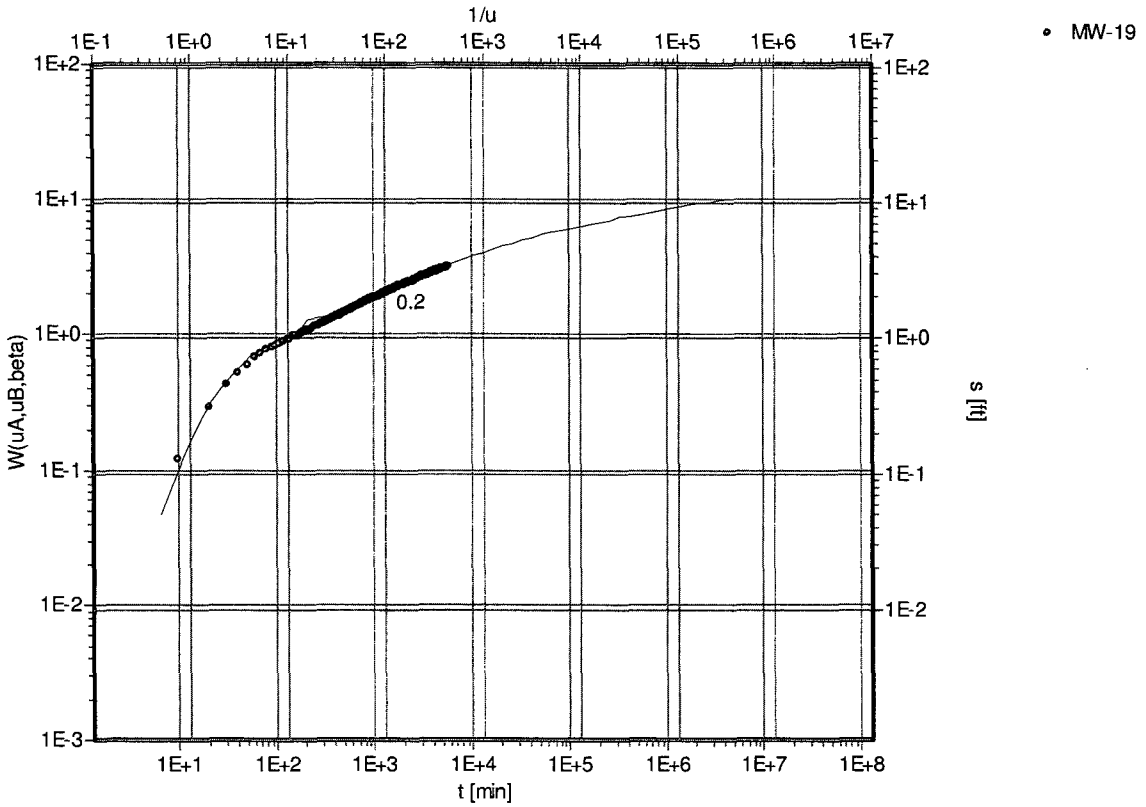
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas

5 Spot Pump Test Barometric Correction [Neuman]



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Neuman**

Analysis Results:	Transmissivity:	3.19E+2 [ft²/d]	Conductivity:	4.43E+0 [ft/d]
	Storativity:	2.39E-3	Specific Yield:	2.39E-2

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Beta:	0.2
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		
	LOG(Sy/S):	1		

Comments:

Evaluated by: EPL

Evaluation Date: 5/28/2008

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Pumping Test Analysis Report

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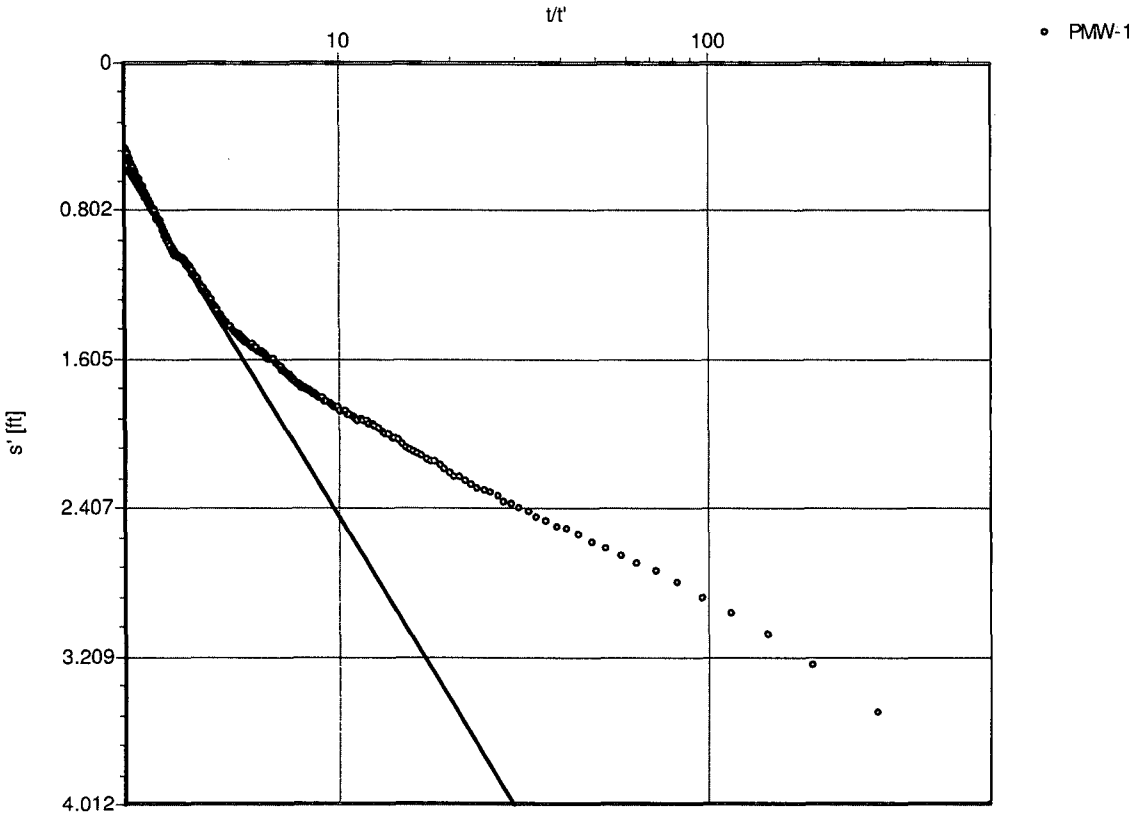
Client: Uranium One, Americas

5 Spot Pump Test Barometric Correction [Theis Recovery]



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Theis Recovery**

Analysis Results:	Transmissivity:	2.37E+2 [ft²/d]	Conductivity:	3.30E+0 [ft/d]

Test parameters:				
	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		
	Pumping Time	5700 [min]		

Comments:

Evaluated by: EPL

Evaluation Date: 5/25/2008

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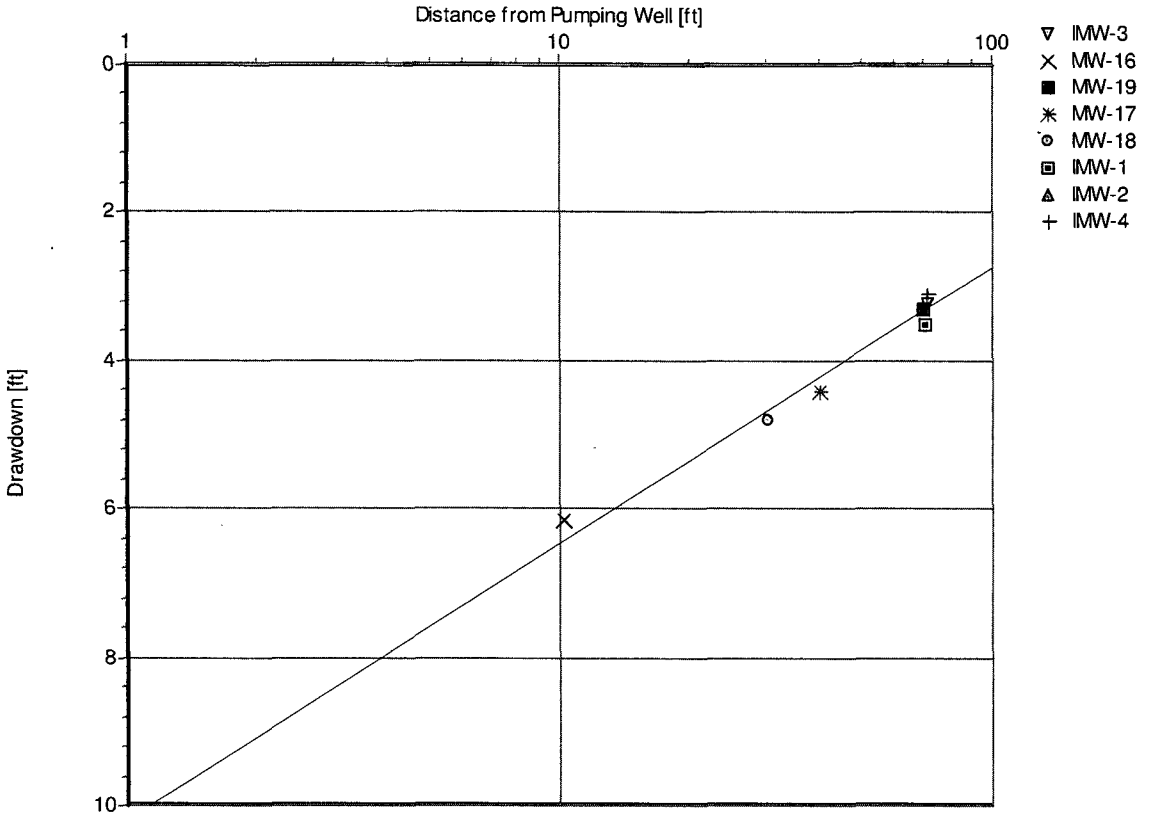
Pumping Test Analysis Report

Project: 5 Spot Test- Moore Ranch

Number:

Client: Uranium One, Americas

5 Spot ExtractionTest-Barometrically Corrected Draw dow n[Cooper-Jacob Distance-Draw dow n]



Pumping Test: **5 Spot Extraction Test BP Corrected**

Analysis Method: **Cooper-Jacob Distance-Drawdown**

Analysis Results:	Transmissivity:	4.22E+2 [ft²/d]	Conductivity:	5.87E+0 [ft/d]

Test parameters:	Pumping Well:	PMW-1	Aquifer Thickness:	72 [ft]
	Casing radius:	0.17 [ft]	Unconfined Aquifer	
	Screen length:	28 [ft]		
	Boring radius:	0.33 [ft]		
	Discharge Rate:	22.32 [U.S. gal/min]		
	Calculation Time:	5700 [min]		

Comments:

Evaluated by:

Evaluation Date: 5/25/2008

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5-SPOT HYDROLOGIC TEST REPORT
VOLUME II
MODEL DEVELOPMENT AND SIMULATIONS

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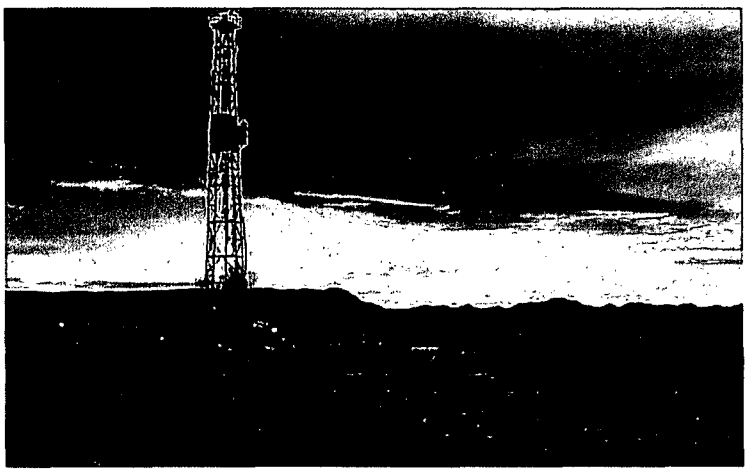

MOORE RANCH PROJECT

CAMPBELL COUNTY, WY

August 2008

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Moore Ranch 5-Spot Hydrologic Test Report
Volume II –Groundwater Model Development and Simulations

Introduction

Uranium One has submitted an application to the U.S. Nuclear Regulatory Commission (NRC) for a Source Materials License (SML) to conduct in-situ recovery (ISR) of uranium from the Moore Ranch Project in Wyoming (Energy Metals, Inc., 2007). The target ore zone is designated as the 70 Sand. Aquifer conditions within the 70 Sand are unconfined across the southern portion of the site. A groundwater model was developed to evaluate potential impacts that unconfined conditions will have on production and restoration phases of the ISR project. The model was developed using data collected from a 5-Spot Hydrologic Test conducted at the site. The hydrogeologic test design, results and analysis were described in detail in Volume I of this report. This volume of the report describes the development of the numerical model and summarizes the results of numerical simulations used to address NRC concerns regarding ISR operations in an unconfined aquifer. Additional modeling will be being performed to address wellfield scale issues related to production and aquifer restoration. Description and results of the larger scale modeling will be covered under a separate report.

Purpose and Objectives

The numerical groundwater flow model was developed to support Uranium One in planning and operation of the ISR project. The numerical model is also used to address NRC comments regarding operational issues specific to ISR of uranium within an unconfined aquifer system.

Data derived from the 5-Spot Hydrologic Test were used to develop a numerical model that is representative of site-specific conditions (including the unconfined nature of the production zone aquifer) on a well pattern scale. The numerical model was calibrated and verified to measured field data from the Test. The calibrated model was then used to demonstrate impacts of an unconfined system on mine design. The results of this modeling will be extrapolated to a wellfield and permit area scale model to evaluate wellfield bleed, operational flare, excursion control, water disposal requirements and restoration operations. The permit area model is described under a separate report titled "Numerical Modeling of Groundwater Conditions Related to Insitu Recovery at the Moore Ranch Uranium Project, Wyoming" (Petrotek Engineering, Inc., 2008).

Conceptual Model

Detailed description of the geology and hydrogeology of the Permit area can be found in the SML application (Energy Metals Corp.2007). Geohydrologic conditions specific to the 5-Spot Hydrologic Test area were described in Volume I of this report. The 5-Spot Hydrologic Test area is located within the central

portion of proposed Wellfield 2 [Figure 5ST(1) Volume I]. A conceptual hydrologic model for the Moore Ranch Project area is summarized below.

The aquifer being simulated is the 70 Sand, which is the uranium production zone for the Moore Ranch Project. The 70 Sand ranges from 85 to 95 feet thick within the area of the 5 Spot Hydrologic Test and dips north-northwesterly at 0.5 to 1 degree. The 70 Sand aquifer is unconfined within the area of the Test. The potentiometric surface prior to the beginning of the 5-Spot Hydrologic Test is shown on Figure 5ST (7) in Volume I. The potentiometric surface has a hydraulic gradient of 0.0026 to 0.0036 ft/ft toward the north. In the area of the Test, the water level within the 70 Sand is approximately 20 feet below the top of the stratigraphic unit. The saturated thickness of the 70 Sand in the wells ranges from 67 to 75 feet. Transmissivity of the 70 Sand, calculated from the 5-Spot Hydrologic Test, ranges from 180 to 680 ft^2/d (1,350 to 5,080 gpd/ft). However, as described in Volume I, the Neuman analytical method, designed for unconfined aquifer evaluation, provides the best visual fit to the observed drawdown curves and is considered most representative of site conditions. The range of transmissivity using the Neuman analytical solution is from 272 to 395 ft^2/d (2,035 to 2,955 gpd/ft). The hydraulic conductivity calculated from the 5-Spot Hydrologic Test using the Neuman analysis ranges from 3.8 to 5.5 ft/d.

Total porosity of the 70 Sand is estimated at 26 percent. Specific yield estimated from the 5-Spot Hydrologic Test, ranges from 0.011 to 0.039. Accurate assessment of the storativity was not possible from the 5-Spot Hydrologic Test because of the unconfined condition of the aquifer. Storativity estimated from other hydrologic testing conducted within the 70 Sand in the vicinity of the Moore Ranch indicates a range of 2.4×10^{-4} to 4.4×10^{-3} for the aquifer.

Within the vicinity of the 5-Spot Hydrologic Test, the 70 Sand is bounded above and below by low permeability clays and silts that act as confining units. The 70 Sand is overlain by a 30 to 40 foot thick confining unit. Water level differences between the 70 Sand and overlying aquifer (72 Sand) range from 50 to 60 feet with the higher levels within the 72 Sand. The unsaturated upper portion of the 70 Sand and the large head difference between the 70 and 72 Sands conclusively demonstrate that the overlying aquifer is not in communication with the production zone aquifer. Water levels between the underlying aquifer (68 Sand) and the production zone aquifer are similar. There is evidence of discontinuity in the confining unit between the 68 and 70 Sands in portions of Wellfield 2. However, as described in Volume I, a 68 Sand monitor well (UMW5) indicated no response attributable to pumping of the 70 Sand for the duration of the Extraction Test. The focus of this model is on operational issues specific to ISR of uranium within an unconfined aquifer system. Therefore, for purposes of this modeling exercise, the 68 Sand is not considered or included in the model.

Recharge occurs to the 70 Sand within a few miles to the south where this hydrostratigraphic unit crops out. There are no known discharge areas from the 70 Sand within the Permit Area.

Model Code

The model code used to simulate the 5-Spot Hydrogeologic Test was MODFLOW-SURFACT, Version 2.2 (SURFACT), developed by HydroGeologic, Inc. (1996). SURFACT is a proprietary version of the widely used and public domain MODFLOW code developed by the U.S. Geological Survey (McDonald, 1988, 1996). MODFLOW simulates groundwater flow using a block-centered, finite-difference approach that is capable of a wide array of boundary conditions. The code can simulate aquifer conditions as unconfined, confined, or a combination of the two. MODFLOW also supports variable thickness layers (i.e. variable aquifer bottoms and tops. Documentation of all aspects of the MODFLOW code is provided in the users manuals (McDonald, 1988 and 1996).

SURFACT was designed to enhance the groundwater flow modeling capabilities of MODFLOW. SURFACT provides significant improvements over the original MODFLOW code with respect to unconfined and unsaturated flow, dewatering and rewetting of cells within the model, and simulation of wells. Similar to the MODFLOW code, SURFACT is modular by design so that specific modules can be incorporated into the model simulation to address characteristics and physical processes of the site being modeled. These modules, or packages, work in conjunction with the original MODFLOW code. Only modules that address specifics of the site need be included in the simulation. Full description of the SURFACT packages, including verification examples, is provided in the MODFLOW-SURFACT Software (Version 2.2) Documentation (HydroGeologic, Inc, 1996). Specific modules of SURFACT employed in the 5-Spot Hydrologic Test Model include the following:

- BCF4 – The block center flow package available in SURFACT provides rigorous treatment of unconfined flow using a variably saturated formulation with psuedo-soil functions. The BCF4 package is superior to earlier versions of block centered flow packages in handling dewatering and rewetting of cells within the model simulation. The formulation has been designed to provide accurate delineation of the water table and capture the delayed yield response of an unconfined system to pumping and recharge

- FWL4 – The SURFACT fracture well package provides rigorous treatment of well withdrawal ((or injection) conditions using one-dimensional fracture tube elements to emulate a well. This package allows accurate representation of wells screened across multi-layers, apportioning flow based on transmissivity and available head in each layer. The package also automatically adjusts flow rate when overpumpage of an unconfined

aquifer occurs to prevent dewatering of the aquifer and can also simulate well bore storage. This package couples with the BCF4 package previously described to define unsaturated flow behavior in well cells such that the water table condition within a well cell is accurately represented.

- ATO4-This adaptive time stepping package provided with SURFACT automatically controls time step size and simulation output. This package allows a simulation to be performed more efficiently and outputs to be reported at specific desired times of the simulation.

- PCG4–SURFACT includes the option of using this Preconditioned Conjuguate Gradient solver. Earlier versions of PCG solvers are available with MODFLOW, however the PCG4 solver is more efficient and robust (HydroGeologic, 1996).

A particle-tracking code was utilized to that could readily incorporate information collected from the MODFLOW/SURFACT groundwater flow model. The code chosen was MODPATH, Version 3 (Pollock, 1994), which was designed to use the output head files from MODFLOW (or SURFACT) to calculate particle velocity changes over time in three dimensions. MODPATH was used to provide computations of groundwater seepage velocities and groundwater flow directions at the site. MODPATH is also a public domain code that is well accepted in the scientific community. Full documentation of the MODPATH code is provided in the MODPATH users guide (Pollock, 1994).

The pre/post-processor Groundwater Vistas (Environmental Simulations, Version 4, 2004) was used to assist with input of model parameters and output of model results. Groundwater Vistas serves as a direct interface with MODFLOW, SURFACT and MODPATH. Groundwater Vistas provides an extensive set of tools for developing, modifying and calibrating numerical models and allows for ease of transition between the groundwater flow and particle tracking codes. Full description of the Groundwater Vistas program is provided in the Users Guide to Groundwater Vistas, Version 4.0 (Environmental Simulations, Inc. 2004).

Model Domain and Grid

The model domain encompasses an area with north-south and east-west dimensions of 1,980 ft. The model grid is centered over the 5 Spot Hydrologic Test. The entire model domain is within an area where the modeled aquifer (70 Sand) is unconfined. The extent of the model domain is illustrated in Figure 5ST(25).

Drawdown results from the 5-Spot Hydrologic Test indicated the development of a steep drawdown cone around the pumped well. The model grid was designed to provide adequate spatial resolution in the area of the 5-Spot Hydrologic Test in order to simulate response of a pumped well in an unconfined aquifer. Cell

dimensions within the area of the 5-Spot well pattern were 1 foot by 1 foot. Cell dimensions are gradually increased to a maximum size of 5 feet by 5 feet near the edges of the model. The model consists of 629 rows and 629 columns and contains 421,201 active cells.

Because of the presence of overlying and underlying confining units, only the 70 Sand was simulated. The model contains a single layer representing the 70 Sand. The base of the model and the top of the model are no flow boundaries that simulate the overlying and underlying confining units. The top and bottom elevation of the 70 Sand correspond the top and base of the model, respectively.

Boundary Conditions

Boundary conditions imposed on a numerical model define the external geometry of the groundwater flow system being studied as well as internal sources and sinks. Boundary conditions assigned in the model were determined from observed conditions. Descriptions of the types of boundary conditions that can be implemented with the MODFLOW and SURFACT code are found in McDonald and Harbaugh (1988) and HydroGeologic Inc., (1996). Boundary conditions used to represent hydrologic conditions at the 5-Spot Hydrologic Test site included general-head (GHB) and wells. The locations of boundary conditions within the model are illustrated in Figure 5ST(25). Discussion of the placement and values for these boundary conditions is provided below.

The GHB was used in the 5-Spot Hydrologic Test model to account for inflow and outflow from the model domain. GHBs were assigned along the edges of the model domain where available water-level data suggest the aquifer is being recharged from, or discharging to, a source external to the model domain. GHBs were used because the groundwater elevation at those boundaries can change in response to simulated stresses. In the 5-Spot model, GHBs were assigned to the south and north boundaries of the model. The values of head assigned to the GHBs ranged from 5,188.75 ft along the south edge of the model 5,195.15 ft, along the north edge. This configuration represents a hydraulic gradient of 0.0032 ft/ft to the north, consistent with water levels measured in the 70 Sand monitor wells.

The model domain was extended a suitable distance from the location of the 5 Spot Hydrologic Test to minimize perimeter boundary effects on the interior of the model where the hydraulic stresses were applied.

The SURFACT well package (FWL4) was used to simulate extraction and injection wells of the 5 Spot Hydrologic Test. The well configuration includes a 5-Spot pattern with an extraction well located in the center, surrounded by four injection wells. The distance between injectors is 100 feet along the sides of the pattern and 141.4 ft diagonally across the pattern. The distance from each injection well to the extraction well is 70.7 feet. Additionally, four monitor wells

were placed throughout the 5-Spot well pattern at distances of 10, 20, 40 and 70 feet from the extraction well. Figure 5ST(26) shows the distribution of injection and extraction wells within the model domain. Extraction and injection rates applied to the wells are described under the calibration and simulation discussions of this report.

Aquifer Properties

Input parameters used in the model to simulate aquifer properties are consistent with site-derived data including; top and bottom elevations of the 70 Sand, saturated thickness, hydraulic gradient, hydraulic conductivity, specific yield, specific storage and porosity.

The top and bottom elevations of the 70 Sand were determined from boring and electric logs from each of the 5-Spot Hydrologic Test wells [Figures 5ST(3) and (4) of Volume I]. Gridded contour maps were generated using the contouring program Surfer, Version 8.0 (Golden Software, 2002). The maps were imported into Groundwater Vistas to represent the top and bottom elevations of the 70 Sand. The initial saturated thickness and potentiometric surface of the 70 Sand were determined from depth to water measurements in each of the wells prior to the beginning of the hydrologic testing [Figure 5ST(7) of Volume I]. A contour map of that surface was also generated in Surfer and used as initial conditions in the model simulations.

Hydraulic conductivity determined from the 5 Spot Hydrologic Test ranged from 2.5 to 9.5 ft/d using several analytical methods. As described in Volume I of this report, the Neuman analytical method for unconfined aquifer systems provided the best fit to the observed drawdown curves. The range of hydraulic conductivity using the Neuman method was 3.8 to 5.5 ft/d [Table 5ST(5)]. Hydraulic conductivity was used as a variable in calibrating the groundwater flow model, as described in the calibration section of this report.

Specific yield and specific storage are also aquifer properties of interest with respect to the response of an aquifer to extraction or injection. Specific yield is the storage term used for unconfined aquifers. Specific yield accounts for the physical draining of the aquifer that occurs in response to lowering of the water table and subsequent dewatering of pore space in the aquifer matrix. Specific yield is equivalent to the drainable porosity within an aquifer and typically ranges from 0.01 to 0.30 (Freeze, 1979). Specific yield calculated from the 5-Spot Hydrologic test ranged from 0.011 to 0.039.

Specific storage is a measure of the water released from storage due to compaction of the aquifer and expansion of water in response to a decline in head. Specific storage is the storage term used for confined aquifers, where lowering of the potentiometric surface in response to pumping does not result in physical dewatering of the aquifer. Specific storage multiplied by the saturated

thickness of an aquifer is referred to as storativity or storage coefficient. Storativity of a confined aquifer system is typically in the range of 5×10^{-3} to 10^{-6} or less. Comparison of the magnitude of the values for specific yield and specific storage indicates that in an unconfined aquifer, the bulk of the water produced is the result of physical dewatering of the aquifer.

Porosity of the aquifer is used in the model to estimate groundwater velocity. Groundwater velocity is calculated from the Darcy equation as follows:

$$v = ki/n$$

where

v = average interstitial groundwater velocity
k = hydraulic conductivity
i – hydraulic gradient
n = porosity (effective)

The porosity for the 70 Sand in the 5-Spot Test area is estimated from site data as 26 percent. However, for purposes of groundwater velocity calculations, the parameter required is effective (essentially interconnected) porosity. For the 5-Spot Test Model, the effective porosity is estimated as ranging from 15 to 20 percent.

Model Simulations

A numerical groundwater flow model was developed to evaluate, in detail, the site-specific hydraulics associated with unconfined flow during typical ISR operations. The 5-Spot Hydrologic Test provided a rare opportunity to compare model simulations to a tightly controlled and intensely monitored hydrologic test in an unconfined aquifer system. The scale of the Test and the model were designed such that detailed evaluation of hydraulic response within a single 5 spot well pattern was possible.

The 5-Spot Extraction Test was described in detail in Volume I. Simulation of that Test was used to calibrate the model to field measured results. The calibrated model was then used to simulate the 5-Spot Extraction/Injection Test in order to verify the model. The calibrated and verified model was then used to demonstrate impacts of an unconfined system on well pattern design and hydrologic testing of the monitor well ring. The 5-Spot Hydrologic Test Model has been extrapolated to a larger scale model that will be used to evaluate wellfield and permit area effects of ISR uranium mining in an unconfined aquifer system. Discussion of the larger scale model and simulations is provided in a separate report titled "Numerical Modeling of Groundwater Conditions Related to Insitu Recovery at the Moore Ranch Uranium Project, Wyoming" (Petrotek Engineering, Inc., 2008).

Calibration Simulation

Groundwater flow model calibration is an integral component of groundwater modeling applications. Calibration of a numerical groundwater flow model is the process of adjusting model parameters to obtain a reasonable match between field measured values and model predicted values of heads and fluxes (Woessner and Anderson, 1992). The calibration procedure is generally performed by varying estimates of model parameters (hydraulic properties) and/or boundary condition values from a set of initial estimates until an acceptable match of simulated and observed water levels and/or flux is achieved. Calibration can be accomplished using trial and error methods or automated techniques (often referred to as inverse modeling). Because of the tight control within the 5-Spot Hydrogeologic Test, in terms of the aquifer geometry and hydraulic stresses applied to the aquifer, only two parameters were varied during the calibration process, hydraulic conductivity and specific yield. Because only two parameters were varied and the fact that detailed analysis of the Extraction Test provided a relatively narrow range of likely values for those parameters, the trial and error method was considered a reasonable approach to calibration.

The adequacy of model calibration is judged by examining model residuals. A residual, as defined for use in this modeling report, is the difference between the observed change in groundwater elevation and the change in groundwater elevation predicted by the model. The objective of model calibration should be the minimization of the residual mean, residual standard deviation, and residual sum of squares (RSS) (Duffield, et al, 1990). The mean residual is the arithmetic average of all the differences between observed and computed water levels. A positive sign indicates that the model has under-predicted the observed water level and a negative sign indicates over-prediction. The residual standard deviation quantifies the spread of the differences between observed and predicted water levels around the mean residual. The ratio of residual standard deviation to the total head change across the model domain should be small, indicating the residual errors are only a small part of the overall model response (Anderson and Woessner, 1992). The RSS is computed by adding the square of each residual and is another measure of overall variability. Minimization of the RSS is typically used as the objective function during model calibration. In other words, as model input parameters are varied during calibration, a decrease in the value of the RSS is usually an indication that the "goodness of fit" is improving. For a statistically accurate model calibration, the residuals and the statistics based on the residual should approach zero.

Calibration was achieved by comparing field-measured (observed) drawdown in the 5-Spot well pattern with drawdown predicted by MODFLOW for the same wells under simulated pumping conditions of the 5-Spot Extraction Test. The Extraction test was described in detail in Volume I but is summarized here. A single well (PMW-1) was pumped at an average rate of 22.32 gpm for a period of

four days. The drawdown measured in each of the four injection wells, four observation wells and the extraction well at 1, 2, 3 and 4 days into the test were used as calibration targets to determine how well the model replicated the field results. Table 5ST (6) lists the values used for calibration targets. Note that all drawdown values have been corrected for barometric pressure changes monitored during the Extraction Test.

As previously stated, hydraulic conductivity and specific yield were varied during the calibration process to determine the best fit to the data. Table 5ST(7) summarizes the results of the calibration simulations. Table 5ST8 is a matrix showing the RSS value for each calibration. Results of model simulations indicate that the best fit to the data (lowest RSS) occurred in the simulation of hydraulic conductivity of 4.0 ft/d and specific yield of 0.025. These values are within the ranges calculated from analysis of the field data and therefore present reasonable estimates of those aquifer properties. Figures 5ST(27) and (28) graph the RSS of the calibration simulations versus the specific yield and hydraulic conductivity, respectively. The range of specific yield and hydraulic conductivity that were determined using the Neuman analysis are also shown on the figures. The potentiometric surface at the end of that simulation is shown in Figure 5ST (29). Figure 5ST(30) indicates the model residuals at the end of the Extraction Test.

The top and bottom elevations and initial saturated thickness, initial potentiometric surface and hydraulic gradient were all field measured values that were imported directly into the model. Therefore no evaluation of these parameters was included in the calibration process. Result of the actual 5-Spot Extraction Test did not indicate any significant hydraulic boundaries (either barrier or recharge) encountered during the period of the test. Therefore, extrapolation of the top and bottom elevations and initial potentiometric surface is considered justified for purposes of this model simulation and no additional calibration of those terms was attempted.

A summary of input parameters used in the final calibration simulation is presented in Table 5ST(9).

Verification Simulation

The numerical groundwater flow model was calibrated to the 5-Spot Extraction Test data. Verification that the model can reproduce hydraulic heads or drawdown under simulated hydraulic stresses in the aquifer other than those simulated for the calibration data set provides additional confidence in the predictive capabilities of the model. The calibrated model was then used to simulate the 5-Spot Extraction/Injection Test as a verification of the model.

As described in Volume I, the 5-Spot Extraction/Injection Test included extraction from a single well (PMW-1) and distribution of the recovered water into four

injection wells. The test included three stages. The first stage included pumping from the extraction well for 2.06 days at a rate of 20 gpm. The recovered water was equally distributed to the four injection wells (5 gpm each). The second stage involved continued extraction at 20 gpm from PMW1, with injection into only two of the injection wells (IMW3 and IMW4 at 10 gpm each) for a period of 1.0 days. The final stage included extraction from PMW1 at 20.5 gpm for a period of 0.92 days and injection of all recovered water into injection well IMW3. Validation targets included the change in water levels in each of the four monitor wells, four injection wells and the extraction well at the end of each stage of the Extraction/Injection Test. The validation targets are included in Table 5ST(9).

The model simulation reproduced the field results reasonably well, with the following exceptions (Table 5ST(10). As described in Volume I, complications encountered during development of well IMW2 resulted in that well not being adequately developed. As a result, the water level rise was significantly larger in that well compared to the other three injection wells during the first stage of the Extraction/Injection Test. Analysis of the data from the Extraction Test indicate that the transmissivity and hydraulic conductivity at this location are similar to the value of those parameters at the other three injection wells. The discrepancy between the simulated and observed values at IMW2 is largely attributed to well inefficiency or incomplete well development. The simulated water level rise in wells IMW3 and IMW4 during the second stage of the Test, and in well IMW3 during the final stage of the Test, were also much less than observed. Again, the discrepancy between the simulated and observed values at IMW3 and IMW4 is largely attributed to well inefficiency or incomplete well development. By comparison, wells that were not used for extraction of injection showed good comparison between simulated and observed data. Figure 5ST(31) shows the simulated potentiometric surface at the end of the 5-Spot Extraction/Injection Test. Residuals from the verification simulation are shown on figure 5ST(32).

Based on the results of the calibration and verification simulations, the 5-Spot Hydrologic Test model adequately simulates hydraulic stresses applied to the production zone aquifer under unconfined conditions. The numerical model is suitable for additional evaluation of site-specific conditions related to ISR uranium mining in an unconfined aquifer.

Additional Simulations

Simulations were performed using the numerical model to address requests for additional information posed by the NRC in response to the SML license application. The additional simulations described in this report include:

- A hydrologic test design to demonstrate hydraulic communication between a pumping well within the wellfield and the monitor well ring at a proposed distance of 500 feet from the wellfield;

- Simulation of the degree of dewatering that could occur and how pulsing wells (alternating between injection and extraction) can minimize or negate the impacts.

A hydrologic testing program is required to demonstrate that the monitor well ring that circumscribes the wellfield is hydraulically connected to the production zone before ISR operations can commence. The unconfined conditions present in portions of the production zone aquifer may limit the horizontal extent of measurable hydraulic response to pumping. The calibrated model was set up to evaluate the amount of drawdown that could be expected at distances of 500 feet or greater using pumping rates that can be sustained from a single extraction location. Observation wells were placed at a distance of 500 feet, 600 feet and 700 feet from the extraction well. The well configuration for simulation of a wellfield hydrologic test design is presented in Figure 5ST(33). Pumping rates of 20, 30 and 40 gpm were simulated. The hydraulic responses of the different simulations are shown on Figure 5ST (34). Results of the simulations for various times, distances and pumping rates are tabulated in Table 5ST(11). The results indicate that it will take numerous pumping tests to demonstrate hydraulic communication with all of the wells in the monitor well ring. Additional modeling will be performed with the wellfield scale model to determine the number of tests that will be required.

The NRC has expressed concerns regarding potential dewatering of the 70 Sand during production operations and how that may effect restoration of the aquifer. As described in Volume I, the drawdown cones associated with extraction wells tend to be steeply sided and of generally small area even without the benefit of reinjection. Injection tends to further decrease the area that may be dewatered during production. However, to ensure that areas that may become temporarily dewatered during a production sequence, pulsing of the production zone (switching extraction wells to injection wells and injection wells to extraction wells) can be used to effectively resaturate essentially all areas within the wellfield that may have been dewatered. The 5 Spot Hydrologic test model that was simulated in the previous discussions was expanded to demonstrate this point. A small-scale wellfield is simulated with a total of 9 extraction wells and 16 16 injection wells, initially. The well configuration is shown in Figure 5ST(35). The simulation includes two stages. The first stage of the simulation is run for a period of 30 days with each of the extraction wells pumping at a rate of 20 gpm for a total of 180 gpm. The total injection rate of the 16 injection wells was also 18 gpm. The net change in water levels at the end of this stage is shown in Figure 5ST(36). The valleys represent net drawdown and the peaks represent net rise in water levels in the aquifer. For the second stage of production, the wells are switched so that the extractors become injectors and the injectors become extractors. The extraction and injection rates are the same as in the previous phase but reversed. This stage is also run for 30 days. The change in water levels at the end of this stage is shown in Figure 5ST (37). Note that the

peaks and valleys are reversed. Wherever drawdown had occurred there is now a peak, or high indicating that all of the area that was dewatered has resaturated. Similar pulsing during restoration will ensure that any areas dewatering during a pumping stage can be sufficiently resaturated.

Discussion and Summary

A numerical model was developed to evaluate the response of an unconfined aquifer to hydraulic stresses imposed by operation of an ISR uranium project. The model was developed using site-specific data regarding top and bottom aquifer elevations, saturated thickness, potentiometric surface and hydraulic gradient, hydraulic conductivity, specific yield, and porosity of the modeled aquifer. The model was calibrated to water level data collected during the 5-Spot Extraction Test within an unconfined portion of the production zone aquifer (70 Sand). The 5-Spot Extraction Test included a centrally located recovery well and 8 observation wells located within 72 feet of the recovery well. The simulated hydraulic conductivity and specific yield values that provided the best calibration results were 4.0 ft/d and 0.025, respectively. These simulated values are within the range of values estimated from analysis of the Extraction Test data.

The calibrated model was then used to simulate the 5-Spot Extraction/Injection Test. The 5-Spot Extraction/Injection Test was conducted in three stages. The first stage included injection into each of the four injection wells at 5 gpm per well for 2 days. The second stage involved injection into two of the wells at 10 gpm per well for 1 day and the third stage included injection of 20.5 gpm into a single well for 1 day. A single extraction well was used for all three stages of the test. Results of the simulation agreed well with the field data with some exceptions at the injection wells. Discrepancies between the simulated and observed water levels are largely attributed to incomplete well development and or well efficiency issues. Simulated water level changes at non-injection observation wells correlated well with the observed data. Simulation of the 5-Spot Extraction/Injection Test provided verification that the calibrated model was adequate for additional simulations of hydraulic stresses to the unconfined production zone aquifer at the Moore Ranch project.

Additional simulations were run to evaluate the maximum lateral extent that hydraulic responses resulting from pumping at a single extraction well can be observed. The results indicate that hydrologic testing to demonstrate hydraulic communication between the production zone in the wellfield and the monitor well ring will require several separate pumping tests.

A pulsing simulation was run in which extraction and injection wells were switched after 30 days of operation. The results of the simulation indicate that any portions of the aquifer that are dewatered during ISR production operations can be readily resaturated by pulsing wells.

The 5-Spot Hydrologic Test Model has been calibrated and verified to site-specific data and hydraulic stress tests. The model provides representative simulation of the unconfined 70 Sand aquifer during production and restoration operations. The numerical model is a useful tool for assessment of the aquifer response to ISR uranium mining at the Moore Ranch Project. This model is expanded to simulate wellfield scale production and restoration operations. Results of those simulations are included in a separate report titled "Numerical Modeling of Groundwater Conditions Related to Insitu Recovery at the Moore Ranch Uranium Project, Wyoming" (Petrotek Engineering, Inc., 2008).

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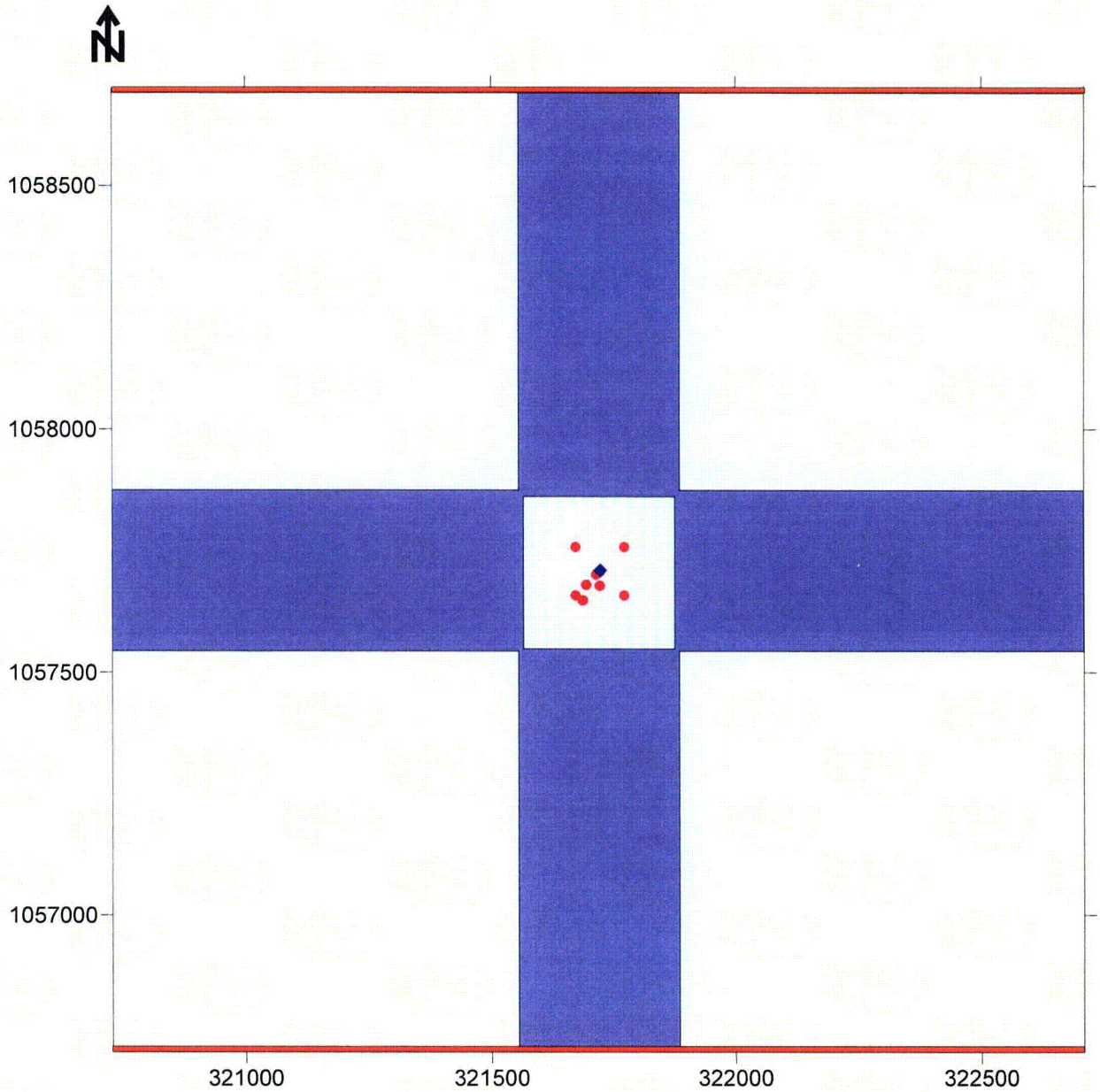

Extraction Well

Injection/Monitor Well

General Head Boundary

Cell Dimensions

1 ft x 1 ft

5 ft x 5 ft

Variable
1 ft x 1 ft to 5 ft x 5 ft

0 200 400
feet

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Figure 5ST(25). Model Domain
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST25.srf Date: 9/08/08

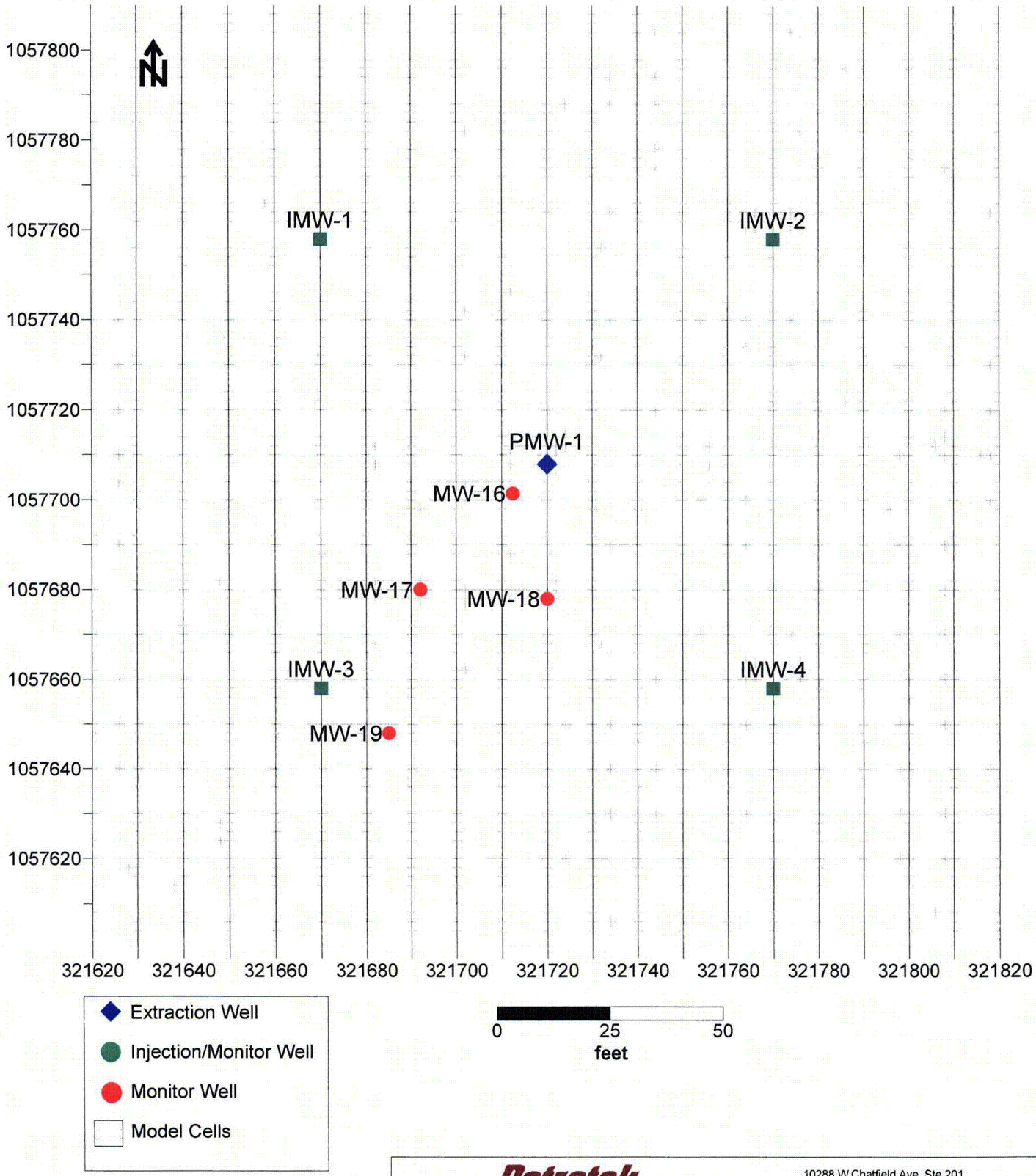

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Figure 5ST(26). Well Configuration, 5-Spot Hydrologic Test Simulations
Moore Ranch Uranium Project, Wyoming

By: EPL | Checked: HD | File ID:fig5ST26.srf | Date: 9/08/08

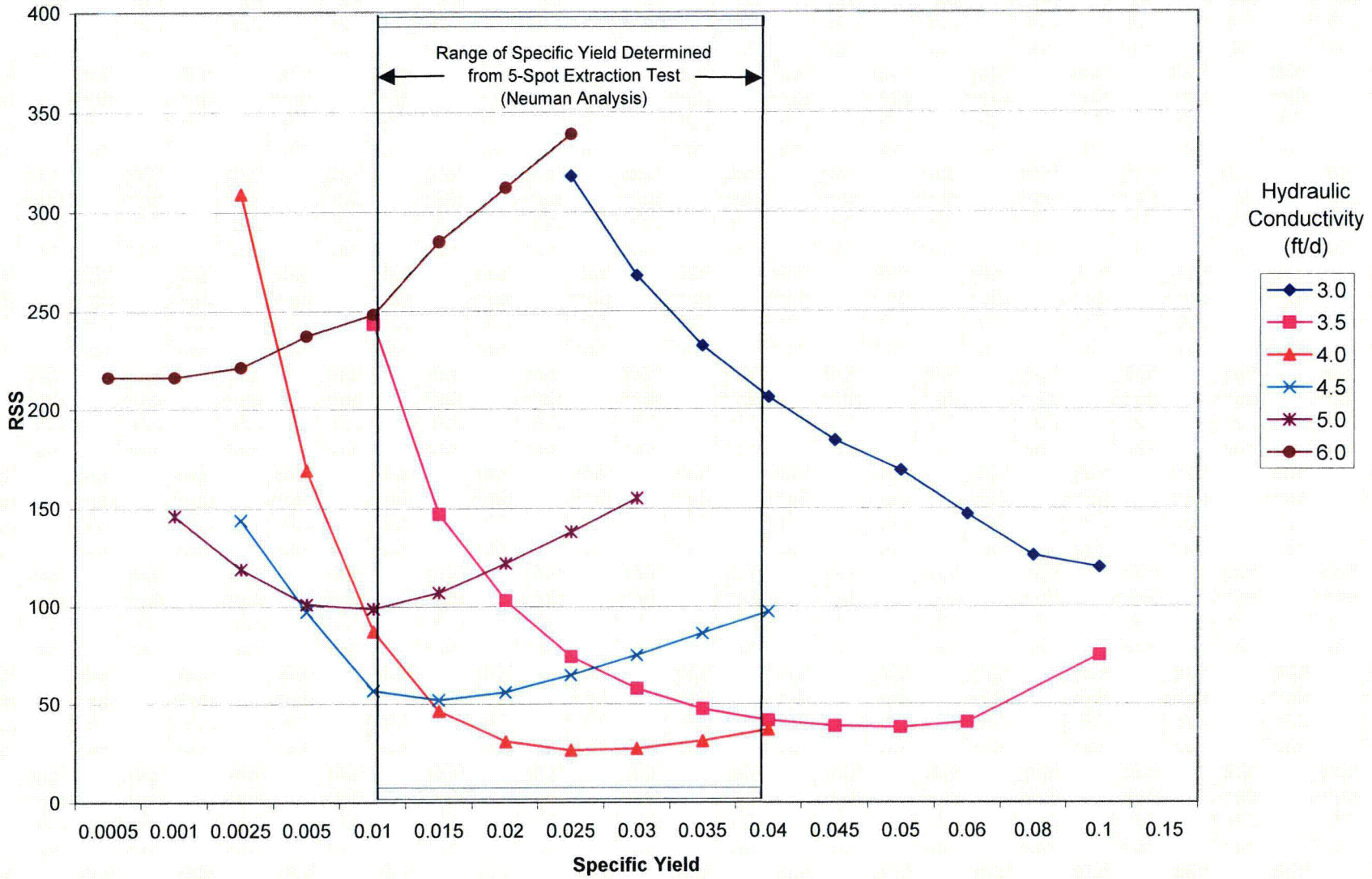

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Figure 5ST(27). Residual Sum of Squares vs Specific Yield Calibration Simulations
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST--27.srf Date: 09/08/08

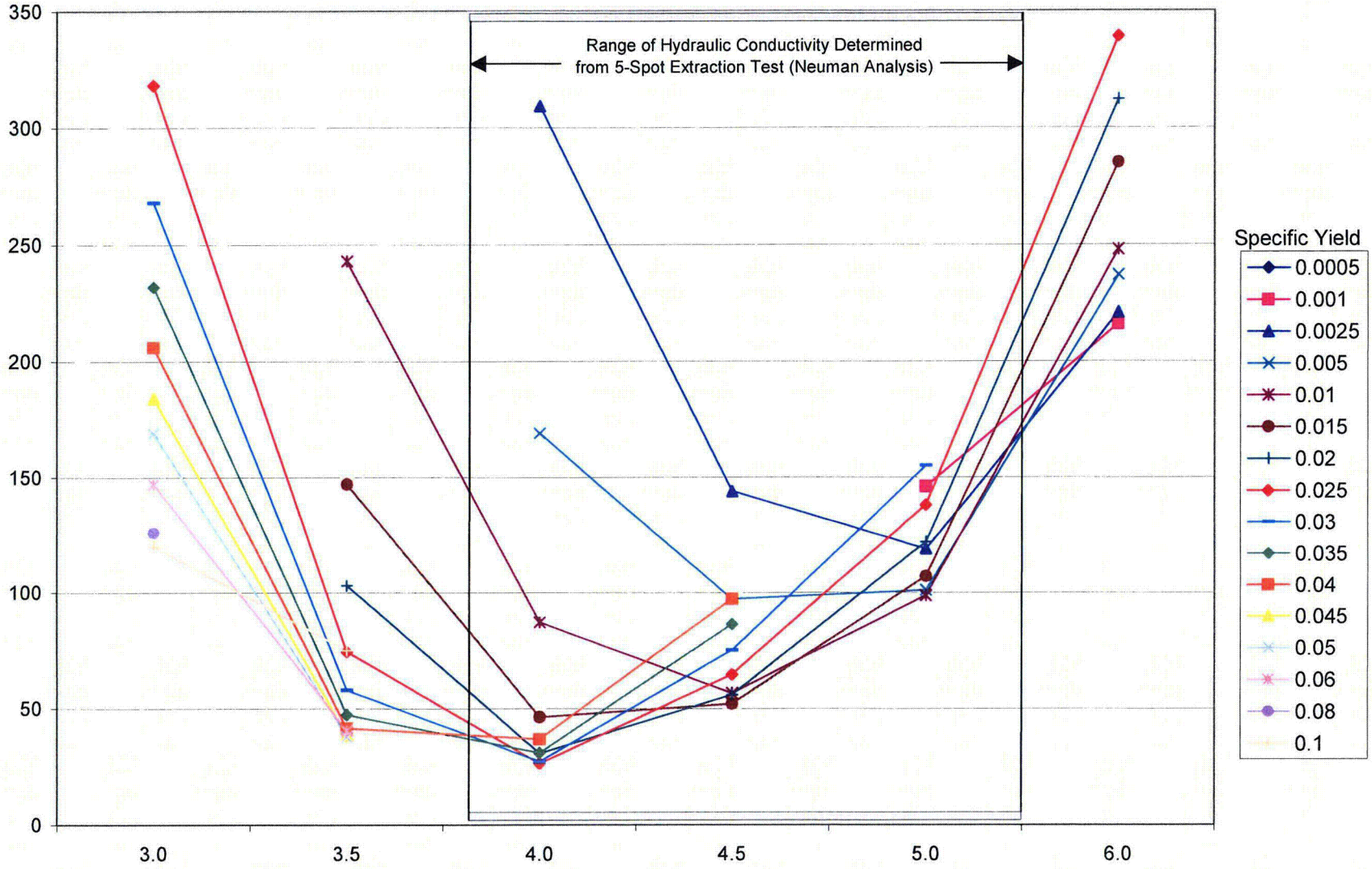

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Figure 5ST(28). Residual Sum of Squares Hydraulic Conductivity Calibration Simulations
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST--28.srf Date: 09/08/08

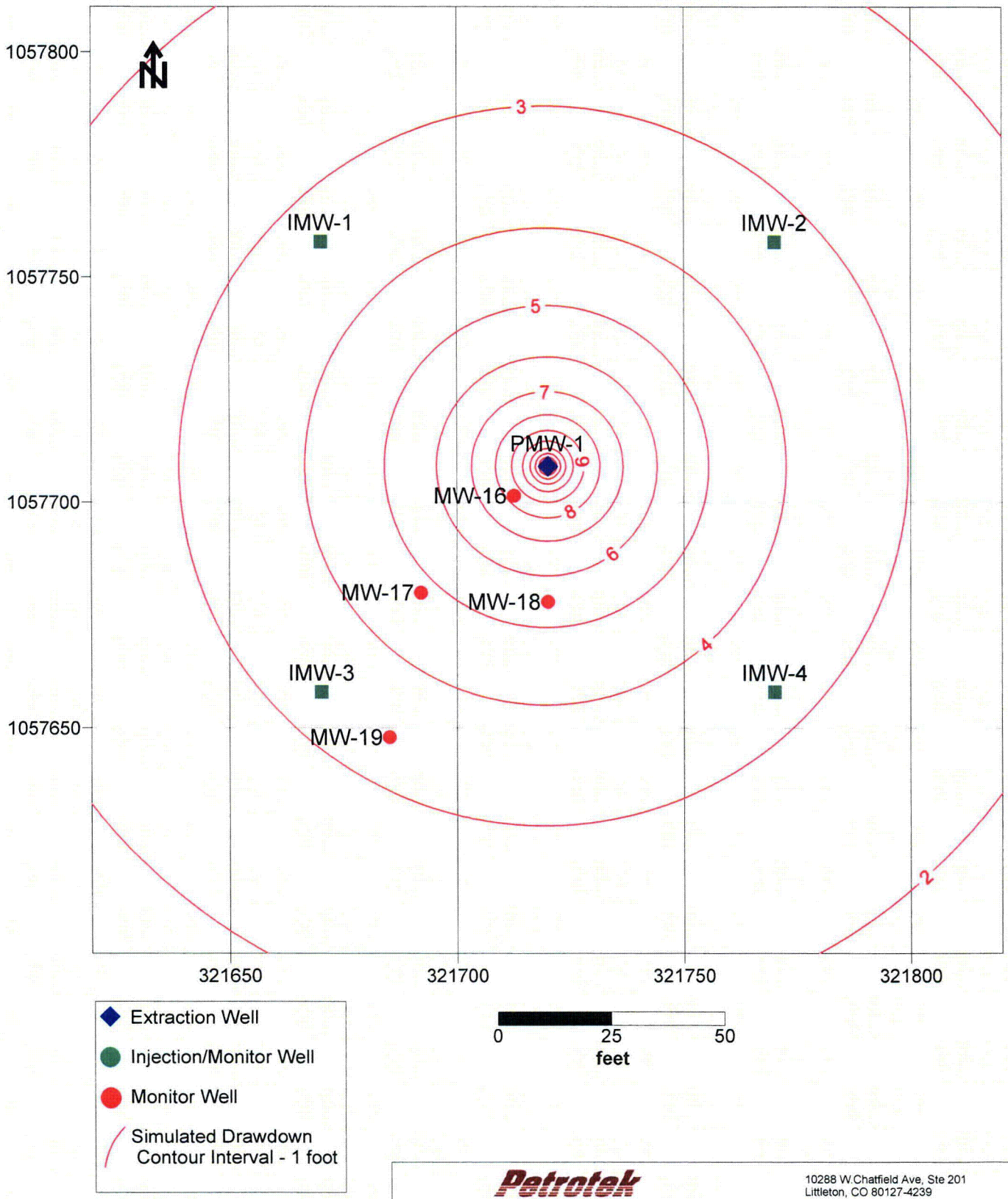

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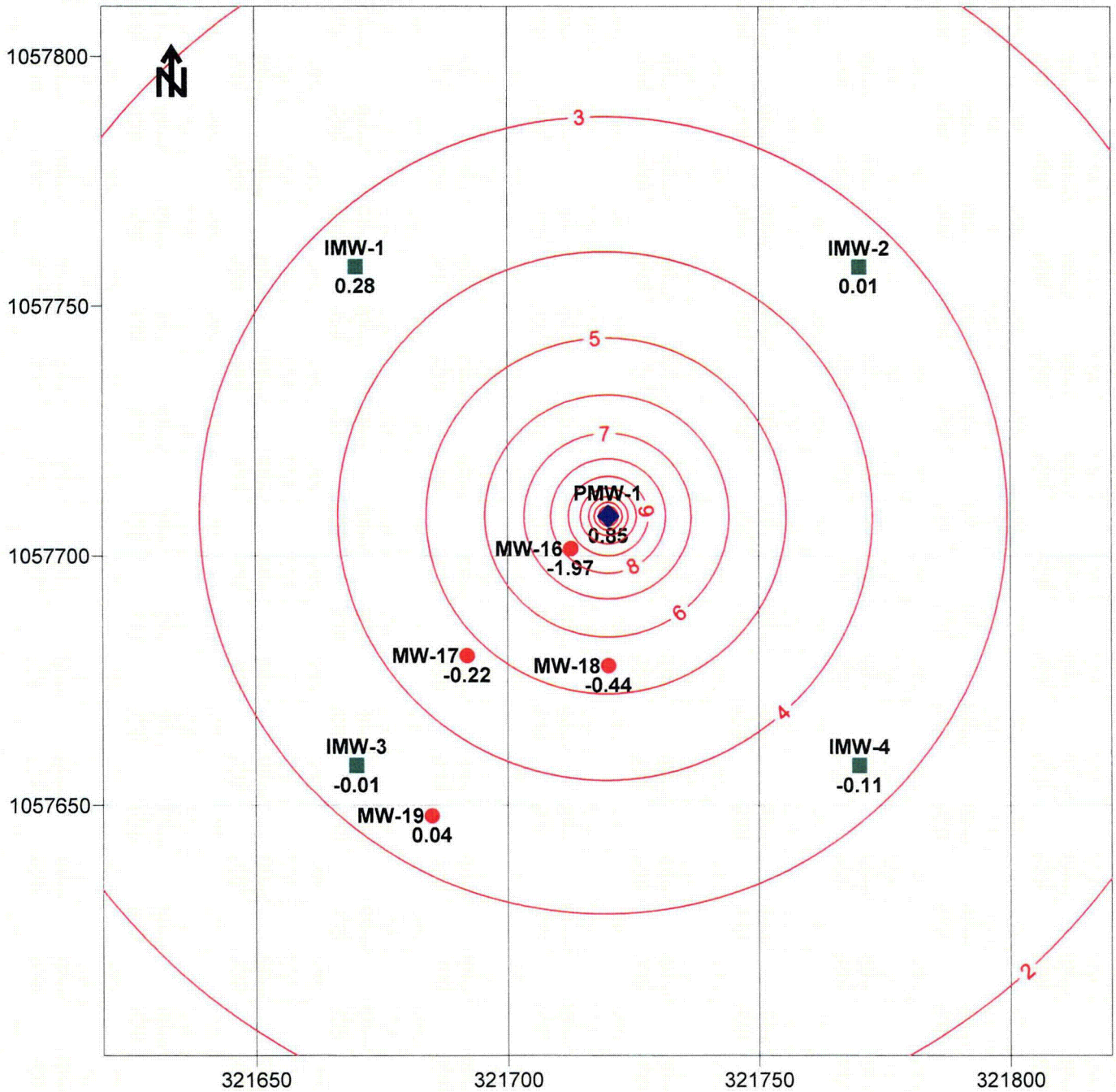
Figure 5ST(29). Drawdown - End of 5-Spot Extraction Test Calibration Simulation
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST29.srf Date: 9/08/08



Extraction Well

Injection/Monitor Well

Monitor Well

Simulated Drawdown Contour Interval - 1 foot

0 25 50
feet

Residual = Observed -Simulated (feet)

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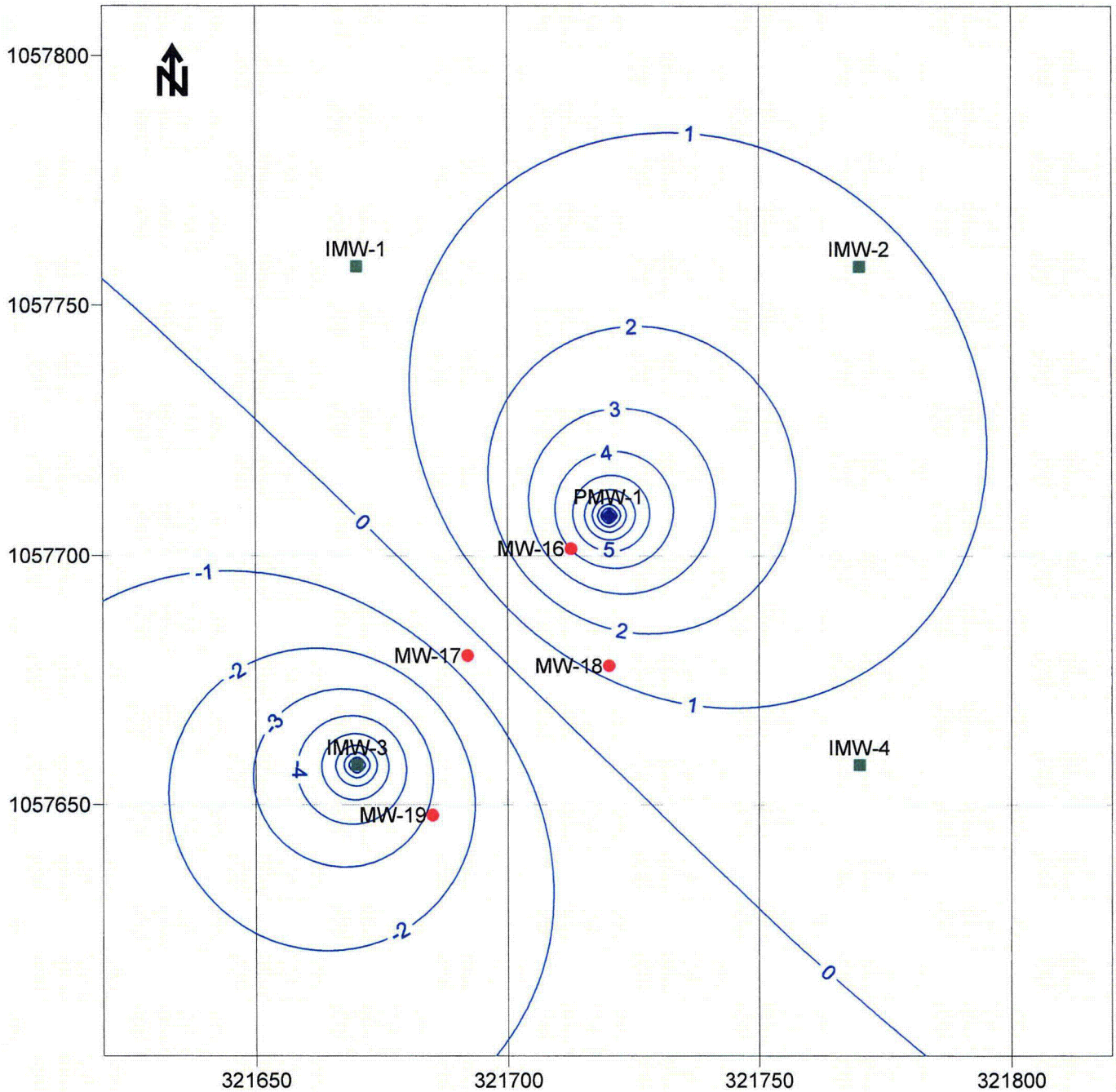
Figure 5ST(30). Residuals - End of 5-Spot Extraction Test Calibration Simulation
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST30.srf Date: 9/08/08



Extraction Well

Injection/Monitor Well

Monitor Well

Simulated Net Change in Water Level
Contour Interval is 1 foot

Positive value indicates drawdown in water level
Negative value indicates rise in water level

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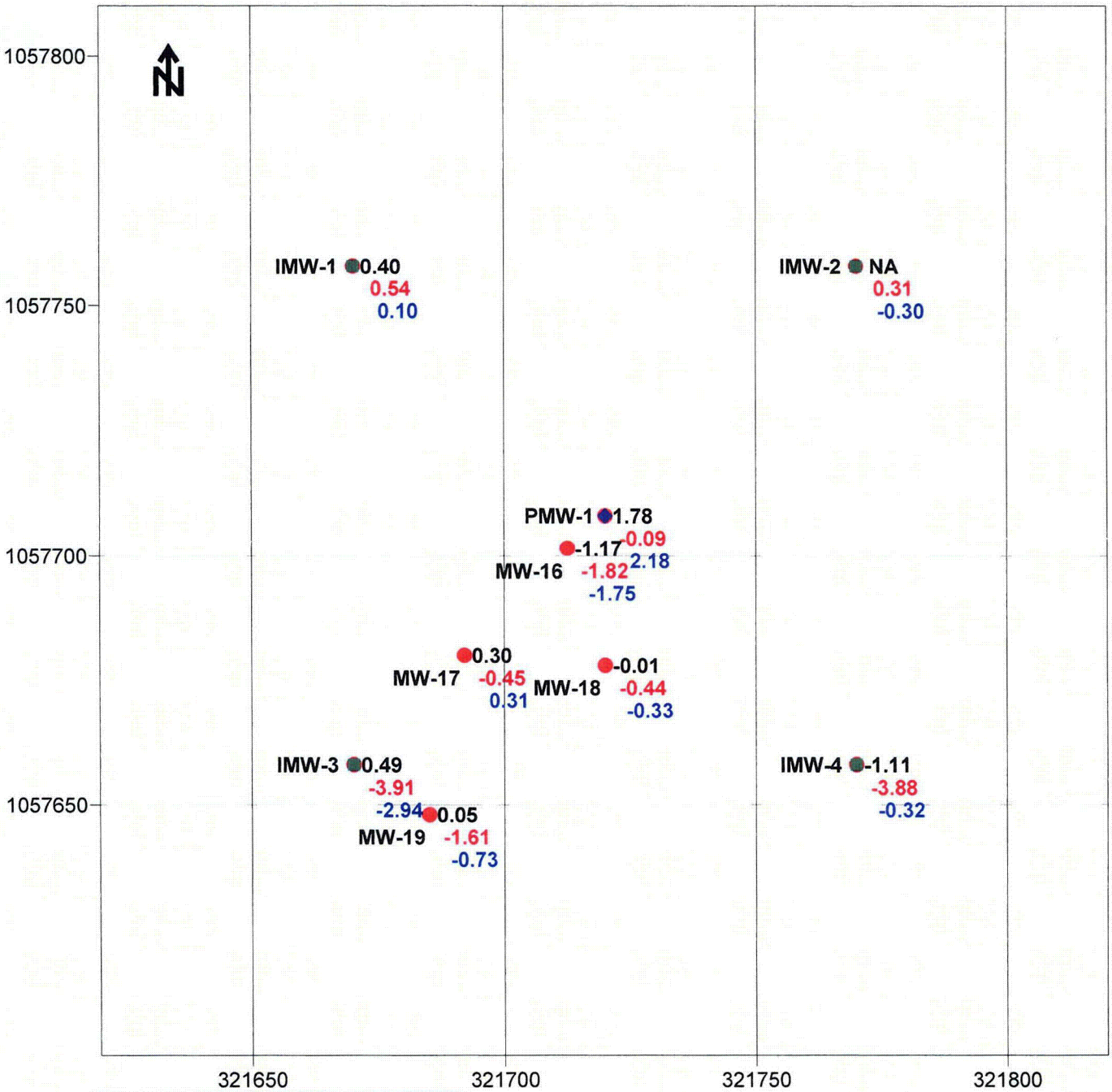
Figure 5ST(31). Net Change in Water Level
End of 5-Spot Extraction/Injection Test Verification Simulation
Moore Ranch Uranium Project, Wyoming

By: EPL | Checked: HD | File ID:fig5ST31.srf | Date: 9/08/08



Extraction Well

Injection/Monitor Well

Monitor Well

Residuals
(Observed - Simulated) (feet)

0.05 End of 1st Stage
-1.61 End of 2nd Stage
-0.73 End of 3rd Stage

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Figure 5ST(32). Residuals-Extraction/Injection Test Verification Simulation
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST32.srf Date: 9/08/08

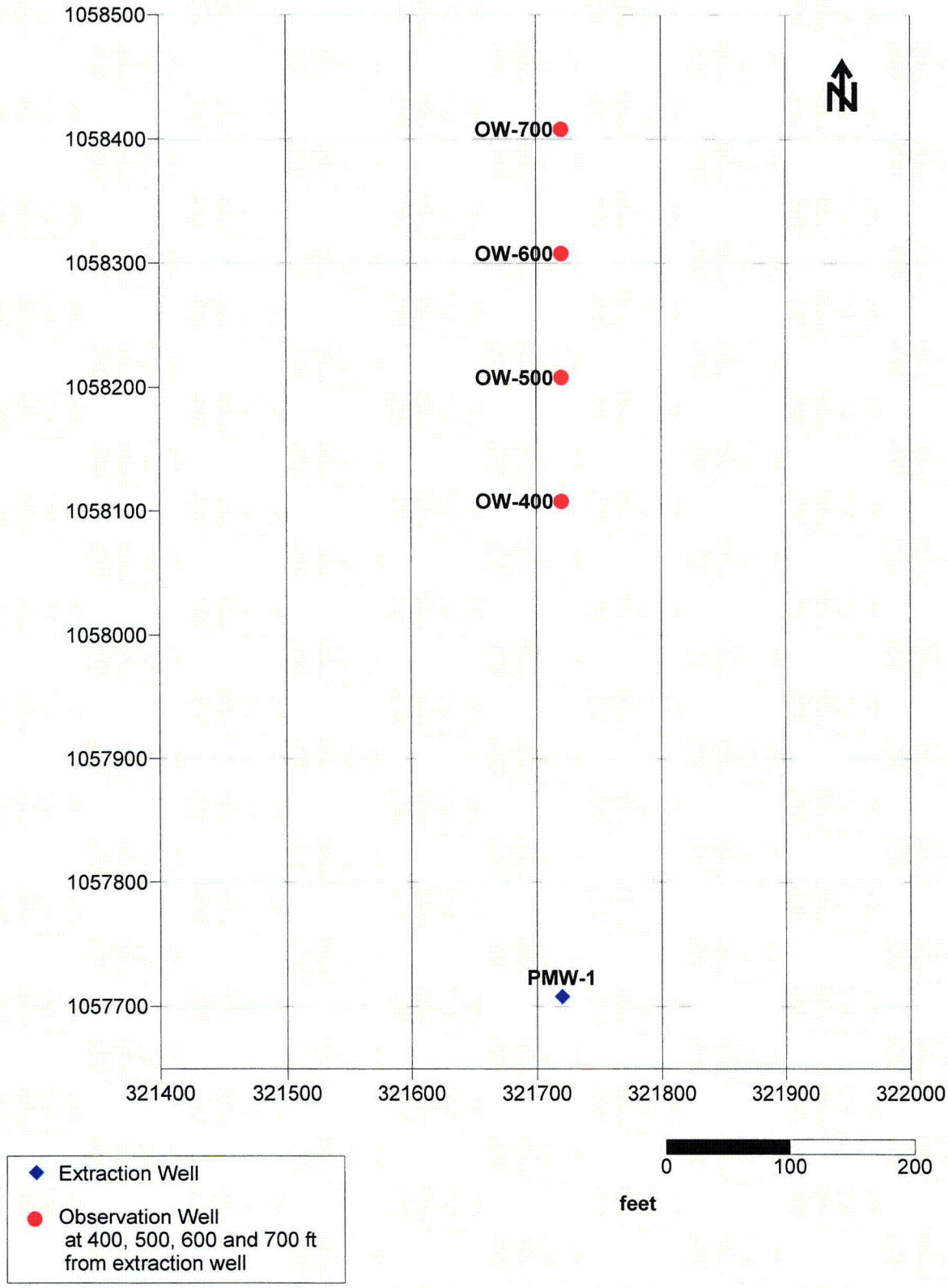

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Figure 5ST(33). Well Configuration, Hydrologic Test Simulations
Moore Ranch Uranium Project, Wyoming

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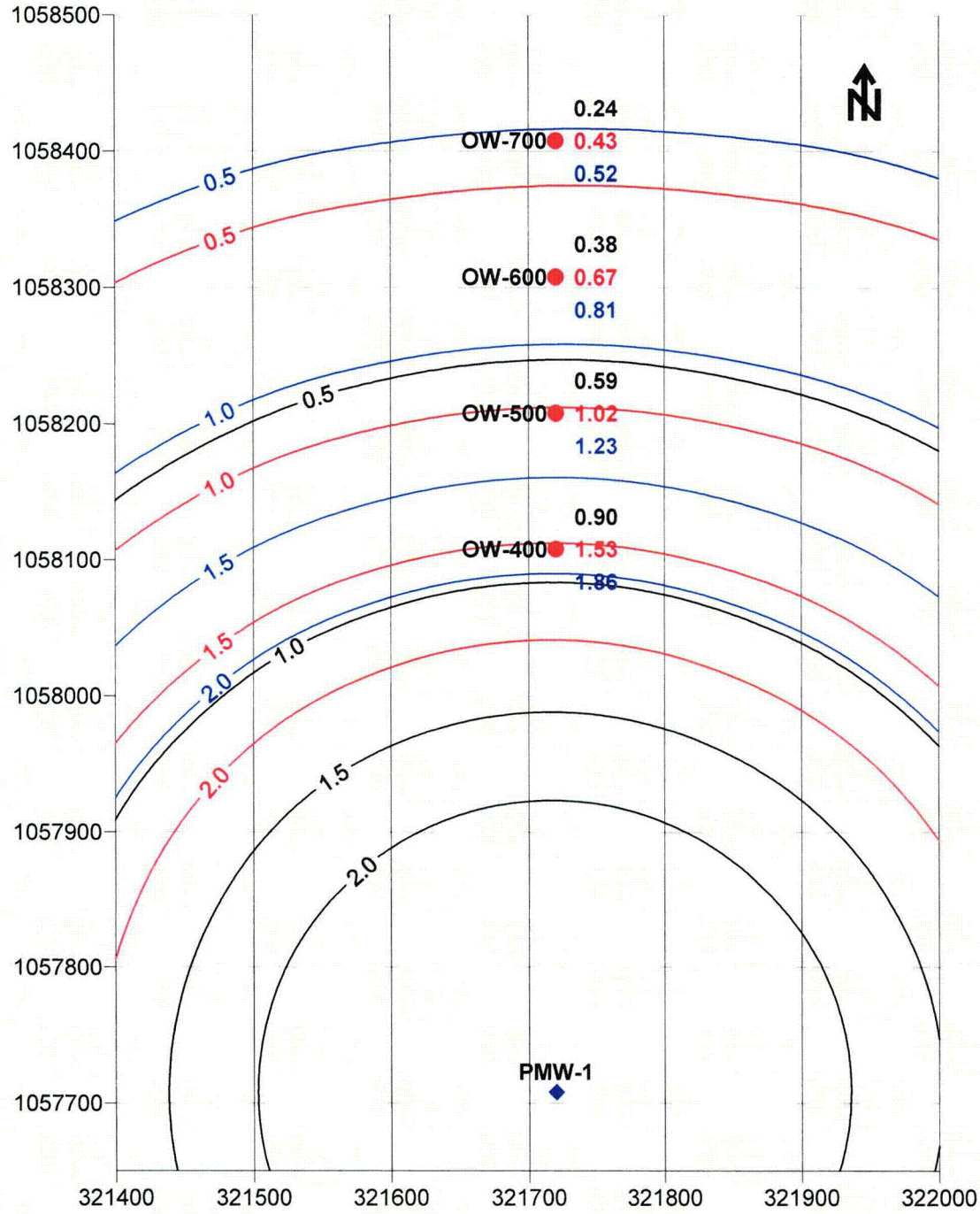

◆ Extraction Well

● Observation Well at 400, 500, 600 and 700 ft from extraction well

Simulated Drawdown After 8 Days of Pumping

0.38 - 20 gpm Simulation
0.67 - 30 gpm Simulation
0.81 - 40 gpm Simulation

0 50 100
feet

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Figure 5ST(34). Drawdown Response, Hydrologic Test Simulations
Moore Ranch Uranium Project, Wyoming

By: EPL | Checked: HD | File ID:fig5ST34.srf | Date: 9/08/08

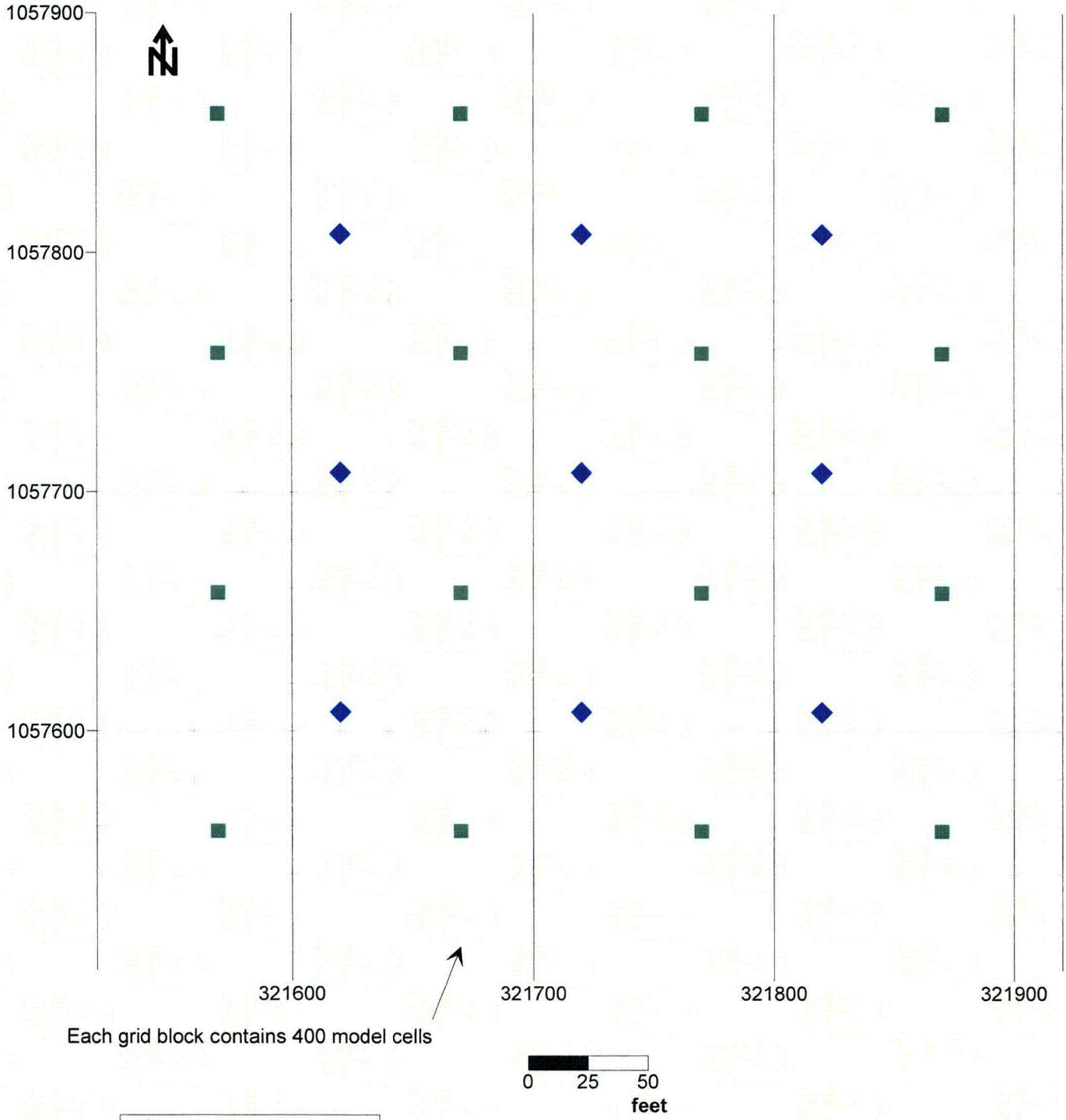

Figure only shows a portion of the model domain.
See Figure 5ST25 for full extent of model domain

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Figure 5ST(35). Well Configuration, Wellfield Pulsing Simulations
Moore Ranch Uranium Project, Wyoming

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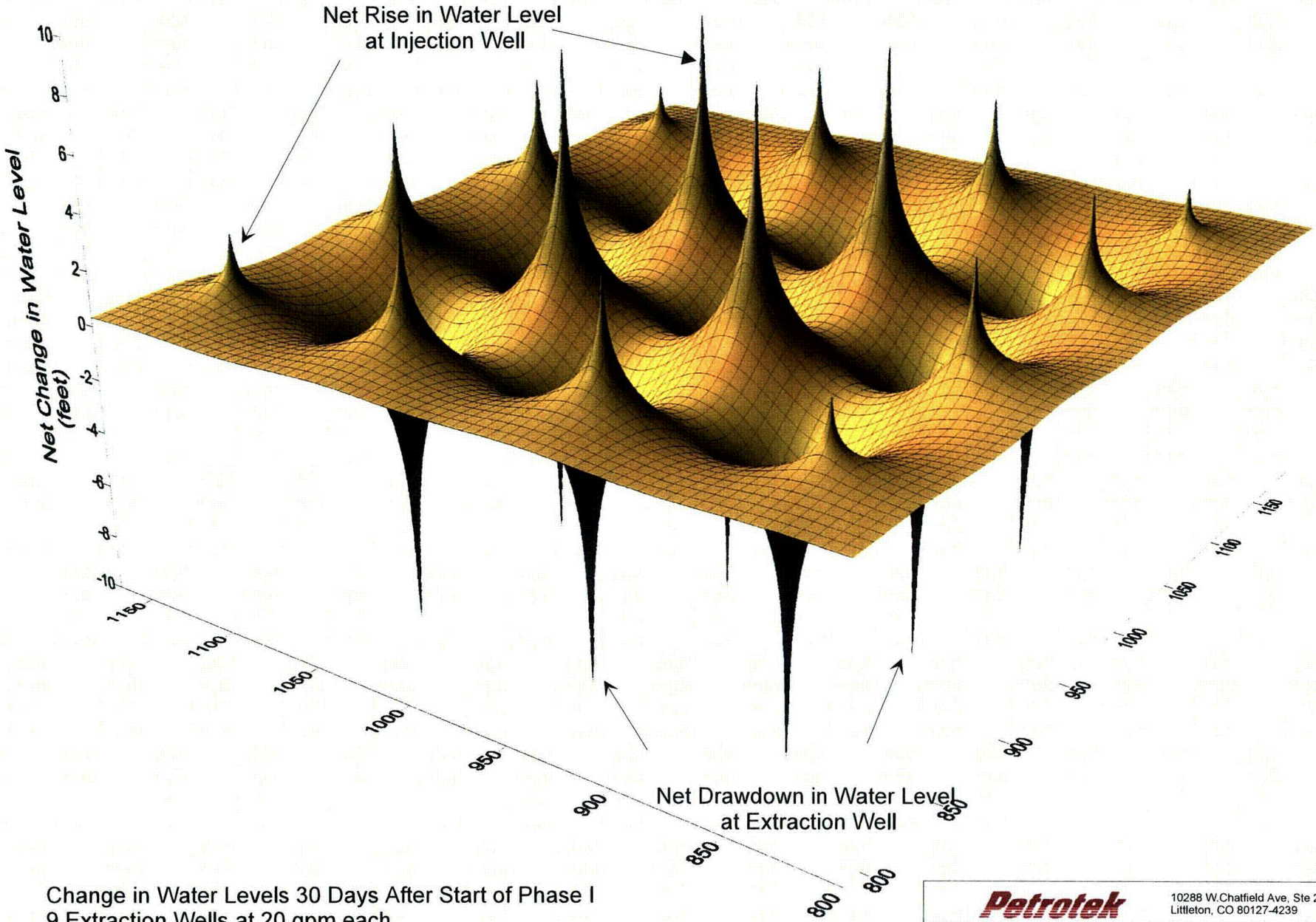

Change in Water Levels 30 Days After Start of Phase I
9 Extraction Wells at 20 gpm each
16 Injection Wells at a total of 180 gpm

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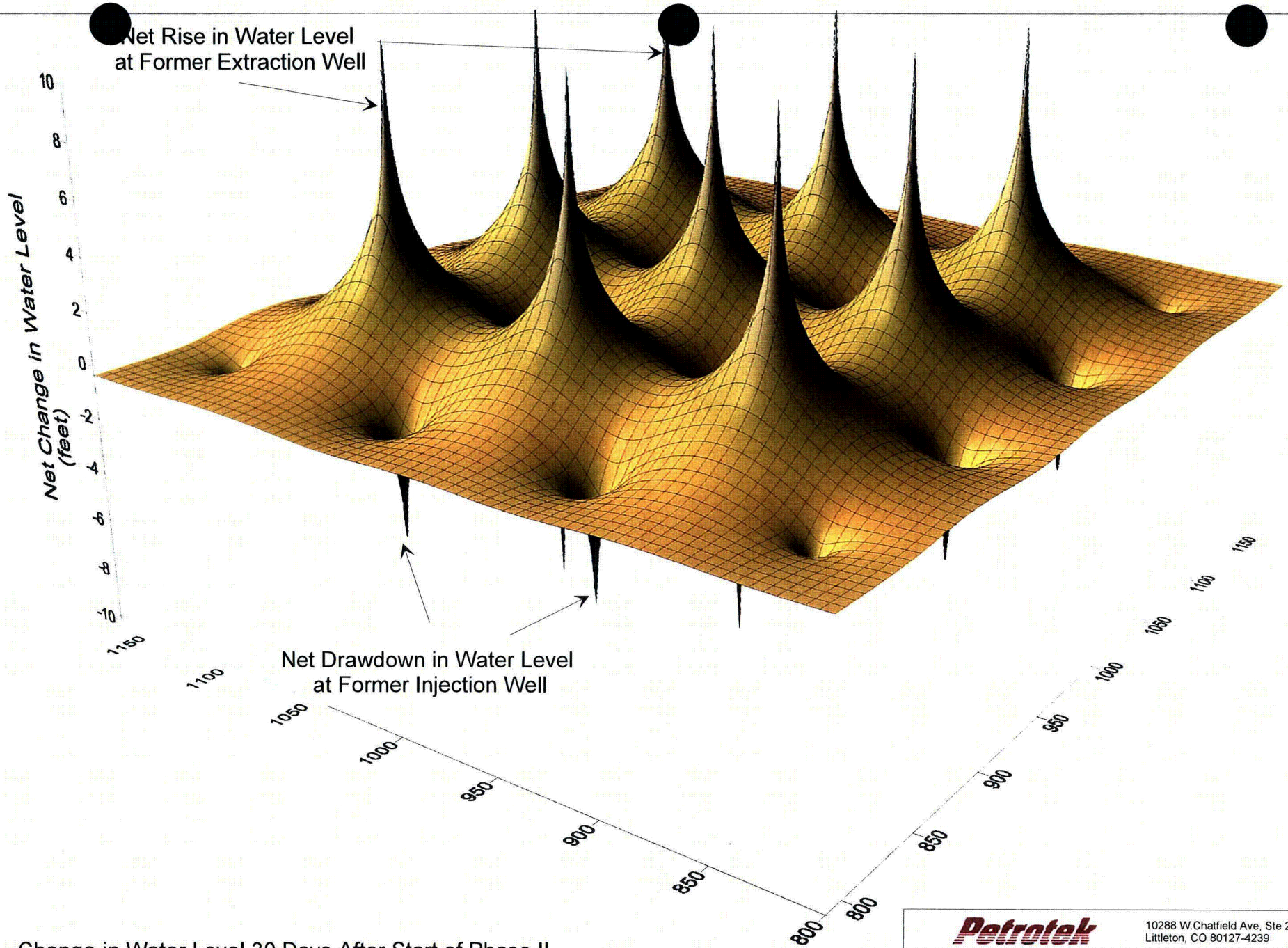
Figure 5ST(36). Net Water Level Change, Phase I Wellfield Pulsing Simulation Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST36.srf Date: 9/08/08



Change in Water Level 30 Days After Start of Phase II
Extraction and Injection Wells are Reversed.

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Figure 5ST(37). Net Water Level Change, Phase II Wellfield Pulsing Simulation
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5ST37.srf Date: 9/08/08

Technical Memorandum

To: **Donna Wichers, Ken Milmine, Uranium One**

From: **Errol Lawrence, Petrotek Engineering Corporation**

Date: **8/08/01**

Subject: Evaluation of Potential Hydraulic Communication Between the Production Zone and Underlying Aquifers, Vicinity of Well 885, Moore Ranch Uranium Project, Wyoming

Introduction

Petrotek Engineering Corporation (PEC) has completed an evaluation of possible hydraulic communication between the production zone aquifer (referred to as the 70 Sand) and the underlying aquifer (referred to as the 68 Sand) within a proposed wellfield area of the Moore Ranch Uranium Project, in Campbell County, Wyoming. In 1977, Conoco reported that a pump test conducted at well 885 indicated that hydraulic communication may exist between the two hydrostratigraphic units. The pump test was repeated by PEC and Uranium One in June 2008 at the same well location as the Conoco test, but at higher rates and for longer duration. Results of the recent pump test indicate that there is no hydraulic communication between the 70 and 68 Sands in the vicinity of the previously pumped well. Additional discussion follows.

Conoco Pump Test of Well 885 (1977)

Conoco reported potential hydraulic communication between a proposed production zone aquifer (70 Sand) and the underlying aquifer (68 Sand) in its 1982 Permit to Mine Application for the Moore Ranch Mine and Sand Creek Mine Projects in Campbell County, Wyoming. The reporting was based on the results of a 1977 pump test conducted at well 885. Well 885 is completed in the 70 Sand. In addition to the pumping well, water levels were monitored at two other 70 Sand monitor wells and one underlying 68 Sand monitor well. The 70 Sand monitor wells were identified as 886 and 888 and were reported as being 64 and 50 ft, respectively from the pumping well. However, based on the coordinates provided in the Conoco Permit to Mine Application, the distances are 161 and 12 feet, respectively. The 68 Sand monitor well was reported by Conoco as being 119 feet from the pumping well. Based on the coordinates in the Conoco to Mine Application, the distance to the pumping well appears to be 159 feet. Well data from the wells monitored during the test are provided in Table CR 2-7c(1). The location of the pumping well and observation wells are shown on Figure CR 2-7.c(1).

Well 885 was pumped at a rate of 3.4 gpm for a period of 1 day (for a total of

4,900 gallons). Conoco reported drawdown at the end of the test in the 70 Sand monitor wells 886 and 888 of 0.74 and 1.95 ft, respectively. Drawdown was also reported in the underlying monitoring well (887) of 0.76 feet. Conoco stated in its report that the well seal was suspect and that the pump test did not conclusively demonstrate hydraulic communication between the production zone aquifer and the underlying aquifer.

Uranium One Pump Test of Well 885 (2008)

In an attempt to verify the hydraulic communication reported by Conoco, Uranium One and PEC conducted a pump test at well 885 on June 4, 2008. Well 885 is located in the southern half of proposed wellfield one of the Moore Ranch Uranium Project. As in the 1977 Conoco test, water levels were monitored during the test in wells 886 and 888 (70 Sand) and well 887 (68 Sand). However, for this pump test, the wells were instrumented with transducers to allow more frequent water level measurements. Figure CR 2-7.c(1) is a map indicating the location of the pumping well and observation wells.

Well 885 was initially pumped at a rate of approximately 10 gpm for 1 hour. The rate was increased to 12.5 gpm for another hour and then increased to rate of slightly over 16.1 gpm for 18 hours. The average pumping rate for the 20 hours pumping period was 15.6 gpm. A total of 18,600 gallons were extracted during the test, providing a significantly larger hydraulic stress to the 70 Sand than the Conoco test.

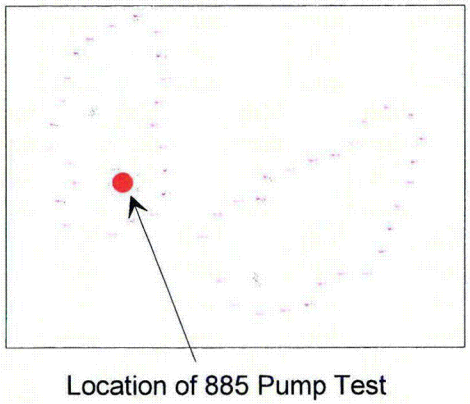
Drawdown in the pumping well (885) was 17.4 feet at the end of the test [Figure CR 2-7.c(2)]. The observed drawdown at the end of the test at 70 Sand monitor well 888 was 2.6 ft [Figure CR 2-7.c(3)]. Note that well 886 showed did not show drawdown during the test and actually showed a slight rise during the test [Figure CR 2-7.c(4)]. At the start of the test, the depth to water at this well was approximately 20 to 25 feet shallower than the depth to water in wells 885 and 888. Well construction data reported by Conoco (1982) indicates this well should be completed in the same interval as the pumping well. However, based on the test results and the depth to water prior to the start of the test, well 886 does not appear to be completed within the same hydrostratigraphic unit as well 885.

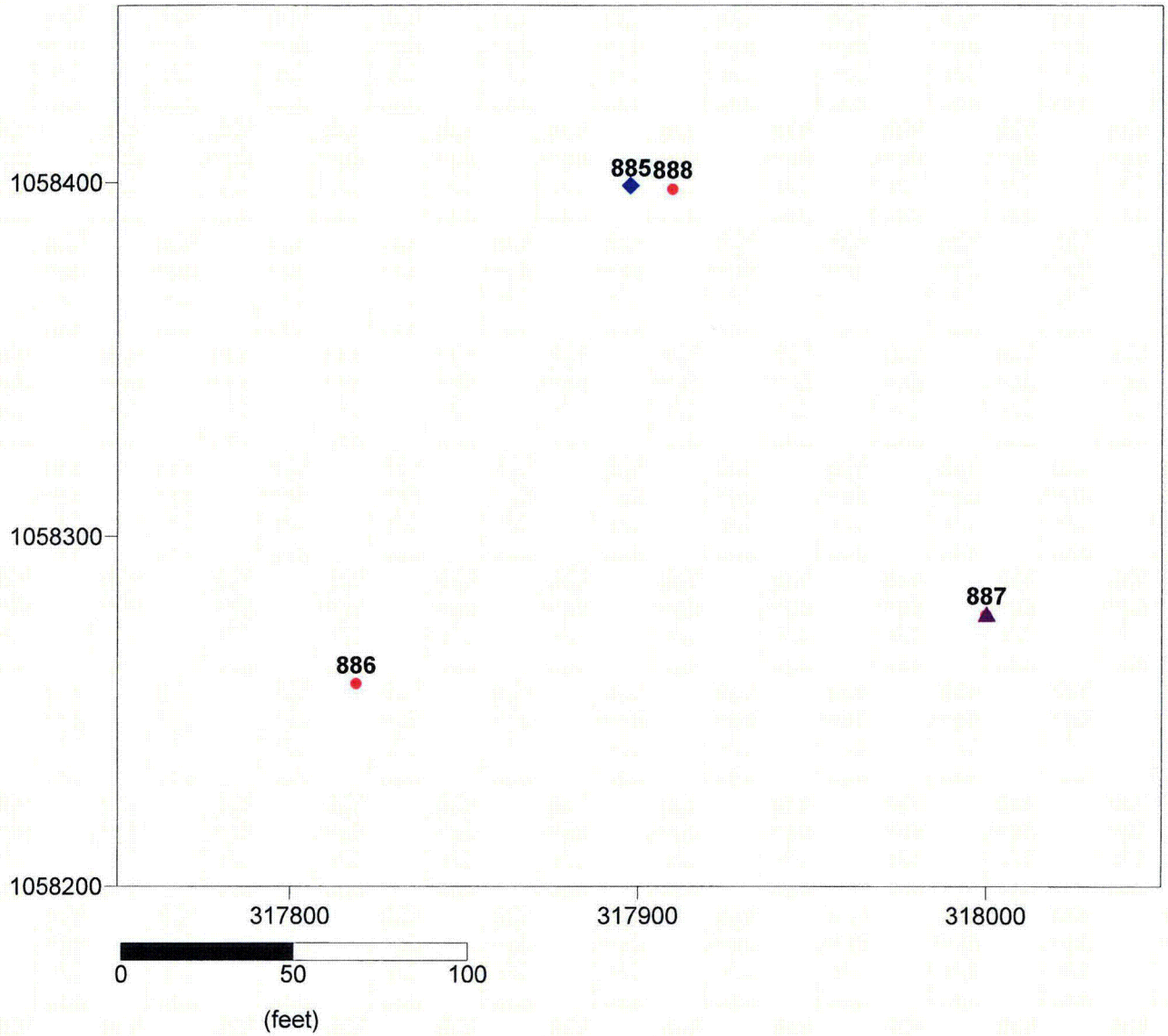
The underlying monitor well (887) showed no response due to pumping of the production zone well (885). There was an unexplained and abrupt increase in the water level at well 887 halfway into the test [Figure CR 2-7.c(5)]. However, the shift does not appear to be related to the pumping test because it was a sharp instantaneous rise in water level of 0.1 feet approximately 11 hours into the test. No drawdown was observed during the duration of the pump test.

Summary

Uranium One and PEC conducted a pump test at well 885 within the Moore Ranch Uranium Project in order to evaluate if hydraulic communication exists

between the production zone aquifer (70 Sand) and the underlying aquifer (68 Sand). The results of the test clearly demonstrate there is no communication between the 70 Sand and 68 Sand in the vicinity of the 885 monitor well. Extensive additional hydrologic testing will be performed to further evaluate the hydraulic relationship between the production zone and overlying and underlying aquifers prior to commencing production as required under Wyoming Department of Environmental Quality regulations.





885 Pumping Well

Observation Well - 70 Sand

Observation Well - 68 Sand

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URANIUM ONE

Figure CR2-7.c(1). MW 885 Pump Test, Monitoring Locations
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig27c1locatemap.srf Date: 08/02/08

Table CR 2-7.c(1) Pumping Well and Observation Well Data, 2008 Pumping Test, Moore Ranch Uranium Project, Wyoming.

Well	Easting	Northing	Completion Zone	Collar Elevation	Total Depth	Casing Depth	Screen Top	Screen Top Elevation	Screen Bottom	Screen Bottom Elevation	Screen Interval
	(feet)	(feet)		(ft amsl)	(ft bgs)	(ft bgs)	(ft bgs)	(ft amsl)	(ft bgs)	(ft amsl)	(feet)
885	317898	1058399	70 SS	5350	240	240	180	5170	240	5110	60
886	317819	1058258	70 SS	5349	240	240	180	5169	240	5109	60
887	318000	1058278	68 SS	5347	320	320	290	5057	320	5027	30
888	317910	1058398	70 SS	5352	250	250	180	5172	240	5112	60

ft amsl - feet above mean sea level
ft bgs - feet below ground surface
TOC - top of casing

Figure CR 2-7.c(2). Response in Well 885 During 2008 Pump Test
Moore Ranch Uranium Project, Wyoming

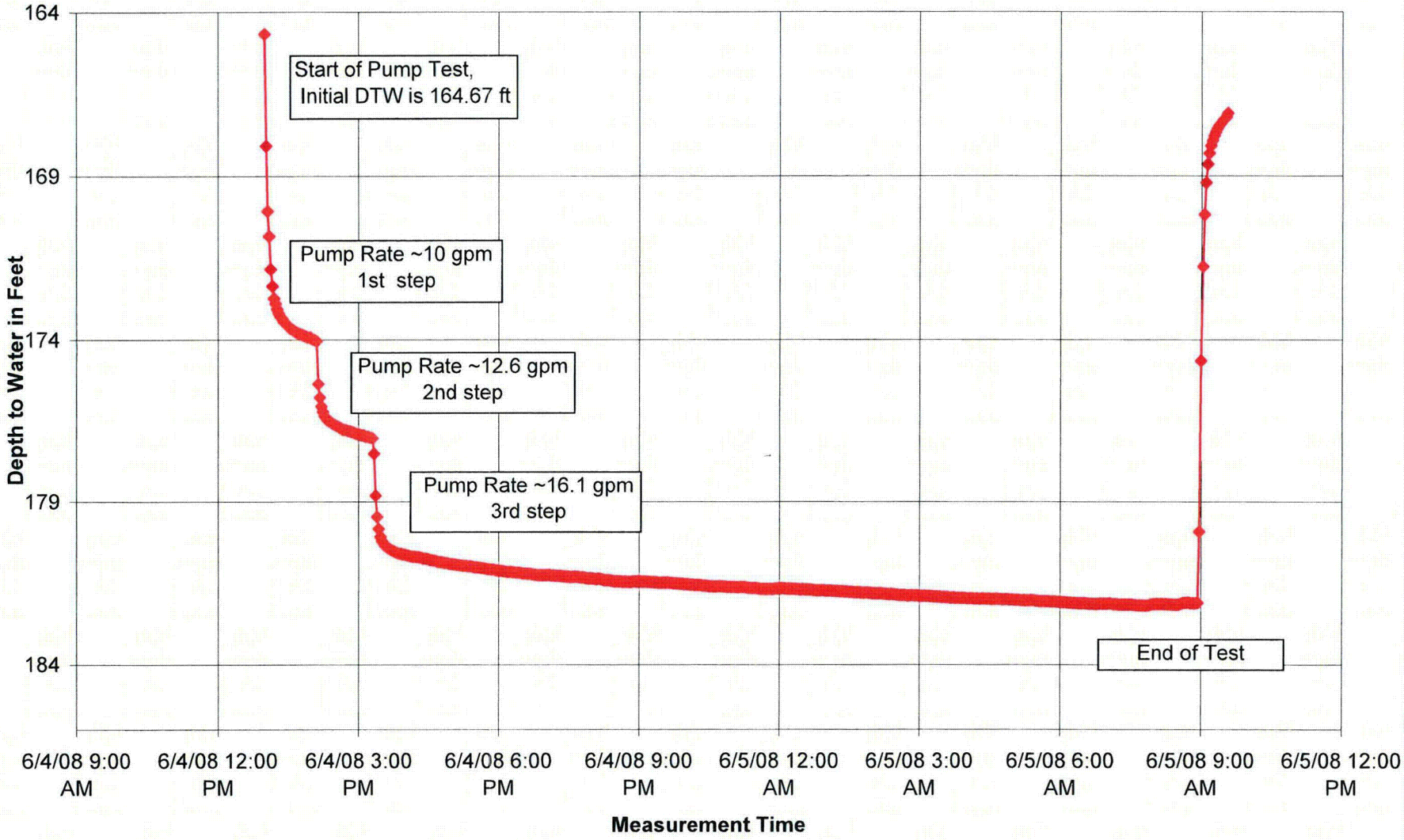


Figure CR 2-7.c(3). Response in Well 885 and 888 During 2008 Pump Test
Moore Ranch Uranium Project, Wyoming

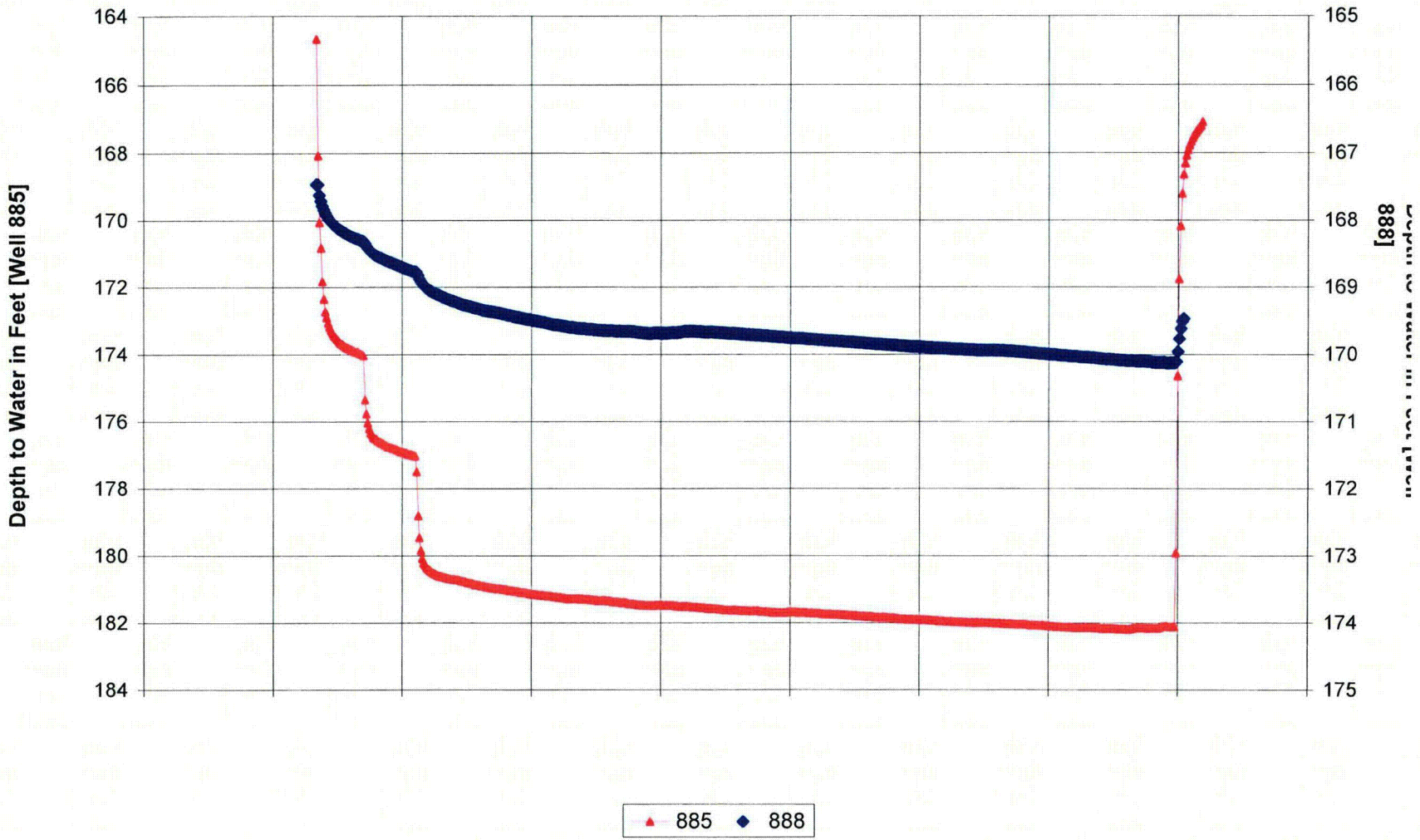


Figure CR 2-7.c(4). Response in Wells 885 and 886 During 2008 Pump Test
Moore Ranch Uranium Project, Wyoming

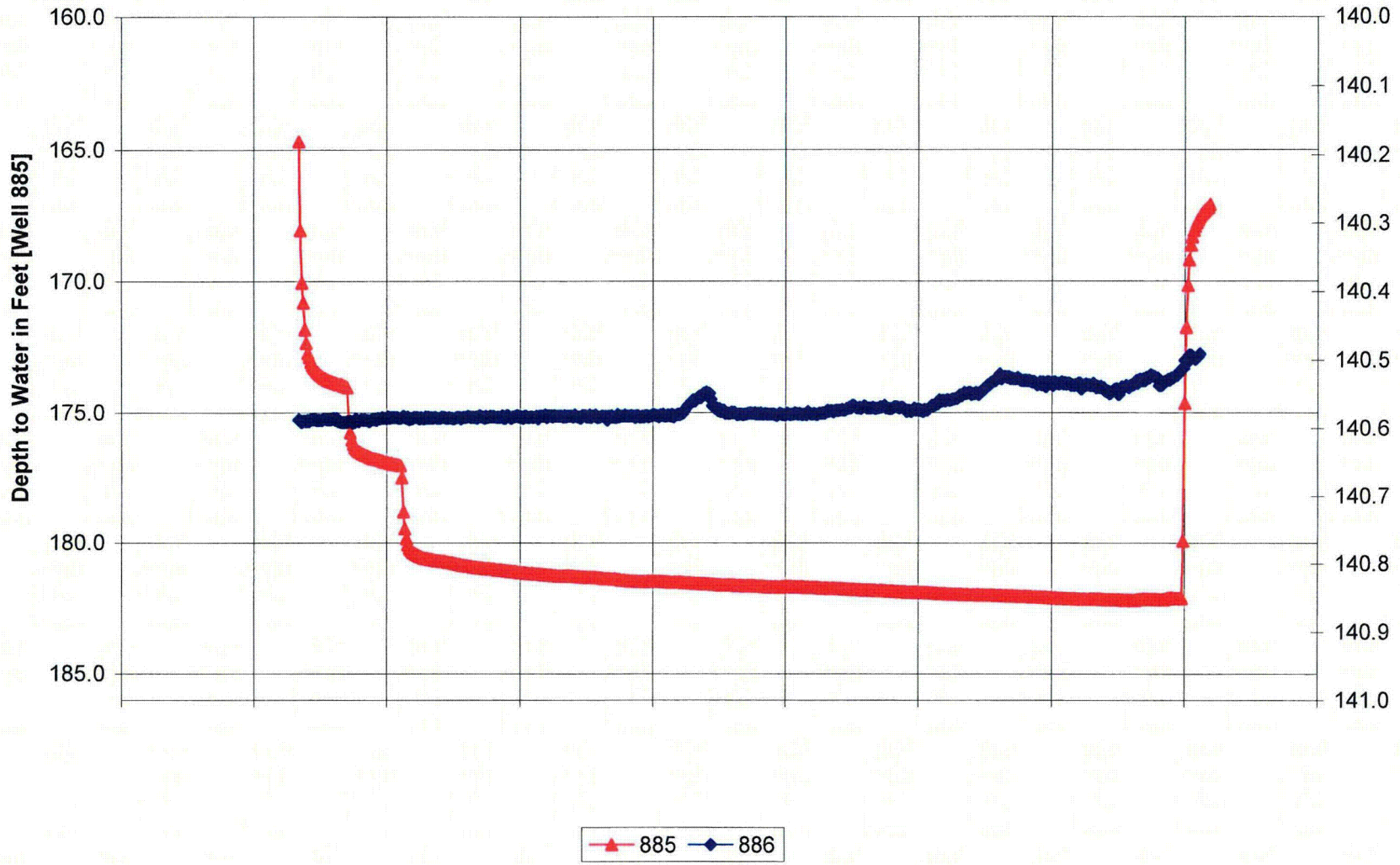
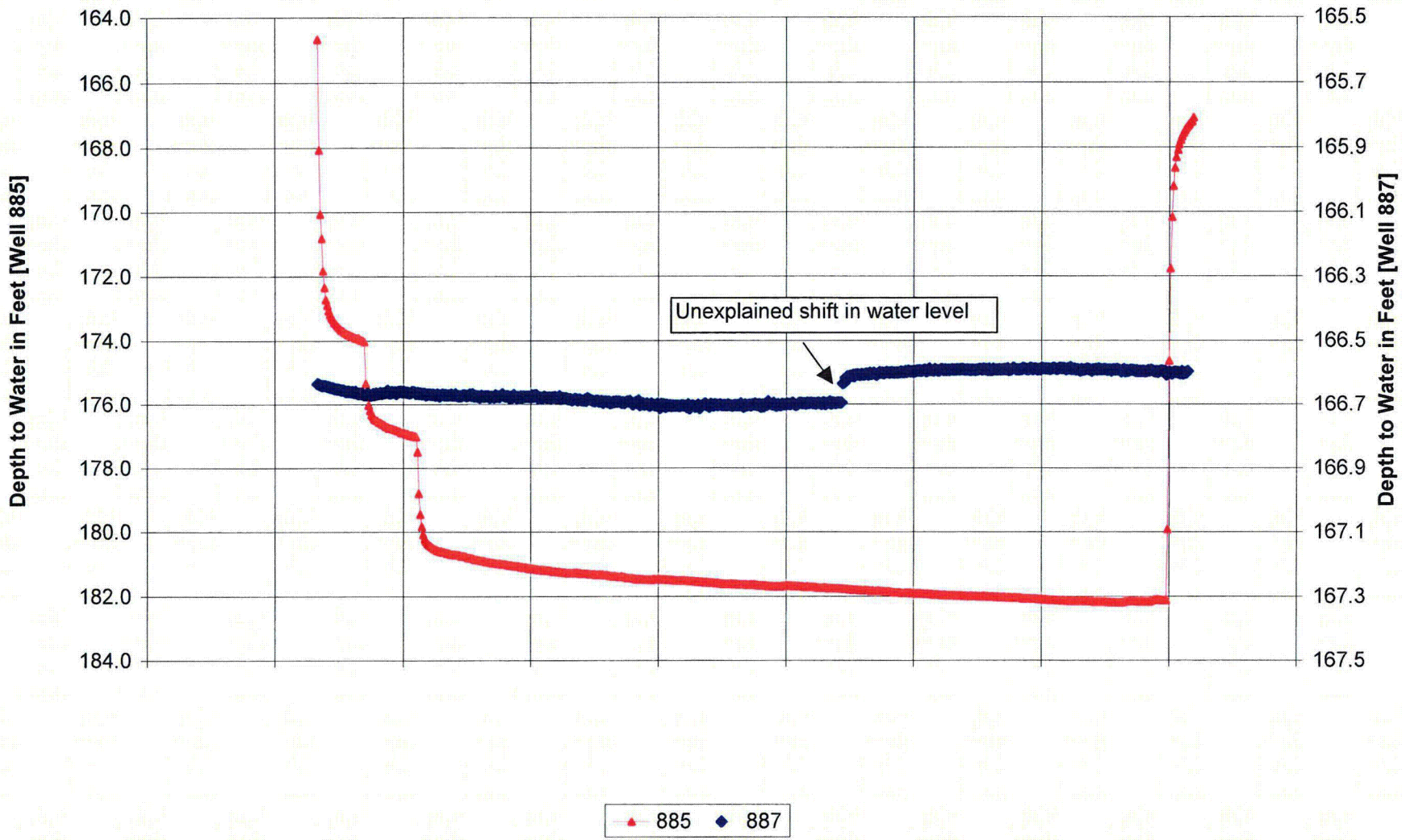


Figure CR 2-7.c(5). Response in Well 885and 887 During 2008 Pump Test
Moore Ranch Uranium Project, Wyoming



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NUMERICAL MODELING OF GROUNDWATER CONDITIONS RELATED TO INSITU RECOVERY AT THE MOORE RANCH URANIUM PROJECT, WYOMING

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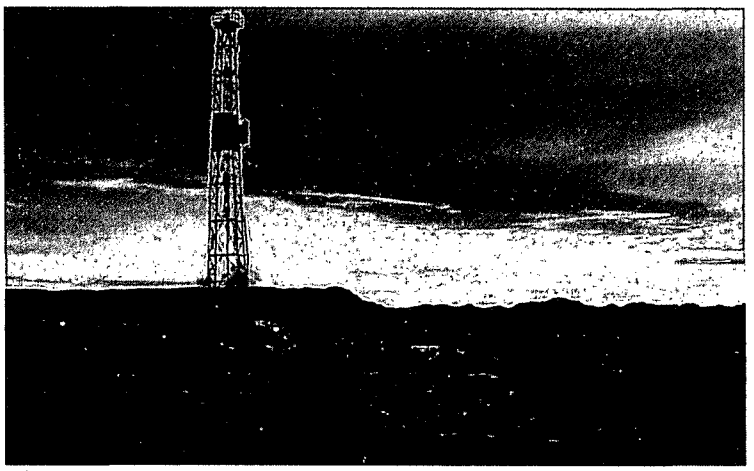

MOORE RANCH PROJECT

CAMPBELL COUNTY, WY

September 2008

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NUMERICAL MODELING OF GROUNDWATER CONDITIONS RELATED TO INSITU RECOVERY AT THE MOORE RANCH URANIUM PROJECT, WYOMING

Introduction

Uranium One has submitted an application to the U.S. Nuclear Regulatory Commission (NRC) for a Source Materials License (SML) to conduct in-situ recovery (ISR) of uranium from the Moore Ranch Project in Wyoming (Energy Metals, Inc., 2007). The target ore zone is designated as the 70 Sand. Aquifer conditions within the 70 Sand transition from unconfined to confined from south to north across the Permit Area.

A numerical groundwater flow model was developed using site-specific data to evaluate wellfield scale issues related to ISR production and restoration operations at the site. This report describes the development of the numerical model and summarizes the results of numerical simulations used to address Uranium One and NRC concerns regarding ISR operations in the 70 Sand aquifer.

Purpose and Objectives

The numerical groundwater flow model was developed to support Uranium One in planning and operation of the ISR project. The numerical model is used to assess impacts of ISR mining on the 70 Sand aquifer. Model simulations were developed to:

- assess the amount of dewatering that may occur, if any, during production and restoration phases of the project,
- estimate flare during wellfield production,
- determine the degree of interference between wellfields that could occur with simultaneous production and restoration operations, and
- design a hydrologic testing program that will verify hydraulic communication with monitor ring wells prior to mining.

The model was developed to allow adequate discretization within the wellfields such that the impacts of individual wells can be discerned. This feature of the model will enable its use as a tool to assist Uranium One in the day-to-day operation of the ISR project.

Conceptual Model

Detailed description of the geology and hydrogeology of the Permit Area can be found in the SML application (Energy Metals, Inc 2007). A conceptual hydrologic model for the Moore Ranch Project area is summarized below.

The aquifer being simulated is the 70 Sand, which is the uranium production zone for the Moore Ranch Project. The 70 Sand ranges from 50 to 120 feet thick within the Permit Area, with an average of 80 feet. The 70 Sand dips north northwesterly at 0.5 to 1 degree. The 70 Sand aquifer is unconfined in the southern portion of the Permit Area, becoming confined to the north. The potentiometric surface of the 70 Sand across the Permit Area has a hydraulic gradient of approximately 0.004 ft/ft (26.6 ft/mile) toward the north. Transmissivity of the 70 Sand ranges from 23 to 735 ft^2/d (172 to 5,500 gpd/ft) based on pumping tests conducted by Conoco (1982) and Petrotek (2007 and 2008). However, as described in the 5 Spot Hydrologic Test Report, a range of 270 to 400 ft^2/d (2,020 to 3,000 gpd/ft) is considered representative of site conditions (Petrotek 2008). Hydraulic conductivity estimates from pumping tests ranged from 0.38 to 18.3 ft/d (Conoco 1982, Petrotek 2007 and 2008). A range of 3.8 to 5.5 ft/d is considered most representative of site conditions (Petrotek 2008).

Total porosity of the 70 Sand is estimated at 26 percent. Specific yield estimated from the 5-Spot Hydrologic Test, ranges from 0.01 to 0.04. Storativity estimated from other hydrologic testing conducted within the 70 Sand in the vicinity of the Moore Ranch indicates a range of 2.4×10^{-4} to 4.4×10^{-3} for the aquifer.

Within the Permit Area, the 70 Sand is generally bounded above and below by low permeability clays and silts that act as confining units. The 70 Sand is overlain by a 30 to 40 foot thick confining unit. Water level differences between the 70 Sand and overlying aquifer (72 Sand) range from 50 to 60 feet with the higher levels within the 72 Sand. The unsaturated upper portion of the 70 Sand and the large head difference between the 70 and 72 Sands conclusively demonstrate that the overlying aquifer is not in communication with the production zone aquifer. Water levels between the underlying aquifer (68 Sand) and the production zone aquifer are similar. There is evidence of discontinuity in the confining unit between the 68 and 70 Sands in portions of Wellfield Two. However, recent testing in the area indicated no response in the underlying 68 Sand during extensive pumping of the 70 Sand (Petrotek 2008). The focus of this model is on operational issues specific to ISR of uranium within the 70 Sand, which transitions from unconfined to confined conditions toward the north. Therefore, for purposes of this modeling exercise, the 68 Sand is not considered or included in the model.

The 70 Sand crops out to the south of the Permit Area. This is an area of direct recharge to the aquifer. Geologic dip and hydraulic gradient are both toward the north. Therefore water passing through the 70 Sand beneath the Permit Area most likely originates from recharge from the outcrop area to the south. Vertical hydraulic gradients do not exhibit a strong upward potential that would suggest recharge of the 70 Sand from deeper aquifers. Furthermore, water levels have remained relatively constant from the early 1980's to the present based on water levels in wells that have been monitored during both periods. Therefore, recharge must be sufficient to maintain water levels in the 70 Sand at near equilibrium

levels since the 1980's. The flux across the Permit Area is calculated, using an average thickness of 80 feet, a width of 4 miles (21,120 ft), a hydraulic conductivity of 4 ft/d and a hydraulic gradient of 0.004 ft/ft. The calculated flux is 27,034 ft^3/d or 140 gpm. The recharge rate updip of the Permit Area must be approximately equivalent to this flux in order for the water levels to maintain their present levels. There are no known discharge areas from the 70 Sand within the Permit Area.

Average groundwater velocity under the stated aquifer conditions of hydraulic conductivity of 4 ft/d, hydraulic gradient of 0.004 ft/ft and porosity of 26 percent is 0.006 ft/d or 22.5 ft/yr.

Uranium One has identified two wellfields that it intends to produce uranium from. Wellfield One is located to the west. Uranium One has estimated that wellfield one will require 160 well patterns to develop. The area that will be under pattern in Wellfield One is approximately 37 acres (1,611,720 ft^2). Wellfield One includes eight header houses. Each header house controls approximately 20 well patterns. Wellfield Two, located east of Wellfield One, will require approximately 229 well patterns to develop, covering an area of 51.6 acres (2,247,696 ft^2). There are 11 header houses in Wellfield Two.

Average ore zone thickness is estimated at 20 feet (Uranium One, personnel communication 2008). Anticipated production rates will be 20 gpm per well pattern with a net 1 to 1.5 percent bleed (overproduction).

Model Code

The model code used to simulate the Moore Ranch ISR project was MODFLOW-SURFACT, Versions 2.2 and 3.0 (SURFACT), developed by HydroGeologic, Inc. (1996 and 2006). SURFACT is a proprietary version of the widely used and public domain MODFLOW code developed by the U.S. Geological Survey (McDonald, 1988, 1996). MODFLOW simulates groundwater flow using a block-centered, finite-difference approach that is capable of a wide array of boundary conditions. The code can simulate aquifer conditions as unconfined, confined, or a combination of the two. MODFLOW also supports variable thickness layers (i.e. variable aquifer bottoms and tops. Documentation of all aspects of the MODFLOW code is provided in the users manuals (McDonald, 1988 and 1996).

SURFACT was designed to enhance the groundwater flow modeling capabilities of MODFLOW. SURFACT provides significant improvements over the original MODFLOW code with respect to unconfined and unsaturated flow, dewatering and rewetting of cells within the model, and simulation of wells. Similar to the MODFLOW code, SURFACT is modular by design so that specific modules can be incorporated into the model simulation to address characteristics and physical processes of the site being modeled. These modules, or packages, work in conjunction with the original MODFLOW code. Only modules that address

specifics of the site need be included in the simulation. Full description of the SURFACT packages, including verification examples, is provided in the MODFLOW-SURFACT Software (Version 2.2) Documentation (HydroGeologic, Inc, 1996). Specific modules of SURFACT employed in the Permit Area Model include the following:

- BCF4 – The block center flow package available in SURFACT provides rigorous treatment of unconfined flow using a variably saturated formulation with psuedo-soil functions. The BCF4 package is superior to earlier versions of block centered flow packages in handling dewatering and rewetting of cells within the model simulation. The formulation has been designed to provide accurate delineation of the water table and capture the delayed yield response of an unconfined system to pumping and recharge

- FWL4 – The SURFACT fracture well package provides rigorous treatment of well withdrawal ((or injection) conditions using one-dimensional fracture tube elements to emulate a well. This package allows accurate representation of wells screened across multi-layers, apportioning flow based on transmissivity and available head in each layer. The package also automatically adjusts flow rate when overpumpage of an unconfined aquifer occurs to prevent dewatering of the aquifer and can also simulate well bore storage. This package couples with the BCF4 package previously described to define unsaturated flow behavior in well cells such that the water table condition within a well cell is accurately represented.

- ATO4-This adaptive time stepping package provided with SURFACT automatically controls time step size and simulation output. This package allows a simulation to be performed more efficiently and outputs to be reported at specific desired times of the simulation.

- PCG4–SURFACT includes the option of using this Preconditioned Conjuguate Gradient solver. Earlier versions of PCG solvers are available with MODFLOW, however the PCG4 solver is more efficient and robust (HydroGeologic, 1996).

A particle-tracking code was utilized that could readily incorporate information collected from the MODFLOW/SURFACT groundwater flow model. The code chosen was MODPATH, Version 3 (Pollock, 1994), which was designed to use the output head files from MODFLOW (or SURFACT) to calculate particle velocity changes over time in three dimensions. MODPATH was used to provide computations of groundwater seepage velocities and groundwater flow directions at the site. MODPATH is also a public domain code that is well accepted in the scientific community. Full documentation of the MODPATH code is provided in the MODPATH users guide (Pollock, 1994).

The pre/post-processor Groundwater Vistas (Environmental Simulations, Versions 4 and 5, 2004 and 2007) was used to assist with input of model parameters and output of model results. Groundwater Vistas serves as a direct interface with MODFLOW, SURFACT and MODPATH. Groundwater Vistas provides an extensive set of tools for developing, modifying and calibrating numerical models and allows for ease of transition between the groundwater flow and particle tracking codes. Full description of the Groundwater Vistas program is provided in the Users Guide to Groundwater Vistas, Version 4.0 and 5.0 (Environmental Simulations, Inc. 2004, 2007).

Model Domain and Grid

The model domain encompasses an area of 100 square miles with north-south and east-west dimensions of 52,800 ft (10 miles). The model grid is centered over the Permit Area in the east west dimension. The south edge of the model generally correlates to the updip limit of the 70 Sand located approximately 1 to 2 miles south of the proposed wellfields. The southern portion of the model corresponds with the area where the 70 Sand is present in outcrop and receives recharge from surface infiltration. The extent of the model domain is illustrated in Figure 1.

The model grid was designed to provide adequate spatial resolution within the Permit Area in order to simulate response of the aquifer to typical extraction and injection rates anticipated for the Moore Ranch uranium project. The model grid was extended a considerable distance from the wellfield boundaries to minimize impacts of exterior boundary conditions on the model solution in the area of interest.

Cell dimensions within the area of the two proposed wellfields are 25 foot by 25 foot. Cell dimensions are gradually increased to a maximum size of 200 feet by 200 feet near the edges of the model. The model consists of 570 rows and 613 columns and contains 349,410 active cells.

Because of the presence of overlying and underlying confining units, only the 70 Sand was simulated. It has been postulated that hydraulic communication may exist between the 70 sand and overlying or underlying units. However, existing water level and pump test data do not indicate that there is hydraulic communication between the production zone aquifer and the overlying and underlying aquifers. If hydraulic communication is observed during additional hydrologic testing, appropriate monitoring and engineering will be employed to ensure that non-production zone aquifers will be not be adversely impacted. For purposes of this modeling effort, the model contains a single layer representing the 70 Sand. The base of the model and the top of the model are no flow boundaries that simulate the overlying and underlying confining units. The top and bottom elevation of the 70 Sand correspond the top and base of the model, respectively. Figures 2 and 3 show the top and bottom elevation of the 70 Sand

used as model inputs. The data within the Permit Area are based on site borings. The geologic dip of the surfaces are projected out to the model limits

Further evaluation of potential ISR impacts resulting from hydraulic communication between the production zone and overlying or underlying aquifers will be performed as additional data are developed (primarily from the wellfield scale pumping tests).

Boundary Conditions

Boundary conditions imposed on a numerical model define the external geometry of the groundwater flow system being studied as well as internal sources and sinks. Boundary conditions assigned in the model were determined from observed conditions. Descriptions of the types of boundary conditions that can be implemented with the MODFLOW and SURFACT code are found in McDonald and Harbaugh (1988) and HydroGeologic Inc., (1996). Boundary conditions used to represent hydrologic conditions at the Moore Ranch site included general-head (GHB), areal recharge and wells. The locations of the GHB and recharge boundary conditions within the model are illustrated in Figure 1. Discussion of the placement and values for these boundary conditions is provided below. The placement and values for the well boundary conditions are described under the simulation discussion.

The GHB was used in the Moore Ranch Permit Area model to account for inflow and outflow from the model domain. GHBs were assigned along the edges of the model domain where available water-level data suggest the aquifer is being recharged from, or discharging to, a source external to the model domain. GHBs were used because the groundwater elevation at those boundaries can change in response to simulated stresses. In the Permit Area model, GHBs were assigned to the west, east and north boundaries of the model. The values of head assigned to the GHBs ranged from 5,232.9 ft along the south edge of the model 5,021.5 ft, along the north edge. This configuration represents a hydraulic gradient of 0.0040 ft/ft to the north, consistent with water levels measured in the 70 Sand monitor wells.

As previously described, the 70 Sand crops out to the south of the Permit Area. This is an area of direct recharge to the aquifer. Recharge to the 70 Sand aquifer upgradient of the Permit Area must be approximately equal to the flux across the Permit boundary. The flux was previously calculated as 140 gpm across a 4 mile cross-section (35 gpm/mi). A zone of recharge was applied the south edge of the model domain to represent infiltration recharge to the 70 Sand in the area where the unit crops out or is very close to ground surface. Recharge was used to calibrate the model under steady state because there are no significant stresses applied within the model domain under non-pumping conditions.

The SURFACT well package (FWL4) was used to simulate extraction and injection wells of the ISR project. The well configuration includes a series of 5-spot well patterns with an extraction well located in the center, surrounded by four injection wells. Each well pattern is approximately 100 feet on a side. Extraction and injection rates applied to the wells are described under the simulation discussions of this report.

The model domain was extended a suitable distance from the location of the proposed production wellfields to minimize perimeter boundary effects on the interior of the model where the hydraulic stresses were applied.

Aquifer Properties

Input parameters used in the model to simulate aquifer properties are consistent with site-derived data including; top and bottom elevations of the 70 Sand, saturated thickness, hydraulic gradient, hydraulic conductivity, specific yield, specific storage and porosity.

The top and bottom elevations of the 70 Sand were determined from picks in over 250 borings provided by Uranium One. Gridded contour maps were generated using the contouring program Surfer, Version 8.0 (Golden Software, 2002). The maps were imported into Groundwater Vistas to represent the top and bottom elevations of the 70 Sand (Figure 2 and 3). The initial saturated thickness and potentiometric surface of the 70 Sand were determined from average depth to water measurements in the baseline monitor wells. Those values are provided in Table 2. A contour map of that surface was also generated in Surfer and used as initial conditions in the model simulations (Figure 4).

Hydraulic conductivity determined from recently conducted site pumping tests ranged from 2.5 to 9.5 ft/d. As described in the 5-Spot Hydrologic Test Report (Petrotek 2008), a hydraulic conductivity of 4.0 ft/d provided the best calibration to simulation of a series of closely monitored extraction and extraction and injection test conducted in Wellfield 2.

Specific yield and specific storage are also aquifer properties of interest with respect to the response of an aquifer to extraction or injection. Specific yield is the storage term used for unconfined aquifers. Specific yield accounts for the physical draining of the aquifer that occurs in response to lowering of the water table and subsequent dewatering of pore space in the aquifer matrix. Specific yield is equivalent to the drainable porosity within an aquifer and typically ranges from 0.01 to 0.30 (Freeze, 1979). Specific yield calculated from the 5-Spot Hydrologic test ranged from 0.011 to 0.039. A value of 0.28 was used for these model simulations

Specific storage is a measure of the water released from storage due to compaction of the aquifer and expansion of water in response to a decline in head. Specific storage is the storage term used for confined aquifers, where lowering of the potentiometric surface in response to pumping does not result in physical dewatering of the aquifer. Specific storage multiplied by the saturated thickness of an aquifer is referred to as storativity or storage coefficient. Storativity of a confined aquifer system is typically in the range of $5x10^{-3}$ to 10^{-6} or less. Comparison of the magnitude of the values for specific yield and specific storage indicates that in an unconfined aquifer, the bulk of the water produced is the result of physical dewatering of the aquifer. The range of storativity calculated from site pumping tests was from 2.5 E-04 to 4.5 E-03. A value of 5.0 E-04 was used for the Permit Area model simulations.

Porosity of the aquifer is used in the model to estimate groundwater velocity. Groundwater velocity is calculated from the Darcy equation as follows:

$$v = ki/n$$

where

v = average interstitial groundwater velocity
k = hydraulic conductivity
i – hydraulic gradient
n = porosity (effective)

The porosity for the 70 Sand in the 5-Spot Test area is estimated from site data as 26 percent. However, for purposes of groundwater velocity calculations, the parameter required is effective (essentially interconnected) porosity. For the 5-Spot Test Model, the effective porosity is estimated to be between 15 and 20 percent.

Calibration Simulation

Groundwater flow model calibration is an integral component of groundwater modeling applications. Calibration of a numerical groundwater flow model is the process of adjusting model parameters to obtain a reasonable match between field measured values and model predicted values of heads and fluxes (Woessner and Anderson, 1992). The calibration procedure is generally performed by varying estimates of model parameters (hydraulic properties) and/or boundary condition values from a set of initial estimates until an acceptable match of simulated and observed water levels and/or flux is achieved. Calibration can be accomplished using trial and error methods or automated techniques (often referred to as inverse modeling).

Because the hydraulic conductivity and specific yield values had been calibrated to the smaller scale 5-Spot Hydrologic Test model (Petrotek 2008) no attempt was made to adjust these parameters for the Permit Area model. Additional information that will be derived from the Wellfield Hydrologic Tests will be incorporated into this model when available. The focus of this model is on the

response of the aquifer to hydraulic stresses imposed on a wellfield scale. .representation of site conditions. The variable that was used to calibrate the model to steady state conditions was recharge along the southern boundary of the model. As previously described, the 70 Sand crops out in this area and is subject to direct recharge from infiltration of precipitation and surface runoff.

The adequacy of model calibration is judged by examining model residuals. A residual, as defined for use in this modeling report, is the difference between the observed change in groundwater elevation and the change in groundwater elevation predicted by the model. The objective of model calibration should be the minimization of the residual mean, residual standard deviation, and residual sum of squares (RSS) (Duffield, et al, 1990). The mean residual is the arithmetic average of all the differences between observed and computed water levels. A positive sign indicates that the model has underpredicted the observed drawdown level and a negative sign indicates overprediction. The residual standard deviation quantifies the spread of the differences between observed and predicted drawdown around the mean residual. The ratio of residual standard deviation to the total head change across the model domain should be small, indicating the residual errors are only a small part of the overall model response (Anderson and Woessner, 1992). The RSS is computed by adding the square of each residual and is another measure of overall variability. For a statistically accurate model calibration, the residuals and the statistics based on the residual should approach zero.

Calibration was achieved by comparing field-measured (observed) water levels in the baseline monitor wells with heads predicted by MODFLOW-SURFACT for the same wells under simulated steady state conditions of the 70 Sand aquifer. The Recharge area (Figure 1) was adjusted until the best fit to the average potentiometric surface observed in the baseline monitor wells was achieved. The potentiometric surface of that simulation is shown in Figure 4. Calibration residuals are presented in Figure 4a. Calibration statistics from that simulation are listed in Table 3.

Model Simulations

This numerical groundwater flow model was developed to evaluate the impacts of ISR operations on the 70 Sand during typical ISR operations. Simulations were performed using the numerical model to address requests for additional information posed by the NRC in response to the SML license application. The simulations described in this report provide:

- a demonstration of the hydraulic impacts that the ISR operation will have on the 70 Sand aquifer, including the sustainability of anticipated production and restoration rates,
- the degree of interference between wellfield that are operating simultaneously,

- estimate of horizontal wellfield flare factor under typical operating rates, and
- a hydrologic test design to demonstrate hydraulic communication between a pumping well within the wellfield and the monitor well ring at a proposed distance of 500 feet from the wellfield.

Initial Conditions

The initial condition for the simulations was based on the average potentiometric surface determined from the baseline wells. As previously stated, the recharge value was adjusted under a steady state model until a reasonable match was achieved between the simulated and observed target values. The potentiometric surface for that simulation is shown in Figure 4.

Hydraulic Impacts of ISR Production

A model simulation was run to represent the full cycle of ISR production and restoration. The operational parameters for this simulation are summarized in Table 3. The configuration of the header houses, extraction and injection wells for Wellfields One and Two are illustrated on Figures 5 and 6, respectively.

Production is initiated in Wellfield Two at a production rate of 2,960 gpm. Seven of the eleven header houses are included in the first phase of production (148 production wells). The net bleed during this phase was 0.8 percent. The production is run for a period of 18 months. The potentiometric surface at the end of the first production phase is shown in Figure 7. Drawdown at the end of the first phase is shown in Figure 8. The overall drawdown across the wellfield is over 1 foot. The maximum drawdown within the wellfield is 16.5 feet. Figure 9 shows a more detailed view of the drawdown within Wellfield Two at the end of the first phase. The impacts of individual wells can be observed at this scale. At the end of the first production phase, the wells in the first seven header houses are shut in.

The remaining four header houses (81 production wells) in Wellfield Two and three header houses (61 production wells) in Wellfield One are turned on to begin the second production phase. The total production rate for this phase is 2,840 gpm. The net bleed for Wellfield Two during the second phase is 1.3 percent. For Wellfield One the net bleed was 1.1 percent. The second phase is run for a period of 18 months and then the wells are shut in. The potentiometric surface across the wellfield at the end the second phase is shown on Figure 10. Drawdown is illustrated in Figure 11. Maximum drawdown at the end of the second stage is 21.1 feet in Wellfield Two and 17.6 feet in Wellfield One. Detailed views of drawdown in Wellfields Two and One are shown on Figures 12 and 13, respectively.

The third stage includes the remaining five header houses (99 production wells) in Wellfield One at a total production rate of 1,980 gpm with a net bleed of 1.0 percent. However, in order to avoid pulling water from Wellfield Two outside of

the monitor ring and toward Wellfield One, groundwater sweep was simulated in Wellfield Two. The rate of withdrawal from Wellfield Two during the third production phase was 20 gpm. The potentiometric surface and drawdown at the end of the third production phase are shown on Figures 14 and 15, respectively. Detailed drawdown in Wellfield One at the end of the third production phase is illustrated on Figure 16. Maximum drawdown in Wellfield One was 21.8 feet. Table 4 provides a summary of the production and injection rates simulated for each of the three production phases.

Wellfield Flare Factor

Results of the production simulation were used to demonstrate the amount of horizontal flare that can be expected during typical ISR operations. Particle tracking was used to illustrate the movement of water from the outer injection wells. Particles were placed at the locations of all injection wells located on the perimeter of each wellfield. The particles associated with wells that were in production during the first phase were initiated at the beginning of that production phase. The particles associated with wells of the second phase of production were initiated when the second phase began and the particles associated with the third phase were initiated when the third phase began.

Figure 17 shows the results of the particle tracking for Wellfield One. An area was circumscribed around the outermost extent of all the particles from the wellfield. The ratio of the area circumscribing the particles to the area under pattern provides the horizontal wellfield flare factor. For Wellfield One, the flare factor is calculated as 1.18. Particle tracking for Wellfield Two is illustrated in Figure 18. The flare factor calculated for Wellfield Two is 1.17.

The simulated horizontal flare factor is similar to 1.2 factor used by Wyoming Department of Environmental Quality in calculating Wellfield Pore Volumes.

Hydraulic Impacts of ISR Restoration

The operations simulation was continued to assess the hydraulic impacts of restoration on the 70 Sand aquifer. Groundwater sweep was only employed on a limited basis in Wellfield Two while production was finishing in Wellfield One. The reason that groundwater sweep is not being utilized in this restoration simulation is because the rates that would be necessary to remove a pore volume within a one year period would result in localized dewatering of the aquifer. Table 4 shows that to achieve 1 PV removal with 1 year of restoration would require rates of 172 gpm for Wellfield One and 240 gpm for Wellfield Two. Application of these rates would dewater large portions of the wellfields, even if performed sequentially.

Restoration will be accomplished primarily through treatment of extracted groundwater by Reverse Osmosis (RO) and reinjection of treated water into the aquifer. The plant will have the capacity to treat approximately 500 gpm of water.

This equates to 250 gpm per wellfield if concurrent restoration of the two wellfields is employed. Approximately 20% of the treated water will be reject brine that will be disposed of in a deep disposal well or through some other waste disposal methods. This results in a net loss of approximately 50 gpm per wellfield during restoration.

Rather than assign extraction and injection rates to select wells to simulate extraction of 250 gpm and reinjection of 200 gpm, the 50 gpm net loss was distributed over all the well patterns within each wellfield. The simulation was run long enough to remove slightly more than six pore volumes (at the 250 gpm rate) from each wellfield. The simulation was run for 4.3 years with both wells in restoration. Figure 19 shows the drawdown at the end of that time. Wellfield One was then shut in and Wellfield Two continued restoration for another 1.7 years. Drawdown at the end of restoration in Wellfield Two is depicted in Figure 20.

Hydrologic Test Design Simulation

A hydrologic testing program is required to demonstrate that the monitor well ring that surrounds the wellfield is hydraulically connected to the production zone before ISR operations can commence. The unconfined conditions present in portions of the production zone aquifer may limit the horizontal extent of measurable hydraulic response to pumping. A numerical simulation was set up to evaluate the amount of drawdown that could be expected at monitor ring well locations using pumping rates that can be sustained from a single extraction location. Because of the limited extent of drawdown from a single well, it will require several pumping tests to demonstrate hydraulic communication across the entire wellfield. A simulation that demonstrates a sequence of pumping tests was run. The simulation includes a total of six pumping wells within Wellfield 1. There are 24 monitor ring wells, located approximately 500 feet from the outer boundary of Wellfield 1. The well configuration is illustrated in Figure 21.

Unconfined conditions are prevalent in the southern portion of the wellfield and confined conditions are present in the northern portion of the wellfield. Therefore, it is anticipated that the radius of influence for pumping wells in the northern portion of the site will be considerably greater than in the south. Each of the pumping wells was operated for a period of 5 days at a rate of 40 gpm. For wells in the unconfined portion of the site, two to three wells were pumped simultaneously on opposite sides of the wellfield.

The northernmost well, located in the confined portion of the aquifer, was pumped first in the simulation. The well is designated as PW1 on Figure 21. The drawdown at the end of the first pumping test is shown in Figure 22. The simulation indicates that 10 of the 24 monitor ring wells have at approximately 1 foot of drawdown or more at the end of the 5-day test. A 10-day recovery period is simulated prior to beginning the second pumping phase. At the end of the 10 days the residual drawdown in the immediate area of the pumping well is less than 0.6 feet (Figure 23).

The second pumping phase was initiated with pumping at wells PW3, and PW6, both located in the unconfined portion of the wellfield (Figure 21). The drawdown after 5 days of pumping is shown on Figure 24. The difference between the unconfined and confined aquifer response is clearly demonstrated. Each of the pumping wells creates drawdown of 0.5 feet or more at only three monitor wells. The residual drawdown after the second 10-day recovery period is shown in Figure 25.

The third pumping phase was initiated with pumping at wells PW2, PW4 and PW5 (Figure 21). Well PW4 is located at the southern end of the wellfield and is within the unconfined portion of the aquifer. Wells PW2 and PW5 are located near the transition to confining conditions. Figure 26 shows the drawdown after 5 days of pumping each well at 40 gpm. At the end of the third pumping phase, all of the monitor ring wells have shown close to a foot of drawdown at some point in the testing.

Discussion and Summary

A numerical model was developed to evaluate the response of the 70 Sand aquifer to hydraulic stresses imposed by operation of the Moore Ranch ISR uranium project. The model is an expansion of a smaller scale model that was calibrated to a closely monitored 5-Spot Hydrologic Test. The model was developed using site-specific data regarding top and bottom aquifer elevations, saturated thickness, potentiometric surface and hydraulic gradient, hydraulic conductivity, specific yield, storativity and porosity of the 70 Sand aquifer.

The model was used to simulate the complete operational cycle of the Moore Ranch ISR uranium project, from production through restoration, of two delineated wellfields. Results of the model simulations indicate the following.

- Production at the projected rates of up to 3,000 gpm (20 gpm per well pattern) with a 1 to 1.5 percent bleed for a period of 4.5 years will not result in dewatering of the aquifer.
- Horizontal wellfield flare factor, determined from the rates simulated above, is slightly less than 1.2, consistent with industry projections. Although not simulated in this model, it is assumed that vertical flare will be similar, resulting in a total wellfield flare factor of approximately 1.4 to 1.5.
- Restoration using RO at the projected rates of 250 gpm per wellfield with a 20 percent reject rate can be sustained throughout the restoration cycle of six pore volumes of removal (4.3 years at Wellfield One and 6.0 years at Wellfield Two).
- Groundwater sweep at rates that will result in removal of a Pore Volume within one year (172 gpm at Wellfield One and 240 gpm at Wellfield Two) will not be sustainable and will result in localized dewatering of the aquifer

and inefficient operation and fluid recovery. Therefore, it is recommended that RO be the primary restoration method utilized.

- Wellfield balancing will be required to prevent fluids from being drawn from one wellfield to another during the project life.
- Hydrologic Test design simulations indicate that it may take six or more individual pump tests per wellfield to adequately demonstrate hydraulic communication between the monitor ring and the production zone.

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Table 1. 70 Sand -Top and Bottom Elevation Data from Site Boring Logs, Moore Ranch Uranium Project, Wyoming

Boring ID	Easting	Northing	Surface Elevation	Depth to Top 70 Sand	Depth to Bottom 70 Sand	Elevation Top 70 Sand	Elevation Bottom 70 Sand
1	322735	1052684	5261.0	4	69	5257.0	5192.0
2	319217	1058115	5382.5	195	268	5187.5	5114.5
3	313835	1060651	5372.6	243	298	5129.6	5074.6
4	320145	1057626	5372.9	173	252	5199.9	5120.9
8	313968	1055770	5344.8	186	259	5158.8	5085.8
9	322776	1068012	5424.3	273	355	5151.3	5069.3
17	322123	1058845	5315.0	118	227	5197.0	5088.0
28	314038	1052228	5328.3	124	201	5204.3	5127.3
43	318920	1057050	5350.0	150	196	5200.0	5154.0
62	322922	1059253	5354.0	153	252	5201.0	5102.0
66	315787	1043991	5294.3	50	150	5244.3	5144.3
103	317740	1056850	5303.0	104	169	5199.0	5134.0
106	318140	1056655	5328.0	135	186	5193.0	5142.0
108	317780	1055750	5335.0	107	154	5228.0	5181.0
110	317340	1056650	5308.0	115	175	5193.0	5133.0
111	314794	1059619	5347.0	189	282	5158.0	5065.0
112	315189	1059996	5345.0	181	250	5164.0	5095.0
113	315190	1059193	5337.0	173	266	5164.0	5071.0
115	315178	1058389	5345.0	160	260	5185.0	5085.0
116	314803	1058423	5357.4	185	290	5172.4	5067.4
121	317525	1057458	5316.6	125	196	5191.6	5120.6
124	319924	1057258	5388.4	195	260	5193.4	5128.4
127	319120	1056650	5330.0	144	195	5186.0	5135.0
128	318720	1056650	5330.0	133	185	5197.0	5145.0
129	318525	1056258	5312.5	113	166	5199.5	5146.5
133	319520	1055650	5330.0	122	175	5208.0	5155.0
135	319920	1055850	5350.0	140	190	5210.0	5160.0
182	320334	1057354	5362.2	159	238	5203.2	5124.2
250	322927	1058554	5359.0	140	258	5219.0	5101.0
264	322232	1057551	5305.0	96	184	5209.0	5121.0
269	321426	1057447	5321.0	112	192	5209.0	5129.0
276	317520	1059150	5373.0	196	270	5177.0	5103.0
278	323422	1059157	5368.0	172	264	5196.0	5104.0
324	320926	1056451	5331.0	120	196	5211.0	5135.0
339	322025	1057052	5313.0	96	192	5217.0	5121.0
350	322724	1057453	5310.0	100	182	5210.0	5128.0
367	325321	1055452	5336.0	118	200	5218.0	5136.0
368	325343	1059499	5343.0	134	223	5209.0	5120.0
381	324346	1056708	5345.0	125	227	5220.0	5118.0
382	325325	1056657	5364.0	144	239	5220.0	5125.0
383	317723	1056452	5301.0	109	176	5192.0	5125.0
398	317219	1057958	5327.5	131	198	5196.5	5129.5
433	319924	1056354	5360.0	151	208	5209.0	5152.0
438	316924	1056846	5311.0	108	174	5203.0	5137.0
439	316934	1056438	5303.0	115	174	5188.0	5129.0
441	317322	1056048	5294.0	105	155	5189.0	5139.0
446	322072	1058048	5312.0	105	205	5207.0	5107.0
463	322378	1057764	5306.6	91	183	5215.6	5123.6
497	322877	1057708	5320.3	98	209	5222.3	5111.3
512	318320	1056050	5310.0	115	163	5195.0	5147.0
524	316420	1058800	5325.0	153	229	5172.0	5096.0
525	316820	1058010	5329.3	143	218	5186.3	5111.3

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Boring ID	Easting	Northing	Surface Elevation	Depth to Top 70 Sand	Depth to Bottom 70 Sand	Elevation Top 70 Sand	Elevation Bottom 70 Sand
527	316420	1057200	5300.0	119	178	5181.0	5122.0
529	315620	1058400	5330.0	155	240	5175.0	5090.0
531	315620	1056800	5345.0	141	194	5204.0	5151.0
532	315620	1057600	5335.0	135	192	5200.0	5143.0
534	315620	1059200	5325.0	155	235	5170.0	5090.0
543	317520	1059560	5391.4	216	283	5175.4	5108.4
567	315620	1058800	5330.0	159	227	5171.0	5103.0
569	317920	1056050	5330.0	119	169	5211.0	5161.0
622	316028	1058008	5327.6	140	228	5187.6	5099.6
649	322379	1057557	5303.2	89	195	5214.2	5108.2
714	322376	1058105	5304.0	97	202	5207.0	5102.0
759	322167	1057430	5318.7	115	212	5203.7	5106.7
833	317667	1059555	5389.3	209	279	5180.3	5110.3
837	323224	1058208	5343.0	126	235	5217.0	5108.0
840	316422	1058397	5329.0	145	221	5184.0	5108.0
851	316434	1059929	5365.0	195	273	5170.0	5092.0
852	316826	1058310	5329.0	140	215	5189.0	5114.0
864	318025	1057649	5332.0	136	206	5196.0	5126.0
872	320130	1056765	5370.8	171	233	5199.8	5137.8
890	323180	1057711	5340.6	141	230	5199.6	5110.6
944	320124	1056908	5375.7	176	240	5199.7	5135.7
1019	322974	1057253	5323.0	110	200	5213.0	5123.0
1059	323370	1058810	5375.9	183	277	5192.9	5098.9
1207	321827	1058206	5328.0	123	217	5205.0	5111.0
1213	321422	1057107	5324.8	120	207	5204.8	5117.8
1238	320120	1056150	5350.0	147	215	5203.0	5135.0
1287	323570	1057710	5342.8	124	221	5218.8	5121.8
1292	323820	1058750	5385.0	184	279	5201.0	5106.0
1361	320770	1056100	5340.0	120	199	5220.0	5141.0
1366	322520	1056700	5320.0	102	189	5218.0	5131.0
1462	321520	1056350	5320.0	108	175	5212.0	5145.0
1474	321920	1056150	5340.0	87	176	5253.0	5164.0
1522	320670	1057350	5340.0	140	227	5200.0	5113.0
1580	320520	1055960	5348.2	132	204	5216.2	5144.2
1603	320420	1057150	5345.0	152	237	5193.0	5108.0
1621	322170	1055700	5320.0	83	187	5237.0	5133.0
1634	324020	1056061	5329.3	101	176	5228.3	5153.3
1642	321370	1056250	5340.0	110	213	5230.0	5127.0
1713	323164	1056686	5303.0	83	197	5220.0	5106.0
1731	322079	1056590	5316.0	99	193	5217.0	5123.0
4001	321925	1060396	5364.0	168	263	5196.0	5101.0
4005	322346	1059785	5368.0	178	269	5190.0	5099.0
4008	322625	1059558	5375.0	180	266	5195.0	5109.0
4009	323271	1059465	5378.0	181	272	5197.0	5106.0
4012	323580	1059561	5388.0	194	281	5194.0	5107.0
4013	323719	1059167	5389.0	187	277	5202.0	5112.0
4014	323567	1059169	5380.2	179	273	5201.2	5107.2
4016	323123	1058964	5358.0	156	247	5202.0	5111.0
4018	323171	1058520	5370.7	158	268	5212.7	5102.7
4019	323075	1058420	5372.2	165	270	5207.2	5102.2
4021	323025	1058313	5364.2	154	268	5210.2	5096.2
4022	322978	1058210	5352.2	138	251	5214.2	5101.2

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4023	322778	1058206	5338.0	130	233	5208.0	5105.0
4025	322775	1058009	5334.0	121	249	5213.0	5085.0
4028	322673	1057915	5326.5	110	229	5216.5	5097.5
4029	322474	1057908	5319.0	114	204	5205.0	5115.0
4031	322813	1056965	5298.0	89	180	5209.0	5118.0
4032	322466	1057109	5306.0	91	179	5215.0	5127.0
4034	322378	1057308	5308.0	92	187	5216.0	5121.0
4036	321774	1057815	5336.8	125	219	5211.8	5117.8
4037	321576	1057813	5327.7	120	202	5207.7	5125.7
4040	321325	1056708	5334.0	113	206	5221.0	5128.0
4041	321056	1056808	5343.0	128	220	5215.0	5123.0
4043	320676	1056810	5352.0	143	230	5209.0	5122.0
4044	320572	1056760	5352.0	142	229	5210.0	5123.0
4046	320629	1056358	5343.0	133	208	5210.0	5135.0
4048	320519	1055558	5351.4	130	207	5221.4	5144.4
4049	320196	1056735	5368.0	161	231	5207.0	5137.0
4050	322521	1058364	5322.0	111	214	5211.0	5108.0
4054	322891	1058257	5300.0	145	257	5155.0	5043.0
4057	322062	1057821	5318.0	106	196	5212.0	5122.0
4059	321710	1056986	5314.0	103	201	5211.0	5113.0
4061	321362	1056855	5332.0	118	205	5214.0	5127.0
4064	321675	1056763	5317.0	99	189	5218.0	5128.0
4065	321716	1057220	5321.8	107	205	5214.8	5116.8
4066	320979	1057010	5352.7	141	230	5211.7	5122.7
4071	320676	1057711	5348.0	144	233	5204.0	5115.0
4072	320131	1057300	5376.6	178	245	5198.6	5131.6
4074	318069	1058710	5374.5	187	273	5187.5	5101.5
4079	317921	1058205	5344.4	159	209	5185.4	5135.4
4086	317126	1059440	5371.0	190	257	5181.0	5114.0
4089	317874	1059855	5407.8	230	298	5177.8	5109.8
4090	317874	1059963	5412.4	235	309	5177.4	5103.4
4091	320099	1057060	5378.9	178	245	5200.9	5133.9
4091	317867	1060110	5416.6	240	316	5176.6	5100.6
4092	317971	1060201	5424.1	250	324	5174.1	5100.1
4097	317894	1060732	5423.5	260	335	5163.5	5088.5
4100	318289	1060745	5407.4	238	316	5169.4	5091.4
4117	317966	1061116	5413.1	252	325	5161.1	5088.1
4128	318627	1060160	5392.0	210	283	5182.0	5109.0
4129	318906	1060121	5392.0	206	291	5186.0	5101.0
4130	318932	1060317	5397.1	219	292	5178.1	5105.1
4131	318966	1060607	5394.5	214	286	5180.5	5108.5
4132	318851	1059823	5392.3	209	280	5183.3	5112.3
4133	318819	1059631	5398.1	212	287	5186.1	5111.1
4134	319121	1059546	5395.0	208	284	5187.0	5111.0
4135	319071	1059380	5393.1	205	282	5188.1	5111.1
4136	319254	1059331	5394.1	206	268	5188.1	5126.1
4137	319216	1059143	5389.0	202	276	5187.0	5113.0
4138	320572	1056485	5347.0	138	198	5209.0	5149.0
4144	318235	1057967	5345.9	153	209	5192.9	5136.9
4145	319813	1056819	5368.3	173	226	5195.3	5142.3
4146	319427	1056804	5351.0	159	210	5192.0	5141.0
4148	317507	1057979	5331.9	133	204	5198.9	5127.9

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Boring ID	Easting	Northing	Surface Elevation	Depth to Top 70 Sand	Depth to Bottom 70 Sand	Elevation Top 70 Sand	Elevation Bottom 70 Sand
4157	320586	1056926	5351.6	144	239	5207.6	5112.6
4160	317998	1058814	5370.5	182	271	5188.5	5099.5
4162	317806	1059590	5392.2	210	285	5182.2	5107.2
4163	317948	1060311	5423.4	253	327	5170.4	5096.4
4206	319520	1056360	5344.2	138	196	5206.2	5148.2
4208	319420	1056160	5336.2	137	186	5199.2	5150.2
4210	319720	1056160	5350.8	140	190	5210.8	5160.8
4212	318920	1056560	5326.2	140	195	5186.2	5131.2
4213	318320	1057057	5322.3	143	204	5179.3	5118.3
4222	317323	1057358	5327.9	144	210	5183.9	5117.9
4227	317671	1058209	5342.6	149	228	5193.6	5114.6
4230	318372	1058358	5367.8	176	260	5191.8	5107.8
4234	317973	1058532	5360.7	167	245	5193.7	5115.7
4235	317470	1058609	5359.4	170	235	5189.4	5124.4
4237	317672	1058777	5359.3	174	250	5185.3	5109.3
4244	317869	1059375	5387.1	203	282	5184.1	5105.1
4248	317952	1059554	5396.1	216	302	5180.1	5094.1
4253	318330	1060312	5405.9	232	304	5173.9	5101.9
4265	317547	1060755	5424.4	263	338	5161.4	5086.4
4280	316819	1059107	5352.6	167	238	5185.6	5114.6
4282	317113	1058708	5359.5	171	245	5188.5	5114.5
4283	316700	1058619	5338.3	147	222	5191.3	5116.3
4299	317872	1059055	5375.1	191	265	5184.1	5110.1
4322	317465	1059958	5393.5	220	292	5173.5	5101.5
4325	320326	1057553	5365.0	164	243	5201.0	5122.0
4327	321125	1057761	5337.7	133	215	5204.7	5122.7
4330	321476	1058058	5338.0	135	212	5203.0	5126.0
4331	321878	1057900	5334.0	122	215	5212.0	5119.0
4343	323379	1058359	5359.0	148	262	5211.0	5097.0
4346	321571	1055809	5320.0	93	193	5227.0	5127.0
4347	321731	1057501	5333.0	120	213	5213.0	5120.0
4360	318325	1061154	5398.2	230	294	5168.2	5104.2
4370	318320	1059155	5391.6	210	279	5181.6	5112.6
4371	318095	1059040	5379.5	196	270	5183.5	5109.5
4377	318275	1060215	5408.6	233	308	5175.6	5100.6
4378	317498	1061055	5425.8	269	340	5156.8	5085.8
4380	315600	1060540	5359.0	197	269	5162.0	5090.0
4381	315800	1060540	5364.1	203	275	5161.1	5089.1
4382	322350	1060399	5378.0	189	274	5189.0	5104.0
4383	317110	1060350	5393.4	220	303	5173.4	5090.4
4386	317110	1059950	5386.6	212	292	5174.6	5094.6
4388	316931	1059489	5363.3	184	258	5179.3	5105.3
4389	318240	1059925	5420.3	245	318	5175.3	5102.3
4402	318400	1060948	5400.3	230	302	5170.3	5098.3
4407	318416	1058050	5357.4	172	221	5185.4	5136.4
4410	318415	1057525	5341.3	143	225	5198.3	5116.3
4412	318643	1059756	5402.8	222	296	5180.8	5106.8
4413	318814	1059445	5391.3	208	274	5183.3	5117.3
4414	318517	1059406	5403.1	221	298	5182.1	5105.1
4415	318622	1059261	5393.6	209	278	5184.6	5115.6
4419	318420	1058750	5381.3	192	271	5189.3	5110.3
4420	317250	1060755	5411.3	248	324	5163.3	5087.3

Table 1. 70 Sand -Top and Bottom Elevation Data from Site Boring Logs, Moore Ranch Uranium Project, Wyoming

Boring ID	Easting	Northing	Surface Elevation	Depth to Top 70 Sand	Depth to Bottom 70 Sand	Elevation Top 70 Sand	Elevation Bottom 70 Sand
4421	316850	1060755	5400.4	238	318	5162.4	5082.4
4422	317250	1061155	5419.3	260	335	5159.3	5084.3
4423	317251	1061655	5438.7	288	382	5150.7	5056.7
4424	316850	1061655	5441.1	292	386	5149.1	5055.1
4425	316850	1062055	5444.2	312	374	5132.2	5070.2
4446	316651	1062455	5453.0	321	392	5132.0	5061.0
4500	326990	1060668	5334.5	130	208	5204.5	5126.5
4501	326990	1063059	5356.3	167	252	5189.3	5104.3
4502	328607	1063059	5358.5	150	245	5208.5	5113.5
4503	330677	1063056	5349.2	132	231	5217.2	5118.2
4504	326990	1058013	5333.8	110	210	5223.8	5123.8
4505	330500	1058010	5315.4	72	183	5243.4	5132.4
196C	322896	1058086	5333.2	127	240	5206.2	5093.2
4051C	320554	1056623	5350.0	141	211	5209.0	5139.0
584C	321968	1057316	5322.7	108	205	5214.7	5117.7
CBMS-12-12	325953	1048026	5220.0		48		5172.0
CBMS-14	327346	1056005	5318.9	89	168	5229.9	5150.9
CBMS-2	328962	1065170	5367.5	200	285	5167.5	5082.5
CBMS-21-11	321712	1049529	5231.0		49		5182.0
CBMS-23-1	327138	1051568	5306.0	70	125	5236.0	5181.0
CBMS-3	316744	1049529	5244.6	35	105	5209.6	5139.6
CBMS-5	315392	1064308	5482.5	402	454	5080.5	5028.5
JWX-1	313789	1065183	5478.3	399	451	5079.3	5027.3
JWX-2	320048	1065002	5430.7	277	346	5153.7	5084.7
KM-1	323861	1059578	5399.8	212	299	5187.8	5100.8
KM-1	315656	1059616	5344.0	181	248	5163.0	5096.0
KM-12	322027	1059891	5374.0	181	278	5193.0	5096.0
KM-2	318367	1059621	5412.9	234	306	5178.9	5106.9
KM-3	316030	1059399	5350.0	176	260	5174.0	5090.0
KM-3	323757	1057163	5328.0	114	205	5214.0	5123.0
KM-4	316616	1059376	5325.0	172	245	5153.0	5080.0
KM-6	310638	1058455	5381.2	255	340	5126.2	5041.2
KM-7	318110	1059641	5384.6	201	294	5183.6	5090.6
KM-8	321100	1059298	5350.0	160	252	5190.0	5098.0
MW-10	320118	1059390	5367.0	178	252	5189.0	5115.0
MW-5	321453	1056690	5329.0	112	199	5217.0	5130.0
MW-6	323791	1058288	5352.0	150	235	5202.0	5117.0
MW-7	322537	1056310	5312.0	87	177	5225.0	5135.0
MW-8	317925	1057973	5338.2	146	206	5192.2	5132.2
MW-9	317102	1059208	5366.8	182	255	5184.8	5111.8
SW-43	323146	1064510	5403.5	257	330	5146.5	5073.5
UMW-1	320113	1057971	5381.6	180	256	5201.6	5125.6
UMW-2	322645	1057720	5313.1	100	200	5213.1	5113.1
UMW-3	317959	1060551	5429.0	258	334	5171.0	5095.0
UMW-4	318709	1056283	5314.4	118	166	5196.4	5148.4
UMW-6	322725	1055350	5291.8	60	157	5231.8	5134.8
UMW-7	321375	1055351	5339.1	110	203	5229.1	5136.1
UMW-8	318700	1055350	5305.1	102	162	5203.1	5143.1
UMW-9	317400	1055350	5289.5	90	145	5199.5	5144.5
WW-1	323056	1055695	5288.0	51	129	5237.0	5159.0

Table 2. Average Water Level Data, Baseline Monitor Wells, Moore Ranch Uranium Project, Wyoming

Well	Easting (x)	Northing (y)	TOC Elevation	Average DTW	Average WL Elevation
MW-1	320100	1057961	5379.28	191.74	5187.54
MW-2	322635	1057708	5312.40	124.91	5187.49
MW-3	317948	1060543	5428.19	250.87	5177.32
MW-4	318697	1056272	5312.59	115.93	5196.66
MW-5	321452	1056678	5328.85	135.44	5193.41
MW-6	323791	1058277	5352.34	168.95	5183.39
MW-7	322535	1056299	5311.73	118.51	5193.22
MW-8	317921	1057961	5336.06	153.91	5182.15
MW-9	317099	1059198	5366.78	184.83	5181.95
MW-10	320115	1059378	5367.28	185.11	5182.17
MW-11	317693	1061868	5414.43	242.28	5172.15
PW-1	320209	1057961	5373.88	186.77	5187.11
885	317898	1058399	5350.00	164.80	5185.20
888	317910	1058398	5352.00	168.58	5183.43
893	317890	1058318	5348.00	164.64	5183.37
1805	322638	1058047	5332.50	145.59	5186.92
1806	322578	1057946	5324.00	132.87	5191.13
1814	320620	1056541	5345.00	151.43	5193.57
1816	320701	1056501	5343.00	149.34	5193.67
1817	320610	1056752	5350.00	156.63	5193.37

Table 3 Calibration Statistics, Permit Area Model, Moore Ranch Uranium Project, Wyoming

Name	X	Y	Observed	Computed	Weight	Residual
BMW-1	320100	1057961	5188.01	5187.41	1	0.60
BMW-2	322635	1057708	5188.34	5188.38	1	-0.04
BMW-3	317948	1060543	5177.78	5177.42	1	0.36
BMW-4	318697	1056272	5197.17	5195.36	1	1.81
BMW-5	321452	1056678	5193.96	5193.23	1	0.73
BMW-6	323791	1058277	5184.05	5186.20	1	-2.15
BMW-7	322535	1056314	5193.39	5195.00	1	-1.61
BMW-8	317921	1057961	5182.99	5187.64	1	-4.65
BMW-9	317099	1059198	5182.07	5182.90	1	-0.83
BMW-10	320115	1059378	5182.79	5181.51	1	1.28
BMW-11	317693	1061868	5172.42	5172.37	1	0.05
PW-1	320209	1057961	5187.53	5187.42	1	0.11
MW885	317898	1058399	5185.20	5185.67	1	-0.47
MW888	317910	1058398	5183.43	5185.67	1	-2.24
MW893	317890	1058318	5183.37	5186.01	1	-2.64
MW1805	322638	1058047	5185.42	5186.94	1	-1.52
MW1806	322578	1057946	5191.13	5187.34	1	3.79
MW1814	320620	1056541	5193.57	5193.81	1	-0.24
MW1816	320701	1056501	5193.67	5194.06	1	-0.39
MW1817	320610	1056752	5193.37	5192.70	1	0.67

Residual Mean	-0.37
Res. Std. Dev.	1.76
Sum of Squares	64.99
Abs. Res. Mean	1.31
Min. Residual	-4.65
Max. Residual	3.79
Range in Target Values	24.75
Std. Dev./Range	0.07

Table 4. Operational Rates for ISR Production and Restoration Simulation, Moore Ranch Uranium Project, Wyoming

Simulation	Wellfield	Injection Rate	Production Rate	Net Bleed	Bleed (%)	Injection Rate	Production Rate	Net Bleed
		(ft3/d)	(ft3/d)	(ft3/d)		(gpm)	(gpm)	(gpm)
Phase 1 Production	Two	565129	569800	4671	0.8%	2935.5	2959.8	24.3
Phase 2 Production	Two	307788	311850	4062	1.3%	1598.8	1619.9	21.1
Phase 2 Production	One	232253	234850	2597	1.1%	1206.4	1219.9	13.5
Phase 3 Production	One	377229	381150	3921	1.0%	1959.5	1979.9	20.4
Phase 1 Restoration	Two	-	9625	-	-	-	-	-
Phase 1 Restoration	One	-	9625	-	-	-	-	-
Phase 2 Restoration	Two	-	9625	-	-	-	-	-

Table 5. Pore Volume Calculations and Estimates of Restoration Times, Moore Ranch Uranium Project, Wyoming

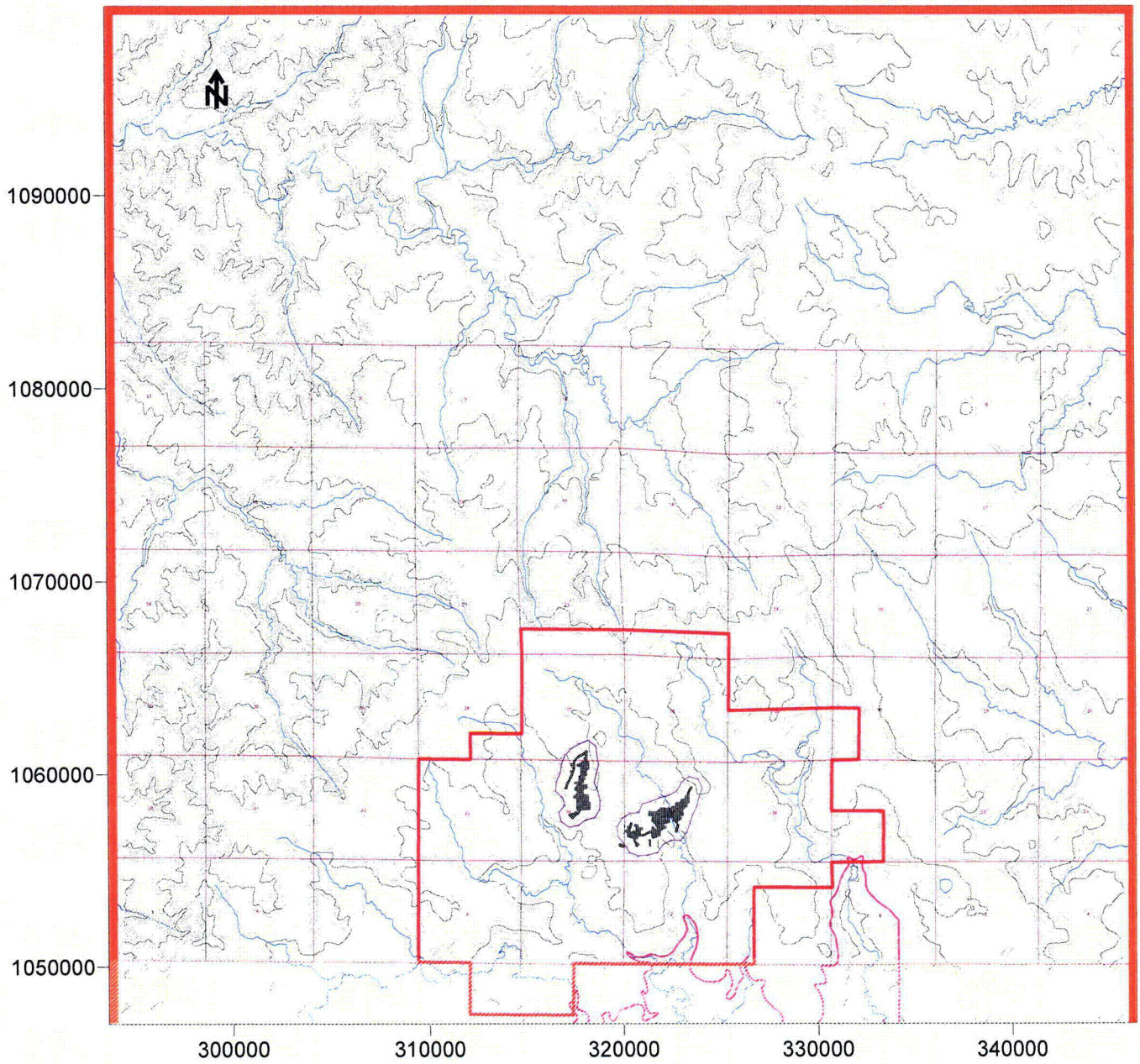
	Acres	Area (ft^2)	Thickness (ft)	Porosity	Flare Factor	1 PV (ft^3)	1 PV (gal)
Wellfield 1 - 37 acres under pattern	37	1611720	20	0.26	1.44	12,068,559	90,272,824
Wellfield 2 - 51.6 acres under pattern	51.6	2247696	20	0.26	1.44	16,830,748	125,893,992

Assumptions:			WF1	WF2
Pay Thickness = 20 feet	Rate to Extract 1 PV in 1 year (GWS)	gpm	171.8	239.5
Porosity = 26%	Time to Extract 1 PV at 250 gpm (RO)	years	0.69	0.96
Flare Factor = 1.44	Time to Extract 6 PV at 250 gpm (RO)	years	4.12	5.75
RO generates 20% reject fluids				
Wellfield Production operates at 1% bleed				

Conversion factors

1 ft^3 = 7.48 gallons

1 acre = 43,560 ft^2



Permit Area Boundary

Outcrop of 70 Sand

Topographic Surface
C.I. = 20 feet

Wellfield Patterns

Monitor Well Ring

Boundary Conditions

General Head

Recharge

0 5000 10000
Feet

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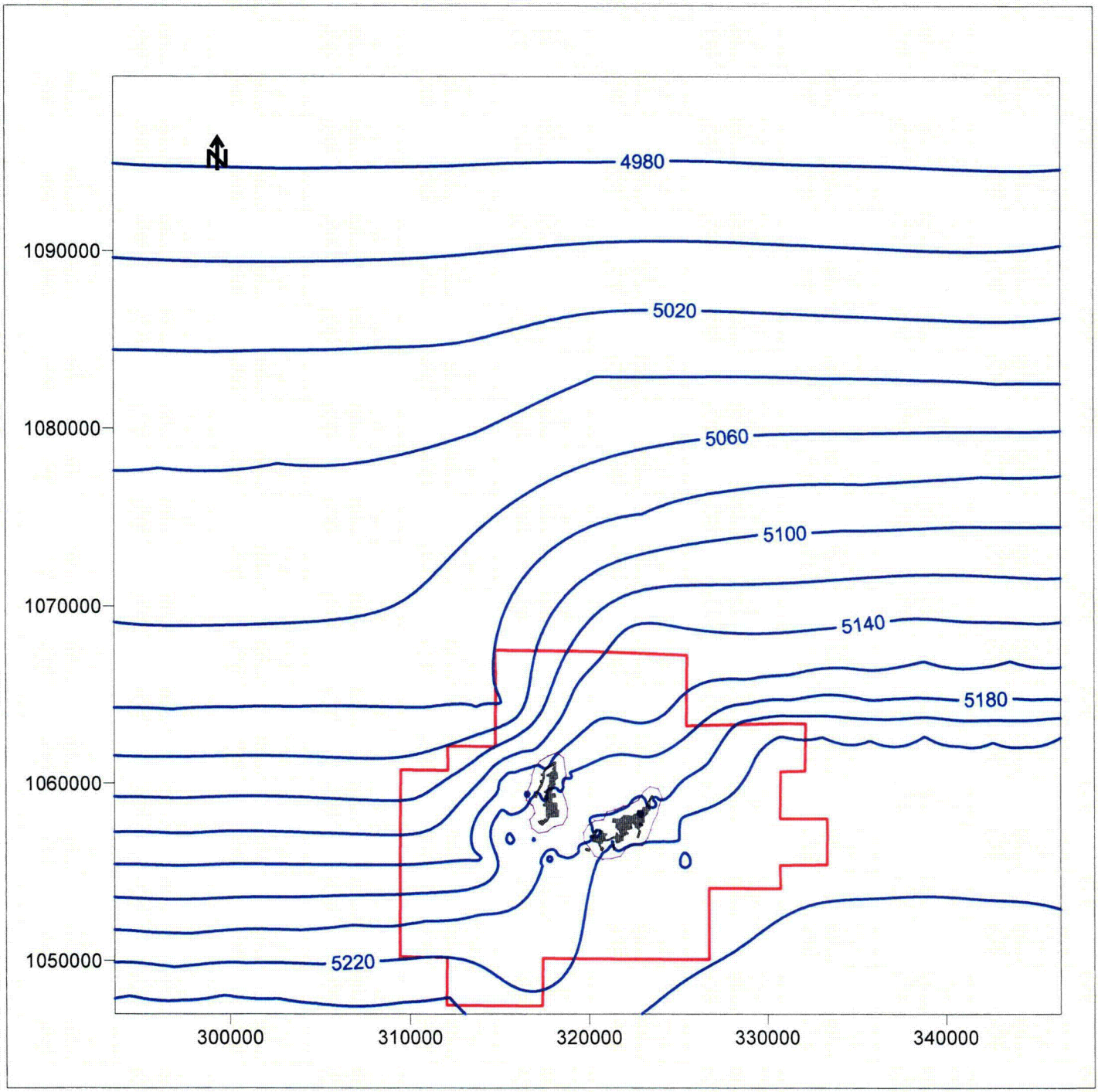
URANIUM ONE

Figure 1. Permit Area Model Domain and Boundary Conditions Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig1MRmodel.srf Date: 9/19/08



Permit Area Boundary

Top of 70 Sand
ft amsl C.I. = 20 feet

Wellfield Patterns

Monitor Well Ring

0 5000 10000
Feet

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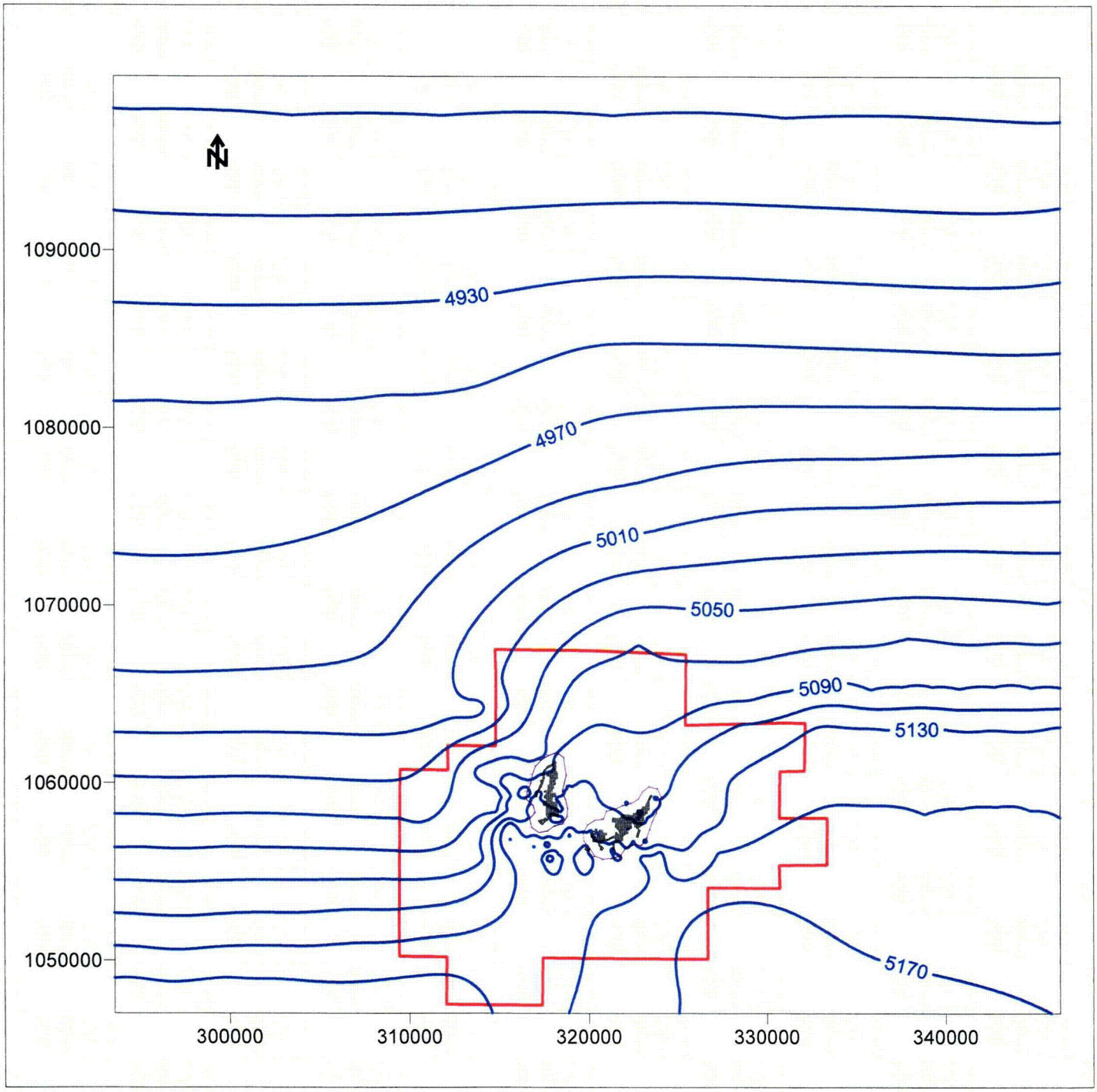
URANIUM ONE

Figure 2. Structure Map - Top of 70 Sand
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig2MRtop70.srf Date: 9/19/08



Permit Area Boundary

Bottom of 70 Sand
ft amsl C.I. = 20 feet

Wellfield Patterns

Monitor Well Ring

0 5000 10000
Feet

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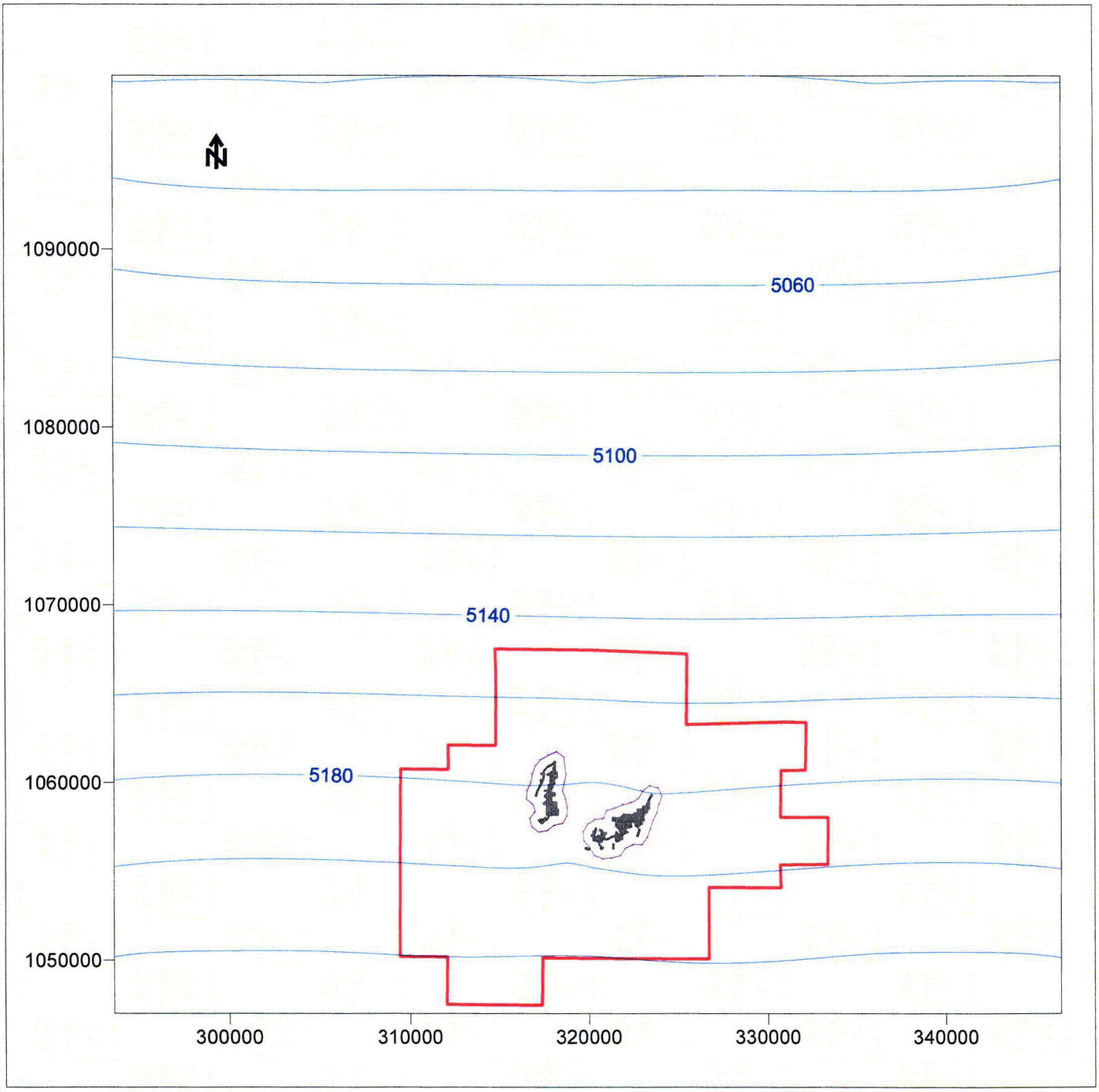
Figure 3. Structure Map - Bottom of 70 Sand
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig3MRbot70.srf Date: 9/19/08



Permit Area Boundary

Potentiometric Surface 70 Sand ft amsl C.I. = 20 feet

Wellfield Patterns

Monitor Well Ring

0 5000 10000
Feet

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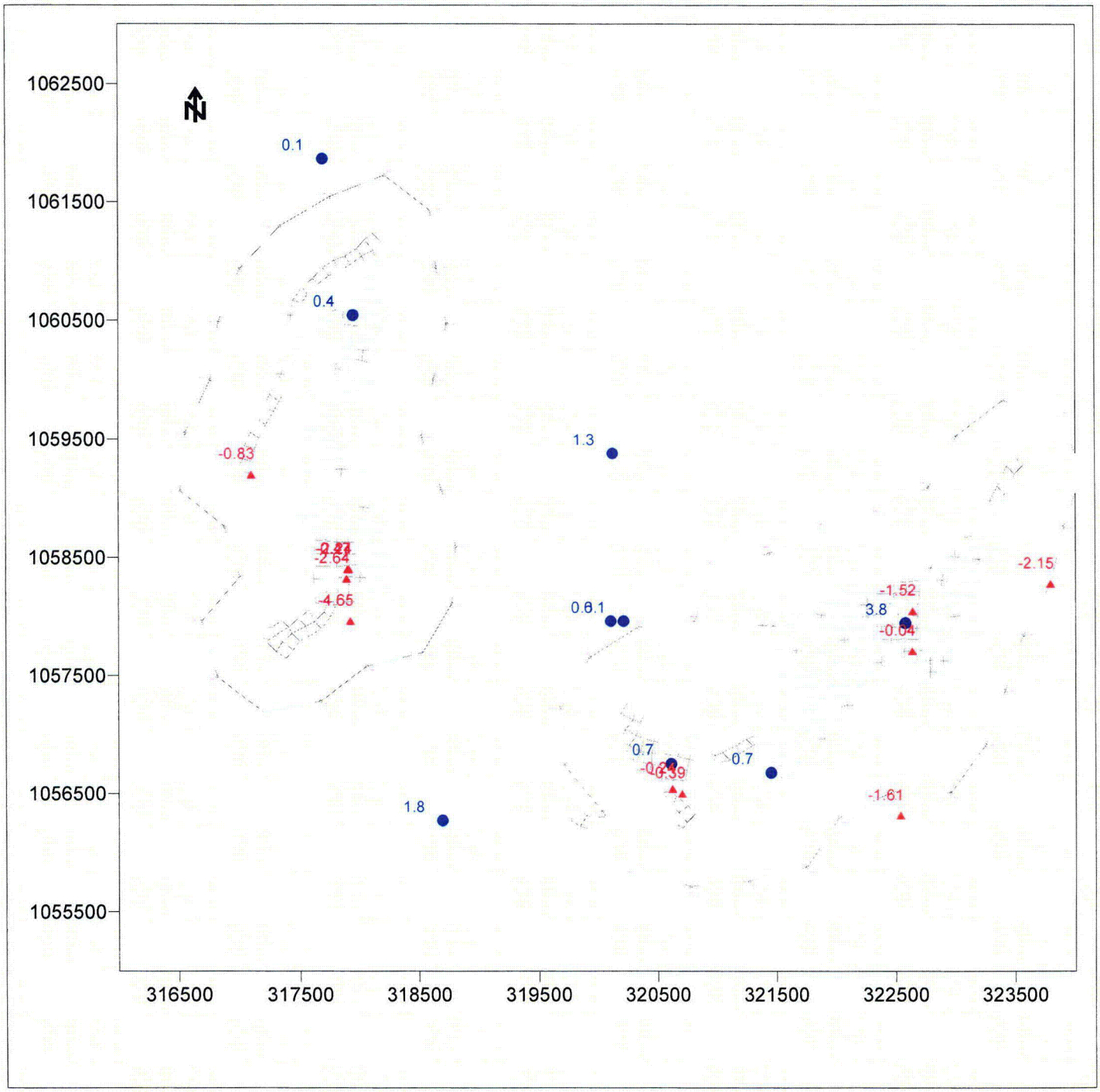
URANIUM ONE

Figure 4. Initial Potentiometric Surface 70 Sand Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig4MRinitialhds.srf Date: 9/19/08



Calibration Residual (positive)

Calibration Residual (negative)

Wellfield Patterns

Monitor Well Ring

0 500 1000
Feet

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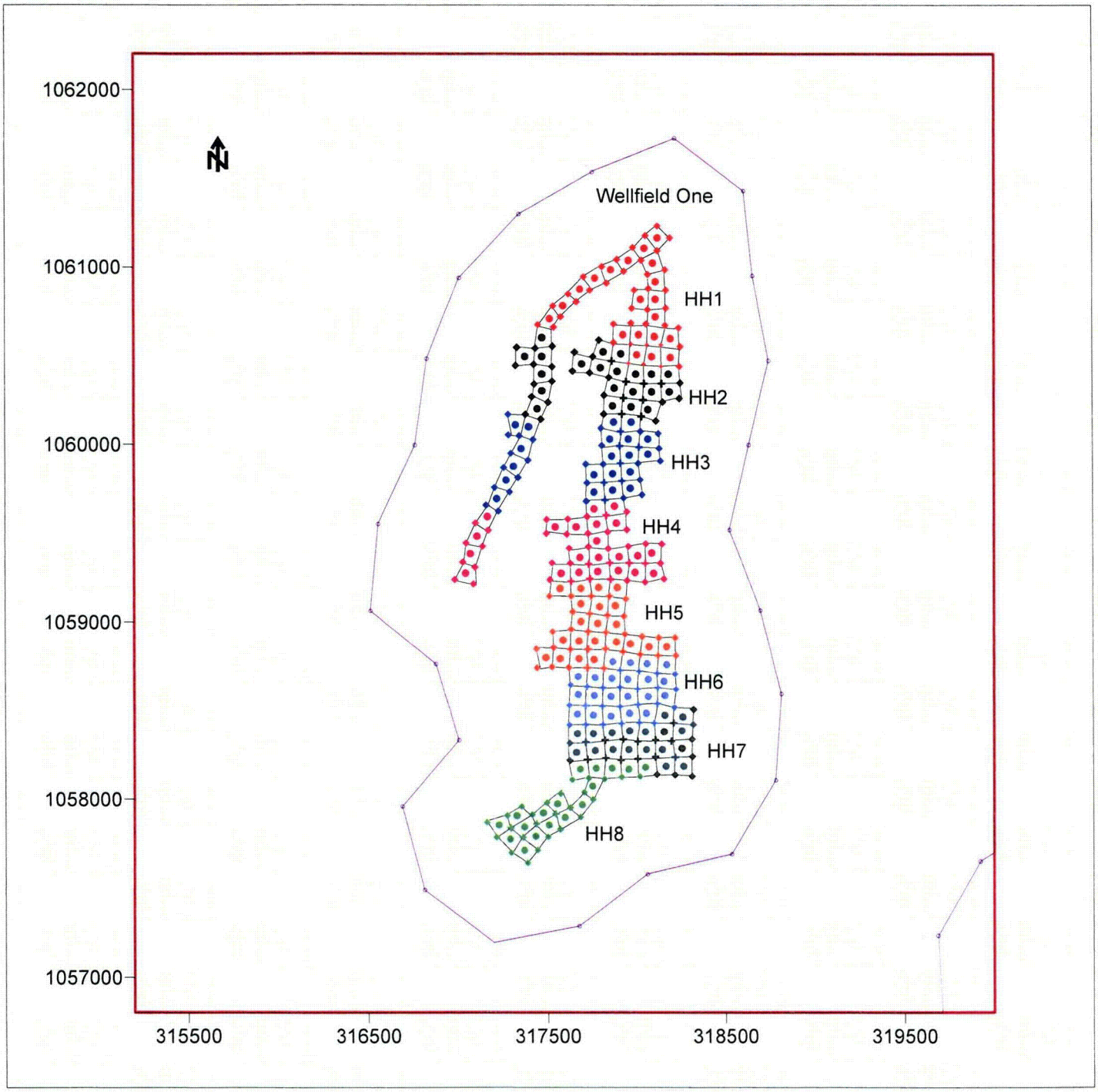
URANIUM ONE

Figure 4a. Calibration Residuals
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig4MRinitialhds.srf Date: 9/19/08



- ● Extraction Well
- ✚ Interior Injection Well
- ◆ Exterior Injection Well
- HH1 Header House — Separate colors denote wells grouped to a single header house
- Wellfield Patterns
- Monitor Well Ring

0 500 1000
Feet

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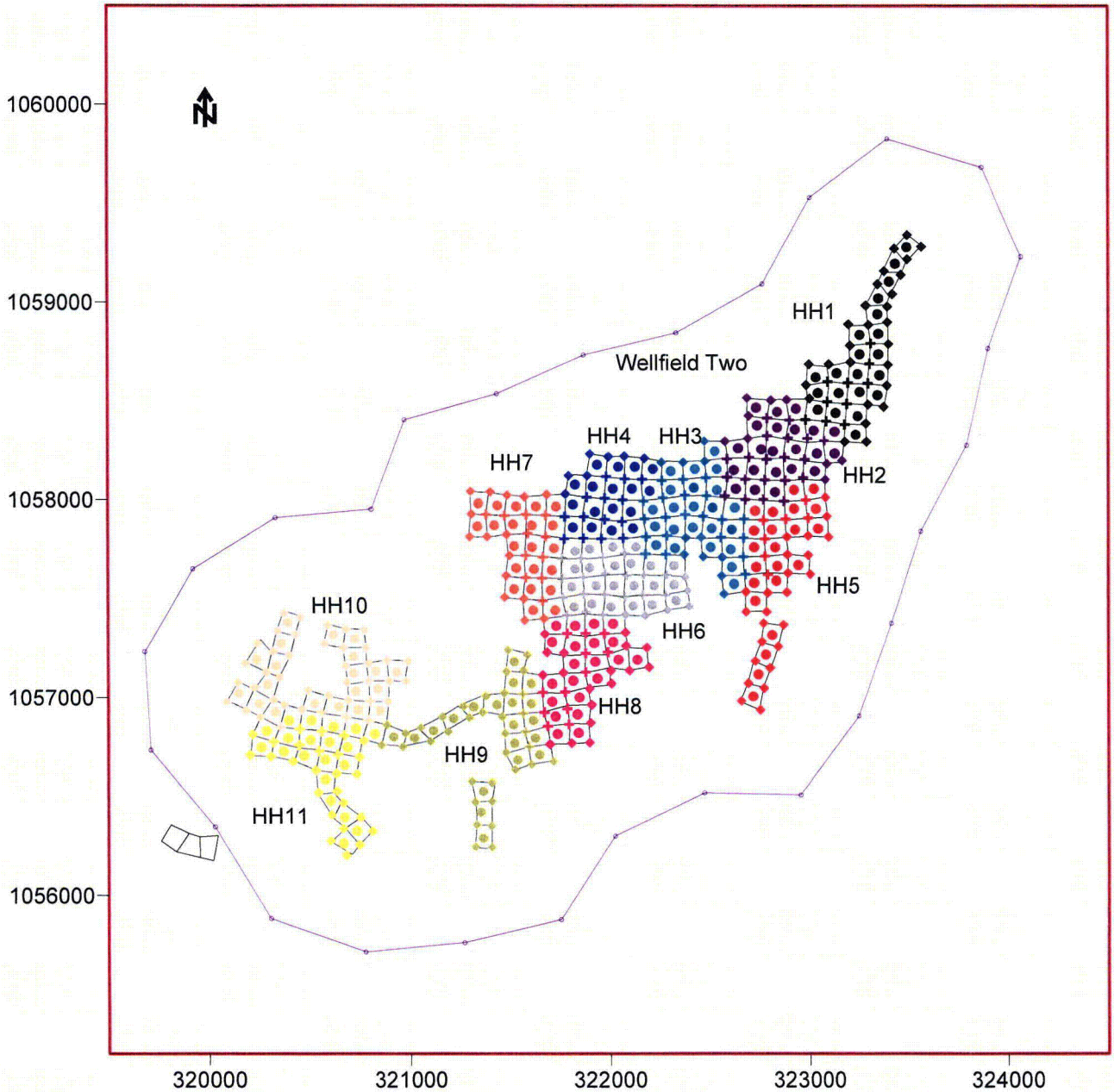
URANIUM ONE

Figure 5. Wellfield One-
Header Houses and Well Patterns
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig5MRWF1wells.srf Date: 9/19/08



●	Extraction Well	
✚	Interior Injection Well	
◆	Exterior Injection Well	
HH1	Header House	Separate colors denote wells grouped to a single header house
	Wellfield Patterns	
	Monitor Well Ring	

0 500 1000
Feet

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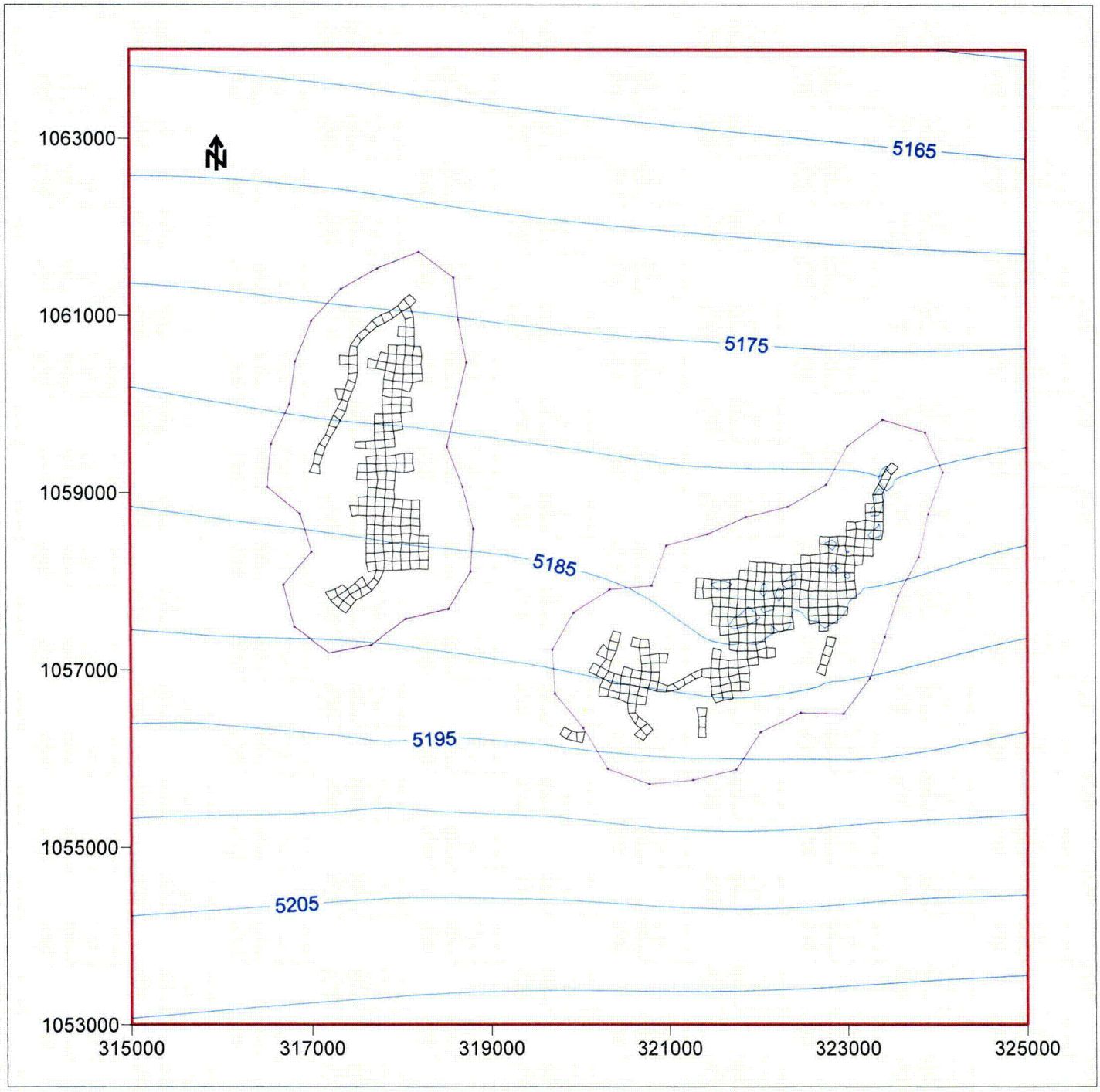
URANIUM ONE

Figure 6. Wellfield Two
Header Houses and Well Patterns
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig6MRWF2wells.srf Date: 9/19/08



Potentiometric Surface - 70 Sand feet amsl C.I. = 5 feet

Wellfield Patterns

Monitor Well Ring

0 1000 2000
Feet

Simulation of Production From Wellfield Two
8 Header Houses, 148 Well Patterns
Production Rate of 2960 gpm for 18 months
Net 0.8% Bleed

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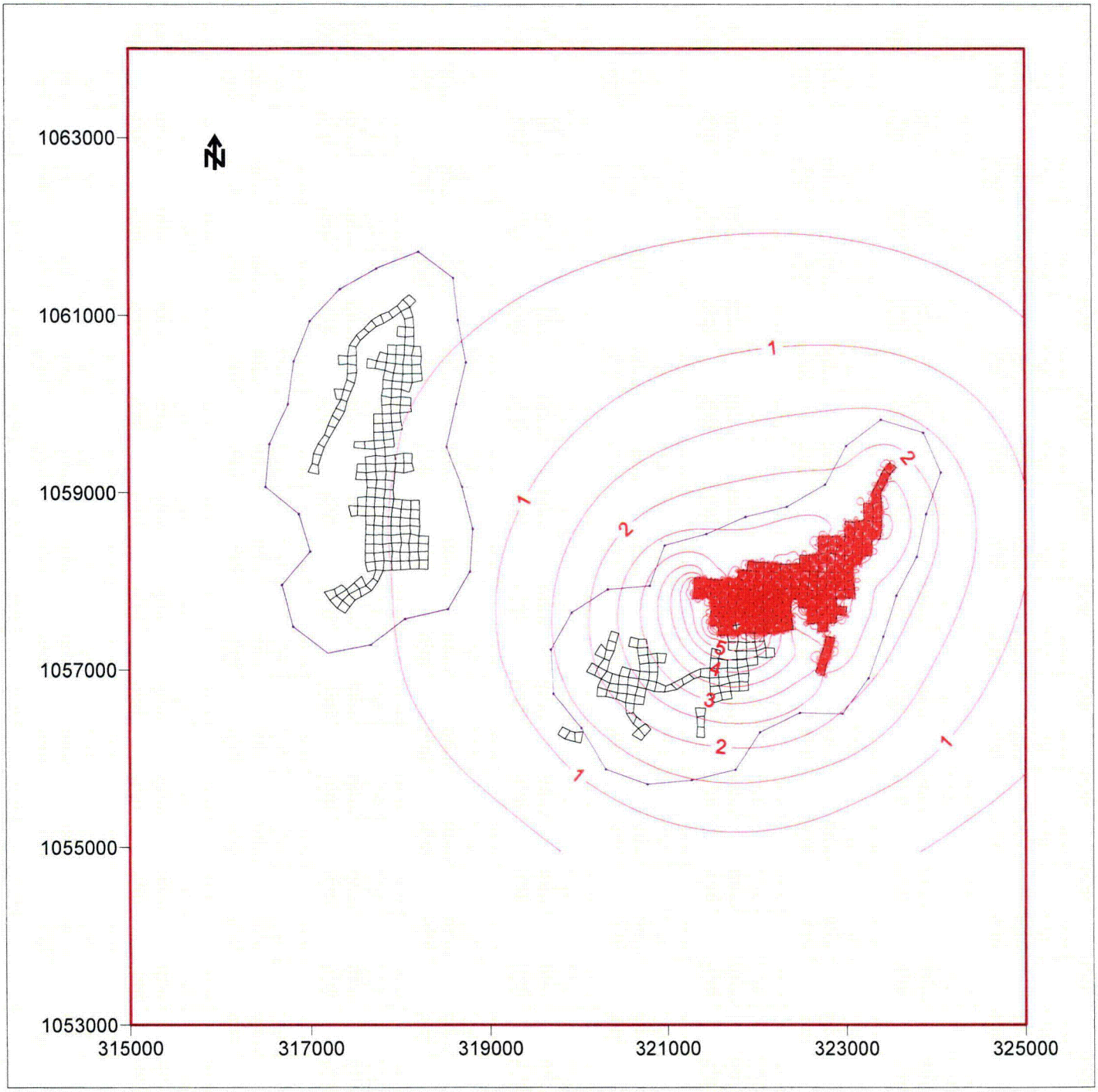
URANIUM ONE

Figure 7. Potentiometric Surface - 70 Sand
End of First Production Phase
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig7MRProd1.srf Date: 9/19/08



Drawdown - 70 Sand
C.I. = 0.5 feet

Wellfield Patterns

Monitor Well Ring

0 1000 2000
Feet

Simulation of Production From Wellfield Two
8 Header Houses, 148 Well Patterns
Production Rate of 2960 gpm for 18 months
Net 0.8% Bleed

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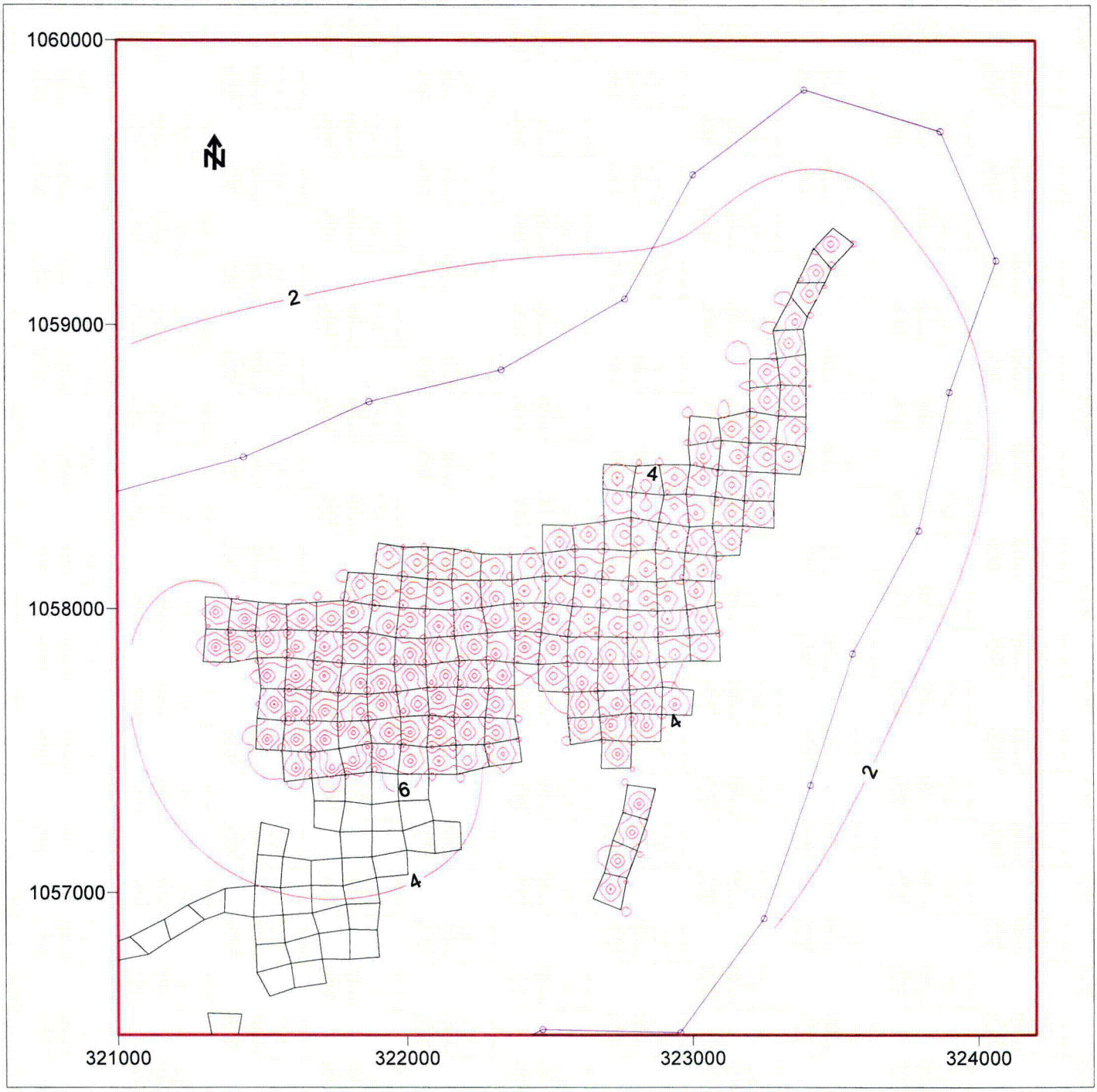
URANIUM ONE

Figure 8. Drawdown - 70 Sand
End of First Production Phase Wellfield Two
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig8MRProd1.srf Date: 9/19/08



Drawdown - 70 Sand
C.I. = 2 feet

Wellfield Patterns

Monitor Well Ring

0 500 1000
Feet

Simulation of Production From Wellfield Two
8 Header Houses, 148 Well Patterns
Production Rate of 2960 gpm for 18 months
Net 0.8% Bleed

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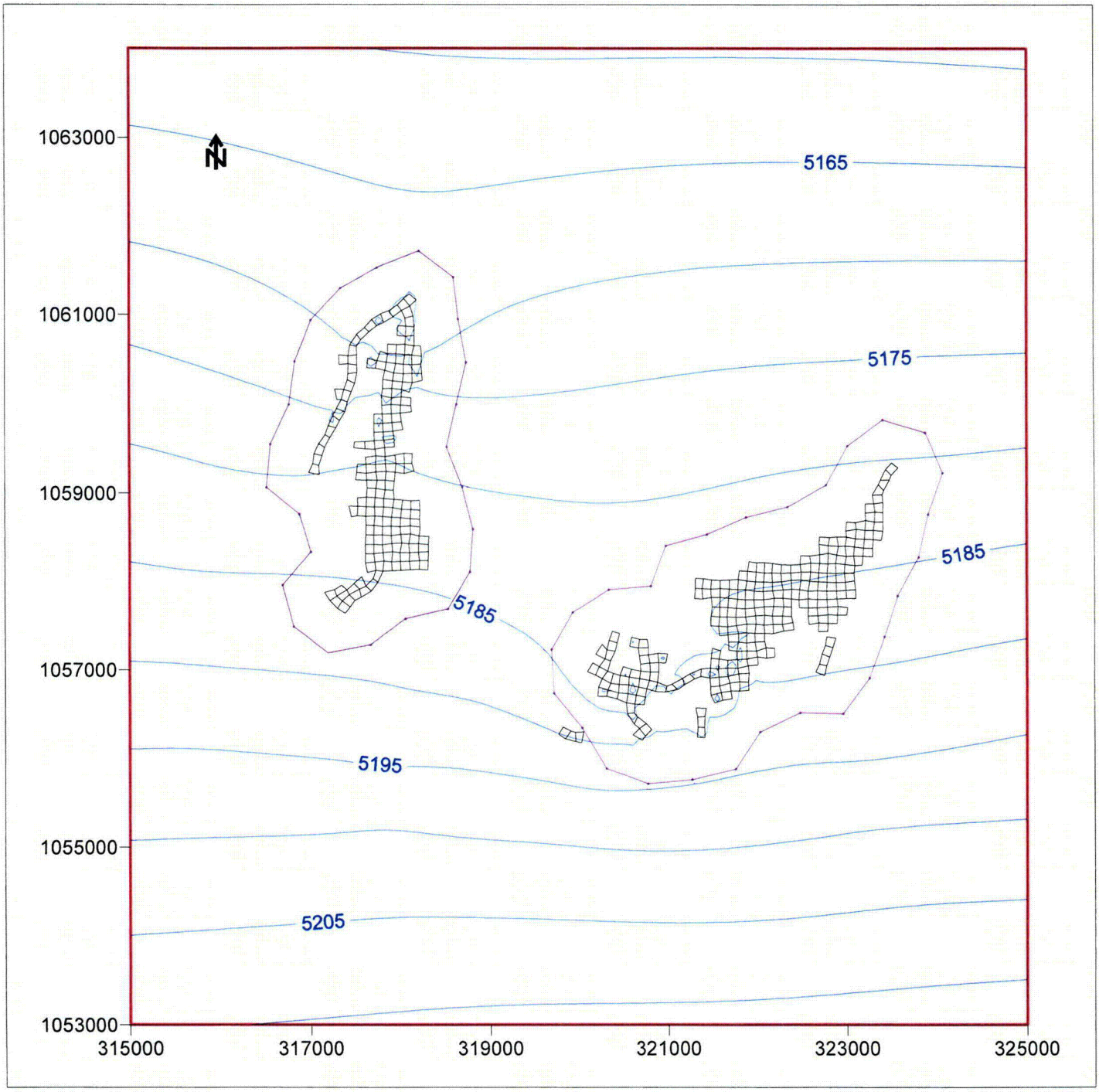
URANIUM ONE

Figure 9. Wellfield Two Drawdown (Detail)
End of First Production Phase
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig9MRProd1.srf Date: 9/19/08



Potentiometric Surface - 70 Sand feet amsl C.I. = 5 feet

Wellfield Patterns

Monitor Well Ring

0 1000 2000
Feet

Simulation of Production From Wellfields One and Two
7 Header Houses, 142 Well Patterns
Production Rate of 2840 gpm for 18 months
Net 1.4% Bleed

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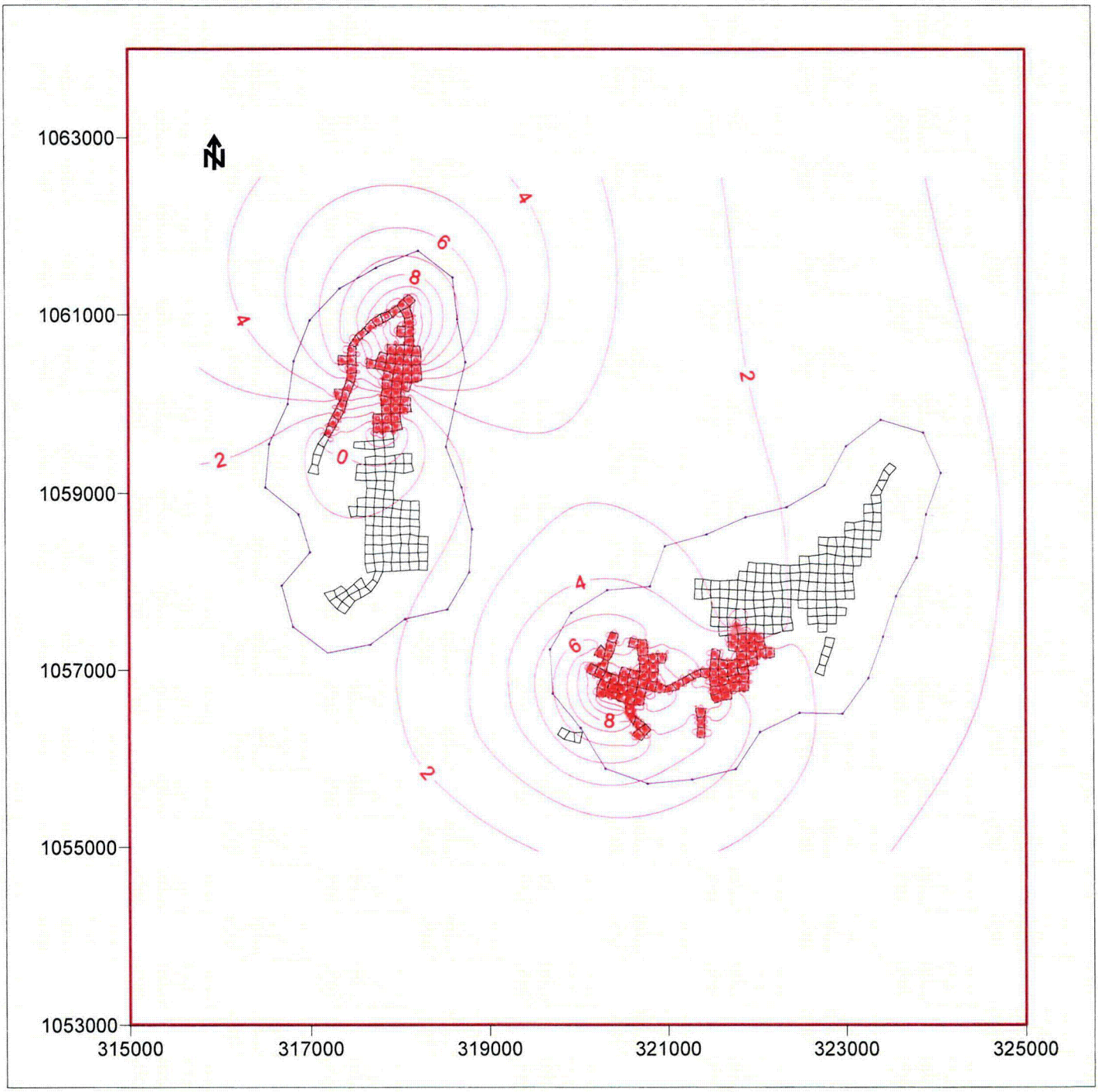
URANIUM ONE

Figure 10. Potentiometric Surface - 70 Sand
End of Second Production Phase
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig10MRProd2.srf Date: 9/19/08



Drawdown - 70 Sand
C.I. = 1 foot

Wellfield Patterns

Monitor Well Ring

0 1000 2000
Feet

Simulation of Production From Wellfields One and Two
7 Header Houses, 142 Well Patterns
Production Rate of 2840 gpm for 18 months
Net 1.4% Bleed

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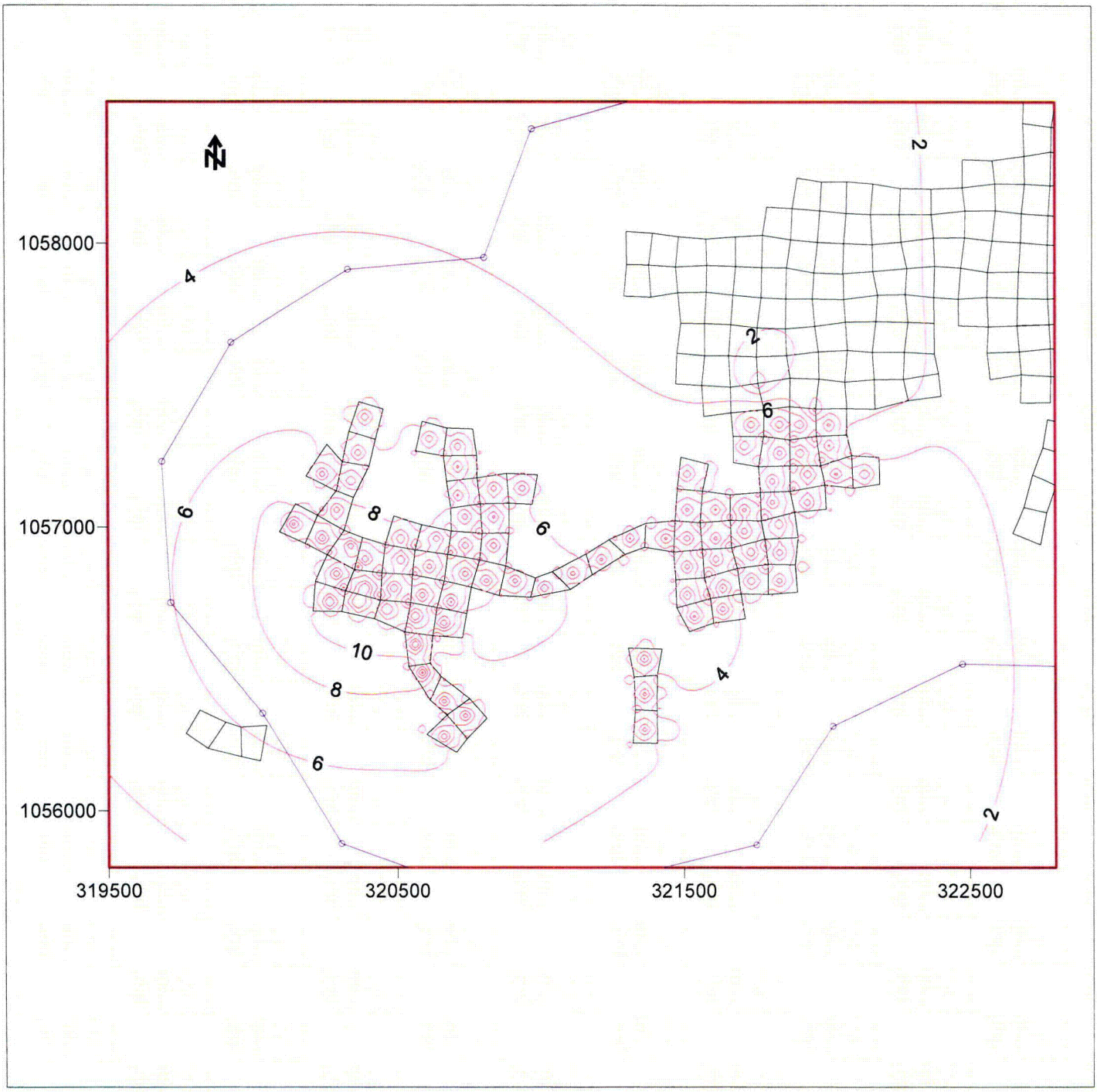
URANIUM ONE

Figure 11. Drawdown - 70 Sand
End of Second Production Phase
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig11MRProd2.srf Date: 9/19/08



Drawdown - 70 Sand
C.I. = 2 feet

Wellfield Patterns

Monitor Well Ring

0 500 1000
Feet

Simulation of Production From Wellfield Two
4 Header Houses, 81 Well Patterns
Production Rate of 1620 gpm for 18 months
Net 1.4% Bleed

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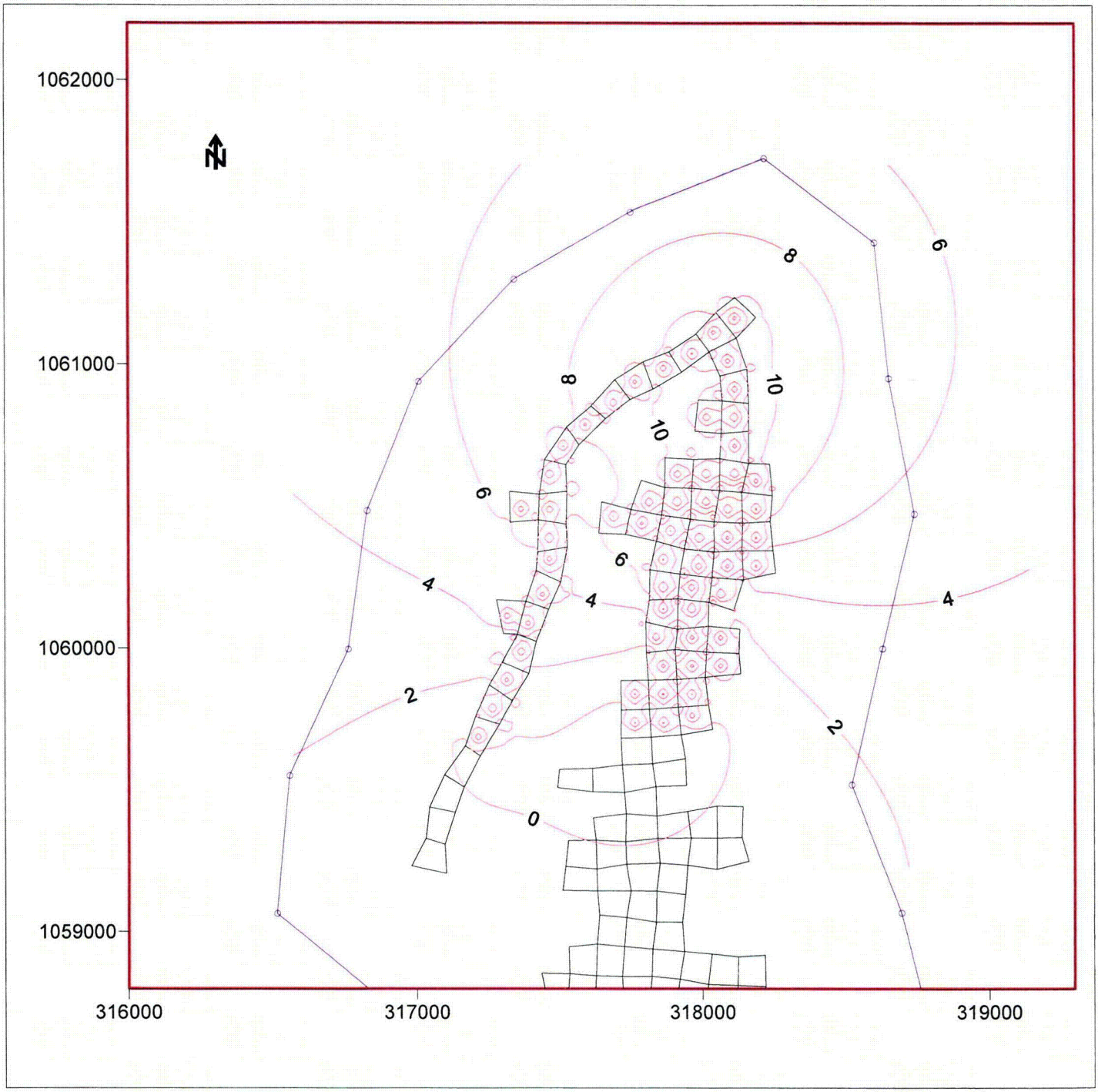
URANIUM ONE

Figure 12. Wellfield Two Drawdown (Detail)
End of Second Production Phase
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig9MRProd1.srf Date: 9/19/08



Drawdown - 70 Sand
C.I. = 2 feet

Wellfield Patterns

Monitor Well Ring

0 500 1000
Feet

Simulation of Production From Wellfield One
3 Header Houses, 61 Well Patterns
Production Rate of 1220 gpm for 18 months
Net 1.4% Bleed

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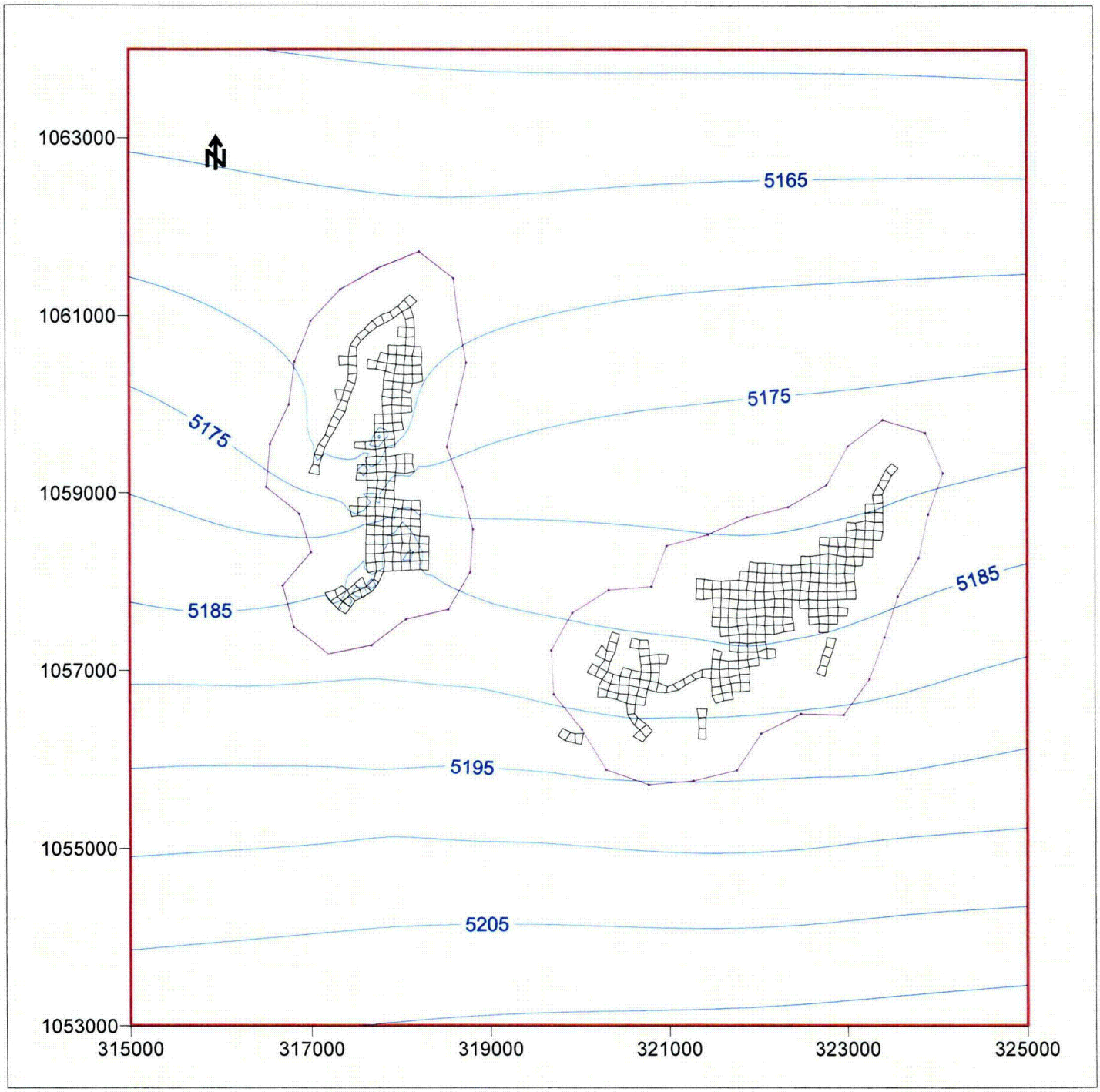
URANIUM ONE

Figure 13. Wellfield One Drawdown (Detail)
End of Second Production Phase
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig13MRProd2.srf Date: 9/19/08



Potentiometric Surface - 70 Sand feet amsl C.I. = 5 feet

Wellfield Patterns

Monitor Well Ring

0 1000 2000
Feet

Simulation of Production From Wellfield One
5 Header Houses, 100 Well Patterns
Production Rate of 2000 gpm for 18 months
Net 1.7% Bleed

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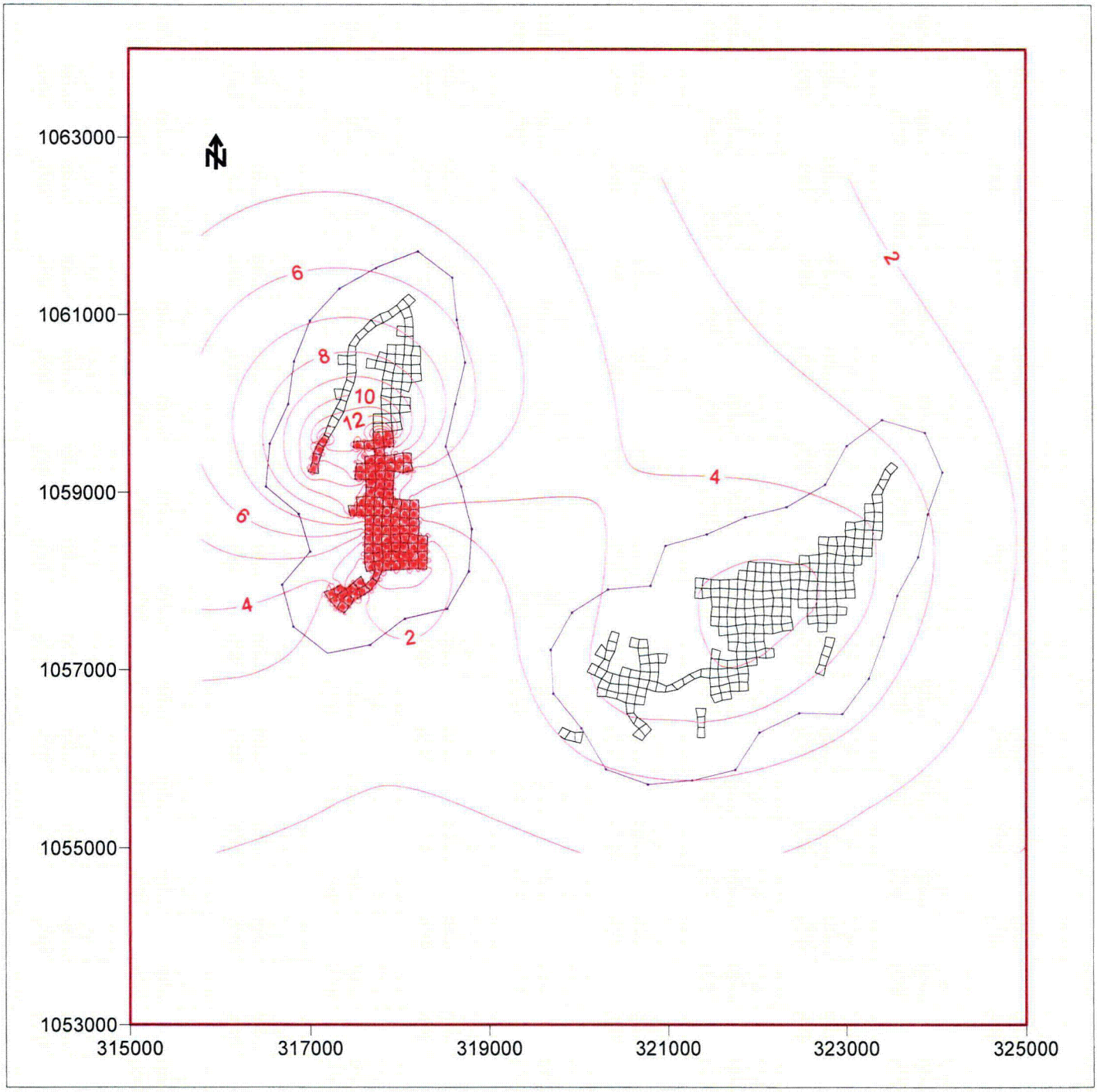
URANIUM ONE

Figure 14. Potentiometric Surface - 70 Sand
End of Third Production Phase
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig14MRProd3.srf Date: 9/19/08



Drawdown - 70 Sand
C.I. = 1 foot

Wellfield Patterns

Monitor Well Ring

0 1000 2000
Feet

Simulation of Production From Wellfield One
5 Header Houses, 100 Well Patterns
Production Rate of 2000 gpm for 18 months
Net 1.7% Bleed

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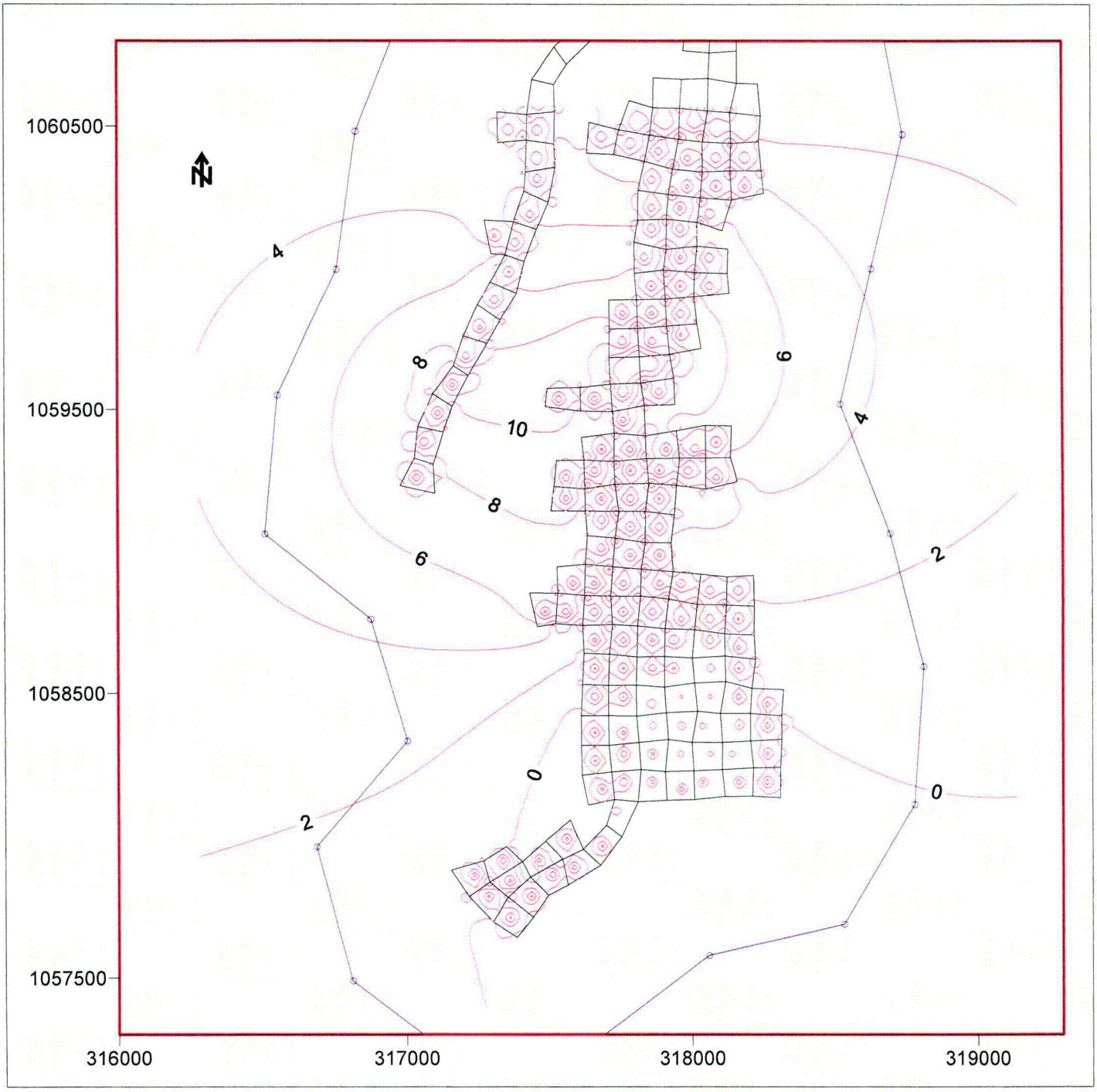
URANIUM ONE

Figure 15. Drawdown - 70 Sand
End of Third Production Phase
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig15MRProd3.srf Date: 9/19/08



Drawdown - 70 Sand
C.I. = 2 feet

Wellfield Patterns

Monitor Well Ring

0 500 1000
Feet

Simulation of Production From Wellfield One
5 Header Houses, 100 Well Patterns
Production Rate of 2000 gpm for 18 months
Net 1.7% Bleed

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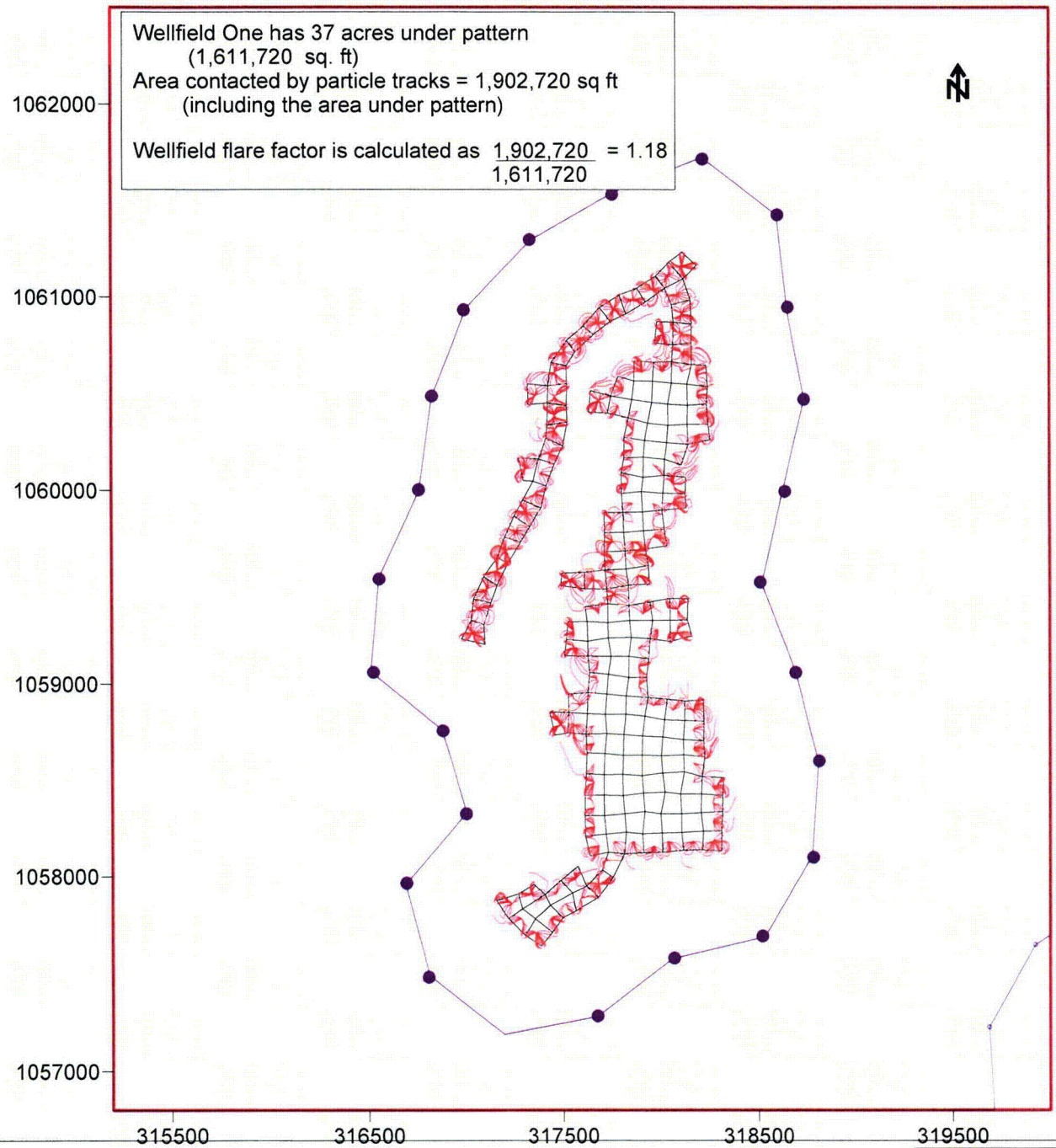
URANIUM ONE

Figure 16. Wellfield One Drawdown (Detail)
End of Third Production Phase
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig13MRProd2.srf Date: 9/19/08



0 500 1000
Feet

Particle Track
Wellfield Patterns
Monitor Well Ring

Combined Simulation of Production From Wellfield One
8 Header Houses, 160 Well Patterns
Production Rate of 3200 gpm for 18 months

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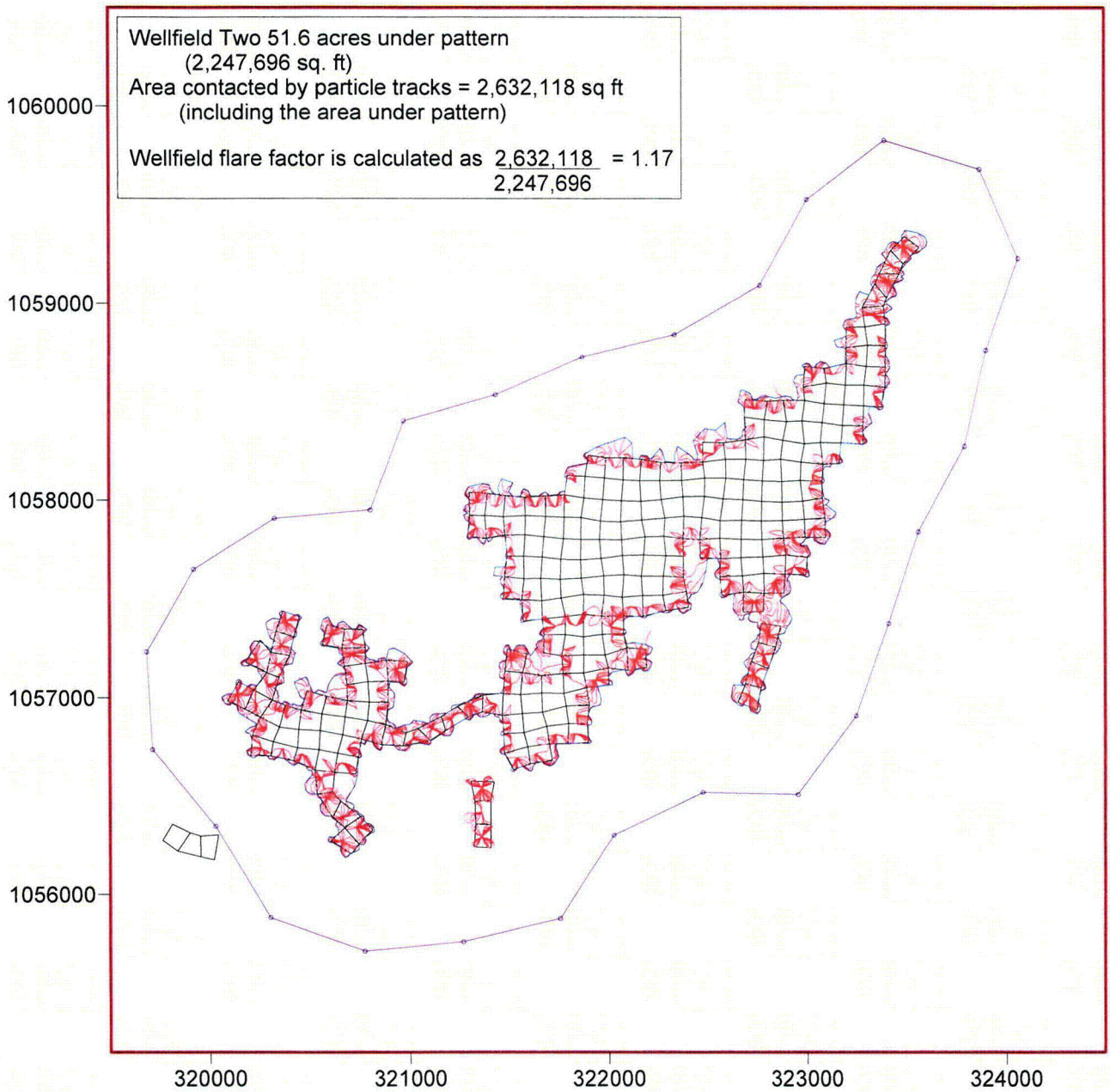
URANIUM ONE

Figure 17 Wellfield One Flare
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig17MRWF1flare.srf Date: 9/19/08



Particle Track

Wellfield Patterns

Monitor Well Ring

0 500 1000
Feet

Combined Simulation of Production From Wellfield Two
11 Header Houses, 229 Well Patterns
Production Rate of 4580 gpm for 18 months

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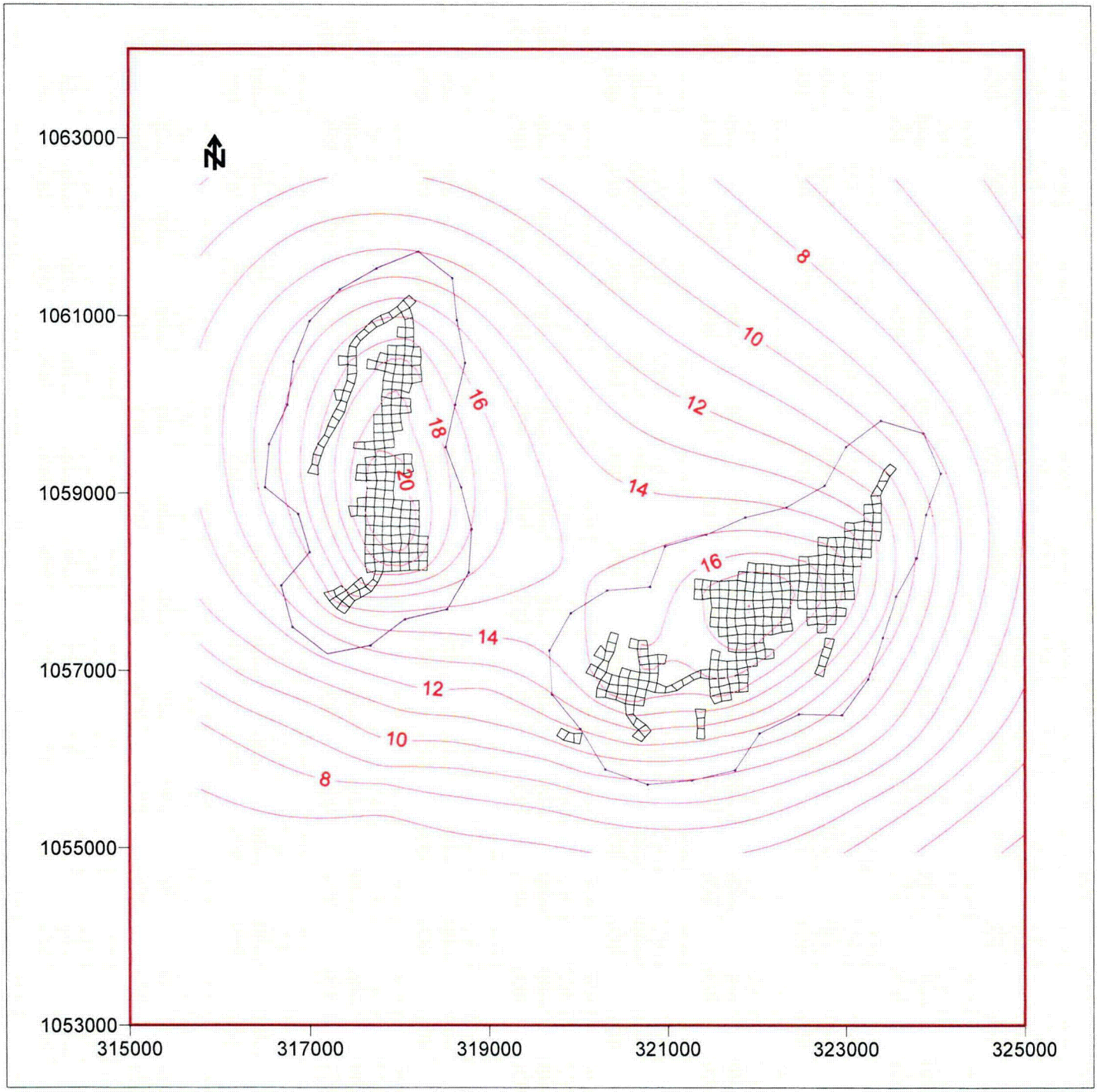
URANIUM ONE

Figure 18. Wellfield Two Flare
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig18MRWF2flare.srf Date: 9/19/08



Drawdown - 70 Sand
C.I. = 1 foot

Wellfield Patterns

Monitor Well Ring

0 1000 2000
Feet

Simulation of Restoration From Wellfields One and Two
Net Withdrawal of 50 gpm per wellfield for 4.33 years

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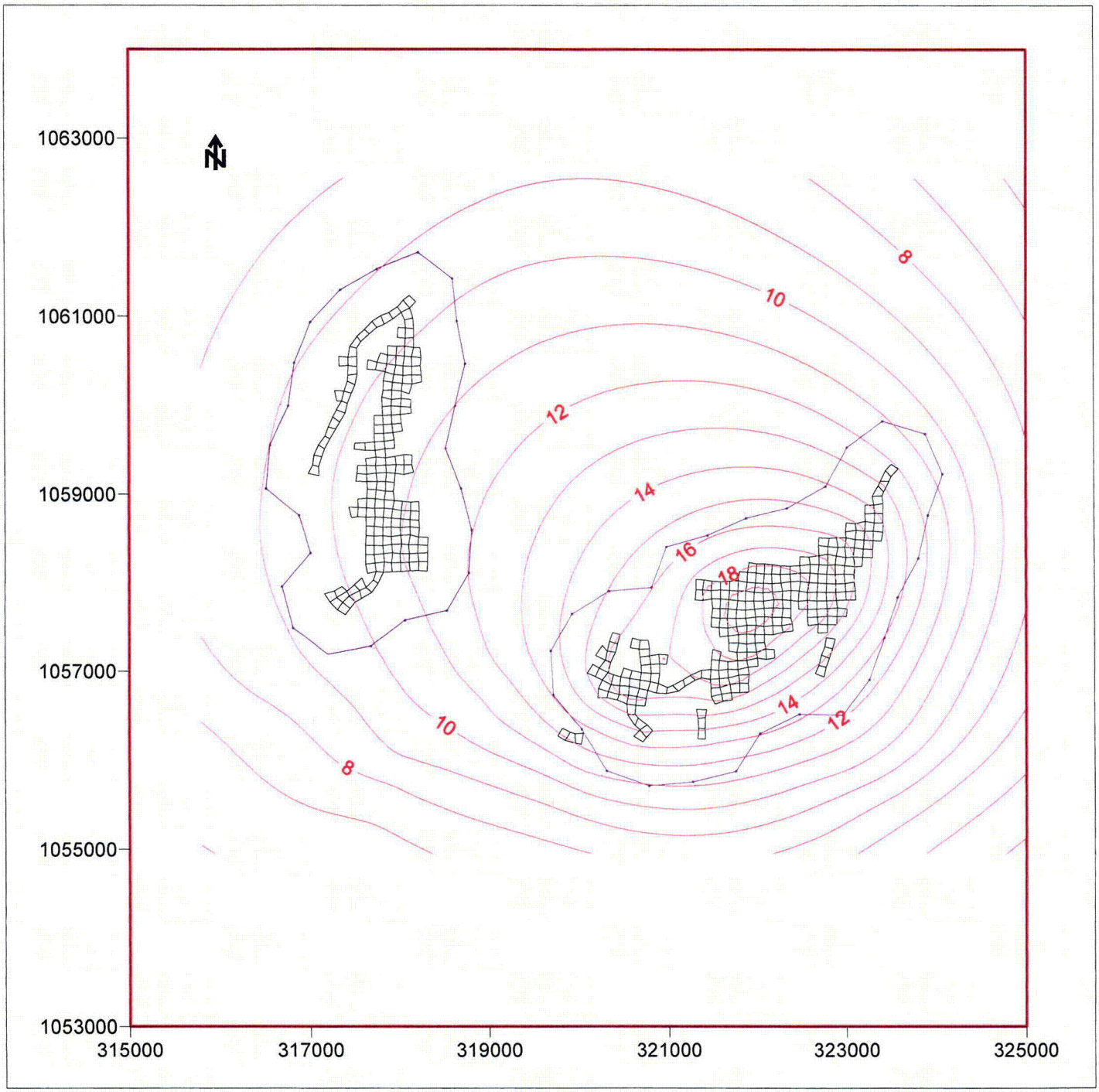
URANIUM ONE

Figure 19. Drawdown - 70 Sand
End of Restoration of Wellfield One
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig19MRRest1.srf Date: 9/19/08



Drawdown - 70 Sand
C.I. = 1 foot

Wellfield Patterns

Monitor Well Ring

0 1000 2000
Feet

Simulation of Restoration From Wellfield Two
Net Withdrawal of 50 gpm for 1.67 years

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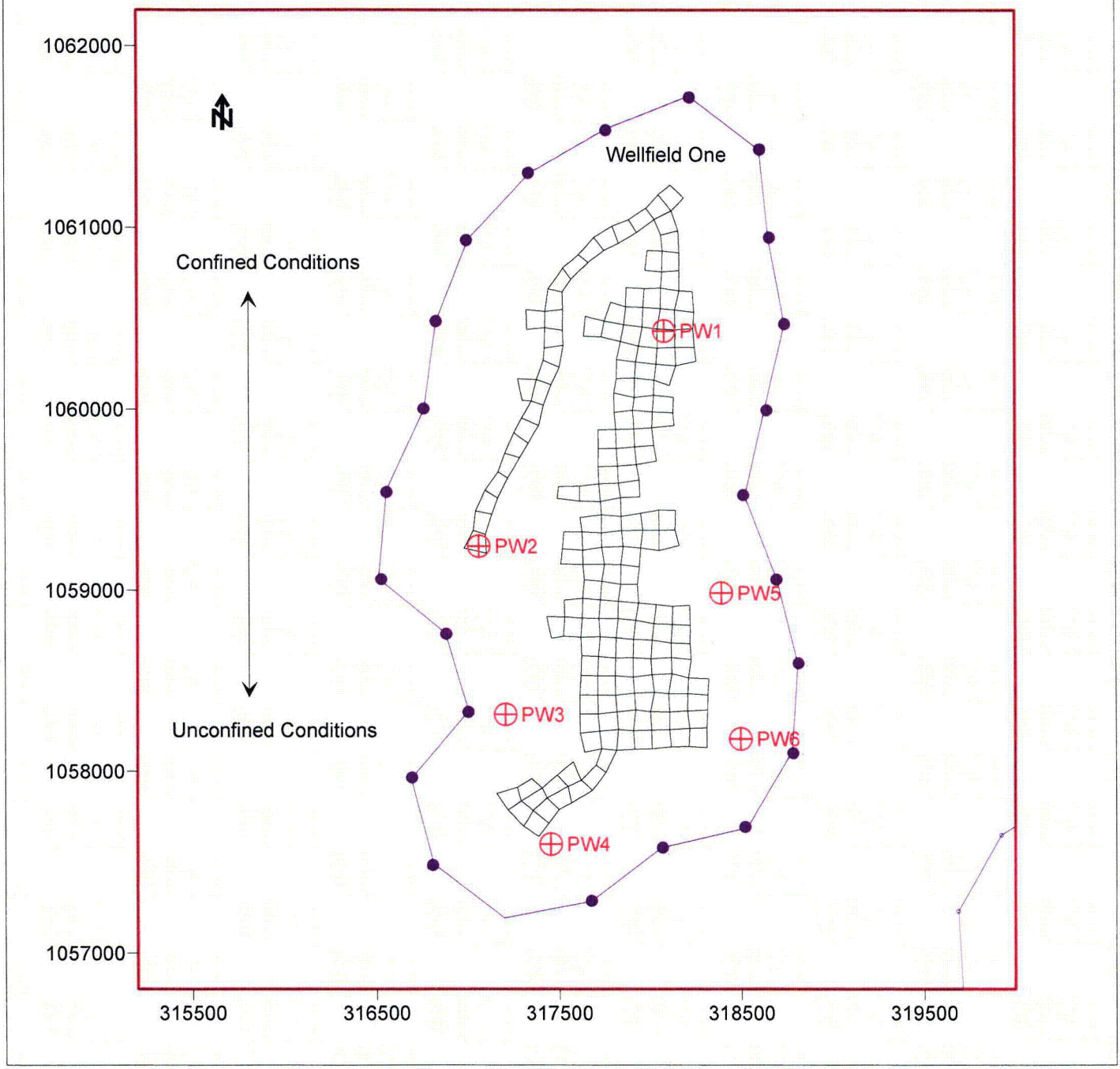
URANIUM ONE

Figure 20. Drawdown - 70 Sand
End of Restoration of Wellfield Two
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig20MRRest2.srf Date: 9/19/08



Pump Test Well

Monitor Ring Well

Wellfield Patterns

Monitor Well Ring

0 500 1000
Feet

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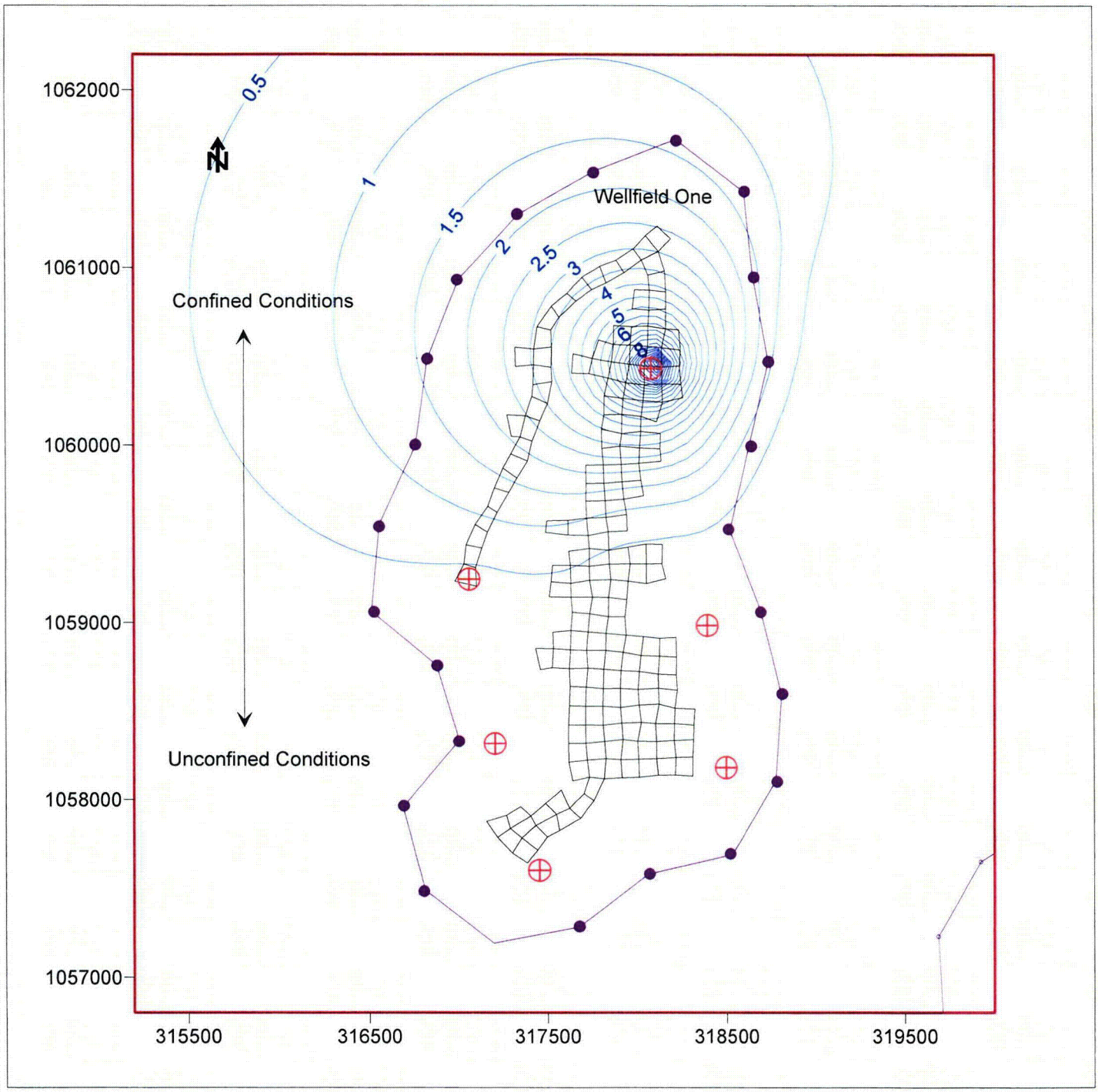
URANIUM ONE

Figure 21. Hydrologic Test Design Pumping and Monitoring Well Layout Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig21MRWF1HT.srf Date: 9/19/08



Pump Test Well

Monitor Ring Well

Drawdown - End of Test
C.I. = 0.5 feet

Wellfield Patterns

Monitor Well Ring

0 500 1000
Feet

Simulated Pump Test of One Well at 40 gpm for 5 Days

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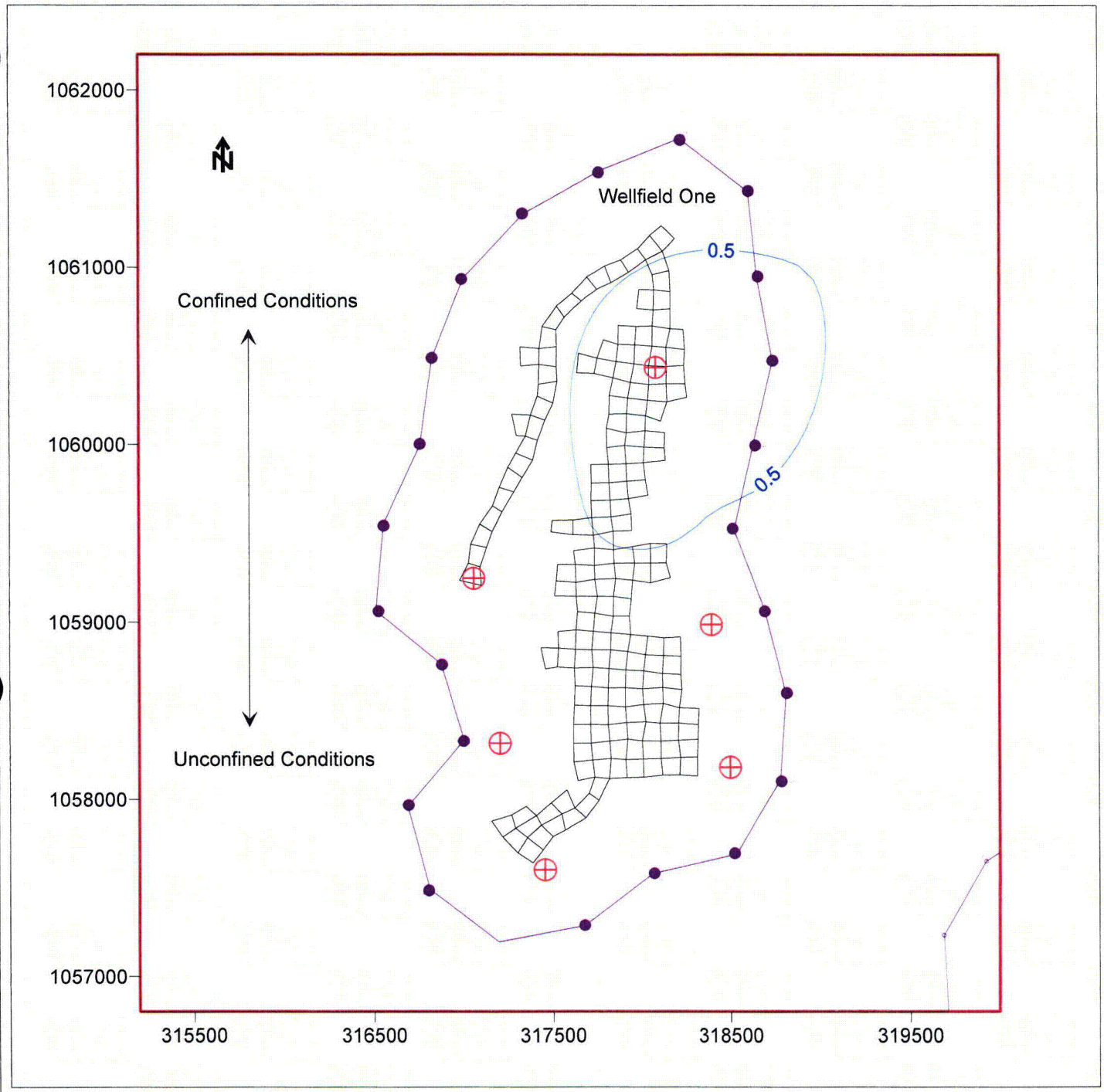
URANIUM ONE

Figure 22. Hydrologic Test Design
Drawdown - End of First Test
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig22MRWF1HT.srf Date: 9/19/08



Pump Test Well

Monitor Ring Well

Drawdown - End of Test
C.I. = 0.5 feet

Wellfield Patterns

Monitor Well Ring

0 500 1000
Feet

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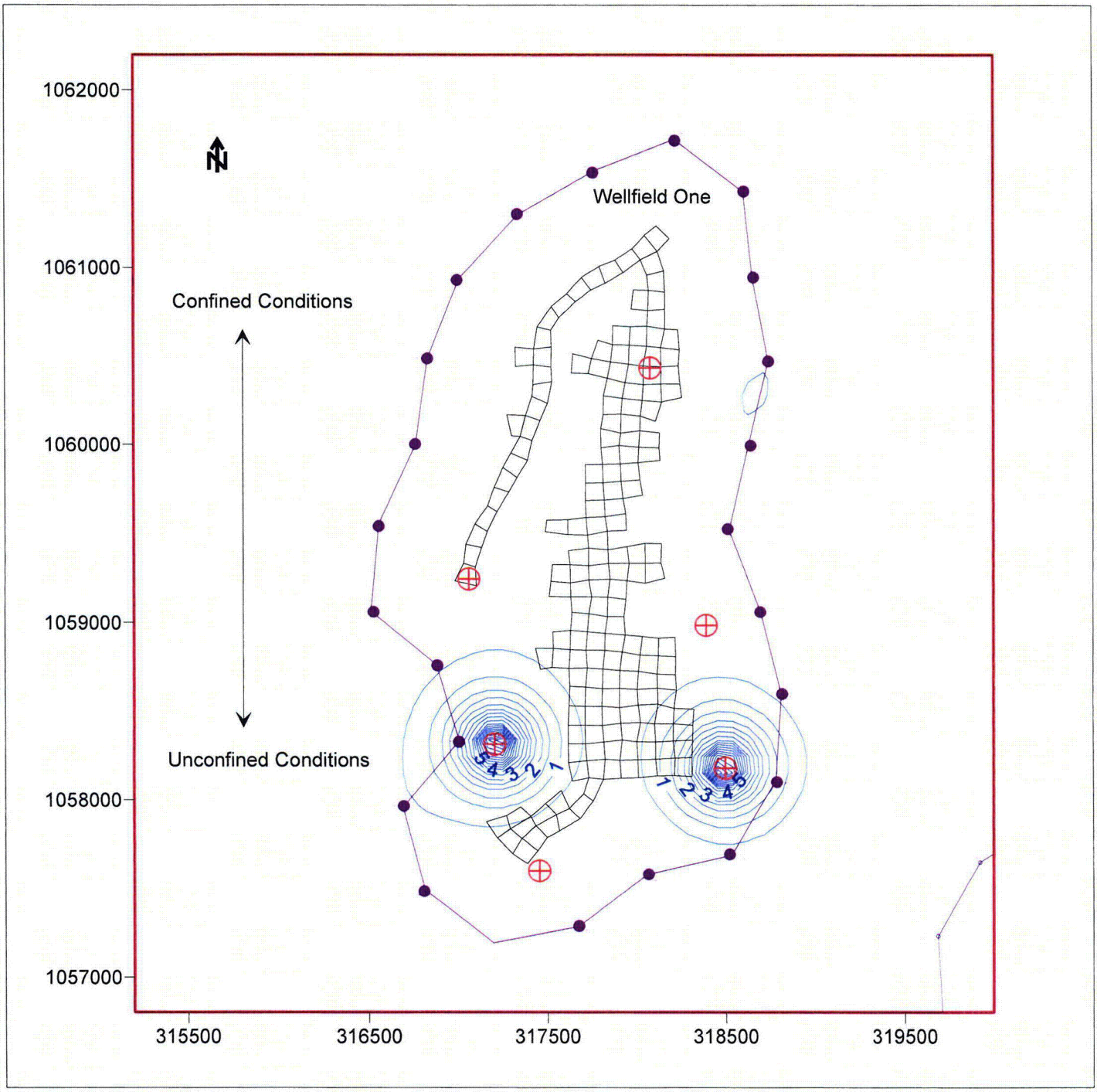
URANIUM ONE

Figure 23. Hydrologic Test Design
Residual Drawdown - End of First Recovery Period
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig23MRWF1HT.srf Date: 9/19/08



Pump Test Well

Monitor Ring Well

Drawdown - End of Test
C.I. = 0.5 feet

Wellfield Patterns

Monitor Well Ring

0 500 1000
Feet

Simulated Pump Test of Two Wells at 40 gpm each for 5 Days

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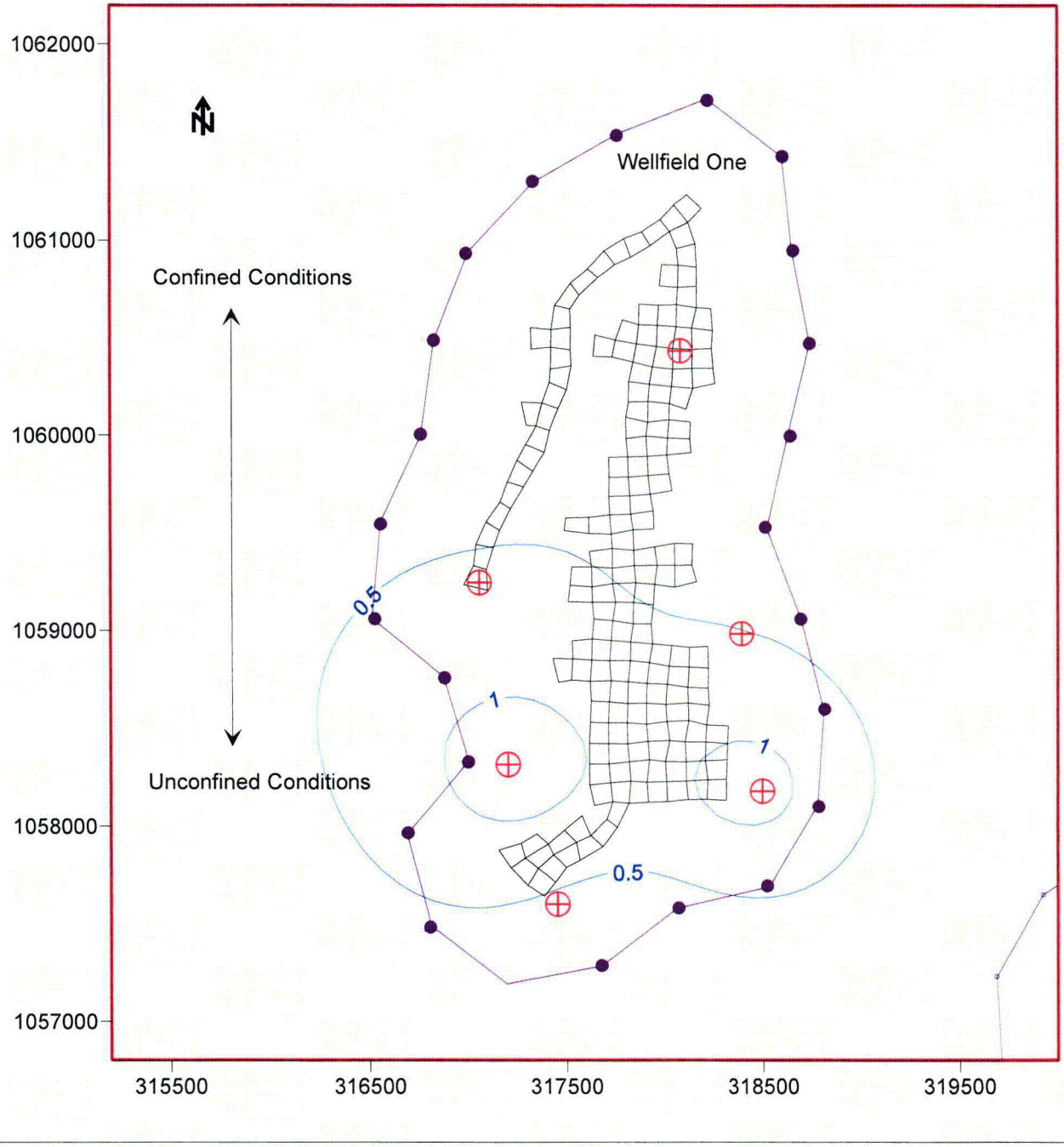
URANIUM ONE

Figure 24. Hydrologic Test Design
Drawdown - End of Second Test
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig24MRWF1HT.srf Date: 9/19/08



Pump Test Well

Monitor Ring Well

Drawdown - End of Test
C.I. = 0.5 feet

Wellfield Patterns

Monitor Well Ring

0 500 1000
Feet

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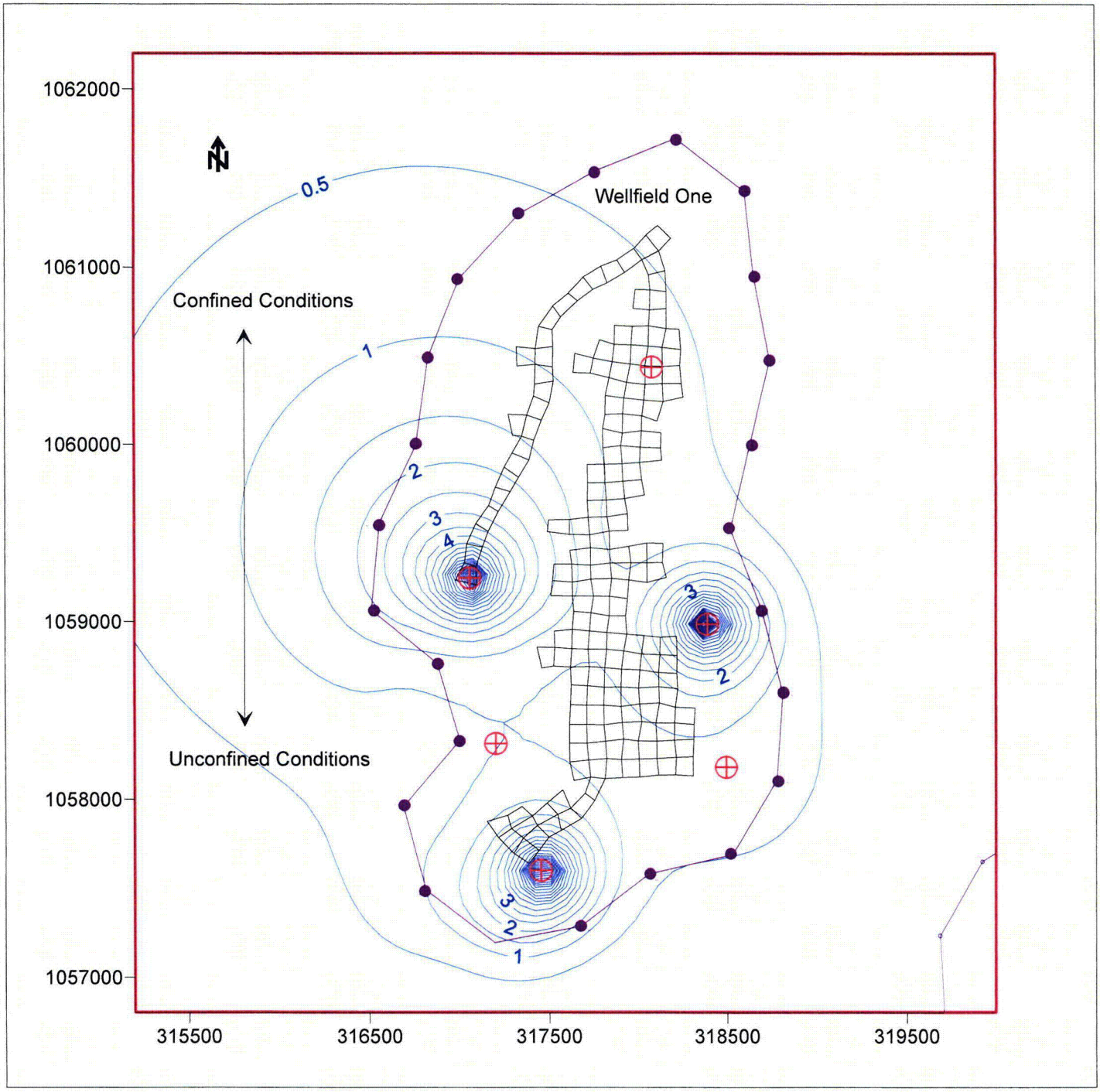
URANIUM ONE

Figure 25. Hydrologic Test Design
Residual Drawdown - End of Second Recovery Period
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig25MRWF1HT.srf Date: 9/19/08



Pump Test Well

Monitor Ring Well

Drawdown - End of Test
C.I. = 0.5 feet

Wellfield Patterns

Monitor Well Ring

0 500 1000
Feet

Simulated Pump Test of Three Wells at 40 gpm each for 5 Days

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URANIUM ONE

Figure 26. Hydrologic Test Design
Drawdown - End of Third Test
Moore Ranch Uranium Project, Wyoming

By: EPL Checked: HD File ID:fig26MRWF1HT.srf Date: 9/19/08

CONOCO INC.

MOORE RANCH MINE/SAND ROCK MILL PROJECT

MINE PERMIT APPLICATION

APPENDIX D-6

HYDROLOGY

APPENDIX D-6 HYDROLOGY

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Revised March, 1982

D-6 HYDROLOGY

The ground-water systems in the vicinity of the evaporation pond (Section 1, T 41 N, R 75 W), and the tailings disposal site in Pit 35N (Section 35, T 42 N, R 75 W) were investigated in detail. Numerous tests have been conducted to define the ground-water hydrology in the mine area. The description of the surface water regime in this area is also important. The relationships of the pits in Sections 34 and 35 and the mill water supply to the local hydrologic systems are addressed.

1.0 GROUNDWATER

The major topics presented in the discussion of the ground-water systems are the geologic setting, recharge areas, aquifer properties, water movement, springs, and ground-water quality.

1.1 GEOLOGIC SETTING

The site is situated in the southwestern part of the Powder River Basin approximately 12 miles east-northeast of the Tertiary Wasatch-Fort Union formation contact. The Wasatch formation, which is the surface geologic unit in this area, is part of the thick Powder River sedimentary series and consists of interbedded sandstones, siltstones, claystones and coals. Seeland (1976) found that the Wasatch sandstones were deposited in a fluvial paleo drainage system which flowed generally northward. These channel deposits are the host rocks for many uranium ore deposits.

The Fort Union formation, which lies under the Wasatch formation, consists primarily of fine grained fluvial silts and clays layered between wedges of arkosic sandstones which were deposited as alluvial fans and

fore, even though the Madison and Tensleep aquifers produce large quantities of water, the quality would probably make these aquifers unusable. Only the Roland coal and the upper Wasatch formation units will be discussed further, because the lower units will not be influenced by this project.

The local surface geology consists of the Wasatch formation for several miles from the proposed mine and mill site. The top of the Roland is approximately 1,100 feet deep in this area. The dip of the top of the Roland coal is to the west-northwest at an average of one degree.

Conoco exploration nomenclature has designated most sands above the Roland coal with decreasing numbers with depth. Cross sections from exploration logs were developed for this area to evaluate the areal distribution of these sands. The 40 and 50 sands are normally separated only by a few feet of shale or mudstone and extend areally. These two sands contain some coarse material in most areas and are considered significant aquifers.

The 60 sand is fairly massive and continuous over most of the area. The 68 sand is the first sand below the 70 sand, which contains the ore deposits in the area. The thickness of the 70 sand is normally in the range of 60 to 80 feet in this area and is areally extensive. Figure D-6-1 presents the elevation of the top of the 70 sand and shows that the dip of the 70 sand is generally less than one degree toward the northwest. The average dip of the 70 sand over the area of the contour coverage is 0.006 ft/ft.

A thin coal exists normally a few feet above the top of the 70 sand and has been labeled by Conoco as the E coal. Figure D-6-1 shows contours of the top of the E coal over the area. The average dip of the E coal is one-half of one degree or 0.008 ft/ft toward the northwest.

The remainder of the lithologic section above the 70 sand consists mainly of mudstones (claystones), and interbedded sandstones and thin coal lenses. The thin sandstone lenses do not correlate well, and the thickness and aerial extent of each of these units varies considerably over the project area. These sandstone lenses and thin coal seams above the 70 sand can be seen in the cross sections presented in Appendix D-5. Piezometers were installed in a number of these upper sand lenses to determine the presence of perched water tables and the hydraulic conductivity (permeability) of these units. Basic well completion data along with static water level information are presented in Table D-6-2. Permeabilities of these upper sands are summarized in Table D-6-4. Ground water quality for several of these upper sand wells is presented in Table D-6-9. The long term effect of shallow aquifer table is discussed in Section 8.1.4 of the Reclamation Plan.

Figure D-6-2 shows a schematic of the lithologic units in the evaporation pond area. A Claystone, referred to as the Lower mudstone, exists below the E coal in the evaporation pond area. Another claystone exists above the E coal in the evaporation pond area and has been labeled the Upper mudstone.

The lithologic units above the E coal in the tailings disposal area of Pit 35N do not correlate well. Figure D-6-1 shows that the structure of the top of the E coal and 70 sand is similar to the structure in the evaporation pond area. The mudstone between the E coal and the 70 sand is

not as thick in the area of Pit 35N as in the evaporation pond area. Thin, noncontinuous sandstone units are interbedded in the mudstones (claystones) above the E coal.

1.2 RECHARGE AREAS

The outcrop area of the 70 sand is important to the flow in this ground-water system. The low permeability materials above the 70 sand should essentially restrict recharge to the 70 sand except in its outcrop area. The quality of water from the claystone and coal above the 70

sand is normally poorer than the 70 sand water quality. This also indicates that very little of the 70 sand water is derived from these upper units. The upper (unsaturated) portion of the 70 sand contains very low permeabilities, which indicates very little water has flowed in this portion of the aquifer to dissolve the cementation.

Figure D-6-3 presents the outcrop of the 70 sand near the project. This outcrop includes areas of the 70 sand which are covered by alluvium and topsoil. The outcrop map is derived mainly from the 70 sand structure map and some known exposures. These areas would be susceptible to recharge to the 70 sand aquifer, also. The 70 sand crops out in a large percentage of Sections 11 and 12 of T41N-R75W and Sections 6 and 7 of T41N-R74W. Water which enters the outcrop area flows down-dip in the 70 sand. Figure D-6-1 gives the structure of the top of the 70 sand and shows that water would be expected to flow north-northwest from the outcrop area.

An outcrop line is shown on Figure D-6-3 for the E coal. This outcrop line is inferred from the structure map of the E coal in Figure D-6-1. Recharge to the E coal and the Lower mudstone should occur mainly in the area of the outcrop line in the eastern half of Section 1, T41N-R75W. Recharge to all units above the 70 sand probably occurs mainly in their outcrop areas, because of alternating low permeability materials.

1.3 PIEZOMETER AND WELL CONSTRUCTION

A total of 47 piezometers and/or wells were constructed in the evaporation pond and tailings disposal site (35N) areas; 17 in and around Pit 35N, and 30 in the area of the evaporation pond. These piezometers and wells have been used to define the static-water levels, permeabilities and

water quality of the shallow geologic units. Table D-6-1 presents basic well data for the evaporation pond area, including date drilled, depth drilled, perforated interval, lithologic unit and water level for each piezometer, while Table D-6-2 gives the same data for the Pit 35N mine area. The location and perforated interval of the Pit 35N piezometer wells are depicted on the cross-sections presented in Figures D-5-16 through D-5-18. Most piezometers were bailed on several different occasions and observed to determine if their water levels would recover. A permeability test was conducted after a satisfactory static water level was established. Bailing information and water level measurements are given in the tables of Appendix A-1.

Twenty-three additional wells have been used to define the groundwater hydrology for the 70 sand and deeper units in other than the evaporation pond and tailings disposal sites. The completion details for these wells is given in Table D-6-3. The location of all wells is shown in Figure D-6-4.

1.4 SUBSOIL AND AQUIFER PROPERTIES

The transmitting (transmissivity and hydraulic conductivity) and storage (storage coefficient and specific yield) abilities of the aquifers and partially saturated material are discussed in this section. Additional material properties, moisture content, bulk density and grain sizes will also be discussed. The pump test theory, including field tests for hydraulic conductivity, is addressed in Appendix A-2.

1.4.1 TRANSMITTING PROPERTIES

The results of the constant head injection recovery tests from the low yielding wells and dry piezometers in the evaporation pond and tailings

disposal areas will be presented first. The permeability and transmissivity results from the 70 sand wells will follow.

Twenty-four constant-head injection tests were conducted to determine the saturated hydraulic conductivity (permeability) of the subsoil materials in the evaporation pond area (Figure D-6-4). The procedures used in conducting the constant-head injection tests are given in Appendix A-2.

The largest permeability found in the evaporation pond area was obtained from piezometer P-18, which is completed in the alluvium of the small drainage channel through the pond area. A permeability of 470 feet/year was obtained for the alluvium at the proposed dam location.

Table D-6-4 summarizes permeabilities obtained from constant-head and pump tests in the project area. The permeabilities from packer tests in the evaporation pond area are summarized in Table D-6-5. The packer tests were normally conducted for 10 to 15 minutes and steady-state analysis was used to calculate the permeability. Therefore, some difference would be expected between the constant-head permeabilities and those obtained by packer tests. Figure D-6-5 presents horizontal permeabilities for the E coal, Upper coal, Lower and Upper mudstone units in the evaporation pond area. Coal and mudstone units in the 35N tailings disposal area are also presented on this figure, which includes permeabilities from only the constant head tests.

Results indicate that approximately one-half of the evaporation pond area has subsoils with permeabilities of less than 1 ft/yr. A zone of higher permeability was observed near the center of the evaporation pond in the E coal and Lower mudstone units. These permeabilities vary from 6.7 to 53 ft/yr. In general, the permeability of the E coal and Lower mudstone is less than 10 ft/yr.

The horizontal permeabilities for the Upper coal and Upper mudstone units are given in Figure D-6-5 in brackets. These permeabilities are listed in Tables D-6-4 and D-6-5. The packer tests on holes PD-19 and PD-24 were conducted on the mudstone next to the Upper sandstone. Generally, the Upper mudstone and Upper coal have permeabilities in the same range as the Lower mudstone and E coal.

Figure D-6-6 shows the permeabilities for the Upper sandstone and 70 sand in the evaporation pond area. This figure presents permeabilities for piezometers P-6, P-7, P-16, P-17, P-20B and P-21, where constant head injection or recovery tests were conducted. The Upper sandstone shows a much larger areal variation in permeability than the other lithologic units. The variation in permeability is probably relative to the degree of weathering of the sandstone and removal of its cementation. A permeability of 1,000 ft/yr is representative of a significant portion of the Upper sandstone.

The permeabilities of the 70 sand aquifer in the evaporation pond area are also given in Figure D-6-6. Values for the unsaturated portion of the 70 sand at piezometers P-16 and P-17 were calculated to be 1.0 and 0.65 ft/yr respectively. Both of these permeabilities are very low, which shows that the unsaturated portion of the 70 sand is not very permeable. Permeabilities of 94 ft/yr, 8.5 ft/yr and 3.7 ft/yr were determined for the saturated portion of the 70 sand near Wells P-7, P-20B and P-21, respectively, from recovery tests.

The largest permeability determined for units above the 70 sand in the tailings 35N area is 42 ft/yr for a sandstone which piezometer 35N-7E

penetrates. Values for the E and Upper coals in the area of 35N-7 were determined to be 41 and 0.09 ft/yr respectively. Table D-6-4 presents these permeabilities while Figure D-6-5 shows the values on a map. Permeabilities of mudstone in the 35N area varied between 0.9 to 4.3 ft/yr. These values agree well with permeabilities which were determined for the mudstones in the evaporation pond area. Sandstones other than the 70 sand were tested at seven sites and values ranged from 0.0012 to 42.1 ft/yr. Permeabilities for the sandstones above the 70 sand in the area of Pit 35N are not as high as some of the values in the evaporation pond area. This is probably attributed to the fact that most of the sandstones in the evaporation pond area were exposed on the surface and therefore, some of their cementation was leached.

The permeability of the unsaturated 70 sand in Pit 35N is low and similar to the values determined in the evaporation pond area. Three piezometers in the unsaturated 70 sand (U70SS) were tested and yielded values of 0.78, 8.5 and 5.5 ft/yr for holes 35N-1C, 35N-2A and 35N-7B respectively. A transmissivity for the saturated 70 sand well, 35N-7A, was computed to be 1170 gal/day/ft from its recovery test. This value compares fairly well to the transmissivities which were earlier determined for other 70 sand wells (1805 and 1806) in the area. The permeability computed from the 35N-7A test is significantly higher than the values determined in the evaporation pond area, which shows that the 70 sand is more permeable in Pit 35N.

Tests on the saturated 70 sand in Wells 886, 888, 1805, 1806, 1814, 1815, 1816 and 1817 are also presented. The analyses of these tests are also presented in Appendix A-2, while Figure D-6-4 gives the location of

the wells. Transmissivities ranged for the 70 sand aquifer from 800-5,500 gal/day/ft, while permeabilities varied from 140 to 6,700 ft/yr. Wells 887 and 1823 are completed in the 68 sand (the first sandstone below the 70) and recovery tests were conducted on these two wells. Permeabilities of 3.1 and 306 ft/yr and transmissivities 1.9 and 190 gal/day/ft were computed for this sand. The transmitting ability of the 68 sand is significantly less than the 70 sand. A recovery test on a 50-40 sand well indicates these sands have a permeability in the range of 300 ft/yr while a similar test on a Roland coal well produced a permeability of 850 ft/yr.

1.4.2 STORAGE PROPERTIES

Storage coefficients (the storage ability of a confined aquifer) were determined at five locations in the 70 sand aquifer. Two 70 sand tests were conducted to measure the specific yield (the storage ability of an unconfined aquifer)for the 70 sand. Table D-6-4 presents these storage values.

1.4.3 ADDITIONAL MATERIAL PROPERTIES

Additional material properties (Chen, 1980) were also used in the hydrological analysis. The porosity of the materials at the site is in the range of 40 per cent while most nonsaturated rock has moisture contents in the range of 15 per cent. The average bulk density of the material is roughly 165.4 pounds/cubic foot.

1.5 WATER LEVEL

Water level data is presented with the basic data for each piezo-

meter in Appendix A-1. Tables D-6-1 and D-6-2 give a static-water level for each piezometer. Several 70 sand wells have been monitored since their installation in 1977, and this data is given in Table D-6-6. Figure D-6-4 gives the location of the preoperational ground-water monitoring sites. A discussion of the water level elevations and changes for each geologic unit is presented below.

The water level elevation map for the 70 sand aquifer is presented in Figure D-6-7 for the project area. The outcrop area of the 70 sand, which is the recharge area for this aquifer, is given in Figure D-6-3. This recharge area and the data points in Table D-6-6 were used to construct the piezometric surface for the 70 sand aquifer. The water level elevation contours are closely spaced next to the recharge areas where the saturated thickness is less. Therefore, steeper gradients are required to transmit the water in this area than further down gradient. The water level elevation is lower in the center of Section 1 (T41N-R75W) than in the center of Section 2 because Section 1 is farther from the outcrop area. The water level elevation varies from a high which is greater than 5,200 feet near the outcrop area to less than 5,160 feet north of the permit area.

Water level changes for six of the 70 sand wells, which have been monitored since 1977, are presented in Figures D-6-8 through D-6-13. These hydrographs show that the water levels in Wells 22-2 and 1809 have varied approximately one foot over this period. Water level fluctuations for Wells 1810, 885 and 1 have been in the range of 2, 3 and 4 feet, respectively.

Water level elevations for the E coal and Lower mudstone units are presented in Figure D-6-14 and Tables D-6-1 and D-6-2. The piezometric contours drawn from these data points are not very uniform but are probably reflective of variations in permeabilities and distances from a recharge source. The high water level elevation in the stock pond upstream from the proposed dam site has created a small local mound in the groundwater piezometric surface. Generally, higher water level elevations are found on the east side of the evaporation pond area. Significant water level changes are expected during the year for E coal and Lower mudstone wells.

Figure D-6-14 gives the water level elevation for the Upper mudstone, Upper coal and Upper sandstone in the evaporation pond area and mudstone and sandstones in the tailings disposal area. The water level elevations of the Upper coal and Upper mudstone are fairly close to the elevations in the Lower mudstone and E coal. The Upper sandstone piezometric level would be expected to be higher than the coal and mudstone levels because the sandstone is much more permeable and higher stratigraphically.

1.5.1 GROUND-WATER MONITORING

Table D-6-7 presents the results of the pre-mine monitoring of the private wells in the area. Pre-mine monitoring of the project wells are given in Tables D-6-8 and D-6-9, respectively. Figures D-6-17 and D-6-18 give the locations of the private wells while Figure D-6-4 shows the location of Conoco's wells. The mining and post-mining ground-water monitoring program will be the same and are defined in Section 3.5.6 of the Mine Plan.

1.6 WATER MOVEMENT

The rate of ground-water flow is governed by permeability, effective porosity and hydraulic gradient of the system. The following equation was used to obtain groundwater velocities:

$$V = Ki/n$$

where: V = velocity, in ft/yr

K = permeability, in ft/yr

i = hydraulic gradient, in ft/ft

n = effective porosity

The permeability and effective porosity were discussed in Section 1.4, Subsoil and Aquifer Properties, and water level elevations were presented in the Water Level section. Hydraulic gradients were obtained from water level contours.

The hydraulic gradient of the 70 sand aquifer can be obtained from Figure D-6-7. The gradient of the water table in the 70 sand varies from 0.012 to 0.0018 ft/ft with an average value of 0.006 ft/ft. An average horizontal rate of movement of the ground water in the 70 sand was estimated to be 120 ft/yr, from an average horizontal permeability of 2,000 ft/yr, an effective porosity of 0.1, and the above average gradient. In general, movement of water in the 70 sand should gradually decrease with distance from the recharge area. Flow directions in the 70 sand are shown in Figure D-6-7.

Hydraulic gradients in Figure D-6-14 vary from 0.004 to 0.05 ft/ft with an average gradient in the range of 0.015 ft/ft. The steeper and flatter gradients should be an indication of lower and higher permeabilities, respectively. An average gradient of 0.015 ft/ft and a permeability

of 5 ft/yr should yield a velocity fairly representative of both the low and high permeability areas. A ground-water velocity of 1.5 ft/yr was calculated from the above hydraulic gradient and permeability values, and an effective porosity of 0.05. This shows that the ground water in the E coal and Lower mudstone moves very slowly. Flow directions for the Lower mudstone and E coal can be estimated from Figure D-6-14.

Water levels in the Upper mudstone and Upper coal piezometers are very close to the water levels in nearby Lower mudstone and E coal wells. Therefore, gradients in the Upper mudstone and Upper coal are thought to be very similar to those in the Lower mudstone and E coal. The slightly higher permeabilities observed in the Upper mudstone and Upper coal units should allow water transmission at a slightly higher rate. An average velocity of the water in the Upper mudstone and Upper coal was computed to be 3 ft/yr using a permeability of 10 ft/yr, a hydraulic gradient of 0.015 ft/ft, and an effective porosity of 0.05.

Water movement in the Upper sandstone would be expected to be significantly higher than the mudstone because of its higher permeabilities. The velocity of ground water in the Upper sandstone was estimated to be in the range of 50 ft/yr from values of 500 ft/yr, 0.01 ft/ft and 0.1 for horizontal permeability, hydraulic gradient and effective porosity. Water flow direction in the Upper sandstone would be expected to be down-dip.

Rates of water movement in the tailings disposal area for the mudstones and sandstones above the 70 sand are estimated to be in the range of the velocities for the E coal - Lower mudstone in the evaporation pond

area. The gradient of the piezometric surfaces should mainly be governed by the dip of the beds, which are similar in the two sites.

1.7 GROUND-WATER QUALITY

The ground-water quality in the project area has been collected from three sources, private wells, Conoco's mine monitoring wells, and the evaporation pond and tailings disposal site wells. The water quality for the three sources are tabulated in Tables D-6-7, D-6-8 and D-6-9 respectively. Figure D-6-4 gives the location of Conoco's wells, while private wells are shown on Figures D-6-17 and D-6-18. The ground-water quality is very hard with total dissolved solids normally greater than 500 mg/l. The major cation is calcium while sulfate is the major anion. The sulfate, hardness and iron in some of the groundwater would make its use undesirable for domestic use. The nitrate concentrations in Well A2 (see Table D-6-7 and Figure D-6-17) are significantly above the recommended drinking water standard.

The conductivity, calcium, sulfate and chloride concentration of wells which penetrate the 70 sand or below is given in Figure D-6-15. Water quality from Wells 8-3, 889 and 1808 is not reflective of the 70 sand aquifer in the area of these wells because their piezometric heads indicate they are influenced by a different sand. Calcium and sulfate follow the same pattern as conductivity. Chloride values of the 70 sand aquifer are all low and are not reflective of other major constituents. The 68 sand water quality seems fairly close to the 70 sand. The water quality from the 50-40 sand, Well 1822, is better than most of the 70 sand's water quality while the Roland coal's water quality is similar to that of the 50 and 40 sands.

Radium and selenium have been detected in the wells in the ore zone. Wells centered in the three pit areas consistently produce Ra-226 concentrations at levels in excess of the 5 pCi/l standard. Selenium has been detected in Well 1 (W-2) at levels in excess of water standards.

Table D-6-9 gives the laboratory water quality results from piezometers in the evaporation pond and tailings areas while the permeability test tables in Appendix A-1 give the field parameters. The conductivity of the water from the E coal - Lower mudstone and other mudstones and sandstones above the 70 sand are plotted in Figure D-6-16. Values for conductivities other than E coal - Lower mudstone are shown in brackets. The conductivity of water in the E coal - Lower mudstone shows a definite pattern in the evaporation pond area. The concentrations around the north and east sides of the evaporation pond are the lowest, and conductivities increase toward the dam. The conductivity of the water from Well 35N-7D (E coal) is 580 umhos/cm, which indicates the concentration does not increase much from just north of the evaporation pond to this well. Conductivities of water from mudstones in the area of Pit 35N vary from 325 to 1,090 umhos/cm while the values of water from the sandstones ranged from 330 to 880 umhos/cm.

2.0 SURFACE WATER

2.1 DRAINAGE BASINS

The project area lies entirely within the drainage basin of Ninemile Creek, which is tributary to Antelope Creek. Antelope Creek flows

into the South Cheyenne River (Wyoming nomenclature) which joins the Belle Fourche River in South Dakota to form the Cheyenne River. The Cheyenne River subsequently flows into the Missouri River. The entire Antelope Creek drainage basin is shown on Figure D-6-19. Ninemile Creek's drainage is shown on Figure D-6-17, and the Ninemile Creek tributaries which are relevant to the project are shown on Figures D-6-17 and D-6-18.

Antelope Creek has a drainage area of 980 square miles with an approximate channel length of 62 miles and an average gradient of 0.006 (ft/ft). The elevation at Antelope Creek's headwaters is approximately 6,225 feet above mean sea level (msl), and 4,400 feet at its confluence with the South Cheyenne River. The U.S. Geological Survey has a stream gaging station on Antelope Creek approximately ten miles upstream from its mouth. The drainage area is 959 square miles, at the gage.

Ninemile Creek has a total drainage area of 63 square miles, a channel length of approximately 20 miles, and an average channel gradient of 0.006 (ft/ft). The elevation difference from headwaters to mouth is 610 feet with a maximum basin elevation of approximately 5,500 feet above msl. Upstream of monitoring site I-7 (Figure D-6-17), 34 square miles of the Ninemile Creek basin drain the project area. The channel length within this area is approximately 10.5 miles with an average gradient of 0.007 (ft/ft).

Simmons Draw is a Ninemile Creek tributary flowing southeasterly through the project (Figures D-6-17 and D-6-18). Its total drainage area is 8.1 square miles. The channel length is 6.8 miles with an average gradient of 0.007 (ft/ft). Total basin elevation difference is 260 feet with a maximum elevation of approximately 5,475 feet above msl.

Pine Tree Draw, with a drainage area of 8.2 square miles, flows from the north into Ninemile Creek on the eastern edge of the project area (Figures D-6-17 and D-6-18). The channel length is approximately 7.6 miles, and the average gradient is 0.009 (ft/ft). The maximum basin elevation approaches 5,470 feet above msl, and the minimum is approximately 5,110 feet.

Simmons Draw has two tributaries which flow in a predominantly southerly direction in the project area. These tributaries are labeled Washes Nos. 1 and 2 on Figures D-6-17 and D-6-18. Wash No. 2 is further subdivided into Upper Wash No. 2 and Lower Wash No. 2 based on the channel reach being upstream and downstream of the proposed mining Pit 35N. Wash No. 4, which is tributary to Ninemile Creek, is also further divided into Upper Wash No. 4 and Lower Wash No. 4 at the location of the proposed mill tailings evaporation pond dam.

Wash No. 1 has a drainage area of 1.7 square miles, a channel length of 2.8 miles, and an average channel gradient of 0.014 (ft/ft). The basin elevation difference is approximately 205 feet with a maximum elevation of 5,475 feet above msl.

Upper Wash No. 2 and Lower Wash No. 2 have drainage areas of 1.9 and 0.95 square miles, respectively. Their respective channel lengths are 3.1 and 2.2 miles with average gradients of 0.012 and 0.007 (ft/ft).

The drainage areas of Upper Wash No. 4 and Lower Wash No. 4 are 0.70 and 0.53 square miles respectively. Channel lengths are 0.46 and 1.3 miles with respective gradients of 0.017 and 0.013 (ft/ft).

Wash No. 3 (see Figures D-6-17 and D-6-18) drains into Pine Tree Draw from the northwest in Section 36 of T42N-R75W. Its drainage area is 1.8 square miles, the channel length and average gradient are 3.2 miles and 0.014 (ft/ft), respectively, and the basin elevation difference is approximately 230 feet. The maximum basin elevation is approximately 5,480 feet above msl.

Drainage basin characteristics for Antelope Creek, Ninemile Creek, and all of the tributaries relevant to the Moore Ranch project area are summarized in Table D-6-10.

2.2 CHANNEL GEOMETRY

Representative channel cross sections for Upper Wash No. 2 in the area of Pit 35N, and upstream from this pit, are shown on Figures D-6-20 and D-6-21, respectively. The location of each cross section is identified with a letter and a dashed line on Figures D-6-17 and D-6-18. Figure D-6-22 shows a typical channel cross section of Upper Wash No. 4 downstream of the proposed mill evaporation pond, and Figure D-6-23 shows a channel cross section for Wash No. 1 west of the backfill storage area. Channel conveyance characteristics including discharge, cross-sectional area, velocity, channel gradient, hydraulic radius, Manning's roughness coefficient and the volumes for the 5-year and 100-year floods are also shown for each of these channel cross sections on their respective figures. Locations of each channel cross section site are shown on Figures D-6-17 and D-6-18. Additional channel cross sections for Lower Wash No. 2, Simmons Draw, Ninemile Creek, and Wash No. 3 at crest stage gage locations are shown on Figures D-6-24, D-6-25, D-6-26, and D-6-27, respectively. Figure D-6-28 shows a channel cross section with channel conveyance characteristics computed for Simmons Draw downstream from the Moore Ranch project area. These channel cross section sites are also shown on Figure D-6-18.

Samples of channel bed material from Simmons Draw, Wash No. 2, and Wash No. 3 were collected and subjected to mechanical and radiation analysis. Typically, only 10 to 15 per cent of the samples passed through the 0.1 millimeter sieve. Curves of grain size distribution are given in Figures D-6-29, D-6-30, and D-6-31.

2.3 SURFACE WATER RUNOFF

In Wyoming at least three techniques are available for estimating flood flows and volumes in ungaged basins for different recurrence intervals. Lowham (1976) presented a basin characteristics technique whereby peak flow was related to drainage area with consideration of different regions in the state. Lowham's regression equations can be used for basins with drainage areas between 5 and 5,300 square miles. However, using a graphical approach, his technique can be used for basins slightly less than one square mile in area.

For small basins (approximately 10 square miles and less) Craig and Rankl (1977) developed basin characteristics regression equations which utilize other basin parameters in addition to drainage area to compute peak flows and flood volumes. Also, for small basins, the U.S. Soil Conservation Service (SCS) has developed a technique to estimate peak flows and flood volumes. These techniques are published in their Engineering Field Manual (1969). The SCS technique utilizes peak rainfall values published by the U.S. Weather Bureau and then takes into consideration soil and vegetation characteristics and basin slope and drainage area to make the flood flow and volume estimates.

Additional Text for Section 2.2

Longitudinal profiles of local drainages within the permit area are provided in Figure D-6-36. Features of the proposed complex (Dam 1A, Dam 2 and Pit 35N) which will lie on these drainages are depicted on the appropriate profiles.

Please note that one proposed feature (Dam 1B) does not occupy a position on a major drainage. For a detailed discussion of all these features, please refer to the Mine Plan.

Table D-6-11 presents flood flow and volume estimates for the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year events. For comparison purposes, values obtained by utilizing the three available techniques are tabulated. Mean annual flows using Lowham's technique are also shown. However, mean annual flow values are questionable for ephemeral or intermittent streams because many zero values must be averaged with the relatively infrequent runoff events.

Values listed in Table D-6-11 under the SCS method were obtained using curve number 75 and 24-hour duration precipitation values from Miller and others (1973). Table D-6-12 shows precipitation for selected recurrence intervals for different duration periods.

At the U.S. Geological Survey stream gaging site on Antelope Creek, discharge data are available for the period of record, October 1977 - September 1979. This can be seen in the Survey's annual report entitled Water Resources Data for Wyoming. Maximum flow observed during this period was 6,600 cubic feet/second, and minimum daily flow was 0.10 cubic feet/second. Mean discharge for water year 1978 was 28.7 cubic feet/second and 7.09 cubic feet/second for water year 1979. Mean monthly discharges for water years 1978 and 1979 are shown on Figure D-6-32.

For the smaller tributaries to Ninemile creek in the project area, long periods of no flow would be expected. Runoff would be observed mainly during snowmelt and rainstorm events occurring between March and August.

2.4 SURFACE CONTROL STRUCTURES

Several small ponds exist downstream of the project. The first major surface water control structure downstream of the project is the

Angostura Reservoir on the Cheyenne River in South Dakota. This reservoir is approximately 320 river kilometers (200 river miles) downstream of the project. Storage capacity of this reservoir for different pool elevations is given in the U.S. Geological Survey Water Supply Papers on surface water data of this area.

2.5 SURFACE WATER QUALITY

The U.S. Geological Survey has operated a stream gaging and water quality monitoring site (Antelope Creek near Teckla, Wyoming) since October 1977. Total dissolved solids ranged from less than 300 to greater than 2,000 mg/l in the first two years of operation. The water is extremely hard with values often exceeding 1,000 mg/l. Calcium, magnesium, and sodium are all present in significant concentrations with no single cation being overwhelmingly dominant. Sulfate and bicarbonate are the dominant anions. With the exception of most major ions, no chemical contaminants seem to be in Antelope Creek near Teckla in excessive concentrations.

Observed suspended sediment concentrations at the Antelope Creek gage ranged from 5 to greater than 1,000 mg/l for the two-year period of record. The sediment content varies directly with water discharge. Therefore, the bulk of the sediment load is transported during spring snowmelt runoff and spring and summer thunderstorms. Figures D-6-33 and D-6-34 show the seasonal relationship and the relationship with stream discharge at the Antelope Creek gage for water years 1978 and 1979, respectively.

Table D-6-13 shows chemical analyses on samples that have been collected from surface water monitoring sites in the project area. All

sites listed on this table are plotted on Figures D-6-17 and D-6-18. Total dissolved solids at these sites range from less than 50 to greater than 2,300 mg/l. Some of the lower values represent samples taken during times of snowmelt runoff. Most samples have calcium as the predominant cation with sodium and magnesium as less, but still significant cations. Sodium is not present in quantities large enough to present a hazard for irrigational use. Sulfate and bicarbonate are the dominant anions as they are downstream at the U.S.G.S. Antelope Creek gage.

Total suspended solids (TSS) in creeks draining the Moore Ranch project area are generally low except during some runoff events. During these times, TSS have exceeded 500 mg/l.

Toxic minor elements have not been detected in excessive or potentially dangerous concentrations. Iron has been occasionally observed in levels that would cause inconvenient sink or laundry staining if used as a domestic water supply.

In summary, high sulfate and hardness concentrations would make the surface water draining the project area inconvenient or unpleasant, but not unsuitable for use as a domestic supply. No trace contaminants, including boron, are present in quantities to prevent use as an agricultural water supply.

2.5.1 SURFACE WATER MONITORING PROGRAM

Table D-6-13 presents pre-mine surface water monitoring results while Figures D-6-17 and D-6-18 show the locations of these sites. The mining and post-mining surface water programs will be the same and are defined in Section 3.5.6 of the Mine Plan.

2.6 PERSPECTIVE OF STREAM CHANNELS IN RELATION TO THE FLUVIAL SYSTEM

The fluvial system in Wash 1, 2 and 4 is very small. Figures D-6-30 and D-6-31 give the grain size distribution curves for a sample from the channel bottom in Wash 2 and 3 respectively. These samples indicate the material in these two channels are mainly medium and coarse sand. A sample from Simmons Draw which is slightly coarser material then the samples from Wash 2 and 3 is given in Figure D-6-29. The arroyo channels in this area are mainly grass covered and very stable. The channel of the lower portion of Ninemile Creek has a significant fluvial system.

3.0 WATER RIGHTS

The ground-water and surface water rights for 10 miles from the project area were searched from the State Engineer's files. Ground-water and surface water rights locations are shown in Figure D-6-35 and are listed in Tables D-6-14 and D-6-15, respectively.

3.1 GROUND-WATER RIGHTS

Table D-6-14 provides well locations to the quarter-quarter section, permit number, use, user, probable aquifer, well depth, water level if reported, and additional information for each of the ground-water rights. Wells 12299 and 39648 through 39656, which are located in the permit area, are held by Conoco, Inc. for the purpose of defining the ground-water hydrology for the project. The only permitted well located in the permit area (not held by Conoco) is Well 14682. This well, which is owned by Taylor Ranch, is 158 feet deep and used for stock watering. Wells 14660 and 14681 are approximately 1/2 mile north of the permit area and are

2.6 ADDITIONAL DISCUSSION OF FLUVIAL SYSTEM

Channel characteristic information (Section 2.2, page 19) is shown on Figures 6-20 through 6-23 and Figure 6-28. Figure D-6-36 presents longitudinal profiles. Further discussion is found in Section 2.6 on page 24.

In general, the ephemeral southeastward trending drainages within and near the proposed permit area must be described as showing evidence of downcutting with no pronounced flood plains or depositional characteristics. Each of the draws or washes which passes through the area has its origin on the divide between the Cheyenne and Powder River drainage system which is located at an elevation of about 5480 feet to the north of Highway 387. Note that the area north of the divide (Figure D-6-17) which is a portion of the origin of the Powder River system, is typically more rugged and contrasts significantly with the topography of the Cheyenne drainage.

Further specific information on soils and vegetation in the drainages can be found in Appendices D-7, D-7A (Soils) and D-8, D-8A (Vegetation). Figure D-8-4 shows a photograph of a typical drainage meadow.

Additional channel information is available in an erosion study for the site which is attached for reference. This report is included as Appendix A-3 at the end of this appendix.

stock-watering wells also. Two deeper wells, Permit Numbers 35330 and 35746, which are 500 feet and 660 feet deep respectively, are located approximately 8,000 feet north of the permit area. These wells are primarily used for stock-watering. Numerous wells, 14675, 14677, 14683, 14684 and 14686, are located within 3 miles of the northeast corner of the permit area. Each of these wells is used for stock-watering. Several wells are located within 3 miles of the east side of the permit area, but only Well 6972 is used for purposes other than stock-watering. This well is used for irrigation and wildlife. Well 17305, which is 2,500 feet from the southeast corner of the permit area, is also used to water stock.

The only two permitted domestic wells within 3 miles of the permit area are Wells 12240 and 3909. The depths of these wells are 180 feet and 273 feet, respectively. A shallow stock well is located approximately 1 mile west of the permit boundary.

3.2 SURFACE WATER RIGHTS

The surface water rights for the project are given in Figure D-6-35 and Table D-6-15. Location, permit number, stream, use and user are given in the table for the surface water rights. Surface water rights north, west and east of the permit area do not receive water which drains from the permit area.

The first two surface water rights downstream of the permit area are Numbers 3308 and 14212 which are located on Ninemile Creek. These two sites are approximately 4.6 miles downstream of the permit area.

Permit 3308 covers the reservoir on Ninemile Creek which is used to store and divert water to the lands to be irrigated under Permit Number 14212. Seventy acres of land were permitted to be irrigated along Ninemile Creek from this reservoir. There is currently no evidence of active irrigation operations which were associated with these 1918 water rights.

4.0 HYDROLOGIC IMPACTS

The main impacts to the hydrologic systems from the project will be the drawdown in the aquifers from pumping. A small impact to the surface water systems will be seen from the containing of some runoff and its usage. The ground-water and surface water impacts are discussed in the Mine Plan under section 3.5.

All of the wells in the permit area are used by Conoco except well 14682. Well 14670 (Permit Number) (see Figure D-6-35 for location) is only 22 feet deep. This well could not be completed in the 70 sand because it is a long distance from the 70 sand outcrop. Mining and milling at the project site should not cause an impact on this well.

Well 17305 is located in the outcrop area of the 70 sand and is only 50 feet deep. This well is likely to be a 70 sand well. A maximum drawdown of four feet in the 70 sand aquifer is expected in this area. The Pine Tree Draw is located near this well and could be very effective in recharging this area of the aquifer. If this is the case, less drawdown should be observed. A drawdown of four feet probably would reduce the maximum yield of the 70 sand in this area by approximately 20 per cent.

Well 6973 is likely to be completed in the 70 sand. A maximum drawdown in the range of three feet is expected in the 70 sand aquifer in this area. This well has 110 feet of standing water in it. A drawdown of three feet in the aquifer in this area should not significantly reduce the maximum yield of the aquifer.

Well 14683 is a stock well and probably is a 70 sand well. A maximum drawdown of approximately seven feet is expected in the aquifer in this area. This quantity of draw-down should result in approximately ten per cent reduction in maximum yield in this well. Well 14683 (P'-8) is proposed as an operational monitoring well.

Well 14682 which is inside the permit boundary, and well 14681 are much shallower than the projected depth to the top of the 70 sand in these areas. These wells are not expected to be impacted by the project. Well 14682 (P'-26) is proposed as an operational monitoring well.

Well 14660 (see Figure D-6-35 for location) is approximately one-half mile north of the permit boundary. This well is probably completed above the 70 sand aquifer. A maximum drawdown in the range of ten feet is expected in the 70 sand aquifer in this area.

Wells which are further from the mine pits will be impacted less. An estimate of the drawdown in the 70 sand aquifer can be obtained from Figures MP-10, MP-11 and MP-12. The reduction in maximum yield for wells other than the ones discussed should be insignificant.

Pine Tree Spring is the only spring close to the project. The ground-water source for this spring is thought to be above the 70 sand

aquifer. Impacts to Pine Tree Spring are therefore not expected. A flume with a continuous recorder will be installed at Pine Tree Spring to determine if any decreases of flow are attributed to the mine dewatering. Pine Tree Spring will also be included in the operational monitoring program.

A discussion of the per cent of watershed blocked by the Sand Rock project is given in Section 3.5.1 of the Mine Plan. Permits 3308 and 14212 are the only surface rights which these reductions could influence. Surface water is not presently being used under these two permits.

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TABLE D-6-1

BASIC COMPLETION AND WATER LEVEL DATA FOR
THE EVAPORATION POND AREA (AREA 10)

Hole No.	Date Drilled	Depth Drilled (ft-LSD)	Perforated Interval (ft-LSD)	Lithologic Unit	Water Level Date	Water Level Depth (ft-MP)	Water Level Elev. (ft-MSL)	Elevation of M.P. (ft-MSL)	M.P. Above LSD (ft)
P-1	9/79	51	38-48	LMS - E Coal	4/3/80	dry	5,236.6	5,287.9	1.6
P-2	3/9/80	50.5	35-50	LMS - E Coal*	4/2/80	43.79	5,250.5	5,294.3	1.8
P-3	3/11/80		39-49	LMS	3/27/80	50.5	5,233.4	5,283.9	2.4
P-4				LMS - E Coal*	3/24/80	23.18	5,266.7	5,289.9	1.1
P-4B	3/3/80	33.2	28-33	UMS - E Coal	3/27/80	21.80			1.8
P-4B-1	3/3/80	33	28-33	UMS - E Coal	3/27/80	20.26			3.1
P-4C	3/3/80	25	12-25	UMS - U Coal	3/27/80	19.22			2.6
P-4CA	3/25/80	30	25-30	UMS	3/27/80	22.65			3.7
P-5	3/9/80	47	43-45.5	E Coal	3/24/80	28.37	5,271.9	5,300.3	2.3
P-6	3/4/80	40	28.5-38.5	USS	3/24/80	35.75	5,278.4	5,314.1	1.7
P-7	3/4/80	160	130-160	70SS	3/4/80	133	5,175.6	5,308.6	0.5
P-7A	3/4/80	160	75-90	U70SS	4/10/80	88.49	5,220.4	5,308.9	0.8
P-8	3/9/80	59.5	32-58	LMS - E Coal	4/2/80	26.09	5,296.9	5,269.0	2.1
P-9	3/10/80	35	25-35	LMS - E Coal*	4/2/80	14.60	5,266.1	5,280.7	2.1
P-9A	3/25/80	18	12-18	UMS	4/9/80	16.04	5,264.3	5,280.3	1.7
P-10	3/10/80	59.5	33-59.5	LMS - E Coal*	3/24/80	28.30	5,268.0	5,296.3	0.5
P-11	3/7/80	20	16.5-19	E Coal	3/27/80	18.60	5,254.0	5,272.6	0.3
P-12	3/9/80	32.5	29-32	E Coal	4/9/80	30.90	5,276.5	5,307.4	1.0
P-13	3/13/80	19.5	9-19	UMS	4/11/80	17.60	5,263.6	5,281.2	0.4
P-13A	3/25/80	28	22-28	E Coal	3/27/80	19.96	5,263.9		3.1
P-15	3/11/80	35	27-35	LMS - E Coal*	3/27/80	23.03	5,263.5	5,286.5	2.0
P-15A	3/25/80	21	17-21	UMS	3/27/80	22.9	5,263.5		1.9
P-16	3/11/80	73	58-73	U 70 SS	3/24/80	75.5	5,218.9	5,294.4	2.4
P-17	3/13/80	89.5	79.5-89.5	U 70 SS	3/24/80	92.7	5,211.9	5,304.6	2.6
P-18		25	14-18	All	3/27/80	22.25	5,250.8	5,273	0.3
P-19	3/14/80	59	30-57	LMS	4/10/80	31.34	5,254.2	5,285.5	3.5
P-20	2/28/80	119.3	107-119	S 70 SS	3/27/80	97.54	5,184.5	5,282.0	0.7
P-20A		107.2	99-107	S 70 SS	3/26/80	98.18			1.1
P-20B		117.5	107-117	S 70 SS	3/26/80	98.79			1.6
P-21	3/18/80	120.4	88-118	S 70 SS	3/24/80	75.32	5,177.5	5,252.8	2.8

NOTE:

M.P. = Measuring Point
LSD = Land Surface Datum
LMS = Lower Mudstone
UMS = Upper Mudstone
E Coal = E Coal
U Coal = Upper Coal
USS = Upper Sandstone
U 70 SS = Upper (Unsaturated) 70 Sand
70 SS = 70 Sandstone
S 70 SS = Saturated 70 Sandstone

* Completion of well questionable.

TABLE D-6-2

BASIC COMPLETION AND WATER LEVEL DATA
FOR THE 35N PIT TAILINGS DISPOSAL AREA

Hole No.	Date Drilled	Depth Drilled (Ft-LSD)	Perforated Interval (Ft-LSD)	Lithologic Unit	Water Level Date	Water Level Depth (Ft-MP)	Water Level Elev. (Ft-MSL)	Elevation of M.P. (Ft-MSL)	M.P. Above LSD (Ft)
35N-1C		178.7	154-179	U70SS	5/15/80	dry	-	5354.8	1.2
35N-1D		43.2	36-44	SS	5/16/80	39.54	5314.9	5354.4	0.8
35N-1E		29.0	21-29	MS	5/15/80	28.86	5326.1	5355.0	1.4
35N-2A		159.5	145-160	U70SS	5/21/80	147.25	5191.0	5338.3	0.8
35N-2B		131.0	126-131	SS	5/19/80	124.28	5214.1	5338.4	0.9
35N-2C		73.3	64-74	MS	5/19/80	69.52	5269.4	5338.9	1.4
35N-3		29.5	20-30	SS	4/09/80	dry	-	5401.9	3.2
35N-4		131.6	112-132	SS-MS	4/09/80	dry	-	5389.3	1.0
35N-5		79.0	69-79	SS	5/19/80	78.4*	5219?	5294.7	1.3
35N-6		90.3	80-90	SS	5/15/80	86.87	5236.5	5323.4	1.2
35N-7A		182.9	143-183	70SS	5/18/80	132.30	5172.9	5305.2	1.1
35N-7B		115.4	101-116	U70SS	5/15/80	dry	-	5305.6	1.5
35N-7C		83.4	74-84	SS	5/15/80	82.09	5229.3	5311.4	4.3
35N-7D		99.0	92-99	E Coal	5/18/80	97.39	5207.9	5305.3	1.2
35N-7E		27.4	22-28	SS	5/15/80	18.90	5289.7	5308.6	1.5
35N-7F		17.7	12-18	MS	5/15/80	14.97	5294.5	5309.5	2.4
35N-7G		59.2	51-59	U Coal	5/18/80	33.14	5272.2	5305.3	1.2

NOTE:

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E Coal = E Coal
U Coal = Upper Coal
USS = Upper Sandstone
U 70 SS = Upper (Unsaturated) 70 Sand
70 SS = 70 Sandstone
S 70 SS = Saturated 70 Sandstone

* Completion of well questionable.

TABLE D-6-3

BASIC WELL COMPLETION DATA
FOR WELLS IN THE MINE AREA

Well No.	Aquifer	Collar Elevation (Ft.Abv.msl)	Depths (Ft.) Total	Casing	Perforated Interval	Gravel Pack	Diameters (In.) Drill Bit	Casing (I.D.)	Type Casing	State Permit	Date Drilled
1810	70SS	5378	265	265	200-260	X	8-3/4	3"	PVC	39650	07/29/77
1808	70-68SS	5377	275	275	195-275	X	9-7/8	5"	PVC	39651	07/28/77
1809	70SS	5356	230	230	135-225	X	8-3/4	3"	PVC	39652	07/28/77
889	70SS	5334	260	260	200-260	X	8-3/4	3"	PVC	39653	07/29/77
890	70-68SS	5410	330	330	240-330	X	8-3/4	3"	PVC	39654	07/29/77
22-2	70SS	5287	165	165	85-165	X	8-3/4	3"	PVC	39655	08/01/77
8-3	70-68SS	5308	175	175	105-175	X	9-7/8	5"	PVC	39656	08/01/77
885	70SS	5350	240	240	180-240	X	9-7/8	5"	PVC	39648	07/22/77
886	70SS	5349	240	240	180-240	X	8-3/4	3"	PVC	——	07/21/77
887	68SS	5347	320	320	290-320	X	8-3/4	3"	PVC	——	07/20/77
888	70SS	5352	250	250	180-240	X	8-3/4	3"	PVC	——	07/21/77
1	70SS	5331	240	240	200-240		6-1/4	5"	PVC	39649	09/17/77
1805	70SS	5331	240	240	120-240	X	8-3/4	3"	PVC	——	07/22/77
1806	70SS	5324	220	220	120-200	X	8-3/4	3"	PVC	——	07/21/77
1807	68SS	5328	290	290	250-290	X	8-3/4	3"	PVC	——	07/22/77
1814	70SS	5345	207	207	143-207		9-7/8	5"	Steel	——	11/02/78
1815	70SS	5348	208	208	142-208	X	5-1/8	3"	PVC	——	11/08/78
1816	70SS	5343	207	207	138-207	X	5-1/8	3"	PVC	——	11/08/78
1817	70SS	5350	233	233	143-233	X	5-1/8	3"	PVC	——	11/08/78
893	70SS	5348	240	240	153-240	X	9-0	5"	Steel	——	11/21/78
1821	Roland Coal	5355	1200	1200	1120-1200		8-3/4	6"	Steel	——	10/22/79
1822	50-40SS	5355	740	740	560-600						
					640-680						
					700-720		8-3/4	6"	Steel	——	10/26/79
1823	68SS	5345	240	240	210-240		8-3/4	6"	Steel	——	~~04/ /80~~ 3/30/80

NOTE:

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E Coal = E Coal
U Coal = Upper Coal
USS = Upper Sandstone
U 70 SS = Upper (Unsaturated) 70 Sand
70 SS = 70 Sandstone
S 70 SS = Saturated 70 Sandstone

• Completion of well questionable.

TABLE D-6-4

SUMMARY OF SUBSOIL HYDRAULIC CONDUCTIVITIES
AND AQUIFER PROPERTIES
(CONSTANT-HEAD AND PUMP TEST)

Well No.	Lithogic Unit	Transmissivity Gal/Day/Ft	Transmissivity M^2/Yr	Hydraulic Conductivity Ft/Yr	Hydraulic Conductivity Cm/Sec	Storage Coefficient	Specific Yield
P-1	LMS - E Coal	3.1	14.	15.	1.5×10^{-5}		
P-2	LMS - E Coal	0.10	0.46	0.70	6.8×10^{-7}		
P-3	LMS	1.6	7.2	7.7	7.5×10^{-6}		
P-4	LMS- E Coal	0.14	0.65	0.70	6.8×10^{-7}		
P-4B	UMS - E Coal	1.6	7.3	15.8	1.5×10^{-5}		
P-4CA	UMS	0.47	2.1	4.6	4.4×10^{-6}		
P-5	E Coal	0.32	1.4	6.2	6.0×10^{-6}		
P-6	USS	1.5	6.6	7.1	6.8×10^{-6}		
P-7	70SS	58.	262.	94.	9.5×10^{-5}		
P-8	LMS - E Coal	1.4	6.6	2.7	2.6×10^{-6}		
P-9	LMS - E Coal	0.079	0.36	0.38	3.7×10^{-7}		
P-9A	UMS	0.31	1.4	2.5	2.4×10^{-6}		
P-10	LMS - E Coal	0.67	3.0	1.2	1.2×10^{-6}		
P-11	E Coal	2.7	12.	53.	5.1×10^{-6}		
P-12	E Coal	0.41	1.9	6.7	6.5×10^{-6}		
P-13	UMS	3.6	17.	180.	1.7×10^{-4}		
P-13A	E Coal	1.8	8.3	14.8	1.4×10^{-5}		
P-15	LMS - E Coal	0.12	0.52	0.71	6.8×10^{-7}		
P15A	UMS	4.5	20.	55.	5.3×10^{-5}		
P-16	U70SS	0.32	1.4	1.0	9.9×10^{-7}		
P-17	U70SS	0.13	0.61	0.65	6.3×10^{-7}		
P-18	ALL	25.	110.	470.	4.6×10^{-4}		
P-20B	70SS	1.7	7.7	8.5	8.2×10^{-6}		
P-21	70SS	2.3	10.3	3.7	3.6×10^{-6}		
35N1-C	U70SS	0.40	1.8	0.78	7.5×10^{-7}		
35N1-D	SS	1.20	5.2	7.0	6.8×10^{-6}		
35N1-E	MS	0.14	0.65	0.9	8.5×10^{-7}		
35N-2A	U70SS	2.6	11.9	8.5	8.2×10^{-6}		
35N-2B	SS	0.82	3.6	7.8	7.6×10^{-6}		
35N-2C	MS	0.9	4.0	4.3	4.2×10^{-6}		
35N-3	SS	7.1	32.2	34.7	3.4×10^{-5}		

TABLE D-6-4

(CONT.)

Well No.	Lithogic Unit	Transmissivity Gal/Day/Ft	Transmissivity M^2/Yr	Hydraulic Conductivity Ft/Yr	Hydraulic Conductivity Cm/Sec	Storage Coefficient	Specific Yield
35N-4	MS-SS	1.1	5.0	2.7	2.6×10^{-6}		
35N-5	SS	0.0025	0.011	0.0012	1.2×10^{-9}		
35N-6	SS	2.1	9.4	10.2	9.8×10^{-6}		
35N-7A	70SS	1170.	5320.	1430.	1.4×10^{-3}		
35N-7B	U70SS	1.7	7.7	5.5	5.4×10^{-6}		
35N-7C	SS	1.7	7.7	8.3	8.0×10^{-6}		
35N-7D	E Coal	5.8	26.4	40.6	3.9×10^{-5}		
35N-7E	SS	5.2	23.5	42.1	4.1×10^{-5}		
35N-7F	MS	0.37	1.7	3.0	2.9×10^{-6}		
35N-7G	U Coal	0.02	0.07	0.09	9.0×10^{-8}		
886	70SS	800.	3600.	650.	6.2×10^{-4}	1.0×10^{-3}	0.015
		1800.	8000.	1430.	1.4×10^{-3}		
888	70SS	170.	770.	140.	1.3×10^{-4}	2.9×10^{-3}	
887	68SS	1.9	8.5	3.1	3.0×10^{-6}		
1805	70SS	910.	4100.	560.	5.4×10^{-4}	5.2×10^{-4}	
1806	70SS	840.	3800.	510.	4.9×10^{-4}	2.8×10^{-4}	
1816	70SS	3800.	17000.	4600.	4.4×10^{-3}	7.0×10^{-4}	0.010
1821	Roland Coal	1400.	6350.	854.	8.3×10^{-4}		
1822	50-40SS	720.	3260.	351.	3.4×10^{-4}		
1823	68SS	190.	860.	306.	3.0×10^{-4}		

NOTE:

M.P. = Measuring Point
LSD = Land Surface Datum
LMS = Lower Mudstone
UMS = Upper Mudstone
E Coal = E Coal
U Coal = Upper Coal
USS = Upper Sandstone
U 70 SS = Upper (Unsaturated) 70 Sand
70 SS = 70 Sandstone
S 70 SS = Saturated 70 Sandstone

* Completion of well questionable.

TABLE D-6-5

SUMMARY OF SUBSOIL PERMEABILITIES FROM PACKER TESTS
EVAPORATION POND AREA

Hole Number	Test Interval (ft-LS)	Lithologic Unit*	Hydraulic Conductivity (Permeability) ft/yr	cm/sec
PD-3	30-40	LMS	<1.0	$<9.7 \times 10^{-7}$
PD-5	11.5-16.5	UMS	<1.4	$<1.4 \times 10^{-6}$
	17-22	UMS	63	6.1×10^{-5}
	31-36	LMS	<0.8	$<7.7 \times 10^{-7}$
PD-6	18-23	UMS	<1.5	$<1.4 \times 10^{-6}$
	25-30	E Coal	2.3	2.2×10^{-6}
	29.5-34.5	LMS	1.6	1.5×10^{-6}
PD-7	10-15	USS	330	3.2×10^{-4}
	16-21	UMS	320	3.1×10^{-4}
	25-30	E Coal	1.5	1.4×10^{-6}
PD-8	7-12	USS	5,070	4.9×10^{-3}
	24-29	UMS	<1.0	$<9.7 \times 10^{-7}$
PD-9	18-23	USS	1.5	1.4×10^{-6}
	28-33	UMS	<0.9	$<8.7 \times 10^{-7}$
	32-37	E Coal	<0.7	$<6.8 \times 10^{-7}$
PD-10	12-17	UMS	1.4	1.4×10^{-6}
	17-22	UMS	1.1	1.1×10^{-6}
	24-29	UMS	<1.0	$<9.7 \times 10^{-7}$
	29-34	UMS	<0.8	$<7.7 \times 10^{-7}$

TABLE D-6-5

(CONT.)

Hole Number	Test Interval (ft-LS)	Lithologic Unit*	Hydraulic Conductivity (Permeability) ft/yr	cm/sec
PD-11	7-12	USS	250	2.4×10^{-4}
	12-17	USS	1.4	1.4×10^{-6}
	17-22	UMS	<1.3	$<1.3 \times 10^{-6}$
PD-11	24-29	U Coal	<0.9	$<8.7 \times 10^{-7}$
	29-34	UMS	<0.8	$<7.7 \times 10^{-7}$
PD-12	17-22	LMS	1.3	1.3×10^{-6}
	26-31	LMS	<1.1	$<1.1 \times 10^{-6}$
	34-39	U70SS	490	4.7×10^{-4}
PD-14	6-11	USS	360	3.5×10^{-4}
	27-32	LMS	1.2	1.2×10^{-6}
PD-15	7-12	USS	<2.1	$<2.0 \times 10^{-6}$
	14.5-19.5	USS	<1.4	$<1.4 \times 10^{-6}$
	27-32	LMS	<1.1	$<1.1 \times 10^{-6}$
PD-16	8-13	UMS	<2.3	$<2.2 \times 10^{-6}$
	17-22	USS	430	4.2×10^{-4}
	20-25	USS-U Coal	410	4.0×10^{-4}
	30-35	UMS	<0.8	$<7.7 \times 10^{-7}$

TABLE D-6-5

(CONT.)

Hole Number	Test Interval (ft-LS)	Lithologic Unit*	Hydraulic Conductivity (Permeability) ft/yr	cm/sec
PD-17	6-11	USS	6.4	6.2×10^{-6}
	8-13	USS	620	6.0×10^{-4}
	17-22	USS	240	2.3×10^{-4}
	20-25	USS-U Coal	630	6.1×10^{-4}
	25-30	UMS	<0.9	$<8.7 \times 10^{-7}$
	35-40	E Coal	0.7	6.8×10^{-7}
PD-18	11-16	USS	34	3.3×10^{-5}
	19-24	USS	1.2	1.2×10^{-6}
PD-19	12-17	USS	1,060	1.0×10^{-3}
	18-23	U Coal	800	7.7×10^{-4}
PD-20	5-10	USS	12	1.2×10^{-5}
	15-20	USS	140	1.4×10^{-4}
	22-27	UMS	1.0	9.7×10^{-7}
PD-21	8-13	USS	2,800	2.7×10^{-3}
	22-27	USS	17	1.6×10^{-5}
PD-22	14-19	USS	1.4	1.4×10^{-4}
PD-24	6-11	USS	210	2.0×10^{-4}
	17-22	UMS	59	5.7×10^{-5}
	22-27	USS	72	7.0×10^{-5}

TABLE D-6-5

(CONT.)

Hole Number	Test Interval (ft-LS)	Lithologic Unit*	Hydraulic Conductivity (Permeability) ft/yr	cm/sec
PD-26	11-16	USS	5.1	4.9×10^{-6}
	20-25	USS	13	1.3×10^{-5}
	27-32	USS	730	7.1×10^{-4}

NOTE:

M.P.	=	Measuring Point	U Coal	=	Upper Coal
LSD	=	Land Surface Datum	USS	=	Upper Sandstone
LMS	=	Lower Mudstone	U 70 SS	=	Upper (Unsaturated) 70 Sand
UMS	=	Upper Mudstone	70 SS	=	70 Sandstone
E Coal	=	E Coal	S 70 SS	=	Saturated 70 Sandstone

TABLE D-6-6

WATER LEVEL DATA FOR THE 70 SAND WELLS

Date	Well 22-2 Depth	22-2 Elev.	885 Depth	885 Elev.	889* Depth	889* Elev.	1 Depth	1 Elev.	1809 Depth	1809 Elev.	1810 Depth	1810 Elev.
8/17/77			181.3	5,168.7			159.8	5,171.2				
8/24/77							159.2	5,171.8				
9/15/77	97.9	5,189.1	180.3	5,169.7	163.3	5,170.7			187.6	5,168.4	207.2	5,170.8
10/26/77	98.1	5,188.9	180.3	5,169.7	164.1	5,169.9	158.2	5,172.8	187.5	5,168.5	207.5	5,170.5
1/24/78			180.2	5,169.8			157	5,174				
2/13/78			180.3	5,169.7			157	5,174				
3/21/78			179.8	5,170.2			156.7	5,174.3				
9/13/78	97.67	5,189.3			17.5	5,316.5			187.83	5,168.2	205.17	5,172.8
2/15/79	98.50	5,188.5	179.58	5,170.4	30.83	5,303.2					205.83	5,172.2
3/1/79	98.33	5,188.7	179.08	5,170.9	38.33	5,295.7	157.67	5,173.3	188.17	5,167.8	205.58	5,172.4
5/30/79	98.17	5,188.8	178.33	5,171.7	42.83	5,291.2	158.17	5,172.8	187.76	5,168.2	205.50	5,172.5
7/19/79	97.87	5,189.2	178.75	5,171.3	49.50	5,284.5	156.17	5,174.8	187.33	5,168.7	205.08	5,172.9
9/4/79	97.58	5,189.4	178.33	5,171.7	50.17	5,283.8	156.42	5,174.6	187.31	5,168.7	205.50	5,172.5
9/29/79							156.00	5,175.0				
11/30/79	97.67	5,189.3	179.67	5,170.3	53.62	5,280.4	156.00	5,175.0	187.71	5,168.3	205.17	5,172.8
12/21/79							156.00	5,175.0				

Date	Well 22-2 Depth	22-2 Elev.	885 Depth	885 Elev.	889 Depth	889 Elev.	1 Depth	1 Elev.	1809 Depth	1809 Elev.	1810 Depth	1810 Elev.
1/2/80	97.58	5,189.4	178.5	5,171.2	62.00	5,272.0	156.08	5,174.9	187.67	5,168.3	205.08	5,172.9
4/15/80					56.17	5,277.8	—	—	187.33	5,168.7	204.83	5,173.2
4/16/80							155.67	5,175.3				

Date	Well 893 Depth	893 Elev.	1814 Depth	1814 Elev.	1815 Depth	1815 Elev.	1816 Depth	1816 Elev.	1817 Depth	1817 Elev.
11/16/78			161.3	5,183.7	162.6	5,185.4	158.3	5,184.7	166.5	5,183.5
12/1/78			161.1	5,183.9	162.4	5,185.6	158.2	5,184.8	166.5	5,183.5
6/19/79	179.0	5,169.0	159.92	5,185.1						
9/26/79	179.0	5,169.0	159.0	5,186.0						
9/27/79	178.5	5,169.5								
12/2/79	178.0	5,170.0	159.67	5,185.3						
4/1/80			159.67	5,185.3						
4/9/80	178.08	5,169.9								

Note: Depth, in ft below LS
Elev., in ft above MSL

* Fluctuations in water level hint at improper completion of well.

TABLE D-6-7

GROUNDWATER QUALITY FOR PRIVATE WELLS NEAR CONOCO'S SAND ROCK PROJECT

Well No.	Well Location	Date	TDS	Conductivity		Temperature	Na	K	Ca	Mg	SO_4	Cl	CO_3	HCO_3	pH	
	41N-74W															
A-1	04 NESE	6/26/79[a]	492	820	(705)	(17)	39	9	101	15	187	6	0	234	7.53	(7.15)
17304		12/7/79[b]	606	870	(839)	(7)	46	9	107	17	215	8	0	278	7.73	(7.70)
A-2	04 SENE	6/26/79[c]	655	1,100	(676)	(17)	13	9	156	10	179	25	0	312	7.91	(7.00)
17302		8/14/79	—	—	(647)	(15)	—	—	—	—	—	—	—	—	—	(7.45)
		12/7/79	670	1,130	(1,069)	(9)	9	9	169	27	160	41	0	307	7.61	(7.70)
P'-6	17 SWSE	6/28/79	831	1,270	(1,083)	(16)	107	10	128	19	460	12	0	151	7.66	(7.30)
9309																
P'-7	17 SWSE	6/28/79	509	940	(795)	(14)	48	8	100	20	212	16	0	239	7.58	(7.05)
12240																
	41N-75W															
P'-9	03 NESW	6/20/79	1,024	1,389	(1,163)	(13)	45	13	201	48	550	7	0	312	7.32	(6.85)
—		9/27/79	1,012	1,365	(1,258)	(12)	42	11	186	46	450	6	0	315	7.57	(6.95)
		3/26/80	964	1,300	(1,249)	(11)	42	13	197	47	516	6	0	327	7.61	(7.30)
P'-11	04 NENW	8/16/79	1,048	1,500	(1,308)	(12.5)	65	12	165	53	548	8	0	283	7.74	(7.45)
—																
	42N-74W															
P'-8	30 NWNW	6/28/79	2,339	2,770	(2,466)	(16)	16	11	512	116	1,270	4	0	366	6.95	(6.60)
14683																
I-30	31 SWNE	6/29/79	1,030	1,450	(1,176)	(30)	31	9	211	54	467	25	0	376	7.83	(8.85)
—		3/25/80	844	1,260	(1,131)	(1)	29	9	162	50	472	21	0	278	7.61	(8.6)
(Pine Tree Spring)																
	42N-75W															
P'-10	33 SWSE	6/20/79	1,566	1,923	(1,608)	(18)	37	5	375	58	910	12	0	359	7.71	(7.45)
—																
T-1	33 SENW	6/26/79	661	1,100	(924)	(15)	87	9	106	17	270	10	0	254	7.49	(7.35)
12299		9/18/79	690	1,060	(896)	(14)	85	9	106	20	284	7	0	249	7.69	(6.90)
		9/25/79	—	—	(920)	(19)	—	—	—	—	—	—	—	—	—	(7.05)
P'-36	36 SENW	10/10/79	604	921	(801)	(15)	15	6	109	43	154	8	0	390	7.72	(7.30)
—		12/10/79	693	1,070	(1,042)	(9.5)	13	5	143	51	251	7	0	398	7.80	(7.70)

Notes: Number below well number is the State Engineer's G.W. Permit Number.

All concentrations are in mg/l except Conductivity, in μmhos/cm @ 25°C; Temperature, in °C; pH in pH units, U; Pb-210, Po-210, Ra-226 and Th-230 in pCi/l; and Charge Balance = difference in major equivalents divided by sum of major equivalents times 100.

( ) Denotes field measurements.

* Denotes less than the value.

(a) Additional parameter for the sample is silver = *0.01.

(b) Additional parameters for this sample are silver = *.01 and alkalinity (as $CaCO_3$) = 228.

(c) Additional parameter for this sample is silver = *0.01.

TABLE D-6-7

(CONT.)

Well No.	Al	NH_3 (as N)	As	Ba	Be	B	Cd	Cr	Cu	F	Fe	Pb	Mn	Hg
A-1	* .05	* .05	* .002	* .02	* .005	* 1.0	* .002	* .01	* .002	0.13	0.011	* .05	0.007	* .001
17304	* .05	* .05	* .002	* .02	* .005	* 1.0	* .002	* .01	0.007	0.19	* .05	* .05	0.02	* .001
A-2	* .05	* .05	* .002	* .02	* .005	* 1.0	* .002	* .01	* .002	0.16	0.024	* .05	* .003	* .001
17302	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	* .05	0.10	* .002	* .02	* .005	* 1.0	.056	* .01	.022	.22	.17	.17	.02	* .001
P'-6	* .05	* .05	* .002	* .02	* .005	* 1.0	* .002	* .01	* .002	.08	.592	* .05	.072	* .001
9309														
P'-7	* .05	* .05	* .002	* .02	* .005	* 1.0	* .002	* .01	* .002	.14	.424	* .05	.078	* .001
12240														
P'-9	* .05	* .05	* .002	* .02	* .005	* 1.0	* .002	* .01	* .002	.13	.069	* .05	.088	* .001
—	* .05	—	* .002	* .02	* .005	* 1.0	* .002	* .01	* .002	* .05	* .05	* .05	.07	* .001
	* .05	0.10	* .002	* .02	* .005	* 1.0	* .005	* .01	0.010	0.12	0.10	0.07	0.08	* .001
P'-11	* .05	0.06	* .002	* .02	* .005	* 1.0	.008	* .01	.009	.14	.02	* .05	.02	* .001
—														
P'-8	* .05	0.09	* .002	* .02	* .005	* 1.0	* .002	* .01	* .002	.31	5.842	* .05	.856	* .001
14683														
I-30	* .05	0.07	* .002	* .02	* .005	* 1.0	* .002	* .01	* .002	0.90	0.038	* .05	0.279	* .001
—	* .05	0.57	* .002	* .02	* .005	* 1.0	* .005	* .01	0.009	0.80	0.10	0.09	0.24	* .001
(Pine Tree Spring)														
P'-10	* .05	* .05	* .002	* .02	* .005	* 1.0	.013	* .01	* .002	.36	.139	* .05	.03	* .001
—														
T-1	* .05	* .05	* .002	* .02	* .005	* 1.0	* .002	* .01	* .002	.17	.012	* .05	.016	* .001
12299	* .05	* .05	* .002	* .02	* .005	* 1.0	* .002	* .01	.005	.23	.12	* .05	.06	* .001
	—	—	—	—	—	—	—	—	—	—	—	—	—	—
P'-36	* .05	2.81	* .002	* .02	* .005	* 1.0	* .002	* .01	.002	.27	5.6	* .05	.08	* .001
—	—	0.14	—	—	—	—	—	—	—	—	—	—	—	—

TABLE D-6-7

(CONT.)

Well No.	Mo	Ni	NO_3	Se	V	Zn	U	Pb-210	Po-210	Ra-226	Th-230	Charge Balance
A-1	• .02	• .01	1.70	• .002	• .02	1.80	37 ± 2	0 ± .3	0.03 ± 0.1	0.15 ± .05	0 ± .1	1.9
17304	• .05	• .01	1.86	• .002	• .02	1.83						1.6
A-2	• .02	• .01	24.0	• .002	• .02	0.054	20 ± 1	0.3 ± .1	0 ± .04	0.15 ± .04	0.4 ± .1	0.8
17302	—	—	—	—	—	—	—	—	—	—	—	—
	• .05	• .01	36.0	• .002	• .05	.135						8.4
P'-6	• .02	• .01	.30	• .002	• .02	.054	0 ± 2	0 ± 1	0 ± .02	0.35 ± .05	0.2 ± .1	1.9
9309												
P'-7	• .02	• .01	.22	• .002	• .02	.041	6 ± 1	0 ± .05	0 ± .06	0.74 ± .07	0.3 ± .1	0.8
12240												
P'-9	• .02	• .01	1.16	.007	• .02	.024	32 ± 2	1.6 ± .2	0.4 ± .05	2.0 ± .1	0.2 ± .1	1.5
—	• .02	• .01	—	• .002	• .02	.006						1.6
	• .05	• .01	0.44	• .002	• .05	0.007						1.3
P'-11	• .02	• .01	.88	• .002	• .02	.050						1.7
—												
P'-8	• .02	• .01	.34	• .002	• .02	0.945	7 ± 1	0 ± .5	0.08 ± .02	0.75 ± .07	0 ± .1	5.1
14683												
I-30	• .02	• .01	1.61	• .002	• .02	0.007	2 ± 1	0 ± .9	0.2 ± .04	0.35 ± .05	137 ± 7	0.1
—	• .05	• .01	2.25	• .002	• .05	0.006						4.5
(Pine Tree Spring)												
P'-10	• .02	• .01	.39	• .002	• .02	.078	17 ± 1	1.9 ± .7	0.10 ± .02	0 ± .08	0 ± .1	0.1
—												
T-1	• .02	• .01	1.43	• .002	• .02	.113	44 ± 2	0 ± .4	0.02 ± .01	0.41 ± .06	0.3 ± .1	3.0
12299	• .02	• .01	3.05	• .002	• .02	.070						3.2
	—	—	—	—	—	—	—	—	—	—	—	—
P'-36	• .02	• .01	1.07	• .002	• .02	.720						0.2
—	—	—	.39	—	—	—						0.3

TABLE D-6-8

GROUNDWATER QUALITY FOR CONOCO'S SAND ROCK MONITORING WELLS

Well No.	Well Location	Date	TDS	Conductivity		Temperature	Na	K	Ca	Mg	SO_4	Cl	CO_3	HCO_3	pH	
	41N-75W															
22-2	02 NWNE	1/3/80	508	725			13	8	96	23	106	5	0	305	6.95	
8-3 (W-4A)	03 NENW	6/28/79	1,460	1,950	(1,610)	(8)	8	12	354	58	980	6	0	361	7.10	(6.85)
		9/27/79	1,426	1,910	(1,660)	(12)	9	12	278	96	750	6	0	371	7.30	(6.50)
		12/6/79	1,566	1,800	(1,680)	(10)	8	13	245	120	936	6	0	361	7.23	(7.75)
		4/9/80	1,398	2,000	(1,750)	(10)	10	14	251	115	860	12	0	256	6.75	(7.1)
	42N-75W															
893 (W-1)	34 NESW	11/30/78	975	1,100		(11.1)	42	10	180	36	470	2	0	235	7.1	
		6/27/79	820	1,250	(1,080)	(15)	47	12	158	35	427	6	0	264	7.54	(7.25)
		9/27/79	870	1,250	(1,150)	(13)	43	11	158	37	408	6	0	278	7.27	(6.95)
		10/10/79	914	1,240	(985)	(15)	45	12	160	34	418	6	0	266	7.45	(7.70)
		12/21/79	874	1,150	(1,120)	(11)	44	12	155	40	410	5	0	266	7.23	(7.65)
		4/9/80	842	1,350	(1,150)	(11)	47	12	159	40	460	10	0	281	7.31	(7.5)
885	34 NESW	4/12/78[a]	836	1,113		—	31.5	8.1	208	33.5	426	3.3	0	281	7.53	
886	34 NESW	4/12/78[b]	827	1,299		—	46	9.5	228	43	75	4.9	0	851	7.44	
887	34 NESW	4/12/78[c]	1,170	1,490		—	54	9.1	265	56	459	11	0	375	7.66	
888	34 NESW	4/12/78[d]	855	1,155		—	54	8.1	180	30	424	6.4	0	311	7.97	
889	34 NWSW	1/3/80	462	640		—	12	8	79	23	198	5	0	134	6.60	
		4/15/80	395	630	(570)	(11)	8	8	78	21	192	6	0	146	7.24	(7.0)
	42N-75W															
1 (W-2)	35 NWSE	4/12/78[a]	286	504		—	8.4	7.0	80	14.0	72.5	•2	0	228	7.87	
		11/30/78[b]	364	510		(11.4)	14	7.7	81	15	73	1	0	172	6.7	
		6/27/79	218	440	(363)	(15)	13	8	47	14	85	6	0	195	7.90	(7.75)
		9/29/79	254	464	(442)	(14)	15	8	54	14	64	3	0	217	7.68	(7.20)
		12/21/79	352	515	(473)	(10)	14	8	67	16	71	4	0	242	7.15	(7.40)
		4/16/80	182	295		—	7	7	35	9	46	4	0	127	7.45	(7.6)
1805	35 NWSE	4/12/78[h]	765	996		—	60	7.7	143	29	433	6.4	0	178	8.06	
1806	35 SWNE	4/12/78[i]	886	1,290		—	41	9.1	234	46	28	4.9	0	975	7.25	
1807	35 SWNE	4/12/78[j]	680	1,100		—	35	8.4	187	35	98	•2.0	0	663	7.44	
1808 (W-4B)	35 NWNE	6/28/79	573	950	(800)	(15)	69	9	93	19	303	10	0	161	7.45	(7.20)
		9/27/79	570	930	(789)	(14)	69	9	86	17	300	8	0	171	7.48	(6.45)
		12/15/79	608	900	(813)	(9)	63	8	84	17	280	6	0	159	7.34	(7.65)
		4/2/80	684	1,010	(988)	(10)	77	10	115	24	405	8	0	173	8.04	(8.2)
1809	35 NESE	4/15/80	877	1,220	(1,160)	(14)	59	12	104	34	432	8	0	317	7.61	(7.5)
1810	35 NWSW	4/15/80	824	1,350	(943)	(13)	47	12	159	40	460	10	0	281	7.31	(7.6)
1814 (W-3)	35 SWSW	11/30/78[c]	1,006	1,130		(13.5)	22	8.3	190	38	497	3	0	248	6.5	
		6/27/79	987	1,440	(1,230)	(13)	42	12	201	45	461	8	0	307	7.29	(7.05)
		9/26/79	1,068	1,480	(1,290)	(13)	45	14	201	46	490	10	0	305	7.19	(6.80)
		12/2/79	1,104	1,380	(1,390)	(10)	41	12	197	51	508	5	0	285	7.09	(7.85)
		4/1/80	1,016	1,370	(1,380)	(10)	44	13	203	52	562	6	0	305	7.47	(7.3)
1821	35 NWNW	10/25/79	680	1,020	(620)	(15)	131	9	78	6	136	12	0	427	7.93	(7.55)
1822	35 NWNW	10/28/79	468	760	(666)	(13)	90	7	53	8	166	10	0	183	7.77	(7.60)

TABLE D-6-8

(CONT.)

Well No.	Al	NH_3 (as N)	As	Ba	Be	B	Cd	Cr	Cu	F	Fe	Pb	Mn	Hg
22-2	< .05	0.13	< .002	< .02	< .005	< 1.0	< .002	< .01	0.003	0.27	1.51	< .05	0.68	< .001
8-3	< .05	0.11	< .002	< .02	< .005	< 1.0	< .002	< .01	< .002	0.03	1.98	< .05	0.33	< .001
(W-4A)	< .05	0.81	< .002	< .02	< .005	< 1.0	< .002	0.01	0.004	0.07	2.4	< .05	0.33	< .001
	< .05	0.47	< .002	< .02	< .005	< 1.0	< .002	< .01	0.002	0.13	2.65	0.07	0.33	< .001
	< .05	0.11	< .002	< .02	< .005	< 1.0	0.006	0.03	0.010	0.09	3.75	0.08	0.32	< .001
893	0.04	0.15	< .002	0.07	—	0.1	< .005	0.01	< .02	0.1	0.3	0.03	0.03	< .0005
(W-1)	< .05	< .05	< .002	< .02	< .005	< 1.0	< .002	< .01	< .002	0.12	4.43	< .05	0.13	< .001
	< .05	0.13	—	< .02	—	< 1.0	< .02	< .01	0.002	0.15	8.7	< .05	0.17	< .001
	< .05	0.36	< .002	< .02	< .005	< 1.0	< .002	< .01	< .002	0.14	7.3	< .05	0.15	< .001
	< .05	0.13	< .002	< .02	< .005	< 1.0	< .002	< .01	0.007	0.13	7.55	< .05	0.16	< .001
	< .05	< .05	< .002	< .02	< .005	< 1.0	< .005	0.03	< .005	0.10	7.25	0.05	0.16	< .001
885	< .1	< .1	0.004	0.19	< .005	0.2	< .005	< .01	< .01	0.1	0.66	—	0.23	0.00003
886	< .1	0.18	0.008	1.5	< .005	0.2	< .005	< .01	< .01	0.4	5.2	—	2.3	< .00002
887	< .1	< .1	< .002	0.22	< .005	0.2	< .005	< .01	< .01	0.2	0.18	—	0.34	< .00002
888	< .1	0.65	0.019	0.22	< .005	0.2	< .005	< .01	< .05	0.2	0.18	—	1.5	< .00002
889	< .05	0.05	< .002	< .02	< .005	< 1.0	< .005	< .01	0.003	0.36	< .05	< .05	0.21	< .001
	< .05	0.09	< .005	< .05	< .005	< 1.0	< .005	0.02	< .005	0.34	< .05	< .05	0.23	< .001
1	< .1	< .1	< .002	0.13	< .005	0.1	< .005	< .01	< .01	0.1	< .005	—	0.02	< .00002
(W-2)	0.05	0.01	< .002	0.06	—	0.1	< .005	0.01	< .03	0.1	0.02	0.01	0.01	< .0005
	< .05	< .05	< .002	< .02	< .005	< 1.0	< .002	< .01	< .002	0.15	< .05	< .05	0.004	< .001
	< .05	0.21	< .002	< .02	< .005	< 1.0	< .002	< .01	< .002	0.17	< .05	< .05	0.02	< .001
	< .05	0.15	< .002	< .02	< .005	< 1.0	< .002	< .01	0.003	0.15	< .05	< .05	0.02	< .001
	< .05	0.05	< .002	< .02	< .005	< 1.0	< .005	0.02	< .005	0.15	< .05	< .05	< .01	< .001
1805	< .1	< .1	0.006	0.15	< .005	0.2	< .005	< .01	< .01	0.2	0.11	—	0.06	< .00002
1806	< .1	0.15	0.029	1.4	< .005	0.2	< .005	< .01	< .01	0.2	12	—	2.2	< .00002
1807	< .1	0.1	0.013	0.67	< .005	0.2	< .005	< .01	< .01	0.2	1.9	—	1.8	< .00002
1080	< .05	0.38	< .002	< .02	< .005	< 1.0	< .002	0.01	< .002	0.21	0.13	< .05	0.09	< .001
(W-4B)	< .05	1.02	< .002	< .02	< .005	< 1.0	< .002	< .01	0.003	0.27	0.21	< .05	0.13	< .001
	< .05	0.10	< .002	< .02	< .005	< 1.0	< .002	< .01	0.005	0.23	0.11	< .05	0.06	< .001
	< .05	< .05	< .002	< .02	< .005	< 1.0	< .005	0.02	< .005	0.20	< .05	0.07	0.05	< .001
1809	< .05	0.33	0.009	< .02	< .005	< 1.0	0.005	0.02	0.019	0.20	2.37	0.07	1.22	< .001
1810	< .05	0.09	< .002	< .02	< .005	< 1.0	< .005	0.02	0.010	0.34	< .05	< .05	1.22	< .001
1814	0.05	0.11	< .002	0.06	—	1.0	< .005	0.01	< .03	0.1	0.4	0.03	0.05	< .0005
(W-3)	< .05	< .05	< .002	< .02	< .005	< 1.0	< .002	< .01	< .002	0.13	5.7	< .05	0.168	< .001
	< .05	< .05	< .002	< .02	< .005	< 1.0	< .02	< .01	0.003	0.14	11.0	< .05	0.21	< .001
	< .05	0.14	< .002	< .02	< .005	< 1.0	< .002	< .01	0.008	0.12	12.1	< .05	0.20	< .001
	< .05	< .05	< .002	< .02	< .005	< 1.0	< .005	0.02	0.009	0.09	10.0	0.08	0.21	< .001
1821	< .05	0.80	< .002	0.06	< .005	< 1.0	0.004	< .01	< .002	0.40	< .05	< .05	0.05	< .001
1822	< .05	0.07	< .002	< .02	< .005	< 1.0	< .005	< .01	< .002	< .05	< .05	< .05	0.02	< .001

TABLE D-6-8

(CONT.)

Well No.	Mo	Ni	NO_3	Ag	Se	V	Zn	U	Pb-210	Po-210	Ra-226	Th-230	Charge Balance
22-2	< .05	< .01	0.89	< .01	< .002	< .05	0.035						0.7
8-3	< .02	< .01	0.58		< .002	< .02	0.047	71 ± 4	0 ± 0.6	0.12 ± .03	0.60 ± .07	0 ± .4	6.8
(W-4A)	< .02	< .01	0.51	< .01	< .002	< .02	0.021						1.4
	< .05	< .01	0.24	< .01	< .002	< .05	0.006						5.8
	< .05	< .01	0.15	< .01	< .002	< .05	0.015						2.8
893	< .01	0.02	0.64		0.0023	< .01	0.3	81	—	—	302 ± 20	—	1.0
(W-1)	< .02	< .01	0.18		< .002	< .02	0.014	58 ± 3	10 ± .5	1.5 ± .1	126 ± 6	0.3 ± .1	1.0
	< .02	< .01	4.20	< .01	—	< .02	0.038						0.5
	< .02	< .01	2.19	< .01	< .002	< .02	0.025						0.7
	< .05	< .01	0.32	< .01	< .002	< .05	0.047						0.8
	< .05	< .01	0.12	< .01	< .002	< .05	0.010						3.2
885	0.002	0.02	0.64	0.006	< .005	< .005	0.03	38			163 ± 20	—	4.5
886	0.004	0.02	0.11	0.006	< .005	< .005	0.03	6.8	—	—	170 ± 15	—	4.6
887	0.004	0.03	< .05	0.009	< .005	< .005	0.02	8.8	—	—	1.2 ± 1.2	—	12.1
888	0.003	0.02	0.21	0.006	< .005	< .005	0.03	4.1	—	—	8.2 ± 3.0	—	0.3
889	< .05	< .05	0.81	< .01	< .002	< .05	0.077						0.8
	< .05	< .01	0.26	< .01	< .002	< .05	0.023						3.0
1	< .002	< .01	0.07	< .005	0.115	< .005	0.02	338	—	—	69 ± 10	—	3.5
(W-2)	< .01	0.01	0.64		0.36	< .01	0.1	399	—	—	27.6 ± 1.7	—	16
	< .02	< .01	0.23	—	0.041	< .02	0.038	294 ± 15	0 ± .2	0.2 ± .03	8.0 ± .4	0.0 ± .1	9.2
	< .02	< .01	0.82	< .01	0.093	< .02	0.051						2.8
	< .05	< .01	0.44	< .01	0.103	< .05	0.037						0.8
	< .05	< .01	0.19	< .01	0.065	< .05	0.008						3.0
1085	0.002	0.02	< .05	< .005	< .005	< .005	0.01	10	—	—	6.6 ± 2.3	—	1.0
1806	< .005	0.03	0.07	0.009	< .005	< .005	0.03	12	—	—	125 ± 17	—	2.2
1807	< .002	0.02	< .05	0.006	< .005	< .005	0.07	3.4	—	—	6.6 ± 2.3	—	3.6
1808	< .02	< .01	0.27	—	< .002	< .02	0.016	71 ± 4	0 ± .6	0.12 ± .03	0.60 ± .07	0 ± .4	1.0
(W-4B)	< .02	< .01	0.38	< .01	< .002	< .02	0.015						1.9
	< .05	< .01	0.35	< .01	< .002	< .05	0.084						0.4
	< .05	< .01	0.16		< .002	< .05	< .005						0.7
1809	< .05	< .01	0.25	< .01	< .002	< .05	0.020						2.0
1810	< .05	< .01	0.26	< .01	< .002	< .05	0.012						3.2
1814	< .01	0.02	0.64	—	0.012	< .01	0.04	352	—	—	753 ± 45	—	-3
(W-3)	< .02	< .01	0.33	—	< .002	< .02	0.035	106 ± 5	0 ± .1	0.26 ± .05	5.1 ± .3	0 ± .1	3.3
	< .02	< .01	0.86	< .01	< .002	< .02	0.087						2.1
	< .05	< .01	0.40	< .01	< .002	< .05	0.099						2.3
	< .05	< .01	0.18		< .002	< .05	0.017						0.6
1821	< .02	< .01	0.35	< .01	< .002	< .02	0.018						1.0
1822	< .02	< .01	0.27	< .01	< .002	< .02	< .005						4.7

TABLE D-6-8

(CONT.)

Notes: Concentration in mg/l except Conductivity, in mhos/cm @ 25°C; Temperature, in °C; pH, in pH units; U, Pb-210, Po-210, Ra-226 and Th-230, in pCi/l and Charge Balance = difference in major equivalents divided by sum of major equivalents time 100.

( ) Field Measurements; (W-3) Conoco monitoring well number.

* Concentration less than value.

(a) Additional parameters for this sample are Silica (as SiO_2) = 10; Alkalinity (as $CaCO_3$) = 188; Total Hardness (as $CaCO_3$) = 219; Redox Potential = 196; Nitrite (as N) = *.05; Phosphorus (as P) = *.02; and Total Iron = *1.0.

(b) Additional parameters for this sample are Phosphate = 0.04 and Nitrite = *.01.

(c) Additional parameters for this sample are Phosphate = 0.025 and Nitrite = *.01.

(d) Additional parameters for this sample are Silica (as SiO_2) = 9.9; Alkalinity (as $CaCO_3$) = 232.5; Total Hardness (as $CaCO_3$) = 560; Redox Potential = 206; Nitrite (as N) = 0.13; Phosphorus (as P) = *.03 and Total Iron = 1.3.

(e) Additional parameters for this sample are Silica (as SiO_2) = 19.2; Alkalinity (as $CaCO_3$) = 703; Total Hardness (as $CaCO_3$) = 640; Redox Potential = 208; Nitrite (as N) = *.05; Phosphorus (as P) = 0.02; and Total Iron = 49.

(f) Additional parameters for this sample are Silica (as SiO_2) = 8.6; Alkalinity (as $CaCO_3$) = 310; Total Hardness (as $CaCO_3$) = 749; Redox Potential = 207; Nitrite (as N) = *.05; Phosphorus (as P) = *.02; and Total Iron = 1.0.

(g) Additional parameters for this sample are Silica (as SiO_2) = 17.1; Alkalinity (as $CaCO_3$) = 257; Total Hardness (as $CaCO_3$) = 494; Redox Potential = 197; Nitrite (as N) = *.05; Phosphorus (as P) = 0.04; and Total Iron = 23.

(h) Additional parameters for this sample are Silica (as SiO_2) = 4; Alkalinity (as $CaCO_3$) = 147; Total Hardness (as $CaCO_3$) = 418; Redox Potential = 196; Nitrite (as N) = *.05; Phosphorus (as P) = *.02; and Total Iron = 4.6.

(i) Additional parameters for this sample are Silica (as SiO_2) = 19.9; Alkalinity (as $CaCO_3$) = 806; Total Hardness (as $CaCO_3$) = 720; Redox Potential = 227; Nitrite (as N) = *.05; Phosphorus (as P) = 0.02; and Total Iron = 54.

(j) Additional parameters for this sample are Silica (as SiO_2) = 12.3; Alkalinity (as $CaCO_3$) = 546; Total Hardness (as $CaCO_3$) = 538; Redox Potential = 210; Nitrite (as N) = *.05; Phosphorus (as P) = 0.02; and Total Iron = 8.8.

TABLE D-6-9

GROUNDWATER QUALITY FOR THE EVAPORATION POND AND TAILINGS SITE FOR CONOCO'S SAND ROCK PROJECT

Well No.	Date	TDS	Conductivity		Temperature	Na	K	Ca	Mg	SO_4	Cl	CO_3	HCO_3	pH	Al	NH_3 (as N)	As	Ba	Be
P-9A & P-4C	4/02/80	4,028	3,700	(2,855)	(7.2 & 8.9)	90	18	532	336	2,860	38	0	281	7.41	0.06	.05*	0.003	.02*	
P-12 & P-4B1	4/02/80	2,624	2,590	(2,170)	(9.0 & 8.0)	37	17	517	131	1,635	29	0	415	7.60	.05*	0.09	0.004	.02*	
P-5	4/02/80	260	550	(420)	(8.5)	19	7	61	19	96	4	0	207	7.60	.05*	.05*	0.005	.02*	
P-13A & P-15	4/02/80	4,516	4,000	(3,160)	(8.5 & 8.0)	86	30	655	342	3,070	58	0	122	6.85	0.21	2.10	0.003	.02*	
P-2 & P-9	4/02/80	3,052	2,980	(2,385)	(8.2 & 8.1)	56	22	493	218	1,940	29	0	293	7.67	.05*	1.04	.002*	.02*	
P-10 & P-19	-	-	-	-	(9.8 & 8.1)	-	-	-	-	-	-	-	-	-	-	-	-	-	
[illegible]	5/23/80	1,743	1,150	(1,462)	(11.1)	38	12	329	75	1,165	27	0	176	7.55	0.05*	.08	.002*	.02*	
[illegible]	5/23/80	1,606	2,220	(1,467)	(11.1)	35	22	349	76	970	27	0	220	7.75	.05*	.15	.002*	.02*	
35N-2A	5/23/80	1,002	1,390	(972)	(11.2)	88	15	152	36	614	9	0	176	7.82	.05*	.11	.002*	.02*	
35N-6	5/23/80	724	1,050	(904)	(10.0)	28	10	149	37	374	7	0	220	8.43	.05*	.16	.002*	.02*	
35N-7A	5/23/80	327	599	(463)	(12.0)	20	10	61	13	102	2	0	215	7.85	.05*	.09	.002*	.02*	
35N-7C	5/23/80	443	680	(534)	(8.5)	24	9	80	24	197	4	0	185	7.78	.05*	.21	.002*	.02*	
35N-7E	5/23/80	288	480	(366)	(9.5)	6	5	57	22	73	4	0	215	7.59	.05*	.08	.002*	.02*	
35N-7F	5/23/80	250	410	(399)	(8.0)	8	5	59	19	40	7	0	195	7.77	.05*	.13	.002*	.02*	
35N-7G	5/23/80	256	488	(334)	(10.0)	18	7	61	16	28	4	0	239	7.72	.05*	.09	.002*	.02*	

Notes: Concentrations in mg/l, except Conductivity which is in umhos/cm @ 25°C, Temperature in °C, pH in pH units, Pb 210, Po 210, Ra 226 and Th 230 in pCi/l, and Charge Balance = Difference in major equivalents.

( ) Denotes field measurements.

* Denotes less than value.

TABLE D-6-9 (cont'd)

B	Cd	Cr	Cu	F	Fe	Pb	Mn	Hg	Mo	Ni	NO_3	Se	V	Zn	U	Pb210	Po210	Ra226	Th230	Charge Balance
1.0*	0.016	0.05	0.039	0.21	.05*	0.13	0.98	.001*	.05*	0.02	0.62	.002*	.05*	0.028	-	-	-	-	-	5.3
1.0*	0.013	0.05	0.029	0.13	.05*	0.14	1.34	.001*	.05*	.01*	1.37	.002*	.05*	0.016	-	-	-	-	-	3.8
1.0*	.005*	.01*	.05*	0.29	.05*	.05*	0.16	.001*	.05*	.01*	0.21	.002*	.05*	0.006	-	-	-	-	-	1.0
1.0*	1.129	0.05	0.036	0.51	22.9	0.17	2.57	.001*	.05*	0.51	0.46	.002*	.05*	0.666	0.12	0±1	0±.1	0.39±.04	2.0±.4	1.6
1.0*	0.014	0.04	0.031	0.20	3.50	0.17	1.50	.001*	.05*	.01*	0.23	.002*	.05*	0.012	0.025	0±1	0±.1	0.66±.06	1.5±.2	0.6
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	.008	0.01*	.02	0.18	0.05*	0.10	0.12	.001*	.05*	.01*	.89	.002*	.05*	.329	-	0 ± 1	0±.1	.84±.08	0±.2	6.4
[illegible]	.008	.01*	.03	.08	.05*	.10	.61	.001*	.05*	.01*	.35	.002*	.05*	.092	-	4±1	0±.2	.10±.03	6.8±.2	2.4
1.0*	.005*	.01*	.02	.16	.05*	.05*	.18	.001*	.05*	.01*	.23	.002*	.05*	.005*	-	0±1	0±.1	3.6±.2	0±.2	3.8
1.0*	.005*	.01*	.01*	.13	.05*	.05*	.14	.001*	.05*	.01*	.44	.002*	.05*	.008	-	0±1	0±.2	.12±.03	1.5±.4	1.6
1.0*	.005*	.01*	.02	.15	.05*	.05*	.11	.001*	.05*	.01*	.06	.002*	.05*	.008	-	4±1	0±.1	86±4	2.0±.2	6.5
1.0*	.005*	.01*	.02	.17	.05*	.05*	.10	.001*	.05*	.01*	.22	.002*	.05*	.006	-	-	-	-	-	0
1.0*	.005*	.01*	.01*	.19	.05*	.05*	.07	.001*	.05*	.01*	.11	.002*	.05*	.101	-	-	-	-	-	1.1
1.0*	.005*	.01*	.02*	.22	.05*	.05*	.01*	.001*	.05*	.01*	.56	.002*	.05*	.005*	-	-	-	-	-	8.2
1.0*	.005*	.01*	.01*	.15	.05*	.05*	.05	.001*	.05*	.01*	.22	.002*	.05*	.005*	-	-	-	-	-	7.1

TABLE D-6-10

DRAINAGE BASIN CHARACTERISTICS FOR THE SAND ROCK PROJECT AREA

Drainage Basin	Drainage Area (mi^2)	Channel Length (mi)	Elevation Differences (ft)	Channel Gradient (ft/mi)	Channel Gradient (ft/ft)
Antelope Creek (total)	980	62	1,825	29.4	0.006
Antelope Creek (at USGS gage)	959	52	1,775	34.1	0.006
Ninemile Creek (total)	63	20	610	30.5	0.006
Ninemile Creek (@ I-7)	34	10.5	390	37.1	0.007
Pine Tree Draw	8.2	7.6	370	48.9	0.009
Simmons Draw	8.1	6.8	260	38.2	0.007
Wash No. 1	1.7	2.8	205	73.2	0.014
Upper Wash No. 2	1.9	3.1	190	61.3	0.012
Lower Wash No. 2	0.95	2.2	80	36.4	0.007
Wash No. 3	1.8	3.2	230	71.9	0.014
Upper Wash No. 4	0.70	0.46	130	90.2	0.017
Lower Wash No. 4	0.53	1.3	90	69.2	0.013

TABLE D-6-11

PEAK FLOOD DISCHARGES AND FLOOD VOLUMES FOR SELECTED RECURRENCE INTERVALS FOR STREAMS IN THE SAND ROCK PROJECT AREA

Stream	Drainage Area (mi^2)	Lowham's Method						Craig and Rank's Method											
		Flood Discharge, ft^3/sec						Flood Discharge, ft^3/sec						Flood Volume, ac-ft					
		Qa*	5-yr	10-yr	25-yr	50-yr	100-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
Antelope Creek (total)	980	20	3,000	5,400	9,500	14,000	19,000	-	-	-	-	-	-	-	-	-	-	-	-
Antelope Creek (at USGS gage)	959	20	3,000	5,400	9,400	14,000	19,000	-	-	-	-	-	-	-	-	-	-	-	-
Ninemile Creek (total)	63	4.7	1,100	2,000	3,400	5,000	6,900	2,400	4,700	6,900	9,800	14,000	18,000	630	1,100	1,500	2,000	2,400	2,800
Ninemile Creek (permit area)	34	3.4	900	1,600	2,700	3,900	5,500	2,100	3,800	5,300	7,300	10,000	13,000	580	980	1,200	1,600	1,900	2,200
Pine Tree Draw	8.2	1.6	540	930	1,600	2,300	3,200	560	1,100	1,600	2,200	3,100	3,900	98	170	230	310	380	450
[illegible]mons Draw	8.1	1.6	540	920	1,600	2,300	3,200	790	1,400	2,000	2,600	3,600	4,500	170	280	360	470	550	640
Wash No. 1	1.7	0.69	310	520	900	1,300	1,800	220	410	580	770	1,100	1,310	32	55	73	96	110	130
Upper Wash No. 2	1.9	0.73	320	540	940	1,400	1,900	270	480	670	890	1,200	1,500	43	71	92	120	140	160
Lower Wash No. 2	0.95	0.50	250	420	730	1,000	1,500	320	500	640	770	990	1,200	70	100	120	150	170	180
Wash No. 3	1.8	0.71	310	530	920	1,300	1,800	210	400	560	760	1,000	1,300	29	51	67	90	110	130
Upper Wash No. 4	0.70	0.43	220	370	650	940	1,300	150	260	360	460	610	740	21	35	44	57	67	78
Lower Wash No. 4	0.53	0.37	200	340	590	850	1,200	160	270	350	440	570	670	27	41	51	64	73	83

*Qa = mean annual flow (ft^3/sec)

TABLE D-6-11

(CONT.)

Stream	Drainage Area (mi^2)	Soil Conservation Service Method												
			Flood Discharge, ft^3/sec						Flood Volume, ac-ft					
		Qa*	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
Antelope Creek (total)	980	20	-	-	-	-	-	-	-	-	-	-	-	-
Antelope Creek (at USGS gage)	959	20	-	-	-	-	-	-	-	-	-	-	-	-
Ninemile Creek (total)	63	4.7	-	-	-	-	-	-	940	2,000	2,800	4,100	5,100	6,100
Ninemile Creek (permit area)	34	3.4	-	-	-	-	-	-	510	1,100	1,500	2,200	2,800	3,300
Pine Tree Draw	8.2	1.6	-	-	-	-	-	-	120	260	360	540	660	800
Simmons Draw	8.1	1.6	-	-	-	-	-	-	120	250	360	530	660	790
Wash No. 1	1.7	0.69	63	150	250	350	450	550	25	53	75	110	140	170
Upper Wash No. 2	1.9	0.73	68	160	260	370	480	580	28	60	84	120	150	180
Lower Wash No. 2	0.95	0.50	43	100	150	240	310	360	14	30	42	62	77	92
Wash No. 3	1.8	0.71	65	160	260	360	470	570	27	57	80	120	150	170
Upper Wash No. 4	0.70	0.43	34	85	140	190	250	300	10	22	31	46	57	68
Lower Wash No. 4	0.53	0.37	28	70	110	150	210	250	7.9	17	23	35	43	51

*Qa = mean annual flow (ft^3/sec)

TABLE D-6-12

PRECIPITATION VALUES FOR SELECTED RECURRENCE INTERVALS AND DURATIONS IN THE SAND ROCK PROJECT AREA

	Precipitation, in.							
Duration	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr	Duration
5-Min	.25	.35	.42	.52	.59	.66	.83	5-Min
10-Min	.38	.54	.65	.80	.92	1.03	1.29	10-Min
15-Min	.48	.69	.83	1.01	1.16	1.30	1.64	15-Min
30-Min	.67	.95	1.14	1.40	1.61	1.81	2.27	30-Min
1-Hour	.85	1.21	1.45	1.78	2.03	2.29	2.87	1-Hour
2-Hour	.95	1.33	1.59	1.94	2.22	2.49	3.12	2-Hour
3-Hour	1.03	1.44	1.71	2.09	2.38	2.67	3.33	3-Hour
6-Hour	1.25	1.71	2.01	2.44	2.77	3.10	3.86	6-Hour
12-Hour	1.47	2.00	2.35	2.84	3.22	3.60	4.47	12-Hour
24-Hour	1.70	2.29	2.69	3.24	3.67	4.10	5.09	24-Hour

TABLE D-6-13

SURFACE WATER ANALYSES FOR THE SAND ROCK PROJECT

Surface Site No.	Location	Date	TDS	Conductivity		Temperature	DO	TSS	Turbidity	Na	K	Ca	Mg
	41N-74W												
1-7s (-) (Old Site 4)	18 SENW	4/21/77[a]	770	935	(-)	(-)	(-)	0.0	—	39	6.3	120	33
		3/27/78[b]	322	475	(815)	(1.0)	(7.4)	1.4		14	4	68	20
		6/22/79	Dry										
		12/2/78	Dry										
		2/25/80			(-)	(-)	(-)	—	—	—	—	—	—
		3/27/80	612	990	(946)	(10)	(8.5)	—	3.0	41	10	121	36
1-7A (-)	18 SENW	2/25/80	867	1,170	(-)	(-)	(-)	—	9.5	48	17	141	44
	41N-75W												
1-34 (-)	01 SWNW	3/25/80	32	73	(56)	(2)	(13.6)		7.2	6	4	6	1
1-21 (-)	02 NENW	6/22/79	304	500	(441)	(26)	2.9	5	7.2	5	4	60	28
		9/28/79	Dry										
		10/30/79	Dry										
Site 2s	02 NESW	3/22/78[c]	54	62	(-)	—	—	3.1	—	0.3	1	14	0.5
1-22 (-)	02 NESW	6/26/79	60	94	(73)	(26)	8.6	37	34.3	2	5	10	3
		9/28/79	Dry										
1-23s (-)	02 SESW	6/26/79	Dry										
		12/2/79	Dry										
		2/20/80			(-)	(-)	(-)	—	—	—	—	—	—
1-24 (-)	02 SENE	6/26/79	Dry										
		2/20/80			(-)	(-)	(-)	—	—	—	—	—	—
1-5 (-)	03 NWNE	6/26/79	Dry										
		12/21/79	Dry										
	41N-75W												
1-6s (1631)	03 SESE	6/22/79	2,386	2,667			8.2	7	10.4	59	20	528	74
		12/21/79	Dry										
		2/20/80	—	—	(-)	(-)	(-)	—	—	—	—	—	—
Site 1s	03 NWSE	3/27/78[d]	566	810	(460)	(10)	(8.5)	1.25	—	14	4	100	61
1-32 (-)	03 NWSE	6/20/79	1,914	2,130	(1,870)	(21)	3.3	• 4.0	2.3	40	13	417	77
		9/28/79	638	945	(918)	(13)	(9.3)	136	172	15	36	131	37
1-10s (-)	04 NENW	6/20/79	Dry										
		12/21/79	Dry										
1-11 (-)	04 NENE	6/22/79	1,310	1,650	(1,380)	(21)	3.9	20	2.4	56	12	195	83
		9/25/79	842	1,120	(1,060)	(19)	(9.4)	—	—	65	19	106	43
		10/30/79	Dry										
1-14 (-)	04 SESE	6/20/79	Dry										
		9/25/79	1,282	1,700				• 4.0	3.2	39	8	133	127
		2/20/80			(1,070)	(19)	(14.0)	—	—	—	—	—	—
1-15 (-)	09 NENE	6/21/79	430	645	(566)	(23)	3.3	• 4.0	5.0	26	10	96	17
		12/10/79	—	—	(940)	(1)	(8.25)	—	—	—	—	—	—
1-15As (-)	10 SENW	12/21/79	Dry										
		2/25/80			(-)	(-)	(-)						
1-15Bs (-)	10 SWNE	3/25/80	1,164		(1,320)	(2)	(9.9)		2.7	32	10	225	70

TABLE D-6-13

(CONT.)

Surface Site No.	Location	Date	TDS	Conductivity		Temperature	DO	TSS	Turbidity	Na	K	Ca	Mg
	41N-75W												
1-33 (9352)	11 NWNW	6/20/79	259	437	(144)	(18)	2.9	• 4.0	3.6	22	5	54	21
		9/18/79	434	700	(586)	(18)		• 4.0	5.7	19	9	83	24
		9/27/79	—	—	(658)	(17)	(7.18)	—	—	—	—	—	—
		12/10/79			(653)	(2)	(4.20)						
		3/25/80	156		(258)	(2)	(5.2)		5.3	6	6	37	9
1-33s (-)	11 NWNE	9/18/79	314	500	—	—	—	• 4.0	6.0	9	16	52	13
		10/10/79	376	580	—	—	—	88	73	9	21	61	24
		10/30/79	—	—	(497)	(3)	(13.0)	—	—	—	—	—	—
1-31 (-)	12 NWSW	6/26/79	308	500	(400)	(25)	6.6	• 4.0	5.0	5	10	58	15
		9/18/79	422	690				• 4.0	3.6	26	8	65	31
		9/28/79	Dry										
		3/25/80	152		(228)	(0)	(11.4)		6.0	3	9	29	6
1-35 (-)	12 NWNW	3/25/80	96		(171)	(0)	(11.6)		9.5	2	7	23	4
	42N-74W												
1-30 (-)	31 SWNE	6/29/79	1,030	1,450	(1,180)	(30)	8.6	• 4.0	6.5	31	9	211	54
(Pine Tree Spring)		3/25/80	844	1,260	(1,130)	(1)	(8.6)	—	6.5	29	9	162	50
	42N-75W												
1-18 (-)	26 SWSW	6/21/79	Dry										
		9/25/79	144	208	(161)	(21)	(16.8)			2	5	32	3
1-25 (-)	26 NENW	6/21/79	88	128	(121)	(24)	3.6	7	7.9	3	7	21	2
1-26s (-)	26NESE	6/21/79	Dry										
		9/28/79	202	322	(265)	(12)	—	• 4.0	14.0	26	22	22	6
		10/30/79	Dry										
		12/21/79	Dry										
		2/20/80	—	—	(-)	(-)	(-)	—	—	—	—	—	—
1-27 (-)	26 SENE	6/29/79	84	110	(79)	(22)	7.3	228	252	4	6	10	1
		9/18/79	202	335	(247)	(21)	—	15	17.8	19	19	27	6
		9/28/79	Dry										
		10/10/79	276	341	(287)	(18)	(12.5)	516	234	32	23	20	7
		12/21/79	Dry										
		4/9/80	85		(99)	(3)	(11.4)		10.9	11	5	13	2
1-28s (-)	26 SESE	6/29/79	Dry										
		9/28/79	Dry										
		10/30/79	Dry										
		12/21/79	Dry										
		2/20/80	—	—	(-)	(-)	(-)	—	—	—	—	—	—
1-16 (-)	27 SENE	6/21/79	106	156	(131)	(22)	3.3	• 4.0	6.0	3	5	26	3
1-17s (-)	27 SESE	6/21/79	Dry										
		9/28/79	Dry										
		10/30/79	Dry										
		12/21/79	Dry										
		2/20/80	—	—	(-)	(-)	(-)	—	—	—	—	—	—
1-2 (-)	28 SESE	6/21/79	49	56	(50)	(24)	3.3	8	4.3	4	6	5	1
1-8 (-)	33 NWNW	6/21/79	83	112	(102)	(21)	2.9	• 4.0	5.0	3	5	17	2
		9/28/79	94	154	(129)	(13)	(5.9)	• 4.0	12.2	1	8	18	3
1-9 (-)	33 SWSE	6/20/79	1,614	2,000	(1,380)	(18)	—	—	—	43	11	354	71
		2/20/80	—	—	(-)	(-)	(-)	—	—	—	—	—	—

TABLE D-6-13

(CONT.)

Surface Site No.	Location	Date	TDS	Conductivity		Temperature	DO	TSS	Turbidity	Na	K	Ca	Mg
1-13 (-)	33 SENW	6/20/79	583	847	(666)	(18)	—	—	—	87	8	53	26
1-1 (-)	34 NESW	6/22/79	438	556	(464)	(24)	3.3	• 4.0	10.0	10	22	78	19
		9/25/79	402	410	—	—	—	354	163	6	34	65	3
		10/30/79	—	—	(538)	(3)	(14.3)	—	—	—	—	—	—
		2/20/80	—	—	(-)	(-)	(-)	—	—	—	—	—	—
1-1As (-)	34 NENE	12/21/79	Dry										
		2/20/80	—	—	(-)	(-)	(-)	—	—	—	—	—	—
1-3 (-)	34 SESW	6/26/79	74	97	(79)	(22)	8.3	10	16.8	1	9	8	2
		9/28/79	Dry										
1-12 (-)	34 SWSE	6/22/79	232	303	(221)	(22)	3.3	124	113	9	14	36	6
		9/28/79	Dry										
		10/30/79	Dry										
		12/21/79	Dry										
1-19 (-)	35 SWNE	6/29/79	76	114	(80)	(18)	2.9	323	440	2	5	12	2
		9/25/79	220	298	(242)	(20)	(18.6)	—	—	5	15	34	6
1-20 (-)	35 SESW	6/20/79	199	156	(144)	(18)	3.3	• 4.0	4.0	3	7	22	5
		9/27/79	—	—	(129)	(19)	(12.2)	—	—	—	—	—	—
		12/10/79	—	—	(298)	(3)	(11.70)	—	—	—	—	—	—
		3/25/80	32	90	(73)	(0)	(11.3)	—	13.0	6	6	7	2
1-19 (-)	36 SENW	6/28/79	81	133	(99)	(24)	8.0	425	510	3	5	14	3
		3/25/80	204	—	(265)	(2)	(15.5)	—	7.9	6	11	35	10
Site 3s	36 NENW	3/22/78[e]	88	96	(-)	(-)	(-)	0.9	—	1	2	16	7

TABLE D-6-13

(CONT.)

Surface Site No.	SO_4	Cl	CO_3	HCO_3	pH		Al	NH_3 (as N)	As	Ba	Be	B	Cd	Cr	Cu	F	Fe
I-7s (-)	290	16	0.0	270	8.0	(-)	• .1	–	• .05	• .5	–	39	• .01	• .1	• .01	0.4	0.25
(Old Site 4)	116	24	0	156	7.53	(6.8)	• .05	0.14	0.02	• .03		0.02	• .002	• .02	• .01	• .1	0.45
	Dry																
	Dry																
	–	–	–	–	–	(-)	–	–	–	–	–	–	–	–	–	–	–
	332	13	0	273	7.71	(7.7)	• .05	• .05	• .002	• .02	• .005	• 1.0	• .005	• .01	.005	.14	• .05
I-7A (-)	446	17	0	271	7.30	(-)	• .05	0.37	• .002	• .02	• .005	• 1.0	0.005	0.02	0.019	0.16	0.23
I-34 (-)	20	2	0	24	6.44	(7.6)	• .05	• .05	• .002	• .02	• .005	• 1.0	• .005	• .01	• .005	• .05	.11
I-21 (-)	33	4	0	300	8.24	(8.15)	• .05	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	0.33	0.029
	Dry																
	Dry																
Site 2s	5	10	0	44	6.18	(-)	0.15	• .1	0.02	• .03	–	0.03	• .002	• .02	• .01	• .1	0.47
I-22 (-)	15	4	0	39	7.00	(6.95)	• .005	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	0.03	0.083
	Dry																
I-23s (-)	Dry																
	Dry																
	–	–	–	–	–	(-)	–	–	–	–	–	–	–	–	–	–	–
I-24 (-)	Dry																
	–	–	–	–	–	(-)	–	–	–	–	–	–	–	–	–	–	–
I-5 (-)	Dry																
	Dry																
I-6s (1631)	1,500	21	0	198	7.79		• .05	0.05	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	0.06	0.031
	Dry																
	–	–	–	–	–	(-)	–	–	–	–	–	–	–	–	–	–	–
Site 1s	344	14	0	122	7.52	(6.8)	0.08	• .1	0.03	• .03	–	0.03	• .002	• .02	0.01	• .1	0.97
I-32 (-)	1,315	15	0	249	7.93	(7.85)	• .05	• .05	• .002	• .02	• .005	• 1.0	0.006	• .01	• .002	0.09	0.238
	74	17	0	527	7.91	(7.35)	• .05	0.16	0.007	• .02	• .005	• 1.0	• .002	• .01	0.004	0.14	0.05
I-10s (-)	Dry																
	Dry																
I-11 (-)	1,000	9	0	93	7.78	(7.75)	• .05	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	0.10	0.014
	410	10	0	234	7.44	(7.15)	• .05	–	• .002	• .02	• .005	• 1.0	• .002	• .01	0.004	0.16	0.06
	Dry																
I-14 (-)	Dry																
	890	17	7	107	8.43		0.08	• .05	• .002	• .02	• .005	• 1.0	• .002	0.01	0.004	0.25	0.08
	–	–	–	–	–	(8.00)	–	–	–	–	–	–	–	–	–	–	–
I-15 (-)	195	6	14	166	8.59	(8.85)	• .05	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	0.05	0.062
	–	–	–	–	–	(7.25)	–	–	–	–	–	–	–	–	–	–	–
I-15As (-)	Dry																
						(-)											
I-15Bs (-)	666	8	0	351	7.68	(7.4)	• .05	• .05	• .002	• .02	• .005	• 1.0	• .005	.02	.012	.11	• .05

TABLE D-6-13

(CONT.)

Surface Site No.	SO_4	Cl	CO_3	HCO_3	pH	Al	NH_3 (as N)	As	Ba	Be	B	Cd	Cr	Cu	F	Fe
1-33 (9352)	46	5	0	232	8.03	(9.35) 0.10	.05	.002	.02	.005	1.0	0.024	.01	.002	0.16	0.095
	99	6	0	295	7.69	(7.05) .05	.05	.002	.02	.005	1.0	.002	.01	.002	0.20	0.05
	—	—	—	—	—	(7.00) —	—	—	—	—	—	—	—	—	—	—
						(7.45)										
	32	3	0	144	7.14	(7.4) .05	.05	.002	.02	.005	1.0	.005	.01	.005	.05	.11
1-33Ss (-)	23	5	0	266	7.86	.05	.05		.02		1.0	.002	.01	.002	0.17	0.08
	19	6	0	325	8.14	.05	.20	.002	.02	.005	1.0	.002	.01	.002	0.19	0.09
	—	—	—	—	—	(7.95) —	—	—	—	—	—	—	—	—	—	—
1-31 (-)	143	6	0	98	8.46	(8.85) .05	.05	.002	.02	.005	1.0	.002	.01	.002	.16	.055
	126	9	0	256	8.09	.05	.05		.02		1.0	.002	.01	.004	.18	.05
	Dry					(-)										
	86	2	0	32	6.61	(8.0) .05	.06	.002	.02	.005	1.0	.005	.01	.005	.05	.05
1-35 (-)	47	2	0	51	7.38	(9.1) .05	.05	.002	.02	.005	1.0	.005	.01	.005	.05	.07
1-30 (-)	467	25	0	376	7.83	(8.05) .05	.07	.002	.02	.005	1.0	.002	.01	.002	.90	0.038
(Pine Tree Spring)	472	21	0	278	7.61	(8.6) .05	.057	.002	.02	.005	1.0	.005	.01	.009	.80	.10
1-18 (-)	Dry															
	17	2	12	105	8.80	(8.55) .05		.002	.02	.005	1.0	.002	.01	.002	.09	.05
1-25 (-)	1.0	4	0	78	7.69	(8.45) .05	.05	.002	.02	.005	1.0	.002	.01	.012	.06	.076
1-26s (-)	Dry															
	26	6	0	173	7.88	(7.75) .05	.08	.002	.02	.005	1.0	.002	.01	.002	.12	.25
	Dry															
	Dry															
	—	—	—	—	—	(-) —	—	—	—	—	—	—	—	—	—	—
1-27 (-)	9	4	0	49	7.03	(6.55) .10	.11	.002	.02	.005	1.0	.002	.01	.002	.05	.126
	22	6	2	168	8.52	(8.50) .05	.20	.002	.02	.005	1.0	.002	.01	.004	.09	.06
	Dry															
	19	8	17	168	8.76	(8.1) .05	.12	.002	.02	.005	1.0	.002	.01	.003	0.15	.49
	Dry															
	17	8	0	68	7.00	(8.4) .05	.67	.002	.02	.005	1.0	.005	.02	.005	.05	.05
1-28s(-)	Dry															
	Dry															
	Dry															
	Dry															
	—	—	—	—	—	(-) —	—	—	—	—	—	—	—	—	—	—
1-16 (-)	9	4	24	88	9.18	(9.70) .05	.05	.002	.02	.005	1.0	.002	.01	.002	.05	0.137
1-17s (-)	Dry															
	Dry															
	Dry															
	Dry															
	—	—	—	—	—	(-) —	—	—	—	—	—	—	—	—	—	—
1-2 (-)	8	4	0	20	7.45	(9.20) .05	.15	.002	.02	.005	1.0	.002	.01	.004	.13	.171
1-8 (-)	8	4	24	63	9.30	(9.6) .05	.07	.002	.02	.005	1.0	.002	.01	.002	.08	.320
	17	4	0	71	7.26	(7.55) .05	.08	.002	.02	.005	1.0	.002	.01	.002	.10	.38
1-9 (-)	834	15		481	8.20	(8.25) .05	.05	.002	.02	.005	1.0	.013	.01	.002	.27	.119
	—	—	—	—	—	(-) —	—	—	—	—	—	—	—	—	—	—

TABLE D-6-13

(CONT.)

Surface Site No.	SO_4	Cl	CO_3	HCO_3	pH	Al	NH_3 (as N)	As	Ba	Be	B	Cd	Cr	Cu	F	Fe
1-13 (-)	426	5	10	46	9.24	(9.40) • .05	• .05	• .002	• .02	• .005	• 1.0	.003	• .01	.010	.16	.127
1-1 (-)	114	19	53	171	9.32	(9.40) • .05	.05	.005	• .02	• .005	• 1.0	• .002	• .01	• .002	.11	.020
	17	18	84	115	9.67	— .17	.14	.009	• .02	• .005	• 1.0	• .002	• .01	.012	.13	.27
	—	—	—	—	—	(8.35) —	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	(-) —	—	—	—	—	—	—	—	—	—	—
1-1As (-)	Dry															
	—	—	—	—	—	(-) —	—	—	—	—	—	—	—	—	—	—
1-3 (-)	• 1.0	2	0	44	6.88	(6.90) • .05	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	.003	.04	.080
	Dry															
1-12 (-)	61	15	0	78	7.46	(9.65) .30	.12	.006	• .02	• .005	• 1.0	.004	• .01	.022	.11	.382
	Dry															
	Dry															
	Dry															
1-19 (-)	• 1.0	4	0	49	7.05	(6.65) .05	.09	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	• .05	.080
	17	8	0	146	7.52	(7.70) • .05	—	• .002	• .02	• .005	• 1.0	• .002	• .01	.003	• .05	• .05
1-20 (-)	19	4	10	81	9.06	9.35 • .05	• .05	• .002	• .02	• .005	• 1.0	.002	• .01	.005	.08	.083
	—	—	—	—	—	(9.40) —	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	(7.20) —	—	—	—	—	—	—	—	—	—	—
	19	2	0	34	6.64	(8.0) .08	• .05	• .002	• .02	• .005	• 1.0	• .005	• .01	• .005	• .05	.13
1-29 (-)	11	4	0	49	6.86	7.05 .70	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	.02	.416
	73	3	0	95	7.21	(9.5) • .05	.07	• .002	• .02	• .005	• 1.0	• .005	• .01	• .005	• .05	.07
Site 3s	25	8	0	44	6.05	(-) 0.31	• .1	0.02	• .03	—	0.03	• .002	• .02	• .01	• .1	0.55

TABLE D-6-13

(CONT.)

Surface Site No.	Pb	Mn	Hg	Mo	Ni	NO_3	Se	V	Zn	U	Pb-210	Po-210	Ra-226	Th-230	Charge Balance
I-7s (-)	• .1	• .05	• .001	• .005	• .1	0.0	• .001	0.007	• .02	32	—	—	—	—	1.7
(Old Site 4)	• .05	0.06	• .001	—	• .02	• .1	• .01	—	0.05	—	—	—	—		0.9
	Dry														
	Dry														
	.06	.01	• .001	• .05	• .01	.72	• .002	• .05		.005					3.1
I-7A (-)	0.06	0.24	• .001	• .05	• .01	0.90	• .002	• .05	0.006						3.7
I-34 (-)	• .05	• .01	• .001	• .05	• .01	.14	• .002		• .05						7.5
I-21 (-)	• .05	0.015	• .001	• .02	• .01	10.0	• .002	• .02	0.006	0±.5	3.0±.3	0.07±.02	0±.05	7.5±.8	0.9
	Dry														
	Dry														
Site 2s	• .01	• .01	• .001	• .02	• .02	• .1	• .01	• .05	0.003	17	—	—	—	—	
I-22 (-)	• .05	0.006	• .001	• .02	• .01	0.31	• .002	• .02	0.007	0±1	0.9±.4	0.13±.04	0±.05	0.2±.1	5.5
	Dry														
I-23s (-)	Dry														
	Dry														
	—	—	—	—	—	—	—	—	—						
I-24 (-)	Dry														
	—	—	—	—	—	—	—	—	—						
I-5 (-)	Dry														
	Dry														
I-6s (1631)	• .05	0.074	• .001	• .02	• .01	0.61	• .002	• .02	0.27						0.7
	Dry														
	—	—	—	—	—	—	—	—	—						—
Site 1s	• .05	0.74	• .001	—	• .02	0.19	• .01	—	0.04	—	—	—	—	—	5.7
I-32 (-)	• .05	0.054	• .001	• .02	• .01	1.35	0.006	• .02	0.021	6±1	1.0±.3	0.17±.03	0±.05	0.2±.1	4.3
	• .05	0.62	• .001	• .02	• .01	4.50	• .002	• .02	0.21						2.3
I-10s (-)	Dry														
	Dry														
I-11 (-)	• .05	0.008	• .001	• .02	• .01	0.32	• .002	• .02	0.014	1.9±.4	5±1	3.2±.4	0.07±.03	13±1	7.8
	• .05	0.64	• .001	• .02	• .01	—	• .002	• .02	0.010						2.1
	Dry														
I-14 (-)	Dry														
	• .05	0.08	• .001	• .02	• .01	0.83	• .002	• .02	0.008						5.0
	—	—	—	—	—	—	—	—	—						—
I-15 (-)	• .05	0.018	• .001	• .02	• .01	0.22	• .002	• .02	0.005	0±1	0±1	0.19±.05	0±.05	0±.1	1.1
	—	—	—	—	—	—	—	—	—						—
I-15As (-)	Dry														
I-15Bs (-)	.08	.26	• .001	• .05	• .01	.17	• .002	• .05	.016						3.1

TABLE D-6-13

(CONT.)

Surface Site No.	Pb	Mn	Hg	Mo	Ni	NO_3	Se	V	Zn	U	Pb-210	Po-210	Ra-226	Th-230	Charge Balance
I-33 (9352)	• .05	0.042	• .001	• .02	• .01	1.20	• .002	• .02	0.040	0±1	0.8±.4	0.21±.04	0±.2	0.6±.1	5.7
	• .05	0.08	• .001	• .02	• .01	0.95	• .002	• .02	0.013						1.2
	—	—	—	—	—	—	—	—	—						—
	—	—	—	—	—	—	—	—	—						—
	• .05	.11	• .001	• .05	• .01	.14	• .002	• .05	• .005						1.8
I-335s (-)	• .05	0.28	• .001	• .02	• .01	0.80	• .002	• .02	0.008						5.5
	• .05	0.50	• .001	• .02	• .01	1.58	• .002	• .02	0.012						.4
	—	—	—	—	—	—	—	—	—						—
I-31 (-)	• .05	0.003	• .001	• .02	• .01	.39	• .002	• .02	0.022	0±1	0±2	0±.03	0±.05	5.8±.4	1.6
	• .05	0.19	• .001	• .02	• .01	.96	• .002	• .02	0.022						1.0
	Dry														
	• .05	.01	• .001	• .05	• .01	.19	• .002	• .05	• .005						1.5
I-35 (-)	• .05	• .01	• .001	• .05	• .01	.13	• .002	• .05	• .005						3.5
I-30 (-) (Pine Tree Spring)	• .05	0.279	• .001	• .02	• .01	1.61	• .002	• .02	.007	2±1	0±.9	0.2±.04	0.35±.05	137±7	0.1
	.09	.24	• .001	• .05	• .01	2.25	• .002	• .05	0.006						4.5
I-18 (-)	Dry														
	• .05	• .01	• .001	• .02	• .01	—	• .002	• .02	0.006						8.3
I-25 (-)	• .05	.005	• .001	• .02	• .01	.94	• .002	• .02	.008	0±1	1.9±5	0.28±.06	0±.05	1.6±.3	4.5
I-26s (-)	Dry														
	• .05	.17	• .001	• .02	• .01	1.59	• .002	• .02	.010						3.8
	Dry														
	Dry														
	—	—	—	—	—	—	—	—	—						—
I-27 (-)	• .05	.078	• .001	• .02	• .01	1.83	• .002	• .02	.009	0±1	0.5±.3	0.2±.1	0±.05	0±.1	9.6
	• .05	.06	• .001	• .02	• .01	2.54	• .002	• .02	.012						4.5
	Dry														
	• .05	.09	• .001	• .02	• .01	1.94	• .002	• .02	.022						5.2
	Dry														
	• .05	.10	• .001	• .05	• .01	.17	• .002	• .05	• .005						8.8
I-28s (-)	Dry														
	Dry														
	Dry														
	Dry														
	—	—	—	—	—	—	—	—	—						—
I-16 (-)	• .05	.015	• .001	• .02	• .01	.23	• .002	• .02	.003	2±1	0±.7	0.11±.03	0±.05	0±.1	17.0
I-17s (-)	Dry														
	Dry														
	Dry														
	Dry														
	—	—	—	—	—	—	—	—	—						—
I-2 (-)	• .05	.006	• .001	• .02	• .01	1.33	• .002	• .02	.017	0.4±1	1.2±.3	0.39±.07	0±.05	0±.2	4.1
I-8 (-)	• .05	.015	• .001	• .02	• .01	.75	• .002	• .02	.004	0±1	14±2	0.29±.05	0±.05	175±8	24.8
	• .05	.04	• .001	• .02	• .01	.36	• .001	• .02	• .005						7.9
I-9 (-)	• .05	.120	• .001	• .02	• .01	1.00	.008	• .02	.027	3±2	0±.3	0.19±.04	0±.07	38±3	0
	—	—	—	—	—	—	—	—	—						—

TABLE D-6-13

(CONT.)

Surface Site No.	Pb	Mn	Hg	Mo	Ni	NO_3	Se	V	Zn	U	Pb-210	Po-210	Ra-226	Th-230	Charge Balance
I-13 (-)	• .05	.006	• .001	• .02	• .01	.84	.011	• .02	.015	5.4±.2	0±1	0.24±.06	0±.05	0.2±.1	7.0
I-1 (-)	• .05	.020	• .001	• .02	• .01	.42	• .002	• .02	.009	0±2	1.4±.2	0.15±.03	0±.05	0±.1	7.3
	• .05	.04	• .001	• .02	• .01	1.65	• .002	• .02	.027						—
	—	—	—	—	—	—	—	—	—						—
	—	—	—	—	—	—	—	—	—						—
I-1As (-)	Dry														
	—	—	—	—	—	—	—	—	—						—
I-3 (-)	• .05	.005	• .001	• .02	• .01	.61	• .002	• .02	.010	0±1	0.7±.3	0.28±.04	1.0±.1	0.5±.1	3.6
	Dry														
I-12 (-)	• .05	.064	• .001	• .02	• .01	1.44	• .002	• .02	.060	2±1	1.2±.3	0.16±.03	0.09±.03	0.0±.1	1.1
	Dry														
	Dry														
	Dry														
I-19 (-)	• .05	.016	• .001	• .02	• .01	.83	• .002	• .02	.012	0±1	0±.7	0.32±.09	0±.05	0.7±.1	2.1
	• .05	• .01	• .001	• .02	• .01	—	• .002	• .02	.011						3.2
I-20 (-)	• .05	• .003	• .001	• .02	• .01	.63	• .002	• .02	.007	0±1	1.1±.4	0.13±.06	0±.05	2.6±.3	8.8
	—	—	—	—	—	—	—	—	—						—
	—	—	—	—	—	—	—	—	—						—
	• .05	.01	• .001	• .05	• .01	.20	• .002	• .05	• .005						4.2
I-29 (-)	• .05	.065	• .001	• .02	• .01	2.24	• .002	• .02	• .023	0±1	0.5±.3	0.13±.03	0.35±.05	0.8±.1	2.5
	• .05	.04	• .001	• .05	• .01	.18	• .002	• .05	• .005						0.8
Site 3s	• .02	0.03	• .001	• .02	• .02	• .1	• .01	• .05	0.003	10					0.1

NOTES: s Denotes flowing stream, the remainder samples are from ponded water.

• Concentration less than this value.

( ) Denotes field measurements.

(2345) Behind site number is State Engineer Permit Number, (-) if no permit.

All concentrations are in mg/l, except Conductivity, in µmhos/cm @ 25°C; Temperature, in °C; DO, in dissolved oxygen units; Turbidity, in NTU; Pb-210, Po-210, Ra-226 and Th-230, in pCi/l; and Charge Balance = Difference in major equivalents divided by sum of major equivalents times 100.

(a) Additional parameters from this sample are: Cyanide - •.02, Phenols - 0.007, M.B.A.S. = •.01, Silver = •.5, Hardness ($CaCO_3$) = 440, Silica (SiO_2) = 10, C.O.D. = 24, Total Kjeldahl Nitrogen = 1.5, Oil and grease = 0.8, Sulfide (S) = •.001 and Total CO_3 = 130.

(b) Additional parameters from this sample are: Alkalinity (as $CaCO_3$) = 128, Hardness (as $CaCO_3$) = 250, Phosphate = 0.04, Air Temperature = 10°C, @ 1,945 hours water ponded with ice cover, no flow measurement.

(c) Additional parameters from this sample are: Alkalinity (as $CaCO_3$) = 36, Hardness (as $CaCO_3$) = 38, Phosphate = •0.01.

(d) Additional parameters from this sample are: Alkalinity (as $CaCO_3$) = 100, Hardness (as $CaCO_3$) = 500, Phosphate = 0.04, @ 1,810 Flow measurement = 1.37 ft^3/sec and air temperature = 14°C.

(e) Additional parameters from this sample are: Alkalinity (as $CaCO_3$) = 36, Hardness (as $CaCO_3$) = 70, and Phosphate = •0.01.

TABLE D-6-14

GROUNDWATER RIGHTS IN AND ADJACENT TO MOORE RANCH PROJECT PERMIT AREA, FEBRUARY 6, 1980.
(NOTE: LOCATIONS ARE SHOWN BY SECTION, QUARTER SECTION, AND QUARTER-QUARTER SECTION)

LOCATION	PERMIT NUMBER	USE[3]	USER	OTHER INFORMATION[1]	PROBABLE AQUIFER	WELL DEPTH (ft)	WATER LEVEL (ft below LS)
T40NR73W							
29, SESE	29926	STO	Bell, R. & C.		Wasatch Sand	1,100	40
31, SWNE	43666	MIS	Woods Petr.	L	" "	810	195
33, SESW	12768	STO	U.S. Forest Service		" "		0
T40NR74W							
3, NWSW	42634	STO	Moore, W.I.	L	Wasatch Sand	600	F[2]
4, NESW	50485	MIS	Apache Corp.				
7, NENE	16591	STO	Moore, W. I.	L	Wasatch Sand	1,120	F
12, SENW	16592	STO	Moore, W. I.	L	" "	500	F
14, SENW	46277	MIS	Woods Petr.-U.S. BLM	L	" "	596	90
26, NESW	35316	MIS	Process Equip				
T40NR75W							
8, SESW	22287	DOM	Moore, E.		Wasatch Sand	450	140
8, SESW	22286	DOM	" "		" "	440	
21, NENW	22288	STO	" "		" "	186	140
29, NENE	29439	STO	" "	L	" "	535	180
32, SESE	34197	DOM-STO	" "	L	" "	400	100
32, SESE	22301	DOM	" "		" "	210	
T40NR76W							
1, SWSW	22295	STO	Moore, E.		Wasatch Sand	300	
4, NESE	22303	STO	" "		" "	400	
8, SESE	22294	STO	" "		" "	186	
17, NENE	41146(exp)	STO	Ogalalla Ranch Co.-Moore, E.				
17, NENE	47626	STO	" " " " "				
19, NWNE	22293	STO	Moore, E.		Ft. Union Sand	200	
20, SWNW	22302	STO	" "		" " "	190	
26, SESW	22289	STO	" "		" " "	210	
28, NESW	22291	STO	" "		" " "	183	
29, SWNE	22292	STO	Moore, E.		" " "	273	
34, NWSE	22290	STO	" "		" " "	200	
T40NR77W							
13, SWSE	8368	STO	Gafford, B.		Ft. Union Sand	12	4
13, SESW	8387	DOM-STO	" "	L	" " "	262	175
24, NENW	8385	STO	" "		" " "	20	10
T41NR73W							
4, NENE	18146	STO	Reno & Sons	L	Wasatch Sand	440	150
6, NWSE	11073	DOM	Turnercrest Ranch		" "	140	5
6, NWNW	11072	STO	" "		" "	120	40
7, NENE	11074	STO	" "		" "	120	30
16, SWSE	18149	STO	Reno & Sons	L	" "	362	100
19, NWNE	9924	STO	Moore, W.I., Jr.		" "		
22, SWNE	18845	STO	Reno & Sons		" "	200	80
30, SWSW	9923	STO	Moore, W.I., Jr.		" "		
30, NWNW	9922	STO	" " " "		" "		
T41NR74W							
3, NWNE	17307	STO	Pine Tree Ranch	L	Wasatch Sand	97	60
4, SENE	17302	DOM-STO	" " "	L	" "	165	90
4, SENE	17301	STO	" " "	L	" "	130	55

TABLE D-6-14

CONT.

LOCATION	PERMIT NUMBER	USE[3]	USER	OTHER INFORMATION[1]	PROBABLE AQUIFER	WELL DEPTH (ft)	WATER LEVEL (ft below LS)
T41NR74W (Cont.)							
4, NESE	17304	DOM-STO	Pine Tree Ranch	L	Wasatch Sand	137	80
5, NWSW	6973	STO	" " "	L	" "	170	60
7, NWNE	17305	STO	" " "	L	" "	50	18
10, SWNW	17303	STO	" " "	L	" "	120	60
17, SWSE	12240	DOM-STO	Moore, J.W.		" "	180	40
17, SWSE	9309	DOM	" " "	L	" "	273	85
20, SENW	24924	STO	Moore, J.W. & V.R.	L	" "	230	120
26, NESE	9925	STO	Moore, W.I., Jr.		" "		
28, SWNE	24923	STO	Moore, J.W. & V.R.	L	" "	120	20
28, SESW	45915	MIS	Apache Corp.				
29, SWSW	12242	STO	Moore, J.W.		Wasatch Sand	200	
31, SWSW	27055	DRI-IND-OIL-TEM	American Quasar Petr.	L	" "	400	60
33, NWNW	12241	STO	Moore, J.W.		" "	100	
34, NWSE	47773	MIS	Apache Corp.	L	" "	340	140
T41NR75W							
2, NENW	39655	MIS	Continental Oil	L, Q	Wasatch Sand	165	99
3, NENW	39656	MIS	" "	L, Q	" "	175	70
5, SENW	14670	STO	Taylor Ranch		" "	22	5
21, SENW	48349	MIS	Woods Petroleum				
25, SENE	28332	DRI-IND-TEM	Continental Oil	L	Wasatch Sand	350	115
27, NWNW	22296	STO	Moore, E.		" "	326	
T41NR76W							
3, SWNE	14669	STO	Taylor Ranch		Wasatch Sand	260	130
4, SWSE	14667	STO	" "		" "	245	
4, SESW	14668	STO	" "		" "	245	
5, NENW	14663	DOM	Taylor Ranch		Wasatch Sand	1,000	
5, NENE	14664	DOM	" "		" "	1,000	
5, NESW	14665	DOM	" "		" "	1,010	
5, SENW	14666	DOM	" "		" "	175	
6, NENW	14661	STO	" "		" "	396	
8, SWSW	25848	STO	Moore Land Co.	L	" "	323	F
16, SENE	14671	STO	Taylor Ranch		" "	165	100
16, NWNW	49663	MIS	Woods Petr.-U.S. BLM				
17, SWSW	25845	STO	Moore Land Co.		Wasatch Sand	700	F
17, SWNW	25847	STO	" " "	L	" "	460	F
18, SENE	25844	DOM-STO	Moore Land Co.	L	" "	750	
18, SWNE	25862	STO	" " "	L	" "	243	F
22, NENW	14672	STO	Taylor Ranch		" "	185	60
23, NWNE	29095	DRI-IND-OIL-TEM	American Quasar Petr.				
28, NENW	14674	STO	Taylor Ranch		Wasatch Sand	275	100
30, NESE	25849	STO	Moore Land Co.				
34, NENW	14673	STO	Taylor Ranch		Wasatch Sand	275	75
T41NR77W							
1, NESW	25859	STO	Moore Land Co.	L	Wasatch Sand	353	F
13, NWNW	25861	STO	" " "	L	" "	266	F
35, SWNE	13630	STO	Flying Diamond Ranch		Ft. Union Sand	110	75
35, NWSW	13631	STO	" " "		" " "	110	75
T42NR73W							
5, NWNE	18851	STO	Reno & Sons		Wasatch Sand	350	110
6, SESW	17460	STO	" "	L	" "	276	130

TABLE D-6-14

CONT.

LOCATION	PERMIT NUMBER	USE[3]/	USER	OTHER INFORMATION[1]/	PROBABLE AQUIFER	WELL DEPTH (ft)	WATER LEVEL (ft below LS)
T42NR73W (Cont.)							
6, NWSE	33284	STO	Reno, H.B.	L	Wasatch Sand	254	90
8, SWNE	18148	DOM	Reno & Sons		" "	450	180
20, NESW	18846	STO	" "		" "	160	60
31, SESW	11071	DOM	Turnercrest Ranch		" "	180	120
31, NENE	14885	STO	Turner, Mary, L.J. & G.W.	L	" "	210	65
31, SESE	48351	MIS	Campbell Co. School Dist.				
T42NR74W							
1, NENW	19245	STO	Laur, A.		Wasatch Sand	120	80
3, SWNE	14680	STO	Taylor Ranch		" "	275	125
3, NENE	37881	STO	Pine Tree Ranch	L	" "	185	125
5, NESE	14678	STO	Taylor Ranch		" "	64	40
7, SESW	14677	STO	" "		" "	275	180
5, NESE	14678	STO	" "		" "	64	40
7, SESW	14677	STO	" "		" "	275	180
7, NENW	14676	STO	" "		" "	275	150
8, NENW	37880	STO	Pine Tree Ranch	L	" "	283	140
9, SWNE	14679	STO	Taylor Ranch		" "	275	100
12, SENW	18852	STO	Reno & Sons		" "	350	120
13, NENW	3827	STO	Turnercrest Ranch	L	" "	237	130
16, SESW	14685	STO	Taylor Ranch		" "	275	150
17, NWNW	14686	STO	" "		" "	220	150
18, SWSW	14684	STO	" "		" "	350	235
23, SWNW	12243	STO	Moore, J.W.		" "	220	
28, SWSE	12244	STO	Moore, J.W. & V.R.		" "	200	100
29, SWNW	17306	STO	Pine Tree Ranch	L	" "	150	40
29, SWNE	37879	STO	" " "		" "	8	4
30, NWNW	14683	STO	Taylor Ranch		Wasatch Sand	275	175
33, SESW	6972	IRR-STO-WIL	Pine Tree Ranch	L	" "	210	95
36, NESW	26304	STO	Wyo Board of Land Comm.	L	" "	336	30
T42NR75W							
2, SESW	11901	STO	Brown Land Co.	L	Wasatch Sand	220	100
4, SESE	11900	STO	" " "		" "	450	140
4, SESE	21943	DOM-STO	" " "		" "	5	0
4, SESE	21942	DOM-STO	" " "		" "	5	0
12, NESE	14675	STO	Taylor Ranch		" "	275	195
14, SESE	35330	STO	" "	L	" "	500	100
22, NWSW	35746	STO	Brown Land Co.		" "	660	320
26, SENW	14682	STO	Taylor Ranch		" "	158	80
26, NWNW	14681	STO	" "		" "	158	80
28, SENE	14660	STO	" "		" "	355	150
33, SENW	12299	DOM-IND	Continental Oil		" "		
34, NESW	39648	MIS	" "	L, Q	" "	240	182
34, NENW	39654	MIS	" "	L, Q	" "	330	163
34, NWSW	39653	MIS	" "	L, Q	" "	260	164
35, NESE	39652	MIS	" "	L	" "	227	189
35, NWNE	39651	MIS	" "	L, Q	" "	275	144
35, NWSW	39650	MIS	" "	L, Q	" "	263	208
35, NWSE	39649	MIS	" "	L, Q	" "	240	160
T42NR76W							
1, NWSE	11890	STO	Brown Land Co.	L	Wasatch Sand	375	105
2, NESW	14674	STO	Taylor Ranch		" "	8	

TABLE D-6-14

CONT.

LOCATION	PERMIT NUMBER	USE[3]/	USER	OTHER INFORMATION[1]/	PROBABLE AQUIFER	WELL DEPTH (ft)	WATER LEVEL (ft below LS)
T42NR76W (Cont.)							
3, NESW	14646	STO	Taylor Ranch		Wasatch Sand	383	80
4, NWNW	14648	STO	" "		" "	600	
4, SWNW	14649	STO	" "		" "	8	
5, SESE	14651	STO	" "		" "	8	
6, SWSE	16452	STO	" "		" "	275	100
8, SWSW	14655	STO	" "		" "	1266	100
13, NWNW	48014	MIS	American Nuclear		" "	500	315
14, NWSE	14675	STO	Taylor Ranch		" "	8	
16, NESE	14653	STO	" "		" "	350	200
19, SWSE	25851	STO	Moore Land Co.	L	" "	812	F
20, SWNE	14654	STO	Taylor Ranch		" "	275	100
24, NWNE	14656	STO	" "		" "	296	60
31, NWNE	25846	STO	Moore Land Co.		" "	1,000	F
32, SESW	14662	DOM	Taylor Ranch		" "	330	
33, SWNE	14658	STO	" "		" "	275	125
34, SWSE	14659	STO	" "		" "	240	
T43NR73W							
4, SESE	2902	DOM	Ed Willard	L	Wasatch Sand	95	70
4, SESE	2888	DOM	" "	L, Q	" "	165	90
4, NWNE	2886	STO	" "	L	" "	169	130
9, NENE	2887	STO	" "	L	" "	152	110
T43NR73W							
27, NWNW	45989	MIS	Rocky Mtn Energy		Wasatch Sand	405	272.65
27, NWNW	45988	MIS	" " "		" "	407	278.88
27, NWNW	45987	MIS	Rocky Mtn Energy		Wasatch Sand	383	276.4
27, NWNW	45986	MIS	" " "		" "	461	296.22
27, NWNW	45985	MIS	" " "		" "	215	183.33
27, NWNW	45984	MIS-RES	" " "	L, Q	" "	413	282.27
28, NENW	2883	STO	Ed Willard		" "	80	60
30, SENW	26955	STO	August Laur	L	" "	174	75
32, NENW	2881	STO	Ed Willard		" "	90	65
32, SWSW	18841	STO	Reno and Sons		" "	300	100
T43NR74W							
1, SENW	5429	STO	Bozwell Moore	L	Wasatch Sand	83	30
2, NWNE	3602	STO	Moore, L.W. & P.J.	L	" "	357	30
5, NWSW	12288	DOM	Ruby Ranch		" "	350	Unknown
5, SESE	37542	IRR-STO	William Camblin	L, Q	" "	555	140
6, NENW	12292	STO	Ruby Ranch		" "	240	Unknown
6, SESE	12293	STO	" "		" "	185	Unknown
7, NWSE	13342	STO	L.E. Gilbertz		" "	Unknown	60
7, SESW	35881	DRI-MIS-TEM	Cleveland Cliffs Iron Co.	L	" "	400	314
7, SESW	40283	MIS	Gilbertz, Larry	L	" "	400	314
9, NENW	35175	STO	Moore, Mike	L	" "	310	125
10, NWSE	5432	STO	Moore, Wayne	L	" "	290	150
13, SWSE	7127	IND-MIS	" "	L	" "	10	0
14, NWNE	20072	STO	Todd, Earl		" "	160	60
16, SESE	19247	STO	Roush, Robert		" "	205	190
17, SWNW	41138	MIS-STO	Van Buggenum, Leroy	L	" "	610	125
19, NESE	13344	STO	Gilbertz, L.E.		" "	116	40
20, NWNW	19240	STO	Laur, August		" "	160	18
21, NWNW	19225	DOM-STO	James H. Roush Estate		" "	80	50
21, SESW	19226	STO	" " " "	L	" "	126	60
22, NESW	20073	STO	Todd, Earl		" "	100	60

TABLE D-6-14

CONT.

LOCATION	PERMIT NUMBER	USE[3]/	USER	OTHER INFORMATION[1]/	PROBABLE AQUIFER	WELL DEPTH (ft)	WATER LEVEL (ft below LS)
T43NR74W (Cont.)							
22, SWSW	36176	DRI-MIS-TEM	Inexco Oil Co.		Ft. Union Sand	2,042	500
24, NWNW	5845	STO	Moore, Wayne		Wasatch Sand	6	F
25, SENE	19244	DOM-STO	Laur, August		" "	180	30
26, SENW	19246	STO	" "	L	" "	190	110
28, SENE	20074	STO	Todd, Earl	L	" "	144	89
28, NESE	20071	DOM-STO	" "		" "	100	40
29, SENE	19239	DOM-STO	Laur, August		" "	160	120
29, SENE	19242	DOM	" "		" "	140	104
29, SWSW	35809	STO	Atwood, Velma L.	L	" "	145	60
30, SENE	26643	STO	Bing, Melissa E.	L	" "	200	90
30, SESE	31065	DRI-IND	Cleveland Cliffs Iron Co.	L	" "	505	317
32, NWNW	35742	DOM	Atwood, E. O.	L	" "	540	75
33, SWSW	35331	STO	Taylor Ranch Co. Limited	L	" "	600	90
35, NWNE	19241	STO	Laur, August		" "	120	90
T43NR75W							
1, NENE	2734	STO	Gilbertz, L.E.	L	Wasatch Sand	430	20
2, SWSW	12294	STO	Ruby Ranch, Inc.		" "	340	Unknown
5, SENW	12283	STO	" " "		" "	350	Unknown
7, NESE	33462	DRI-MIS-TEM	Cleveland Cliffs Iron Co.	L	" "	320	228
9, SESW	12289	STO	Ruby Ranch, Inc.	L	" "	703	360
13, SESW	13346	STO	Gilbertz, L.E.		" "	120	20
15, NESW	15070	STO	Brown Land Co.	L	" "	6	F
18, NENW	35984	STO	" " "		" "	700	310
22, SENW	8892	STO	Ruby Ranch	L	" "	800	400
24, SENW	19243	STO	Laur, August		" "	180	140
28, NWNW	35336	STO	Ruby Ranch, Inc.	L	" "	960	200
28, NWSE	12295	STO	" " "		" "	610	Unknown
29, SENW	12290	STO	" " "	L	" "	510	175
30, SWSW	11898	STO	Brown Land Co.		Wasatch Sand	400	115
31, NENW	12296	STO	Ruby Ranch, Inc.		" "	800	Unknown
32, SWNW	11899	STO	Brown Land Co.		" "	420	125
36, SWNE	11895	STO	" " "	L	" "	162	90
T43NR76W							
3, NESW	15106	STO	Brown Land Co.	L	Wasatch Sand	275	125
3, SWNE	29162	STO	Brown, Franklin	L	" "	720	310
7, NESE	35744	STO	Brown Land Co.	L	Wasatch Sand	740	F
10, SWNE	11897	STO	" " "	L	" "	570	50
14, NWNW	27514	IND	Cleveland Cliffs Iron Co.	L	" "	520	95
14, NWNW	28297	MIS	" " " "	L	" "	160	Unknown
14, NWNW	28298	MIS	" " " "	L	" "	160	Unknown
14, NWNW	28299	MIS	" " " "	L	" "	160	Unknown
14, NWNW	28300	MIS	" " " "	L	" "	160	Unknown
14, NWNW	28301	MIS	" " " "	L	" "	150	Unknown
14, NWNW	28302	MIS	" " " "	L	" "	160	Unknown
14, NWNW	28303	MIS	" " " "	L	" "	160	Unknown
14, NWNW	28304	MIS	" " " "	L	" "	160	Unknown
14, NWNW	28305	MIS	" " " "	L	" "	150	Unknown
14, NWNW	28306	MIS	" " " "	L	" "	175	Unknown
14, NWNE	28307	MIS	" " " "	L	" "	160	Unknown
14, NWNW	28308	MIS	" " " "	L	" "	160	Unknown
14, NWNW	35883	DRI-MIS-TEM	" " " "	L	" "	520	95
19, NENW	11894	STO	Brown Land Co.	L	" "	310	F
20, NESW	11891	STO	" " "		" "	370	F

TABLE D-6-14

CONT.

LOCATION	PERMIT NUMBER	USE[3]	USER	OTHER INFORMATION[1]	PROBABLE AQUIFER	WELL DEPTH (ft)	WATER LEVEL (ft below LS)
T43NR76W (Cont.)							
20, SWNW	13634	STO	Flying Diamond Ranch		Wasatch Sand	360	Unknown
21, NWNE	11896	STO	Brown Land Co.		" "	405	F
22, SENE	11902	STO	" " "	L	" "	455	F
22, SENE	11904	DOM-STO	" " "	L	" "	550	90
22, SENW	15107	STO	" " "	L	" "	253	48
22, SESE	32364	MIS	American Nuclear Corp.	L	" "	820	0.00
22, SESE	33631	STO	" " "	Q	" "	820	0.00
23, SWSW	11905	STO	Brown Land Co.	L	" "	690	80
23, SWNW	45994	STO	" " "	L	" "	560	82
27, NWNW	11903	STO	" " "	L	" "	960	F
30, NWSE	13626	STO	Flying Diamond Ranch		" "	360	Unknown
31, NWNW	13637	STO	" " "		" "	490	Unknown
32, SWSE	14650	STO	Taylor Ranch Co.		" "	135	60
35, SENE	33461	DRI-MIS-TEM	Cleveland Cliffs Iron Co.	L	" "	485	82
35, SENE	41140	MIS	" " " "	L	" "	502	444
35, SENE	41141	MIS	" " " "	L	" "	504	448
35, SENE	41142	MIS	" " " "	L	" "	465	407
35, SENE	41143	MIS	" " " "	L	" "	475	428
35, SENE	41144	MIS	" " " "	L, Q	" "	396	312
35, SENE	41145	MIS	" " " "	L	" "	501	493
T42NR77W							
1, NESW	25854	STO	Moore Land Co.			Unknown	Unknown
12, NWNE	25853	STO	" " "	L	Wasatch Sand	560	F
14, NENE	25852	STO	" " "	L	" "	460	F
14, SWNE	25856	STO	" " "	L	" "	720	F
14, SENE	49722	MIS	Uranerz U.S.A., Inc.				
14, SENE	49723	MIS	Uranerz U.S.A., Inc.				
14, SENE	49724	MIS	" " "				
14, SENE	49725	MIS	" " "				
14, SENE	49727	MIS	" " "				
14, SENE	49728	MIS	" " "				
14, SENE	49729	MIS	" " "				
14, SENE	49730	MIS	" " "				
14, SENE	49731	MIS	" " "				
14, SENE	49732	MIS	" " "				
14, SENE	49733	MIS	" " "				
23, SWNE	25857	STO	Moore Land Co.	L	Wasatch Sand	585	6.00
24, SWNE	25850	STO	" " "	L	" "	530	F
25, SENE	25860	DOM-STO	" " "			Unknown	F
26, SENW	25858	STO	" " "	L	Wasatch Sand	200	F
T43NR77W							
11, SESE	13632	STO	Flying Diamond Ranch		Wasatch Sand	410	Unknown
13, SWSE	13633	STO	" " "		" "	400	Unknown
23, SWSE	13625	STO	" " "		" "	480	Unknown
23, NENE	13627	STO	" " "		" "	420	Unknown
24, NESE	13635	STO	" " "		" "	400	Unknown
35, NWNE	13622	STO	" " "		" "	655	Unknown
36, SWN	26091	STO	" " "		" "	387	360

NOTES:

1/ L = Well log available
Q = Water quality analysis available

2/ F = Piezometric evaluation greater than land-surface elevation or flowing well

3/ DOM = Domestic (Residential)
DRI = Drilling
IND = Industrial
IRR = Irrigation
MIS = Miscellaneous, includes silt storage, medicinal, institutional, highway rest area or unknown
OIL = Oil Refining/Production
RES = Reservoir Supply
STO = Stock
TEMP = Temporary Use

TABLE D-6-15

SURFACE-WATER RIGHTS WITHIN 16 KILOMETERS (10 MILES) OF THE SAND ROCK PROJECT

Location	Permit Number	Stream	Use	User
40N - 73W				
07	3251	Ellen Draw	STK	Fred Taylor
07	20371	Antelope Creek	IRR	Fred Taylor
07	26379	Ellen Draw	IND	Woods Petroleum Corp.
08	20372	Antelope Creek	IRR	Fred Taylor
08	3908	Taylor Draw	STK	USA Forest Service
17	6264	Jenson Draw	—	Fred Taylor
41N - 73W				
16	6131	Bates Creek	—	Floyd Reno & Sons
32	3159	Charley Draw	STK	Fred M. Taylor
33	3160	Fred's Draw	STK	Fred M. Taylor
42N - 73W				
18	7319	Mary Draw	STK	Turnercrest Ranch
31	7320	Turner Draw	STK	Turnercrest Ranch
32	5420	Turner Dry Lake	STK	U.S. Agri. Forest Service
43N - 73W				
05	25002	Belle Fourche R.	—	Wyoming State Highway Dept.
18	24842	Belle Fource R.	—	Wyoming State Highway Dept.
21	967	Dry Gulch to Belle Fourche	—	Geo. A. Keeline
40N - 74W				
04	4033	Berry's Draw	STK	William I. Moore
06	1960	Berry's Draw	STK	Fred M. Taylor
08	13059	Antelope Creek	—	R. L. O'Dell
14	4034	Macker Draw	STK	William I. Moore

TABLE D-6-15

(cont'd)

Location	Permit Number	Stream	Use	User
41N - 74W				
01	5168	Bates Creek	STK	John W. Moore
12	5169	Mexican Springs	STK	John W. Moore
42N - 75W				
06	19788	Glen Spring	IRR	Earl Brown
06	19789	Glen Spring #2	IRR	Earl Brown
18	28	Collins Draw	STK	Earl Brown
43N - 75W				
01	14226	Four Mile Creek	--	Florence L. Eychaner
01	3315	Four Mile Creek	--	Florence L. Eychaner
11	29	South Branch 4 Mile Creek	STK	Earl Brown
17	4479	Davis Draw	--	Cecil Davis
24	5439	Little Butte Draw	STK	Lewella Laur
40N - 76W				
07	3954	Wind Creek	STK	Tye & Eddie Moore
12	2512	Spring	STK	Ogalalla Sheep & Cattle Co.
23	2511	Spring	STK	Ogalalla Sheep & Cattle Co.
24	4637	Smyth Draw	STK	Edward D. Moore
28	5147	Findley Draw	IRR	Leroy Moore
41N - 76W				
06	2542	Loading Chute Dr.	STK	Robert B. Moore
15	14431	Meadow Draw	--	Delbert Pierce
15	3365	Meadow Draw R.	--	D. Pierce
19	14063	Dry Fork Power R.	--	Nora H. McPhillamey
19	3280	Dry Fork Power R.	--	Nora H. McPhillamey
19	5217	Dry Fork Power R.	STK	Moore Sheep Co.
19	4706	Red Draw	STK	Moore Sheep Co.
31	6384	S. Prong Dry Fk. - Power R.	--	Moore Land Co.

TABLE D-6-15

(cont'd)

Location	Permit Number	Stream	Use	User
42N - 76W				
02	20567	Water stored in Artesian Lower Reservoir Supplied from Artesian Creek	STK	The Taylor Ranch Co.
02	5777	Artesian Creek	STK	The Taylor Ranch Co.
12	5776	Artesian Creek	STK	The Taylor Ranch Co.
42N - 74W				
03	12407	Belle Fourche	—	B. J. Reno
03	799	Belle Fourche	—	George A. Keeline
03	2653	Belle Fourche	—	B. J. Reno
23	1296	Ralph Draw	STK	John Moore
28	1685	West Bates Creek	STK	John Moore
32	2199	Peak Draw	STK	U. S. Archibald
43N - 74W				
07	6260	Gilbertz Draw	STK	Larry Gilbertz
13	14201	All Night Creek	—	A. H. Hoodenpyle et al.
13	1583	All Night Creek	STK	D. B. Moore
16	798	All Night Creek to Belle F.	—	George A. Keeline
28	1246	All Night Creek	—	Glenn & Graham
31	1874	Dangle Draw	STK	Claus H. Sievers
40N - 75W				
12	8935	Wind River	STK	Flyn Sheep Co.
15	2508	Br. Little Wind R.	STK	Ogalalla Sheep & Cattle Co.
17	26415	Wind Creek	IND	Spearhead Energy, Inc. & St. Bd. Land Commissioners
41N - 75W				
13	14212	Nine Mile Creek	IRR	Bernice Middaugh
13	3308	Nine Mile Creek	IRR	Bernice Middaugh

TABLE D-6-15

(cont'd)

Location	Permit Number	Stream	Use	User
42N - 75W				
04	8156	Cottonwood Creek	STK	Brown Land Co.
04	8157	Cottonwood Creek	STK	Brown Land Co.
42N - 76W				
24	3775	Wintermute Draw	STK	The Taylor Ranch Co.
28	3776	Nichols Draw	STK	The Taylor Ranch Co.
43N - 76W				
35	8099	Collins Draw	STK	Cleveland Cliffs Iron Co.
40N - 77W				
13	5700	North Fork Wind Cr.	STK	Brida and Roy Gaff
41N - 77W				
01	8064	J. J. Draw	STK	Moore Land Co.
25	6012	Bob Draw	STK	Robert Moore
42N - 77W				
12	26124	Dry Fork Powder River	IND	Woods Petroleum Corp.
26	6490	Crawford Draw	STK	Robert B. Moore

STK = Stock
IRR = Irrigation
IND = Industrial

APPENDIX A-1

CONSTANT HEAD TEST

TABLES AND FIGURES

APPENDIX A-1

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TABLE A-1.1 CONSTANT HEAD TEST DATA FOR HOLE P-1
(LOWER MUDSTONE AND E COAL)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
12/4/79					Dry
12/10/79	1231	0			Dry
	1247	16	0.276	3.62	
	1300	29	0.205	4.88	
	1313	42	0.185	5.40	
	1327	56	0.178	5.62	
	1342	71	0.170	5.88	
	1358	87	0.164	6.10	
	1418	107	0.162	6.17	
	1433	122	0.159	6.29	
	1448	137	0.157	6.37	
	1514	163	0.158	6.33	
4/3/80					Dry

TABLE A-1.2 CONSTANT HEAD TEST DATA FOR HOLE P-2 (LOWER MUDSTONE AND E COAL?)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
3/17/80	1159				42.05
	1201	Started bailing			
	1206	Stopped bailing ≈ 1 1/4 gal			
	1209				50.25
	1419				50.1
3/18/80	1053				49.05
	1055	Started bailing			
	1059	Stopped bailing ≈ 1/4 gal			
	1100				50.2
3/24/80	1241				
	1242	Started bailing			
	1249	Stopped bailing ≈ 3/4 gal			
	1251				>51.3
4/2/80	1307	T = 8.2°C Cond = 2010			43.79
4/11/80	1140				43.08
	1145	Started injection			
	1153	8	0.031	32.7	
	1220	35	0.019	53.3	
	1235	50	0.015	67.3	
	1317	92	0.013	76.0	
	1337	112	0.011	93.3	
	1403	138	0.011	89.3	
	1534	229	0.0095	105	

TABLE A-1.3 CONSTANT HEAD TEST DATA FOR HOLE P-3 (LOWER MUDSTONE)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
3/17/80	1134				47.37
	1138	Started bailing			
	1142	Stopped bailing = 3/4 gal			
	1144				51.6
	1411				51.6
3/18/80	1018				51.5
3/24/80	1509				50.8
3/27/80	1540	Bailed T = 9.1°C	Cond = 3380 μmhos/cm @ 25°C		50.5
4/2/80	1421				51.35
4/9/80	-	Saturated hole			
4/10/80	0853	Started injection test			
	0904	11	.0068	148	
	0920	27	.0060	165	
	0936	43	.0055	180	
	0956	63	.0055	181	
	1016	83	.0055	182	
	1047	114	.0055	182	
	1117	144	.0055	181	
	1144	171	.0055	181	
	1218	205	.0055	182	
	1245	232	.0055	182	
	1325	272	.0055	182	

TABLE A-1.3- CONSTANT HEAD TEST DATA FOR HOLE P-3 (Cont'd)
(LOWER MUDSTONE)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
4/10/80	1401	308	.0055	183	
	1443	350	.0054	184	
	1503	370	.0054	184	
	1542	409	.0054	184	

TABLE A-1.4 CONSTANT HEAD TEST DATA FOR HOLE P-4 (LOWER MUDSTONE AND E COAL)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
3/13/80	1050				19.67
	1200	Started bailing			
	1212	Stopped bailing ≈ 7.5 gal			
	1223				46.50
	1547				33.81
3/17/80	1053				23.81
3/24/80	1350				23.18
3/27/80	1612				23.19
		T = 9.9° C	Cond = 1250 μmhos/cm @ 25°C, near water level		
		T = 10.1	Cond = 1660 @ ≈ 48' below LSD		
4/2/80	1051				23.16
4/3/80	0917	T = 9.8	Cond = 1470		23.19
	0938	0	Started test		
	0953	15	.0064	157	0.0
	1021	43	.0026	380	
	1118	100	.0024	413	
	1219	161	.0022	457	
	1320	222	.0024	420	
	1421	283	.0022	452	
	1521	343	.0023	444	

TABLE A-1.5
CONSTANT HEAD TEST DATA FOR HOLE P-4B

Date	Time	Time Since Injection Started (min)	Discharge (Q, in GPM)	I/Q (min/gal)	Water Level (ft-mp)
3/13/80	1100				20.88
	1126	Started bailing			
	1131	Stopped bailing	3.0 gal		
	1217				31.83
	1549				26.83
3/17/80	1057				20.94
3/24/80	1352				21.07
	1359	Started bailing			
	1409	Stopped bailing	3.0 gal		
3/27/80	-	T = 10.0°C	Cond = 2000 umhos/cm @ 25°C near top		
		T = 10.1°C	Cond = 2220 umhos/cm @ 25°C near bottom		
	1615				21.8
4/03/80	1239				20.87
		T = 9.0°C	Cond = 1996 umhos/cm @ 25°C		
5/22/80	1019	Started test			
	1047	28	0.250	4.00	
	1114	55	0.214	4.67	
	1140	81	0.217	4.60	
	1206	107	0.207	4.83	
	1229	130	0.167	6.00	
	1304	165	0.119	8.40	
	1344	205	0.143	7.00	
	1404	225	0.136	7.33	
	1429	250	0.127	7.90	
	1454	275	0.124	8.10	

TABLE A-1.7 CONSTANT HEAD TEST DATA FOR HOLE P-4CA
(UPPER MUDSTONE)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
3/27/80	1603				22.65
		T = 10.0°C	Cond = 2040 µmhos/cm @ 25°C		top of W.L.
		T = 10.1	Cond = 2150		near bottom of well
		Bailed = 3 gal	T = 9.9	Cond = 2150	
	1645				32.3
4/2/80	1055				22.49
4/3/80	0910	T = 9.1	Cond = 2010		22.53
	0931	0	Test started		
	0943	12	0.0101	99.2	0.0
	1004	33	0.0094	106	
	1039	68	.0082	122	
	1100	89	.0085	117	
	1136	125	.0082	123	
	1206	155	.0077	129	
	1236	185	.0084	119	
	1306	215	.0083	120	
	1339	248	.0078	127	
	1409	278	.0072	139	
	1439	308	.0071	141	
	1509	338	.0080	126	
	1539	368	.0078	128	
	1609	398	.0076	132	

TABLE A-1.8 CONSTANT HEAD TEST DATA FOR HOLE P-5 (E COAL)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
3/17/80	1110				27.40
	1112	Started bailing			
	1118	Stopped bailing = 3 gal			
	1120				46.25
	1404				40.14
3/24/80	1439				28.37
4/2/80	1105	Sample taken			28.44
		T = 8.5°C Cond = 420 μmhos/cm @ 25°C			
4/9/80	1010				
		T = 10.2 Cond = 390			28.54
	1016	0	Started injection		
	1043	27	0.012	82.7	
	1213	117	0.0099	101	
	1329	193	0.0091	109	
	1357	221	0.0091	110	
	1418	242	0.0090	111	
	1452	276	0.0090	111	
	1514	298	0.0088	114	
	1540	324	0.0088	113	
4/10/80	0912	1376	0.0038	267	
	1214	1558	0.0036	279	
	1554	1778	0.0033	301	

TABLE A-1.9 CONSTANT HEAD TEST DATA FOR HOLE P-6 (UPPER SANDSTONE)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
3/17/80	1313				35.58
	1317	Started bailing			
	1320	Stopped bailing ≈ 1/2 gal			
	1322				37.28
	1434				35.75
3/18/80	1108				35.72
	1110	Started bailing			
	1117	Stopped bailing ≈ 3/4 gal			
	1120				38.25
3/24/80	1343				35.75
4/3/80	0947	T = 8.5°C	Cond = 480 μmhos/cm @ 25°C		35.80
	0954	0	Started test		
	1001	7	0.96	1.04	
	1012	8	0.57	1.75	
	1022	28	0.42	2.38	
	1038	44	0.38	2.64	
	1049	55	0.31	3.19	
	1106	72	0.28	3.50	
	1116	82	0.27	3.68	
	1126	92	0.27	3.70	
	1139	105	0.26	3.88	
	1155	121	0.19	5.18	
	1210	136	0.18	5.46	

TABLE A-1.9 CONSTANT HEAD TEST DATA FOR HOLE P-6 (UPPER SANDSTONE) (Cont'd)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
4/3/80	1225	151	0.18	5.71	
	1235	161	0.19	5.20	
	1245	171	0.17	6.00	
	1255	181	0.17	5.73	
	1310	196	0.16	6.33	
	1316	202	0.16	6.27	
	1321	207	0.15	6.67	
	1336	222	0.15	6.47	
	1346	232	0.16	6.33	
	1356	242	0.16	6.27	
	1406	252	0.15	6.67	
	1416	262	0.15	6.67	
	1426	272	0.15	6.87	
	1436	282	0.14	6.93	
	1446	292	0.14	6.93	
	1501	307	0.14	7.00	
	1511	317	0.14	7.00	
	1521	327	0.14	7.07	
	1531	337	0.14	7.00	
	1541	347	0.14	7.07	
	1551	357	0.14	7.07	

TABLE A-1.10
BAILING AND RECOVERY DATA FOR WELL P-7 (70SS)

Date	Time	t (min)	t' (min)	t/t'	Water Level (ft below mp)	Drawdown (ft)	Discharge (gpm)
5/22/80	1000				33.67		
	1100				33.41		
	1402				33.47		
	1404	0	Start bailing				
	1412	8	T = 14.0°C , Cond = 1438 umhos/cm @ 25°C				0.19
	1429	25	T = 12.9°C , Cond = 1425 umhos/cm @ 25°C				0.20
	1453	49	T = 11.0°C , Cond = 1492 umhos/cm @ 25°C				0.21
	1505	61			36.24	2.74	
	1508	64	Sample collected				
	1515	71	T = 11.1°C , Cond = 1462 umhos/cm @ 25°C				0.23
	1516	72			36.87	3.37	
	1535	91	T = 11.2°C , Cond = 1485 umhos/cm @ 25°C				0.25
	1545	101			36.66	3.16	
	1555	111	0				
			T = 12.0°C , Cond = 1457 umhos/cm @ 25°C				0.25
	1600	116	5	23.2	36.40	2.90	
	1609	125	14	8.93	35.20	1.70	
	1615	131	20	6.55	34.69	1.19	
	1620	136	25	5.44	34.46	0.96	
	1629	145	34	4.26	34.18	0.68	
	1645	161	50	3.22	33.96	0.46	
	1800	236	125	1.89	33.69	0.19	

Note: t = time since pumping started
t' = time since pumping stopped

TABLE A-1.11 CONSTANT HEAD TEST DATA FOR HOLE P-8
(LOWER MUDSTONE AND E COAL)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
3/17/80	1234				26.59
	1236	Started bailing well			
	1300	Stopped bailing	15 gal		
	1301				48.26
	1427				27.19
3/24/80	1446				26.96
4/2/80	0949	T = 8.4°C C = 740 μmhos/cm @ 25°C			26.09
	0956	0	Started test		
	1013	17	0.160	6.25	0.0
	1031	35	0.166	6.03	
	1048	52	0.095	10.6	
	1103	67	0.087	11.5	
	1118	82	0.087	11.4	
	1133	97	0.089	11.2	
	1148	112	0.100	10.0	
	1203	127	0.094	10.6	
	1218	142	0.095	10.5	
	1239	163	0.097	10.3	
	1257	181	0.078	12.8	
	1309	193	0.080	12.5	
	1325	209	0.080	12.5	

TABLE A-1.11 CONSTANT HEAD TEST DATA FOR HOLE P-8
(LOWER MUDSTONE AND E COAL) (Cont'd)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
4/2/80	1333	217	0.077	12.9	
	1348	232	0.096	10.4	
	1402	246	0.102	9.8	
	1420	264	0.107	9.4	

TABLE A-1.12 CONSTANT HEAD TEST DATA FOR HOLE P-9
(LOWER MUDSTONE AND E COAL)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
3/17/80	1030				14.98
	1035	Started bailing			
	1041	Stopped bailing = 4 gal			
	1043				35.2
	1359				29.48
3/18/80	1616				15.68
	1619	Started bailing			
	1623	Stopped bailing = 4 gal			
	1632				35.35
3/24/80	1429				15.01
3/27/80	1551	T = 8.5°C	Cond = 2890 µmhos/cm @ 25°C near top of water		15.02
		T = 9.5	Cond = 3030 near well bottom		
4/2/80	0921	T = 8.1	Cond = 2900		14.60
		Sample collected			
	0934	Started injection			
	0941	7	0.0107	93.4	
	0958	24	.0107	93.4	
	1020	46	.0099	101	
	1055	81	.0072	139	
	1138	124	.0064	156	
	1222	168	.0055	182	

TABLE A-1.12 CONSTANT HEAD TEST DATA FOR HOLE P-9
(LOWER MUDSTONE AND E COAL) (Cont'd)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
4/2/80	1305	205	.0052	192	
	1355	255	.0046	217	
	1440	298	.0042	238	
	1507	315	.0040	250	

TABLE A-1.13 CONSTANT HEAD TEST DATA FOR HOLE P-9A
(UPPER MUDSTONE)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
3/27/80	1556				19.65
4/2/80	1243				16.98
4/9/80	0935				16.04
	0939	0	Started injection		
	0944	5	0.075	13.3	
	0949	10	0.073	13.7	
	0956	17	0.032	31.2	
	1009	30	0.014	73.7	
	1035	56	0.0050	197	
	1139	60	0.0012	823	
	1255	196	0.0012	850	
	1417	278	0.0012	848	
	1512	333	0.0012	866	

TABLE A-1.14 CONSTANT HEAD TEST DATA FOR HOLE P-10
(LOWER MUDSTONE AND E COAL)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
3/13/80	1401				28.09
	1404	Started bailing			
	1426	Stopped bailing = 15 gal			
	1429				51.78
	1556				28.65
3/17/80	1127				28.35
3/24/80	1433				28.30
4/2/80	1127	T = 9.8°C	Cond = 2010 μmhos/cm @ 25°C		28.33
		Sample taken			
	1138	0	Started injection		
	1141.6	3.6	0.019	51.5	
	1147.8	9.8	0.017	57.9	
	1154	16	0.016	61.9	
	1202	24	0.016	61.3	
	1208	30	0.016	62.9	
	1217	39	0.015	68.0	
	1227	49	0.015	67.7	
	1243	65	0.014	69.1	
	1257	79	0.015	68.3	
	1313	95	0.014	72.5	
	1331	113	0.014	72.0	

TABLE A-1.15 CONSTANT HEAD TEST DATA FOR HOLE P-11
(E COAL)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
3/17/80	1151				18.35
3/18/80	1023				18.4
	1025	Started bailing			
	1027	Stopped bailing = 1/4 gal			
	1029				19.7
	1607				19.75
3/24/80	1258				18.95
3/27/80	1445	Bailed = 1/4 gal			18.60
		T = 9.0°C Cond = 2990 μmhos/cm @ 25°C			
4/2/80	0855				19.1
	0900	0	Started test		
	0904	4	0.015	65.3	0.0
	0913	13	0.025	40.0	
	0924	24	0.019	51.7	
	0939	39	0.022	45.1	
	0950	50	0.027	37.1	
	1004	64	0.021	48.0	
	1009	69	0.024	41.3	
	1028	88	0.023	42.7	
	1046	106	0.024	41.6	
	1106	126	0.023	43.5	
	1128	148	0.024	41.9	

TABLE A-1.15 CONSTANT HEAD TEST DATA FOR HOLE P-11 (E COAL) (Cont'd)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
4/2/80	1146	166	0.024	41.9	
	1210	190	0.022	45.3	
	1232	212	0.028	34.7	
	1256	236	0.027	37.1	
	1315	255	0.027	37.3	
	1343	283	0.027	36.5	
	1408	308	0.029	34.7	
	1428	328	0.031	32.0	
	1450	350	0.032	31.2	
	1505	365	0.035	28.4	

TABLE A-1.16 CONSTANT HEAD TEST DATA FOR HOLE P-12
(E COAL)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
3/13/80	1347				30.61
3/24/80	1447				27.70
	1450	Started bailing			
	1454	Stopped bailing ≈ 3/4 gal			
	1457				33.3
3/27/80	1528	Bailed ≈ 3/4 gal			
		T = 10.1°C Cond - 2090 μmhos/cm @ 25°C			
		Bailed ≈ 3/4 gal T = 9.9 Cond = 2080			
4/2/80	1355	T = 9.0 Cond = 2070			30.88
4/9/80	0855				30.9
	0908	Started injection			
	0912	4	0.089	11.3	
	0927	19	0.051	19.6	
	0939	31	0.043	23.3	
	0952	44	0.036	27.9	
	1002	54	0.033	30.7	
	1012	64	0.032	31.3	
	1022	74	0.031	32.7	
	1032	84	0.029	34.1	
	1042	94	0.029	34.9	
	1052	104	0.028	35.9	
	1102	114	0.027	36.8	
	1222	194	0.022	46.4	

TABLE A-1.16 CONSTANT HEAD TEST DATA FOR HOLE P-12 (Cont'd)
(E COAL)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
4/9/80	1309	241	0.020	51.2	
	1344	276	0.019	53.3	
	1407	299	0.018	54.7	
	1434	326	0.018	55.5	
	1502	354	0.018	55.5	
	1523	375	0.018	56.0	
	1547	399	0.018	55.2	

TABLE A-1.17 CONSTANT HEAD TEST DATA FOR HOLE P-13
(UPPER MUDSTONE)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
3/17/80	1513	Bailed			18.44
	1518				19.45
3/18/80	1035	Bailed ≈ 1/4 gal			19.17
	1039				19.71
	1612				19.95
3/24/80	1306				18.08
	1307	Started bailing			
	1311	Stopped bailing ≈ 1/3 gal			
	1313				19.8
3/27/80	1410				18.4
4/2/80	1325	T = 7.0°C Cond = 3900 μmhos/cm @ 25°C			17.68
4/11/80	0945				17.60
	0948	Started injection			
	0952	4	0.091	11.0	
	1001	13	0.075	13.3	
	1008	20	0.072	13.9	
	1021	33	0.068	14.8	
	1039	51	0.067	14.9	
	1102	74	0.073	13.7	
	1112	84	0.076	13.2	
	1121	93	0.087	11.5	
	1211	143	0.100	10.0	

TABLE A-1.17 CONSTANT HEAD TEST DATA FOR HOLE P-13 (Cont'd)
(UPPER MUDSTONE)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
4/11/80	1303	195	0.144	6.93	
	1345	237	0.158	6.33	
	1413	265	0.172	5.80	
	1438	290	0.176	5.67	

TABLE A-1.18 CONSTANT HEAD TEST DATA FOR HOLE P-13A
(E COAL)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
3/27/80	1414	Bailed ≈ 10 gal			20.86
		T = 9.8°C Cond = 3210 μmhos/cm @ 25°C			
4/2/80	1331	T = 8.5°C Cond = 3250			19.82
4/9/80	1114				19.81
	1115	Start permeability test			
	1117	2	1.82	0.55	
	1130	15	1.82	0.55	
	1140	25	2.0	0.50	
	1150	35	1.97	0.51	
	1200	45	1.94	0.52	
	1210	55	1.85	0.54	
	1220	65	1.85	0.54	
	1231	76	1.24	0.81	
	1240	85	1.74	0.575	
	1252	97	1.62	0.62	
	1305	110	1.33	0.75	
	1320	125	1.14	0.875	
	1335	140	0.56	1.78	
	1350	155	0.64	1.57	
	1405	170	0.59	1.68	
	1425	190	0.22	4.58	
	1445	210	0.39	2.54	

TABLE A-1.18 CONSTANT HEAD TEST DATA FOR HOLE P-13A (Cont'd)
(E COAL)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
4/9/80	1515	240	0.36	2.80	
	1545	270	0.25	3.96	
4/11/80	0956				19.86
	1432				19.87

TABLE A-1.19 CONSTANT HEAD TEST DATA FOR HOLE P-15
(LOWER MUDSTONE AND E COAL)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
3/17/80	1336				23.34
	1340	Started bailing			
	1345	Stopped bailing ≈ 3 gal			
	1347				35.2
	1440				34.77
3/18/80	1004				30.42
	1006	Started bailing			
	1012	Stopped bailing ≈ 2 gal			
	1013				35.95
	1553	Bailed			34.35
	1600				36.27
3/24/80	1504				23.10
3/27/80	1501	Bailed ≈ 2 gal			23.03
		T = 10.0°C Cond = 3060 μmhos/cm @ 25°C			
		Bailed ≈ 1 gal T = 9.1°C Cond = 3130 pH = 6.6			
	1521				35.8
4/2/80	1409	T = 8.0°C Cond = 3070			23.05
		Sample taken			
4/10/80	0947	Started injection test			
	0959	12	.0100	100	
	1029	42	.0065	153	
	1100	73	.0062	161	

TABLE A-1.19 CONSTANT HEAD TEST DATA FOR HOLE P-15 (Cont'd)
(LOWER MUDSTONE AND E COAL)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
4/10/80	1128	101	.0058	173	
	1236	169	.0054	184	
	1307	200	.0055	183	
	1340	233	.0053	187	
	1426	279	.0051	195	
	1526	339	.0049	206	
	1554	367	.0048	209	

TABLE A-1.20 CONSTANT HEAD TEST DATA FOR HOLE P-15A (UPPER MUDSTONE)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
3/27/80	-				dry
4/9/80	-	Saturated hole			
4/10/80	0948	Started injection test			
	0953	5	0.048	20.9	
	1006	18	0.042	24.0	
	1037	49	0.041	24.3	
	1108	80	0.040	25.2	
	1136	108	0.040	25.1	
	1151	123	0.039	25.5	
	1227	159	0.039	25.9	
	1258	190	0.040	25.1	
	1349	241	0.039	25.3	
	1416	268	0.039	25.7	
	1453	305	0.038	26.3	
	1517	329	0.038	26.4	
	1546	358	0.037	26.9	
	1607	379	0.037	27.1	
	1651	423	0.054	18.7	
	1658	430	0.053	18.8	

TABLE A-1.21 CONSTANT HEAD TEST DATA FOR HOLE P-16
(UPPER 70 SAND)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
3/13/80					75.0
3/18/80					Dry
3/24/80					Dry
4/9/80		Saturated zone			
4/10/80	1015	0	--	--	
	1023	8	0.138	7.27	
	1048	33	0.088	11.40	
	1106	51	0.064	15.73	
	1131	76	0.071	14.13	
	1155	100	0.067	14.93	
	1230	135	0.061	16.27	
	1312	177	0.058	17.20	
	1355	220	0.055	18.27	
	1445	270	0.051	19.60	
	1530	315	0.049	20.40	
	1615	360	0.046	21.73	

TABLE A-1.22 CONSTANT HEAD TEST DATA FOR HOLE P-17
(UPPER 70 SAND)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
3/17/80	-				Dry
3/24/80	1542				Dry
4/9/80	1200	Added water to begin saturating formation			
	1600	Added more water to saturate formation			
4/10/80	1600	Added water to saturate formation			
4/11/80	0935	Begin permeability test			
	0944	9	0.03	32.00	
	0952	17	0.031	32.27	
	1028	53	0.030	32.80	
	1108	93	0.026	38.93	
	1141	126	0.023	42.62	
	1217	162	0.023	42.67	
	1255	200	0.022	45.87	
	1333	238	0.019	53.33	
	1415	280	0.020	48.80	
	1451	316	0.020	49.87	
	1520	345	0.0190	52.53	

TABLE A-1.23 CONSTANT HEAD TEST DATA FOR HOLE P-18 (ALLUVIUM)

DATE	TIME	TIME SINCE INJECTION STARTED (MIN)	DISCHARGE (Q, IN GPM)	1/Q (MIN/GAL)	WATER LEVEL (FT-MP)
3/24/80	1227				22.54
	1230	Begin bailing			
	1233	End bailing (< 1/2 gal)			
	1234				24.4
3/27/80	1405				23.6
4/3/80	1409	T = 8.1°C Cond = 94 μmhos/cm @ 25°C			21.79
4/10/80	1321				22.25
4/11/80	1000	Start permeability test			
	1017	17	0.44	2.27	
	1024	24	0.42	2.40	
	1059	59	0.375	2.67	
	1116	76	0.20	4.93	
	1148	108	0.19	5.20	
	1225	145	0.20	4.93	
	1311	191	0.20	4.93	
	1341	221	0.197	5.07	
	1425	265	0.192	5.20	
	1500	300	0.192	5.20	

TABLE A-1.23A WATER-LEVEL DATA FOR WELLS P-20 AND P-20A DURING BAIL TEST OF WELL P-20B

DATE	TIME	WATER LEVEL (ft below MP)
		WELL P-20
5-21-80	1330	97.62
5-22-80	1122	97.55
	1124	START BAIL TEST ON WELL P-20B
	1141	97.54
	1204	97.56
	1244	97.57
	1304	STOP BAIL TEST ON WELL P-20B
	1313	97.57
		WELL P-20A
5-21-80	1245	98.25
	1430	98.17
5-22-80	1119	98.09
	1124	START BAIL TEST ON WELL P-20B
	1131	98.08
	1145	98.08
	1159	98.10
	1234	98.10
	1304	STOP BAIL TEST ON WELL P-20B
	1306	98.09
	1333	98.11
	1354	98.09

TABLE A-1.23B
BAILING AND RECOVERY DATA FOR WELL P-20B (70SS)

Date	Time	Time Since Bailing Started (t, in min)	Time Since Pumping Stopped (t', in min)	t/t'	Water Level (ft below mp)	Drawdown (ft)	Discharge (gpm)
5/22/80	1118				97.95		
	1124	0	Start bailing				
	1137	13			105.9	7.95	
	1143	19	T = 12.5°C , Cond = 1020 umhos/cm @ 25°C				0.26
	1156	32			111.9	13.95	
	1215	51	T = 12.8°C , Cond = 1416 umhos/cm @ 25°C				0.16
	1220	56	T = 11.0°C , Cond = 1682 umhos/cm @ 25°C				
	1228	64			116.04	18.09	
			Water sample collected				
	1302	98	T = 11.7°C , Cond = 1467 umhos/cm @ 25°C				0.10
	1304	100	0	Stop bailing			
	1311	107	7	15.3	116.15	18.20	
	1320	116	16	7.25	114.12	16.17	
	1325	121	21	5.76	113.08	15.13	
	1330	126	26	4.85	112.11	14.16	
	1340	136	36	3.78	109.99	12.04	
	1351	147	47	3.13	108.09	10.14	
	1430	186	86	2.16	103.28	5.33	
	1551	267	167	1.60	99.00	1.05	
	1655	331	231	1.43	98.53	-0.22	

TABLE A-1.23C
BAILING AND RECOVERY DATA FOR WELL P-21 (70SS)

Date	Time	t	t'	t/t'	Water Level (ft-mp)	Residual Drawdown
3/24/80	1523				75.32	
4/03/80	1302				75.57	
	Bailed 10 times		T = 9.0°C Cond = 713 umhos/cm @ 25°C			
4/10/80	1522				75.27	
5/18/80	1348				73.80	
	1440	0	Started Bailing			
			T = 11.0	Cond = 1370		
	1455		T = 10.0	Cond = 1335		
	1506		T = 10.1	Cond = 1360		
	1516		T = 10.5	Cond = 1470		
	1517		Stopped Bailing			
	1525	45	8	5.62	116.64	42.84
	1536	56	19	2.95	114.35	40.55
	1544	64	27	2.37	112.60	38.80
	1550	70	33	2.12	111.24	37.44
			AVG. Q = 0.41 gpm			
5/22/80	1541				73.40	

Note: t = time since bailing started, in min.
t' = time since bailing stopped, in min.

TABLE A-1.24
CONSTANT HEAD TEST DATA FOR HOLE 35N-1C (U 70SS)

Date	Time	Time Since Injection Started (min)	Discharge (Q, in GPM)	I/Q (min/gal)	Water Level (ft-mp)
4/09/80	1425				179.4
		Bailed dry			
5/15/80	1539				Dry
		Saturated hole			
5/16/80	1148	Started test			
	1217	29	0.149	6.73	
	1243	55	0.122	8.20	
	1303	75	0.119	8.41	
	1322	94	0.125	7.99	
	1342	114	0.113	8.83	
	1408	140	0.396	2.52	
	1410	142	0.30	3.33	
	1428	160	0.288	3.47	
	1457	189	0.30	3.33	
	1523	215	0.288	3.47	
	1611	263	0.263	3.80	
	1642	294	0.250	4.0	

TABLE A-1.25
CONSTANT HEAD TEST DATA FOR HOLE 35N-1D (SS)

Date	Time	Time Since Injection Started (min)	Discharge (Q, in GPM)	I/Q (min/gal)	Water Level (ft-mp)
4/03/80	1539				39.68
		Bailed nearly dry			
		T = 8.5°C Cond = 281 umhos/cm @ 25°C			
4/09/80	1435				39.44
		T = 9.4°C Cond = 339 umhos/cm @ 25°C			
		Bailed dry			
4/10/80	1423				39.39
5/15/80	1542				39.53
5/16/80	1152				39.54
		T = 10.5°C Cond = 405 umhos/cm @ 25°C			
					39.54
5/16/80	1301	Started test			
	1310	9	0.153	6.52	
	1324	23	0.132	7.57	
	1344	43	0.113	8.83	
	1410	69	0.113	8.83	
	1431	90	0.101	9.88	
	1459	118	0.116	8.62	
	1526	145	0.091	10.94	
	1558	177	0.086	11.56	

TABLE A-1.26
CONSTANT HEAD TEST DATA FOR HOLE 35N-1E (MS)

Date	Time	Time Since Injection Started (min)	Discharge (Q, in GPM)	I/Q (min/gal)	Water Level (ft-mp)
4/03/80	1526				27.85
		T = 6.8°C Cond = 301 umhos/cm @ 25°C			
		Bailed nearly dry			
4/09/80	1450				28.53
		T = 9.4°C Cond = 325 umhos/cm @ 25°C			
		Bailed dry			
4/10/80	1420				29.50
5/15/80	1530				28.86
		Saturated hole			
5/16/80	1151	0	Start		
	1211	10	0.0047	211	
	1238	37	0.0059	170	
	1258	57	0.0060	168	
	1318	77	0.0058	172	
	1338	97	0.0055	183	
	1401	120	0.0057	175	
	1423	142	0.0052	192	
	1453	172	0.0050	202	
	1532	211	0.0047	211	
	1603	242	0.0045	222	

TABLE A-1.27
BAILING AND RECOVERY DATA FOR WELL 35N-2A (U70SS)

Date	Time	t (min)	t' (min)	t/t'	Water Level (ft below MP)	Drawdown (ft)	Discharge (gpm)
4/11/80		Bailed - 4 gal					
5/15/80	1443				144.15		
5/19/80	1257				141.32		
	1259	Started bailing					
	1302	T = 12.0°C Cond = 953 umhos/cm @ 25°C					
	1310	T = 11.2°C Cond = 972 umhos/cm @ 25°C					
		Sample taken					
	1325	T ≐ 11.0°C Cond = 950 umhos/cm @ 25°C					
	1333	Stopped bailing - 12 gal					
	1335				154.3		
	1347	48	14	3.42	156.92		
	1352	53	19	2.79	156.51		
	1403	64	30	2.13	155.83		
	1414	75	41	1.83	155.15		
	1427	88	54	1.63	154.34		
	1546	167	133	1.26	150.86		
	1549				150.77		
	1649	230	196	1.17	149.06		
5/21/80	955				147.25		
	1010				147.22		
	1124				147.17		
	1525				146.83		

Note: t = time since pumping started
t' = time since pumping stopped

TABLE A-1.28
CONSTANT HEAD TEST DATA FOR HOLE 35N-2B (SS)

Date	Time	Time Since Injection Started (min)	Discharge (Q, in GPM)	I/Q (min/gal)	Water Level (ft-mp)
4/11/80					99.0
5/15/80	1453				124.22
5/19/80	1247				124.28
	1249	Started bailing			
	1251	T = 11.0°C Cond = 475 umhos/cm @ 25°C			
	1256	Stopped bailing			
	1329				130.19
	1338				129.88
	1343				129.77
	1350				129.58
	1418				128.87
5/20/80	1910	Saturated hole			
5/21/80	1000	Started saturation			
	1020	20	0.103	9.67	
	1045	45	0.100	10.0	
	1100	60	0.0926	10.8	
	1130	90	0.0920	10.9	
	1155	115	0.0857	11.7	
	1310	190	0.0824	12.1	
	1440	280	0.0806	12.4	

TABLE A-1.29
CONSTANT HEAD TEST DATA FOR HOLE 35N-2C (MS)

Date	Time	Time Since Injection Started (min)	Discharge (Q, in GPM)	I/Q (min/gal)	Water Level (ft-mp)
5/15/80	1457				69.4
5/19/80	1239				69.52
	1241	Started bailing			
	1243	T = 11.5°C Cond = 1086 umhos/cm @ 25°C			
	1248	Stopped bailing	2.0 gal		
	1313				72.87
	1330				72.65
	1409				72.49
5/20/80	1855	Saturated hole			
5/21/80	1010	Started injection test			
	1035	25	0.428	2.34	
	1052	42	0.341	2.93	
	1105	55	0.236	4.23	
	1135	85	0.171	5.86	
	1305	175	0.195	5.13	
	1445	275	0.168	5.97	

TABLE A-1.30
CONSTANT HEAD TEST DATA FOR HOLE 35N-3 (SS)

Date	Time	Time Since Injection Started (min)	Discharge (Q, in GPM)	1/Q (min/gal)	Water Level (ft-mp)
4/09/80					Dry
5/15/80	-	Saturated hole			
5/19/80	-	Saturated hole			
5/20/80	1505	Start test			
	1525	20	0.660	1.52	
	1550	45	0.445	2.25	
	1620	85	0.414	2.42	
	1710	135	0.418	2.39	
	1750	165	0.410	2.44	
	1850	225	0.276	3.62	
	1915	250	0.250	4.00	
	1950	285	0.214	4.66	

TABLE A-1.31
CONSTANT HEAD TEST DATA FOR HOLE 35N-4 (MS)

Date	Time	Time Since Injection Started (min)	Discharge (Q, in GPM)	I/Q (min/gal)	Water Level (ft-mp)
4/09/80	1400				131.73
		T = 10.4°C Cond = 386 umhos/cm @ 25°C			
5/16/80	-	Saturated hole			
5/19/80	-	Saturated hole			
5/20/80	1450	Start test			
	1525	35	0.054	18.67	
	1545	55	0.054	18.67	
	1605	75	0.052	19.29	
	1640	110	0.051	19.56	
	1730	160	0.050	20.00	
	1852	242	0.049	20.33	

TABLE A-1.32
CONSTANT HEAD TEST DATA FOR HOLE 35N-5 (SS)

Date	Time	Time Since Injection Started (min)	Discharge (Q, in GPM)	I/Q (min/gal)	Water Level (ft-mp)
4/09/80	1510				23.64
		Started bailing			
		T = 9.0°C Cond = 171 umhos/cm @ 25°C			
		T = 9.0°C Cond = 428 umhos/cm @ 25°C			
		T = 8.9°C Cond = 543 umhos/cm @ 25°C			
5/15/80	1420				74.6
		Started bailing			
		T = 9.1°C Cond = 640 umhos/cm @ 25°C			
		Bailed nearly dry			
5/19/80	1433				80.2
		T = 11.8°C Cond = 732 umhos/cm @ 25°C			
5/20/80	2010	Started saturation			
5/21/80	9:40	Start test			
	1059	158	4.0×10^{-5}	24,920	
	1322	129	3.5×10^{-5}	28,725	
	1613	213	3.7×10^{-5}	26,876	

TABLE A-1.33
CONSTANT HEAD TEST DATA FOR HOLE 35N-6 (SS)

Date	Time	Time Since Injection Started (min)	Discharge (Q, in GPM)	I/Q (min/gal)	Water Level (ft-mp)
4/09/80	1600				86.70
		T = 9.0°C Cond = 841 umhos/cm @ 25°C			
		T = 8.9°C Cond = 858 umhos/cm @ 25°C			
		Bailed - ½ gal			
5/15/80	1359				86.87
		T = 9.8°C Cond = 769 umhos/cm @ 25°C			
		Sample taken			
5/16/80	0857				86.87
		T = 10.0°C ; C = 904 umhos/cm @ 25°C			
		Sample taken			
		T = 10.5°C , C = 879 umhos/cm @ 25°C			
	0930	0	Start		
	1025	55	2.93	0.342	
	1056	86	1.90	0.525	
	1124	114	1.60	0.625	
	1202	152	1.20	0.833	
	1232	182	1.07	0.933	
	1300	210	1.00	1.000	
	1330	240	0.909	1.100	
	1355	265	0.858	1.165	
	1416	286	0.811	1.233	
	1437	307	0.828	1.21	

TABLE A-1.34
BAILING AND RECOVERY DATA FOR WELL 35N-7A (70SS)

Data	Time	t_1 (min)	t_2 (min)	t_3 (min)	t_4 (min)	$\frac{t_1 t_3}{t_2 t_4}$	Water Level (ft below mp)	Discharge (gpm)
5/15/80	0915						132.30	
5/19/80	1051						132.44	
	1056		Start bailing					
	1104		T = 10.9°C , C = 290 umhos/cm @ 25°C					
	1117		T = 11.1°C , C = 300 umhos/cm @ 25°C					0.48
	1136		T = 11.0°C , C = 390 umhos/cm @ 25°C					0.50
			Stop bailing					
	1138						132.58	
5/20/80	1625						132.3	
5/21/80	1150						132.3	
	1152						132.25	
	1340						132.24	
	1528						132.21	
	1545	0	Start bailing					
	1550	5	T = 11.0°C , C = 434 umhos/cm @ 25°C					0.54
	1603	18	T = 12.0°C , C = 463 umhos/cm @ 25°C					
	1610	25	T = 11.2°C , C = 452 umhos/cm @ 25°C					0.71
	1615	30	T = 11.5°C , C = 489 umhos/cm @ 25°C					0.73
	1625	40	T = 11.8°C , C = 452 umhos/cm @ 25°C					0.53
	1635	50	T = 12.0°C , C = 450 umhos/cm @ 25°C					0.49
	1650	65	T = 11.0°C , C = 468 umhos/cm @ 25°C					0.68
	1700	75	0 T = 11.0°C , C = 461 umhos/cm @ 25°C					0.79
	1740	115	40	0	T = 11.0°C , C = 414 umhos/cm @ 25°C			0.97
	1750	125	50	10	0	Stop bailing		
	1751	126	51	11	1	27.2	131.87	
	1755	130	55	15	5	7.1	132.27	
	1805	140	65	25	15	3.6	132.20	
	1810	145	70	30	20	3.1	132.19	
	1815	150	75	35	25	2.8	132.19	

Note: t_1 = Time since pumping started, first time
t_2 = Time since pumping stopped, first time
t_3 = Time since pumping started, second time
t_4 = Time since pumping stopped, second time

TABLE A-1.35
CONSTANT HEAD TEST DATA FOR HOLE 35N-7B (U70SS)

Date	Time	Time Since Injection Started (min)	Discharge (Q, in GPM)	1/Q (min/gal)	Water Level (ft-mp)
5/15/80	0925				Dry
5/19/80	-	Saturated hole			
5/20/80	1625	Saturated hole			
5/21/80	1040	Started test			
	1050	10	0.395	2.53	
	1110	30	0.288	3.47	
	1150	70	0.254	3.93	
	1237	117	0.250	4.00	
	1355	195	0.214	4.67	
	1548	308	0.214	4.67	
	1715	395	0.207	4.83	

TABLE A-1.36
CONSTANT HEAD TEST DATA FOR HOLE 35N-7C (SS)

Date	Time	Time Since Injection Started (min)	Discharge (Q, in GPM)	I/Q (min/gal)	Water Level (ft-mp)
4/09/80	1630				83.79
	Bailed - 1.5 gal	T = 8.9°C	Cond = 500 umhos/cm @ 25°C		
4/10/80	1343				83.76
5/15/80	0958				82.09
	Sample taken	T = 8.5°C	Cond = 530 umhos/cm @ 25°C		
	1105	Start permeability test			
	1132	27	1.71	0.583	
	1150	45	1.60	0.625	
	1212	67	1.60	0.625	
	1233	88	1.26	0.792	
	1336	151	0.80	1.25	
	1407	182	0.73	1.38	
	1441	216	0.65	1.54	
	1513	248	0.60	1.67	

TABLE A-1.37
CONSTANT HEAD TEST DATA FOR HOLE 35N-7D (E Coal)

Date	Time	Time Since Injection Started (min)	Discharge (Q, in GPM)	I/Q (min/gal)	Water Level (ft-mp)
5/15/80	0931				96.45
5/18/80	0911				97.39
		Bailed - ½ gal			
5/19/80	1101				97.6
	1154	Started bailing			
		T = 10.5°C Cond = 577 umhos/cm @ 25°C			
	1157	Bailed dry - 1 gal			
5/21/80	1150	Start saturation			
	1345	115	1.67	0.600	
	1450	180	1.41	0.708	
	1547	237	1.20	0.835	
	1715	325	1.20	0.835	
	1749	359	1.18	0.850	

TABLE A-1.38
CONSTANT HEAD TEST DATA FOR HOLE 35N-7E (SS)

Date	Time	Time Since Injection Started (min)	Discharge (Q, in GPM)	I/Q (min/gal)	Water Level (ft-mp)
4/03/80	1445				17.41
	Bailed nearly dry	T = 8.5°C	Cond = 380 umhos/cm @ 25°C		
4/09/80					17.56
	Bailed - 1.5 gal	T = 8.0°C	Cond = 360 umhos/cm @ 25°C		
4/10/80	1338				17.65
5/15/80	0953				18.90
	Sample taken	T = 9.5°C	Cond = 370 umhos/cm @ 25°C		
	1042	Permeability test started			
	1046	4	0.022	45.2	
	1105	23	0.016	61.5	
	1135	53	0.015	64.7	
	1155	73	0.014	69.4	
	1227	105	0.015	67.8	
	1256	134	0.014	69.4	
	1357	195	0.015	67.8	
	1436	234	0.014	72.6	
	1503	261	0.014	72.6	
	1542	300	0.014	74.1	

TABLE A-1.39
CONSTANT HEAD TEST DATA FOR HOLE 35N-7F (MS)

Date	Time	Time Since Injection Started (min)	Discharge (Q, in GPM)	I/Q (min/gal)	Water Level (ft-mp)
4/03/80	1435				13.82
	Bailed - 2 gal	T = 7.0°C	Cond = 410 umhos/cm @ 25°C		
4/09/80	1620				13.80
	Bailed - 1 gal	T = 6.8°C	Cond = 390 umhos/cm @ 25°C		
4/10/80	1336				14.10
5/15/80	0951	T = 8.0°C	Cond = 390 umhos/cm @ 25°C		14.97
		Sample taken			
	1050	Permeability test started			
	1056	6	0.007	139	
	1129	39	0.006	158	
	1148	58	0.006	164	
	1221	91	0.006	177	
	1249	119	0.005	192	
	1350	180	0.006	183	
	1430	220	0.006	183	
	1456	246	0.005	196	
	1536	286	0.005	186	

TABLE A-1.40
CONSTANT HEAD TEST DATA FOR HOLE 35N-7G (U COAL)

Date	Time	Time Since Injection Started (min)	Discharge (Q, in GPM)	I/Q (min/gal)	Water Level (ft-mp)
5/15/80	0948				31.80
5/18/80	0848				33.14
		T = 11.8°C Cond = 333 umhos/cm @ 25°C			
		Pumped hole			
5/19/80	1115				52.15
	1140	Started bailing			
	1142	T = 10.0°C Cond = 334 umhos/cm @ 25°C			
	1150	Stopped bailing - 5 gal			
		Sample taken			
	1152				59.50
	1221				58.95
5/21/80	1145	Started test			
	1155	10	0.0103	97.3	
	1240	55	0.0059	169.0	
	1355	130	0.0031	321.0	
	1600	275	0.0025	407.0	

TABLE A-1.41 DRAWDOWN DATA FOR OBSERVATION WELLS 887, 886 and 888 FROM PUMPING WELL 885

Well 887 Distance: 115' 68SS			Well 886 Distance: 64' 70SS			Well 888 Distance: 50' 70SS		
Date	Elapsed Time (min)	Drawdown (ft)	Date	Elapsed Time (min)	Drawdown (ft)	Date	Elapsed Time (min)	Drawdown (ft)
8-17-77	0	0	8-17-77	0	0	8-17-77	0	0.00
	Pumping 3.4 gpm			Pumping 3.4 gpm			Pumping 3.4 gpm	
	37	0.02		30	0.05		17	0.00
	50	0.02		40	0.17		25	0.00
	75	0.02		60	0.26		35	0.00
	105	0.02		195	0.35		50	0.05
	200	0.02		315	0.36		80	0.30
				405	0.43		185	0.79
							245	1.02
							320	1.11
							410	1.41
8-18-77	570	0.57	8-18-77	570	0.48	8-18-77	570	1.66
	925	0.86		747	0.51		873	1.86
	995	0.82		915	0.55		1108	1.88
	1065	0.82		1175	0.68		1275	1.90
	1365	0.74		1269	0.75		1360	1.94
				1385	0.76		1440	Pump Off
	1440	Pump Off		1440	Pump Off			

TABLE A-1.42
RECOVERY TEST FOR WELL 886 (705S)
(6/24/78)

Time of Measurement	Time since Pumping Started t, minutes	Time since Pumping Stopped t', minutes	$\frac{t}{t'}$	Water Level (Ft-MP)	Residual Drawdown s', feet
12:01	61	1	61	182.23	4.33
12:02	62	2	31	179.13	1.23
12:03	63	3	21	178.55	0.65
12:04	64	4	16	178.39	0.49
12:05	65	5	13	178.30	0.40
12:06	66	6	11	178.26	0.36
12:07	67	7	9.6	178.22	0.32
12:32	92	32	2.9	177.42	0.10
2:30	210	150	1.4	177.33	0.01

Discharge rate, Q = 2 gallons per minute

TABLE A-1.43
RECOVERY TEST FOR WELL 887 (68SS)
(6/24/78)

Time of Measurement	Time since Pumping Started t, minutes	Time since Pumping Stopped t', minutes	$\frac{t}{t'}$	Water Level (Ft-MP)	Residual Drawdown s', feet
15:20	60	0	-	196.63	12.53
15:21	61	1	61	196.42	12.32
15:22	62	2	31	196.25	12.15
15:23	63	3	21	195.92	11.82
15:24	64	4	16	195.71	11.61
15:25	65	5	13	195.46	11.36
15:26	66	6	11	195.25	11.15
15:28	68	8	8.5	194.83	10.73
15:30	70	10	7.0	194.50	10.40
15:34	74	14	5.3	193.83	9.73
15:36	76	16	4.8	193.25	9.15
15:44	84	24	3.5	192.08	7.98
15:49	89	29	3.1	191.50	7.40
15:57	97	37	2.6	190.50	6.40
16:07	107	47	2.3	189.67	5.57
16:20	120	60	2.0	188.67	4.57
16:40	140	80	1.8	187.71	3.61
16:50	150	90	1.7	187.29	3.19
17:30	190	130	1.5	186.21	2.11
18:03	223	163	1.4	185.68	1.58
18:33	253	193	1.3	185.40	1.30
19:03	283	223	1.27	185.08	0.98
20:03	343	283	1.21	184.79	0.69
21:10	410	350	1.17	184.63	0.53
21:45	445	385	1.16	184.54	0.44
09:30	1150	1090	1.06	184.40	0.30

Discharge rate, Q = 0.1 gallons per minute

TABLE A-1.44
DRAWDOWN DATA FOR OBSERVATION WELL 1805 (70SS)
ON AFTERNOON OF 6/25/78

Time of Measurement	Time Since Pumping Started (t, min)	Water Level (Ft-MP)	Drawdown (s, ft)
15:00	0	158.75	0
15:10	10	159.25	0.50
15:20	20	159.33	0.58
15:25	25	159.35	0.60
15:42	42	159.40	0.65
15:52	52	159.42	0.67
16:20	80	159.44	0.69
16:35	95	159.45	0.70
17:15	135	159.46	0.71
17:20	140	159.46	0.71

Discharge rate, Q = 3.5 gallons per minute
r = 36 ft.

TABLE A-1.45
DRAWDOWN DATA FOR OBSERVATION WELL 1806 (70SS)
(6/25/78)

Time of Measurement	Time Since Pumping Started (t, min)	Water Level (Ft-MP)	Drawdown (s, ft)
15:00	0	150.00	0
15:07	7	150.21	0.21
15:15	15	150.33	0.33
15:28	28	150.42	0.42
15:38	38	150.46	0.46
15:55	55	150.50	0.50
16:15	75	150.52	0.52
16:45	105	150.54	0.54
17:10	130	150.54	0.54

Discharge rate, Q = 3.5 gallons per minute
r = 73 ft

TABLE A-1.46
DRAWDOWN DATA FOR OBSERVATION WELL 1807 (68SS)
(6/25/78)

Time of Measurement	Time Since Pumping Started (t, min)	Water Level (Ft-MP)	Drawdown (s, ft)
10:30	0	155.44	0
11:17	47	155.50	0.06
11:25	55	155.58	0.14
11:30	60	155.63	0.19
11:35	65	155.67	0.23
11:42	72	155.71	0.27
11:53	83	155.75	0.31
12:06	96	155.79	0.35
12:30	120	155.81	0.37
13:00	150	155.81	0.37
13:20	170	155.81	0.37

Discharge rate, Q = 2.5 gallons per minute
r = 111 ft.

TABLE A-1.47
DRAWDOWN FOR OBSERVATION WELL 1816 (70SS)
ON 12/01/78

Time since pumping started (t, min)	Drawdown (s, ft)
3	0.12
5	0.23
9	0.29
10	0.31
15	0.34
20	0.38
25	0.42
30	0.45
35	0.46
45	0.55
60	0.61
90	0.73
120	0.84
180	1.03
240	1.14
300	1.29
360	1.41
420	1.49
480	1.67
750	1.67
1140	1.87

Discharge rate, Q = 19 gallons per minute

r = 54.6 ft

TABLE A-1.48
PUMPING AND RECOVERY DATA FOR WELL 1823 (68SS)

Date	Time	Time Since Pumping Started (t,min)	Time Since Pumping Stopped (t',min)	t/t'	Water Level ft below mp)	Discharge (gpm)
5/21/80	1555				110.74	
5/22/80	1704	0	Pump on			
	1714	10	T = 13.0°C , C = 1228, umhos/cm @ 25°C			1.73
	1722	18	T = 11.6°C , C = 1204			1.72
	1733	29	T = 11.5°C , C = 1206			1.71
	1753	49	T = 11.5°C , C = 1206			1.73
			Sample collected			
	1809	65	T = 11.6°C , C = 1203			1.69
	1814	70	0	Pump off		
	1828	84	14	6.0	116.98	
	1836	92	22	4.18	115.30	
	1848	104	34	3.06	114.20	
	1859	115	45	2.56	113.77	
	1914	130	60	2.17	113.53	
	1929	145	75	1.93	113.40	

TABLE A-1.49
WATER-LEVEL DATA FOR WELL 1816 DURING PUMP TEST OF WELL 1823

Date	Time	Water Level (ft below mp)
5/21/80	1620	157.42
	1725	157.42
5/22/80	1704	Pump on in well 1823
	1709	157.23
	1715	157.16
	1721	157.18
	1725	157.21
	1739	157.24
	1749	157.20
	1813	157.08
	1814	Pump off in well

TABLE A-1.50 PUMPING AND DRAWDOWN DATA FOR WELL 1814 (70 SAND)

DATE	TIME	TIME SINCE PUMPING STARTED (t, in min.)		WATER LEVEL (ft below MP)	DRAWDOWN	DISCHARGE (gpm)	TOTALIZER (gal)
08/13/80	0958	-		159.40	-	-	-
	1130		PUMP ON				
	1150	20		-	-	17.1	-
	1151	21		-	-	-	171860.6
	1158	28	T = 11.0°C,	COND = 840	μmhos/cm @ 25°C		
	1159	29		-	-	17.1	-
	1212	42		187.23	27.83	-	-
	1222	52		187.84	28.44	-	-
	1223	53		-	-	17.1	-
	1225	55	T = 11.5°C,	COND = 870	-	-	-
	1226	56		-	-	-	172454.1
	1235	65		187.66	28.26	-	-
	1251	71		187.81	28.41	-	-
	1252	72	T = 11.0°C.	COND = 790	-	16.7	-
	1316	96		188.44	29.04	-	-
	1348	128		-	-	16.7	173822.3
	1349	129	T = 11.1°C, COND = 800	188.76	29.36	-	-
	1438	178		189.07	-	-	-
	1441	181		-	-	-	-
	1550	250		189.91	-	-	-
	1726	346		188.73	29.33	17.0	-
	1731	351	T = 12.0°C,	COND = 800	-	-	-
	2004	504		189.42	30.02	16.9	-

TABLE A-1.50 PUMPING AND DRAWDOWN DATA FOR WELL 1814 (70 SAND) (cont'd)

DATE	TIME	TIME SINCE PUMPING STARTED (t, in min.)		WATER LEVEL (ft below MP)	DRAWDOWN	DISCHARGE (gpm)	TOTALIZER (gal)
08/14/80	0156	856	T = 11.0°C, COND = 690	190.88	31.48	-	-
	0706	1166	T = 10.9°C, COND = 700	191.45	32.05	17.6	-
	1228	1488	T = 11.0°C, COND = 730	190.84	31.44	16.9	-
	1612	1712	T = 12.5°C, COND = 760	190.12	30.72	16.3	-
	2305	2125		190.95	31.55	-	-
	2313		PUMP OFF				
	2328		PUMP ON				
08/15/80	0632	2572	T = 10.9°C, COND = 680	189.81	30.41	16.6	-
	1528	3108	T = 12.0°C, COND = 560	189.55	30.15	15.9	-
08/16/80	0900	PUMP WENT OFF IN MIDDLE OF NIGHT					

TABLE A-1.51 DRAWDOWN DATA FOR OBSERVATION WELL 1815 (70 SAND)

DATE	TIME	TIME SINCE PUMPING STARTED (t, in min.)	WATER LEVEL (ft below MP)	DRAWDOWN (ft)
08/13/80	1102	-	161.68	-
	1130	PUMP ON IN WELL 1814		
	1133	3	161.71	.03
	1135.5	5.5	161.78	.10
	1137.5	7.5	161.82	.14
	1139	9	161.84	.16
	1144	14	161.89	.21
	1149	19	161.91	.23
	1156	26	161.94	.26
	1205	35	161.96	.28
	1216	46	162.00	.32
	1230	60	161.98	.30
	1245	75	162.03	.35
	1248	78	162.04	.36
	1259	89	162.04	.36
	1321	111	162.08	.40
	1348	138	162.07	.39
	1448	198	162.16	.48
	1544	254	162.19	.51
	1736	366	162.26	.58
	2012	522	162.37	.69
08/14/80	0148	858	162.54	.86
	0716	1186	162.65	.97
	1240	1510	162.72	1.04
	1559	1719	162.71	1.03
	2253	2133	162.75	1.07
08/15/80	0623	2583	162.87	1.19
	1537	3137	162.95	1.27

TABLE A-1.52 DRAWDOWN DATA FOR OBSERVATION WELL 1816 (70 SAND)

DATE	TIME	TIME SINCE PUMPING STARTED (t, in min.)	WATER LEVEL (ft below MP)	DRAWDOWN (ft)
08/13/80	1047	-	157.28m	-
	1050	-	157.42e	-
	1130	PUMP ON	-	-
	1131	1	157.25	-.03
	1132	2	157.34	.06
	1133	3	157.34	.06
	1134	4	157.42	.14
	1135	5	157.42	.14
	1136	6	157.61	.23
	1137	7	157.59	.21
	1138	8	157.67	.39
	1139	9	157.74	.45
	1140	10	158.99	.71
	1143	13	158.30	1.02
	1146	16	158.45	1.17
	1152	22	158.41	1.13
	1157	27	158.61	1.33
	1207	37	157.80	.52
	1217	47	157.82	.54
	1227	57	157.89	.61
	1242	72	157.97	.69
	1257	87	158.11	.83
	1313	103	158.10	.82
	1350	140	158.26	.98
	1443	193	158.46	1.18
	1537	247	158.55	1.27
	1750	380	159.01	1.73
	2002	512	159.02	1.74

TABLE A-1.52 DRAWDOWN DATA FOR OBSERVATION WELL 1816 (70 SAND) (cont'd)

DATE	TIME	TIME SINCE PUMPING STARTED (t, in min.)	WATER LEVEL (ft below MP)	DRAWDOWN (ft)
08/14/80	0202	872	159.37	2.09
	0710	1180	158.99	1.71
	1231	1501	159.53	2.25
	1602	1711	159.39	2.11
	2250	2119	159.49	2.21
08/15/80	0629	2578	160.15	2.87
	1527	3116	159.71	2.43
08/16	1600	-	158.58	-

NOTES:

e = 1000' Electric Tape used

m = Metal Tape used

TABLE A-1.53 DRAWDOWN DATA FOR OBSERVATION WELL 1817 (70 SAND)

DATE	TIME	TIME SINCE PUMPING STARTED (t, in min.)	WATER LEVEL (ft below MP)	DRAWDOWN (ft)
08/13/80	1112	-	165.09	-
	1130	PUMP ON IN WELL 1814		-
	1141	11	165.15	.06
	1146.5	16.5	165.16	.07
	1153	23	165.18	.09
	1202	32	165.19	.10
	1220	50	165.19	.10
	1237	67	165.19	.10
	1256	86	165.19	.10
	1319	109	165.20	.11
	1353	143	165.19	.10
	1444	194	165.19	.10
	1601	271	165.20	.11
	1741	371	165.18	.09
	1958	508	165.21	.12
08/14/80	0206	876	165.20	.11
	0703	1179	165.26	.17
	1237	1513	165.27	.18
	1608	1724	165.18	.09
	2258	2134	165.20	.11
08/15/80	0627	2583	165.24	.15
	1532	3128	165.28	.19

TABLE A-1.54 DRAWDOWN DATA FOR OBSERVATION WELL 1823 (68 SAND)

DATE	TIME	TIME SINCE PUMPING STARTED (t, in min.)	WATER LEVEL (ft below MP)	DRAWDOWN (ft)
08/13/80	1054	-	112.61m	-
	1054		112.71e#3	-
	1105	-	112.50e#2	-
	1130	PUMP ON	-	-
	1131	1	111.62	-.99
	1134	4	110.86	-1.75
	1136.5	6.5	108.95	-3.66
	1142	12	108.95	-3.66
	1148	18	111.90	-.71
	1154	24	112.70	.09
	1159	29	112.71	.10
	1209	39	112.72	.11
	1220	50	112.59	-.02
	1230	60	112.66	.05
	1237	67	112.37	-.24
	1253	83	112.57	-.04
	1302	92	112.49	-.12
	1315	105	112.52	-.09
	1353	143	112.52	-.09
	1444	194	112.52	-.09
	1540	250	112.50	-.11
	1738	368	112.48	-.13
	2009	519	112.49	-.12
08/14/80	0152	862	112.50	-.11
	0713	1183	112.51	-.10
	1226	1496	112.50	-.11
	1605	1715	112.42	-.19
	2301	2131	112.48	-.13
8/15/80	0637	2589	112.36	-.25
	1529	3121	112.15	-.46

NOTES: e = Electric Tape used m = Metal Tape used

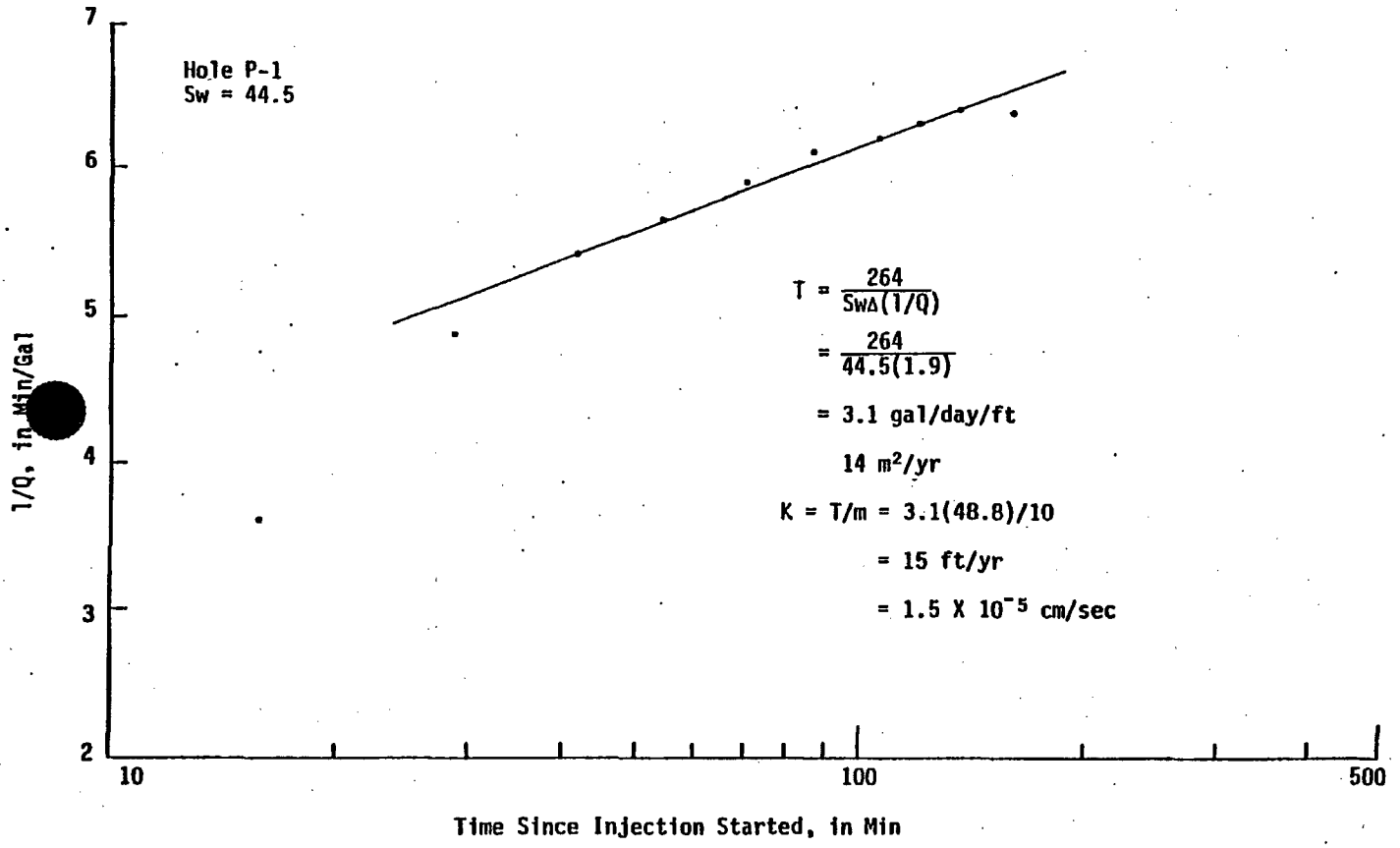


FIGURE A-1.1 CONSTANT HEAD TEST FOR HOLE P-1 (LOWER MUDSTONE AND E COAL)

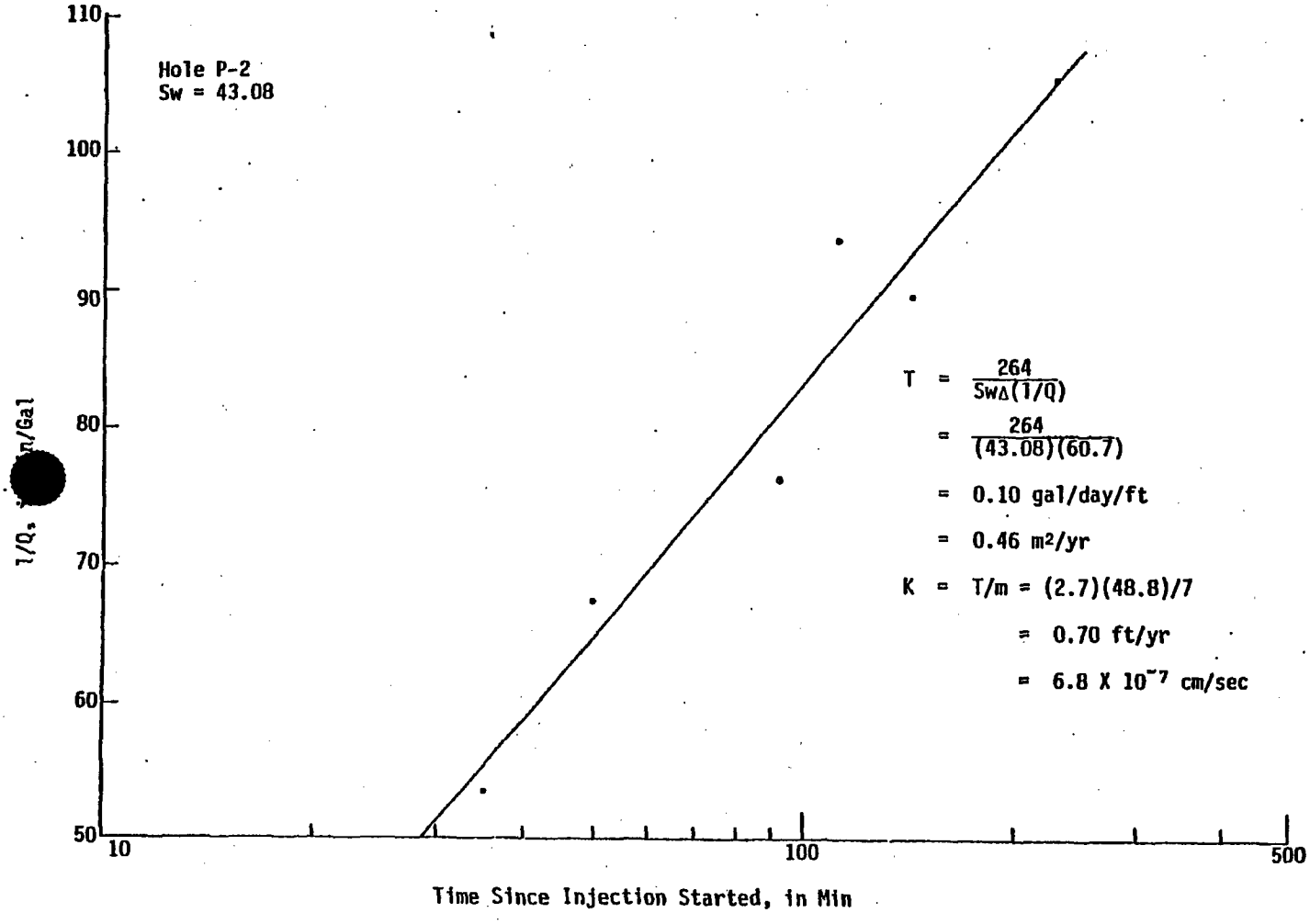


FIGURE A-1.2 CONSTANT HEAD TEST FOR HOLE P-2 (LOWER MUDSTONE AND E COAL)

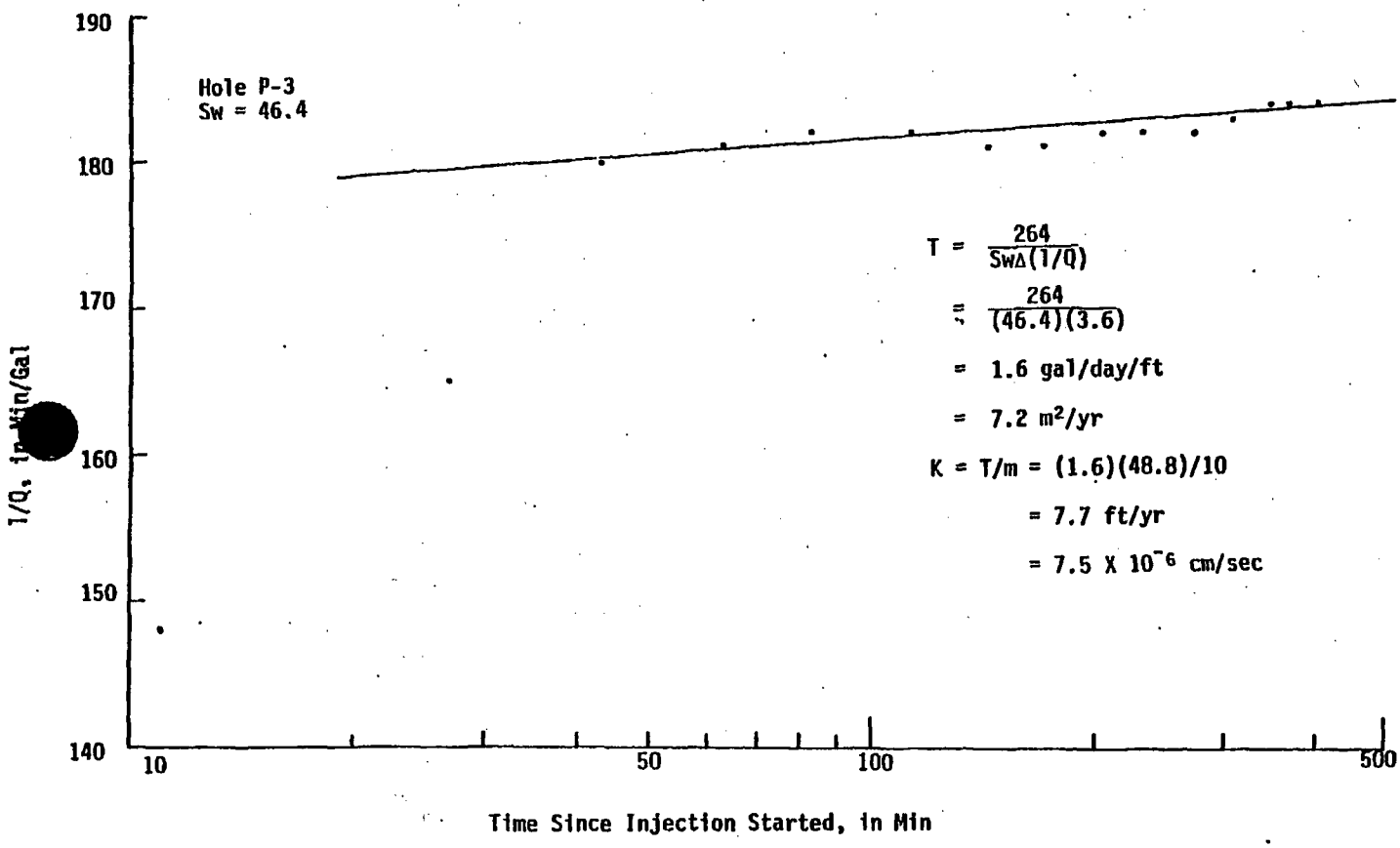


FIGURE A-1.3 CONSTANT HEAD TEST FOR HOLE P-3 (LOWER MUDSTONE)

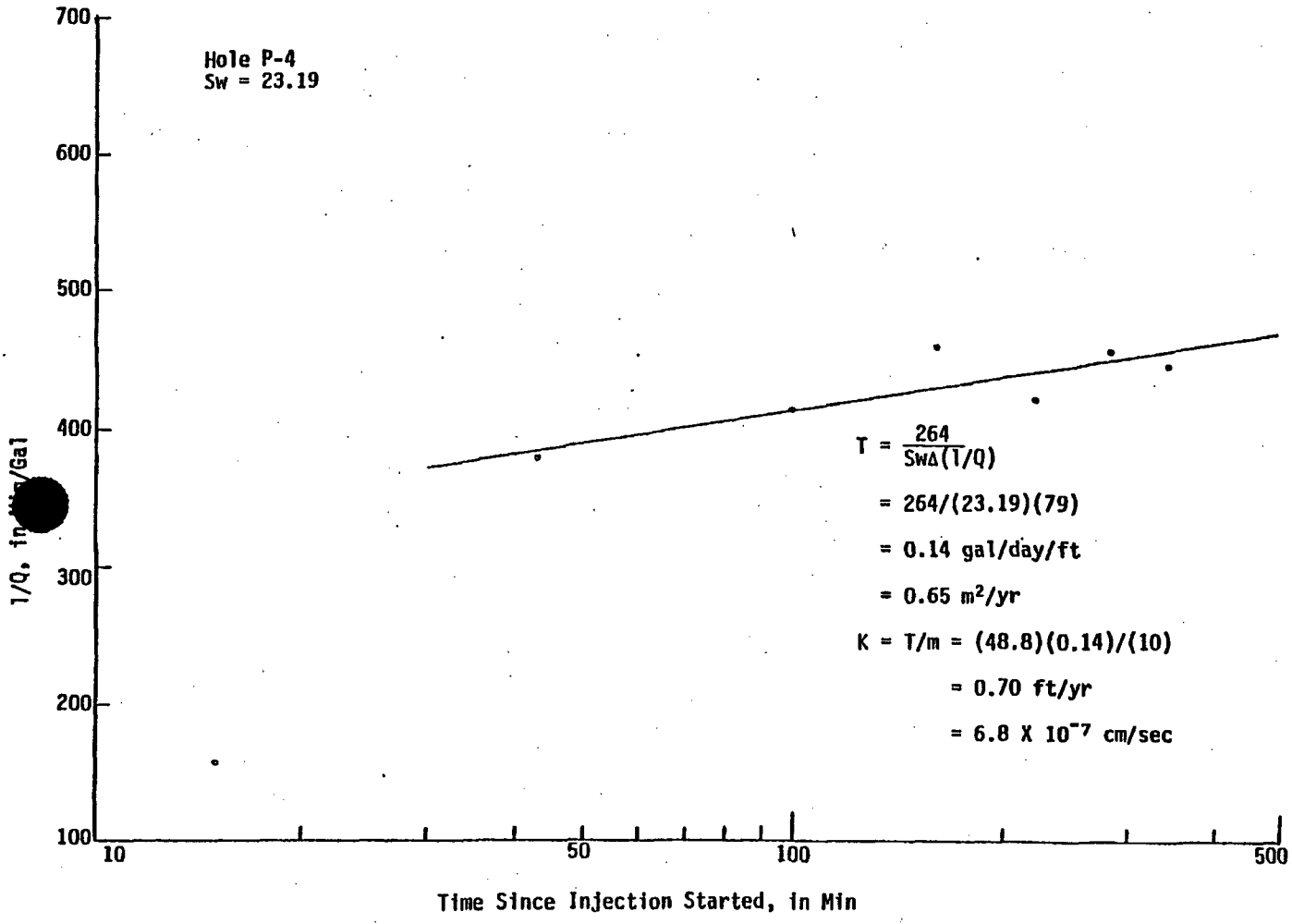


FIGURE A-1.4 CONSTANT HEAD TEST FOR HOLE P-4 (LOWER MUDSTONE AND E COAL)

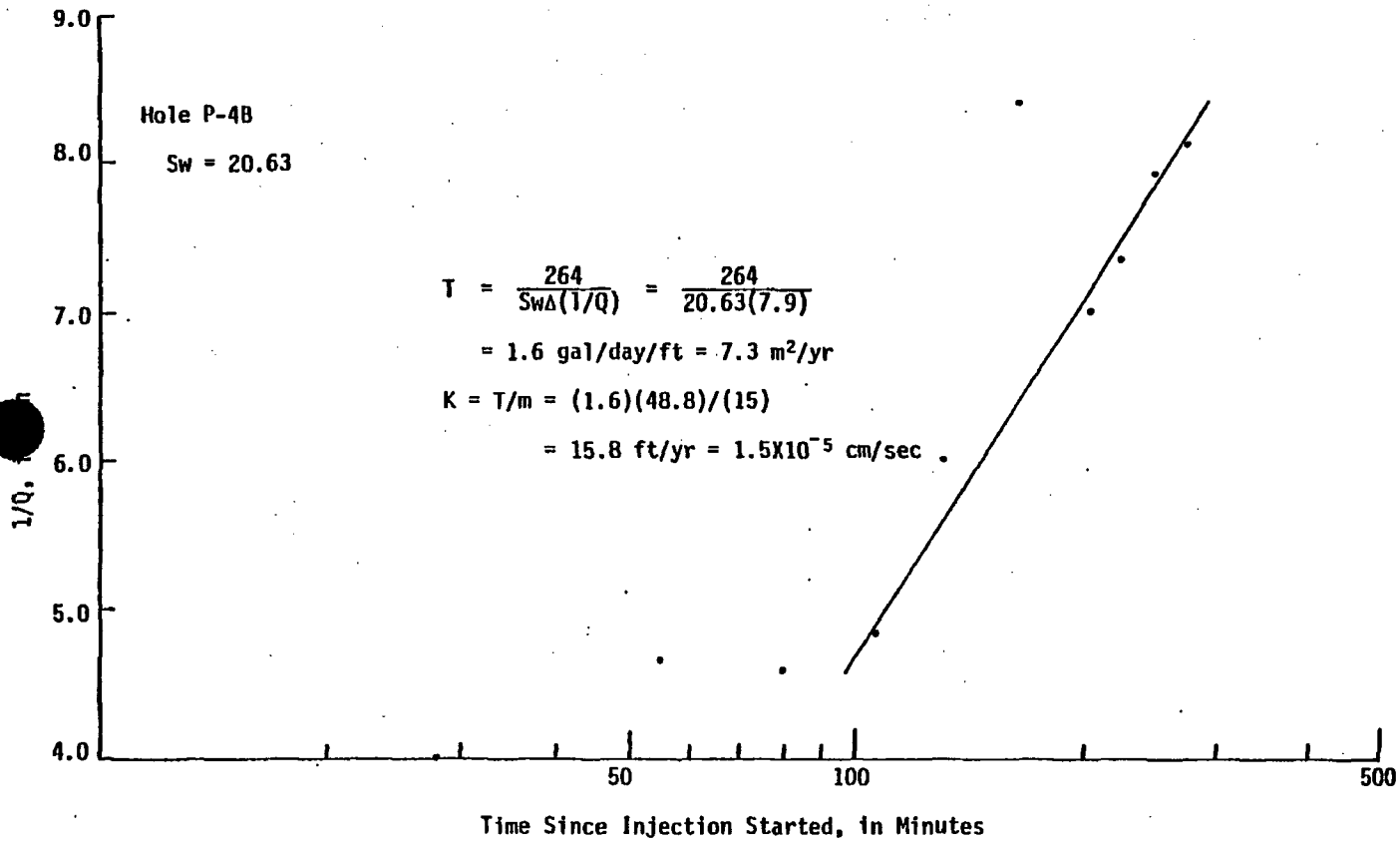


FIGURE A-1. 5 CONSTANT HEAD TEST FOR HOLE P-4B

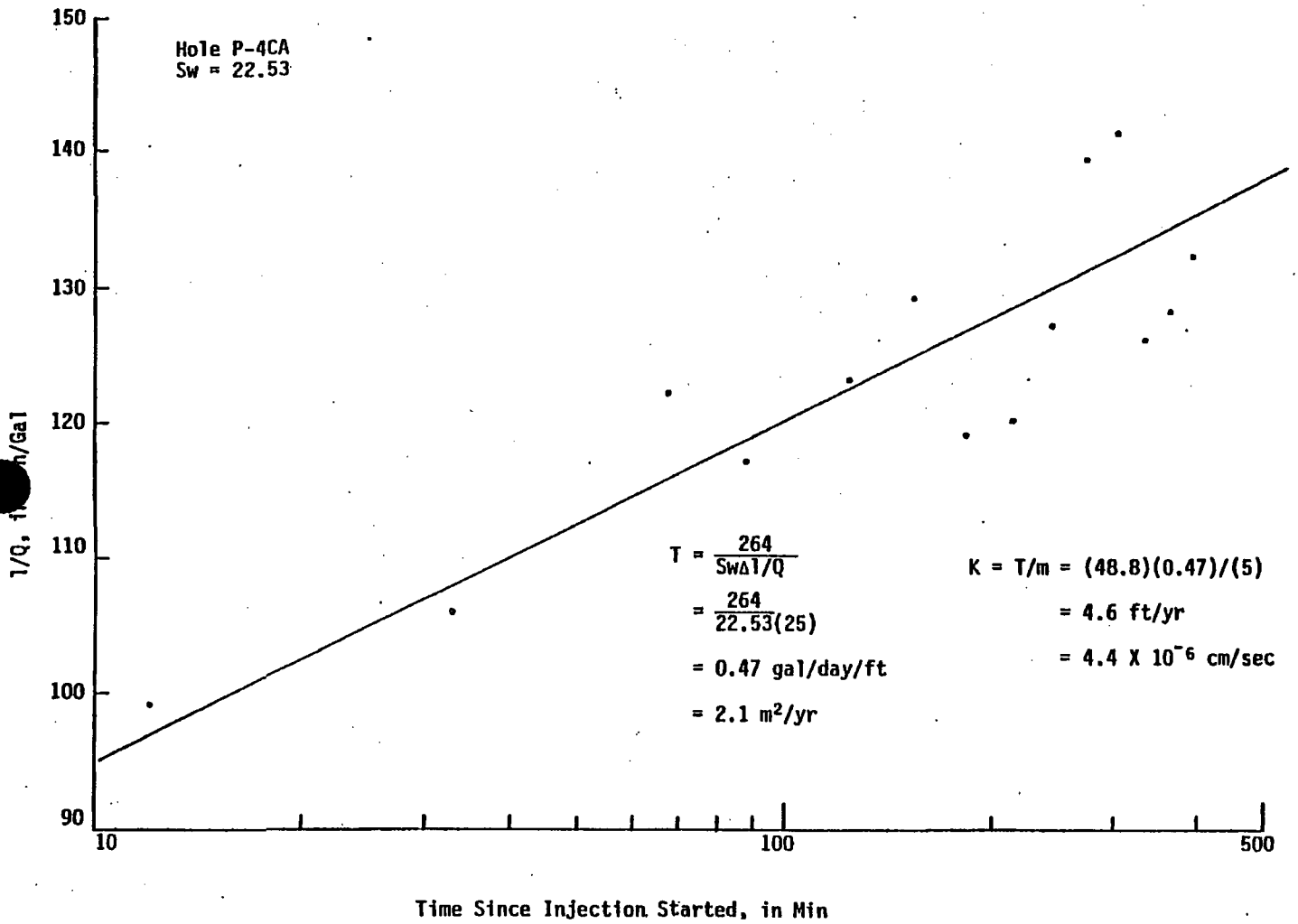
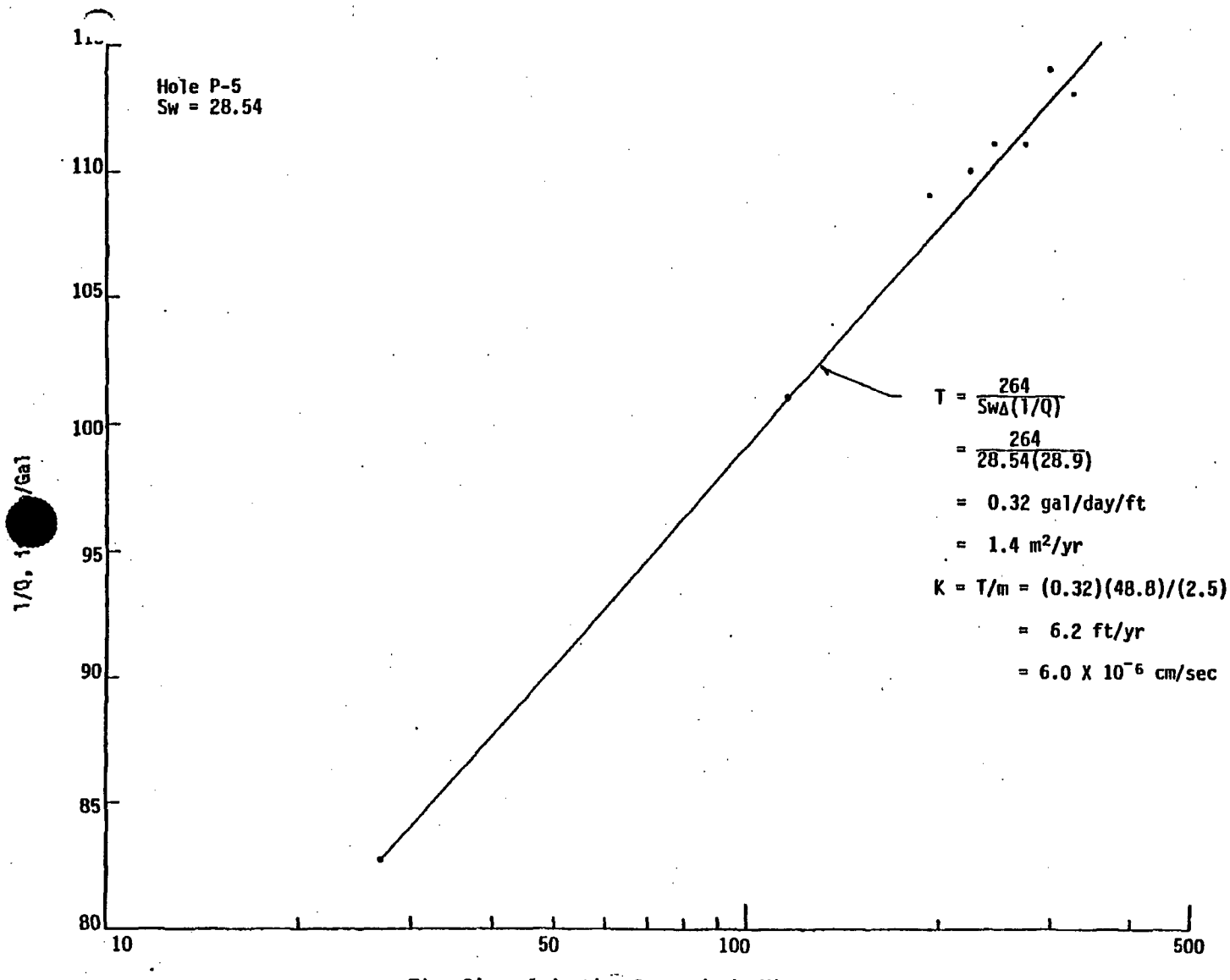


FIGURE A-1.7 CONSTANT HEAD TEST FOR HOLE P-4CA (UPPER MUDSTONE)


Hole P-5
Sw = 28.54
1/Q, 1/Gal
110
105
100
95
90
85
80
10
50
100
500
Time Since Injecti Started, in Min
T = 264 / SwΔ(1/Q)
= 264 / 28.54(28.9)
= 0.32 gal/day/ft
= 1.4 m²/yr
K = T/m = (0.32)(48.8)/(2.5)
= 6.2 ft/yr
= 6.0 X 10⁻⁶ cm/sec

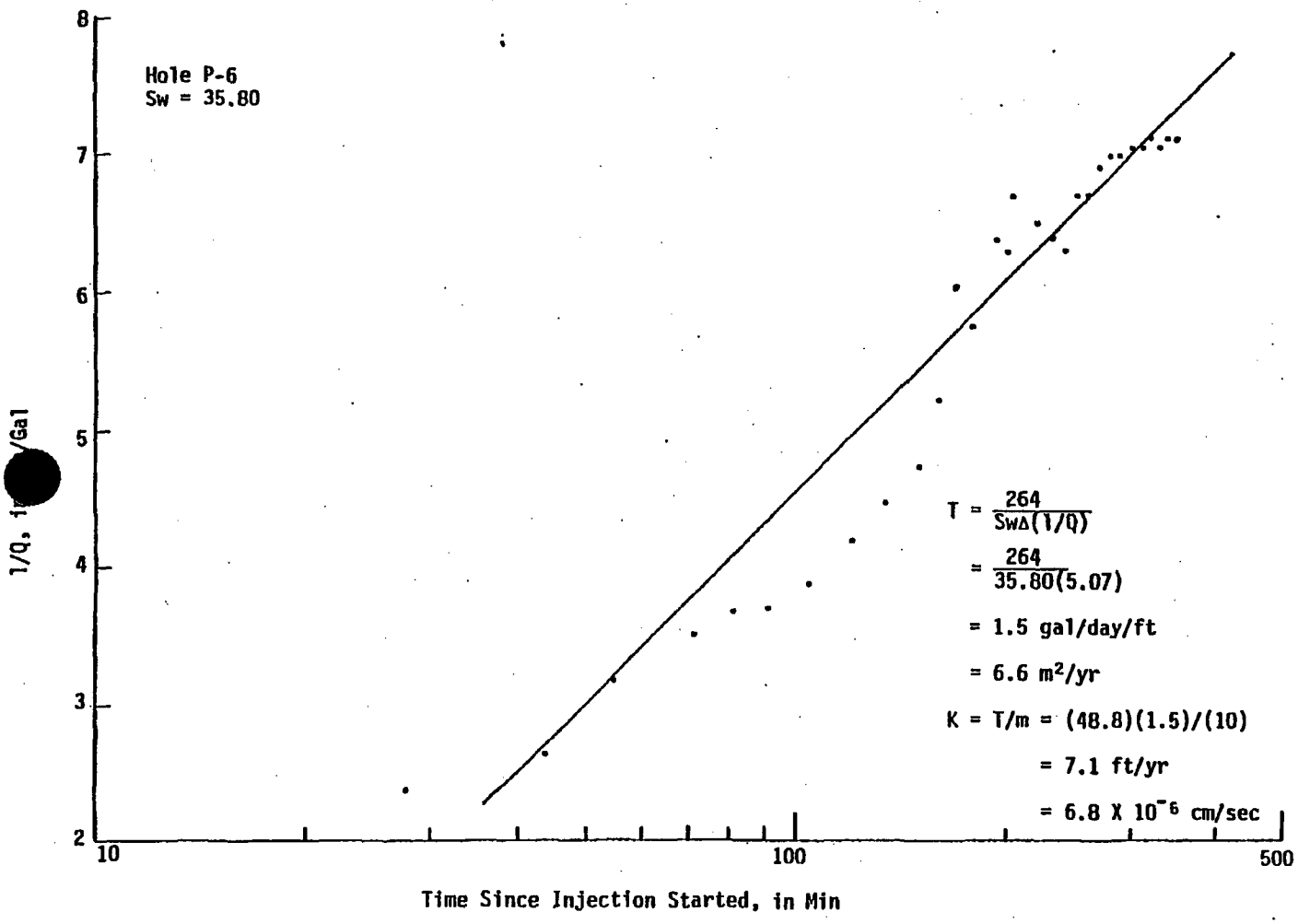


FIGURE A-1.9 CONSTANT HEAD TEST FOR HOLE P-6 (UPPER SANDSTONE)

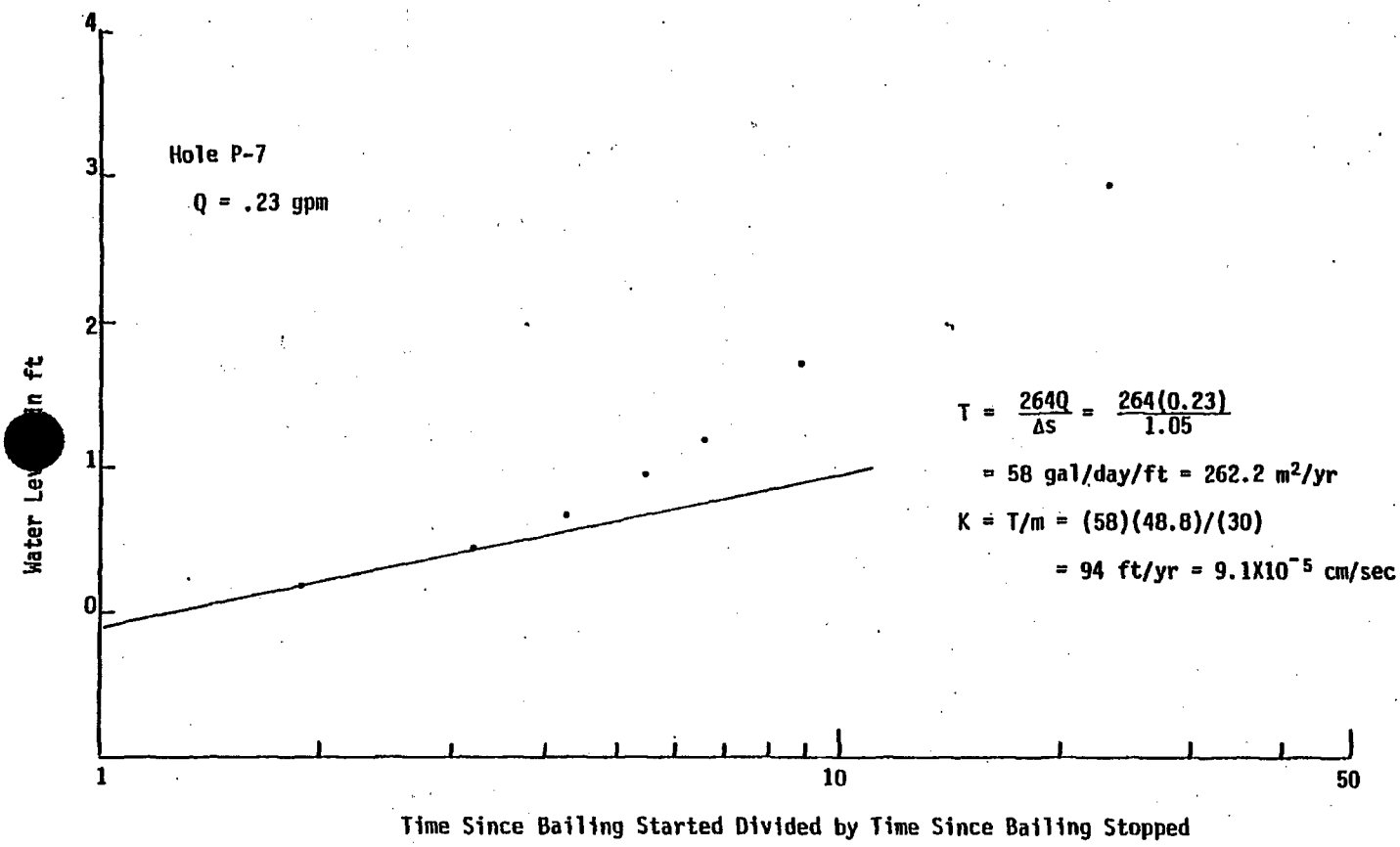


FIGURE A-1.10 . RECOVERY TEST FOR HOLE P-7 (70 SAND)

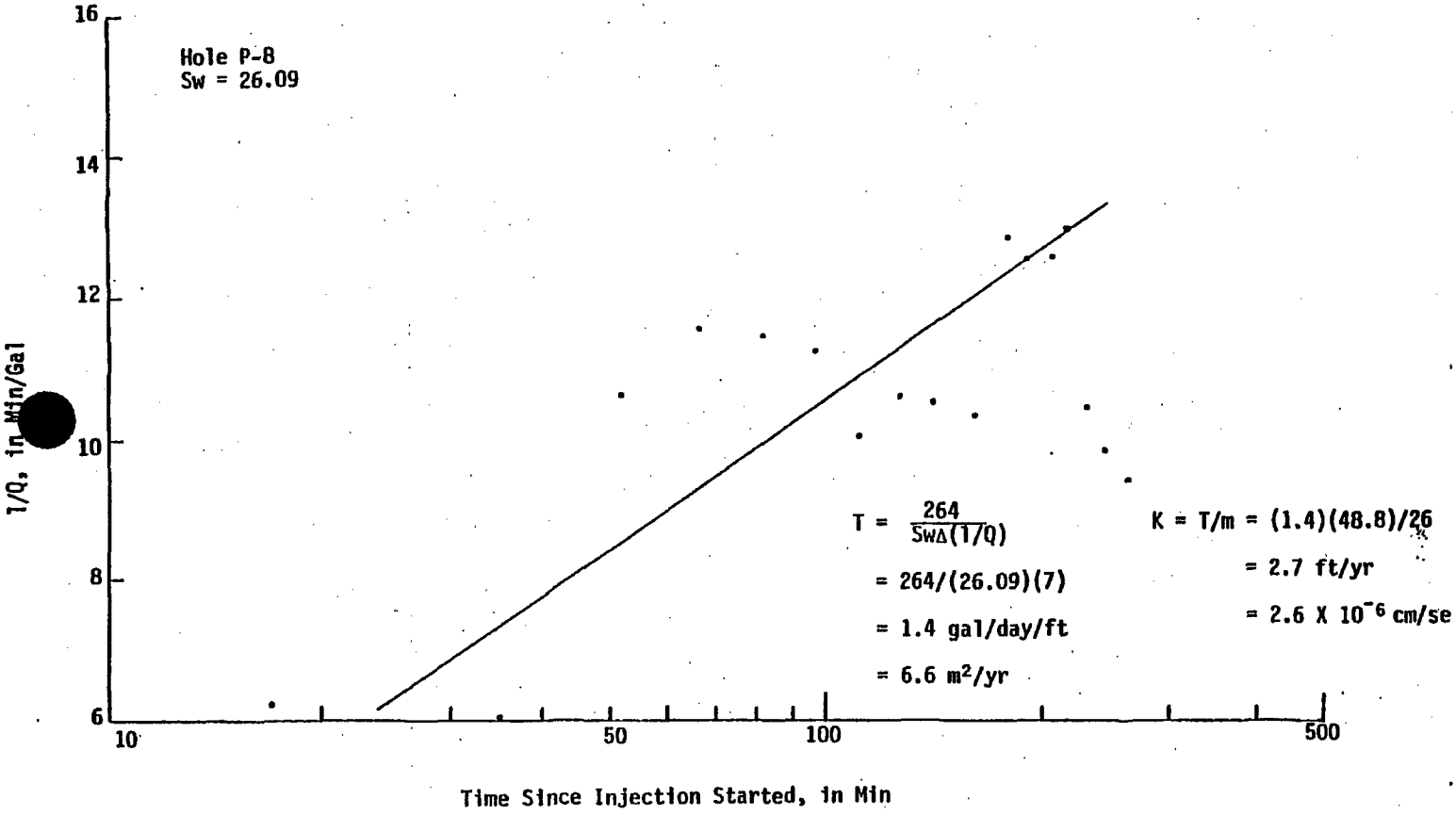


FIGURE A-1.11 CONSTANT HEAD TEST FOR HOLE P-8 (LOWER MUDSTONE AND E COAL)

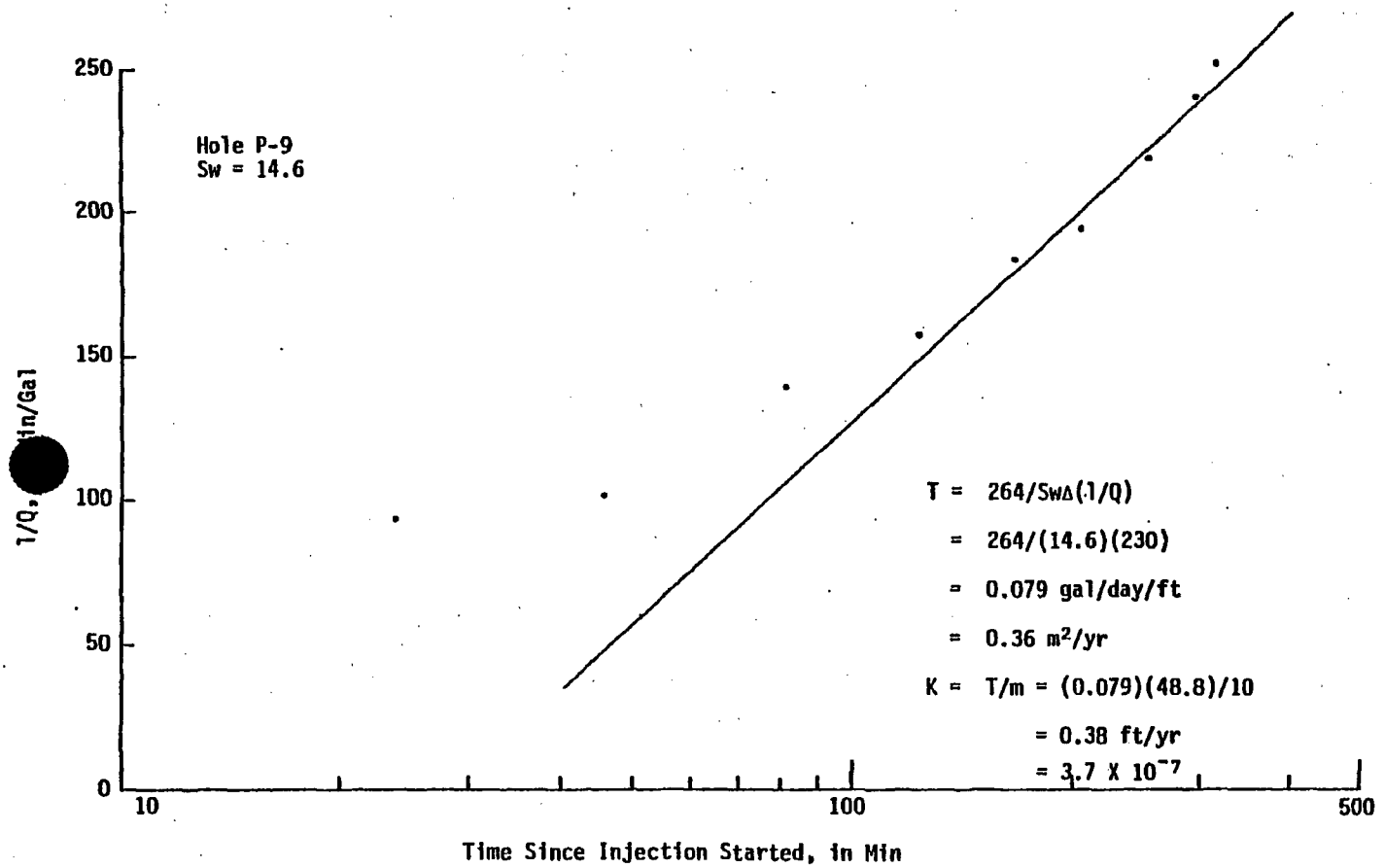


FIGURE A-1.12 CONSTANT HEAD TEST FOR HOLE P-9 (LOWER MUDSTONE AND E COAL)

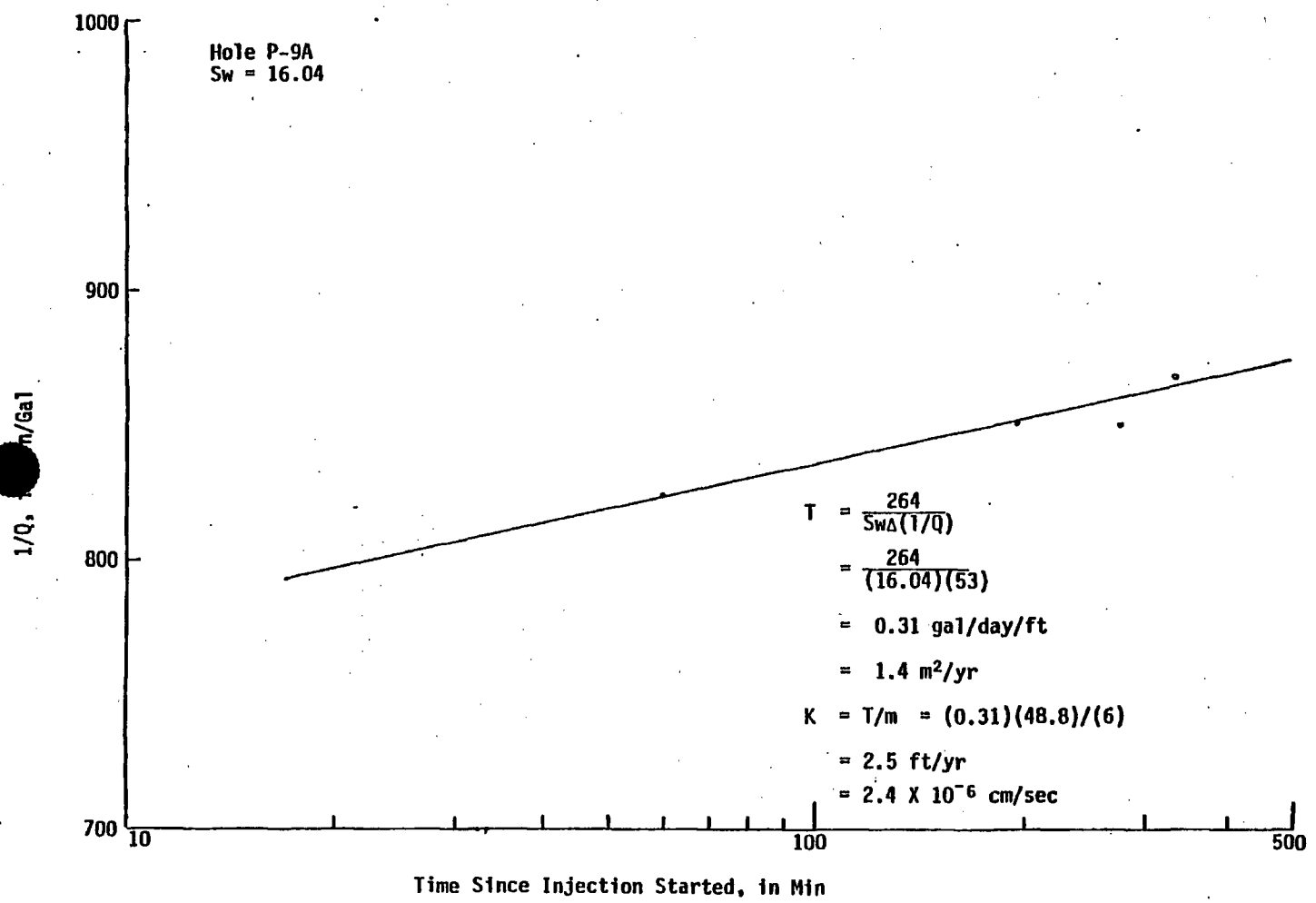


FIGURE A-1.13 CONSTANT HEAD TEST FOR HOLE P-9A (UPPER MUDSTONE)

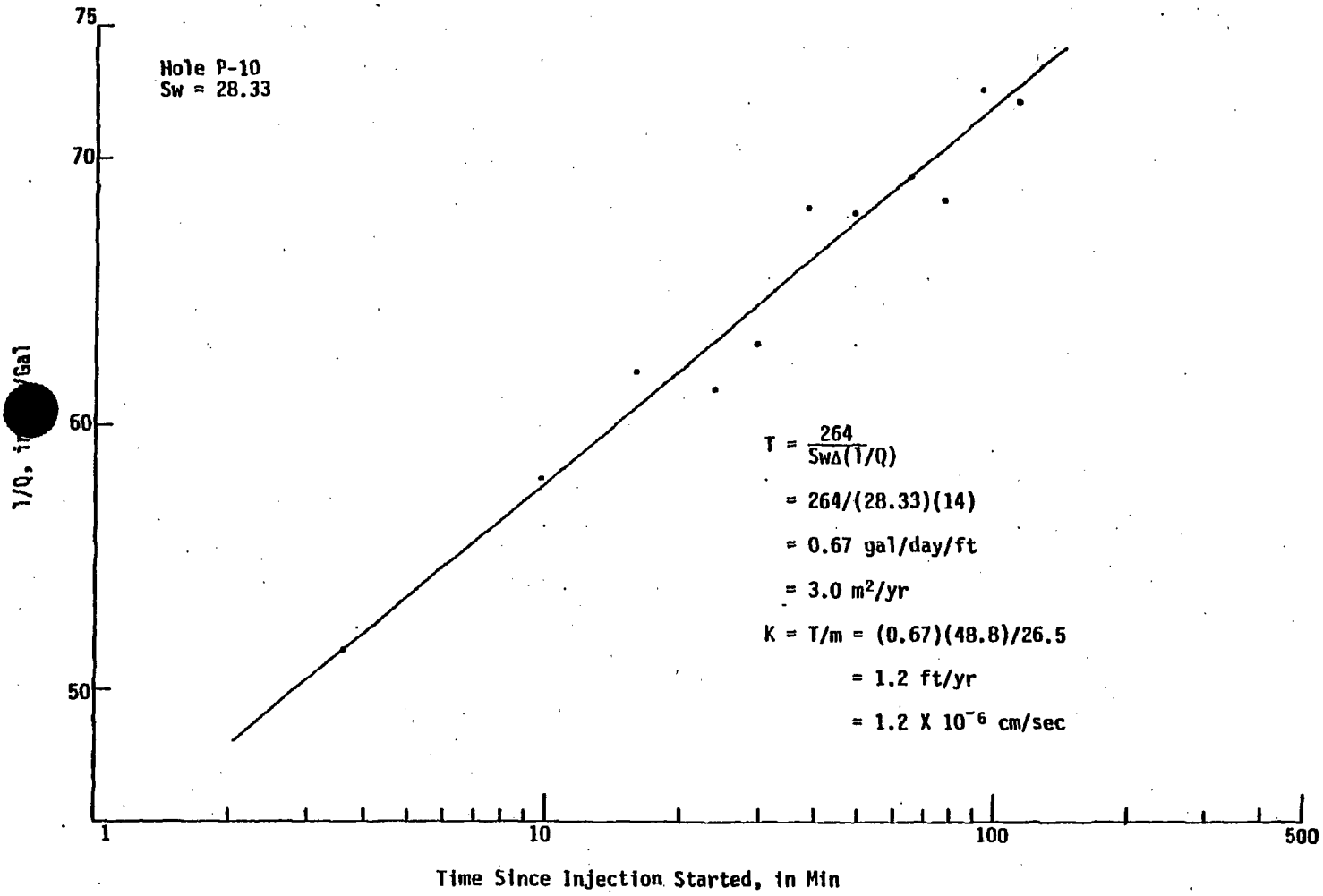


FIGURE A-1 14 CONSTANT HEAD TEST FOR HOLE P-10 (LOWER MUDSTONE AND E COAL)

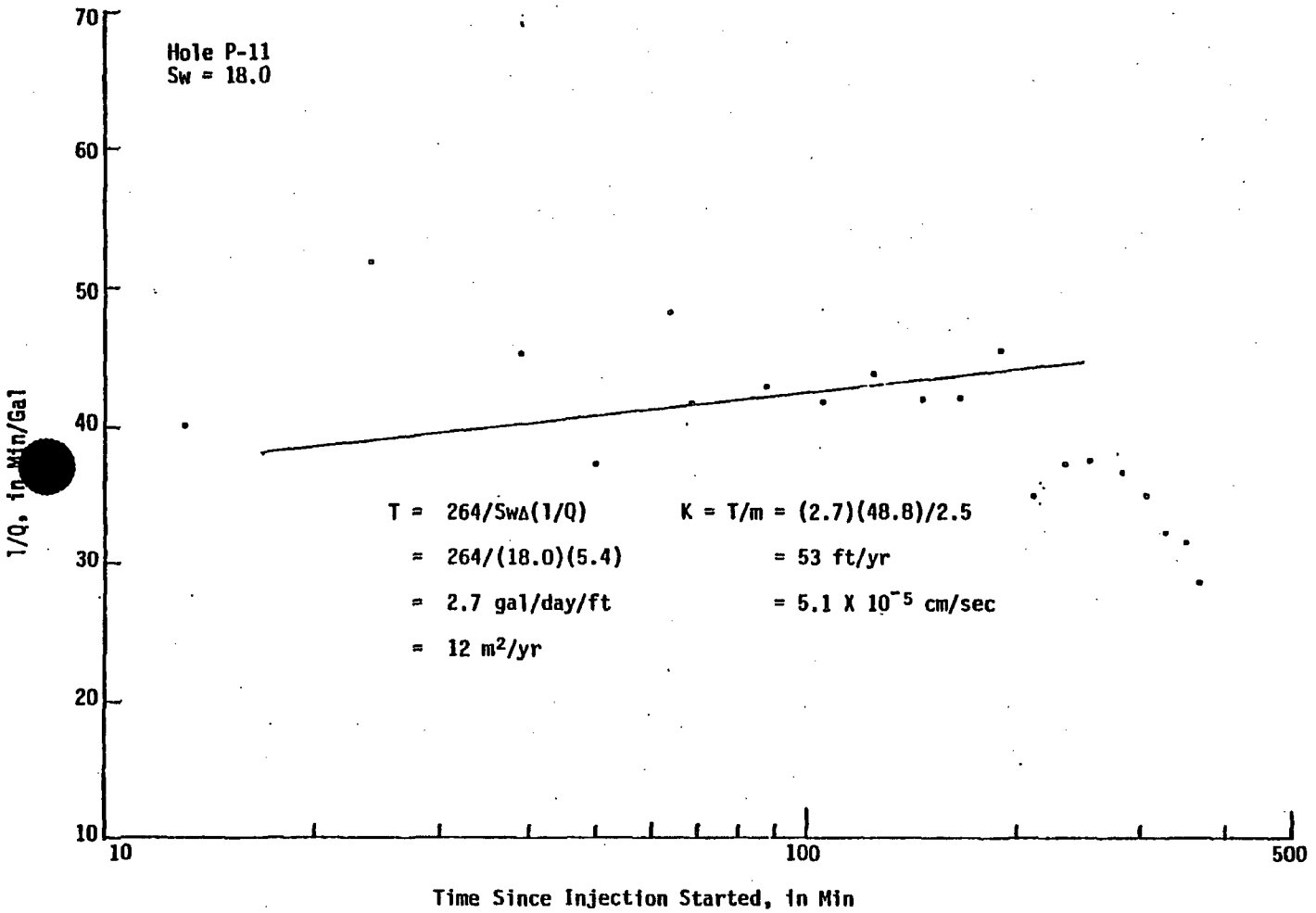


FIGURE A-1.15 CONSTANT HEAD TEST FOR HOLE P-11 (E COAL)

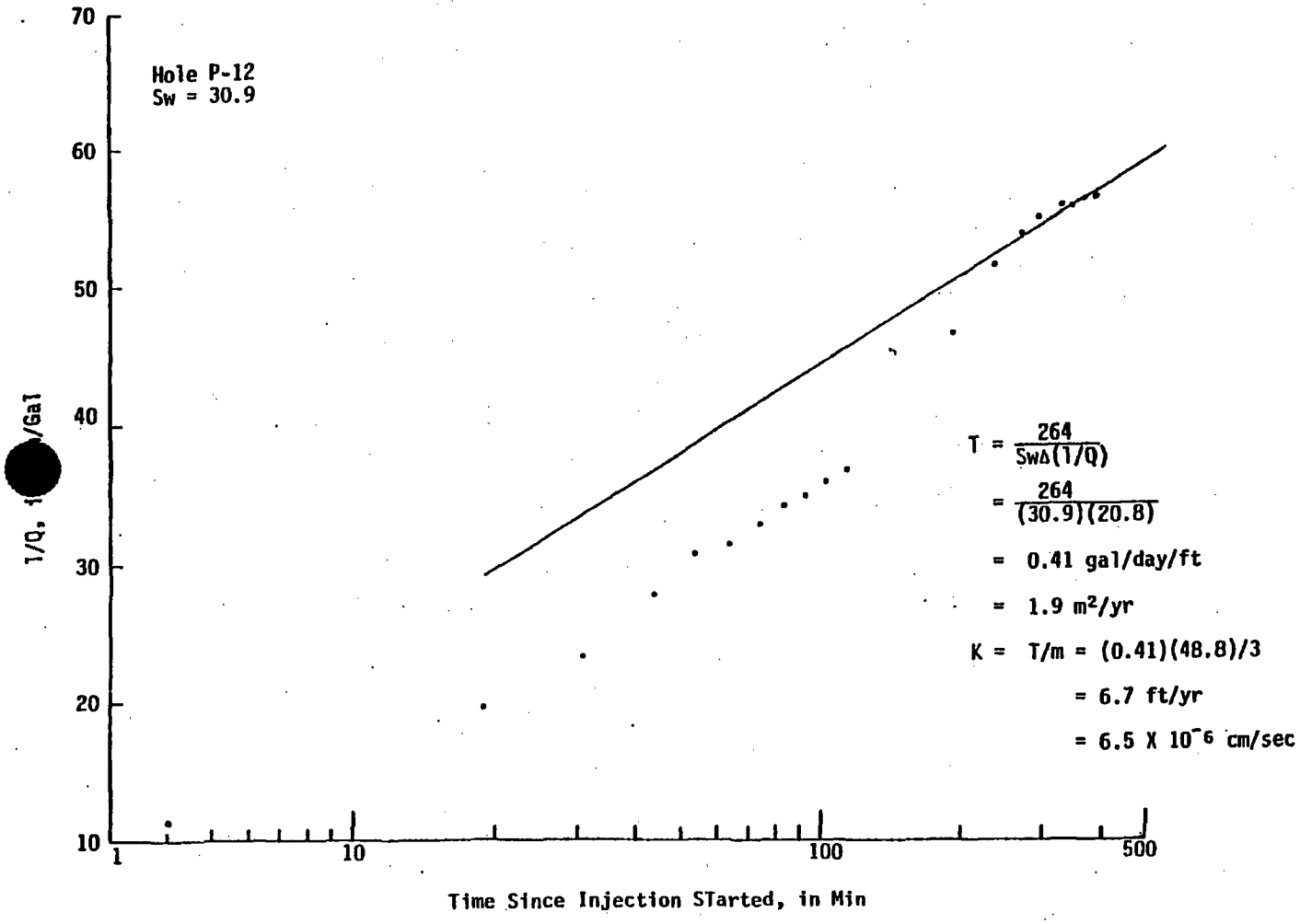


FIGURE A-1.16 CONSTANT HEAD TEST FOR HOLE P-12 (E COAL)

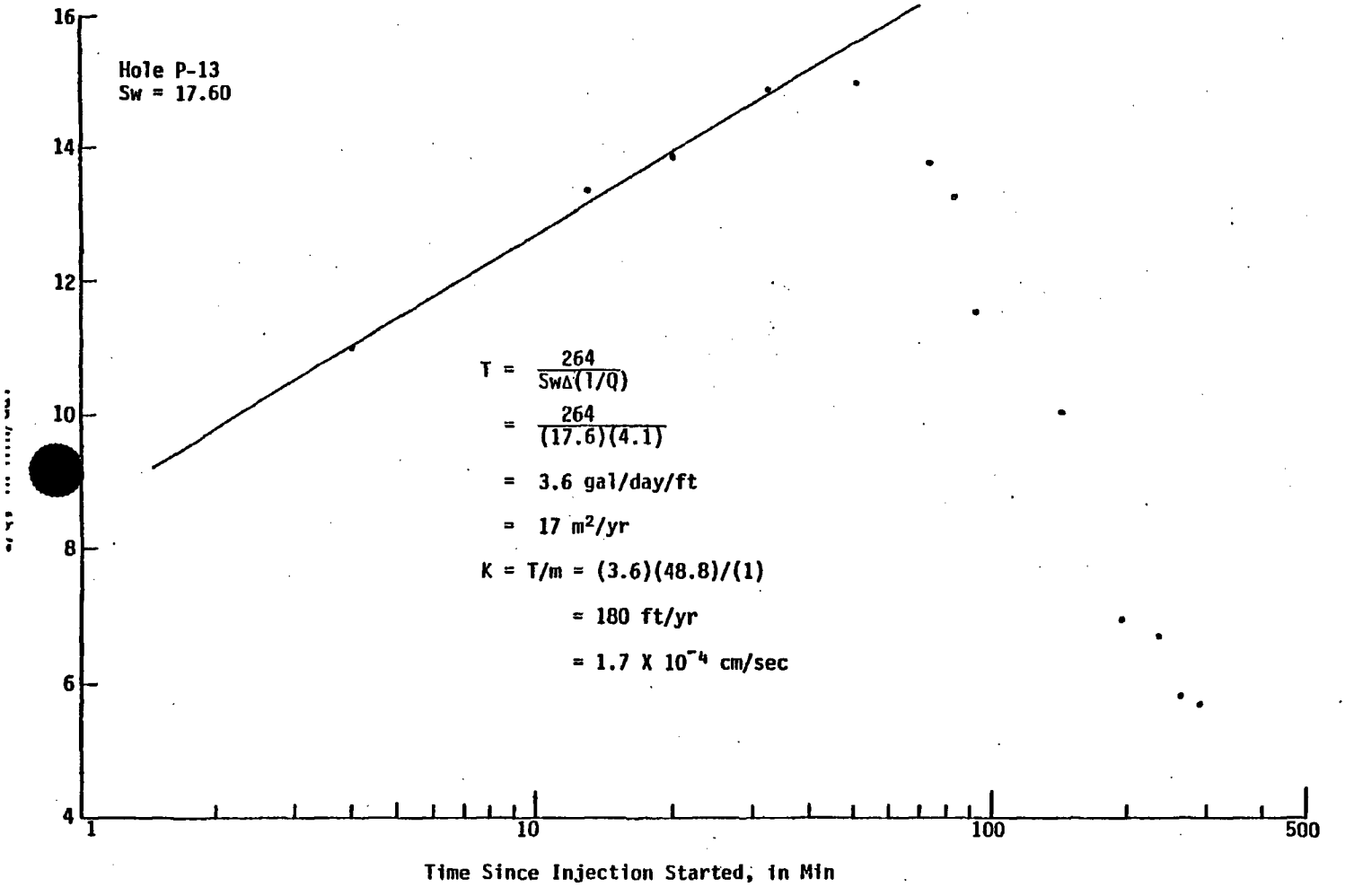
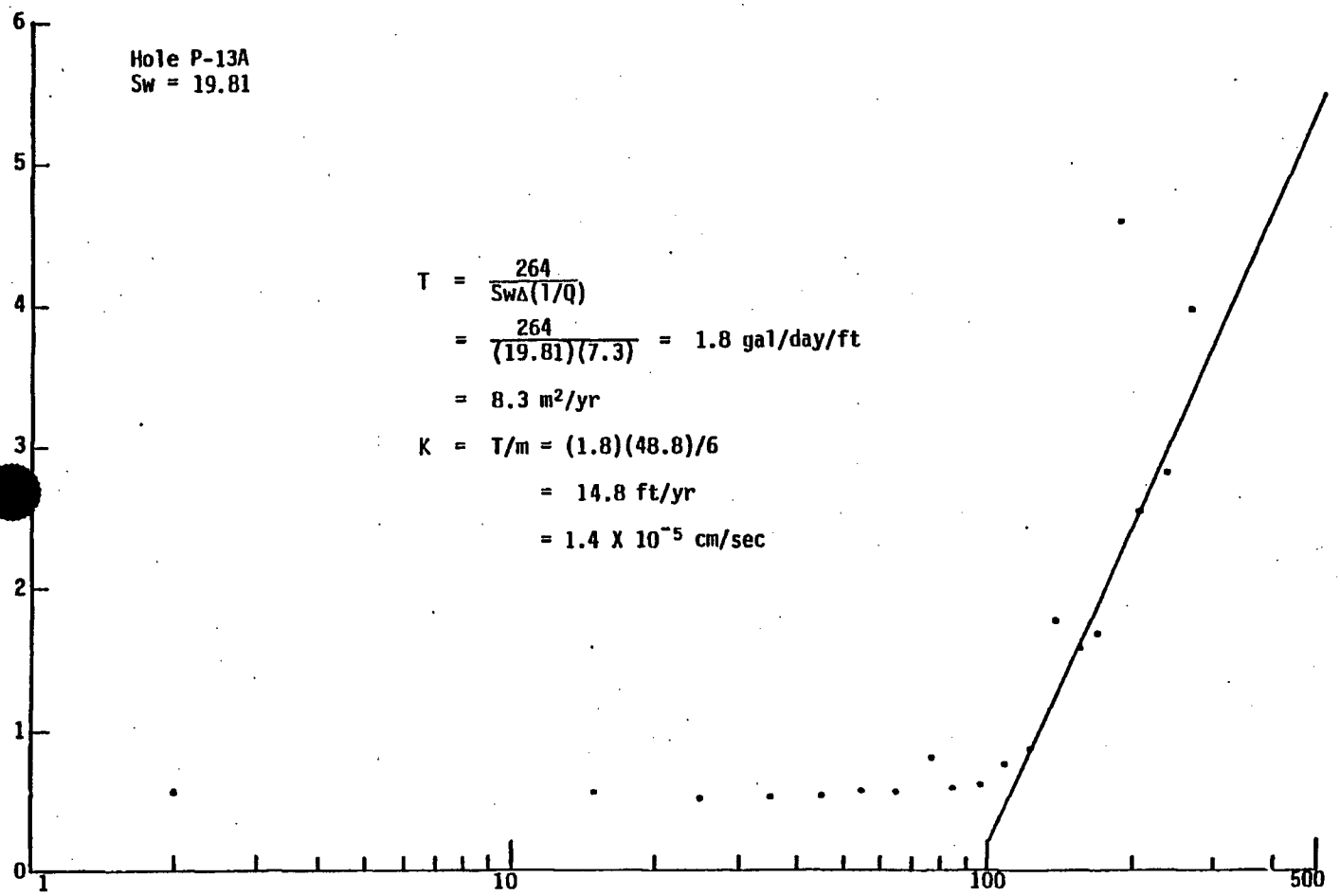


FIGURE A-1.17 CONSTANT HEAD TEST FOR HOLE P-13 (UPPER MUDSTONE)



$$T = \frac{264}{Sw\Delta(1/Q)}$$

$$= \frac{264}{(19.81)(7.3)} = 1.8 \text{ gal/day/ft}$$

$$= 8.3 \text{ m}^2/\text{yr}$$

$$K = T/m = (1.8)(48.8)/6$$

$$= 14.8 \text{ ft/yr}$$

$$= 1.4 \times 10^{-5} \text{ cm/sec}$$

FIGURE A-1.18 CONSTANT HEAD TEST FOR HOLE P-13A (E COAL)

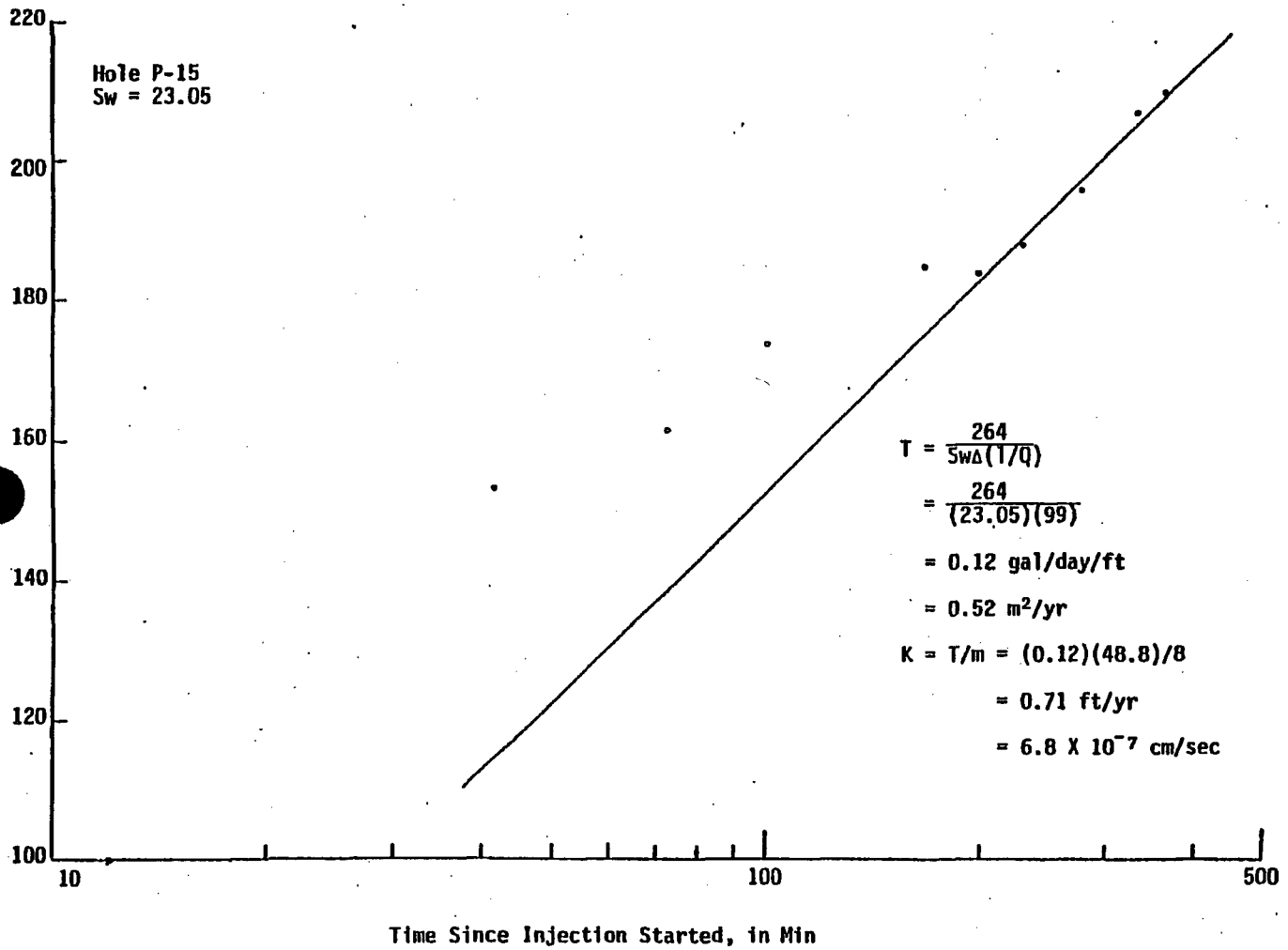


FIGURE A-1.19 CONSTANT HEAD TEST FOR HOLE P-15 (LOWER MUDSTONE AND E COAL)

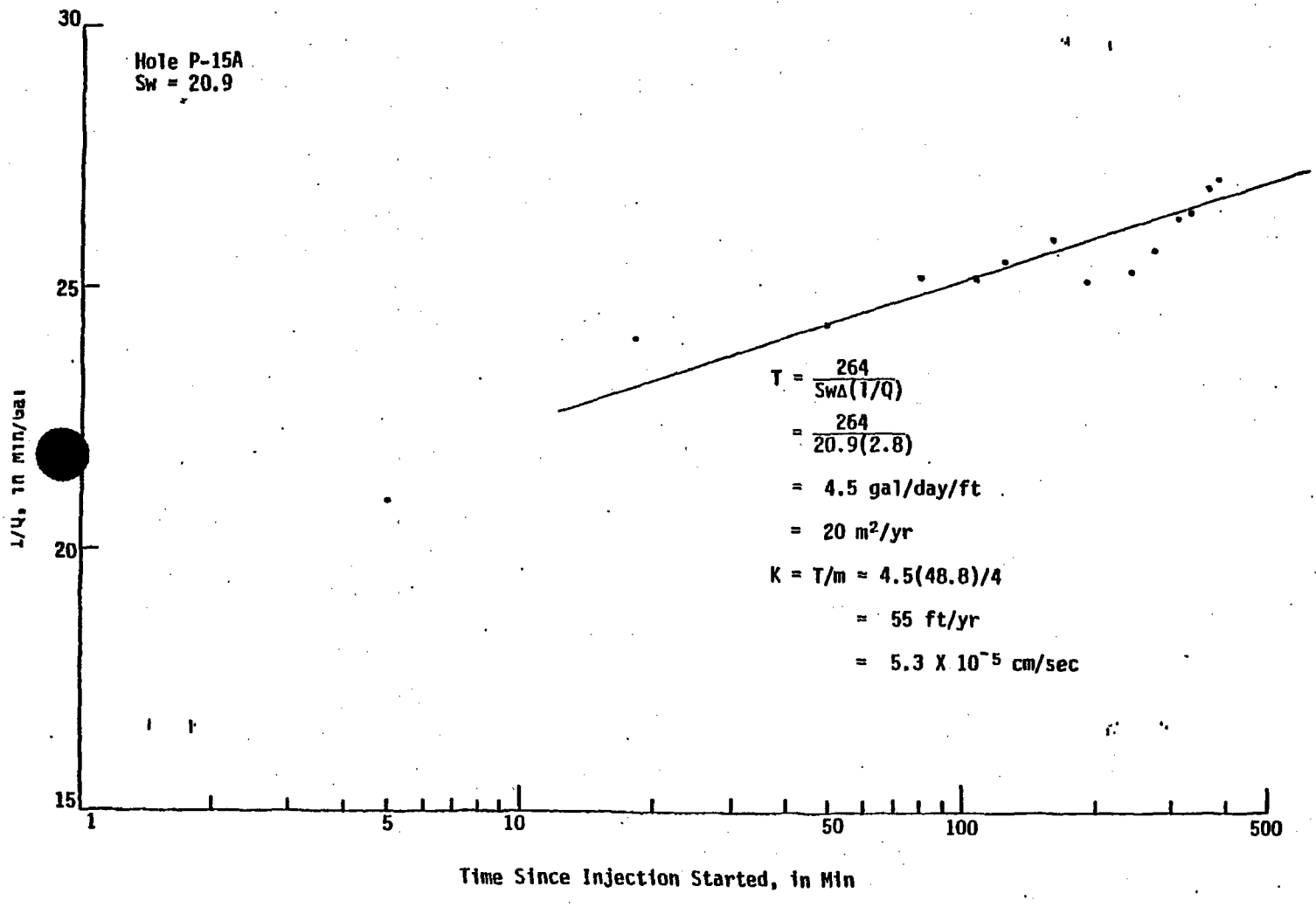


FIGURE A-1.20 CONSTANT HEAD TEST FOR HOLE P-15A (UPPER MUDSTONE)

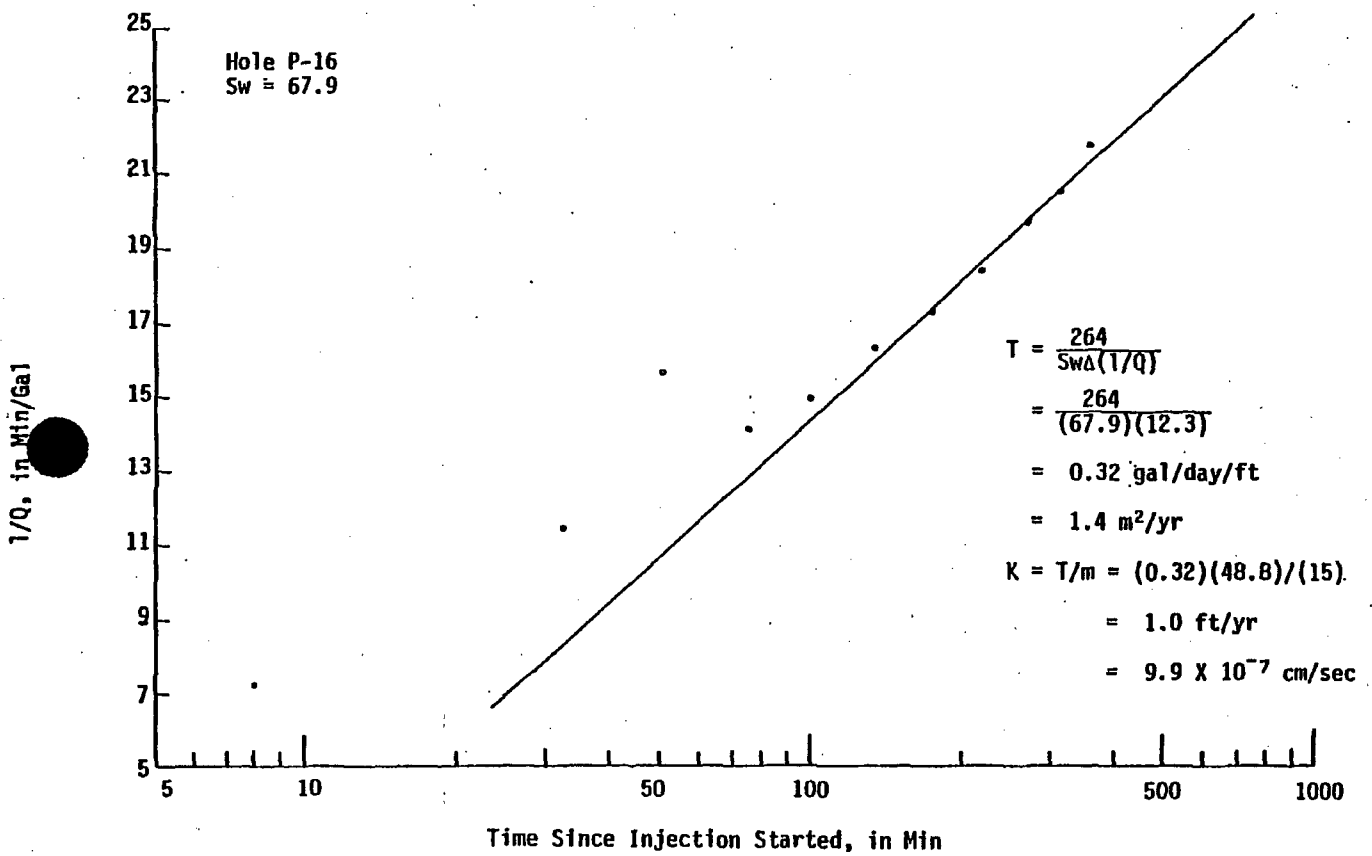


FIGURE A-1.21 CONSTANT HEAD TEST FOR HOLE P-16 (UPPER 70 SAND)

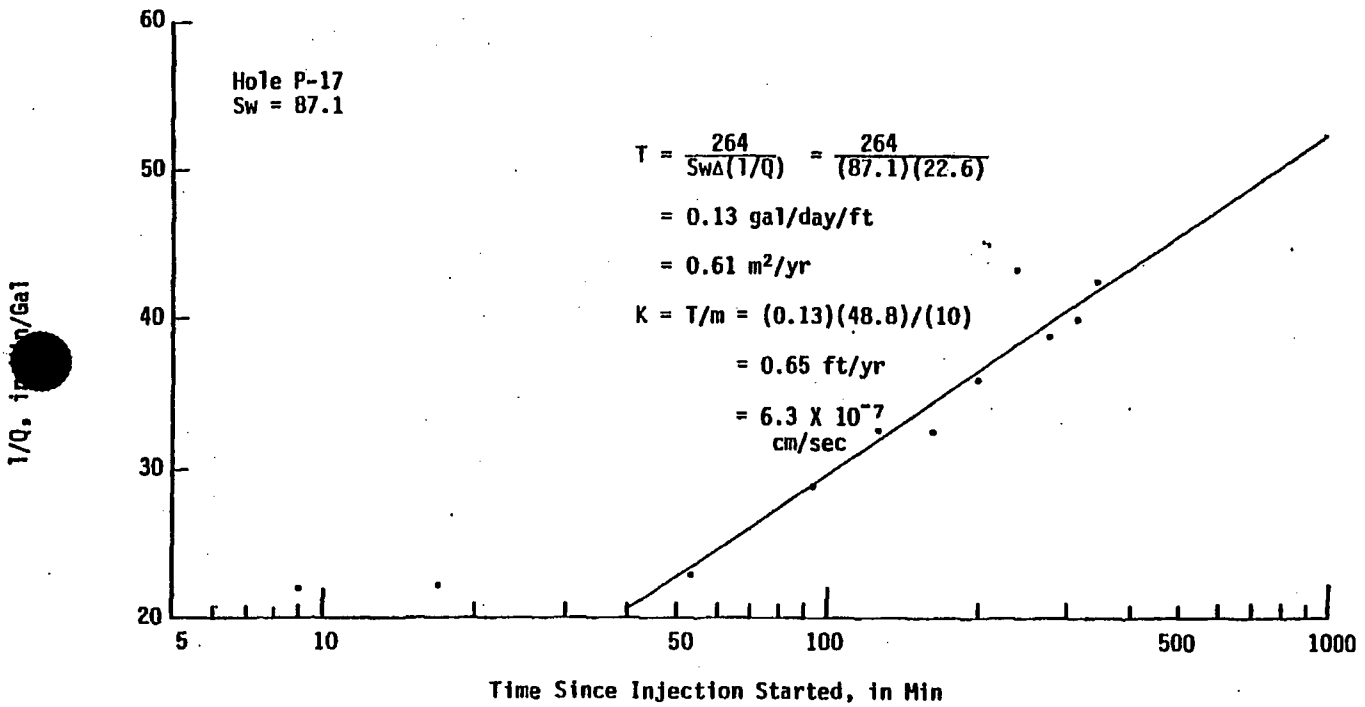


FIGURE A-1.22 CONSTANT HEAD TEST FOR HOLE P-17 (UPPER 70 SAND)

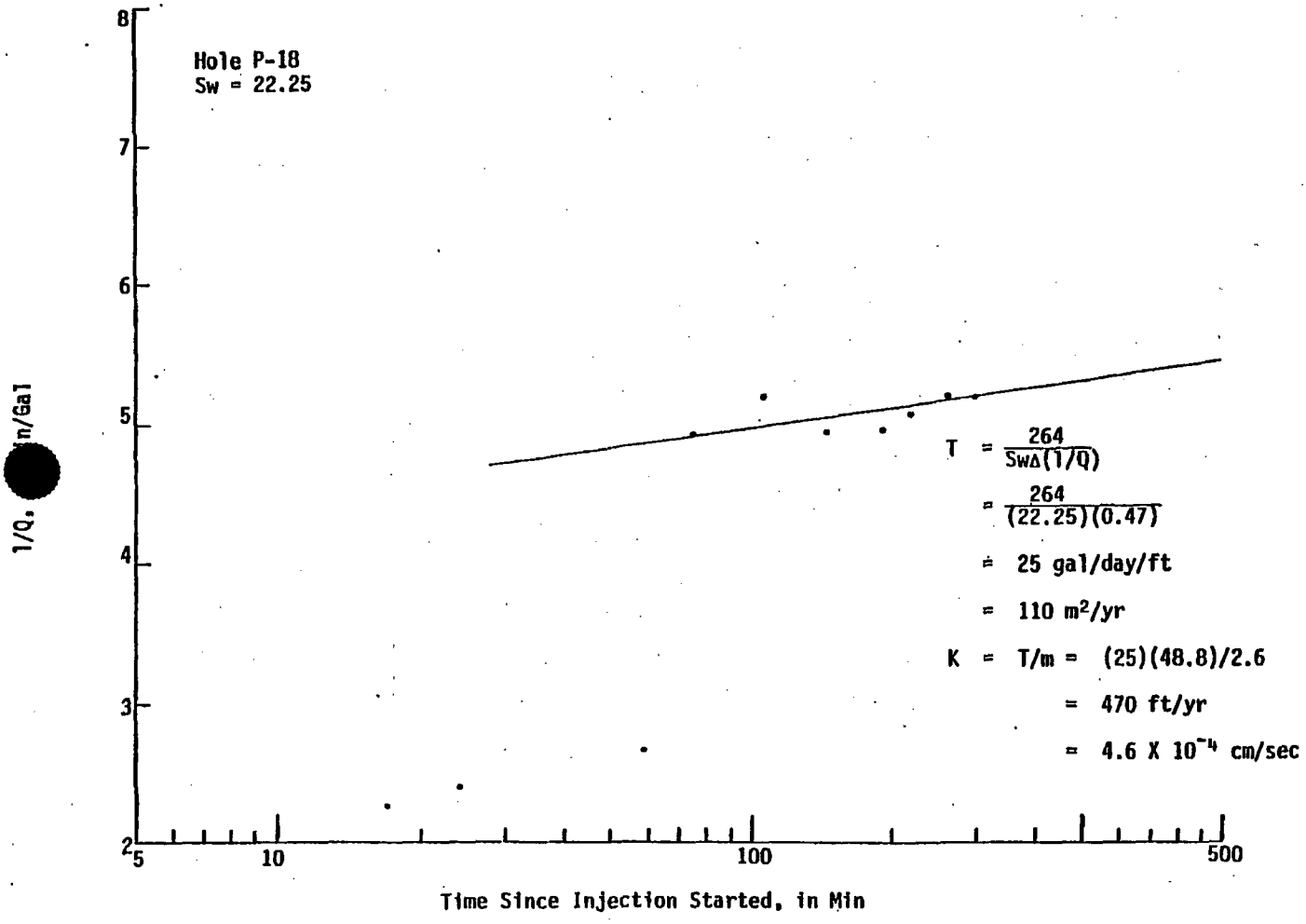


FIGURE A-1.23 CONSTANT HEAD TEST FOR HOLE P-18 (ALLUVIUM)

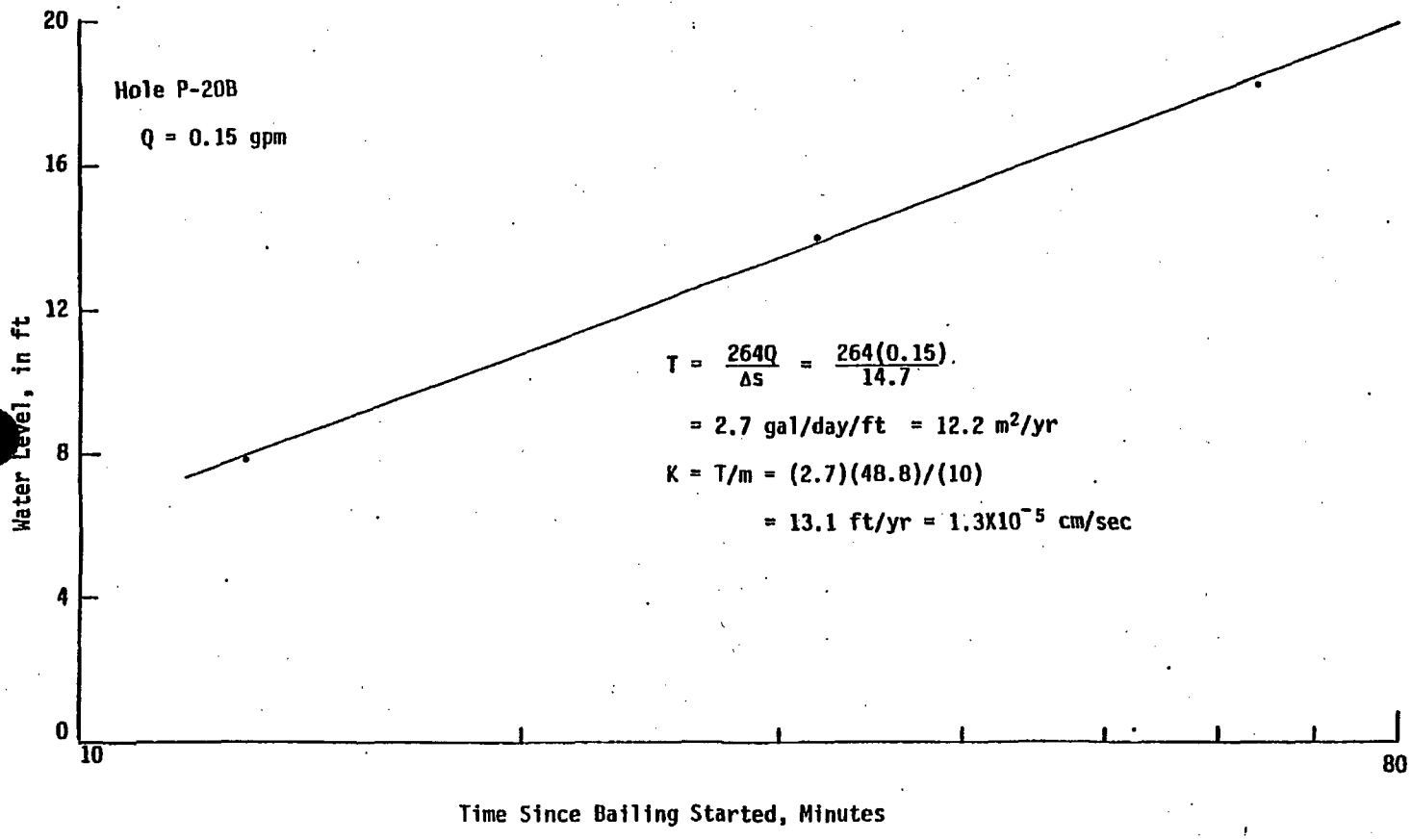


FIGURE A-1.23A. DRAWDOWN TEST FOR HOLE P-20B

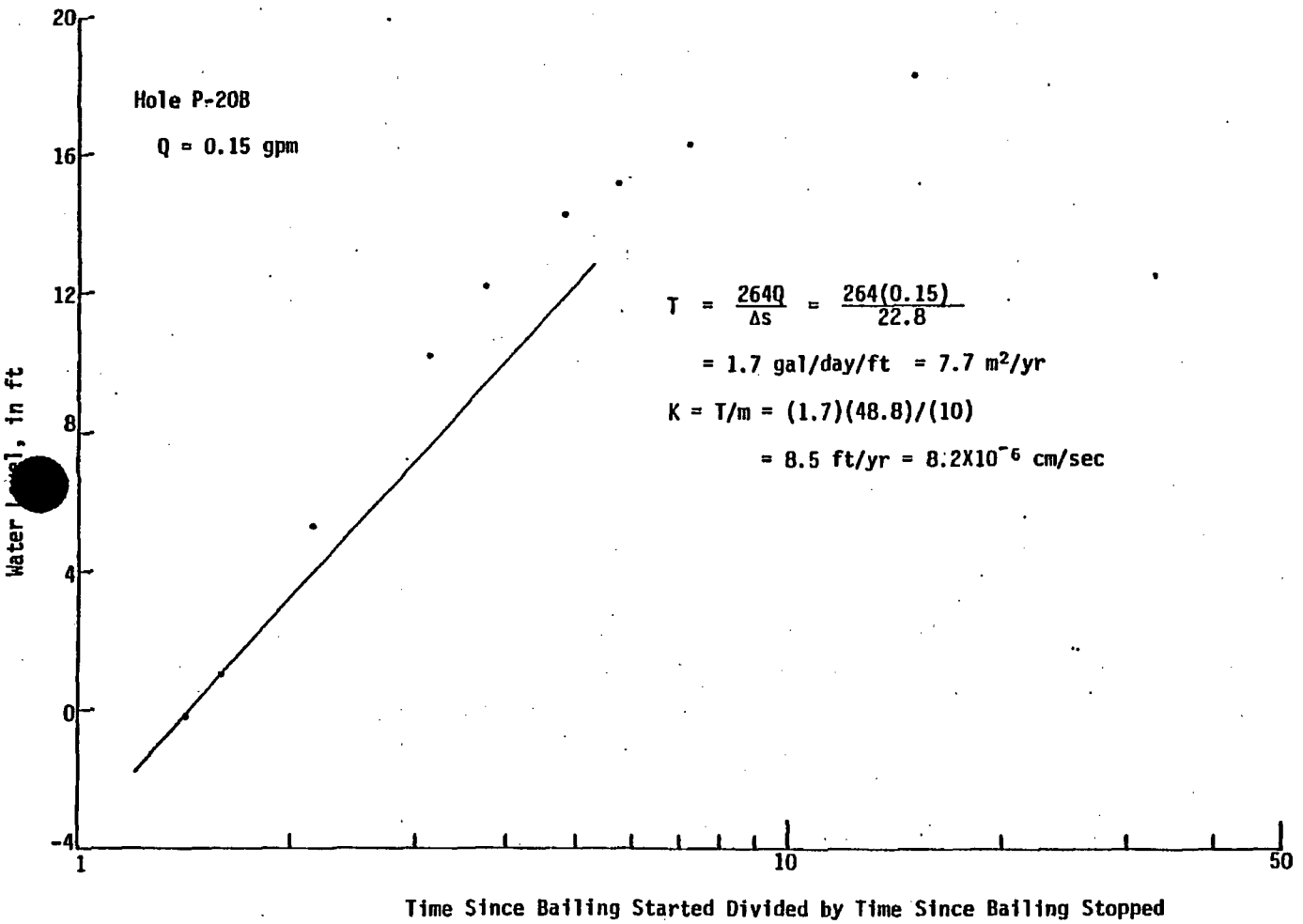


FIGURE A-1.23B. RECOVERY TEST FOR HOLE P-20B (70 SAND)

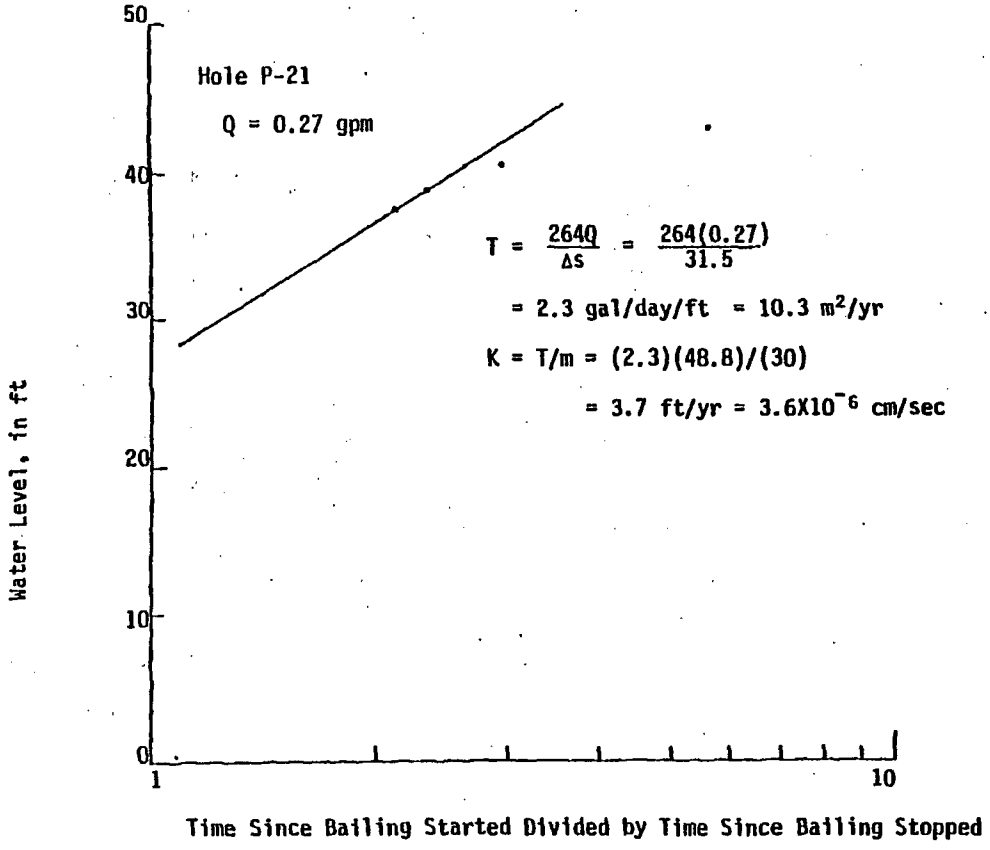


FIGURE A-1.23C. RECOVERY TEST FOR HOLE P-21 (70 SAND)

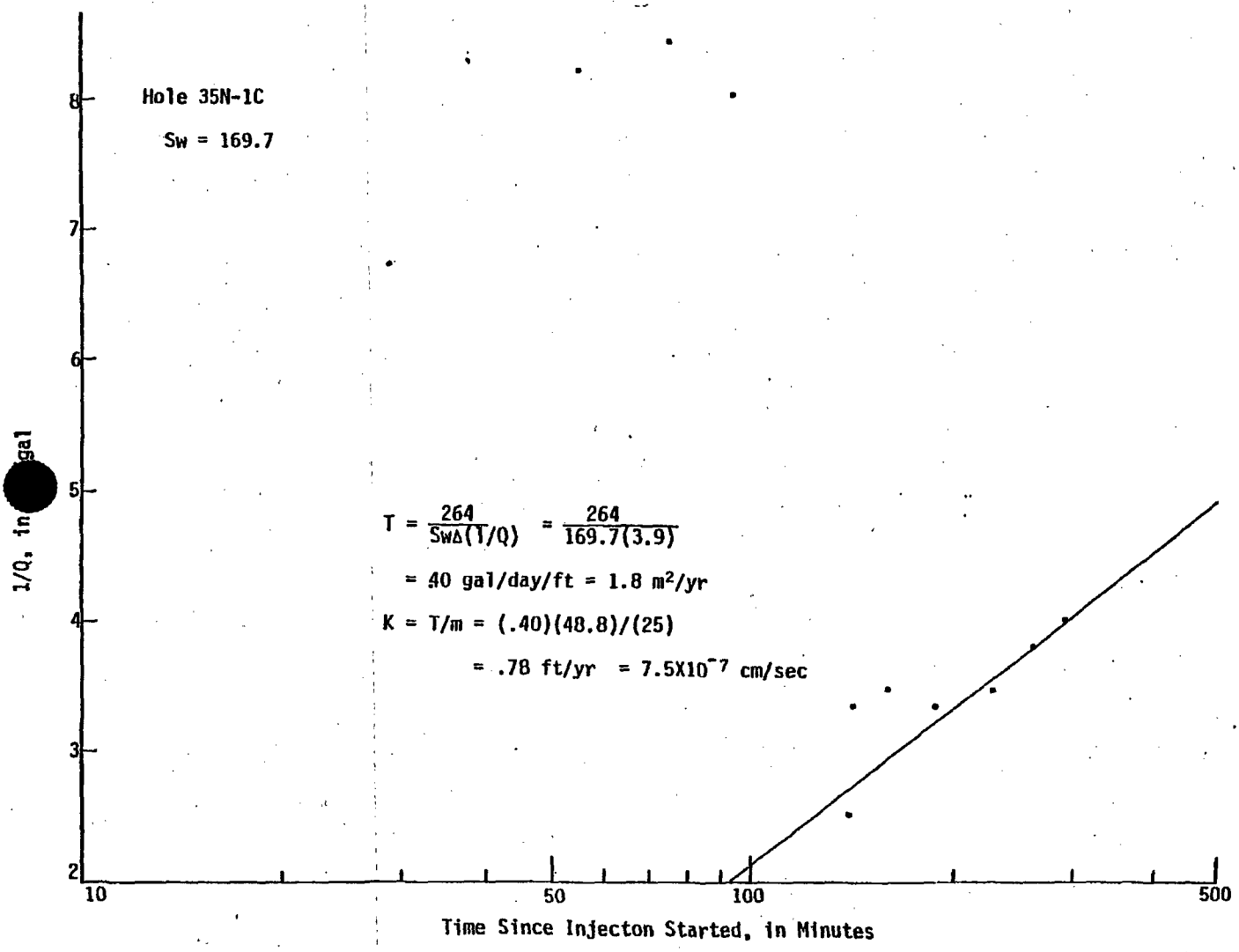


FIGURE A-1.24. CONSTANT HEAD TEST FOR HOLE 35N-1C (UPPER 70 SANDSTONE)

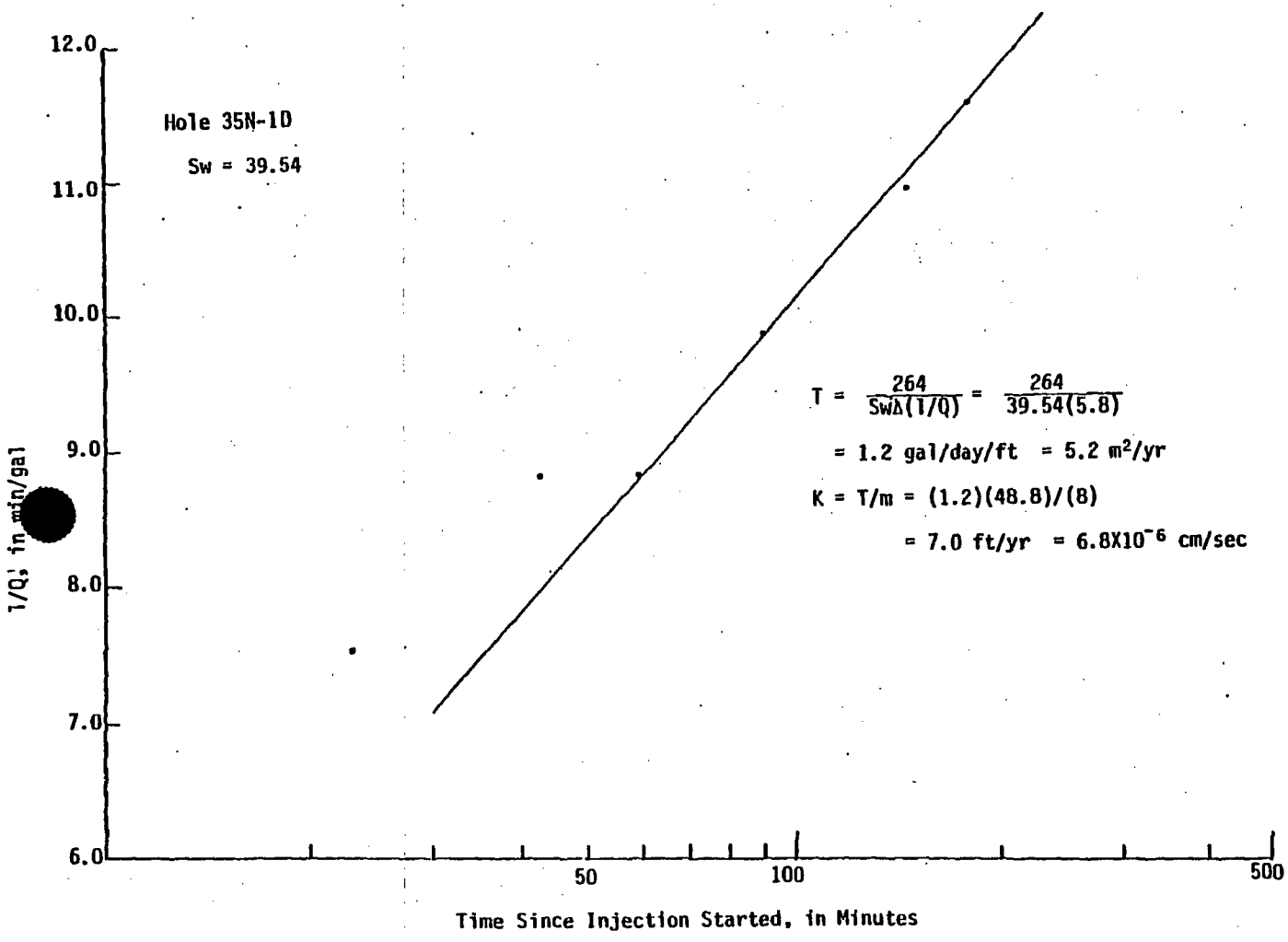


FIGURE A-1.25. CONSTANT HEAD TEST FOR HOLE 35N-1D (SANDSTONE)

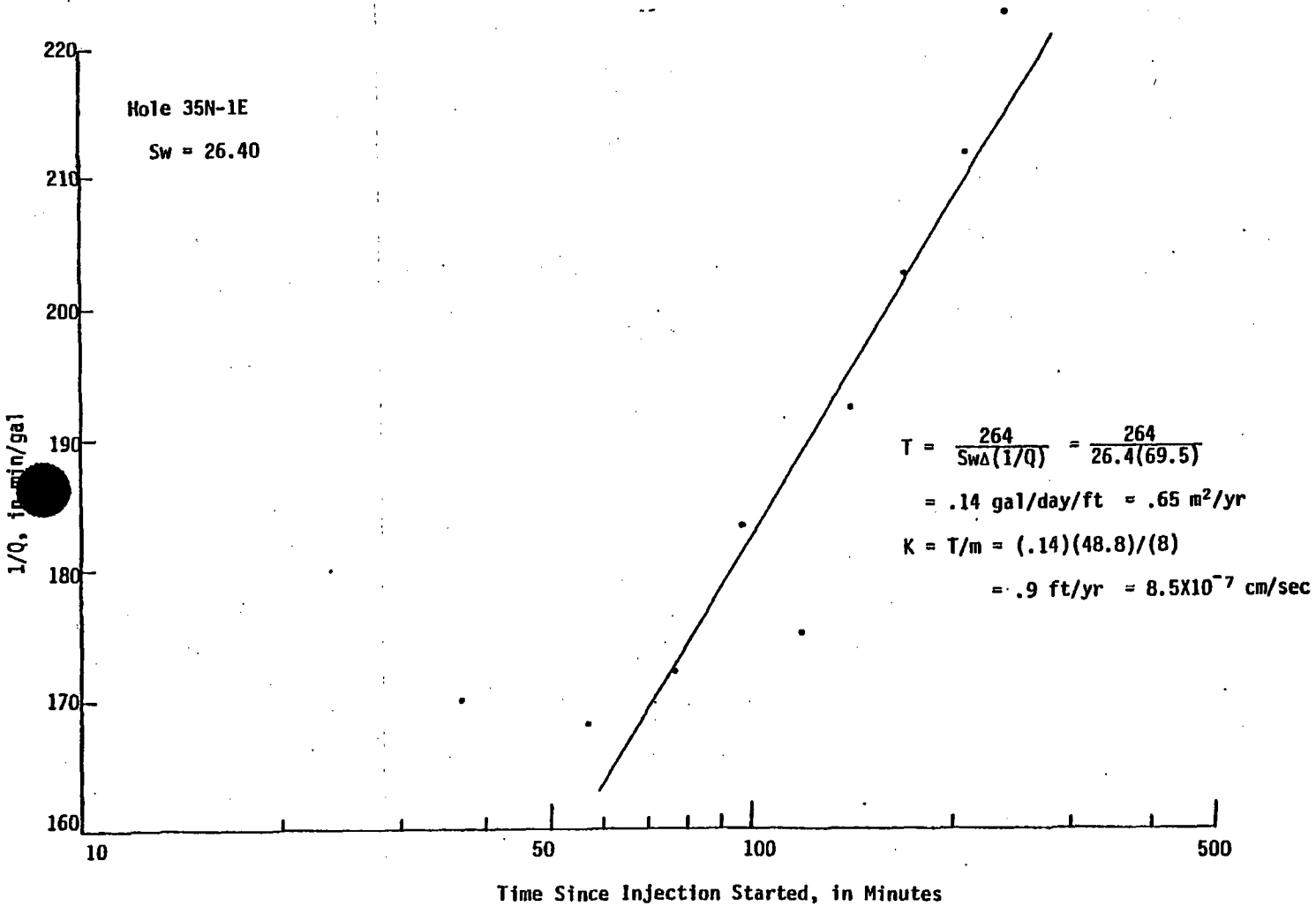


FIGURE A-1.26. CONSTANT HEAD TEST FOR HOLE 35N-1E (MUDSTONE)

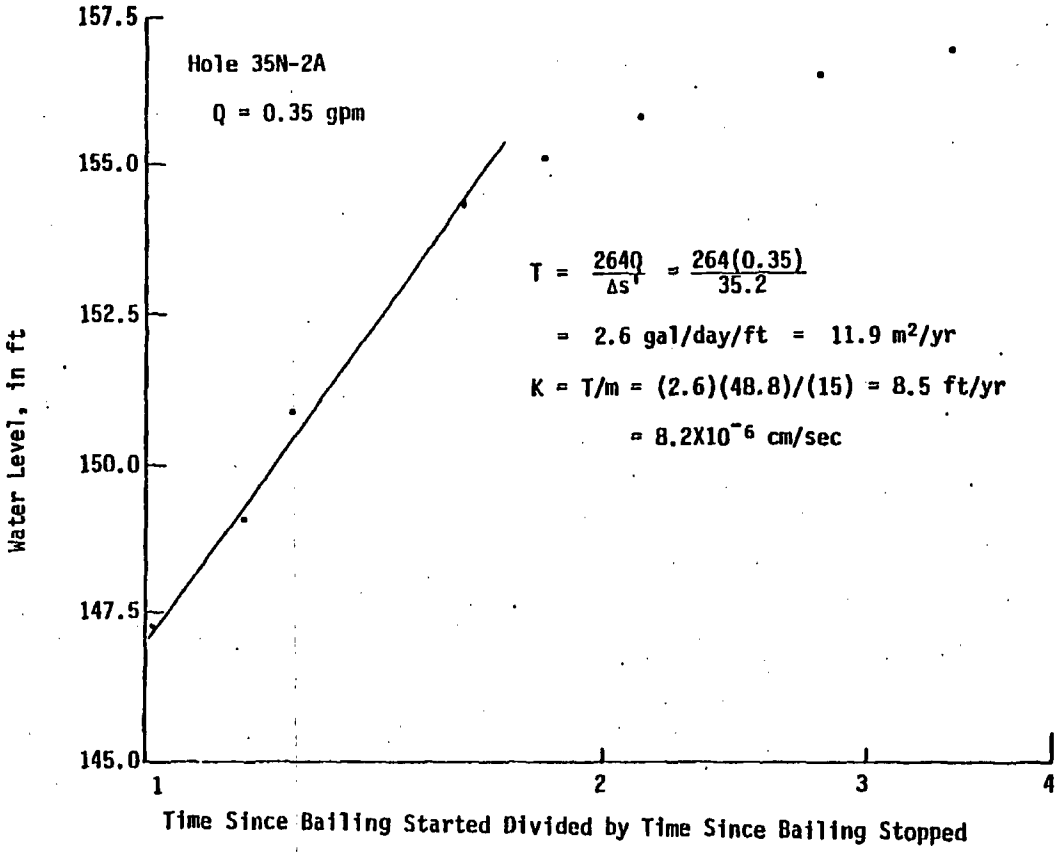


FIGURE A-1.27 RECOVERY TEST FOR HOLE 35N-2A (UPPER 70 SANDSTONE)

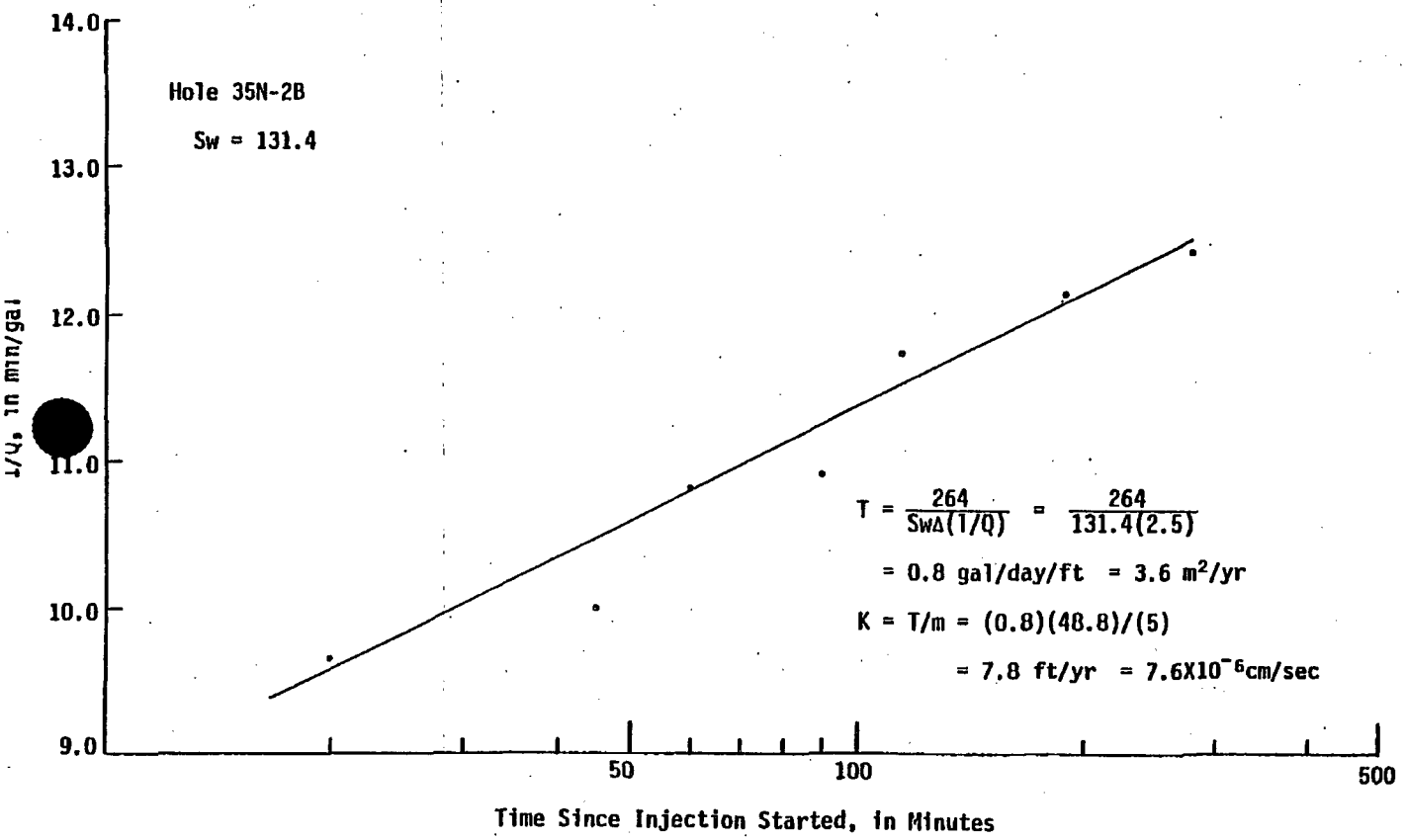


FIGURE A-1.28. CONSTANT HEAD TEST FOR HOLE 35N-2B (SANDSTONE)

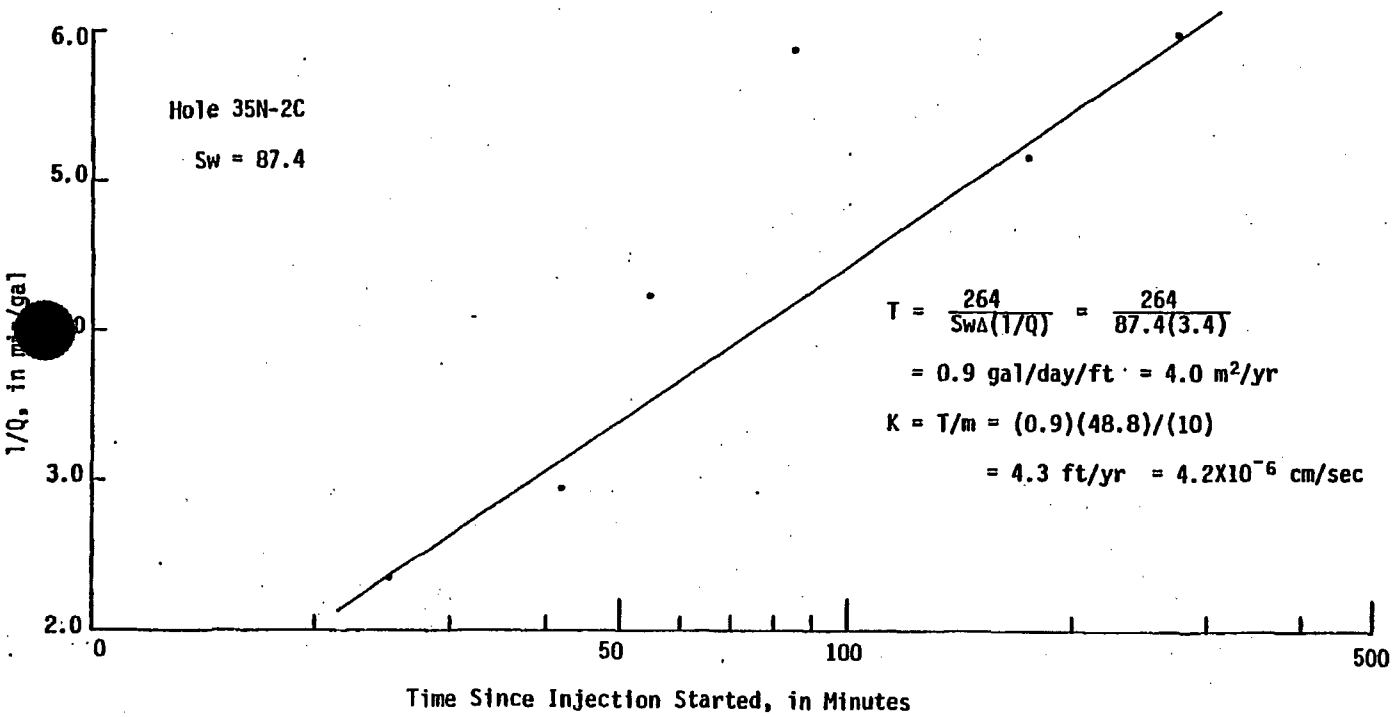


FIGURE A-1.29. CONSTANT HEAD TEST FOR HOLE 35N-2C (MUDSTONE)

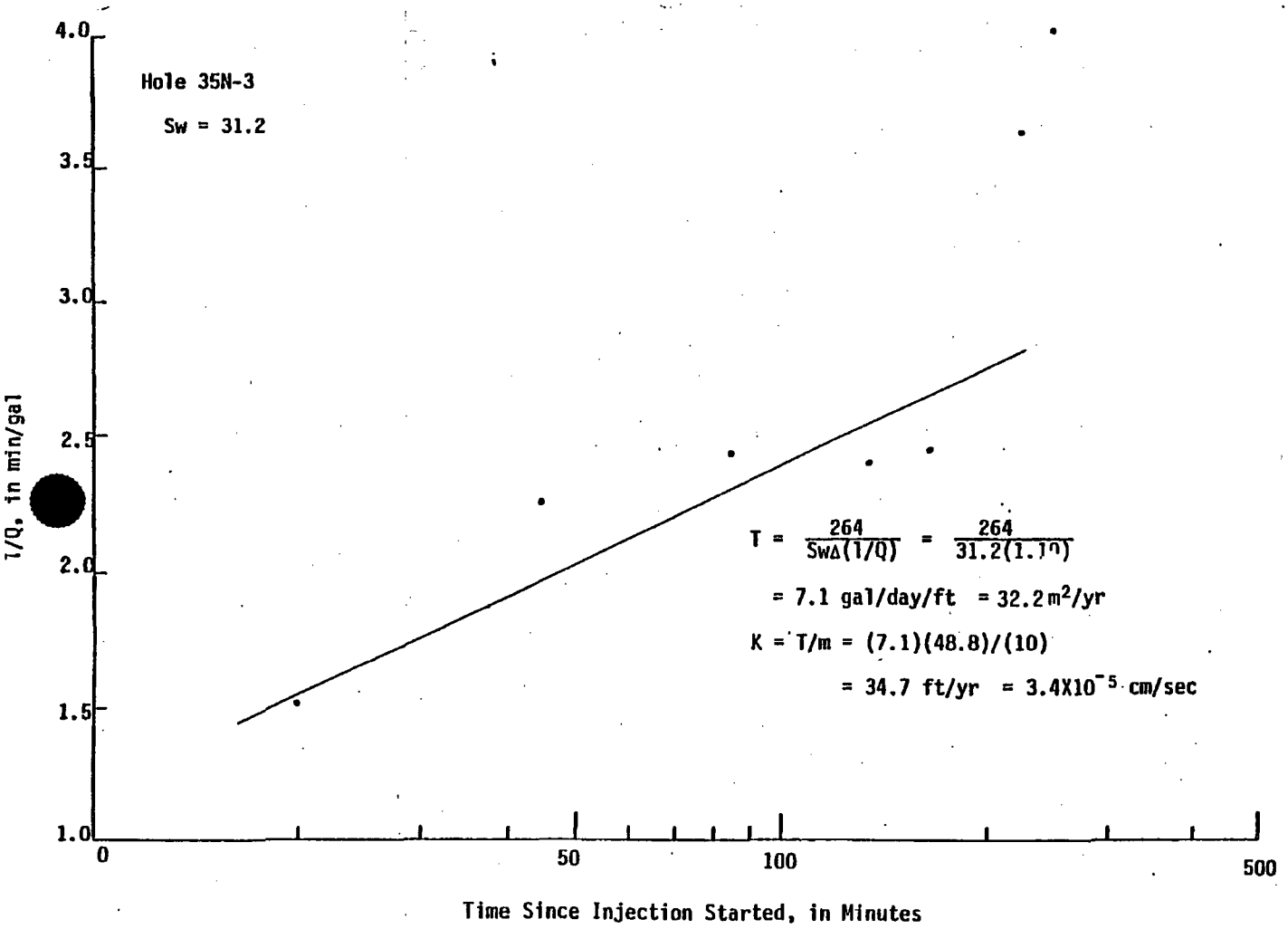


FIGURE A-1.30. CONSTANT HEAD TEST FOR HOLE 35N-3 (SANDSTONE)

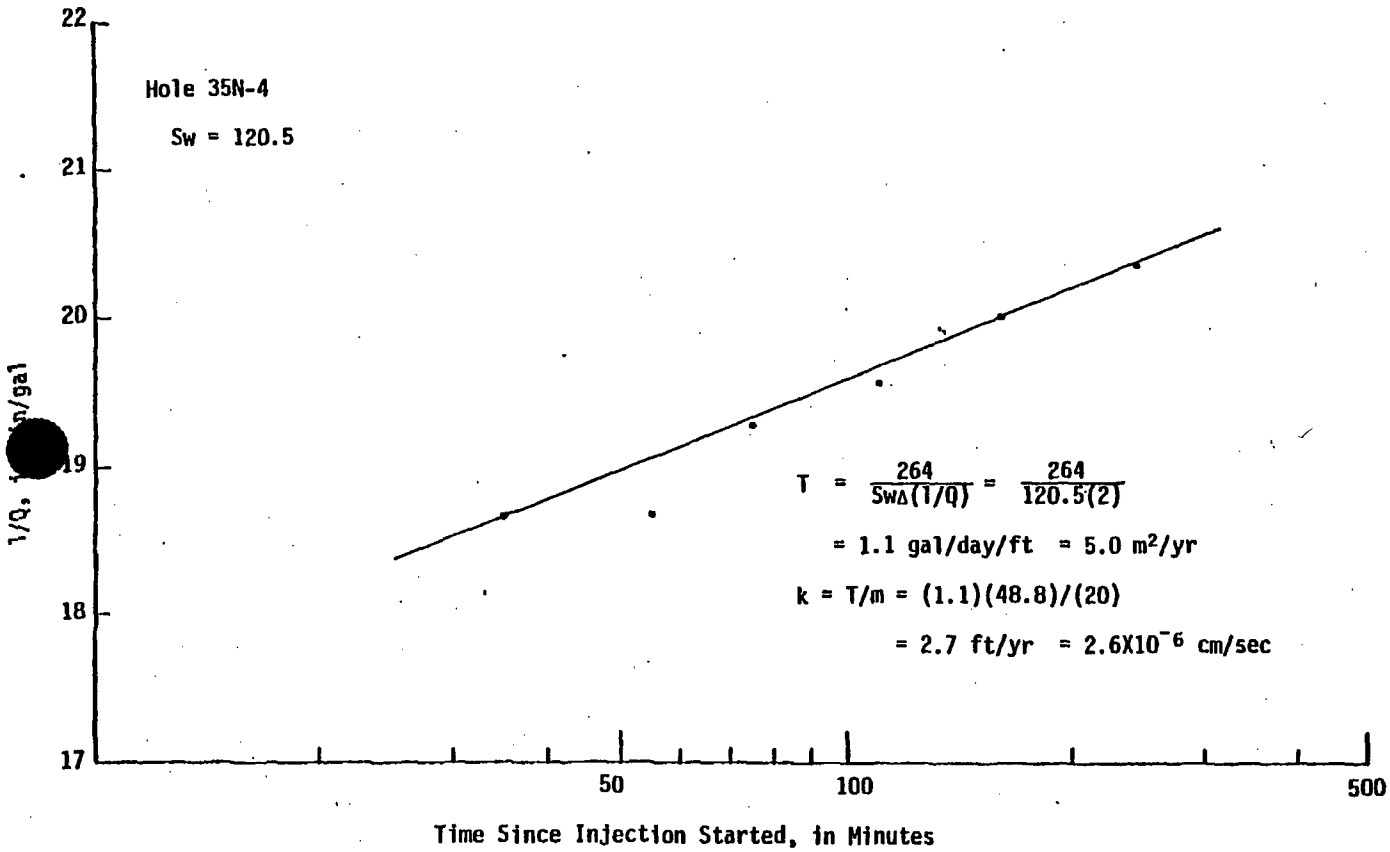


FIGURE A-1.31. CONSTANT HEAD TEST FOR HOLE 35N-4 (MUDSTONE)

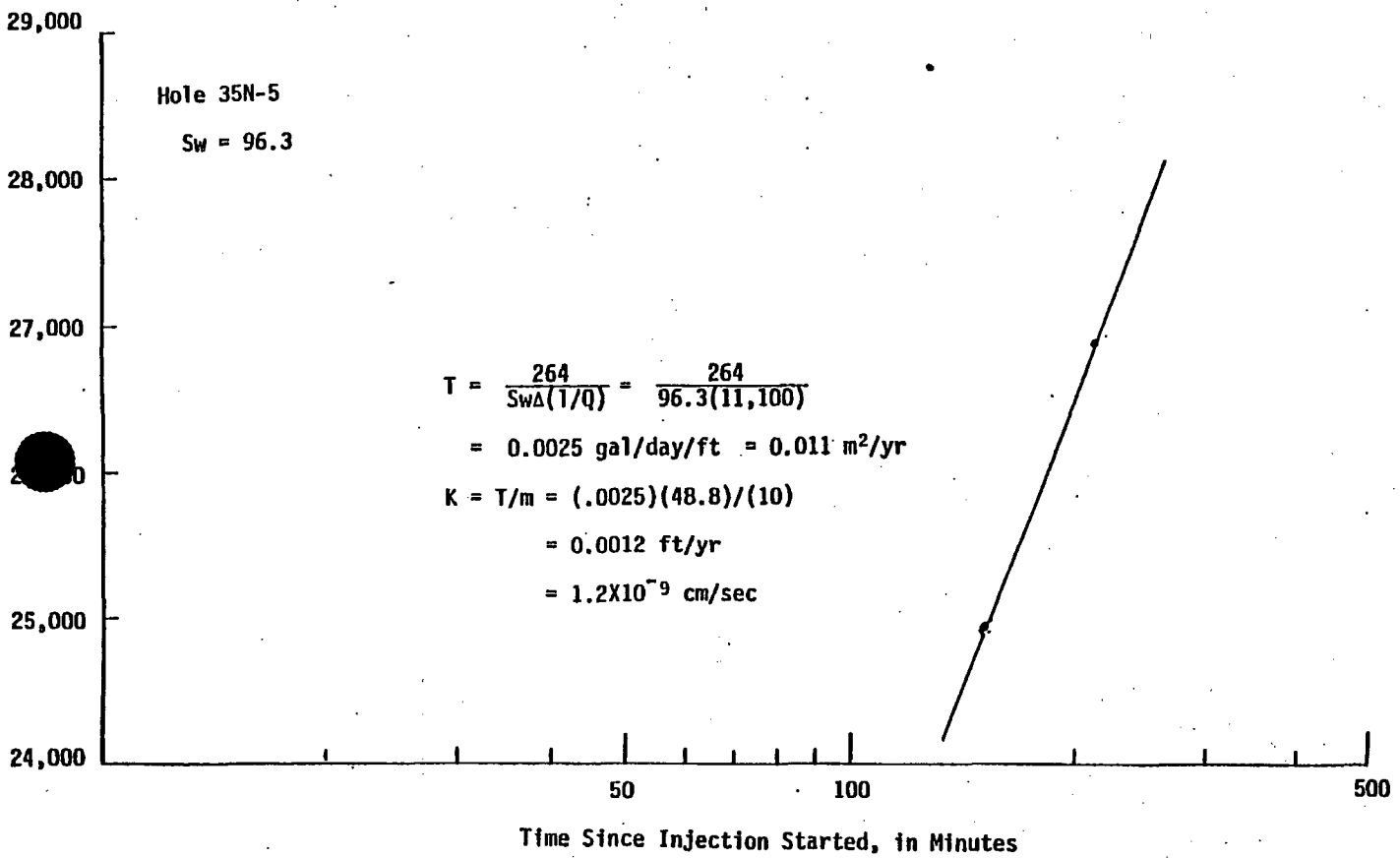


FIGURE A-1.32. CONSTANT HEAD TEST FOR HOLE 35N-5 (SANDSTONE)

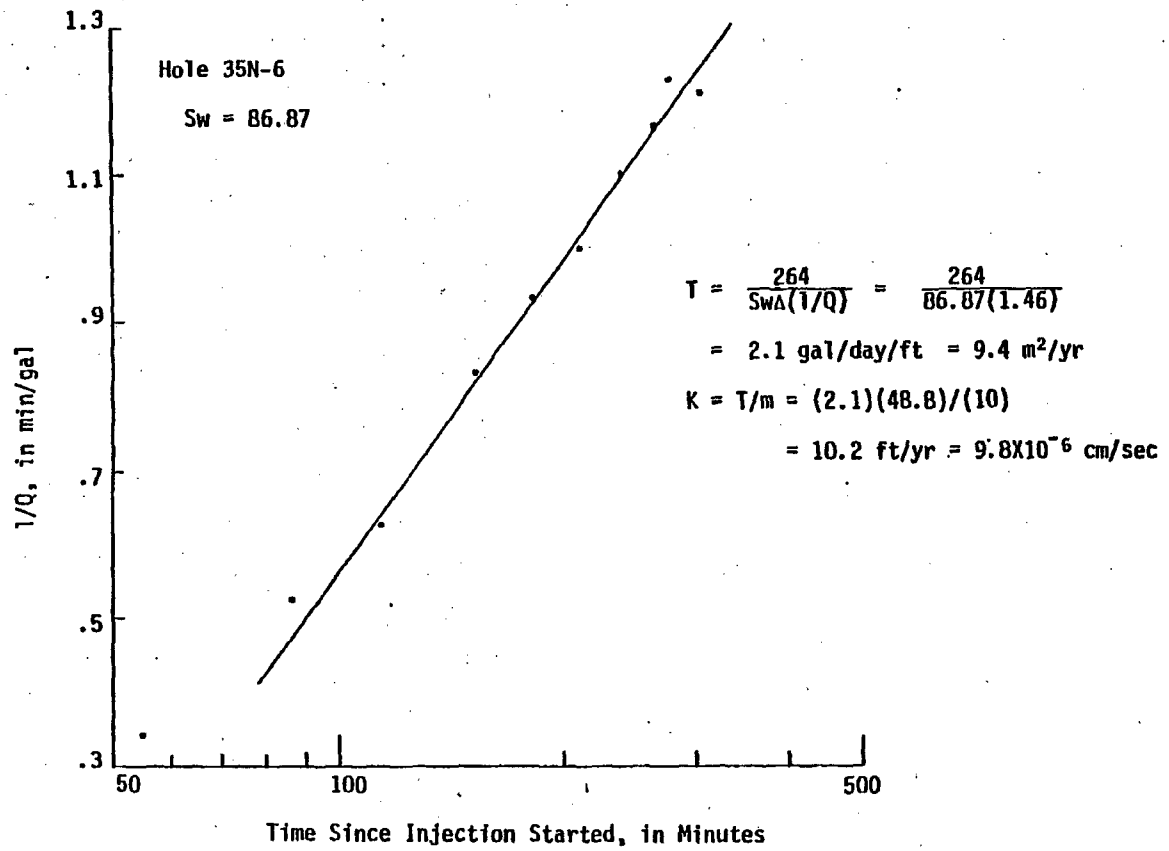


FIGURE A-1.33. CONSTANT HEAD TEST FOR HOLE 35N-6 (SANDSTONE)

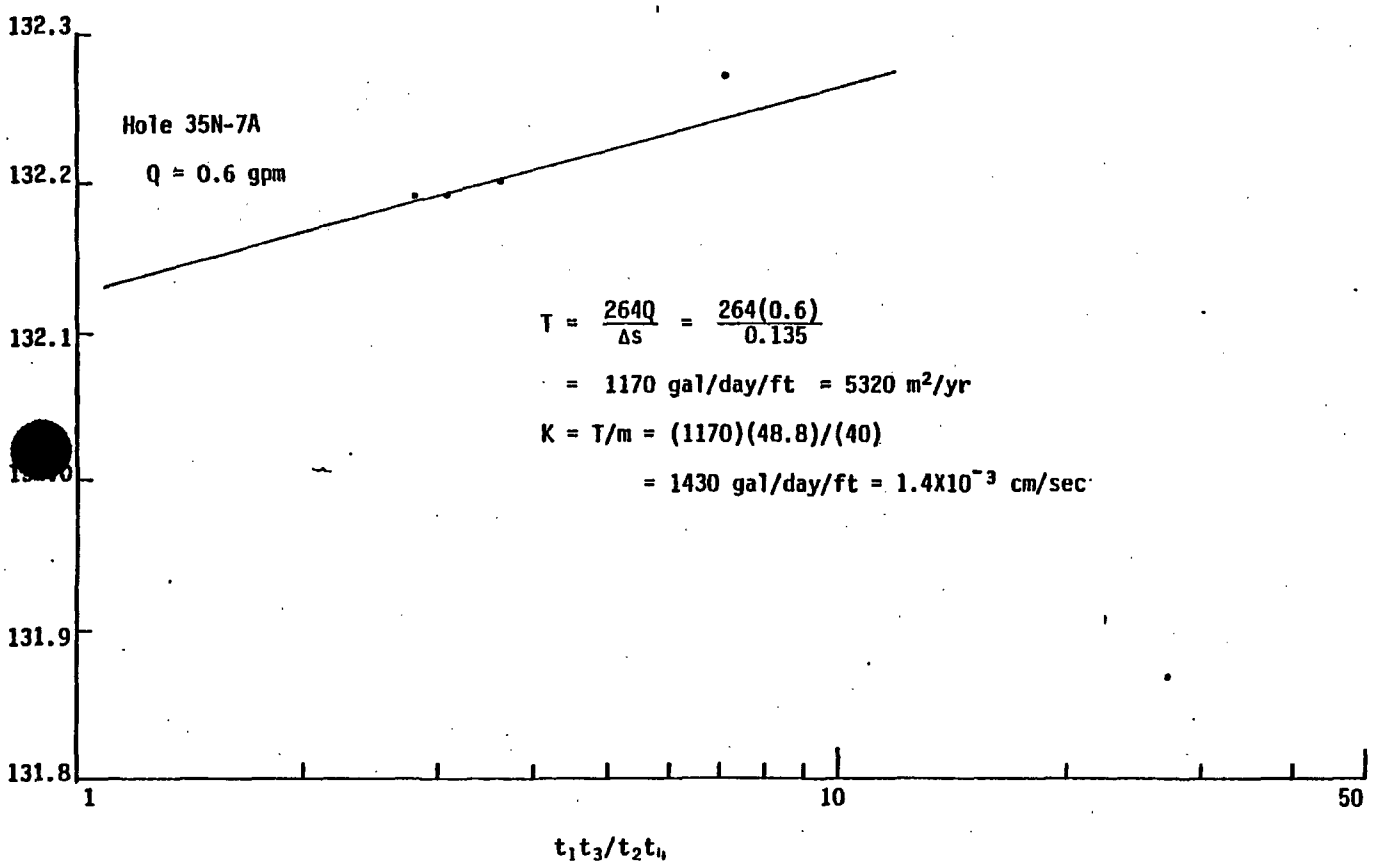


FIGURE A-1.34. RECOVERY TEST FOR HOLE 35N-7A (70 SANDSTONE)

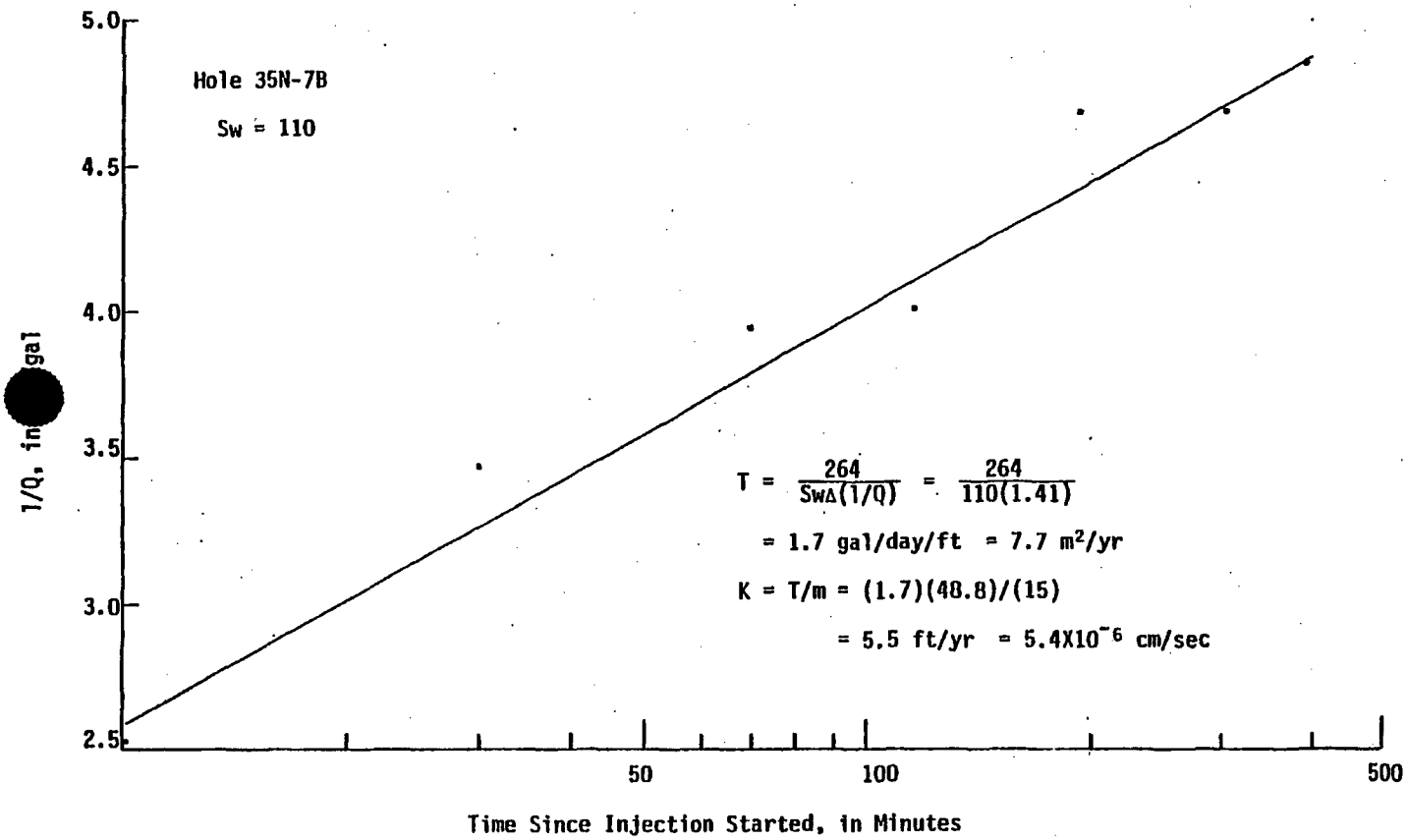


FIGURE A-1.35. CONSTANT HEAD TEST FOR HOLE 35N-7B (UPPER 70 SANDSTONE)

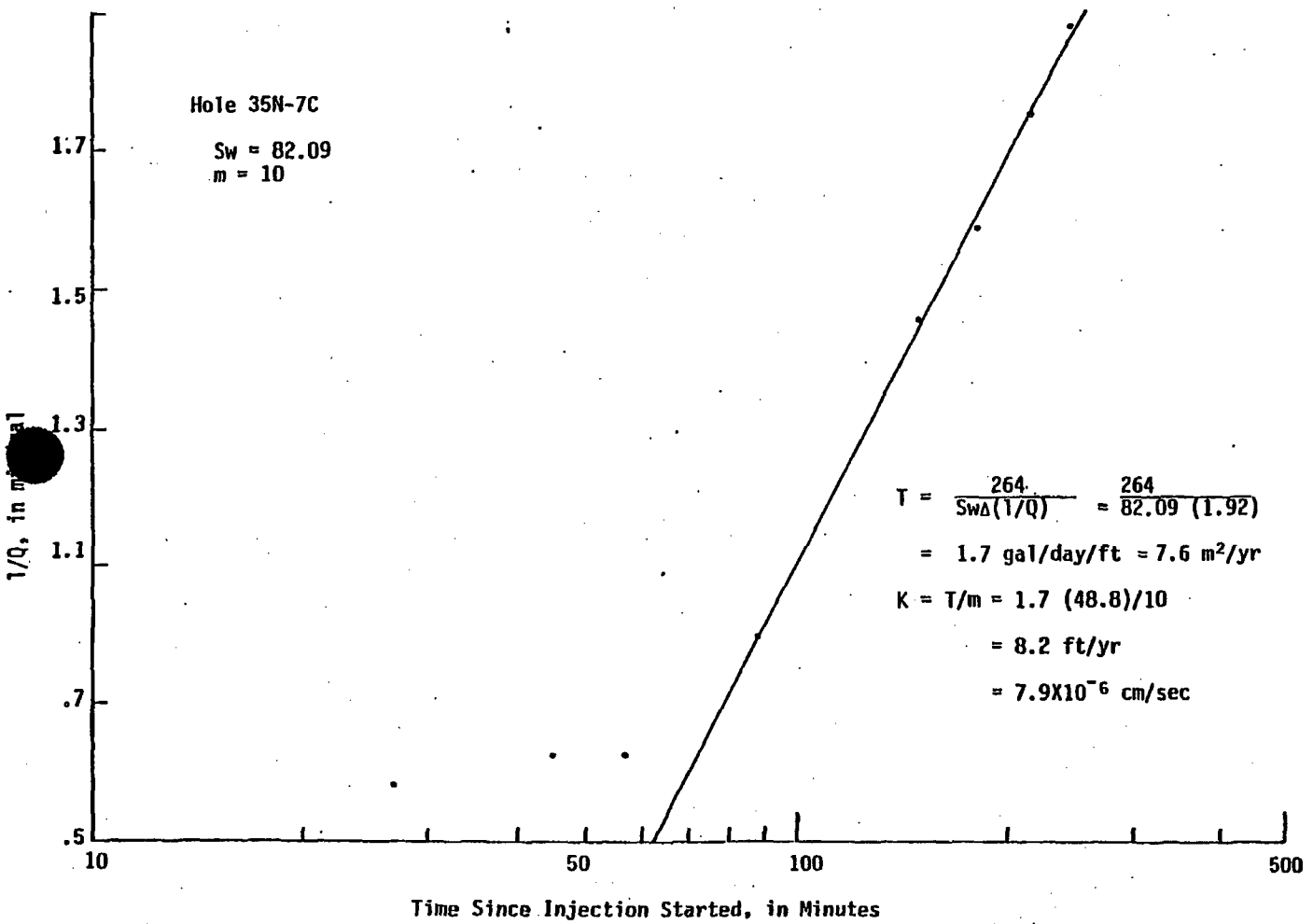


FIGURE A-1.36. CONSTANT HEAD TEST FOR HOLE 35N-7C (SANDSTONE)

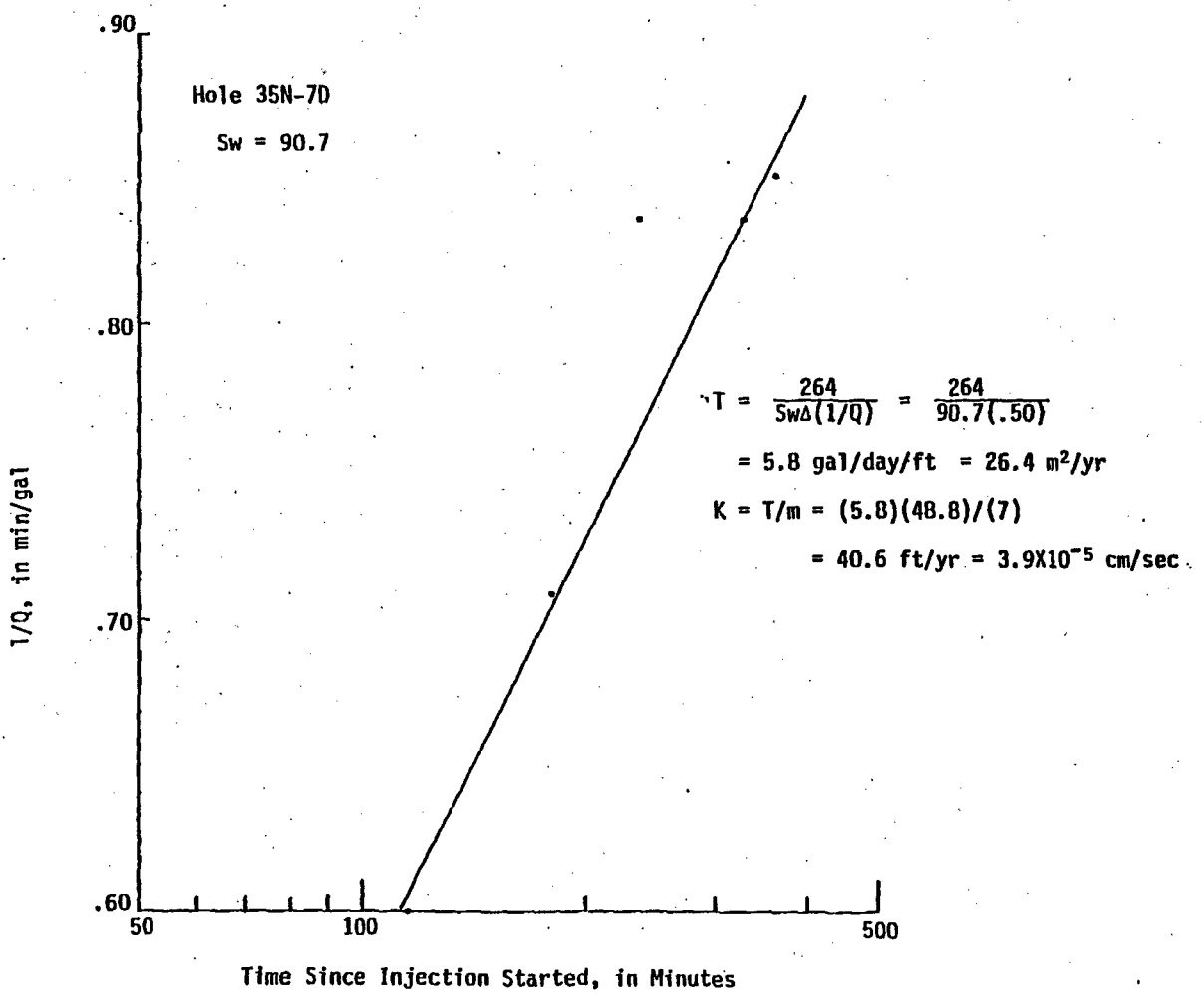


FIGURE A-1.37. CONSTA HEAD TEST FOR HOLE 35N-7D (E COAL)

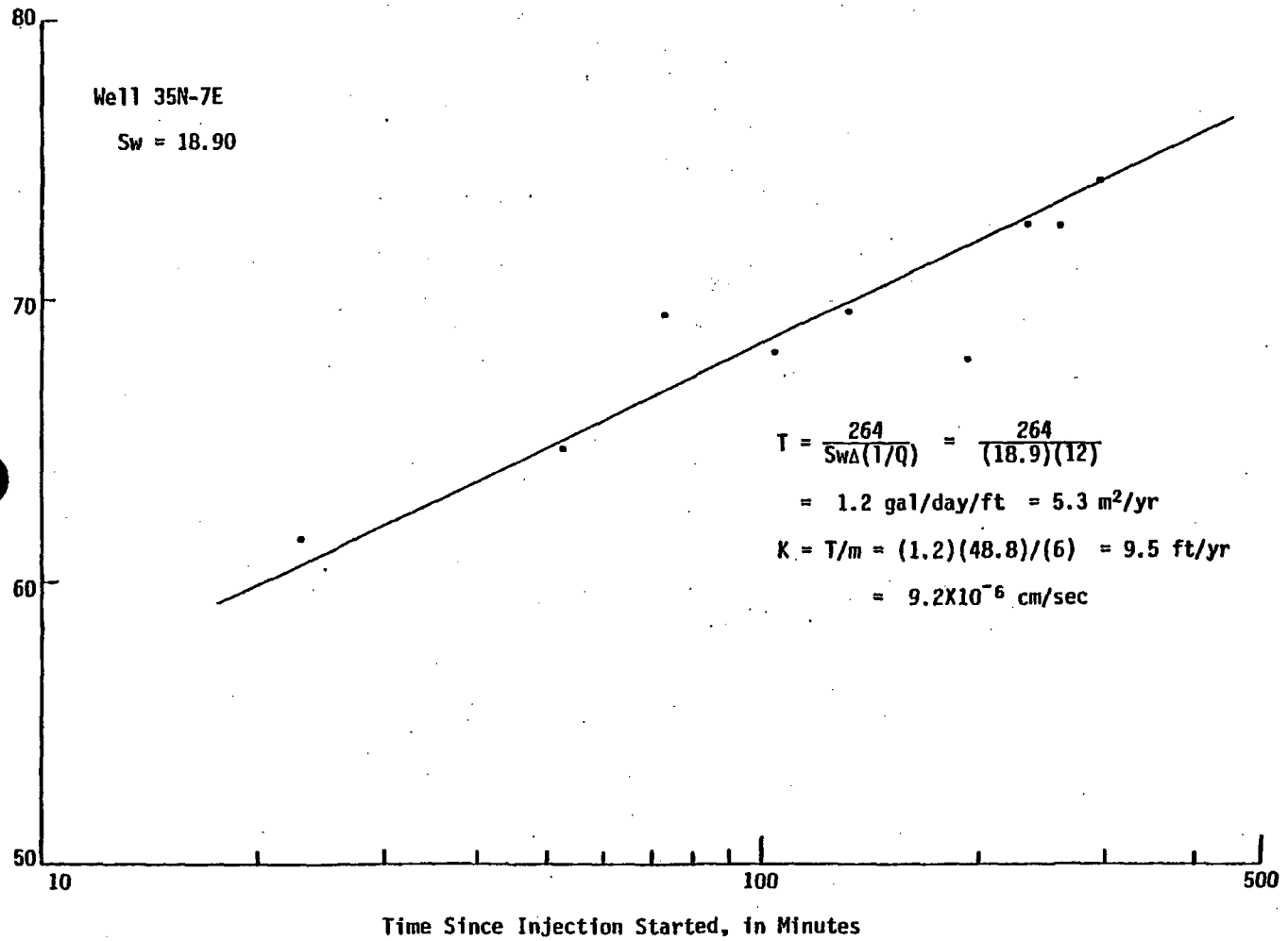


FIGURE A-1.38. CONSTANT HEAD TEST FOR HOLE 35N-7E (SANDSTONE)

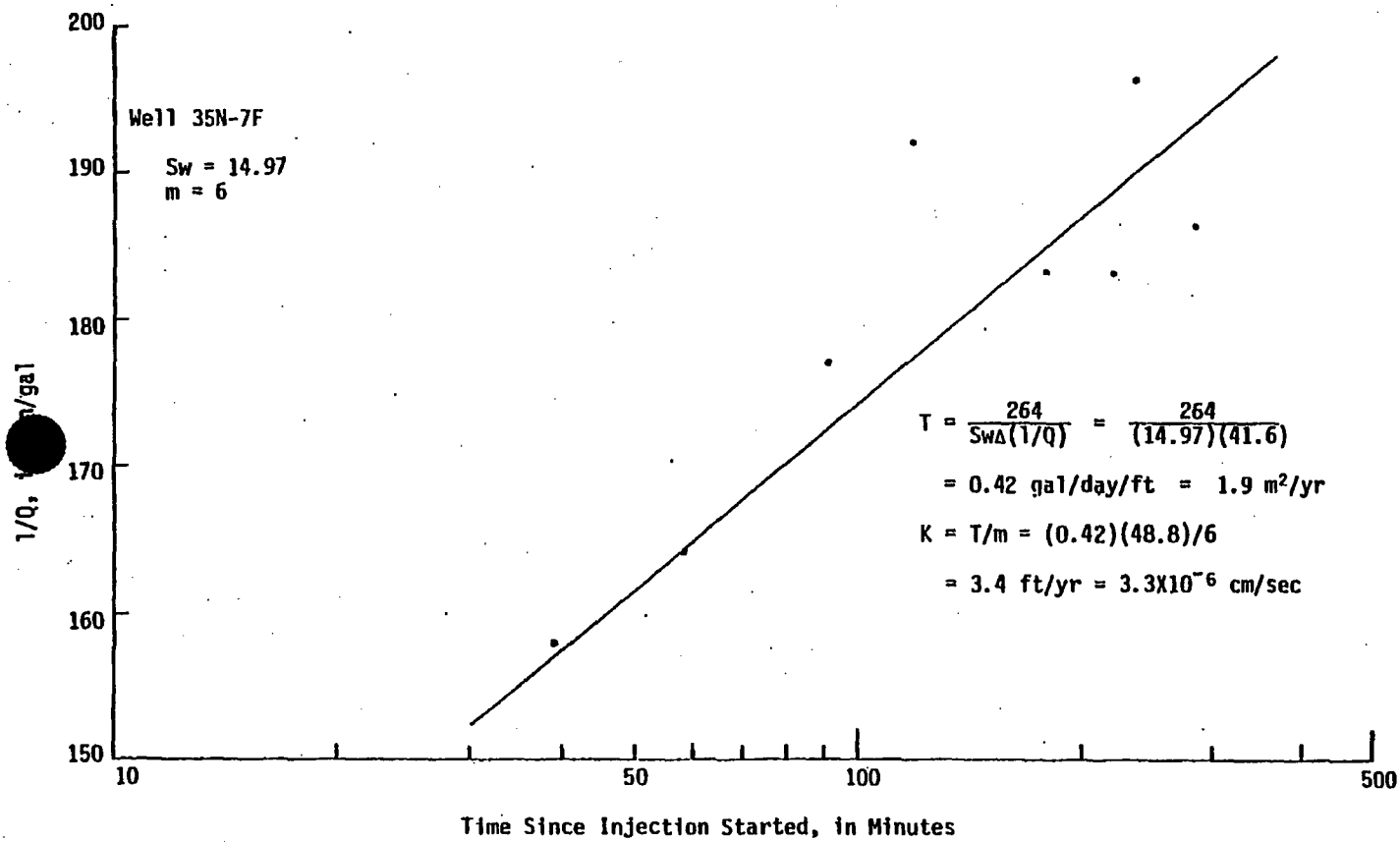


FIGURE A-1.39. CONSTANT HEAD TEST FOR HOLE 35N-7F (MUDSTONE)

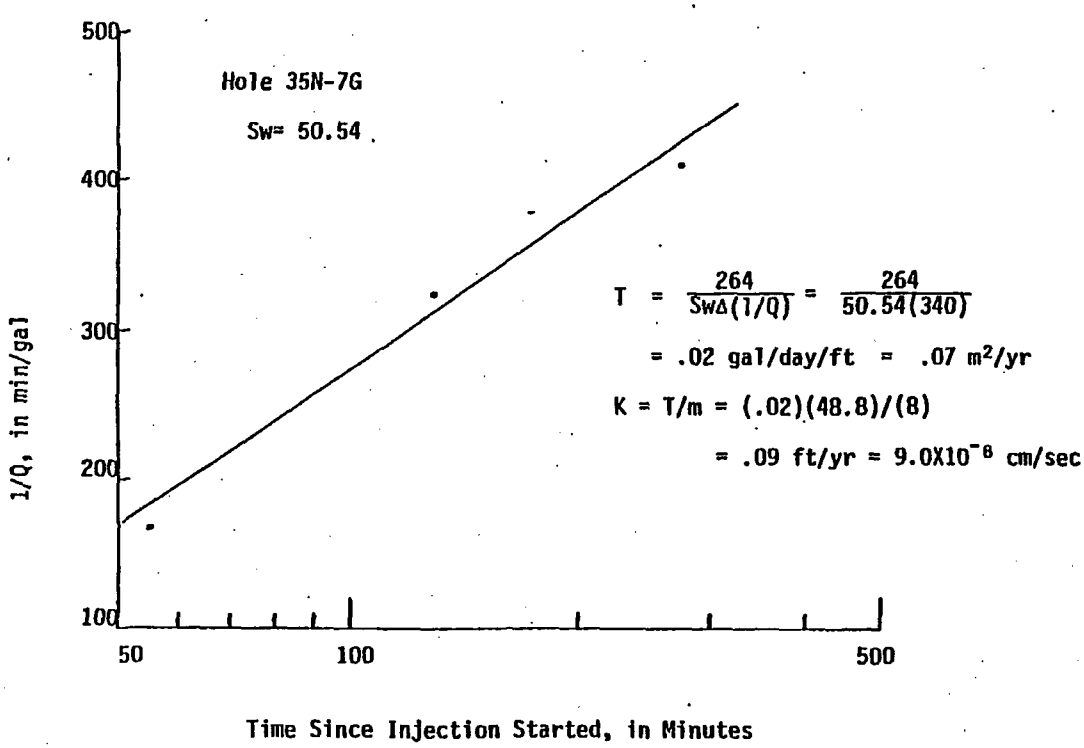


FIGURE A-1.40. CONSTANT HEAD TEST FOR HOLE 35N-7G (U COAL)

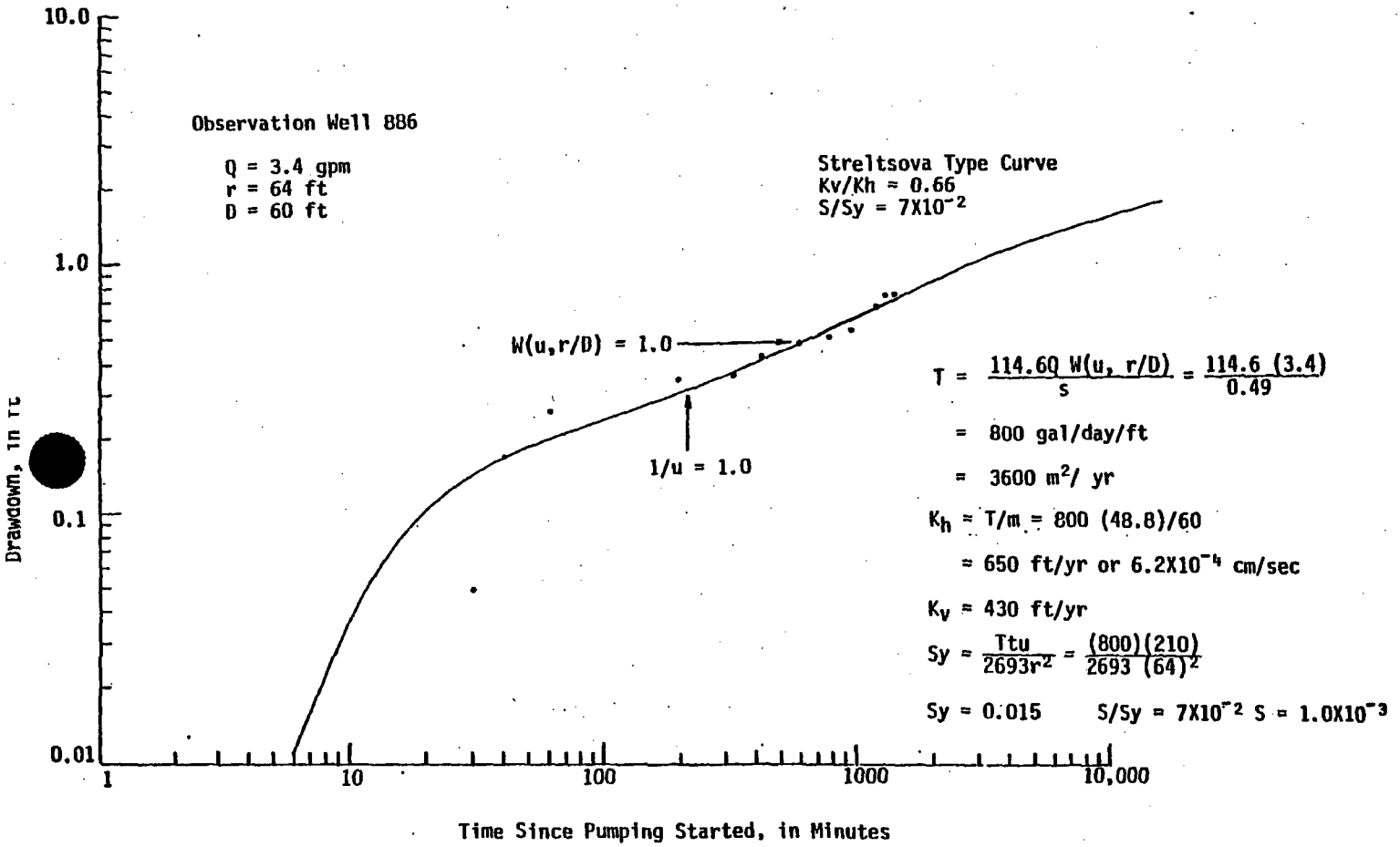


FIGURE A-1.41. DRAWDOWN IN OBSERVATION WELL 886 FROM PUMPING WELL 885 (70 SAND)

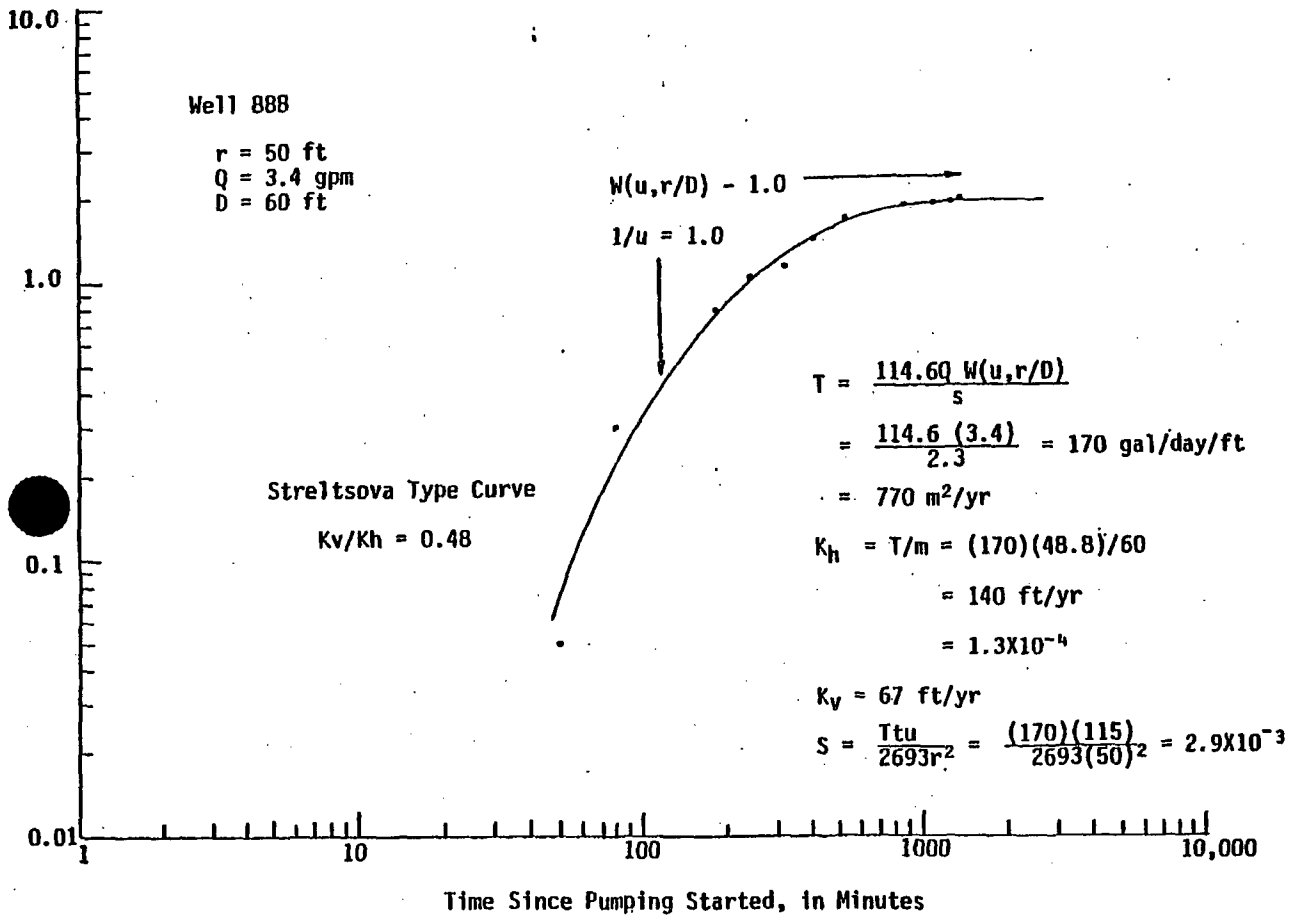


FIGURE A-1.42. DRAWDOWN IN OBSERVATION WELL 888 FROM PUMPING WELL 885 (70 SAND)

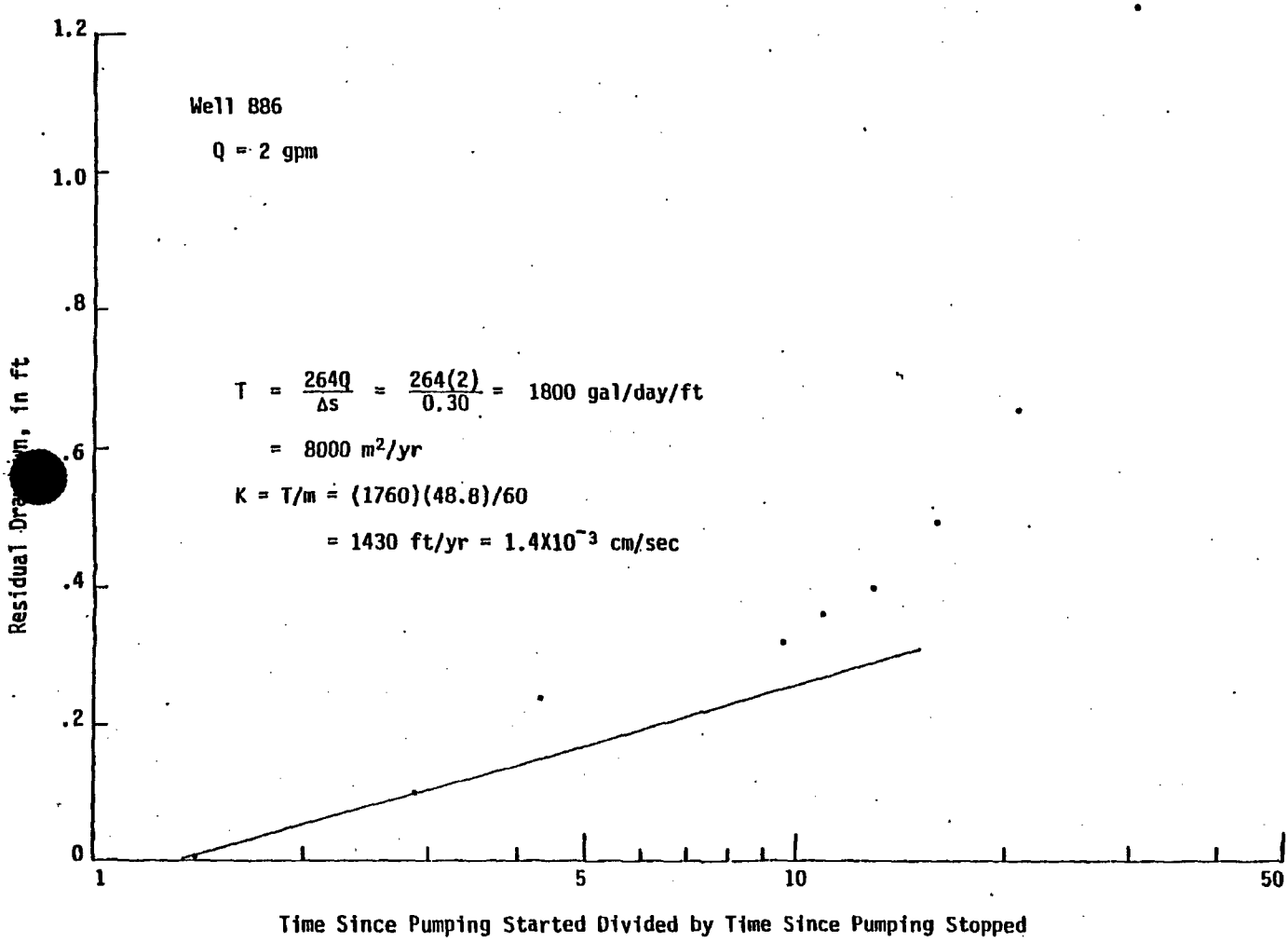


FIGURE A-1.43. RECOVERY OF PUMPING WELL 886 (70 SAND)

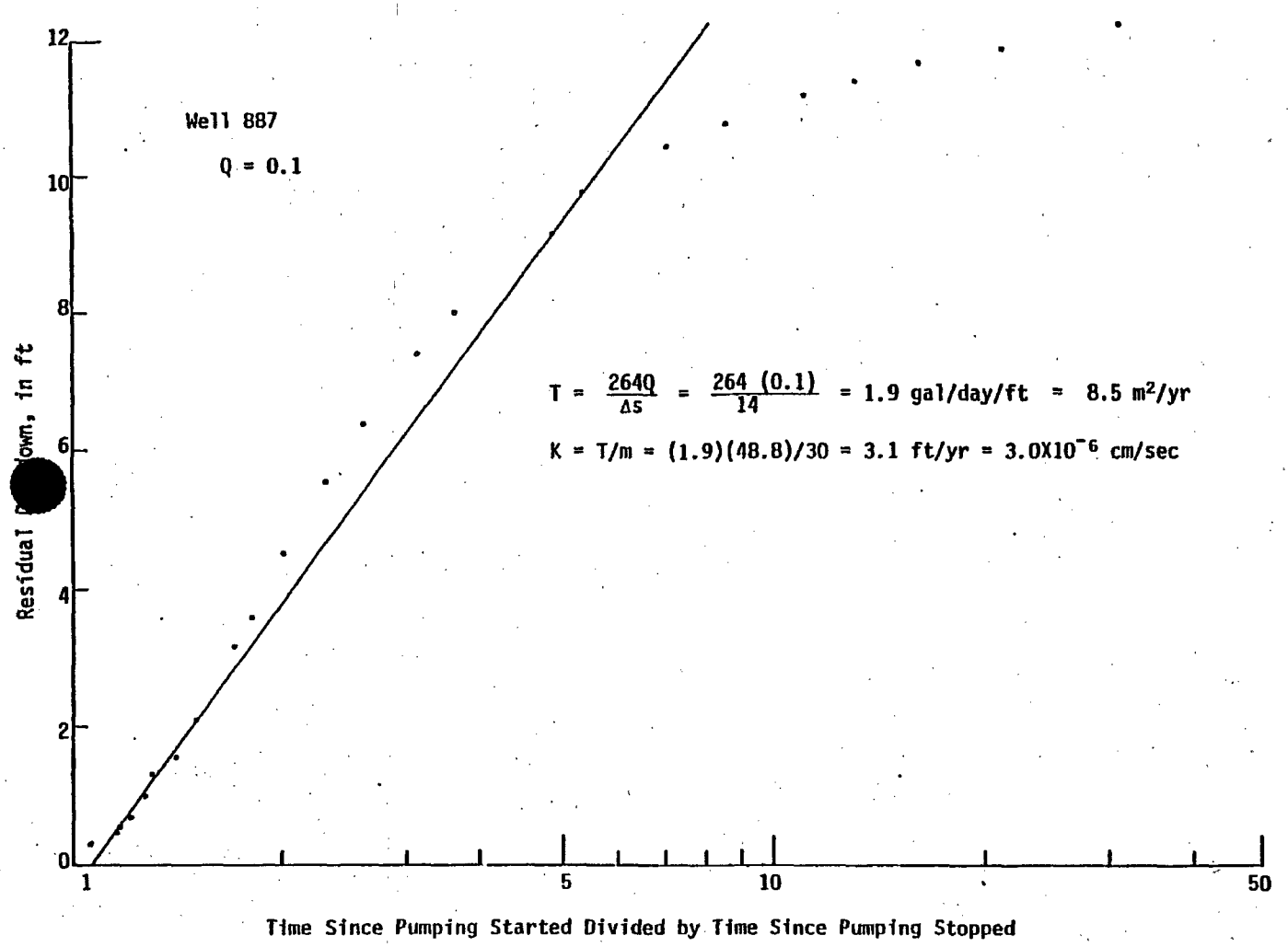
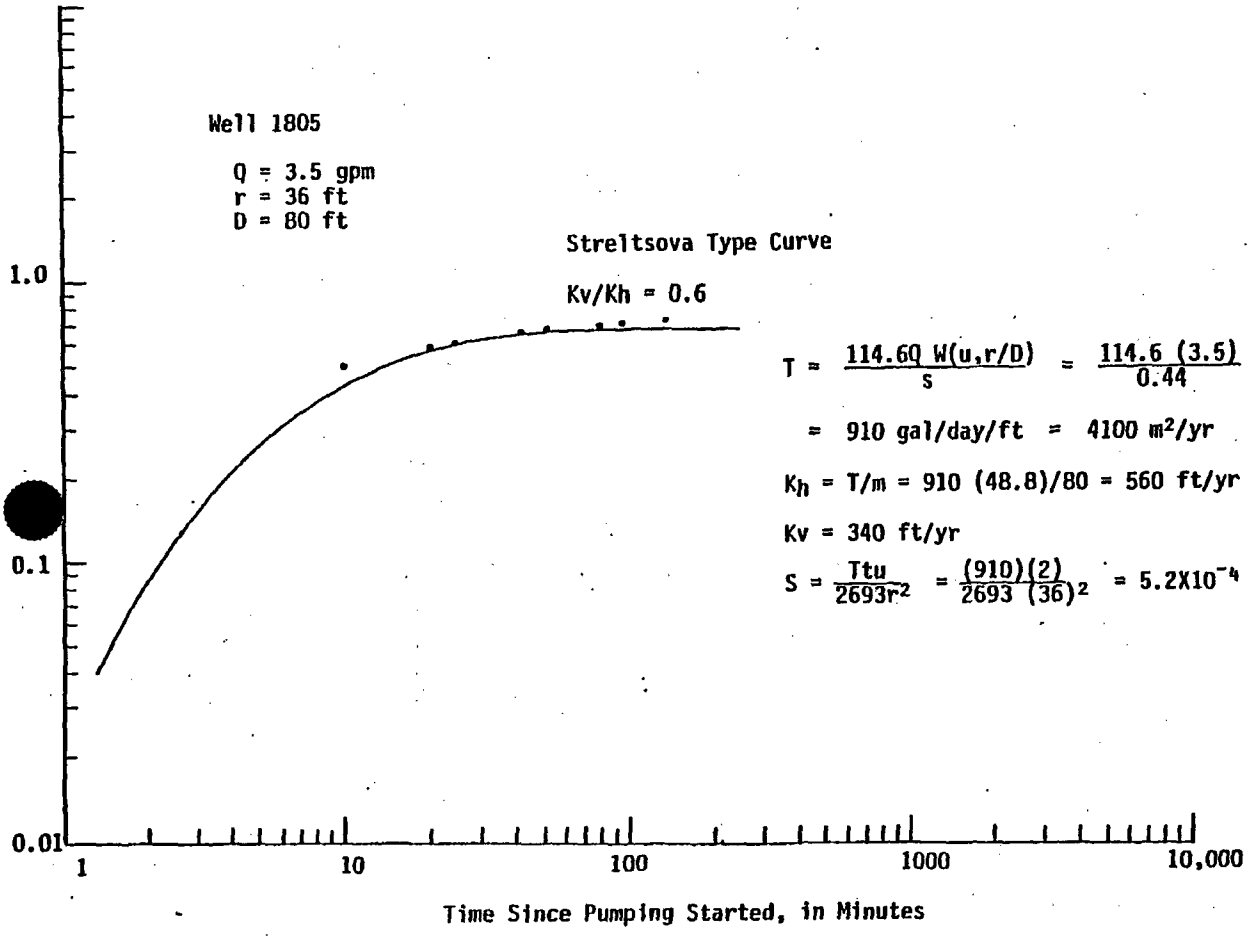


FIGURE A-1.44. RECOVERY OF PUMPING WELL 887 (68 SAND)



$$T = \frac{114.6Q\ W(u,r/D)}{s} = \frac{114.6\ (3.5)}{0.44}$$

$$= 910 \text{ gal/day/ft} = 4100 \text{ m}^2\text{/yr}$$

$$K_h = T/m = 910\ (48.8)/80 = 560 \text{ ft/yr} = 5.4\text{X}10^{-4} \text{ cm/sec}$$

$$K_v = 340 \text{ ft/yr}$$

$$S = \frac{Ttu}{2693r^2} = \frac{(910)(2)}{2693\ (36)^2} = 5.2\text{X}10^{-4}$$

FIGURE A-1.45. DRAWDOWN IN OBSERVATION WELL 1805 FROM PUMPING WELL 1 (70 SAND)

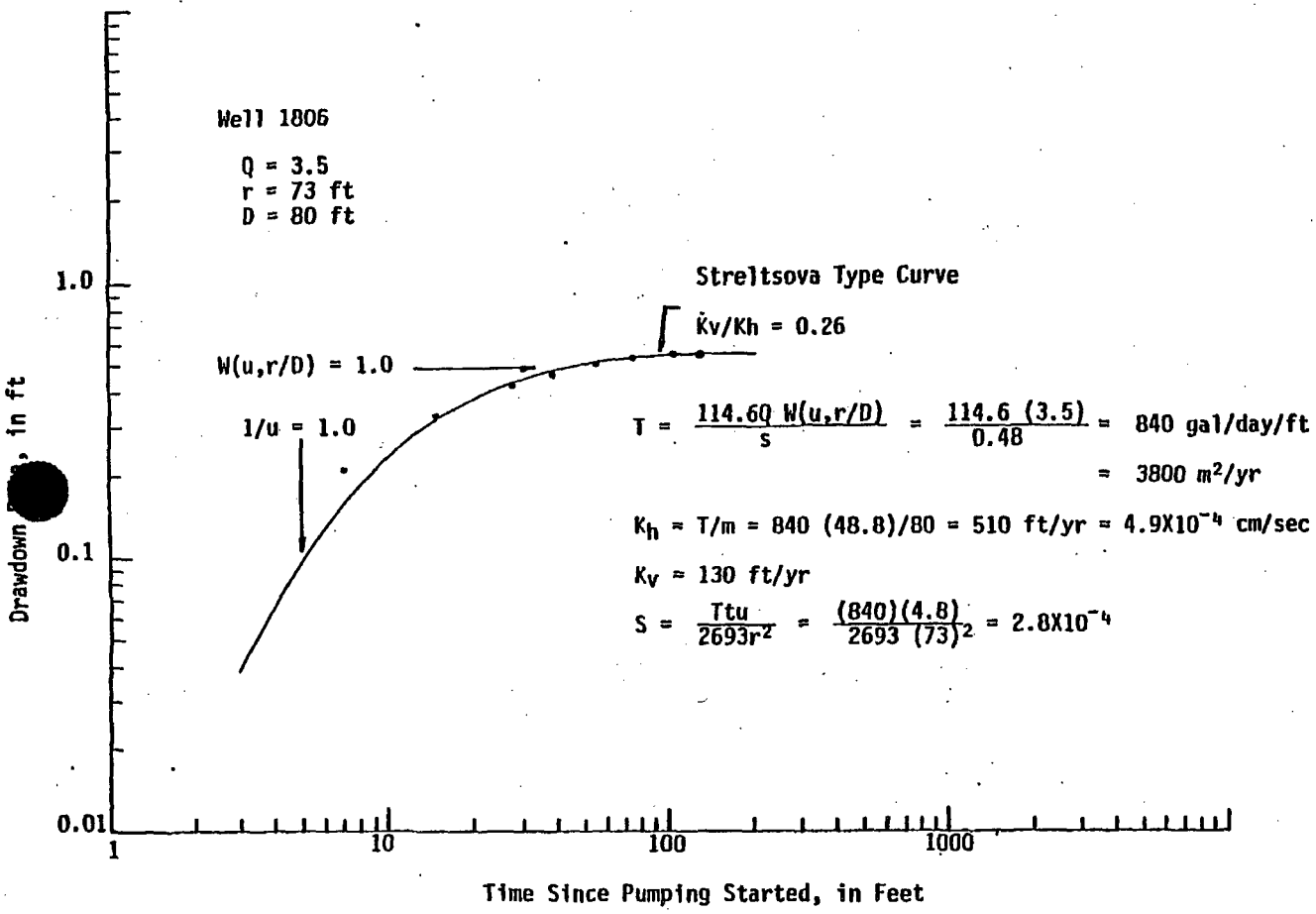


FIGURE A-1.46. DRAWDOWN IN OBSERVATION WELL 1806 FROM PUMPING WELL 1 (70 SAND)

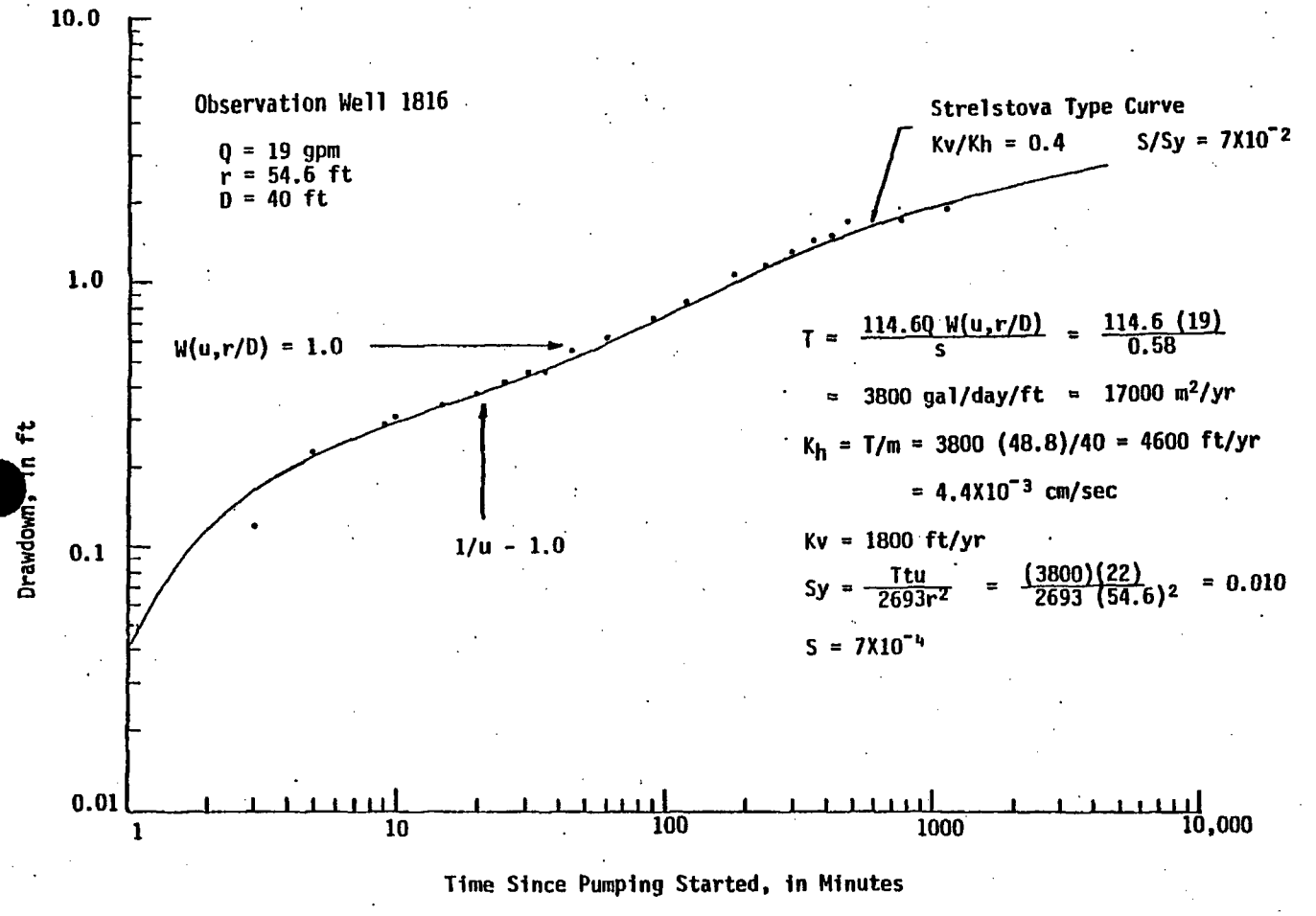


FIGURE A-147. DRAWDOWN IN OBSERVATION WELL 1816 FROM PUMPING WELL 1814 (70 SAND)

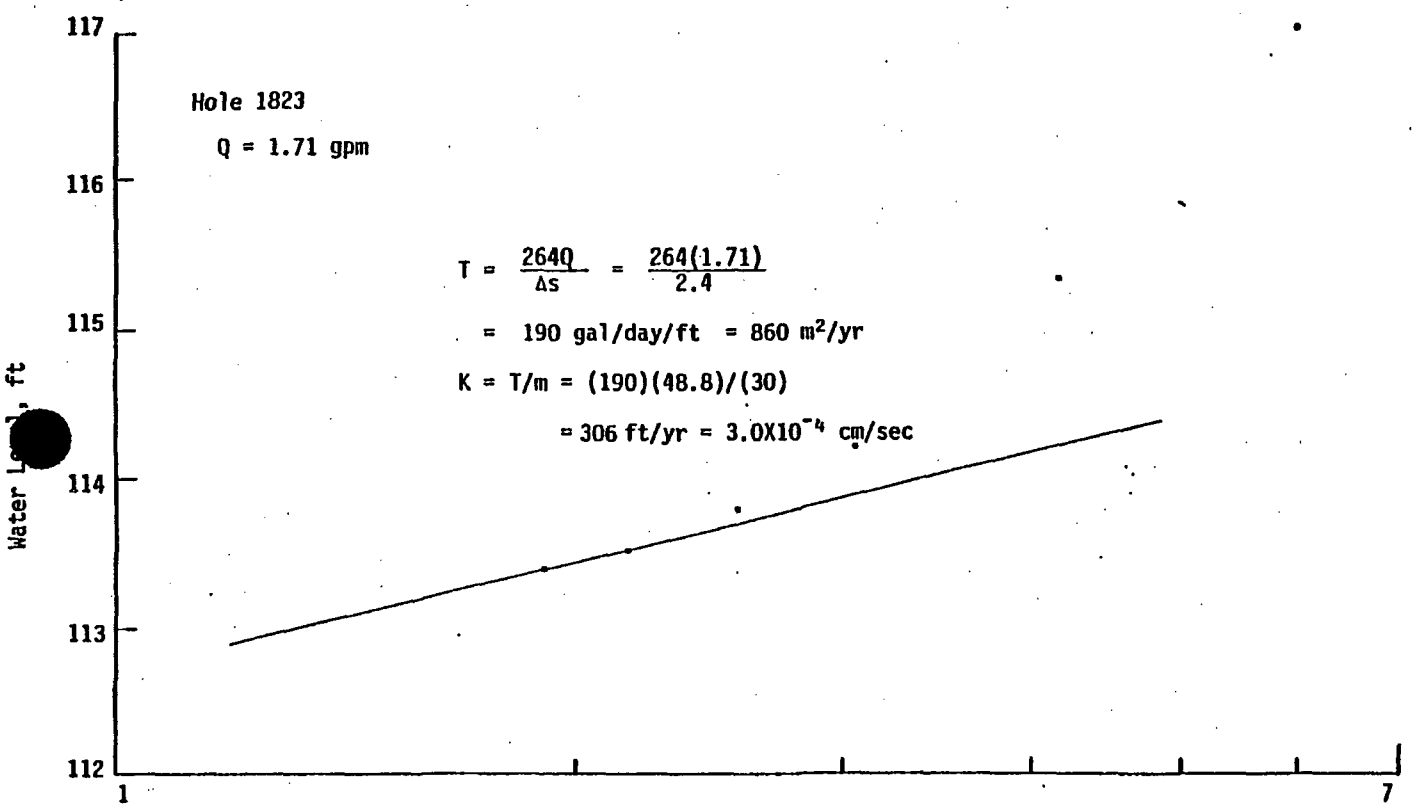


FIGURE A-1.48. RECOVERY OF PUMPING WELL 1823

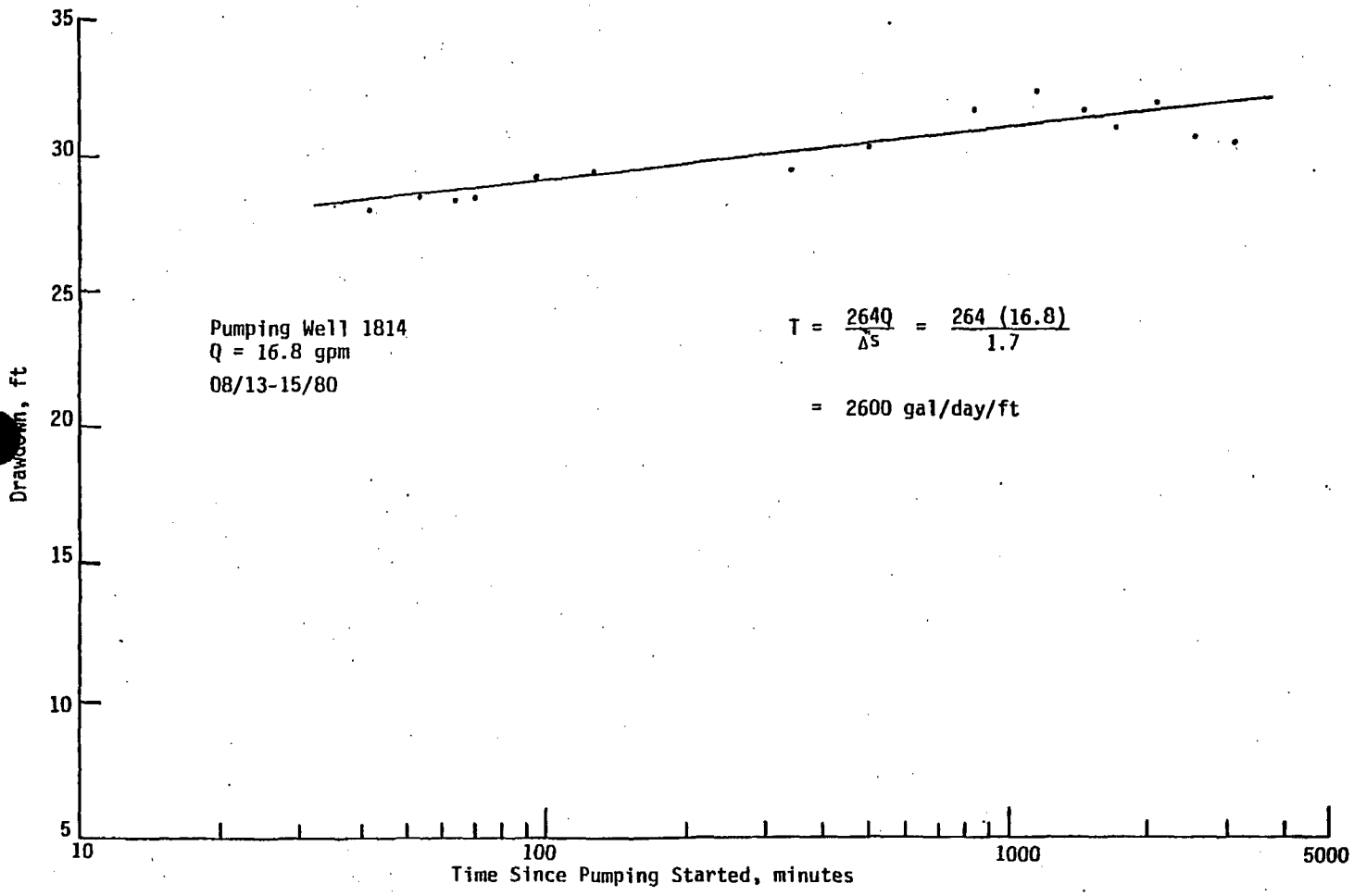


FIGURE A-1.49 DRAWDOWN DATA FOR PUMPING WELL 1814 (70 SAND)

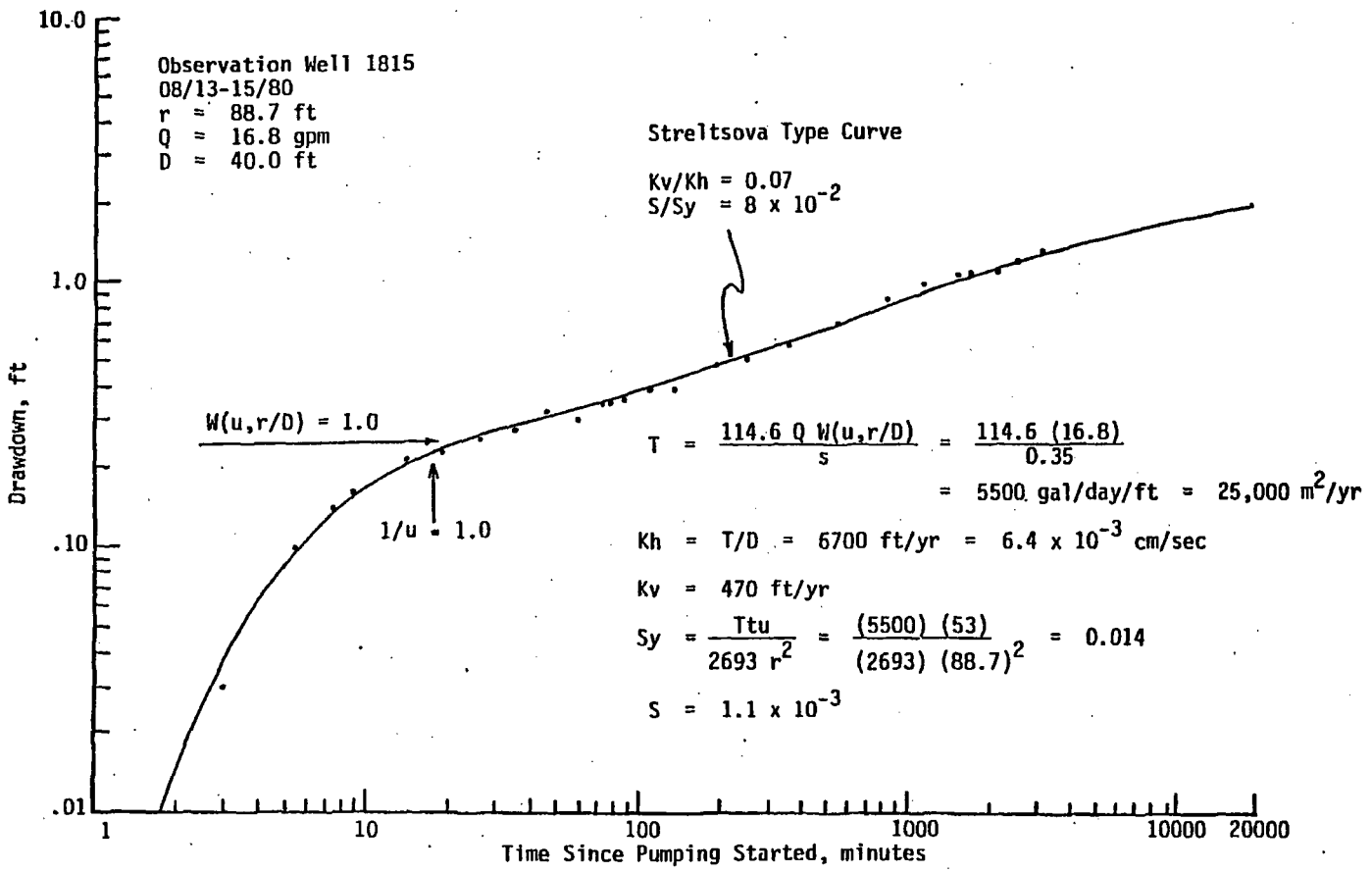


FIGURE A-1.50 DRAWDOWN DATA FOR WELL 1815 FROM PUMPING WELL 1814 (70 SAND)

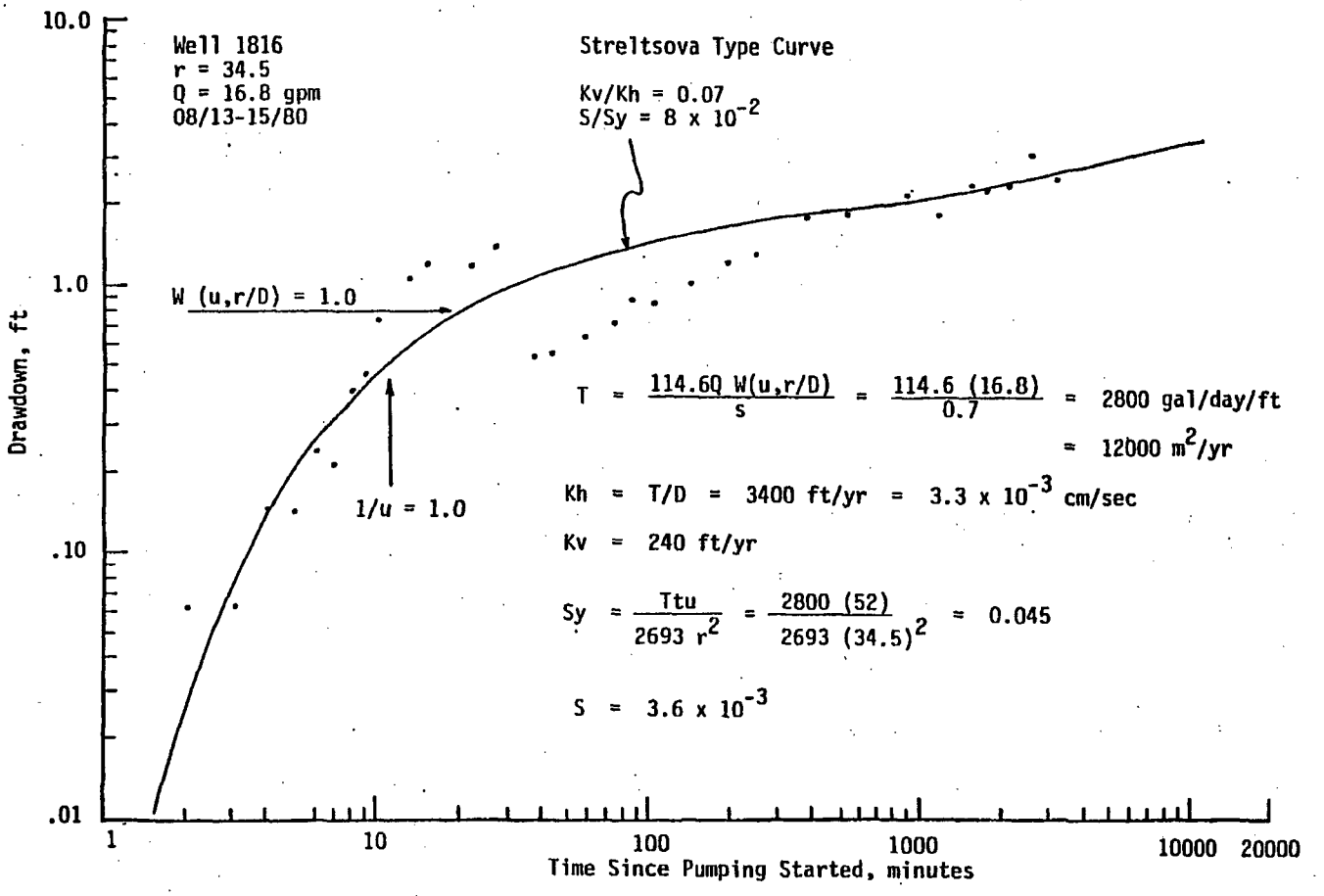


FIGURE A-1.51 DRAWDOWN DATA FOR WELL 1816 FROM PUMPING WELL 1814 (70 SAND)

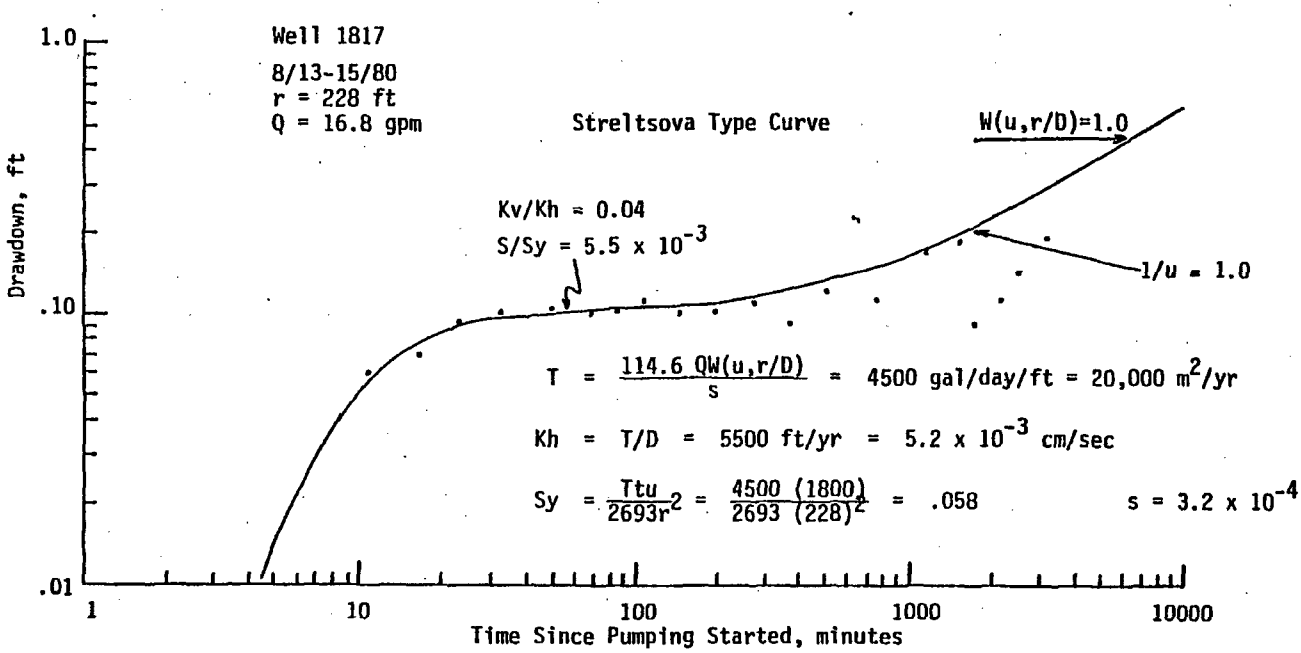


FIGURE A-1.52 DRAWDOWN DATA FOR WELL 1817 FROM PUMPING WELL 1814 (70 SAND)

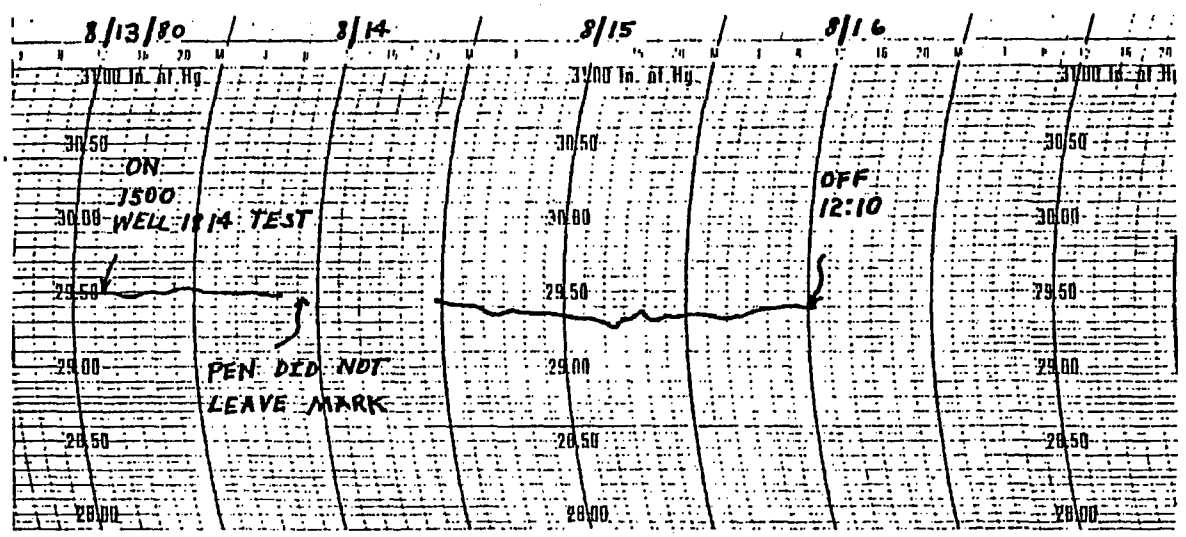


FIGURE A-1.53 BAROMETRIC PRESSURE DURING THE 8/13-15/80 PUMP TEST

APPENDIX A-2

PUMP TEST

THEORY AND ANALYSES

APPENDIX A-2

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APPENDIX A-2

TEST ANALYSES

Pump and Constant Head Test Theories

The theory used to analyze transmissivities and hydraulic conductivities from nonpumped wells is presented first. Theories used to evaluate aquifer properties from the pump tests are given last.

Hydraulic conductivities (permeabilities) in wells which yield only small amounts of water were determined by constant head injection tests. Dry drill holes were also tested using this method after saturating the rock unit outside the perforated casing interval. Lohman (1972, pages 23-29) presents the theory for a constant-head drawdown or injection test. Briefly, this technique utilizes a form of Jacob's straight-line semi-log plot method and the equation:

$$T = \frac{264}{\Delta(sw/Q/\Delta \log_{10}(t/r_w^2)}$$

$$= \frac{264}{sw\Delta(1/Q)} \qquad \text{change in } 1/Q \text{ for one log cycle of } \log_{10}t$$

where Q = discharge, in gpm

sw = constant drawdown, or head, in ft

T = transmissivity, in gal/day/ft

t = elapsed time, in min

r = effective well radius, in ft

The inverse of the injection rate was plotted against elapsed time since injection started on semi-log paper with time on the log scale. The inverse of the injection rate should gradually increase with time and form a straight line. The change in the injection rate from the straight line over one log cycle is used with the above equation to compute the transmissivity of the unit. The hydraulic conductivity was obtained by dividing the transmissivity by the test interval. Theis, in 1935, introduced his equation which describes a nonleaky confined aquifer. The following is a general definition of the Theis equation:

$$T = 114.6QW(u)/s$$

$$u = 2693r^2S/Tt$$

where:

s = drawdown, in ft

Q = discharge in gallon per minute (gpm)

$W(u)$ = well function

T = transmissivity in gallons (gal)/day/ft

u = well function variable

r = observation well radius from pumping well, in ft

S = storage coefficient

t = time since pumping started in minutes (min)

Pump test data are analyzed by matching the log-log plot of drawdown versus time to Theis' type curve (W(u) vs. 1/u) and applying the above equations to the match. Pages 92-98 of Ferris and others (1962) present a more thorough discussion of the Theis equation.

Theis' equation can be modified to handle recovery of a well or multiple pumping periods by summation of the well functions. The following equation in the solution of Theis' equation for one pumping and recovery cycle (Recovery equation).

$$T = 264\ Q \log_{10} (t/t')/s$$

or

$$264Q/\ s'$$

where:

t = time since pumping started, in min

t' = time since pumping stopped, in min

s = residual drawdown, in ft

s' = change in residual drawdown over one log cycle of time on a semi-log plot, in ft

Therefore, when residual drawdown is plotted on an arithmetic scale versus t/t' on a logarithmic scale, the above equation can be used for the straight line fit. Pages 100-102 of Ferris and others (1962) should be consulted for a discussion of Theis' recovery method. Theis' recovery equation is for a nonleaky confined aquifer also.

Theis' equation with Jacob's (1944) correction for aquifer thinning has been used extensively to analyze unconfined aquifer tests. However, this equation does not take into account the free surface boundary of the water table. Theories of unconfined aquifers are more complicated than Theis' equation with the moving boundary at the phreatic surface. Boulton

(1954) presented an unconfined flow equation for drawdown at the free surface. This equation has not been used very extensively, because drawdowns at the phreatic surface and from a well which penetrates the aquifer are considerably different. Stallman (1963, 1965) developed some type curves for an unconfined aquifer from an electric analog, but these curves have not been used extensively because they are for limited well conditions. Dagan (1967) and Neuman (1972, 1974) have developed computer programs which compute type curve values for unconfined aquifer conditions. Neuman showed that unconfined aquifers have some storage from compression of the aquifer structure and the expansion of the fluid. His equation, therefore, has both a storage coefficient and a specific yield term. Dagan's equation considers only the specific yield for storage. All of these unconfined aquifer equations produce equal type curves for the same conditions except Neuman's curves, which depart from the other curves at early pumping times. The confining nature of most unconfined aquifers is only significant at early pumping times. Some of the pump tests on the 70 sand were conducted long enough to define only the early time drawdown. Neuman's pump test theory was selected for our pump test analyses because it defines the early drawdown also.

Development of Neuman (1974) type curves requires an execution of a computer program for each individual pump test. Streltsova (1972, 1973) developed an approximation of the vertical flow equation and has shown this approximation is the same as Boulton's (1963) flow equation. Streltsova's approximation allows Boutlon's type curves to be used to analyze an unconfined aquifer with consideration of vertical flow if all wells are fully penetrating. The following form of Steltsova's equation will be used in this report:

$$T = 114.6\ Q\ W(u,r/D)/s$$

$$S_y = Ttu/2693r^2$$

The relationship between this equation and Boulton's equation is as follows:

$$r/B = r/D\sqrt{3K_v k_h}$$

where: T = Transmivsivity, in gal/day/ft

Q = Discharge, in gpm

s = Drawdown, in feet

$W(u,r/D)$ = Streltsova well function

S_y = Specific yield

t = Time since pumping started, in minutes

u = Well function variable

r = Distance from pumping well, in feet

D = Aquifer thickness, in feet

B = $\sqrt{\alpha S_u/T}$ (Boulton's equation)

α = $3K_v/S_y/D$ (Boulton's equation)

K_v = Vertical hydraulic conductivity, in ft/day

K_h = Horizontal hydraulic conductivity, in ft/day

Test Results

The results of the permeability tests from the low yielding wells and dry piezometers in the evaporation pond area will be presented first with the 70 sand tests from this area given second. The permeability and transmissivity results from the 35N area will be given last.

Twenty-one constant head injection and three recovery tests were conducted to determine the saturated hydraulic conductivity (permeability) of the subsoil materials in the evaporation pond area (see Figure D-6-2) for a schematic of lihologic units). Fifteen constant head injection tests and two recovery tests were conducted in the 35N tailings area.

Several pump tests were conducted on the 70 and 68 sands in the mine area. The injection rates necessary to maintain the water level at the top of the casing were measured. Most of the injection tests were conducted approximately three to four hours. The constant head used in the permeability computation was static water level for previously saturated units, or the depth to the center of the perforations for unsaturated rock units. These two depths were measured from the top of the well casing. Dry piezometers were filled with water for one or two days prior to the tests to saturate the perforated unit.

Table A-1.1 presents the basic data for the constant head test conducted on hole P-1, a Lower mudstone (claystone) and E coal piezometer. This test was conducted for a period slightly less than three hours. This piezometer was developed by bailing and filling with water prior to the tests. The injection rate (discharge) for piezometer P-1 started at approximately one-fourth gallon per minute and gradually decreased to 0.158 gpm at the end of the test. The inverse of the injection rate was plotted versus time since the injection started on semi-log paper with time on the log scale. The straight line fit of the inverse injection rate produced a transmissivity of 3.1 gal/day/ft for the Lower mudstone and E coal near hole P-1. A permeability of 15 ft/yr was computed from this transmissivity.

The constant head test for piezometer P-2 is presented in Table A-1.2 and Figure A-1.2. The test data for this hole shows that the piezometer would take only .0095 gpm at the end of the 229 minute injection period. A permeability of 0.7 ft/yr was computed for the Lower mudstone and E coal formations near hole P-2.

The test results for another Lower mudstone test hole, P-3, are presented in Table A-1.3 and Figure A-1.3. This hole was saturated the day before the test because only a small amount of water was present in the bottom of this piezometer. A permeability of 7.7 ft/yr was computed from this test for the Lower mudstone near hole P-3.

Piezometer P-4 is perforated in the Lower mudstone and E coal. A constant head test on this hole was conducted on April 3, 1980. This piezometer would take only a small injection rate of .0023 gpm after 343 minutes of injection. Transmitting properties of 0.14 gal/day/ft and .70 ft/yr were computed for the Lower mudstone and E coal near P-4 for the transmissivity and permeability, respectively.

Piezometer P-4B was injected at a constant head while the water level in piezometer P-4B1 was observed. Both wells are completed in the Upper mudstone and E coal. Table A-1.5 presents the injection rate data for hole P-4B. A gradual water level rise in piezometer P-4B1 was observed during the injection test after approxiately 30 minutes with a total drawdown of greater than one-tenth of a meter at 275 minutes. Well P-4B1 is approximately 5 feet from well P-4B. A permeability of 16 ft/yr was computed from the injection test.

An Upper mudstone piezometer, P-4CA, was tested by injecting water to maintain a constant head at the top of the casing. Table A-1.7 gives the basic test data for piezometer P-4CA, which was taking .0076 gpm after 398 minutes of injection. The straight line fit of this data produced a permeability of 4.6 ft/yr for the Upper mudstone near piezometer P-4CA. Figure A-1.7 presents the plot of this data, which is considerably scattered.

The test on piezometer P-5, an E coal well, yielded a permeability of 6.2 ft/yr. Figure A-1.8 gives the straight line fit of this data, and Table A-1.8 contains the test data.

Piezometer P-6 is completed in the Upper sandstone, which is saturated only in the bottom few feet of the formation. The data plot, which is shown in Figure A-1.9, does not follow a good straight line. The initial partial saturation of this sandstone unit could have caused some of the variation in the injection rate. The best fit of the data produced a permeability of 7.1 ft/yr for the sandstone. This test shows that the permeability of the Upper sandstone is low at this interval in this area.

Piezometer P-8 is completed in the Lower mudstone and E coal and was tested on April 2, 1980, with questionable results. Table A-1.11 presents the basic test data, while Figure A-1.11 gives the semi-log plot. This plot shows a large scatter in the injection rates, indicating that factors in addition to those assumed by theory are influencing the system. Results from this test should not be weighted very heavily.

An injection test on piezometer P-9 was conducted for slightly more than five hours with an ending injection rate of .004 gpm. A permeability of 0.38 ft/yr was obtained from this test for the Lower mudstone and E coal.

A second piezometer was completed at the P-9 site in the Upper mudstone. The test on this piezometer, P-9A, indicates that the Upper mudstone at this site has a permeability of 2.5 ft/yr.

The permeability test information for piezometer P-10 is given in Table A-1.14 and Figure A-1.14. The straight line fit produced a permeability of 1.2 ft/yr for the Lower mudstone and E coal in this area.

The injection rate for the constant head test on piezometer P-11 was fairly steady for the first 200 minutes and then steadily increased with time. The pattern of these injection rates did not follow the constant head theory, and, therefore, results from this test are questionable.

The constant head test data for piezometer P-12, which is perforated in the E coal, is presented in Table A-1.16 and Figure A-1.16. The static water level in P-12 is near the top of the E coal, which is approximately three feet thick at this location. A permeability of 6.7 ft/yr was obtained for the E coal near piezometer P-12.

The injection test on piezometer P-13 produced a reasonable semi-log plot for the first 40 minutes of injection. Then a steady increase in the injection rate occurred contrary to theoretical expectation.

The constant head test for hole P-13A produced a transmissivity and permeability for the E coal of 1.8 gal/day/ft and 14.8 ft/yr respectively. Figure A-1.18 gives the plot for this test.

Two piezometers were completed at the P-15 site, one in the Lower mudstone and E coal and one in the Upper mudstone. Constant head tests conducted on these piezometers produced permeabilities of 0.71 ft/yr and 55 ft/yr for the Lower mudstone - E coal and Upper mudstone respectively.

Well P-18, which is an alluvial well in the evaporation pond area, produced a permeability of 470 ft/yr for the alluvium in this area. Figure A-1.23 gives the plot of this test.

The upper portion of the 70 sand is not saturated and was tested for permeability at two sites in the evapotation pond area. Permeabilities of 1.0 ft/yr and 0.65 ft/yr were determined for the unsaturated portion of the 70 sand. The low permeabilities from these tests are reflective of the large amount of cementation present within this sandstone above the water table.

Recovery tests were conducted on the three 70 sand wells in the evaporation pond area. Well P-20B was pumped but went dry very quickly. Recovery tests after bailing wells were conducted because the wells would not yield a sustained flow. Permeabilities of 15.8 ft/yr and 3.7 ft/yr were calculated for wells P-7, P-20B and P-21 respectively. Figures A-1.10, A-1.23B and A-1.23C give the recovery plots for these three wells.

Table A-1.24 presents the basic data for the constant head test conducted on hole 35N-1C, an upper 70 sandstone well. This test was conducted slightly less than five hours. This piezometer was developed by bailing and filling with water prior to the tests. The inverse of the injection rate was plotted versus time since injection started on semi-log paper with time on the log scale. Figure A-1.24 shows the graphical representation of the data. The straight line fit of the inverse injection rate produced a transmissivity of 0.40 gal/day/ft. A permeability of 0.78 ft/yr was computed from this transmissivity.

The constant head test data for hole 35N-10 is presented in Table A-1.25. The test for this hole shows that the piezometer would take 0.086 gpm at the end of the 177 minute injection period. A permeability of 7.0 ft/yr was computed for the sandstone formation near hole 35N-1D.

Table A-1.26 presents the data for the constant head test for hole 35N-1E, a mudstone formation. This piezometer was prepared for the constant head test by bailing the hole dry then saturating the hole the day prior to the test. The piezometer would take only .0045 gpm over the 242 minute injection period. The permeability computed for this mudstone formation was 0.9 ft/yr. Refer to Figure A-1.26 for the graphical representation of the constant head test.

Table A-1.27 presents the data for the recovery test conducted on hole 35N-2A. The piezometer was bailed for 34 minutes and the water level was measured over a 133 minute period after bailing had stopped. The water level versus the ratio of time since pumping started to time since pumping stopped was plotted on semi-log paper with the ratio of times on the log scale. Figure A-1.27 shows the graphical representation of the data. A

transmissivity of 2.6 gal/day/ft was computed by using an average flow rate of 0.35 gpm. A permeability of 8.5 ft/yr was computed from this transmissivity.

The constant head test data for hole 35N-2B, which is completed in sandstone, is shown in Table A-1.28. The hole was developed prior to the test by bailing and then by saturating. The piezometer took .0806 gpm over the 280 minute injection period. The transmissivity computed for this hole was 0.82 gal/day/ft. Figure A-1.28 shows the straight line fit of the inverse injection rate. A permeability of 7.8 ft/yr was computed from the transmissivity.

Table A-1.29 shows the data for the constant head test for hole 35N-2C, a mudstone piezometer. The injection period was 275 minutes with an injection rate of 0.168 gpm at the end of the test. The transmissivity was computed to be 0.9 gal/day/ft. From this transmissivity a permeability of 4.3 ft/yr was computed.

Table A-1.30 shows the data for the constant head test for hole 35N-3, a sandstone piezometer. The piezometer was developed by bailing and then by saturating prior to the test. The permeability was computed to be 34.7 ft/yr.

The constant head test data for hole 35N-4 is presented in Table A-1.31. The piezometer took .049 gpm over the 242 minute injection period. The transmissivity was computed to be 1.1 gal/day/ft. Figure A-1.31. shows a graphical representation of the constant head data. From the computed transmissivity, a permeability of 2.7 ft/yr was computed.

The data for the constant head test for hole 35N-5 can be found in Table A-1.32. The piezometer was developed prior to the test by bailing and then by saturating. The transmissivity was computed to be 0.0025 gal/day/ft. From this transmissivity a permeability of 10.2 ft/yr was computed.

Table A-1.33 shows the data for the constant head test for hole 35N-6, a sandstone formation. This test was conducted over a five-hour period. The inverse of the injection rate was plotted versus time since injection started on semi-log paper with time on the log scale. Figure A-1.33 shows the graphical representation of the data. The straight line fit of the inverse injection rate produced a transmissivity of 2.1 gal/day/ft. A permeability of 10.2 ft/yr was computed from this transmissivity.

Table A-1.34 presents the data for the recovery test conducted on hole 35N-7A (70 sand well). The data shows that the recovery was measured after two different intervals (bailing cycles). Figure A-1.34 shows the graphical representation of the data. The permeability was computed to be 1,430 ft/yr.

The constant head test data for hole 35N-7B, an upper 70 sandstone, is presented in Table A-1.35. The test for this hole shows that the piezometer took 0.207 gpm at the end of the 395 minute injection period. A permeability of 5.5 ft/yr was computed for this formation.

Table A-1.36 presents the constant head test data for hole 35N-7C, a sandstone formation. The hole was developed prior to the test by bailing and then by saturating. The transmissivity was computed to be 1.7 gal/day/ft. From this transmissivity the permeability was computed to be 8.3 ft/yr.

Table A-1.37 presents the constant head test data for hole 35N-7D, an E coal piezometer. This piezometer was developed by bailing and filling with water prior to the tests. The inverse of the injection rate was plotted versus time since injection started on semi-log paper with time on the log scale. Figure A-1.37 shows the graphical representation of the data. The straight line fit of the inverse injection rate produced a transmissivity of 5.8 gal/day/ft. A permeability of 40.6 ft/yr was computed from this transmissivity.

The constant head test data for hole 35N-7E is presented in Table A-1.38. This piezometer took 0.014 gpm over a 300 minute period. The permeability was computed to be 42.1 ft/yr.

Table A-1.39 presents the constant head test data for hole 35N-7F, a mudstone formation. The transmissivity was computed to be 0.37 gal/day/ft. Figure A-1.39 shows a graphical representation of the data. From the transmissivity a permeability of 3.0 ft/yr was computed.

The constant head test data for hole 35N-7G, an upper coal, is presented in Table A-1.40. The piezometer was developed by bailing and by saturating prior to the test. The piezometer took only 0.0025 gpm over a 275 minute injection period. The permeability was computed to be 0.09 ft/yr.

Pump tests have been conducted in each of the proposed mine pits to define the aquifer properties of the 70 sand aquifer. Well 885, which is inside the limits of Pit 34, was pumped at 3.4 gpm for approximately one day. Table A-1.41 presents the drawdown for the three obervation wells.

Wells 885, 886 and 888 are 70 sand wells, while well 887 penetrates only the 68 sand, which is the next sand below the 70 sand. The drawdown and its best fit Streltsova type curve (Kv/Kh = 0.66 and S/Sy = 7 x 10^{-2}) in observation well 886 are shown in Figure A-1.41. This match produced a transmissivity of 800 gal/day/ft for the 70 sand aquifer in the area of pit 34. Horizontal and vertical permeabilities of 650 ft/yr and 430 ft/yr, respectively, were computed for the 70 sand aquifer. These values show that the 70 sand is only slightly anisotropic in this area. Storage values of 0.015 and 1.0 x 10^{-3} were computed for the specific yield and storage coefficient respectively. The shape of the drawdown curve in well 888 is considerably different that the shape of the curve for well 886. The match of the drawdown data for well 888 (see Figure A-1.42)produces a much lower transmissivity. A similar storage coefficient and anisotropic ratio (Kv/Kh) were obtained from the analysis of the drawdown from well 888 as well 886. The drawdown in observation well 887, which is perforated in the 68 sand, is given in Table A-1.41. The drawdown in this well indicates connection between the 70 and 68 sands, but this well is not analyzed because it is questionable if the well was sealed between the two sands.

Recovery tests were also conducted on wells 886 and 887 by air lifting 2 and 0.1 gpm respectively from these two wells. Tables A-1.42 and 43 give the recovery data, while the recovery plots are shown in Figures A-1.43 and 44. The straight line fit of the recovery data for wells 886 and 887 produced a transmissivity of 1800 gal/day/ft and 1.9 gal/day/ft respectively. This information indicates that the 68 sand has a low transmitting capacity in this area.

A pump test was also conducted on wells in the area of Pit 35N. Well 1 was pumped while wells 1805, 1806 and 1807 were observed for drawdown. Wells 1, 1805 and 1806 are 70 sand wells, while well 1807 is a 68 sand well. Tables A-1.44, 45 and 46 give the drawdown data for the three Pit 35N observation wells. A Streltsova type curve of Kv/Kh = 0.6 (see Figure A-1.45) was matched to the drawdown data to yield a transmissivity of 910 gal/day/ft. A horizontal permeability of 560 ft/yr was computed from the transmissivity and aquifer thickness of 80 feet, while a vertical permeability of 340 ft/yr was obtained from the anisotropic ratio. The analysis of this test also produced a storage coefficient of 5.2×10^{-4} for the 70 sand aquifer near well 1805. The results from observation well 1806 are similar to those from well 1805 and are given in Figure A-1.46. The completion of well 1807 has shown that a good seal was not obtained. The drawdown in observation well 1807 (68 sand) indicates a possible connection between the 68 and 70 sands in this area, but this test was not conclusive on the connection between these two systems.

Well 1816 was observed while well 1814 in Pit 35S was pumped. The match in Figure A-1.47 indicates the anisotropic ratio of the aquifer near well 1816 is 0.4. This test was conducted long enough to obtain a specific yield of the aquifer of 0.01. The transmissivity of 3800 gal/day/ft indicates that the 70 sand is more permeable in the area of Pit 35S.

Pumping and recovery data for well 1823 is presented in Table A-1.48. The well was pumped for 49 minutes. The water level of the well was then measured at different intervals over an 80-minute period after pumping was stopped. The water level versus the time since pumping started divided by the time since pumping stopped was then plotted on semi-log

paper with time on the log scale. Figure A-1.48 shows the graphical representation of the data. The transmissivity was computed to be 190 gal/day/ft. The permeability computed from this transmissivity was 306 ft/yr. Table A-1.49 presents the water level in well 1816 during the pumping of well 1823. This data indicates no measurable connection between the 68 and 70 sands in this area.

A three day pump test was conducted on 8/13-15/80. Well 1814 was pumped at an average discharge rate of 16.8 gpm, while wells 1815, 1816, 1817 and 1823 were observed. All of these wells are 70 sand wells except well 1823, which is a 68 sand well. Table A-1.50 presents the pumping and drawdown data for the pumping well 1814, while Tables A-1.51, A-1.52 and A-1.53 present the drawdown data for observation wells 1815, 1816 and 1817, respectively. The water level measurements for well 1823 show a typical water level rise in the adjacent aquifer shortly after pumping starts. The water level in the 68 sand then returns to a level close to the static conditions. The rise at the end of the test is probably attributed to a decrease in barometric pressure. Figure A-1.53 presents the barometric pressure during the pump test.

The semi-log of the drawdown in the pumping well is given in Figure A-1.49. The fit of the straight line yields a transmissivity of 2600 gal/day/ft for the transmissivity of the 70 sand near well 1814. Streltsova's type curve for an anisotropic ratio (Kv/Kh) of 0.07 and storage ratio (S/Sy) of 8×10^{-2} matched the drawdown data in observation well 1815. Figure A-1.50 presents this match of the type curve to the drawdown data. Values of 5500 gal/day/ft, 6700 ft/yr and 470 ft/yr were calculated for the transmissivity, horizontal and vertical permeability,

respectively. Storage values of 0.014 and 1.1×10^{-3} were computed from the type curve match for the specific yield and storage coefficient.

Drawdown in observation well 1816 reacted very strangely which questions the accuracy of results obtained from this well. Figure A-1.51 presents the match and results from this observation well.

Observation well 1817 is 228 feet from pumping well 1814, and therefore the confining portion of the unconfined aquifer is the major portion of the drawdown curve observed. Figure A-1.52 presents the results of the match for well 1817. A better fit of the late time data would probably be obtained if the drawdowns were corrected for barometric pressure changes.

Appendix A-3 to Appendix D-6 (Hydrology)

EROSION POTENTIAL OF THE SAND ROCK MILL PROJECT SITE

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1.0 INTRODUCTION

1.1 Objectives

The primary purposes of the Sand Rock Mill erosion study were to (1) identify and describe erosional processes actually or potentially active in the study area, (2) provide order of magnitude estimates of past or present erosion rates, and (3) predict future erosional conditions on the site. This information can be used as a basis for designing mitigation programs for potential erosion problems that might arise.

1.2 Methods

Estimates of past and present erosion rates were based on published geological information, analysis of existing topography and geomorphology in the area, calculations of the Universal Soil Loss Equation, discussions with USGS personnel, and limited field investigations. Section 5.0 provides detailed calculations by which quantitative estimates of erosion rates were derived. Assumptions used for each calculated rate are shown.

For the purposes of this study, three time estimates were utilized. "Past" ranges from 100 years B.P. (before present) to 26 million years B.P. The latter figure is the age of the Pumpkin Buttes erosional remnant (i.e., post-Oligocene; Sharp et al. 1964) and therefore represents a convenient starting point for dating regional erosion. "Present" includes the interval from 100 years B.P. to today. "Future" or "Long-term" erosion includes the next 1,000 years (i.e., from now until about 3000 A.D.). The 1,000 year limit was selected because it coincides with the proposed standards for long-term disposal of hazardous uranium mill tailings required by the Environmental Protection Agency (EPA).

Major erosional processes identified in the study area are sheet and rill erosion, stream erosion, gully formation, and wind erosion. The past, present, and anticipated future rates of erosion attributable to each of these processes are discussed in Sections 2.1 - 2.4 of this report.

1.3 Site Description

The Sand Rock Mill site is located in the drainage of Ninemile Creek, which is tributary to Antelope Creek and within the Cheyenne River basin. Several ephemeral washes drain southward across the site toward Ninemile Creek. This study dealt primarily with an ephemeral drainage designated as Wash #2 by Conoco. Wash #2 is of particular interest to Conoco because it crosses the proposed location of a tailing disposal site, Pit 35N (Section 35, T42N, R75W).

Wash #2 has a total drainage area of 2.42 square miles, about half of which is above Pit 35N. Present plans call for Pit 35N to be covered with 10-30 feet of overburden material, a clay cap, and soil, and then revegetation as part of the reclamation process.

The site is dominated by gently rolling terrain, with occasional sandstone outcrops and blowouts. Parent material is the Tertiary Wasatch Formation; soils are predominantly sandy and have high infiltration rates. Average annual precipitation at the site is about 12-15 inches, mostly falling in spring and summer rainstorms. Vegetation consists of mixed grassland and sagebrush steppe, with fairly well developed cover. This combination of coarse-textured soil, gentle terrain, vegetational cover, and limited rainfall results in very low runoff (1.5 acre-feet per square mile per year) and low erosional rates (Hadley and Schumm 1961).

2.0 RESULTS

2.1 Sheet and Rill Erosion

Sheet erosion is the removal of surface material by water flowing across a surface in sheets (i.e., not confined to channels). Rill erosion is the removal of surface material by water flowing in small channels, usually only a few inches in depth and width.

Present rates of sheet and rill erosion of the Wasatch Formation throughout the Cheyenne River basin are low (1.0 ft/1000 yrs), based on sediment yield studies of Hadley and Schumm (1961). This value assumes a sediment delivery rate of 20 percent and that all sediment is the result of sheet and rill erosion. The Hadley and Schumm study included a small gully-plug stock pond in Section 30, T41N, R75W, about 4 miles west-northwest of Pit 35N. Sediment yields between 1931 and 1954 indicate an erosion rate of 0.8 ft/1000 yrs (Table 1).

Future rates of sheet and rill erosion have been estimated for reclaimed areas using the Universal Soil Loss Equation (Wischmeier and Smith 1978). Assuming slopes with an average gradient of 7 percent, an erodibility factor of 0.3 (U.S. Forest Service 1978), an average density for sandy loam of 1.5 g/cm^3, and vegetation cover of 50 percent (roughly the premining average in a typical year), this method of analysis predicts a postmining erosion rate of about 0.8 ft/1000 yrs (Table 1).

2.2 Stream Erosion

Stream erosion is the cyclical process of erosion and deposition in the lower portions of a drainage basin. At present, Wash #2 appears stable, based on the meandering pattern of the active channel and the mostly vegetated sideslopes. Minor lateral cutting along the outside banks of meanders and downcutting through grassy channel bottoms occurs in a few places.

Thicknesses of alluvium in the area indicates the depth of valley cutting in Wash #2 that has occurred in the past. For example, Conoco hydrology consultant George Hoffman (personal communication, 1980) reports that the alluvium is about 7.5 ft deep in a well 500 ft west of the Pit 35N site. The well is near the edge of the lowermost terrace, and alluvium thicknesses probably are greater toward the middle of the channel. According to Conoco project geologist John Barr (personal communication, 1980), the alluvium in Wash #2 probably is about 6-10 ft deep, based on well cuttings, lithologic logs, and geophysical logs. The depth of stream erosion in Wash #2 might be controlled by bedrock in the vicinity of a sandstone outcrop in Section 2, T41N, R75W to the south.

Table 1. Summary of erosion rates estimated for the Sand Rock Mill study area.

Process	Rate (ft/1000 yrs)	Method	Interval Measured	Area Where Calculated	Source
Sheet and Rill Erosion	1.0	sediment accumulation	present	Wasatch Formation, Cheyenne River Basin, Wyoming	Hadley and Schumm (1961)
"	0.8	sediment accumulation	1931-1954 A.D.	Section 30, T41N, R75W	"
"	0.8	Universal Soil Loss Equation (USLE)	projected post-reclamation	site specific	This Study
Stream Erosion	2.0	terrace stratigraphy	5000 yrs B.P. to present	Ninemile Creek	"
"	in progress	radiocarbon (C^{14})	—	site specific	"
Wind Erosion	$\leq$ 2.5	soil loss tolerance	present	site specific	"
Denudation	0.03	Pumpkin Buttes erosion surface	26 million years B.P. to present	South Pumpkin Butte, Wyoming	"
"	0.8	clinker bed fission track dating	0.7 million years B.P. to present	Little Thunder Creek, Wyoming	Coates (1980)
"	1.1-2.4	sediment accumulation	130-580 yrs B.P., 2500-4000 yrs B.P.	Powder River Basin, Wyoming	Leopold and Miller (1954)

Based on correlation of terrace stratigraphy at Ninemile Ranch (Merith Reheis, USGS, personal communication, 1980), valley cutting of Ninemile Creek has proceeded at an average rate of about 2 ft/1000 yrs (Table 1) during the last 5,000 years.

An estimate of stream erosion rates in Wash #2 currently is being obtained using a radiocarbon (C^{14}) dating method. The C^{14} age date is being calculated for organic matter collected from a buried soil A horizon in a low terrace adjacent to the active channel. The low terrace represents the most recent stage of alluvial deposition in Wash #2, and the C^{14} date represents the minimum age of the terrace. The height of the terrace divided by the minimum age of the terrace will indicate the maximum rate of recent stream cutting (Table 1).

2.3 Gully Formation

Gullies are deep, steep-sided channels, generally formed by ephemeral streams in areas of occasionally high runoff and readily erodible substrate. Gullies are common throughout the West, where steep slopes, sparse vegetation, and intense thunderstorm precipitation events combine to produce short-duration episodes of rapid downcutting.

At present, none of the washes in the Sand Rock Mill area shows signs of gully formation, nor is gullying a common feature of drainages on Wasatch Formation substrate elsewhere in the Cheyenne River basin. The scarcity of gullies in the area probably is attributable to the preponderance of sandy materials, which have higher infiltration rates and typically support fairly dense plant cover.

Because gullying does not appear to be a significant problem on the site at present, no attempt was made to quantify rates of gully formation in the region. Susceptibility of Wash #2 to future gullying probably is low. It is possible that sandstone outcrops near the confluence of Wash #2 and Simmons Draw will provide a bedrock control of downcutting in the area of Pit 35N.

2.4 Wind Erosion

Wind (aeolian) processes generally fall into two categories. Sand-sized particles are moved short distances and deposited as dunes. Finer particles are lifted to considerable heights and may be transported out of the area entirely.

The relatively sparse vegetation and high average wind speeds characteristic of the region have resulted in a long history of erosional and depositional aeolian processes. The Casper Distributary Current is a wind corridor that flows north and east from Casper across the site (Johnson and Bryant 1979). Aeolian deposits occur throughout the wind belt, often as sandy areas on the leeward slopes of hills or, less frequently, as dune fields.

Deflation hollows or "blowouts" are fairly common on the site, usually less than 0.25 acres in extent and 1 to 3 feet deep. Most blowouts on the site are located along and above stream banks on slopes facing the prevalent wind direction (i.e., west). Hollows as much as 10 feet deep occur along the eastern side of Wash #2.

Present wind erosion rates on the site are estimated to be less than 2.5 ft/1000 yrs, based on soil and vegetation conditions. This figure is based on the assumption that wind erosion currently is below 5 tons per acre per year, the level above which the effects of soil loss would be obvious and widespread. It must be emphasized that this value is a maximum, and that actual rates probably are less.

Future rates of wind erosion are expected to be no greater than present, assuming that reclamation procedures will re-establish vegetation cover comparable to premining conditions.

3.0 CONCLUSIONS

Denudation is the overall lowering of a land surface and therefore represents the total of all erosional and depositional processes active in an area. Past rates of denudation in the Pumpkin Buttes region have been very slow (0.03 ft/1000 yrs) (Table 1). This figure was derived by dividing the average relief of South Pumpkin Butte (693 feet) by the maximum age of its erosional surface (26 million years).

More recent denudation rates apparently are higher than the long-term mean. For example, Coates (1980) estimated regional denudation at 0.8 ft/1000 yrs for the past 0.7 million years (Table 1), based on fission track dating of clinker (burned coal) deposits in the Little Thunder Creek area. Hadley and Schumm (1961) arrived at similar values for sheet and rill erosion (see Section 2.1, page 3).

Leopold and Miller (1954) calculated volumes of alluvium deposited during the intervals 130-580 and 2500-4000 years B.P. Assuming a sediment delivery ratio of 20 percent (Schumm 1971), erosion rates averaged 1.1 ft/1000 yrs and 2.4 ft/1000 yrs (Table 1), respectively, during those intervals.

In summary, a number of techniques for quantifying erosional processes were used to estimate past and present rates in the area, mostly ranging from 0.8 to 2.5 feet per 1000 years. These figures may be used to extrapolate erosion rates after decommissioning and reclamation are complete; however, they should be considered as approximations. The reliability of these estimates is based on the accuracy of assumptions inherent in each calculation, and the continuation of environmental conditions active in shaping the present landscape.

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5.0 CALCULATIONS

Sheet and Rill Erosion

Method: Direct measurement of sediment accumulation, divided by source area.

Assumptions:

1. Annual sediment accumulation rate calculated by Hadley and Schumm (1961) to be 0.13 acre-feet per square mile per year for four reservoirs in the region and 0.10 acre-feet per square mile per year for a small pond in Section 30, T41N, R75W.

2. Average delivery ratio is 20 percent (Schumm 1977).

3. All sediment delivered to the reservoirs comes from sheet and rill erosion (rate therefore a maximum).

Calculation:

$$(0.13 \text{ ac-ft/mi}^2\text{/yr})(1.56 \times 10^{-3} \text{ mi}^2\text{/ac})(1000 \text{ yrs}) \div 20 \text{ percent} = 1.0 \text{ ft/1000 yrs}$$

$$(0.10 \text{ ac-ft/mi}^2\text{/yr})(1.56 \times 10^{-3} \text{ mi}^2\text{/ac})(1000 \text{ yrs}) \div 20 \text{ percent} = 0.8 \text{ ft/1000 yrs}$$

Method: Universal Soil Loss Equation (USLE).

Assumptions:

1. See Wischmeier and Smith (1978) for a discussion of assumptions and conditions associated with use of the USLE.

2. Erodibility factor (K) = 0.30; Gradient factor (LS, length/slope) = 1.6; Rainfall factor (R) = 50; Crop factor (C) = 0.07, based on typical premining cover of 50 percent; Practice factor (P) = 1, based on typical rangeland methods. See U.S. Forest Service (1978).

3. Average density of soil lost is 1.5 g/cm^3, the value for sandy loams.

Calculation:

$$A = K \times LS \times R \times C \times P$$

$$A = 0.30 \times 1.6 \times 50 \times 0.07 \times 1 = 1.7 \text{ tons/acre/year}$$

$$1.5 \text{ g/cm}^3 = (4.8 \text{ tons/acre})(907.18 \text{ kg/ton})(2.47 \times 10^{-4} \text{ ac/m}^2) = 0.4 \text{ kg/m}^2$$

$$(0.4 \text{ kg/m}^2)(0.67 \text{ cm}^3\text{/g})(10^3 \text{ g/kg})(10^{-4} \text{ m}^2\text{/cm}^2) = 0.02 \text{ cm}$$

$$(0.02 \text{ cm})(0.3937 \text{ in/cm})(0.08 \text{ ft/in})(1000 \text{ yrs}) = 0.8 \text{ ft/1000 yrs}$$

Stream Erosion

Method: Height of first terrace along Ninemile Creek, divided by approximate age.

Assumptions:

1. Age of first terrace is about 5000 years B.P. (Reheis, USGS geologist, personal communication, 1980).
2. Average height of first terrace is about 10 feet above the active floodplain.
3. No episodes of downcutting below present levels have occurred during past 5000 years.

Calculation:

$$10 \text{ ft} \div 5000 \text{ yrs} = 2 \text{ ft}/1000 \text{ yrs}$$

Wind Erosion

Method: Maximum soil loss on vegetated hillslopes converted to erosion rate.

Assumptions:

1. Owing to absence of active wind erosion features, present soil loss is below the SCS tolerance level of 5 tons per acre per year.

2. Average density of soils on the site is 1.5 g/cm^2.

Calculation:

$$(5\ \text{tons/acre})(907.18\ \text{kg/ton})(2.47 \times 10^{-4}\ \text{ac/m}^2) = 1.12\ \text{kg/m}^2$$

$$(1.12\ \text{kg/m}^2)(0.67\ \text{cm}^3/\text{g})(10^3\ \text{g/kg})(10^{-4}\ \text{m}^2/\text{cm}^2) = 0.08\ \text{cm}$$

$$(0.08\ \text{cm/yr})(0.3937\ \text{in/cm})(0.08\ \text{ft/in})(1000\ \text{yrs}) = 2.5\ \text{ft/1000 yrs}^*$$

*This value is a maximum; actual rates probably are lower.

Worksheet 1, No. I --
GROUNDWATER RESTORATION

Cost Item	Mining Unit Wellfield 1	Wellfield 2	Sub Total	Notes
Technical Assumptions				
Wellfield Area (Ft^2)	1,611,720	2,247,696		
Wellfield Area (Acres)	37.00	51.60		
Affected Ore Zone Area (Ft^2)	1,611,720	2,247,696		
Avg Completed Thickness (Ft)	20	20		
Factor for Flare	1.4	1.4		
Affected Volume:	45,128,160	62,935,488		
Porosity	0.2	0.2		
Gallons per Cubic Foot	7.48	7.48		
Gallon per Pore Volume	67,511,727	94,151,490		
Number of Wells in Unit(s)				
Recovery Wells	160	195		
Injection Wells	245	227		
Monitor Wells	63	81		
Average Well Spacing (Ft)	112	112		
Average Well Depth (Ft)	265	245		
I Groundwater Sweep				
A. Plant & Office				
Operating Assumptions:				
Flowrate (gpm)	500	500		
PV's Required	1.00	1.00		
Total Gallons for Treatment	67,511,727	94,151,490		
Total Kgals for Treatment	67,512	94,151		
Cost Assumptions:				
Power				
Avg Connected Hp	100	100		
Kwh's/Hp	0.75	0.75		
$/Kwh	0.05	0.05		$.02 plus demand charges per quote
Gallons per Minute	500	500		
Gallons per Hour	30000	30000		
Cost per Hour	$3.75	$3.75		
Cost per Kgal ($)	$0.125	$0.125		
Chemicals				
Barium Chloride ($/Kgals)	$0.041	$0.041		Costs from operating ISR facility experience (Cogema)
Antiscalent ($/Kgals)	$0.000	$0.000		Costs from operating ISR facility experience (Cogema)
Elution ($/Kgals)	$0.099	$0.099		Costs from operating ISR facility experience (Cogema)
Repair & Maintenance ($/Kgals)	$0.061	$0.061		Costs from operating ISR facility experience (Cogema)
Analysis ($/Kgals)	$0.164	$0.164		Costs from operating ISR facility experience (Cogema)
Total Cost per Kgal	$0.49	$0.49		
Total Treatment Cost	$33,081	$46,134		
Utilities				
Power ($/Month)	1,800	1200		plant building only, i.e., lights, etc. (35,000 SF at $0.05/sf.)
Propane ($/Month)	800	400		
Time for Treatment				
Minutes for Treatment	135,023	188,303		
Hours for Treatment	2,250	3,138		
Days for Treatment	94	131		
Average Days per Month	30	30		
Months for Treatment	3.1	4.4		
Years for Treatment	0.26	0.36		
Utilities Cost ($)	$8,126	$6,974		
TOTAL PLANT & OFFICE COST	**$41,207**	**$53,108**	**$94,316**	
B. WELLFIELD				
Cost Assumptions:				
Power				
Avg Flow/Pump (gpm)	5	5		
Avg Hp/Pump	5	5		
Avg # of Pumps Required	100	100		
Avg Connected Hp	500	500		
Kwh's/Hp	0.75	0.75		
$/Kwh	0.05	0.05		
Gallons per Minute	500	500		
Gallons per Hour	30000	30000		
Costs per Hour ($)	$18.75	$18.75		
Costs per Gallon ($)	$0.0006	$0.0006		
Costs per Kgal ($)	$0.63	$0.63		
Repair & Maintenance ($/Kgals)	$0.016	$0.016		
Total Cost per Kgal	$0.641	$0.641		
TOTAL WELLFIELD COST	$43,275	$60,351		
TOTAL GROUNDWATER SWEEP COST	**$84,482**	**$113,460**	**$197,942**	

Worksheet 1, No. II
GROUNDWATER RESTORATION

Cost Item	Mining Unit Wellfield 1	Mining Unit Wellfield 2	Sub Total	Notes
II GW Treatment - RO				
A. PLANT				
Operating Assumptions:				
Flowrate (gpm)	250	250		
PV's Required	6.00	6.00		
Total Gallons for Treatment	405,070,364	564,908,940		
Total Kgals for Treatment	405,070	564,909		
Feed to RO (gpm)	250	250		
Permeate Flow (gpm)	187.5	187.5		
Brine Flow (gpm)	62.5	62.5		
Average RO Recovery	75%	75%		
Cost Assumptions:				
Power				
Avg Connected Hp	20	20		
kWh/Hp	0.75	0.75		
$/Kwh	0.05	0.05		$.02 plus demand charges per quote
Gallons per Minute	250	250		
Gallons per Hour	15000	15000		
Cost per Hour ($)	$0.75	$0.75		
Cost per Gallon ($)	$0.0001	$0.0001		
Cost per Kgal ($)	$0.05	$0.05		
Chemicals				
Sulfuric Acid ($/Kgals)	$0.076	$0.076		Costs from operating ISR facility experience (Cogema)
Caustic Soda ($/Kgals)	$0.111	$0.111		Costs from operating ISR facility experience (Cogema)
Hydrochloric Acid ($Kgals)	$0.009	$0.009		Costs from operating ISR facility experience (Cogema)
Hydrochloric Sulfide ($Kgals)	$0.304	$0.304		Costs from operating ISR facility experience (Cogema)
Repair & Maintenance ($Kgals)	$0.279	$0.279		Costs from operating ISR facility experience (Cogema)
Sampling & Analysis ($/Kgals)	$0.164	$0.164		Costs from operating ISR facility experience (Cogema)
Total Cost per Kgal ($)	$0.99	$0.99		
Total Pumping Cost ($)	$402,235	$560,955		
Utilities				
Power ($/Month)	1,800	1,200		plant building only, i.e., lights, etc. (35,000 SF at $0.05/sf.)
Propane ($/Month)	800	400		
Time for Treatment	0	0		
Months for Treatment	52	72		
Utilities Cost ($)	$135,200	$115,200		
TOTAL PLANT COST	**$537,435**	**$676,155**	**$1,213,589**	
B. WELLFIELD				
Cost Assumptions:				
Power				
Avg Flow/Pump (gpm)	1.56	1.28		
Avg Hp/Pump	5	5		
Avg # of Pumps Required	160	195		Using Recovery Pumps
Avg Connected Hp	800	975		
Kwh's/Hp	0.75	0.75		
$/Kwh	0.05	0.05		
Gallons per Minute	250	250		
Gallons per Hour	15000	15000		
Costs per Hour ($)	$30.00	$36.56		
Costs per Gallon ($)	$0.0020	$0.0024		
Costs per Kgal ($)	$2.00	$2.44		
Repair & Maintenance ($/Kgals)	$0.016	$0.016		
Total Cost per Kgal	$2.016	$2.454		
MIT cost ($150/well)	$36,750.000	$34,050.000		
TOTAL WELLFIELD COST	**$816,622**	**$1,386,004**	**$2,202,626**	
TOTAL GW TREATMENT RO COST	**$1,390,807**	**$2,096,209**	**$3,487,015**	