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Aquifer Test Data Analyses (Phase II, Part 2)

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M O A B P R O J E C T

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Calculation Cover Sheet

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Moab Ground Water

Site:
Moab, Utah

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Aquifer Test Data Analyses (Phase II, Part 2)

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August, September, and November 2002 Hydrogeologic Investigation

Sources of Formulae and References:

Driscoll, F.G., 1986, *Groundwater and Wells*, 2nd Edition, Johnson Division, St. Paul, Minnesota.

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———, 2002b. *Work Plan for Characterization of Groundwater Brine Zones for Interim Action at the Moab, Utah, UMTRA Project Site, Addendum A,* GJO–MOA 19.1.2-2, prepared for the U.S. Department of Energy Grand Junction Office, Grand Junction, Colorado.

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Preliminary Calc. ☐ **Final Calc.** ☒ **Supersedes Calc. No.** ______________

Rev. No.	Revision	Calculation by	Date	Checked by	Date	Approved by	Date
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Introduction

The U.S. Department of Energy (DOE) is designing an interim action to reduce risk to endangered species of fish from ammonia discharging from the unconfined alluvial system to backwaters of the Colorado River adjacent to the Moab Project Site. Fresh water in the unconfined alluvial system at the Moab Project Site is underlain by a salt water brine zone. Pumping from the shallow fresh water system (during pump-and-treat remediation) may cause the salt water to rise to a higher elevation and intrude the fresh water. Salt water intrusion would result in degradation of the overlying fresh water, which could adversely affect the tamarisk plant communities that are providing beneficial phytoremediation at the site. Besides causing salt water intrusion into the shallow ground water, rising salt water may bring higher ammonia concentrations to the surface and cause added contamination flux to the river. For these reasons, additional characterization of the aquifer to support the well field design for the interim action is required.

Previous results from field tests conducted in March 2002 are presented in the *Characterization of Groundwater Brine Zones at the Moab, Utah, UMTRA Project Site, Phase I,* June 2002 (DOE 2002a). Phase I results suggest that the design of the pumping well used to conduct the tests, which was screened from the upper fresh water zone (less than 5,000 milligrams per liter total dissolved solids [TDS]) to the lower brine unit, prevented the development of a definitive conclusion regarding the relationship between drawdown in a remediation extraction well and upwelling in the underlying brine zone. For this reason, additional testing (Phase II) was conducted with a well screened only in the upper fresh water zone. Data collected from the August 2002 short-term aquifer tests are presented in Calculation No. Moab 10–2002–03–03–00, titled *Aquifer Test Data Analyses (Phase II, Part 1)* (DOE 2002c).

Purpose and Scope

This calculation set presents results for five different aquifer tests–two long-term and three short-term tests–conducted as Part 2 of the Phase II characterization. The first long-term test was performed in August 2002, and the second test was conducted in September 2002. The three short-term tests were conducted during November 2002. All work was performed in accordance with Addendum A of the *Work Plan for Characterization of Groundwater Brine Zones for Interim Action at the Moab, Utah, UMTRA Project Site* (DOE 2002b).

The methods used for and results from two long-term tests conducted in August and September 2002 are presented in this calculation set. The primary objectives of these tests were to determine the sustainable pumping rate for well 449 and to assess whether brine upconing will affect the shallow zone of the aquifer as a result of the long-term pumping. The November 2002 short-term aquifer tests, which were conducted to determine aquifer parameters for use as input to a flow model to support the design of the interim action well field, are also discussed in this report.

Procedures

Aquifer Test Procedures

Each aquifer test designed to characterize the shallow zone of the alluvial aquifer (i.e., August and September 2002 long-term tests and November 2002 short-term tests) was conducted using well 449 as the pumping well, equipped with a 4-inch submersible pump with the intake set at a depth of approximately 27 feet below top of casing (ft btoc). In addition to monitoring water level response in well 449 during the long-term tests, water level data were collected from wells 450, PW01, PZ1S, PZ1M, and PZ1D2 (Figure 1). Water levels in well 406 (located approximately 220 ft northwest of 449) were measured to monitor background ground water fluctuations.

All water level responses were measured using pressure transducers and manually with electric sounders. Water generated from each test was discharged 200 ft southwest of the pumping well and observation wells.

On November 5 and 6, 2002, three additional observation wells (0460, 0461, and 0462) and one piezometer (0463) were installed within the PW01 cluster. These wells, which were also equipped with pressure transducers, were installed within approximately 10 ft of well 449 to measure drawdown during the November 2002 short-term aquifer tests. Piezometer 463 was installed to determine if pumping from well 449 produced vertical groundwater flow during the short-term tests. Table 1 lists the screened intervals and distance from the pumping well 449 for each observation well associated with these tests.

Table 1. Well Screen Interval and Distance From the Pumping Well 449

Location	Screen Interval (ft bgs)	Distance from Pumping Well 449 (ft)
0449	13.6 – 27.6	na
0450	13.0 – 28.0	14.9
0460	15.4 – 20.3	3.3
0461	15.1 – 20.0	6.4
0462	15.4 – 20.3	10.4
0463	na	2.1
SMI–PW01	20.1– 60.1	11.8
SMI–PZ1S	13.9 – 19.1	16.4
SMI–PZ1M	55.5 – 60.8	12.0
SMI–PZ1D	69.8 – 75.0	18.5

Notes:
na = not applicable; ft bgs = feet below ground surface

Drawdown and residual drawdown data collected during the three aquifer tests in November were analyzed using AquiferWin32 (Environmental Simulations, Inc., Version 2.17). Drawdown data collected from wells in which a significant response was measured were analyzed using a variety of methods. For tests in which significant drawdown data were measured in at least three observation wells, the Distance-Drawdown Method (e.g., Driscoll 1989), as described in Kruseman and DeRidder (1994), was used to analyze the data. Residual drawdown data were analyzed using the Theis Recovery Method (1935) for unconfined aquifers (Kruseman and DeRidder 1994).

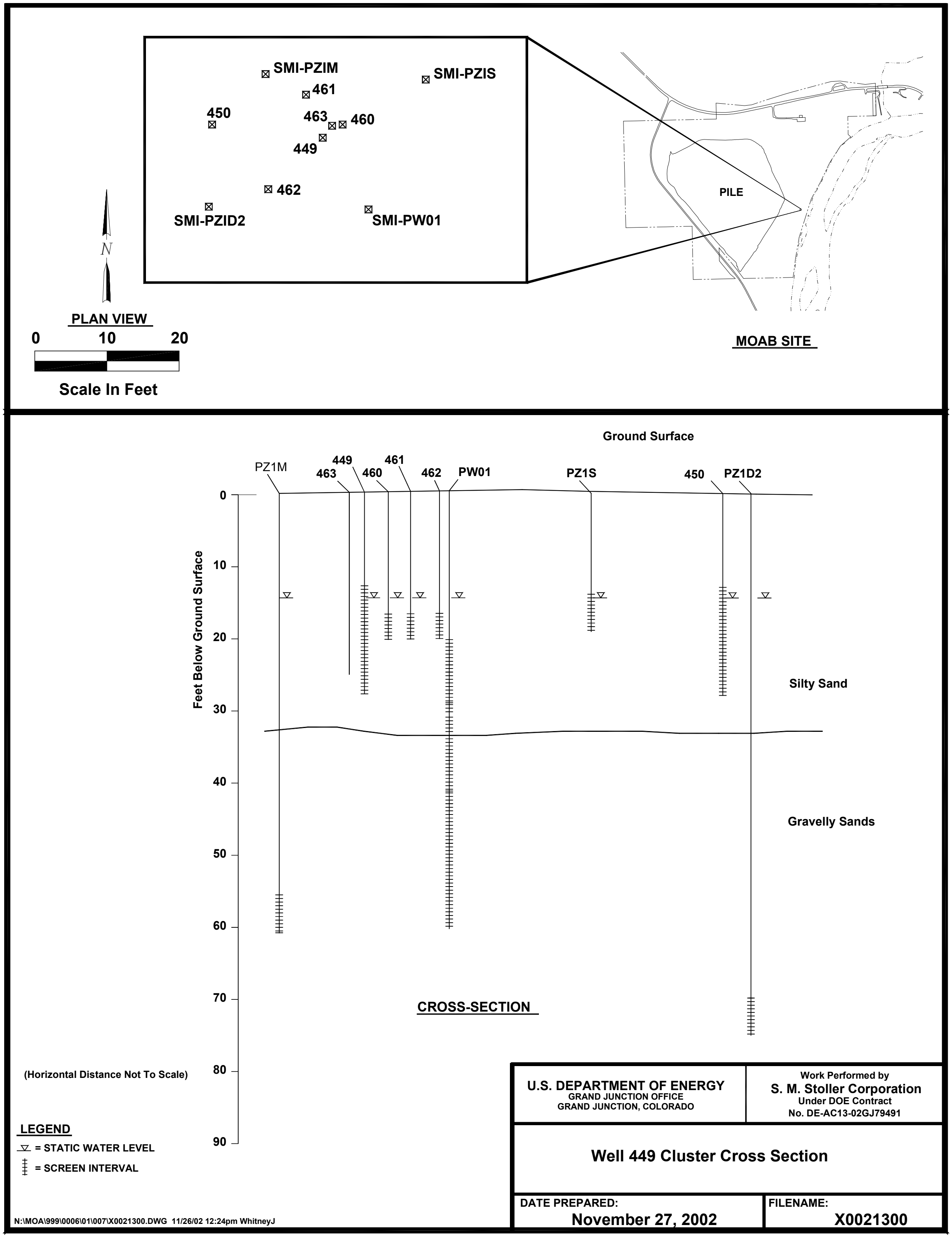


Figure 1. Well 449 Cluster Map and Cross Section

Ground Water Sampling

The following ground water sampling procedures applied to the long-term aquifer tests. Samples were not collected during the short-term tests. Before the start of the August/September 2002 long-term aquifer test, baseline ground water samples were collected from pumping well 449 and observation wells 450, PZ1S, PW01, and PZ1M. As with ground water samples collected before and during previous tests at this location (DOE 2002a), samples were collected using a peristaltic pump, with the pump intake attached to the end of a line that was lowered down the well to the desired depths. Prior to the collection of each sample, the intake line was purged to ensure that the sample collected was representative of the desired depth.

To confirm that the line was adequately purged, a YSI meter was set up at the surface to monitor temperature, pH, and conductivity of the discharge from the peristaltic pump. The sample was not collected until the field parameters stabilized.

The samples were filtered in the field using a 0.45 micrometer filter and collected in a 500-milliliter (mL) high-density polyethylene container and preserved. Each sample was analyzed at the Grand Junction Office Environmental Sciences Laboratory for density, conductivity (which was later converted to specific conductance), ammonia (as N), chloride, sulfate, and uranium. A 125-mL split of each sample was submitted to the Grand Junction Office Analytical Chemistry Laboratory for TDS analysis.

In Situ Specific Conductance Data Collection

To further evaluate the impact of pumping from the shallow zone on brine upconing, Troll 8000 probes were installed in pumping well 449 and observation wells PZ1S, PW01, and PZ1M. These probes are designed to frequently log the ground water temperature, pH, and conductivity (which can then be converted to specific conductance) inside a well. Although the specific conductance data associated with the ground water samples are more accurate, the downhole probes can detect relative changes in conductivity that may indicate changes in the ground water flow system.

Figure 2 shows the location of each probe. A probe was installed inside well PW01 at a depth of 58 ft btoc because previous studies (DOE 2002a) have shown that conductivity increases sharply at this depth. As a result, any fluctuation in conductivity detected by a probe set just above this boundary may indicate upward migration of the brine in the alluvial aquifer deep zone.

Results—August 2002 Long-Term Aquifer Test

Before the start of this long-term aquifer test, ground water samples were collected from pumping well 449 and observation wells 450, PZ1S, PW01, and PZ1M to determine baseline water chemistry conditions within the wells. Figure 3 shows the sample depths and results of the baseline sampling at the pumping and observation wells before the aquifer test.

An aquifer test was started at 15:00 on August 22, 2002, pumping 3 gallons per minute (gal/min) from well 449. The submersible pump intake was set at a depth of approximately 27 ft btoc. After approximately 16 hours of pumping, ground water samples were collected from the well, the 449 discharge line, and from each of the four observation wells.

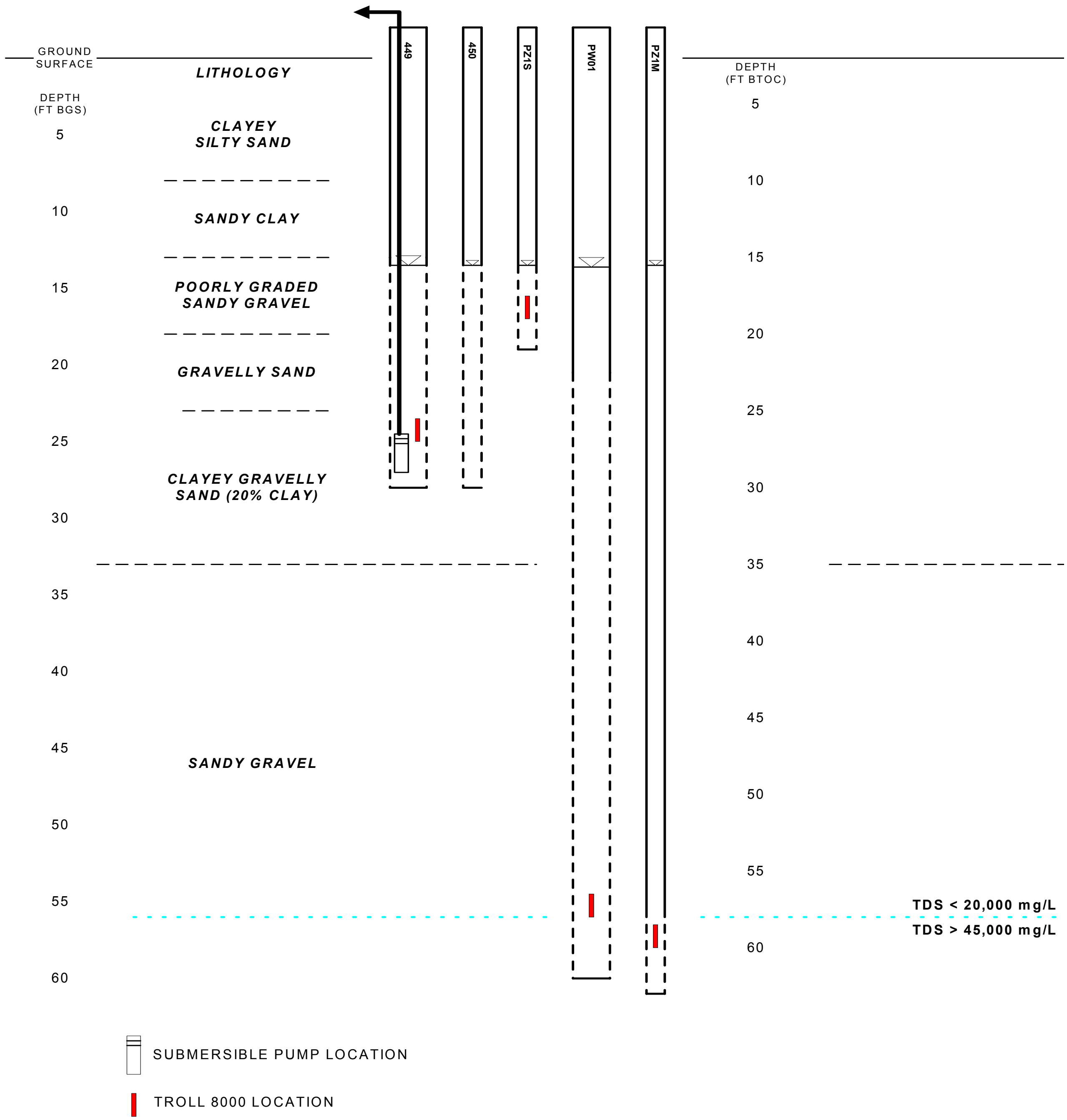
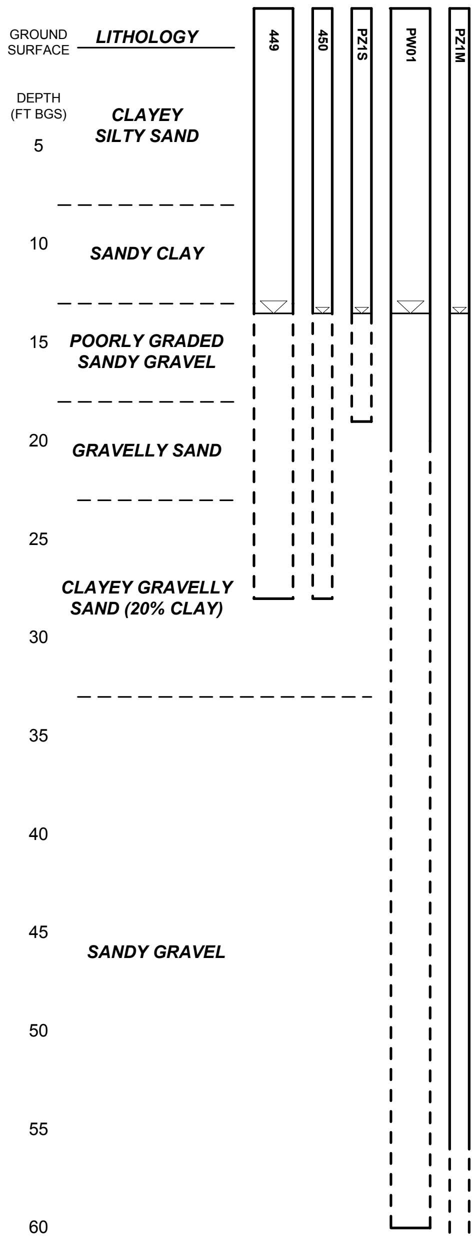


Figure 2. Troll 8000 Locations for In-Situ Specific Conductance Measurements



WELL NO.	DEPTH (ft btoc)	SPECIFIC CONDUCTANCE (uS/cm)	DENSITY (g/cm^3)	TDS (mg/L)	NH_3 as N (mg/L)	Cl (mg/L)	SO_4 (mg/L)	U (mg/L)
PZ1S	19	15119	1.0079	12260	425	1407	7290	1.269
PW01	25	14782	1.0077	12420	500	1437	7259	1.211
449	27	14819	1.0079	12400	410	1379	7118	1.28
450	27	15282	1.008	12340	470	1414	7354	1.409
PZ1M	60	45732	1.0271	37500	1475	9684	16574	3.402

Figure 3. Baseline Sampling Results for the August 2002 Long-Term Aquifer Test

August 2002 Long-Term Aquifer Test—Water Level Data

This test was designed to run for a minimum of 4 weeks. However, after only approximately 20 hours of pumping, a fitting on the discharge line broke, and the pump instantly started pumping at its maximum pumping rate. Once the broken fitting was discovered, the test was shut down.

Figure 4 presents the water level response in pumping well 449, observation wells 450 and PW01, and background well 406 during the entire time that well 449 was pumped. As the figure shows, there was no response to pumping in observation well 450, which is located 14.9 ft from the pumping well and screened over the same interval. This lack of response is significant because it occurred during the time period when there was maximum drawdown in the pumping well after the discharge line fitting broke. The behavior of water levels in observation well 450 was identical to that in background well 406 (located 220 ft northeast of the pumping well), suggesting the cone of depression extended less than 15 ft from the pumping well during the test. Figure 4 shows observation well PW01 also did not respond to the pumping of well 449.

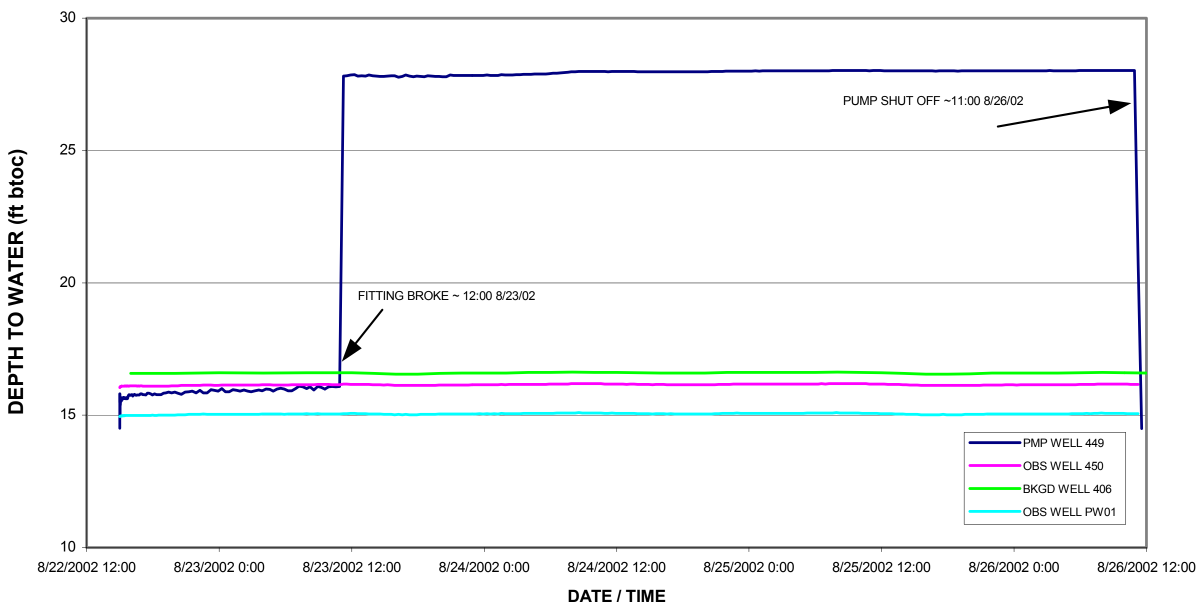


Figure 4. August 2002 Long-Term Aquifer Test Depth to Water Data

Because of the lack of control of the pumping rate during the test, analysis of any recovery data would not have provided representative aquifer parameter estimates (Kruseman and DeRidder 1994). As a result, recovery data were not analyzed.

August 2002 Long-Term Aquifer Test—Ground Water Sampling Data

Table 2 presents the analytical results from the samples collected during this test. Appendix A contains a copy of the ESL data report. The specific conductance, density, and TDS data provide indicators of whether pumping from well 449 drew the brine upwards. With the exception of observation well PW01, the data in Table 2 indicate no significant changes in these parameters in the pumping well or observation wells during the test.

Table 2. Sample Results From the August 2002 Long-Term Aquifer Test

Sample Location/Depth	Date/Time Collected	Time Since Test Started (hours)	Density (g/cm^3)	Specific Conductance (µS/cm)	Ammonia NH_3-N (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	SO_4/Cl Ratio	Uranium (mg/L)	TDS (mg/L)
PMP WELL 449 / 27	8/22/02 13:05	–1.9	1.0079	14,819	410	1,379	7,118	5.16	1.28	12,400
PMP WELL 449 / 27	8/23/02 7:15	16.25	1.0075	15,288	420	1,407	7,274	5.17	1.236	12,320
OBS WELL 450 / 27	8/22/02 13:30	–1.5	1.008	15,282	470	1,414	7,354	5.20	1.409	12,340
OBS WELL 450 / 27	8/23/02 7:20	16.3	1.0078	15,818	460	1,452	7,563	5.21	1.393	12,640
OBS WELL PW01 / 25	8/22/02 13:50	–1.2	1.0077	14,782	500	1,437	7,259	5.05	1.211	12,420
OBS WELL PW01 / 25	8/23/02 7:40	16.6	1.0089	16,205	575	1,342	8,066	6.01	1.503	13,230
OBS PZ1S / 19	8/22/02 14:00	–1	1.0079	15,119	425	1,407	7,290	5.18	1.269	12,260
OBS PZ1S / 19	8/23/02 7:30	16.5	1.0078	15,317	450	1,412	7,310	5.18	1.173	12,300
OBS PZ1M / 60	8/22/02 14:05	–0.9	1.0271	45,732	1,475	9,684	16,574	1.71	3.402	37,500
OBS PZ1M / 60	8/23/02 7:50	16.8	1.028	46,993	525	10,570	16,580	1.57	2.84	39,050

Notes:
Depth refers to feet below top of casing.
A minus sign indicates that the sample was collected prior to the start of the test.
PMP WELL = pumping well
OBS WELL = observation well
mg/L = milligrams per liter
g/cm^3 = grams per cubic centimeter
µS/cm = microsiemens per centimeter

Differences in the sulfate/chloride ratio over the pumping period may be indicative of a well being affected by different water types (DOE 2002a). The ratio change shown in the data from observation well PW01 (see Table 2) located 11.8 ft from the pumping well is likely a function of the well's screened interval. This observation well is screened from approximately 20 to 60 ft below ground surface and provides a direct conduit from the shallow aquifer zone to the deeper alluvial aquifer zone.

August 2002 Long-Term Aquifer Test—In Situ Specific Conductance Data

Figures 5, 6, 7, and 8 present the data collected from wells 449, PZ1S, PW01, and PZ1M, respectively. The data from each location were compared to the water level changes in pumping well 449 during the August 2002 long-term aquifer test.

The Troll 8000 data collected from the pumping well showed a significant specific conductance decrease once the fitting on the discharge line broke and the water level reached the pump intake (Figure 5). However, these data are misleading because the probe was set at approximately the same depth as the pump intake; consequently, the probe was not fully submersed during this time and provided unreliable data. Figure 6 indicates that pumping from well 449 did not affect observation well PZ1S.

As shown in Figure 7, observation well PW01 showed a significant increase in specific conductance once the test was started. This response could be attributed to the direct conduit well PW01 provides to the brine zone as a result of its screened interval. The response observed in observation well PZ1M does not appear to be associated with the changes in drawdown measured in well 449 (Figure 8).

Results—September 2002 Long-Term Aquifer Test

After the discharge line was repaired, another attempt was made to complete a long-term test. The well was further developed (for approximately 3 hours), and another long-term test began at 15:30 on September 4, 2002, again using a flow rate of 3 gal/min and the pump intake set approximately 27 ft btoc. To determine baseline conditions ground water samples were collected from pumping well 449 and observation wells 450, PZ1S, PW01, and PZ1M prior to starting this long-term aquifer test. Figure 9 shows the sample depths and results of the baseline sampling at the pumping and observation wells before the start of the aquifer test.

After approximately 16, 190, and 356 hours of pumping (September 5, 12, and 19, respectively), ground water samples were collected from pumping well 449, its discharge line, and each of the four observation wells.

September 2002 Long-Term Aquifer Test—Water Level Data

Although the second test was also designed to run for a minimum of 4 weeks, the pump unexpectedly stopped working after only 17 days of pumping. Consequently, no recovery data were collected. Figure 10 presents the water level response in pumping well 449, observation wells 450 and PW01, and background well 406 during the pumping period.

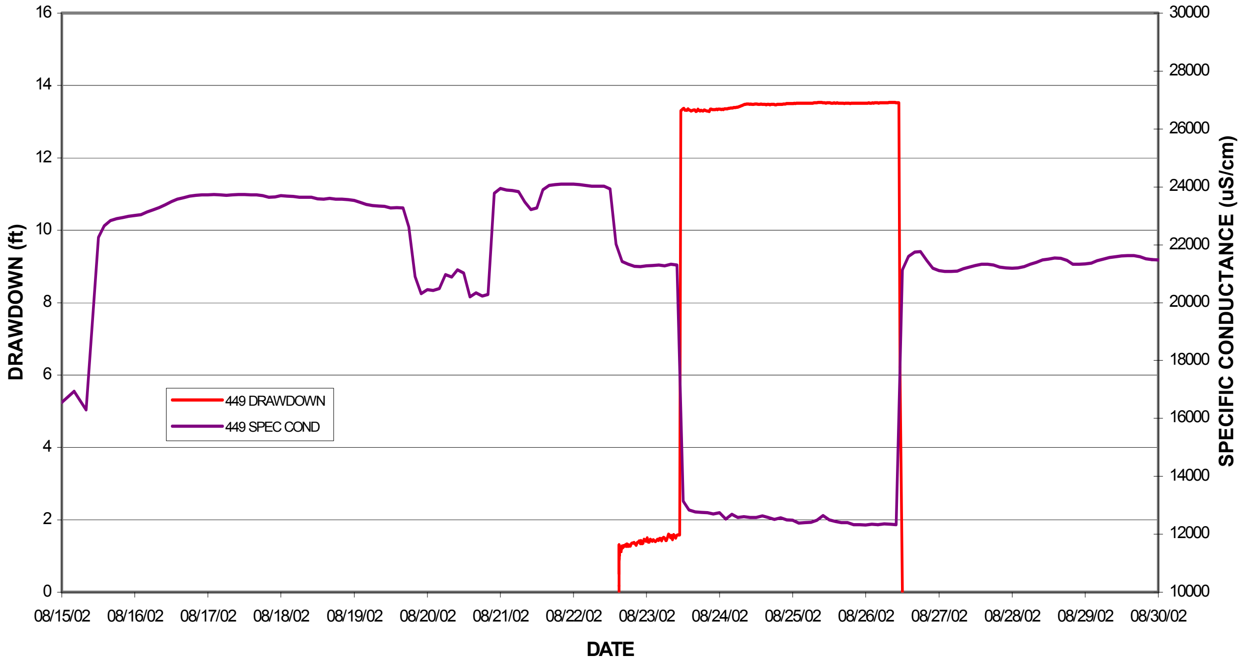


Figure 5. Troll 8000 Specific Conductance Data From Well 449 (Pumping Well), August 2002 Test

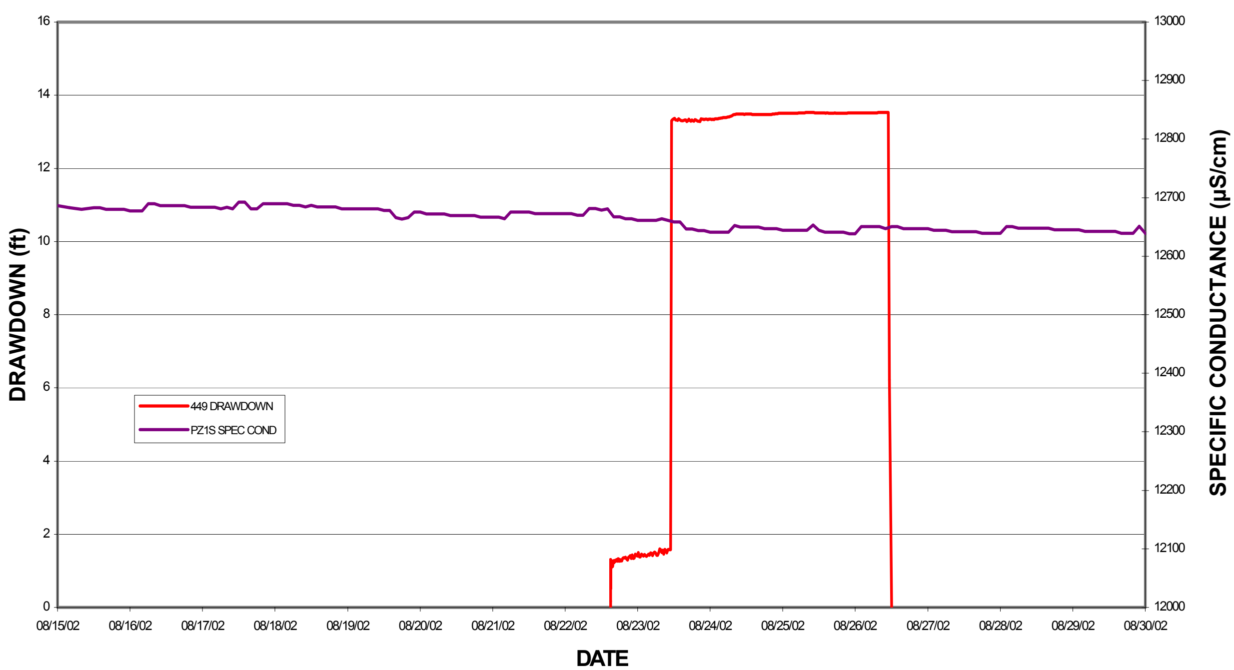


Figure 6. Troll 8000 Specific Conductance Data From Well PZ1S, August 2002 Test

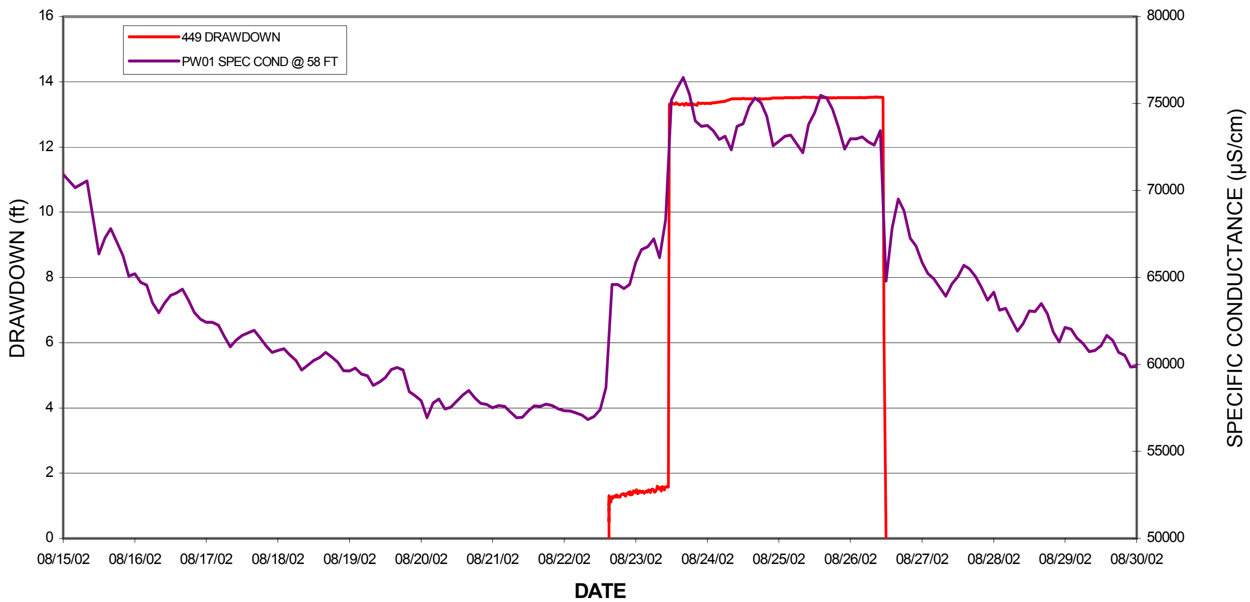


Figure 7. Troll 8000 Specific Conductance Data From Well PW01, August 2002 Test

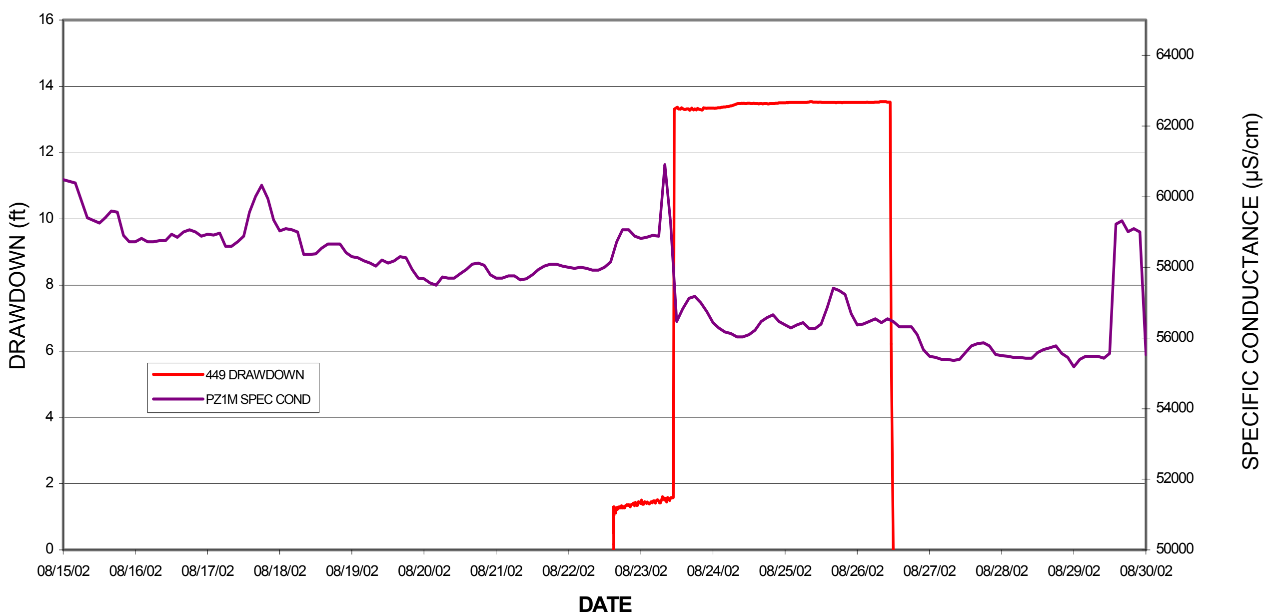
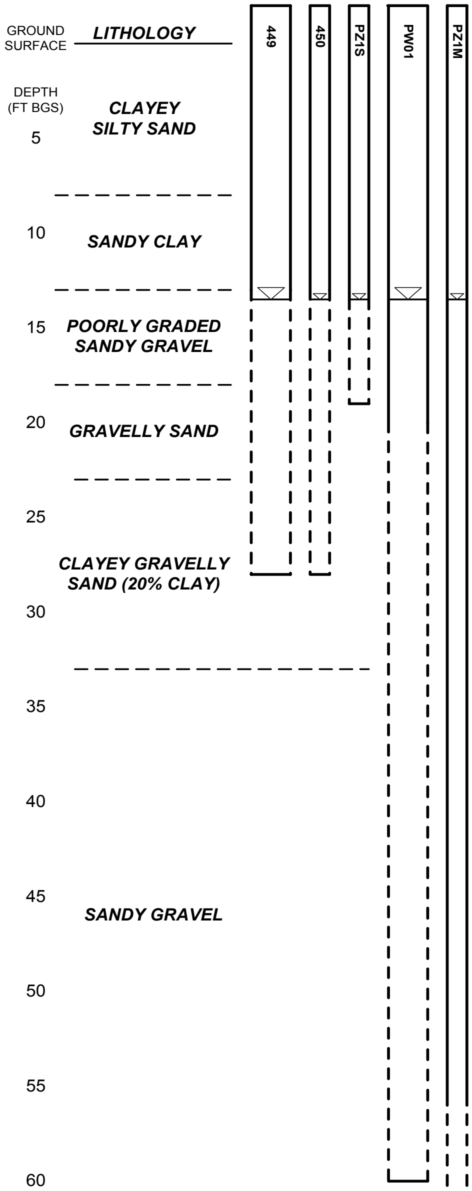


Figure 8. Troll 8000 Specific Conductance Data From Well PZ1M, August 2002 Test



WELL NO.	DEPTH (ft btoc)	SPECIFIC CONDUCTANCE (uS/cm)	DENSITY (g/cm^3)	TDS (mg/L)	NH_3 as N (mg/L)	Cl (mg/L)	SO_4 (mg/L)	U (mg/L)
PZ1S	19	18039	1.0067	12240	400	1378	7074	1.256
PW01	25	17848	1.0067	11930	370	1365	7034	1.215
449	27	17603	1.0064	12230	420	1369	7136	1.274
450	27	19081	1.0071	11950	480	1419	7488	1.598
PZ1M	60	51935	1.026	34733	1350	9062	16248	3.595

Figure 9. Baseline Sampling Results for the September 2002 Long-Term Aquifer Test

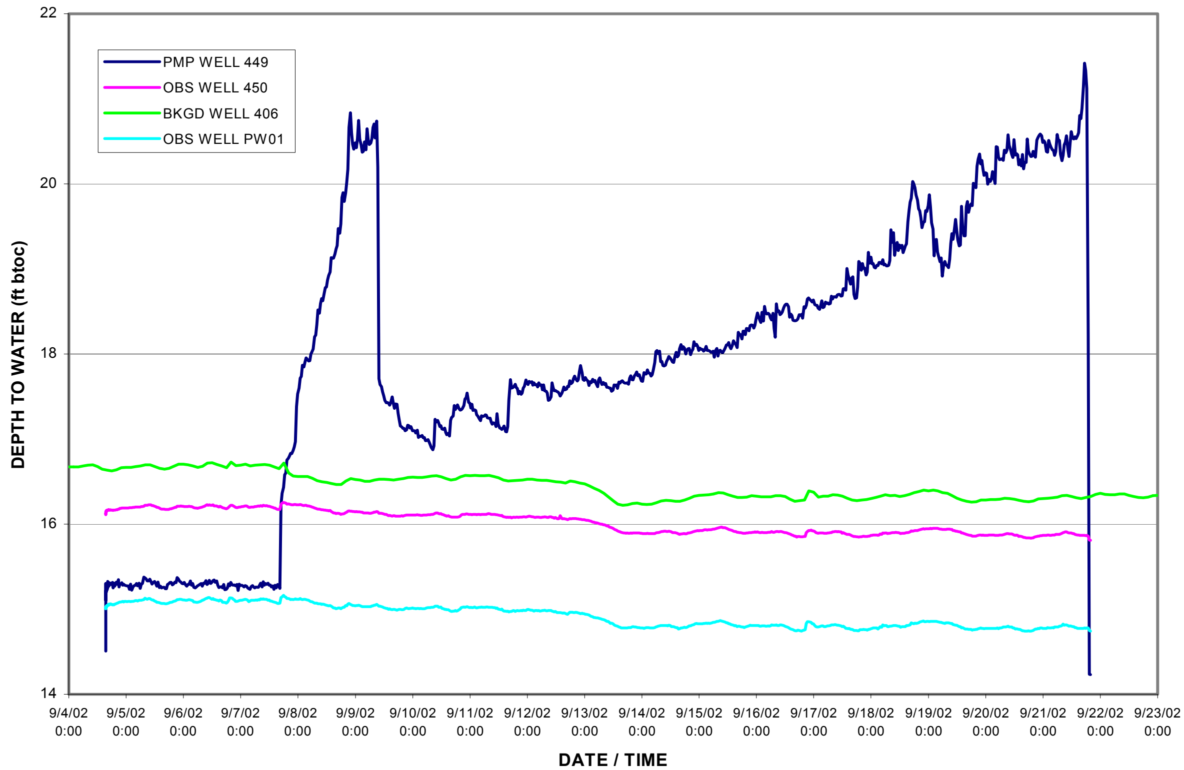


Figure 10. Depth to Water Data During the September 2002 Long-Term Aquifer Test

As Figure 10 shows, drawdown in pumping well 449 increased dramatically on September 7 for 2 days, abruptly partially recovered on September 9, and then slowly increased until the pump stopped working on September 22. The pumping rate was measured intermittently during the test. These measurements combined with continually monitored drawdown suggested that a pumping rate of 2.9 to 3.1 gal/min was maintained. The observed water level changes inside the pumping well, particularly the anomalous drawdown observed between September 4 and 10, may have occurred in response to well efficiency problems associated with this well (DOE 2002c).

Similar to the first long-term aquifer test, water level data collected during the second test indicated no response in the observation wells. The water level behavior in observation well 450 was identical to that in background well 406, again suggesting the cone of depression extended less than 15 ft from the pumping well during this longer test.

September 2002 Long-Term Aquifer Test—Ground Water Sampling Data

Table 3 presents analytical results from the samples collected during the second long-term test. Appendix A contains a copy of the ESL data report for these samples. As with the first long-term test, the pumping well and most of the observation wells indicated no significant changes in water quality parameters during the test. The one exception to this rule occurred in well PW01, which showed noticeable increases in specific conductance and concentrations of ammonia, sulfate, uranium, and TDS during the test.

Table 3. Sample Results From the September 2002 Long-Term Aquifer Test

Sample Location/Depth	Date/Time Collected	Time Since Test Started (hours)	Density (g/cm^3)	Specific Conductance (µS/cm)	Ammonia NH_3-N(mg/L)	Chloride (mg/L)	Sulfate (mg/L)	$S0_4$/Cl Ratio	Uranium (mg/L)	TDS (mg/L)
PMP WELL 449 / 27	9/4/02 9:45	–5.75	1.0063	17,321	360	1,358	6,980	5.14	1.305	12,320
PMP WELL 449 / 27	9/4/02 14:20	–1.2	1.0064	17,603	420	1,369	7,136	5.21	1.274	12,230
PMP WELL 449 / 27	9/5/02 7:57	16.5	1.0068	17,414	400	1,387	7,078	5.10	1.22	12,070
PMP WELL 449 / 27	9/12/02 13:35	190.1	1.0064	17,528	420	1,366	7,083	5.19	1.217	12,280
PMP WELL 449 / 27	9/19/02 11:18	355.6	1.0062	17,212	410	1,358	7,083	5.22	1.21	12,050
OBS WELL 450 / 27	9/4/02 14:10	–1.3	1.0071	19,081	480	1,419	7,488	5.28	1.598	11,950
OBS WELL 450 / 27	9/5/02 7:37	16.1	1.0071	19,261	550	1,408	7,424	5.27	1.675	12,820
OBS WELL 450 / 27	9/12/02 13:50	190.3	1.0073	19,220	560	1,452	7,753	5.34	1.686	12,840
OBS WELL 450 / 27	9/19/02 11:27	356	1.0066	18,203	520	1,448	7,694	5.31	1.627	11,830
OBS WELL PW01 / 25	9/4/02 14:00	–1.5	1.0067	17,848	370	1,365	7,034	5.15	1.215	11,930
OBS WELL PW01 / 25	9/5/02 7:50	16.3	1.0072	19,157	510	1,325	8,003	6.04	1.401	12,920
OBS WELL PW01 / 25	9/12/02 13:58	190.5	1.0087	20,529	660	1,338	8,722	6.52	1.754	14,020
OBS WELL PW01 / 25	9/19/02 11:42	356.2	1.0076	20,009	670	1,329	8,911	6.71	1.757	14,090
OBS PZ1S / 19	9/4/02 14:05	–1.4	1.0067	18,039	400	1,378	7,074	5.13	1.256	12,240
OBS PZ1S / 19	9/5/02 7:44	16.25	1.0067	17,603	440	1,396	7,151	5.12	1.1	12,240
OBS PZ1S / 19	9/12/02 14:05	190.6	1.0068	18,179	430	1,362	7,038	5.17	1.195	12,180
OBS PZ1S / 19	9/19/02 11:34	356.1	1.0062	17,223	430	1,388	7,197	5.19	1.295	11,990
OBS PZ1M / 60	9/4/02 14:15	–1.25	1.026	51,935	1,350	9,062	16,248	1.79	3.595	34,733
OBS PZ1M / 60	9/5/02 7:30	16	1.026	50,998	1,450	9,174	16,463	1.79	3.523	35,067
OBS PZ1M / 60	9/12/02 13:47	190.25	1.0267	53,127	1,400	9,568	16,247	1.70	3.689	35,767
OBS PZ1M / 60	9/19/02 11:49	356.3	1.0284	54,123	1,500	11,269	16,329	1.45	3.435	38,700

Notes:
Depth refers to feet below top of casing.
A minus sign indicates that the sample was collected prior to the start of the test.
PMP = pumping well
OBS = observation well
mg/L = milligrams per liter
g/cm^3 = grams per cubic centimeter
µS/cm = microsiemens per centimeter

The data in Table 3 suggest that the increase in specific conductance may be the result of increasing levels of dissolved sulfate. If the increase in specific conductance were associated with brine upconing, then the chloride concentrations would also be expected to increase. Table 3 indicates the chloride concentrations remained constant throughout the pumping phase.

Figure 11 provides a plot of specific conductance results for all wells during the test interval, and Figure 12 provides a plot of associated sulfate/chloride ratios. With the exception of well PW01, the data presented in Figure 12 suggest that pumping from well 449 did not impact the wells within the cluster.

September 2002 Long-Term Aquifer Test—In Situ Specific Conductance Data

As in the case of the first attempt at a long-term test, data from Troll 8000 probes were used during the second long-term test to evaluate the impact of pumping from the shallow zone on brine upconing. Figure 2 shows the location of the probe used in each well.

Figures 13, 14, 15, and 16 present the Troll 8000 specific conductance data collected from wells 449, PZ1S, PW01, and PZ1M, respectively, during the second long-term test. This data from each location are compared to water level changes in pumping well 449.

Figure 13 shows that specific conductance in well 449 increased noticeably during the initial 4 days of the test and then tended to decrease slightly as the drawdown in the well increased. Once the pump was shut off, there was a slight increase in specific conductance. Other data indicate that pumping from well 449 did not impact observation well PZ1S (Figure 14). The specific conductance data collected from the probe within well PZ1M also showed no correlation with well 449 drawdown (Figure 16).

As shown in Figure 15, specific conductance in observation well PW01 showed a significant increase once the test was started on September 4, another distinct increase with the spike in drawdown during September 8 and 9, and relatively constant values during the remainder of pumping. Such behavior was similar to that observed in this well during the first long-term test, and was assumed to result from the deep screened interval for well PW01.

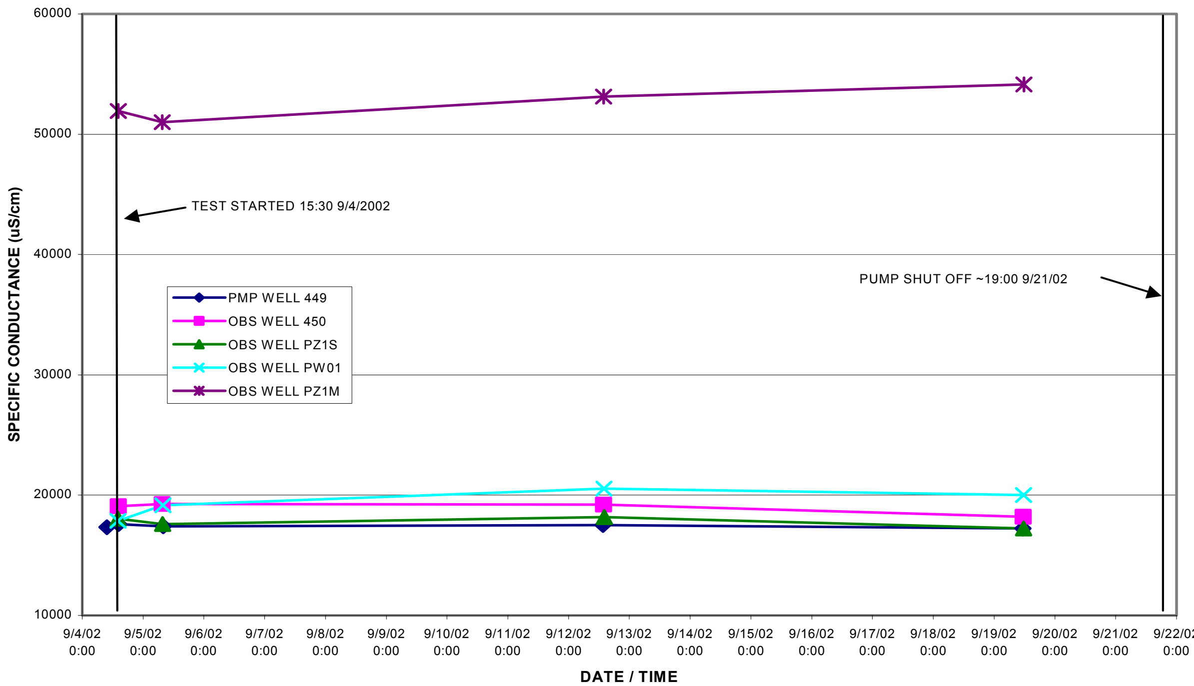


Figure 11. Specific Conductance versus Time, September 2002 Long-Term Aquifer Test

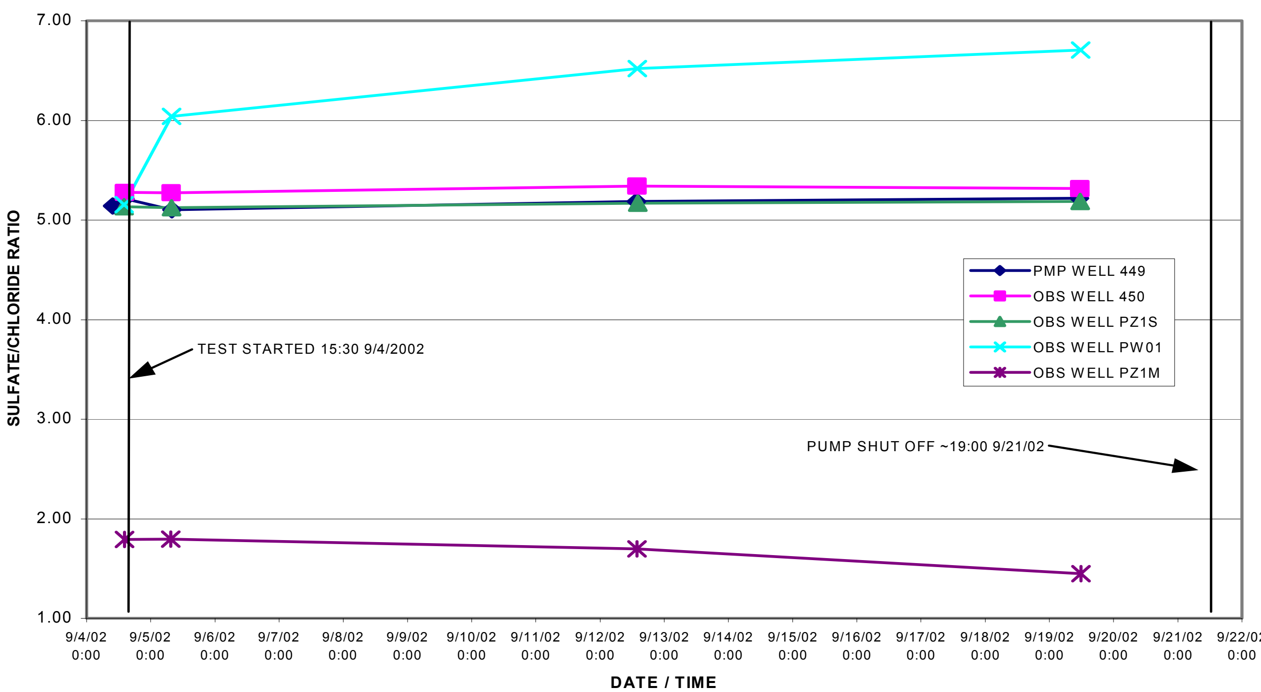


Figure 12. Sulfate/Chloride Ratio versus Time, September 2002 Long-Term Aquifer Test

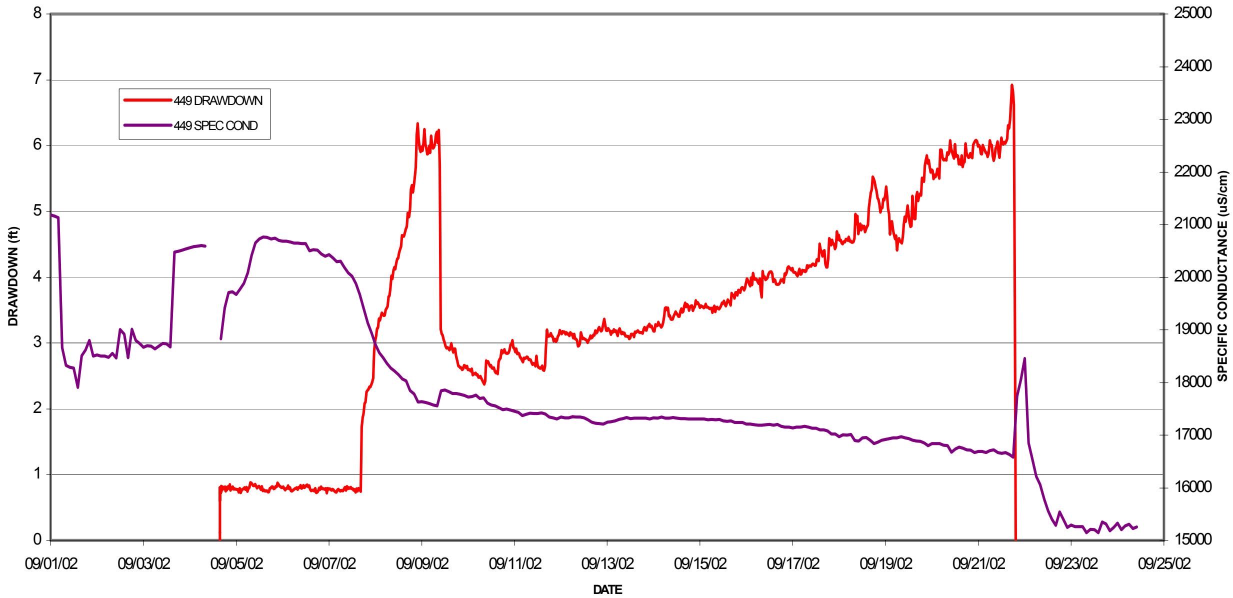


Figure 13. Troll 8000 Specific Conductance Data From Well 449, During the September 2002 Long-Term Test

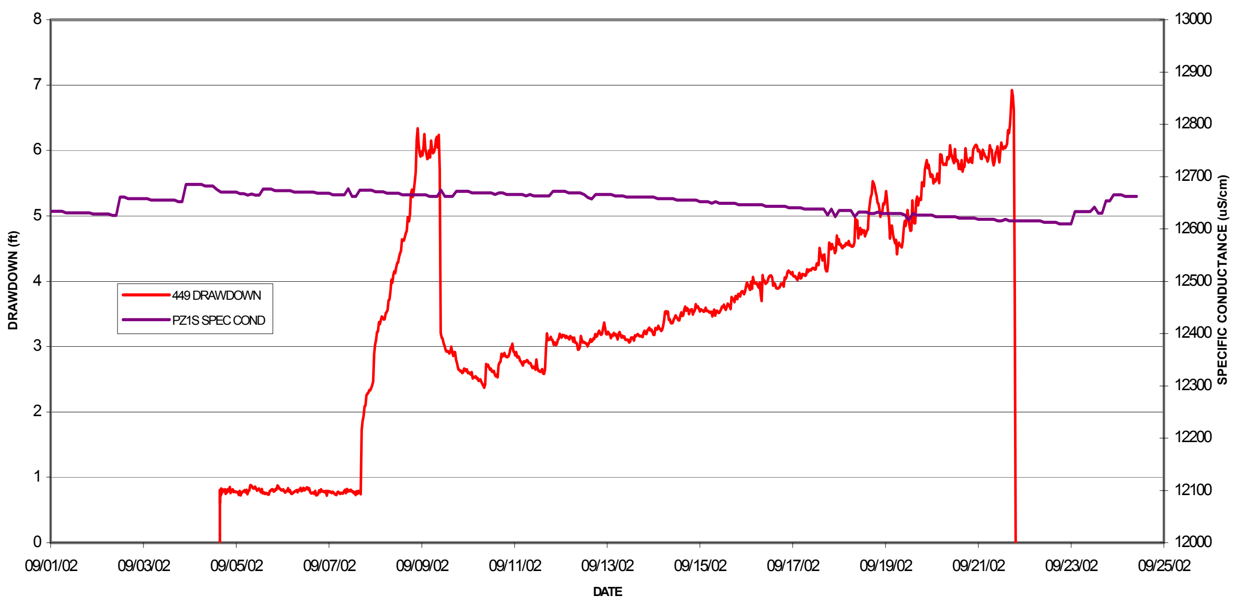


Figure 14. Troll 8000 Specific Conductance Data From Well PZ1S, During the September 2002 Long-Term Test

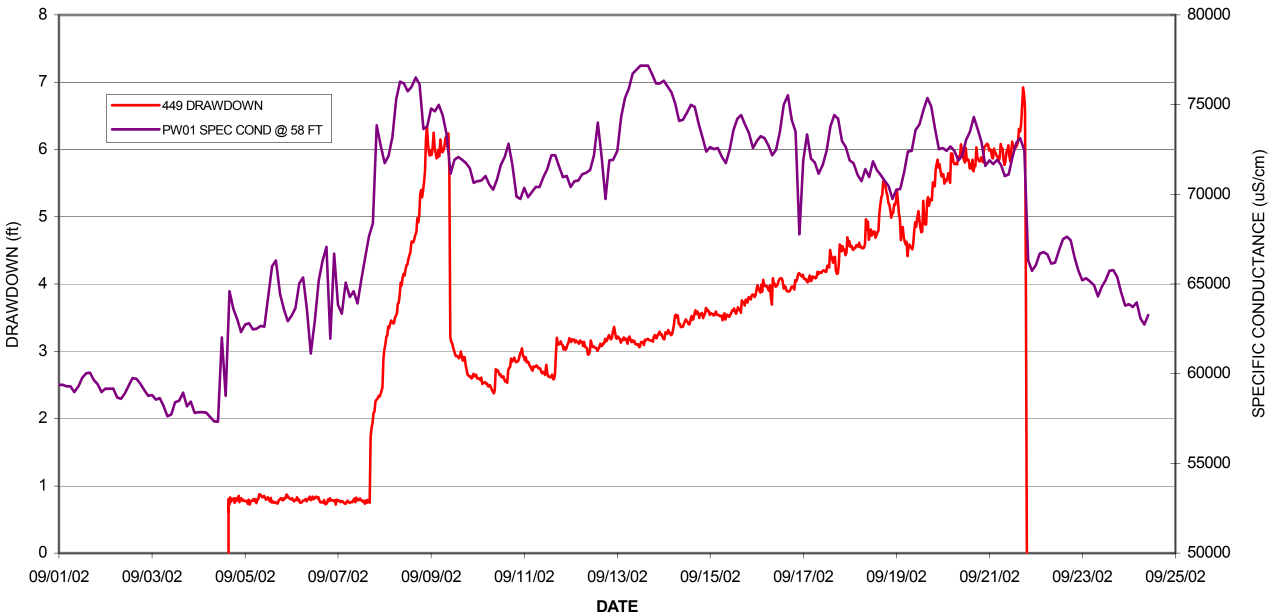


Figure 15. Troll 8000 Specific Conductance Data From Well PW01, During the September 2002 Long-Term Test

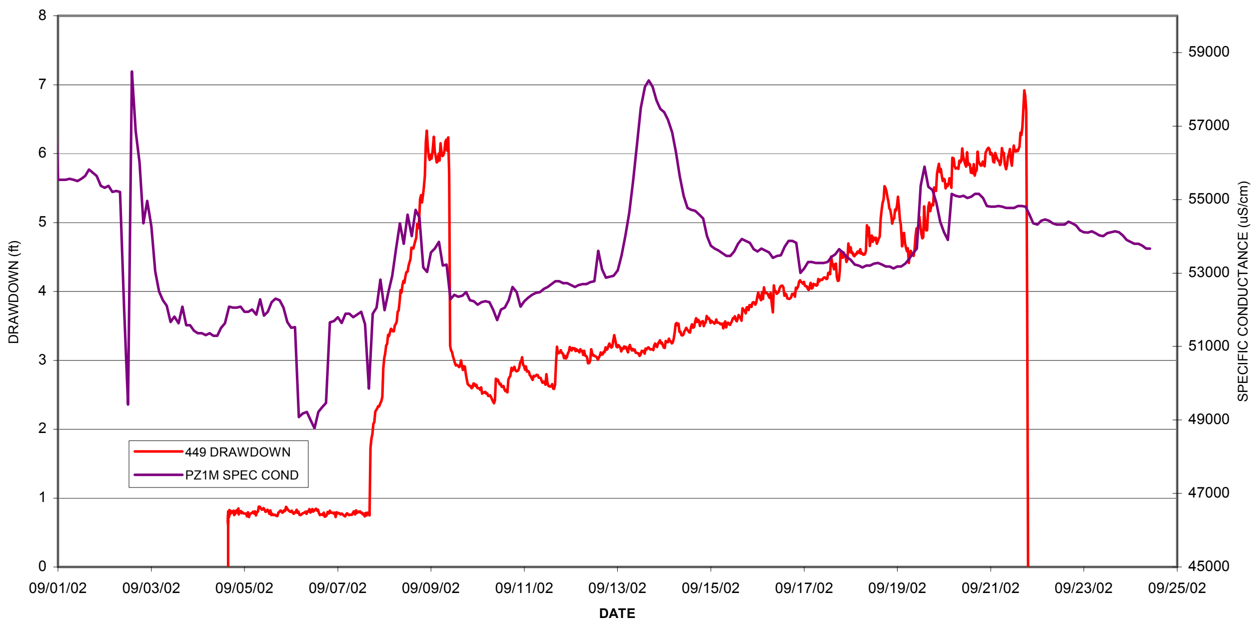


Figure 16. Troll 8000 Specific Conductance Data From Well PZ1M, During the September 2002 Long-Term Test

Results—November 2002 Short-Term Aquifer Tests

Review of the drawdown data collected from the long-term tests suggested that the apparent inefficiency of the pumping well (well 449) could be remedied with additional well development and a shorter pumping period. The data also indicated that a series of short-term tests (lasting less than 24 hrs) could be designed to provide better estimates of aquifer parameters and more fully characterize the shallow zone of the alluvial aquifer.

Prior to starting these short-term tests, pumping well 449 was further developed and additional observation wells were installed. Between November 12 and November 14, 2002, three short-term aquifer tests were conducted using well 449 as the pumping well. Two major observations were made during each of the three short-term tests:

(1) Steady-state conditions were observed in the pumping well (well 449) and in all observation wells affected by the test pumping, and
(2) The farthest distance away from the pumping well at which drawdown was observed was 10.4 ft, at well 462.

Though it is possible that any of a number of factors could have provided an explanation for these observations, it was likely that such phenomena were the result of upward vertical movement of groundwater from relatively high permeability sandy gravels and gravelly sands located a few to several feet below the shallow, pumped zone. This meant that, in effect, the more permeable sediments at depth were acting as a zone of infinite water supply (i.e., a constant head boundary). Under this scenario, the pumping and observation wells behave as if they are located in a leaky aquifer, with recharge to the aquifer occurring from an aquifer horizon located below an aquitard at the bottom of the pumped zone. Unfortunately, little to no data exist to support the presence of a thick and pervasive aquitard layer at the base of the tested zone. Nonetheless, some of the estimates of shallow aquifer hydraulic parameters were derived using leaky aquifer concepts (e.g., Hantush and Jacob, 1955; Kruseman and de Ridder, 1994).

In the following sections, water level data collected during each test are discussed individually. On the other hand, in-situ specific conductance data collected by the Troll 8000 instruments from all three tests are combined and analyzed together.

4.3 gal/min Short-Term Aquifer Test—Water Level Data

The first short-term test was started at 14:00 on November 12, 2002, using a submersible pump to withdraw 4.3 gal/min from well 449. After 18 hours of pumping, the pump was shut off and residual drawdown data were collected. Table 4 presents the pumping drawdown data collected at each well after 18 hours of pumping. Figure 17 presents the water level responses in pumping well 449, observation wells 450, 460, 461, and 462, and background well 406 during the pumping period.

Table 4. Drawdown Measured During the 4.3 gal/min Short-Term Aquifer Test

Location	Distance from Pumping Well 449 (ft)	Drawdown Measured After Pumping 4.3 gal/min from Well 449 (ft)
449	na	1.69
450	14.9	0.07
460	3.3	0.48
461	6.4	0.18
462	10.4	0.12
463	2.1	0.0
SMI–PW01	11.8	0.10
SMI–PZ1S	16.4	0.10
SMI–PZ1M	12.0	0.0
SMI–PZ1D	18.5	0.0

Notes:
na = not applicable; ft = feet

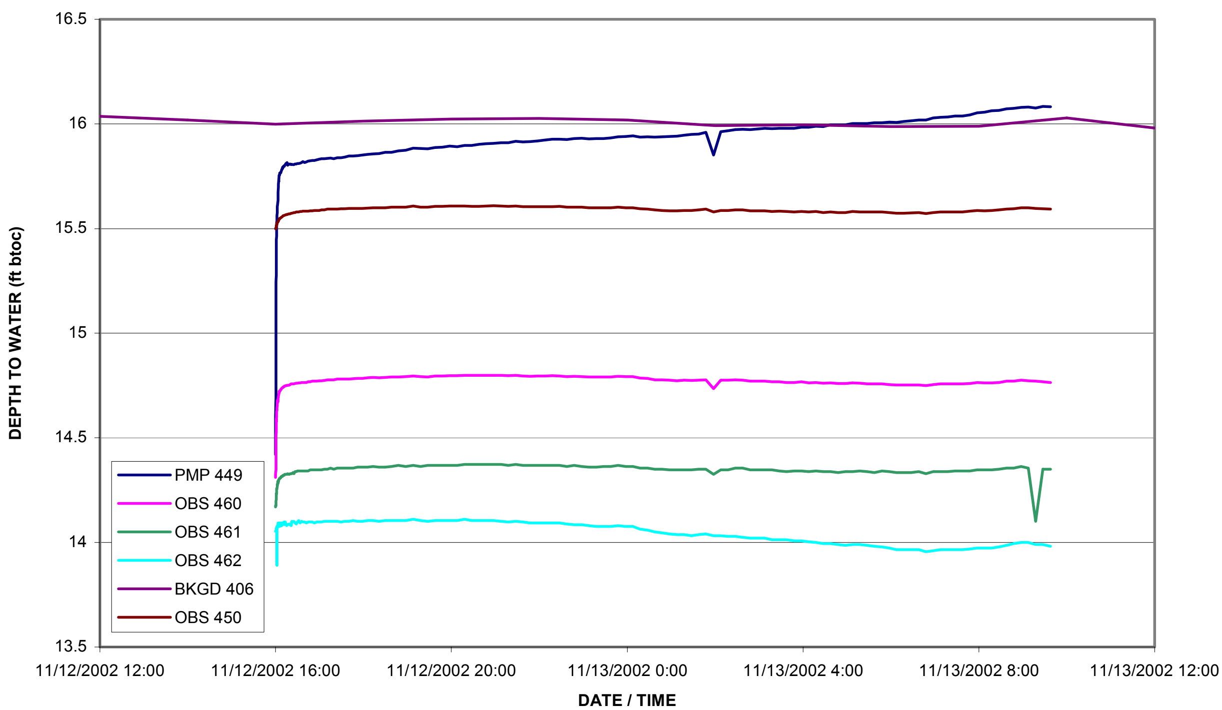


Figure 17. Depth to Water Data During the 4.3 gal/min Short-Term Aquifer Test

Prior to the test, the water level in piezometer 463 was rebounding after installation. This trend continued throughout the 4.3 gal/min pumping period and the well showed no response to pumping. During the pumping period, 0.06 ft of water level fluctuation was observed in background well 406.

Taking into account the small amount of drawdown measured during the test, observation well screened intervals, and background water level fluctuation, only the drawdown data from wells 460 and 461 were analyzed using the Hantush and Jacob Method (1955) for leaky aquifers. As previously mentioned, the conceptual model of the ground water flow system does not conform to a classic leaky aquifer scenario. The conceptual model consists of a three-dimensional (3-D) ground water flow system that reaches steady state during the pumping period as a result of vertical ground water flow from very permeable sediments located below the pumped aquifer layer. The Hantush and Jacob Method (1955) was found to adequately simulate the 3-D flow system during the 4.3 gal/min short-term test. In addition to applying this leaky aquifer technique, residual drawdown data from the observation wells were analyzed using the Theis Recovery Method (1935), as adopted for unconfined aquifers.

Results of the analyses are presented in Table 5. Hydraulic conductivity estimates are based upon a 15-ft saturated thickness, which is the length of the pumping well screen interval. The AquiferWin32 plots used for the analyses are contained in Appendix B.

Table 5. Well 449 4.3 gal/min Short-Term Aquifer Test Results for Transmissivity (T), Hydraulic Conductivity (K) and Storage Coefficient (S)

Well	Analysis Method					
	Hantush and Jacob				Theis Recovery	
	T (ft^2/d)	K (ft/d)	r/B	S	T (ft^2/d)	K (ft/d)
460	410.2	27.3	0.28	0.011	402.0	26.8
461	810.5	54.0	0.34	0.020	1098.2	73.2

Notes:
T = Transmissivity (ft^2/day); K = Hydraulic Conductivity (ft/day);
r/B = Hantush and Jacob Type Curve Used For Analysis (dimensionless);
S = Storage Coefficient (dimensionless)

As shown in Table 5, analysis of drawdown data collected from observation well 460 produced an aquifer transmissivity of 410.2 ft^2/day with a storage coefficient of 0.011, while analysis of the residual drawdown in this well during the recovery test resulted in a transmissivity of 402.0 ft^2/day. Analysis of drawdown data from observation well 461 resulted in a significantly larger transmissivity of 810.5 ft^2/day and a storage coefficient of 0.02. Residual drawdown analysis at well 461 produced an estimated transmissivity of 1098.2 ft^2/day. The larger estimates of T and K were derived from well 461, which is located further from the pumping well (6.4 ft) than well 460 (3.3 ft).

The estimates of aquifer hydraulic conductivity resulting from the initial short-term test in November were considerably different from previous estimates of this parameter based on measured drawdowns in the pumping well only (DOE 2002c). Specifically, the earlier estimates of K ranged from 0.5 to 7.1 feet per day, whereas the K values produced from the 4.3 gal/min test in November range from 27.3 to 73.2 ft/day (Table 5). These observations are significant for two reasons. First, the aquifer hydraulic conductivity is larger than was previously thought on the basis of aquifer test analysis. Second, the well efficiency problems suspected in well 449 during the earlier short-term tests do appear to radically affect test analysis findings.

The two estimates of storage coefficient produced by the 4.3 gal/min test in November (0.011 and 0.020) are also significant. Both values are much smaller than the specific yield values that would be expected in an unconfined aquifer, but are also much larger than S values that would be expected from a well screened over only 15 vertical feet of a confined aquifer. On the basis of these estimated storage coefficients, it appears that, over relatively short pumping periods, water delivered to the pumping well (well 449) in the shallow system is derived from both elastic storage (characteristic of a confined aquifer) and gravity drainage (characteristic of an unconfined aquifer).

The general findings derived from the 4.3 gal/min test regarding transmissivity, hydraulic conductivity, and storage coefficients were also observed in subsequent short-term tests in November 2002, as discussed in the following sections.

7.5 gal/min Short-Term Aquifer Test—Water Level Data

The second short-term test was started at 14:00 on November 13, 2002, using a submersible pump to withdraw 7.5 gal/min from well 449. After approximately 10.5 hours of pumping, the pump shut off unexpectedly, and residual drawdown data were not collected. Table 6 presents the measured drawdown data in all wells after 10.5 hours of pumping at a rate of 7.5 gal/min. Figure 18 presents the water level response in pumping well 449, observation wells 450, 460, 461, and 462, and background well 406 during the pumping period.

Table 6. Drawdown Measured During the 7.5 gal/min Short-Term Aquifer Test

Location	Distance from Pumping Well 449 (ft)	Drawdown Measured After Pumping 7.5 gal/min from Well 449 (ft)
449	na	4.10
450	14.9	0.20
460	3.3	0.72
461	6.4	0.32
462	10.4	0.20
463	2.1	0.0
SMI–PW01	11.8	0.23
SMI–PZ1S	16.4	0.22
SMI–PZ1M	12.0	0.14
SMI–PZ1D	18.5	0.0

Notes:
na = not applicable; ft = feet

As in the case of the 4.3 gal/min test, the water level in piezometer 463 showed no response to pumping at a higher rate of 7.5 gal/min. During the pumping period, 0.05 ft of water level fluctuation was observed in background well 406.

Again taking into account the small amount of drawdown measured during the test, the screened intervals of observation wells, and monitored background fluctuations, only wells 460 and 461 were analyzed using the Hantush and Jacob Method (1955). The drawdown data collected from well 462, which is located 10.4 ft from the pumping well, did not provide a reasonable fit to any of the Hantush and Jacob type curves; however, measured drawdown in this well was used to estimate the transmissivity and storage coefficient via the Distance-Drawdown Method.

Table 7 presents the results of both the Hantush and Jacob and distance-drawdown analyses. Hydraulic conductivity estimates are based on an assumed 15-ft saturated thickness, which is the length of the pumping well screen interval. The AquiferWin32 plots used for the analyses are contained in Appendix B.

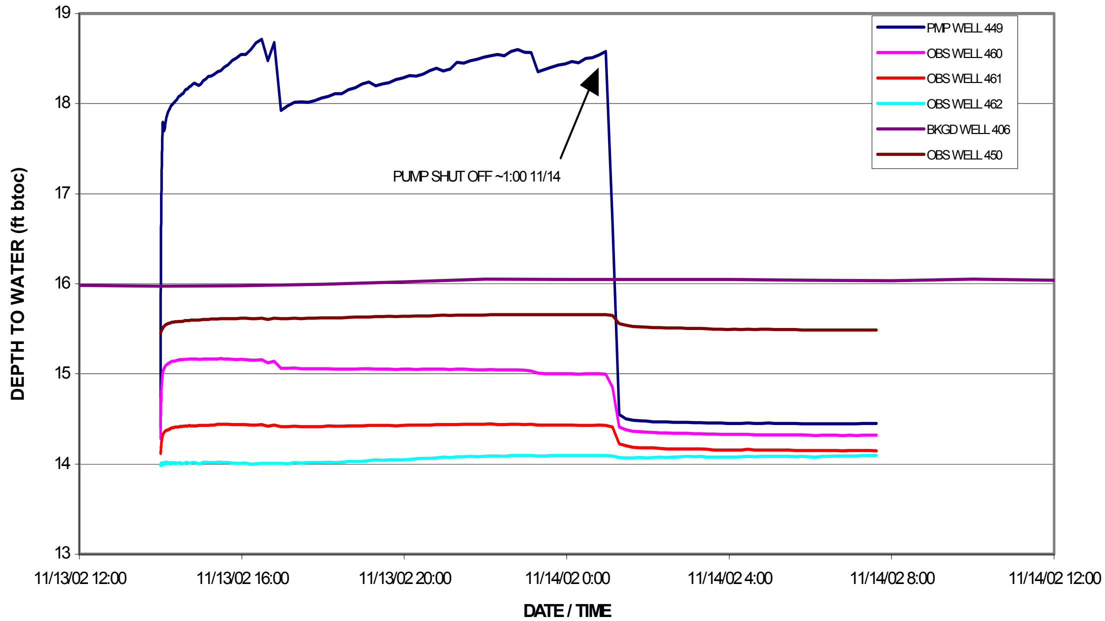


Figure 18. Depth to Water Data During the 7.5 gal/min Short-Term Aquifer Test

Table 7. Well 449 7.5 gal/min Short-Term Aquifer Test Results for Transmissivity (T), Hydraulic Conductivity (K) and Storage Coefficient (S)

Well(s)	Analysis Method						
	Hantush and Jacob				Distance-Drawdown		
	T (ft^2/d)	K (ft/d)	r/B	S	T (ft^2/d)	K (ft/d)	S
460	406.0	27.1	0.30	0.010	na	na	na
461	1023.2	68.2	0.29	0.020	na	na	na
460/461/462	na	na	na	na	399.5	26.6	0.006

Notes:
T = Transmissivity (ft^2/day); K = Hydraulic Conductivity (ft/day);
r/B = Hantush and Jacob Type Curve Used For Analysis (dimensionless);
S = Storage Coefficient (dimensionless); na = not applicable

Similar to the trend shown in the 4.3 gal/min test, analysis of observation well 460 data produced lower estimates of the transmissivity and storage coefficient compared to the results obtained from observation well 461. Analysis of drawdown data from observation well 460 and 461 estimated transmissivities of 406.0 and 1023.2 ft^2/day, respectively. The storage coefficient estimated from analysis of observation 460 was 0.010, while a storage coefficient of 0.020 was estimated using well 461 data. Analysis of the distance drawdown data collected from observation wells 460, 461, and 462 produced an estimated transmissivity of 399.5 ft^2/day, a hydraulic conductivity of 26.6 ft/day, and a storage coefficient of 0.006.

7.1 gal/min Short-Term Aquifer Test—Water Level Data

The third short-term test was conducted so that a residual drawdown analysis could be performed, which was not achieved during the earlier 7.5 gal/min test, after equipment failure. A test was started at 09:15 on November 14, 2002, pumping 7.1 gal/min from well 449. After 4 hours of pumping, the pump was shut off, and residual drawdown data were collected. Table 8 presents the drawdown data at all wells after 4 hours of pumping 7.1 gal/min. Figure 19 presents the water level response in pumping well 449, observation wells 450, 460, 461, and 462, and background well 406 during the pumping period.

Table 8. Drawdown Measured During the 7.1 gal/min Short-Term Aquifer Test

Location	Distance from Pumping Well 449 (ft)	Drawdown Measured After Pumping 7.1 gal/min from Well 449 (ft)
449	na	3.85
450	14.9	0.13
460	3.3	0.64
461	6.4	0.25
462	10.4	0.17
463	2.1	0.0
SMI–PW01	11.8	0.14
SMI–PZ1S	16.4	0.14
SMI–PZ1M	12.0	0.0
SMI–PZ1D	18.5	0.0

Notes:
na = not applicable; ft = feet

Similar to the previous two short-term tests, the water level in piezometer 463 showed no response to pumping. During the pumping period, 0.03 ft of water level fluctuation was measured in background well 406.

As with the previous tests, only the drawdown data from wells 460 and 461 were analyzed using the Hantush and Jacob Method (1955) for leaky aquifers. Similar to the 7.5 gal/min test, the measured drawdowns in wells 460, 461, and 462 were analyzed using the Distance-Drawdown Method. Residual drawdown data from observation wells 460 and 461 were also analyzed using the Theis Recovery Method (1935), as applied to unconfined aquifers.

Results of all analyses are presented in Table 9. Hydraulic conductivity estimates are based on a 15 ft saturated thickness, which is the length of the pumping well screen interval. The AquiferWin32 plots used for the analyses are contained in Appendix B.

Similar to the 4.3 and 7.5 gal/min short-term tests, analysis of drawdown data from observation well 461 produced a significantly higher transmissivity than estimated from well 460 data. Analysis of drawdown data collected from observation well 460 estimated a transmissivity of 525.7 ft^2/day, while drawdown data from observation well 461 suggested a transmissivity of 1064.4 ft^2/day. Residual drawdown data analysis showed the same trend as transmissivity results from analysis of wells 460 and 461; 454.4 and 1,219.5 ft^2/day, respectively. The distance-drawdown method resulted in an estimated transmissivity of 520.8 ft^2/day. Storage coefficients estimated from analyses of the 7.1 gal/min data ranged from 0.015 to 0.031, again indicating release of ground water under both elastic storage and gravity drainage conditions.

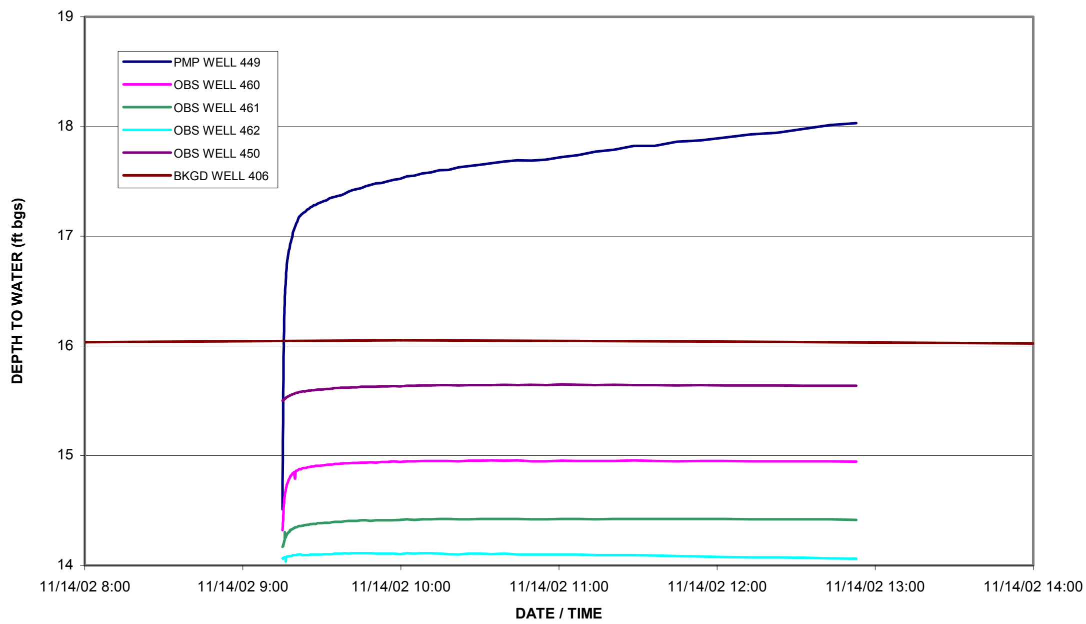


Figure 19. Depth to Water Data During the 7.1 gal/min Short-Term Aquifer Test

Table 9. Well 449 7.1 gal/min Short-Term Aquifer Test Transmissivity, Hydraulic Conductivity and Storage Coefficient Results

Well(s)	Analysis Method								
	Hantush and Jacob				Theis Recovery		Distance-Drawdown		
	T (ft^2/d)	K (ft/d)	r/B	S	T (ft^2/d)	K (ft/d)	T (ft^2/d)	K (ft/d)	S
460	525.7	35.0	0.25	0.017	454.4	30.3	na	na	na
461	1064.4	71.0	0.37	0.031	1219.5	81.3	na	na	na
461/462/463	na	na	na	na	na	na	520.8	34.7	0.015

Notes:
T = Transmissivity (ft^2/day); K = Hydraulic Conductivity (ft/day);
r/B = Hantush and Jacob Type Curve Used For Analysis (dimensionless);
S = Storage Coefficient (dimensionless); na = not applicable

November 2002 Short-Term Aquifer Tests—In Situ Specific Conductance Data

Figures 20, 21, 22, and 23 present the Troll 8000 data collected from wells 449, PZ1S, PW01, and PZ1M, respectively during the three tests in November. These data are compared to water level changes in pumping well 449.

Figure 20 shows that the specific conductance measured in well 449 showed a steady increase during the 4.3 and 7.5 gal/min tests, but no distinct correlation with well 449 water levels. During the 7.1 gal/min test there was a slight decrease in the specific conductance in well 449. The data indicate that pumping from well 449 did not impact observation well PZ1S (Figure 21).

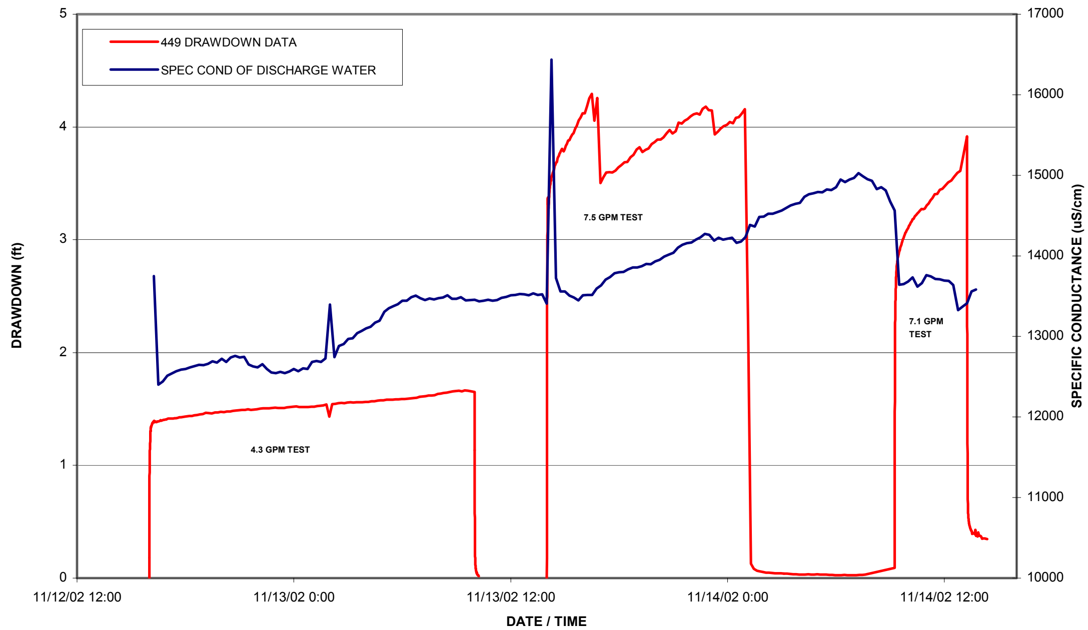


Figure 20. Troll 8000 Specific Conductance Data From Well 449, During the November 2002 Short-Term Tests

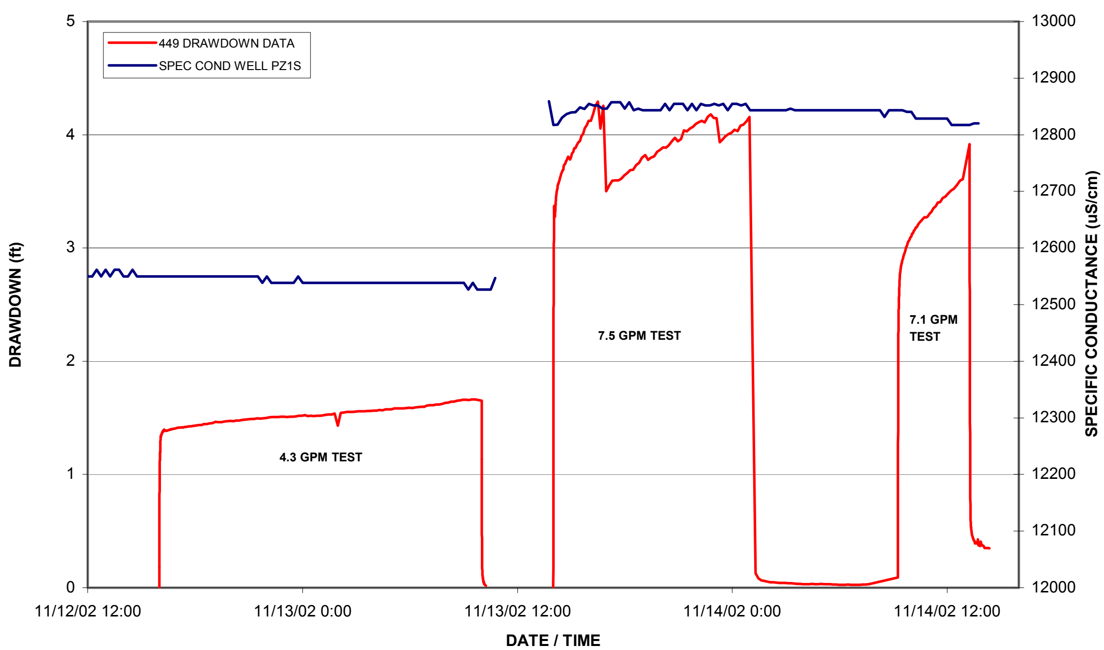


Figure 21. Troll 8000 Specific Conductance Data From Well PZ1S, During the November 2002 Short-Term Tests

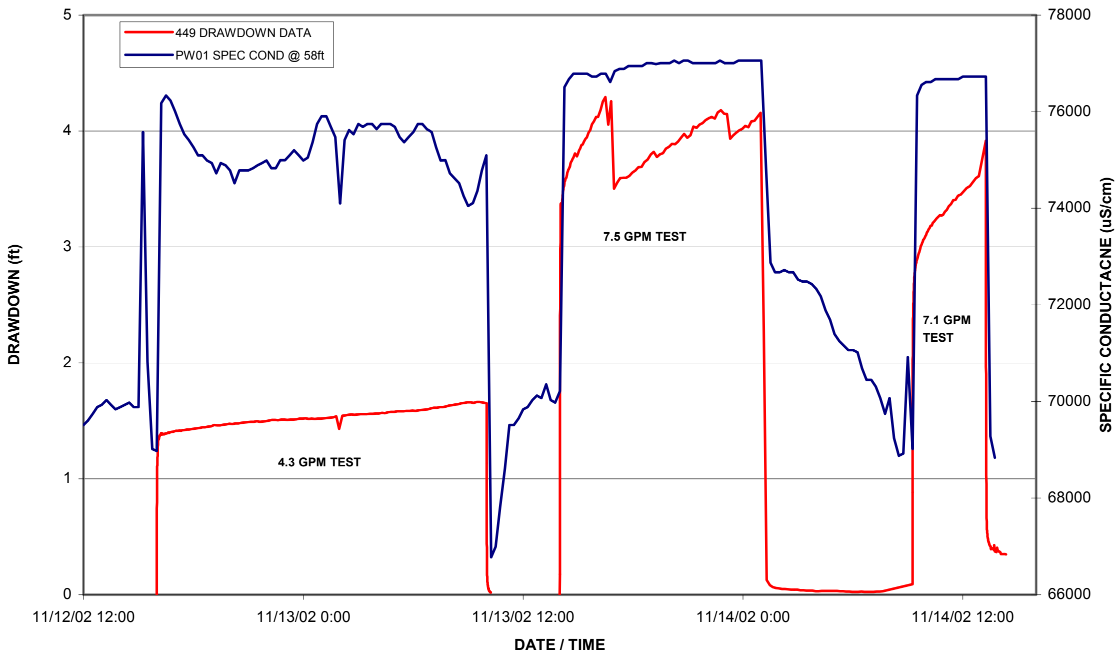


Figure 22. Troll 8000 Specific Conductance Data From Well PW01, During the November 2002 Short-Term Tests

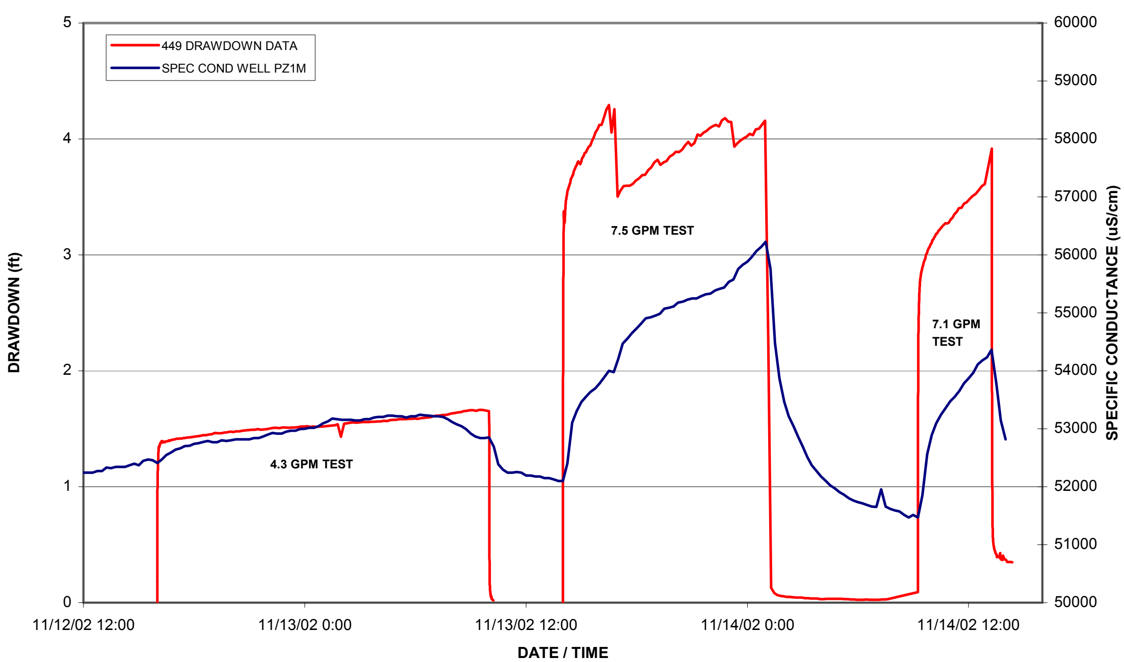


Figure 23. Troll 8000 Specific Conductance Data From Well PZ1M, During the November 2002 Short-Term Tests

As shown in Figure 22, specific conductance in observation well PW01 showed a significant increase during the short-term test pumping periods once the test was started. Specific conductance in well PZ1M also showed a response to pumping (Figure 23). The specific conductance increase in PZ1M was greater during the 7.5 and 7.1 gal/min tests in comparison to the specific conductance measured in this well during the 4.3 gal/min test.

Summary—Long-Term Aquifer Tests

The following is a summary of findings from the August and September 2002 long-term aquifer tests completed under Task 2 of the 2002 Work Plan (DOE 2002b):

- Long-term pumping at a rate of 3 gal/min from a well screened over the shallow, finer-grained portion of the aquifer does not increase the specific conductance of the discharge water.
- Pumping from well 449 was not sufficient to affect an observation well located about 15 ft away.
- Long-term pumping from well 449 does affect well PW01 to some degree. However, this response may be a direct result of the length of screen in well PW01, which provides a conduit from the shallow aquifer zone to the deeper zone. Similar responses were observed from the Troll 8000 specific conductance data and the sulfate/chloride ratio data.
- The efficiency of well 449 likely decreased with increasing pumping time. An improvement in pumping well efficiency is expected when formal well design techniques (screen slot size and gravel pack size) are applied for the interim action pumping wells to be installed in the shallow zone.
- Both attempts at completing long-term tests were hampered by equipment problems. After 17 days of pumping during the second long-term test, no significant drawdown was measured in observation well 450, located just 14.9 ft from the pumping well. In addition, recovery data from the pumping well were either not analyzed due to loss of control of the pumping rate or not collected because the pumping stopped unexpectedly. As a result of inadequate information, aquifer parameters were not estimated from water level data collected from either long-term test.
- Data collected from these initial long-term tests suggest pumping from the shallow, finer-grained portion of the aquifer does not result in brine migration through the subsurface on the scale observed from pumping a well screened over the deeper, more conductive zone (DOE 2002a). Ultimately, the observational method will be used to provide a long-term solution regarding brine migration.

Summary—Short-Term Aquifer Tests

The following is a summary of findings from the November 2002 short term aquifer tests completed under Task 2 of the 2002 Work Plan (DOE 2002b):

- Pumping well 449 can sustain approximately 7 gal/min for short periods of time (approximately 24 hours). This is in contrast to the initial step test conducted on this well, which indicated the well could not sustain over 3 gal/min. Specific capacities for the 4.3, 7.5, and 7.1 gal/min short-term tests were 2.54, 1.83, and 1.84 gal/min/ft, respectively. The initial step test results showed a specific capacity of less than 0.41 gal/min/ft when the pumping rate was 4 gal/min.

- Table 10 presents a summary of the transmissivity, hydraulic conductivity, and specific storage results from the November 2002 short-term aquifer tests.

Table 10. November 2002 Short-Term Aquifer Test Summary

Test	Well(s)	Analysis Method								
		Hantush and Jacob				Theis Recovery		Distance-Drawdown		
		T (ft^2/d)	K (ft/d)	r/B	S	T (ft^2/d)	K (ft/d)	T (ft^2/d)	K (ft/d)	S
4.3 gal/min	460	410.2	27.3	0.28	0.011	402.0	26.8	na	na	na
	461	810.5	54.0	0.34	0.020	1098.2	73.2	na	na	na
7.5 gal/min	460	406.0	27.1	0.30	0.010	na	na	na	na	na
	461	1023.2	68.2	0.29	0.020	na	na	na	na	na
	461/462/463	na	na	na	na	na	na	399.5	26.6	0.006
7.1 gal/min	460	525.7	35.0	0.25	0.017	454.4	30.3	na	na	na
	461	1064.4	71.0	0.37	0.031	1219.5	81.3	na	na	na
	461/462/463	na	na	na	na	na	na	520.8	34.7	0.015

Notes:
T = Transmissivity; K = Hydraulic Conductivity; S = Storage Coefficient
All K values calculated from T, using a saturated thickness of 15 ft;
r/B = Hantush and Jacob Type Curve Used For Analysis (dimensionless); na = not applicable

- Analyses of drawdown data indicate the transmissivity of the shallow zone of the alluvial aquifer ranges from 399.5 to 1064.4 ft^2/day, with observation well 461 consistently producing higher estimates compared to observation well 460. Using a saturated thickness of 15 ft (which is equal to the screen length of the pumping well), corresponding hydraulic conductivities range from 26.6 to 71.0 ft/day.

- Analyses of the drawdown data also indicate the storage coefficient ranges from 0.006 to 0.031.

- Analyses of the residual drawdown data indicate the transmissivity ranges from 402.0 to 1219.5 ft^2/day. Assuming a saturated thickness of 15 ft, corresponding hydraulic conductivities range from 26.8 to 81.3 ft/day.

- Drawdown data were analyzed using the Hantush and Jacob Method for leaky aquifers. The hydrogeologic conceptual model of the site suggests a three-dimensional ground water flow system, and not a classic leaky aquifer scenario. However, the Hantush and Jacob method was found to best simulate the 3-D flow system. Aquifer parameter estimates derived from this method can be used for well field design purposes.

- Taking into account the r/B values derived and the radial distance of the observation well, the leakage factor (B) can be determined (Table 11). In addition, the vertical conductance of aquifer material underlying the pumping well, which is defined as the ratio of hydraulic conductivity to the underlying material's thickness (McWhorter and Sunada 1977), can be calculated. The drawdown data from the November 2002 short-term aquifer tests indicate the underlying material conductance ranges from 2.10 to 3.56 day^{-1}.

Table 11. Conductance Estimates Based on Hantush and Jacob Method Analysis

Test	Well	r (ft)	r/B	B	T (ft^2/d)	K' / b' (day^{-1})
4.3 gal/min	460	3.3	0.28	11.79	410.2	2.95
	461	6.4	0.34	18.82	810.5	2.29
7.5 gal/min	460	3.3	0.30	11.00	406.0	3.36
	461	6.4	0.29	22.07	1023.2	2.10
7.1 gal/min	460	3.3	0.25	13.20	525.7	3.02
	461	6.4	0.37	17.30	1064.4	3.56

Notes:
r = observation well radial distance from pumping well;
r/B = Hantush and Jacob Type Curve Used for Analysis;
B = Leakage Factor; T = Transmissivity (ft^2/day);
K' / b' = Aquitard Conductance (ft^{-1})

- It is important to stress that the conductance term, and the material thickness and hydraulic conductivity that comprise it, do not necessarily represent actual physical properties of the porous medium. Rather the conductance term is a parameter that can be used for well design purposes, specifically to account for influx of water from underlying aquifer materials during pumping.

Conclusions

This document presents the results of five aquifer tests (two long-term and three short-term) that were conducted as Part 2, Phase II characterization of the Moab Project Site. These tests were designed to provide additional hydrological parameter estimations for the shallow zone of the alluvial aquifer that were presented in the Phase II, Part 1 (Calc. No. Moab-10-2002-03-03-00).

Previous results indicated the hydraulic conductivity of the shallow zone of the alluvial aquifer ranged from 0.5 to 7.1 ft/day, and wells completed within this zone could not sustain over 3 gal/min. Subsequent testing resulted in a hydraulic conductivity ranging from approximately 25 to 80 ft/day, with a storage coefficient ranging from 0.006 to 0.031. In addition, sustainable flow rates of wells completed within this same zone ranged from approximately 4 to 7 gal/min.

This information will be used to update the flow model, which will assist in the design of the interim action remediation well field. While the data presented provides expected flow rates, actual long-term sustainable flow rates will be determined through the observational approach once the system is in operation.

Appendix A

Pump Test Ground Water Samples

ESL–DP–2003–01
MOA 19.1.2

Environmental Sciences Laboratory Data Package

Moab Project Site

Pump Test
Ground Water Samples

November 2002

Prepared for
U.S. Department of Energy
Grand Junction Office
Grand Junction, Colorado

Work Performed Under DOE Contract Number DE–AC13–02GJ79491
Task Order Number ST03–104

X0023800

WORK SUBMITTAL TO ENVIRONMENTAL SCIENCES LABORATORY

Submittal Date 8/12/02 Date Required As Needed

Submitted By K Pill Signature K Pill

Formal ESL Report ? Yes ___ No ✓

Data Report Only? Yes ___ No ✓

Project: ___ Charge No. 110 402-211

Analysis Type (check one): Kd ___ Leaching ___ Other ✓

±50 water samples from Mine Wells

PW01 locations

Sample Numbers ___

Analytes Cl, SO4, NH4, Cond Temp Density U

split to ACL for TDS

Solution Composition

Comments (attach procedure if needed) K Pill aware that results might be delayed due to travel.

spread sheet only.

Moab Pump Tests

MOA01-05-01

8/15/02 Receive 25 samples. Filtered and cooled. Split submitted to ACL by K Pill

8/16/02	ACL#	Cond	T	Den	Cl	NO_3	SO_4	NH_3 Hach	U	
MOA450-15	NDS951	13540	17.6	1.0072	1348	<500	6906	450	~~1215~~	1244
-19	953	14210	17.2	1.0052	1374	↓	7074	430	~~1260~~ gm	1299
-23	954	14290	16.9	1.0068	1365		7060	450	~~1390~~	1190
-28	955	15530	19.2	1.0080	1445		7697	600	~~1578~~	1743
MOA449-15	959	14550	15.5	1.0073	1338		6897	450	1215	
19	958	14440	18.5	1.0064	1373		7074	450	1260	
23	957	14630	18.0	1.0068	1341		7168	480	1390	
28	956	14840	19.4	1.0072	1300		7469	550	1578	
PW01-0813-0	960	14150	18.4	1.0066	1336		6830	425	1427	
PZ1S-0813-0	961	14440	17.9	1.0067	1354	↓	6998	475	1351	
PZ1M-0813-0	962	41800	17.9	1.0249	9018	514	15808	1425	3545	
MOA450-0813-0	963	15060	17.5	1.0060	1394	<500	7287	450	1443	
MOA449-0813-0	964	14760	17.5	1.0058	1335	↓	7086	400	1369	
-0813-1	965	14610	17.4	1.0057	1363		7061	400	1306	
-0813-2	966	14560	17.8	1.0057	1356		7071	420	1268	
-0813-3	967	14570	17.8	1.0059	1381	↓	7245	420	1335	
PZ1M-0813-1	968	44300	17.4	1.0261	10081	552	16257	550	3307	
PZ1S-0813-1	969	14730	17.4	1.0059	1409	<500	7220	520	1229	
PW01-0813-1	970	15830	17.8	1.0071	1388	↓	8088	400	1348	
MOA450-0813-1	971	15860	19.7	1.0083	1475		7889	525	1701	
MOA449-0814-1	972	14790	20.0	1.0072	1350		7211	450	1089	
MOA450-0814-1	973	15640	19.0	1.0071	1466	↓	7790	560	16.89	
PZ1M-0814-1	974	43900	20.6	1.0272	9878	541	16399	1375	3307	
PZ1S-0814-1	975	14580	19.6	1.0067	1380	<500	7167	425	1229	
PW01-0814-1	NDP401	14610	20.4	1.0070	1404	↓	7215	220	1348	

Moab Pump Tests

MOA01-05-02

8/26/02 Receive 10 samples. Filtered and cooled. Split submitted to ACL by K.Lee

	ACL #	Cond	T	Dens	Cl	NO_3	SO_4	NH_3 Hach	U
MOA 449-0822	NDP 402	13800	21.4	1.0079	1379	<500	7118	410	1280
450-0822	403	14290	21.6	1.0080	1414		7354	470	1409
PW01-0822	404	13850	21.7	1.0077	1437		7259	500	1211
PZ1S-0822	405	14310	22.2	1.0079	1407		7290	525	1269
PZ1M-0822	406	42500	21.3	1.0271	9684	547	16574	1475	3402
MOA449-0823	407	14120	21.0	1.0075	1407	<500	7274	420	1236
450-0823	408	14670	22	1.0078	1452		7563	460	1393
PZ1S-0823	409	14410	21.9	1.0078	1412		7310	450	1173
PW01-0823	410	15400	22.4	1.0089	1342		8066	575	1503
PZ1M-0823	411	44300	22.0	1.0280	10570	561	16580	525	2840
	MQ =		22.5°	0.9967					

EFFICIENCY LINE™ 22-210

Moab Pump Test

MOA01-05-03

9/5/02 Receive 11 samples from K Pill. Place in refrigerator

9/9/02 800 Power failure over weekend (Sun noon). Samples still cool. Place w/ice in icechest

9/10/02

	Acc	Cond	T °C	Den	Cl	NO_3	SO_4	NH_3 Hach	U
MOA 449-1-0904	NDT351	14840	17.5	1.0063	1358	363	6980	360	1305
MOA 449-2-0904	356	14880	16.9	1.0064	1369	343	7136	420	1274
450-0904	354	15910	16.3	1.0071	1419	349	7488	480	1598
PW01-0904	352	14780	16.0	1.0067	1365	349	7034	370	1215
PZ1S-0904	353	15110	16.5	1.0067	1378	367	7074	400	1256
PZ1M-0904	355	43900	16.9	1.0260	9062	530	16248	1350	3595
449-0905	363	14820	17.2	1.0068	1387	345	7078	400	1220
450-0905	358	16060	16.3	1.0071	1408	366	7424	550	1675
PW01-0905	362	16010	16.4	1.0072	1325	340	8003	510	1401
PZ1S-0905	359	14880	16.9	1.0067	1396	377	7151	440	1100
PZ1M-0905	357	43400	17.2	1.0260	9174	543	16463	1450	3523
MQ			23.7	0.9967					

Note: NO_3 numbers can only be reported as <500 mg/L (if number is <500) numbers <500 are out of cal range with this dilution

EFFICIENCY LINE 22-210

Moab Pump Test

MOA01-05-0~~8~~4

9/12/02	Received 5 samples after COB								
9/13/02	Acc	Cond	T	Den	Cl	NO_3	SO_4	U	NH_3 (Hach)
MOA 449-0912	NDP415	14950	17.3	1.0064	1366	<500	7083	1217	420
450-0912	412	16100	16.5	1.0073	1452	<500	7753	1686	560
PW01-0912	416	17000	16.0	1.0087	1338	<500	8722	1754	660
PZ1S-0912	414	14950	15.7	1.0068	1362	<500	7038	1195	430
PZ1M-0912	413	44400	16.4	1.0267	9568	545	16247	3689	1400

EFFICIENCY LINE™ 22-210

Moab Pump Test

MOA01-05-06

9/19/02	Receive 5 samples @ COB.				Samples are filtered. Refrigerate					
9/26/02		Acc	Cond	T	Den	Cl	NO_3	SO_4	NH_3 Hach	U
MOA 449-0919		NDP417	14220	15.9	1.0062	1358	338	7083	410	1210
450-0919		418	15630	17.6	1.0066	1448	367	7694	520	1627
PW01-0919		420	16990	17.1	1.0076	1329	333	8911	670	1757
PZ1S-0919		419	14690	17.3	1.0062	1388	374	7197	430	1295
PZ1M-0919		421	47300	18.4	1.0284	11269	557	16329	1500	3435
	MQ =	0.9971 @ 22.4								

	A	B	C	D	E	F	G	H	I	J	K
1	Moab Brine Sampling/ Pump Test 8/2002										
2											
3											
4	LOCATION	DENSITY	TEMP	CONDUCTIVITY	AMMONIA	CHLORIDE	SULFATE	URANIUM	TDS	ACL #	NH3 analysis
5		(g/cm3)	(*C)	(uS/cm)	NH3-N(mg/L)	(mg/L)	(mg/L)	(ug/L)	(mg/L)		date
6					(Hach Kit)						
7											
8											
9	MOA 450-15	1.0072	17.6	13540	450	1348	6906	1244		NDS 951	08/29/2002
10	MOA 450-19	1.0052	17.2	14210	430	1374	7074	1299		NDS 953	08/29/2002
11	MOA 450-23	1.0068	16.9	14290	450	1365	7060	1190		NDS 954	08/29/2002
12	MOA 450-28	1.008	19.2	15530	600	1445	7697	1743		NDS 955	08/29/2002
13	MOA 449-15	1.0073	15.5	14550	450	1338	6897	1215		NDS 959	08/29/2002
14	MOA 449-19	1.0064	18.5	14440	450	1373	7074	1260		NDS 958	08/29/2002
15	MOA 449-23	1.0068	18	14630	480	1341	7168	1390		NDS 957	08/29/2002
16	MOA 449-28	1.0072	19.4	14840	550	1300	7469	1578		NDS 956	08/29/2002
17	PW01-0813-0	1.0066	18.4	14150	425	1336	6830	1427		NDS 960	08/29/2002
18	PZ1S-0813-0	1.0057	17.9	14440	475	1354	6998	1351		NDS 961	08/29/2002
19	PZ1M-0813-0	1.0244	17.9	41800	1425	9018	15808	3545		NDS 962	08/29/2002
20	MOA 450-0813-0	1.006	17.5	15060	450	1394	7287	1443		NDS 963	08/29/2002
21	MOA 449-0813-0	1.0058	17.5	14760	400	1335	7086	1369		NDS 964	08/29/2002
22	MOA 449-0813-1	1.0057	17.4	14610	400	1363	7061	1306		NDS 965	08/29/2002
23	MOA 449-0813-2	1.0059	17.8	14560	420	1356	7071	1268		NDS 966	08/29/2002
24	MOA 449-0813-3	1.0059	17.8	14570	420	1381	7245	1335		NDS 967	08/29/2002
25	PZ1M-0813-1	1.0261	17.4	44300	550	10081	16257	3307		NDS 968	08/29/2002
26	PZ1S-0813-1	1.0059	17.4	14730	520	1409	7220	1229		NDS 969	08/29/2002
27	PW01-0813-1	1.0071	17.8	15830	400	1388	8088	1348		NDS 970	08/29/2002
28	MOA 450-0813-1	1.0083	19.7	15860	525	1475	7889	1701		NDS 971	08/29/2002
29	MOA 449-0814-1	1.0072	20	14790	450	1350	7211	1289		NDS 972	08/29/2002
30	MOA 450-0814-1	1.0071	19	15640	560	1466	7790	1689		NDS 973	08/29/2002
31	PZ1M-0814-1	1.0272	20.6	43900	1375	9878	16399	3307		NDS 974	08/29/2002
32	PZ1S-0814-1	1.0067	19.6	14580	425	1380	7167	1229		NDS 975	08/29/2002
33	PW01-0814-1	1.007	20.4	14610	220	1404	7215	1348		NDP 401	08/29/2002
34	MOA 449-0822	1.0079	21.4	13800	410	1379	7118	1280		NDP 402	08/29/2002
35	MOA 450-0822	1.008	21.6	14290	470	1414	7354	1409		NDP 403	08/29/2002
36	PW01-0822	1.0077	21.7	13850	500	1437	7259	1211		NDP 404	08/29/2002

	A	B	C	D	E	F	G	H	I	J	K
37	PZ1S-0822	1.0079	22.2	14310	425	1407	7290	1269		NDP 405	08/29/2002
38	PZ1M-0822	1.0271	21.3	42500	1475	9684	16574	3402		NDP 406	08/29/2002
39	MOA 449-0823	1.0075	21	14120	420	1407	7274	1236		NDP 407	08/29/2002
40	MOA 450-0823	1.0078	21.2	14670	460	1452	7563	1393		NDP 408	08/29/2002
41	PZ1S-0823	1.0078	21.9	14410	450	1412	7310	1173		NDP 409	08/29/2002
42	PW01-0823	1.0089	22.4	15400	575	1342	8066	1503		NDP 410	08/29/2002
43	PZ1M-0823	1.028	22	44300	525	10570	16580	2840		NDP 411	08/29/2002
44											
45											
46	MilliQ = 0.9967g/cm @ 22.5*C										

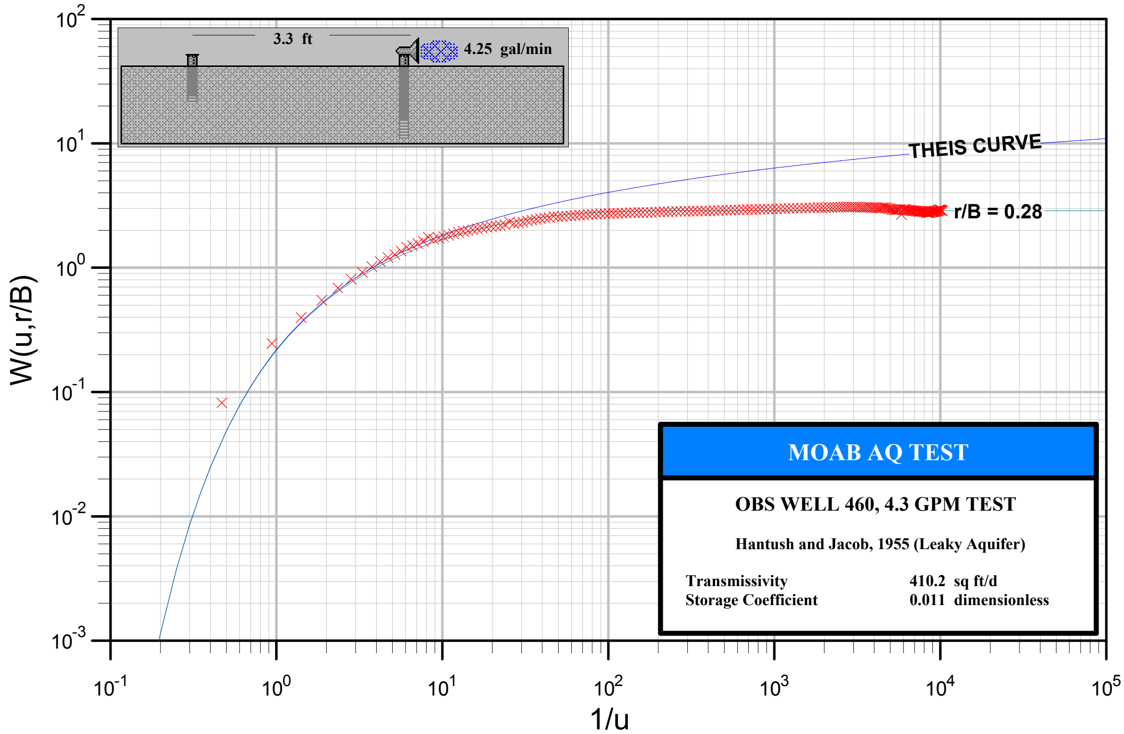
	A	B	C	D	E	F	G	H	I	J	K
1	Moab Brine Sampling/ Pump Test 8/2002										
2											
3											
4	LOCATION	DENSITY	TEMP	CONDUCTIVITY	AMMONIA	CHLORIDE	SULFATE	URANIUM	TDS	ACL #	NH3 analysis
5		(g/cm3)	(*C)	(uS/cm)	NH3-N(mg/L)	(mg/L)	(mg/L)	(ug/L)	(mg/L)		date
6					(Hach Kit)						
7											
8											
9	MOA 449-1-0904	1.0063	17.5	14840	360	1358	6980	1305		NDT 351	09/11/2002
10	MOA 449-2-0904	1.0064	16.9	14880	420	1369	7136	1274		NDT 356	09/11/2002
11	MOA 450-0904	1.0071	16.3	15910	480	1419	7488	1598		NDT 354	09/11/2002
12	PW01-0904	1.0067	16	14780	370	1365	7034	1215		NDT 352	09/11/2002
13	PZ1S-0904	1.0067	16.5	15110	400	1378	7074	1256		NDT 353	09/11/2002
14	PZ1M-0904	1.026	16.9	43900	1350	9062	16248	3595		NDT 355	09/11/2002
15	MOA 449-1-0905	1.0068	17.2	14820	400	1387	7078	1220		NDT 363	09/11/2002
16	MOA 450-0905	1.0071	16.3	16060	550	1408	7424	1675		NDT 358	09/11/2002
17	PW01-0905	1.0072	16.4	16010	510	1325	8003	1401		NDT 362	09/11/2002
18	PZ1S-0905	1.0067	16.9	14880	440	1396	7151	1100		NDT 359	09/11/2002
19	PZ1M-0905	1.026	17.2	43400	1450	9174	16463	3523		NDT 357	09/11/2002
20											
21	MilliQ = 0.9967g/cm @ 23.7*C										
22											
23	MOA 449-0912	1.0064	17.3	14950	420	1366	7083	1217		NDP 415	09/13/2002
24	MOA 450-0912	1.0073	16.5	16100	560	1452	7753	1686		NDP 412	09/13/2002
25	PW01-0912	1.0087	16	17000	660	1338	8722	1754		NDP 416	09/13/2002
26	PZ1S-0912	1.0068	15.7	14950	430	1362	7038	1195		NDP 414	09/13/2002
27	PZ1M-0912	1.0267	16.4	44400	1400	9568	16247	3689		NDP 413	09/13/2002
28											
29											
30	MOA 449-0919	1.0062	15.9	14220	410	1358	7083	1210		NDP 417	09/26/2002
31	MOA 450-0919	1.0066	17.6	15630	520	1448	7694	1627		NDP 418	09/26/2002
32	PW01-0919	1.0076	17.1	16990	670	1329	8911	1757		NDP 420	09/26/2002
33	PZ1S-0919	1.0062	17.3	14690	430	1388	7197	1295		NDP 419	09/26/2002
34	PZ1M-0919	1.0284	18.4	47300	1500	11269	16329	3435		NDP 421	09/26/2002
35											
36	MilliQ = 0.9971@22.4*C										

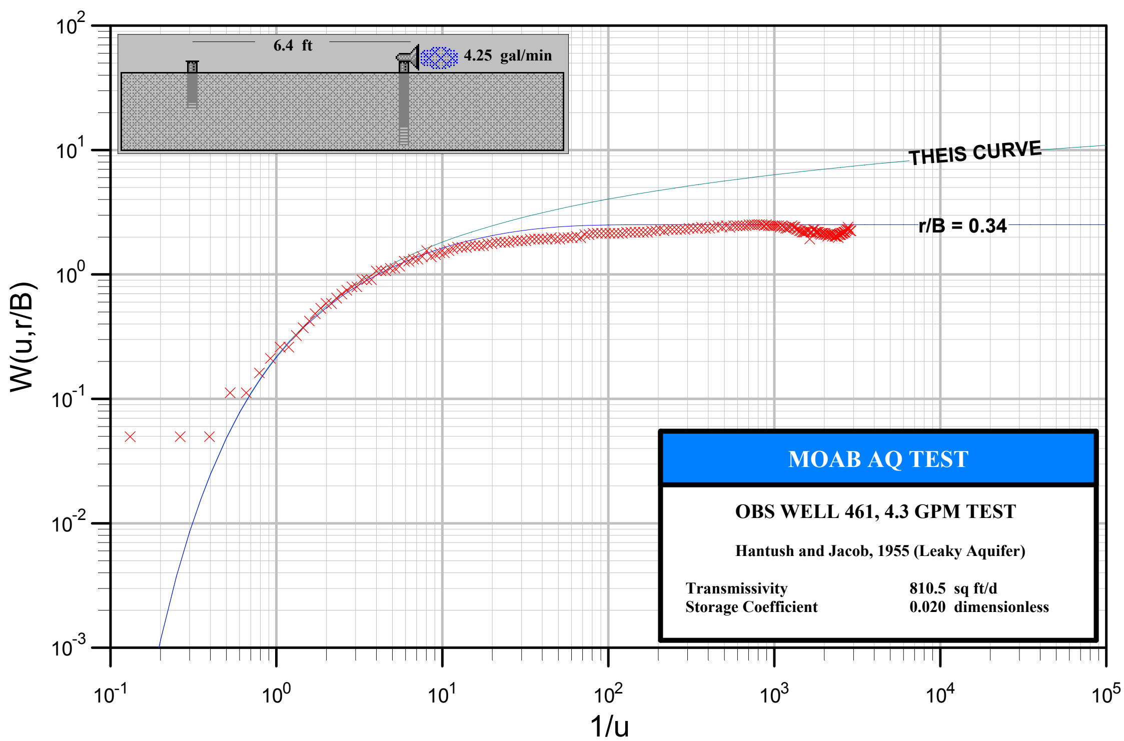
Appendix B

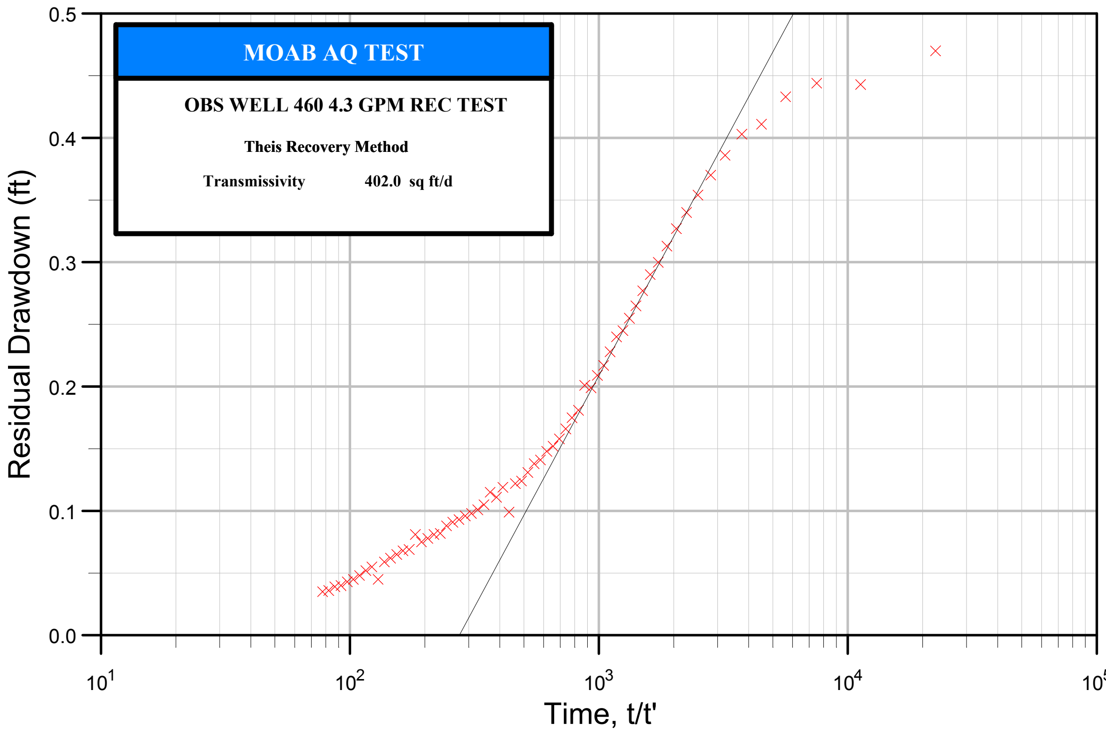
AquiferWin 32 Plots for November 2002 Short-Term Aquifer Tests

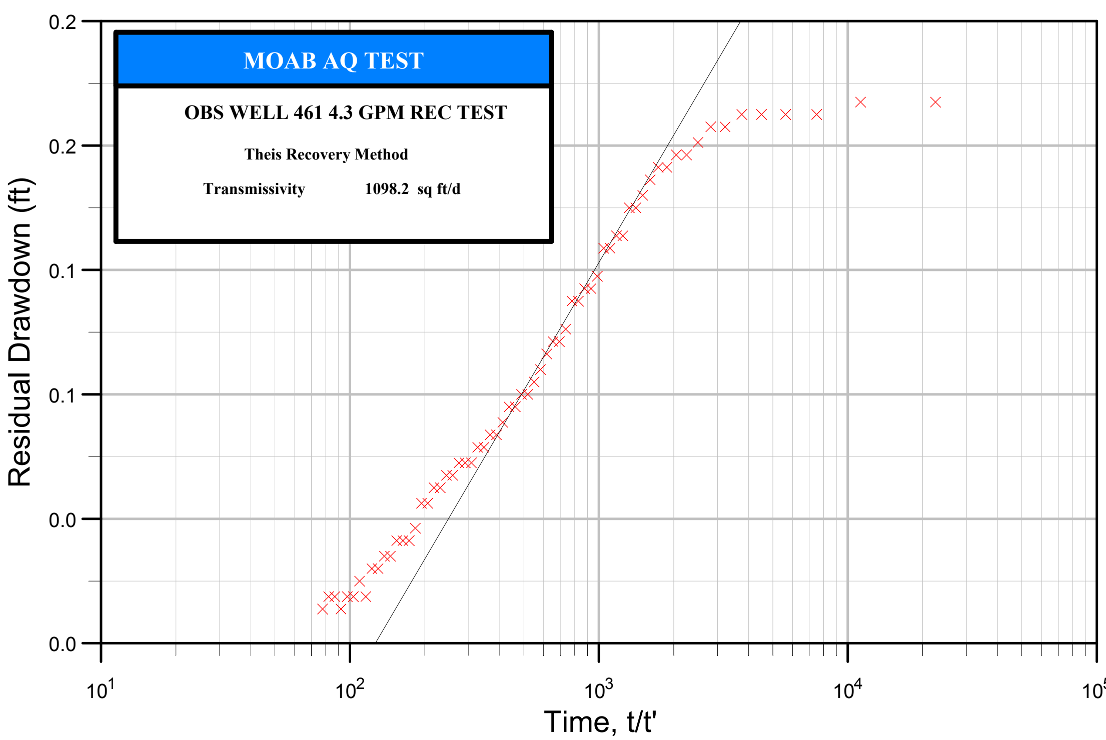
4.3 GPM TEST

AquiferWin 32 Plots


3.3 ft
4.25 gal/min
THEIS CURVE
r/B = 0.28
W(u,r/B)
1/u
MOAB AQ TEST
OBS WELL 460, 4.3 GPM TEST
Hantush and Jacob, 1955 (Leaky Aquifer)
Transmissivity 410.2 sq ft/d
Storage Coefficient 0.011 dimensionless

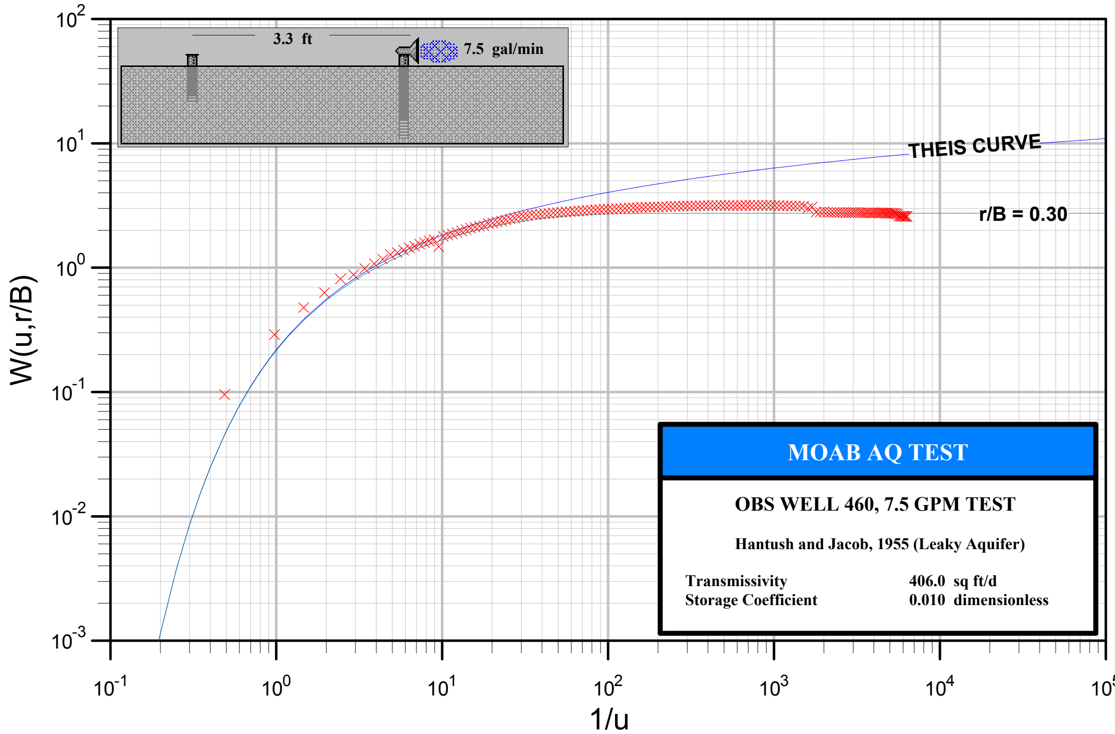

6.4 ft
4.25 gal/min
THEIS CURVE
r/B = 0.34
W(u,r/B)
1/u
MOAB AQ TEST
OBS WELL 461, 4.3 GPM TEST
Hantush and Jacob, 1955 (Leaky Aquifer)
Transmissivity 810.5 sq ft/d
Storage Coefficient 0.020 dimensionless

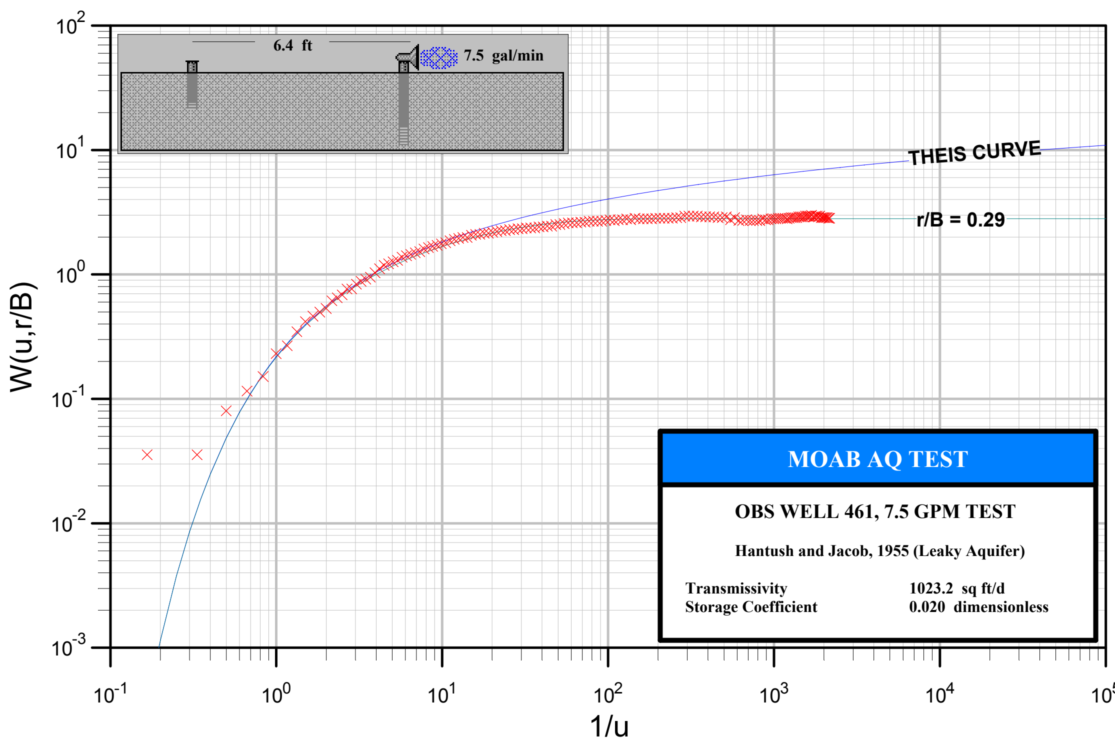

MOAB AQ TEST
OBS WELL 460 4.3 GPM REC TEST
Theis Recovery Method
Transmissivity 402.0 sq ft/d
Residual Drawdown (ft)
0.5
0.4
0.3
0.2
0.1
0.0
10^1
10^2
10^3
10^4
10^5
Time, t/t'

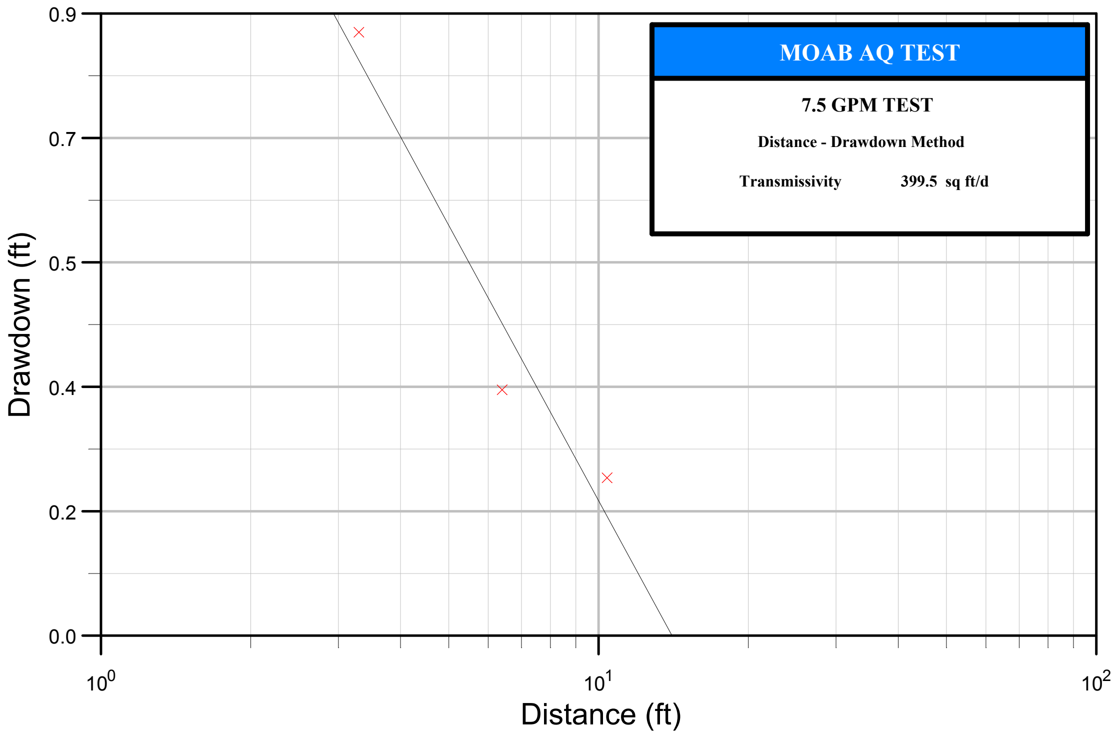

MOAB AQ TEST
OBS WELL 461 4.3 GPM REC TEST
Theis Recovery Method
Transmissivity 1098.2 sq ft/d
Residual Drawdown (ft)
0.2
0.2
0.1
0.1
0.0
0.0
10^1
10^2
10^3
10^4
10^5
Time, t/t'

7.5 GPM TEST

AquiferWin 32 Plots

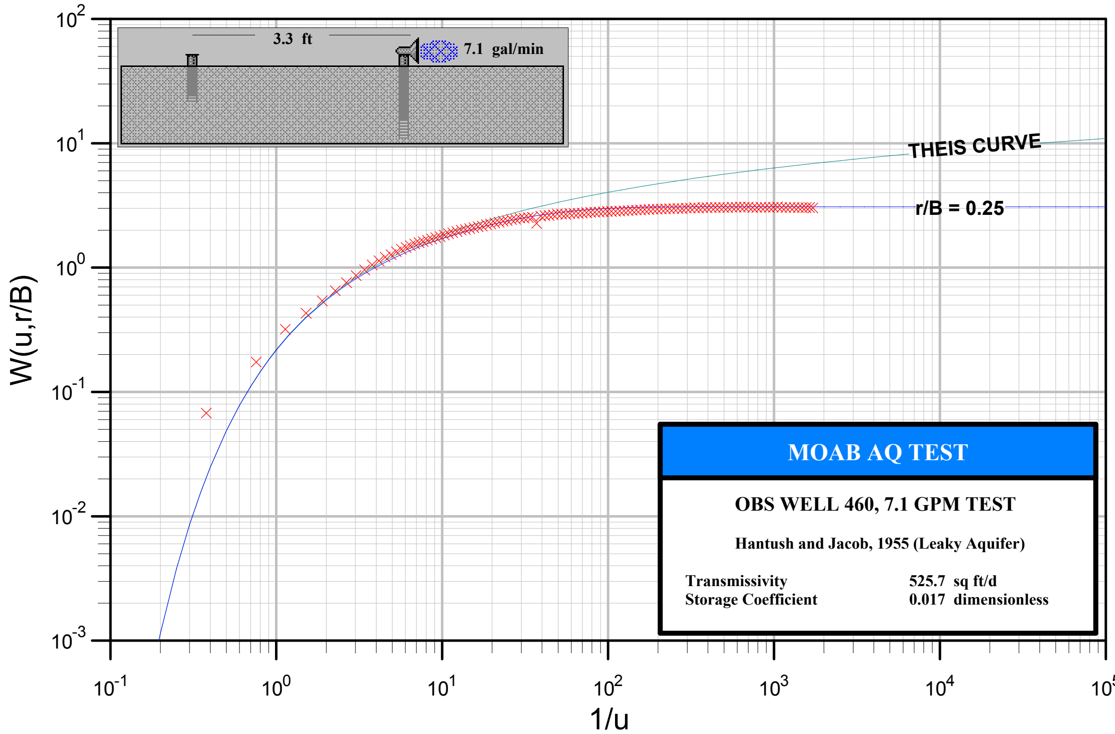

3.3 ft
7.5 gal/min
THEIS CURVE
r/B = 0.30
W(u,r/B)
1/u
MOAB AQ TEST
OBS WELL 460, 7.5 GPM TEST
Hantush and Jacob, 1955 (Leaky Aquifer)
Transmissivity 406.0 sq ft/d
Storage Coefficient 0.010 dimensionless

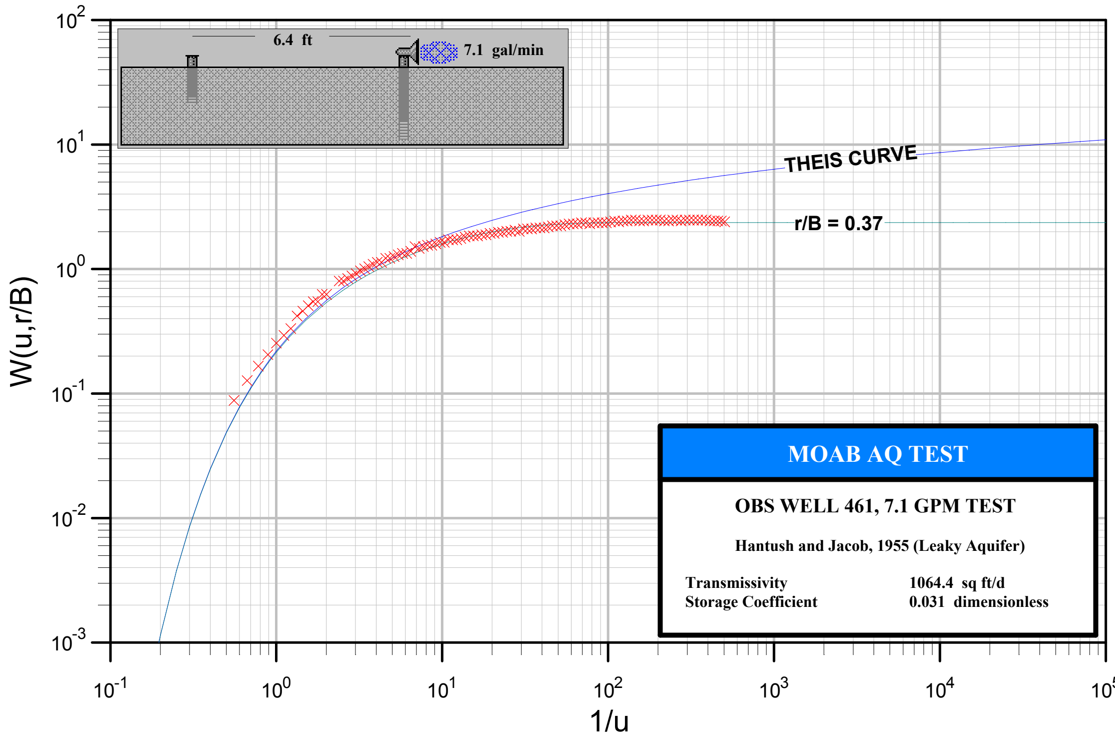

6.4 ft
7.5 gal/min
THEIS CURVE
r/B = 0.29
W(u,r/B)
1/u
MOAB AQ TEST
OBS WELL 461, 7.5 GPM TEST
Hantush and Jacob, 1955 (Leaky Aquifer)
Transmissivity 1023.2 sq ft/d
Storage Coefficient 0.020 dimensionless

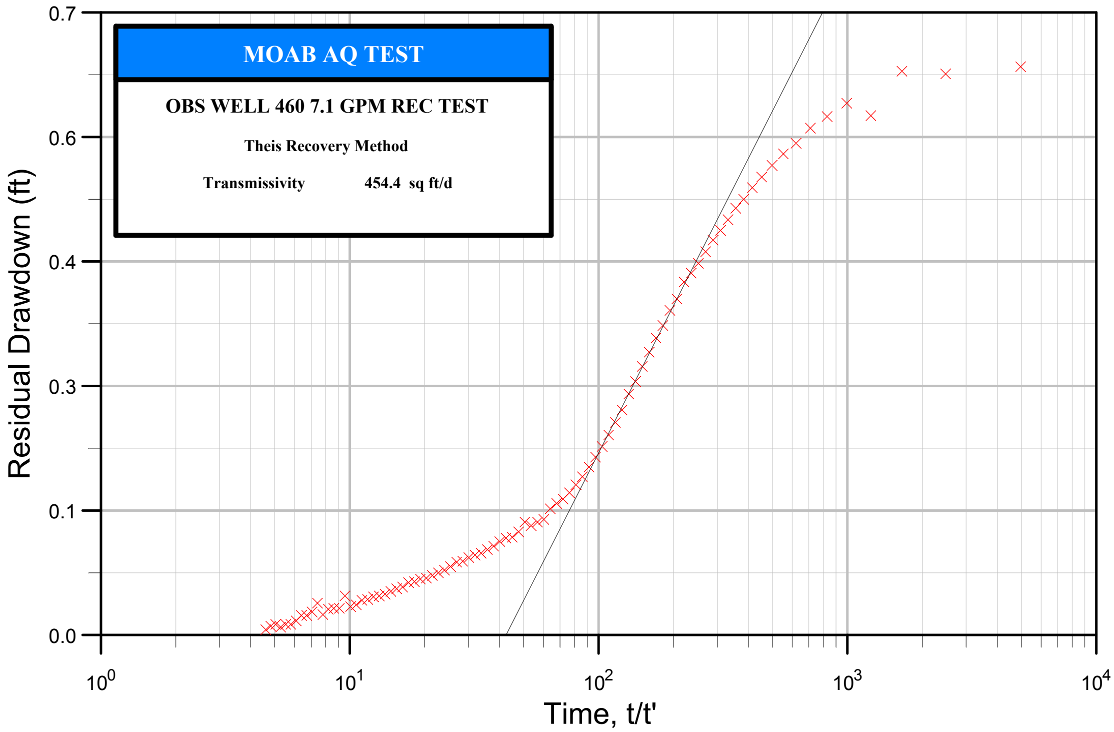

MOAB AQ TEST
7.5 GPM TEST
Distance - Drawdown Method
Transmissivity 399.5 sq ft/d
0.9
0.7
0.5
0.4
0.2
0.0
10^0
10^1
10^2
Distance (ft)
Drawdown (ft)

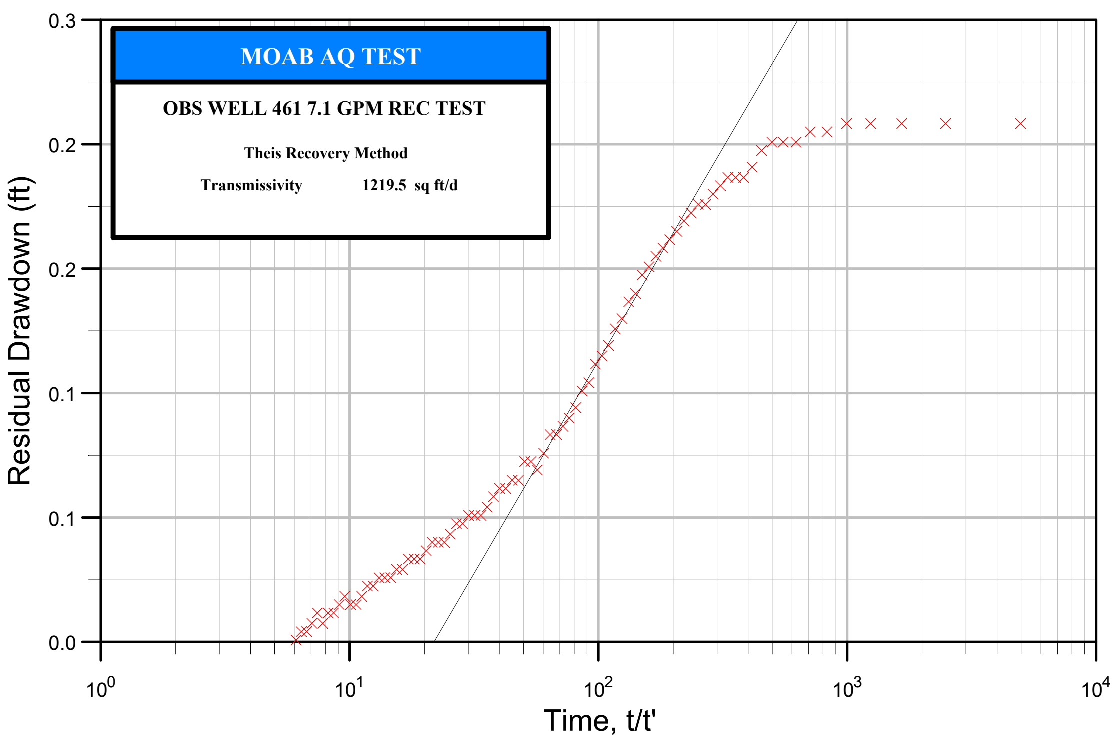
7.1 GPM TEST

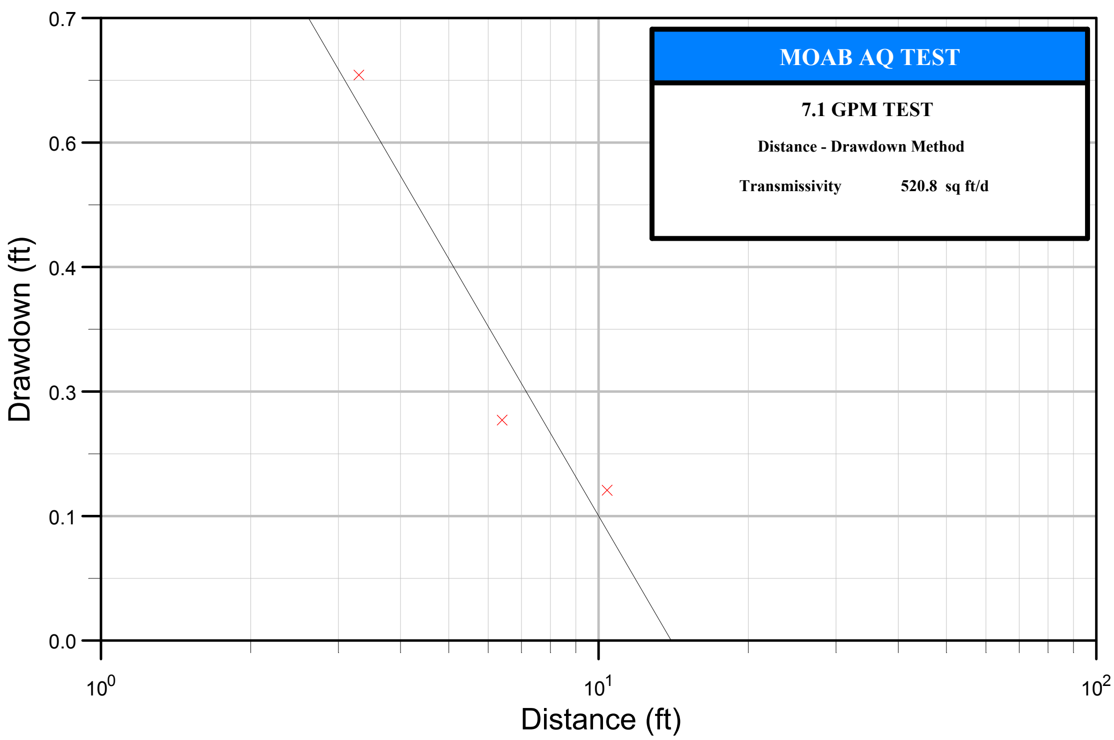
AquiferWin 32 Plots


3.3 ft
7.1 gal/min
THEIS CURVE
r/B = 0.25
W(u,r/B)
1/u
MOAB AQ TEST
OBS WELL 460, 7.1 GPM TEST
Hantush and Jacob, 1955 (Leaky Aquifer)
Transmissivity 525.7 sq ft/d
Storage Coefficient 0.017 dimensionless


6.4 ft
7.1 gal/min
THEIS CURVE
r/B = 0.37
W(u,r/B)
1/u
MOAB AQ TEST
OBS WELL 461, 7.1 GPM TEST
Hantush and Jacob, 1955 (Leaky Aquifer)
Transmissivity 1064.4 sq ft/d
Storage Coefficient 0.031 dimensionless


MOAB AQ TEST
OBS WELL 460 7.1 GPM REC TEST
Theis Recovery Method
Transmissivity 454.4 sq ft/d
Residual Drawdown (ft)
0.7
0.6
0.4
0.3
0.1
0.0
10^0
10^1
10^2
10^3
10^4
Time, t/t'


MOAB AQ TEST
OBS WELL 461 7.1 GPM REC TEST
Theis Recovery Method
Transmissivity 1219.5 sq ft/d
Residual Drawdown (ft)
0.3
0.2
0.2
0.1
0.1
0.0
10^0
10^1
10^2
10^3
10^4
Time, t/t'


MOAB AQ TEST
7.1 GPM TEST
Distance - Drawdown Method
Transmissivity 520.8 sq ft/d
Drawdown (ft)
Distance (ft)
0.7
0.6
0.4
0.3
0.1
0.0
10^0
10^1
10^2