Uranerz
ENERGY CORPORATION

Nichols Ranch ISR Project
WDEQ Permit to Mine No. 778
NRC SUA-1597
Nichols Ranch Unit PA#1
Wellfield Package
Hydrologic Test

Uranerz Energy Corporation
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Casper, WY 82605-0850
307-265-8900

March 2012

URANERZ ENERGY CORPORATION
NICHOLS RANCH URANIUM ISR PROJECT
NICHOLS RANCH UNIT

PRODUCTION AREA #1 HYDROLOGIC TEST

FOR:

March 2012

WDEQ/LQD PERMIT NO. 778
NRC License No. SUA- 1597

BY:

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EXECUTIVE SUMMARY

The Production Area #1 (PA#1) Hydrologic Test Plan was submitted in September of 2011 by Uranerz Energy Corporation to the Wyoming Department of Environmental Quality – Land Quality Division (WDEQ-LQD). On October 25, 2011 the WDEQ-LQD found the test plan in order. The multi-well pump tests were conducted in December of 2011 and February in 2012. The wells were pumped at average rate of 33 to 34 gpm (gallons per minute) for 3 days creating greater than 200 feet of drawdown. This stress on the A Sand aquifer resulted in drawdowns in the A Sand monitoring wells including the monitoring ring wells of 3.4 to 39.1 feet. Communication with each of the monitoring ring wells was defined.

The PA#1 pump test data shows adequate confinement between the A Sand and the Overlying and Underlying aquifers. No drawdown was observed in the Overlying and Underlying wells during the two multi-well pump tests.

The PA#1 pump test produced an average transmissivity of 50 to 35 ft^2/day for the northern and southern halves of PA#1 respectfully, and an average hydraulic conductivity of 0.48 and 0.35 ft/day. The average storage coefficient for the northern pump test was 1.4E-4 and 1.2E-4 for the southern pump test.

The PA#1 hydrologic test demonstrated the following:

1) All A Sand monitoring ring wells are in communication with the A Sand production zone.

2) Adequate confinement exists between the A Sand aquifer and the Underlying aquifer. Adequate confinement exists between the A Sand aquifer and the Overlying aquifer.

3) The A Sand aquifer characteristics have been adequately defined.

1.0 INTRODUCTION

The Nichols Ranch Uranium ISR Project is located in the southern Powder River Basin of east central Wyoming, along the Campbell and Johnson County lines. Uranerz Energy Corporation (URZ) is developing an in-situ recovery (ISR) uranium wellfield within the Nichols Ranch Unit permit. This Pump Test Report provides a summary of the hydrogeologic testing results for Production Area (PA #1). The report presents the information necessary to initiate operation of PA #1.

PA #1 is located in Sections 7, 8, 17 and 18 of T43N, R76W. Figure 1-1 shows the location of PA #1 and its relationship to the Nichols Ranch Unit of the Nichols Ranch ISR Project permit. Figure 1-2 presents a preliminary wellfield outline, monitoring well locations, and the pumping well locations. Mining operations in PA #1 are regulated under URZ's Source Material License #SUA-1597 and the Wyoming Department of Environmental Quality, Land Quality Division (WDEQ/LQD) Permit to Mine #778.

The objectives of the pump test described in this Plan, as stated in the WDEQ-LQD Permit to Mine and NRC License Application, are to:

1. Determine the hydrologic characteristics of the Production Zone (A Sand) Aquifer;
2. Demonstrate hydrologic communication between the Production Zone and the surrounding Production Zone monitor well ring;
3. Assess the presence of hydrologic boundaries, if any, within the Production Zone Aquifer;
4. Evaluate the degree of hydrologic communication, if any, between the Production Zone and the overlying and underlying aquifers; and,
5. Evaluate, if applicable, the vertical hydraulic conductivity of the overlying and underlying confining units.

PA #1 production is anticipated to begin in 2012. The pumping phase of the pump tests were conducted as follows:

MRN-23:	START	12/06/2011 10:40	MRN-29:	START	2/15/2012 10:40
	STOP	12/09/2011 13:05		STOP	2/18/2012 13:00

No existing ISR Wellfield production from the A Sand is known to exist. No previously existing surface or underground mining operations exist within a mile of PA #1.

The site-specific hydrogeologic conditions are presented in Section 2 while monitor well information and pump test details for the MRN-23 and MRN-29 tests are given in Sections 3. Section 4 presents the pump test design for the MRN-23 test. Section 5 presents the results from the production zone (A Sand) while Section 6 gives the confining unit results for the MRN-23 test (southern half of PA #1). Sections 7, 8 and 9 present the corresponding sections for the MRN-29 test (northern half of PA #1).

Aquifer test theory is presented in Section10. Summary and conclusion are presented in Section 11.

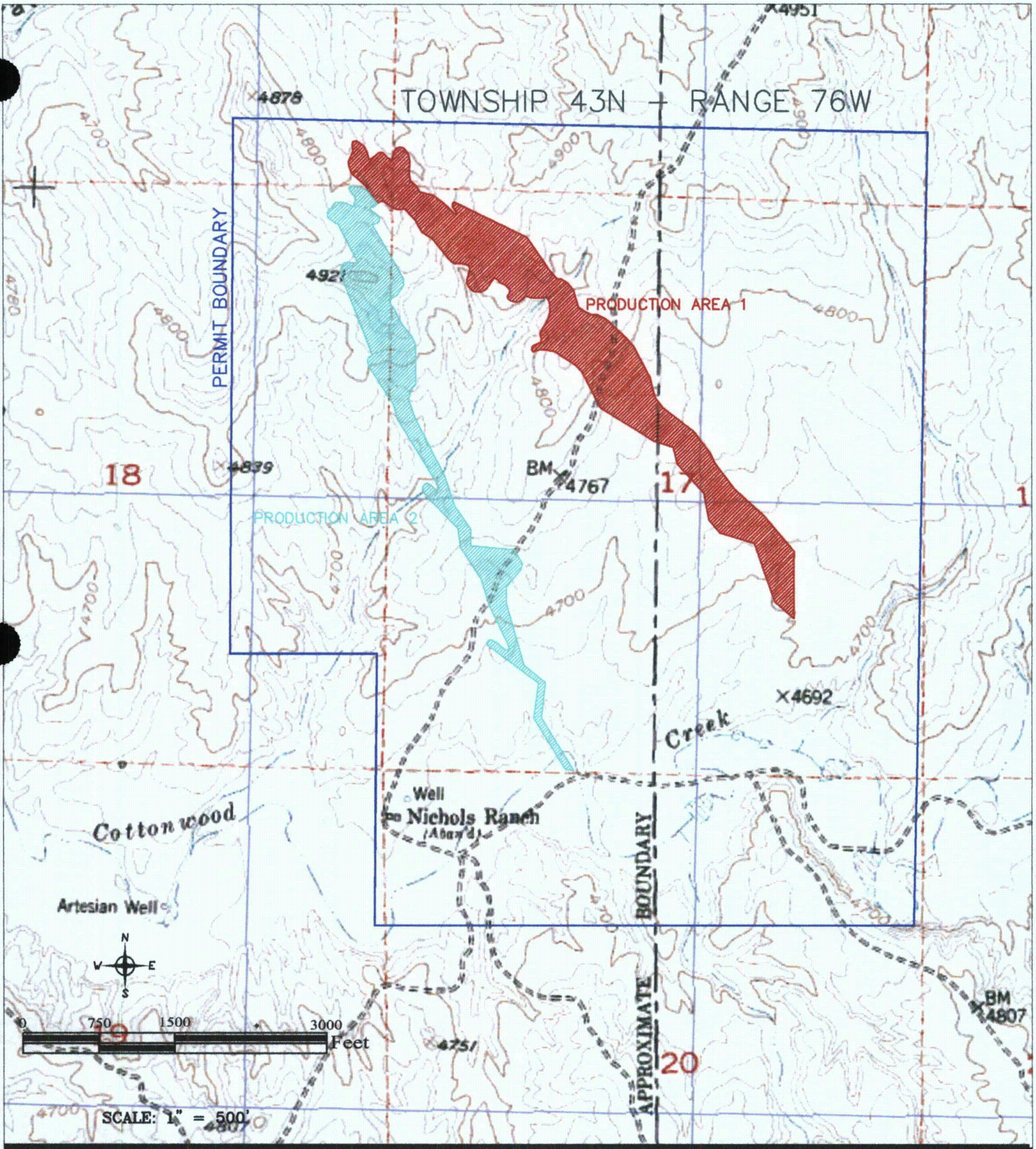

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FIGURE 1-1
NICHOLS RANCH PRODUCTION AREA #1
LOCATION MAP

TOWNSHIP 43N, RANGE 76W

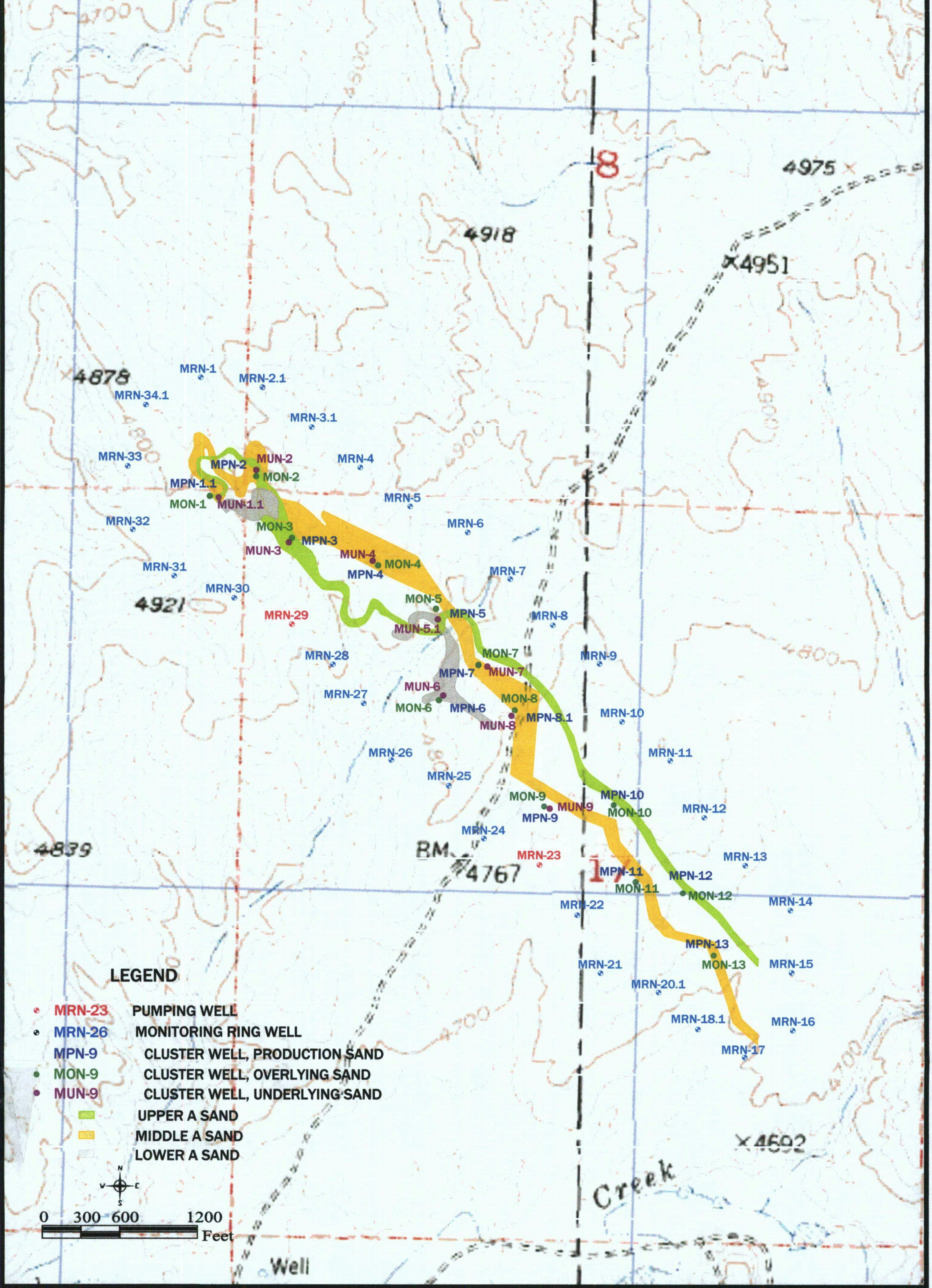

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Figure 1-2
Nichols Ranch Unit Production Area #1
Plan Map

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2.0 SITE SPECIFIC HYDROGEOLOGIC CONDITIONS

Ore-grade uranium deposits underlying Nichols Ranch are predominantly located at the base of the Eocene Age Wasatch Formation. The Wasatch Formation is composed of interbedded, uranium-enriched, fluvial sandstones and shales. Sandstones vary widely in thickness depending on the coalescing nature of the fluvial deposited sandstone. The confining layers of the sandstones consist of the mudstones deposited from the distal overbank facies that thin away from the channels of major deposition. Based on site data, these confining layers are continuous across the PA #1 area. The general stratigraphy underlying the site is summarized in Table 2-1.

TABLE 2-1
GENERALIZED STRATIGRAPHIC SECTION WITHIN PRODUCTION AREA #1 IN THE NICHOLS RANCH UNIT PERMIT AREA

Depth (feet)	Description
0-40	G Sand
40-110	F-G Mudstone
110-180	F Sand
180-220	C-F Mudstone
180-200	C Sand
200-240	B-C Mudstone
220-460	B Sand
390-500	A-B Mudstone
440-550	A Sand
580-590	1-A Mudstone
590-760	1 Sand

Figures 2-2 through 2-7 are the geologic cross-sections for PA #1 (see Figure 2-1 for cross-section location). The A Sand is shown with a green pattern on these cross sections.

The confining layers are composed of mudstones that form ubiquitous facies within the Nichols Ranch Unit Permit area. These confining layers were most likely deposited laterally away from the major braided channel systems as distal overbank facies.

2.1 OVERLYING UNITS: A-B MUDSTONE CONFINING UNIT AND B SAND

The B Sand is overlain by the B-C Mudstone and underlain by the A-B Mudstone. This sand varies from 80 to 180 feet in thickness (see Figure 2-8). It is present across the entire PA#1 area. This is the aquifer that is located above the A Sand (production) and is isolated from A Sand by the A-B Mudstone.

The A-B Mudstone is the overlying confining unit that separates the production sand (A Sand) from the overlying aquifer (B Sand). The A-B Mudstone confining unit is continuous across the mine unit (see Figure 2-9).

2.2 PRODUCTION ZONE: A SAND

Commercial uranium deposits in the vicinity of PA#1 are encountered in the A Sand, and consist of stacked, braided, fluvial sandstone units. Figure 2-10 presents the A Production Sand (ore sand) thickness map with thickness slightly greater than 80 feet to roughly 110 feet. The A Sand is irregular as indicated by variable net sand thicknesses, grain size, and shale content. This is characteristic of many production host sand units in the Powder River Basin.

Five previous multi-well hydrologic tests have been conducted on the Nichols Ranch Unit A Sand near PA#1. These tests produced hydraulic conductivities from 0.23 to 0.54 ft/day. A transmissivity of 350 gal/day/ft (47 ft^2/day) and a storage coefficient of 1.8E-4 are thought to best represent the A Sand in the Nichols Ranch Unit. The results from these tests are summarized below in Table 2-2.

TABLE 2-2
SUMMARY OF RESULTS FROM THE A SAND
MN-1, MN-6, MN-2, URZNA-7 & URZNA-9 PUMP TESTS

Test	MN-1	MN-6	MN-2	URZNA-7	URZNA-9
Transmissivity (T; ft^2/d)	40	47	24	37	39
Hyd. Cond. (k; ft/day)	0.54	0.44	0.23	0.4	0.39
Net Sand Thickness (h; ft)	73	108	102	93	100
Storativity (S)	$1.4x10^{-4}$	$2.6x10^{-4}$	$1.0x10^{-4}$	$1.1x10^{-4}$	$1.2x10^{-4}$

2.3 UNDERLYING UNITS: 1-A MUDSTONE CONFINING UNIT AND 1 SAND

The 1-A Mudstone is the underlying confining unit that separates the A Production Sand from the underlying lower 1 Sand aquifer. Figure 2-11 presents the contours of the 1-A Mudstone which vary from slightly greater than 15 to over 100 feet thick. The thinnest thickness of the 1-A Mudstone is between 15 and 20 feet thick with the majority of the thickness greater than 50 feet.

Figure 2-12 is an isopach map of the 1 Sand. It varies in thickness from zero to 60 feet thick. This sand is confined to a channel incised into the mudstone (see cross-sections, Figures 2-3, 2-4, 2-5, and 2-7). It is present under all but the southeast portion of the PA#1 area.

The original 1 Sand Isopach map (Nichols Ranch ISR Project Permit, Figure D5-17) was based upon thin sandstones that, after further drilling, appear to be very

discontinuous and relatively impermeable pods. The URZN1-11 well(in Figure 2-2) shows two thin sand lenses that were tested and found to be without any measurable recharge. This hole indicates that the thin sand lenses mapped earlier are not aquifers. Recent drilling shows that a deeper sand, partially included in the original 1 Sand Isopach map, is present under most of the Mine Unit. This sand was mapped in Nichols Ranch ISR Project Permit, Figure D5-17, in the central eastern portion of the permit area (measured thickness of greater than 20 feet) and is shown in the Cross Section A-A' (Nichols Ranch ISR Permit, Exhibit D5-1, CC-47) and Cross Section M-M' (Nichols Ranch ISR Permit, Exhibit D5-12). MUN wells 1 through 9 have been completed in this thicker 1 Sand (Figure 2-7). MUN holes 10 through 13 were drilled outside the 1 Sand channel and have no aquifers for at least 110 feet below the base of the A sand (Figures 2-3, 2-4, 2-5, and 2-7).

2.4 POTENTIOMETRIC SURFACE OF THE A SAND

Figure 2-13 is a potentiometric surface map of the A Sand Production Zone within the PA #1 area based on water level just prior to the start of the pump tests. The water level elevation was very flat prior to the start of the pump tests. A small ridge in the water surface existed in the middle of PA #1. The gradient in PA #1 is mainly the northeast at 0.001 to 0.004 ft/ft. This peizometric map for the A Sand is similar to the map presented in the Nichols Ranch ISR Project Permit to Mine and Source Material License.

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"FIGURE 2-1 CROSS SECTION LOCATION MAP"

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"FIGURE 2-2 GEOLOGIC CROSS-SECTION A-A' "

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"FIGURE 2-3 GEOLOGIC CROSS-SECTION B-B' "

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"FIGURE 2-6 GEOLOGIC CROSS-SECTION E-E' "

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"FIGURE 2-7 GEOLOGIC CROSS-SECTION F-F' "

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"FIGURE 2-8 "B" SAND ISOPACH "

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"FIGURE 2-9 "A-B" MUDSTONE ISOPACH "

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"FIGURE 2-10 "A" PRODUCTION SAND ISOPACH"

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"FIGURE 2-11 1-A MUDSTONE AQUITARD"

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"FIGURE 2-12 1 SAND ISOPACH"

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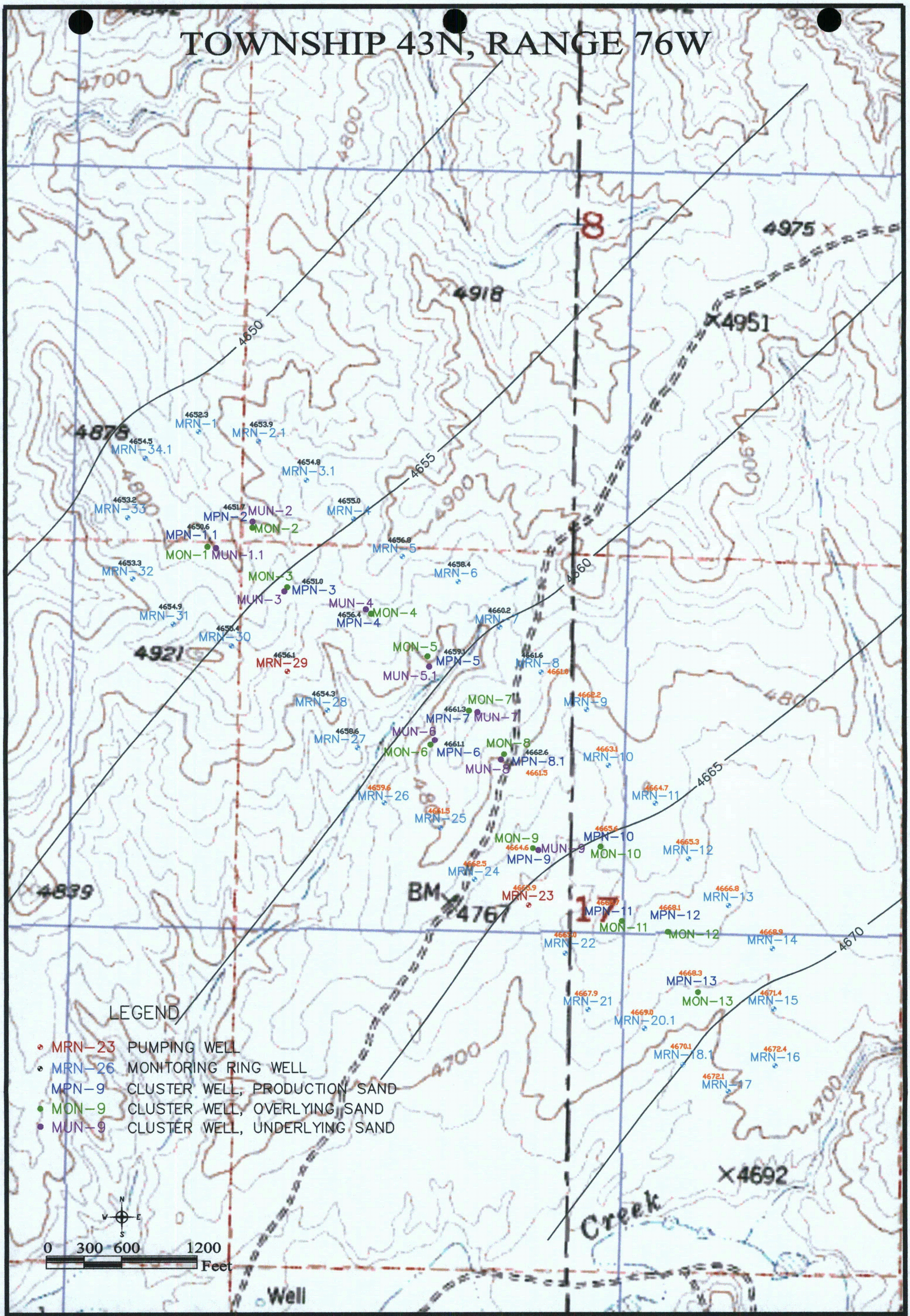

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— WATER ELEVATION CONTOUR

4656.1 WATER ELEVATION PRIOR TO MRN-29 PUMPTEST

4665.9 WATER ELEVATION PRIOR TO MRN-23 PUMPTEST

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FIGURE 2-13
INITIAL PIEZOMETRIC SURFACE MAP:
A-SAND; FT-MSL

3.0 MONITORING WELL SPACING and COMPLETION

3.1 WELL SPACING

To conduct the pump tests in PA #1, URZ installed two pumping wells in the A Sand (Figure 1-2). The wells are located in Section 17, Township 43 North, Range 76 West within the existing permit boundary. The hydraulic properties of the subsurface formations encountered during the installation of the pumping wells were consistent with the Nichols Ranch Unit permit area, and the stratigraphic section presented in Table 2-1.

The PA #1 monitoring wells are located in accordance with the URZ's WDEQ/LQD Permit and the NRC License. The perimeter ore zone monitor wells (referred to as MRN wells) are located in a uniform pattern around the wellfield. The distance between the monitor wells typically is 500 feet. The distance between the monitor wells and the production patterns typically is 500 feet. The monitor well spacing for PA #1 is based on the Nichols Ranch permit standard of 500 feet from the outer limits of the wellfield pattern area and 500 feet between the wells. Two wells were monitored in both of the pump tests to demonstrate continuity between the two PA #1 multi-well tests.

Monitor wells were installed with the overlying and underlying aquifers at a density of one type of each well per every three acres of pattern area. However, spacing between overlying (MONs) and underlying (MUNs) monitor wells in the same zone shall not exceed 1,000 feet. Only nine of the MUN wells were installed because the 1 Sand does not exist in some of PA#1. It is greater than 50 feet to a sand below the A Sand in the 10, 11, 12 and 13 well clusters where the 1 Sand pinches out, and therefore these clusters do not have a 1 Sand well. Thirteen of the production zone monitor wells (MPNs) adjacent to the overlying and underlying monitor wells were also monitored during the PA #1 Pump Tests.

3.2 WELL INSTALLATION AND COMPLETION

To conduct the pump tests in PA #1, URZ used two MRN wells (MRN-23 and MRN-29) that are fully penetrating in the A Production Sand. The pumping wells are 5-inch PVC casing with a portion of the sand intervals underreamed to 10.5 inches.

The monitoring wells were drilled and completed consistent with URZ's WDEQ/LQD permits. Drilling and completion information is in included in Appendix B.

The monitoring wells were constructed with a 5-inch PVC casing. The MRN wells fully penetrate the A Sand and the MPN wells were screened across the portion of the A Sand that will be mined in a particular area of PA #1 (Table 3-1). The wells were developed using standard water well construction techniques, such as pumping, surging and/or air lifting. Completion reports for each well are provided in Appendix B.

3.3 ABANDONMENT OF EXISTING WELLS

No historic wells that require abandonment were identified in PA #1. Should such wells be identified in the future, abandonment would be performed in accordance with WS-35-11-404 and Chapter VIII of the LQD Rules and Regulations.

TABLE 3.1 PRODUCTION AREA #1 WELL INFORMATION

WELL	COORDINATES UTM13, NAD 27 METERS		SECTION	TOWNSHIP & RANGE	SURFACE ELEVATION (ft)	CASING STICKUP (ft)	STATIC DEPTH TO WATER (ft)	STATIC WATER ELEVATION (ft)	DRILLED DEPTH (ft:bgs)	CASING DEPTH (ft:bgs)	COMPLETION INTERVAL		COMPLETION LENGTH (ft)
	NORTHING	EASTING									TOP (ft:bgs)	BOTTOM (ft:bgs)	
MPN-01.1	4839798	417078	7	43, 76	4800.49	1.33	151.54	4650.55	610	585	559	570	11
MPN-02	4839835	417165	8	43, 76	4804.33	1.42	154.32	4651.71	620	605	561	570	9
MPN-03	4839668	417261	17	43, 76	4852.78	1.08	201.74	4651.03	645	740	628	636	8
MPN-04	4839620	417456	17	43, 76	4843.53	1.83	189.36	4656.37	670	666	629	640	11
MPN-05	4839521	417603	17	43, 76	4804.51	1.92	147.74	4659.07	640	605	581	590	9
MPN-06	4839307	417631	17	43, 76	4830.76	1.25	170.92	4661.34	660	658	629	635	6
								SECOND COMPLETION INTERVAL			645	649	4
MPN-07	4839373	417710	17	43, 76	4850.62	1.00	190.73	4661.09	665	665	605	612	7
MPN-08.1	4839280	417798	17	43, 76	4806.80	1.25	146.84	4661.46	615	615	574	582	8
MPN-09	4839056	417858	17	43, 76	4755.33	2.17	93.31	4664.62	565	640	535	542	7
MPN-10	4839063	418022	17	43, 76	4764.38	1.92	101.04	4665.64	540	519	497.5	500.5	3
								SECOND COMPLETION INTERVAL			506.5	511	4.5
MPN-11	4838886	418052	17	43, 76	4768.29	2.08	104.09	4666.70	600	600	560	568	8
MPN-12	4838872	418182	17	43, 76	4742.02	2.25	76.64	4668.08	520	520	482	487	5
								SECOND COMPLETION INTERVAL			493	501	8
MPN-13	4838703.8	418240	17	43, 76	4714.79	1.33	48.10	4668.29	510	510	489	498	9
MON-01	4839793	417067	7	43, 76	4807.93	1.63	159.90	4649.99	465	350	342	465	123
MON-02	4839835	417177	7	43, 76	4809.47	1.92	157.14	4654.63	469	360	355	469	114
MON-03	4839685	417259	17	43, 76	4847.36	1.17	192.44	4654.92	501	501	396	496	100
MON-04	4839624	417645	7	43, 76	4848.35	2.17	190.38	4660.58	493	402	396	493	97
MON-05	4839521	417603	17	43, 76	4803.48	1.67	144.18	4661.30	450	350	344	450	106
MON-06	4839305	417608	17	43, 76	4821.82	1.83	162.15	4661.87	460	385	374	460	86
MON-07	4839390	417701	17	43, 76	4852.56	1.92	191.56	4663.30	486	396	386	486	100
MON-08	4839285	417793	17	43, 76	4808.07	2.17	145.13	4665.54	435	345	321	435	114
MON-09	4839041	417860	17	43, 76	4752.64	1.17	88.69	4682.10	392	293	286	392	106
MON-10	4839056	418020	17	43, 76	4764.38	1.92	98.82	4667.86	454	305	300	454	154
MON-11	4838877	418074	17	43, 76	4764.74	2.00	98.72	4617.67	462	304	296	462	166
MON-12	4838849	418186	17	43, 76	4737.51	1.75	70.51	4669.10	440	285	266	440	174
MON-13	4838702	418257	17	43, 76	4712.81	1.75	44.86	4750.84	395	235	226	395	169
MUN-01.1	4839784	417093	7	43, 76	4801.46	1.75	155.40	4647.40	707	665	657	707	50
MUN-02	4839850	417180	8	43, 76	4805.41	1.58	158.02	4647.39	730	682	681	730	49
MUN-03	4839678	417258	17	43, 76	4848.63	0.83	201.28	4647.35	761	740	733	761	28
MUN-04	4839635	417453	17	43, 76	4843.52	0.58	196.03	4647.49	770	730	722	770	48
MUN-05.1	4839524	417613	17	43, 76	4806.10	1.83	159.96	4646.14	730	695	695	730	35
MUN-06	4839317	417619	17	43, 76	4820.74	0.92	172.81	4647.93	736	700	691	736	45
MUN-07	4839385	417725	17	43, 76	4849.72	1.00	202.16	4647.56	765	715	707	765	58
MUN-08	4839271	417783	17	43, 76	4802.39	2.08	153.91	4650.98	699	699	657	699	42
MUN-09	4839051	417871	17	43, 76	4749.44	2.17	100.38	4689.15	630	576	576	628	52
MRN-01	4840068	417050	7	43, 76	4776.35	1.50	125.86	4652.29	607	510	503	607	104
MRN-02.1	4840044	417196	8	43, 76	4817.22	1.92	165.57	4653.95	626	530	522	626	104
MRN-03.1	4839950	417312	8	43, 76	4845.82	2.00	193.46	4654.76	667	565	558	667	109
MRN-04	4839854	417424	17	43, 76	4851.29	1.92	198.57	4655.02	578	575	567	678	111
MRN-05	4839763	417544	17	43, 76	4862.68	2.00	208.32	4656.76	680	567	576	680	104
MRN-06	4839706	417681	17	43, 76	4833.16	2.33	177.57	4658.39	648	555	543	648	105
MRN-07	4839593	417780	17	43, 76	4824.22	2.08	166.55	4660.17	636	545	536	636	100
MRN-08	4839482	417878	17	43, 76	4814.61	1.17	155.00	4661.01	620	527	523	620	97
MRN-09	4839392	417986	17	43, 76	4794.30	1.17	133.49	4662.21	600	505	496	600	104
MRN-10	4839252	418041	17	43, 76	4773.57	1.83	112.63	4663.14	580	500	481	580	99
MRN-11	4839163	418155	17	43, 76	4787.43	1.75	124.88	4664.65	600	515	497	600	103
MRN-12	4839028	418235	17	43, 76	4766.93	1.08	102.90	4665.33	580	492	474	580	106
MRN-13	4838916	418334	17	43, 76	4739.28	1.00	73.69	4666.79	565	465	457	565	108
MRN-14	4838808	418440	17	43, 76	4723.76	1.00	56.11	4668.85	542	455	450	542	92
MRN-15	4839027	417783	17	43, 76	4714.66	2.25	45.95	4671.41	540	430	422	542	120
MRN-16	4838524	418444	17	43, 76	4705.34	2.00	35.30	4672.44	517	421	413	517	104
MRN-17	4838459	418329	17	43, 76	4695.96	2.08	26.41	4672.05	502	412	405	502	97
MRN-18.1	4838526	418220	17	43, 76	4692.20	2.17	24.73	4670.07	502	407	401	502	101
MRN-20.1	4838614	418128	17	43, 76	4712.19	2.17	45.80	4668.99	543	438	401	502	101
MRN-21	4838663	417991	17	43, 76	4745.63	2.17	80.32	4667.91	560	463	452	560	108
MRN-22	4838796	417935	17	43, 76	4739.33	1.17	75.69	4665.04	557	463	458	557	99
MRN-23	4838913	417845	17	43, 76	4719.47	2.67	56.80	4665.87	527	439	415	527	112
MRN-24	4838978	417717	17	43, 76	4762.68	1.08	101.50	4662.48	557	475	458	557	99
MRN-25	4839097	417633	17	43, 76	4810.64	1.42	150.81	4661.53	622	515	518	622	104
MRN-26	4839164	417497	17	43, 76	4780.42	1.17	122.19	4659.63	605	539	531	605	74
MRN-27	4839296	417432	17	43, 76	4766.58	1.67	110.00	4658.59	600	506	499	600	101
MRN-28	4839390	417356	17	43, 76	4802.47	0.00	148.18	4654.29	640	550	542	640	98
MRN-29	4839487	417263	17	43, 76	4820.48	1.08	165.70	4656.08	667	565	557	667	110
MRN-30	4839549	417127	18	43, 76	4882.86	2.17	230.06	4655.39	725	620	612	725	113
MRN-31	4839601	416986	18	43, 76	4838.73	2.00	186.20	4654.94	660	560	554	660	106
MRN-32	4839710	416887	7	43, 76	4810.14	1.63	158.79	4653.30	633	536	527	633	106
MRN-33	4839860	416874	7	43, 76	4834.42	1.83	183.41	4653.21	656	555	549	656	107
MRN-34.1	4840002	416904	7	43, 76	4789.95	2.17	138.05	4654.50	595	505	493	595	102

Note: All Wells have a DIA of 5"
All wells used screen in the completion section except MON-03 and MUN-05,1, which is open-hole.

4.0 PUMP TEST DESIGN AND WATER-LEVEL DATA FOR MRN-23 TEST

4.1 TEST DESIGN

The MRN-23 pump test was conducted with the following objectives for the southern half of PA #1:

- Demonstrate hydraulic communication between the Production Zone and the surrounding monitor well ring (MRN wells);
- Determine the hydrologic characteristics of the Production Zone aquifer;
- Evaluate the presence or absence of hydrologic boundaries within the Production Zone; and,
- Demonstrate sufficient hydrologic isolation between the Production Zone and the Overlying and Underlying sands for the purposes of ISL mining.

The pump test was designed to cause a minimum of 1 to 2 feet of water level drawdown in the A Sand at a radius of 2,500 feet from the pumping well.

Figure 4-1 presents the wellfield outline and the locations of the pumping and observation (monitoring) wells used during the MRN-23 hydrologic test. The pumping well (MRN-23) was screened across 100 feet of the A Production Sand (Table 3-1). The pump was installed to a depth of 400 feet without a check valve.

The general testing procedures were as follows:

- ♦ Install automated monitoring equipment in the wells selected to be used in the test. Verify setting depths and head reading with manual water level measurements.
- ♦ Measure and record background water levels at least every 12 hours for a minimum of 48 hours prior to the start of the test.
- ♦ Pump Well MRN-23 at a constant rate (or as close as possible). Record water levels and barometric pressure throughout the background, pumping and recovery periods.

4.2 EQUIPMENT LAYOUT

Prior to the background monitoring period for the test, URZ installed a 35 gpm electric submersible pump in the pumping well. A totalizer meter was used to measure instantaneous flowrate and record total gallons pumped.

The monitoring equipment layout for the test is shown on Figure 4-1. All the monitor wells for the test were equipped with automated water level recorders, 31 Heron Instruments data logger/transducers. A transducer was not installed in the pumping well during the pre and pumping phases due to a bent drawdown tube. A transducer was installed in the pumping well discharge tube for some of the recovery period. Water levels were also measured periodically by hand to verify that the automated equipment was functioning properly. The pumping equipment performed as designed. For consistency, occasional erroneous data (e.g., inaccurate readings that resulted when the equipment tried to log data while data was being downloaded) were edited out of the database.

Prior to the test, HYDRO personnel selected the transducer layout. HYDRO personnel installed the monitoring equipment prior to testing and provided day-to-day downloads.

The monitor wells used for the test, distance from each monitor well to the pumping well and the drawdown observed are presented in Table 4-1. The equipment layout and head ratings for each transducer, is shown on Table 4-2. Figure 4-1 shows the location of the data loggers/transducers. Appendix C presents the tabulation of water levels for all of the MRN-23 pump test wells.

4.3 BACKGROUND MONITORING, TEST PROCEDURES AND DATA COLLECTION

A potentiometric map for the A Sand, based on water level prior to the start of the MRN-23 and MRN-29 tests, is shown in Figure 2-11. The static water levels prior to the two tests were used because all of the northern A Sand wells were not installed prior to the MRN-23 test. Pre-MRN-23 water level data along with the pumping and recovery period data for the A Sand monitoring wells are shown on Figures 4-2 through 4-11. These plots present the depth to water versus time on a linear scale and show that each of the A Sand wells responded to the pumping of well MRN-23 with the minimum drawdown of 4.6 feet in well MRN-17. Water levels in the A Sand were gradually rising prior to the start of the MRN-23 pump test. This water level rise is due to a small recovery in the aquifer from the past use of MRN-23. A prior trend correction was not made because the correction would have been small compared to the amount of drawdown observed. The barometric pressure changed 0.3 inches of mercury during the pumping phase of the test. Barometric correction to the water levels were not made because they would have been very small compared to the amount of drawdown observed in the A Sand monitoring wells. A tabulation of the water level data is presented in Appendix C.

The pump test was performed by pumping MRN-23 at an average rate of 34.3 gpm from 10:40 on December 6, 2011 until 13:05 on December 9, 2011. The total pumping duration was 74.4 hours (4,465 minutes). The drawdown achieved in the pumping well was 309 feet; drawdown in the A Sand monitoring wells ranged from 4.6 to 39.1 feet (Table 4-1). Water levels were automatically measured and recorded at an interval of 15 minutes during the pumping and recovery periods in the monitoring wells, 5 minute increments were using in the pumping well during the recovery. Pumping rate data for

MRN-23 are shown on Table 4-3. Water level recovery was monitored for 3 days. A list of A Sand monitoring wells, the distance of those wells from the pumping well, and the drawdown measured during the pumping period for all the wells are summarized in Table 4-1.

Table 4-1.
MONITORING WELL DISTANCE AND MAXIMUM DRAWDOWN DURING THE MRN-23 TEST

1st Start Date & Time	12/6/2011 10:40				
1st End Date & Time	12/9/2011 13:05				
Duration	4465 min.				
Avg. Pumping Rate	34.3 G.P.M.				
Pumping Well	MRN-23	Distance from Pumping Well (ft)	Depth to Water Before Test (ft)	Water Elevation Before Test (ft)	Maximum Drawdown During Test (ft)
Monitoring Wells					
	MRN-23	0	56.80	4665.87	308.7
Ore Zone Completions	MPN-8.1	1169	146.84	4661.46	9.2
	MPN-9	449	93.31	4664.62	36.4
	MPN-10	756	101.04	4665.64	26.8
	MPN-11	686	104.09	4666.70	30 e
	MPN-12	1113	76.64	4668.08	17.7
	MPN-13	1476	48.10	4668.29	10.4
	MRN-8	1859	155.00	4661.01	5.0
	MRN-9	1631	133.49	4662.21	6.0
	MRN-10	1278	112.63	4663.14	8.9
	MRN-11	1291	124.88	4664.65	10.5
	MRN-12	1326	102.90	4665.33	11.7
	MRN-13	1593	73.69	4666.79	9.4
	MRN-14	1978	56.11	4668.85	6.8
	MRN-15	2123	45.95	4671.41	6.5
	MRN-16	2352	35.30	4672.44	4.9
	MRN-17	2181	26.41	4672.05	4.6
	MRN-18.1	1770	24.73	4670.07	7.0
	MRN-20.1	1359	45.80	4668.99	10.1
	MRN-21	970	80.32	4667.91	13.8
	MRN-22	494	75.69	4665.04	34.2
	MRN-24	472	101.50	4662.48	39.1
	MRN-25	928	150.81	4661.53	17.0
	MRN-26	1400	122.19	4659.63	8.3
Overlying Completions	MON-8	1216	145.13	4665.54	*
	MON-9	408	88.69	4682.10	*
	MON-10	739	98.82	4667.86	*
	MON-11	756	98.72	4617.67	*
	MON-12	1134	70.51	4669.10	*
	MON-13	1524	44.86	4750.84	*
Underlying Completions	MUN-8	1166	153.91	4650.98	*
	MUN-9	433	100.38	4689.15	*

Note: * = No Drawdown Observed
e = estimated maximum drawdown because water level was below trans

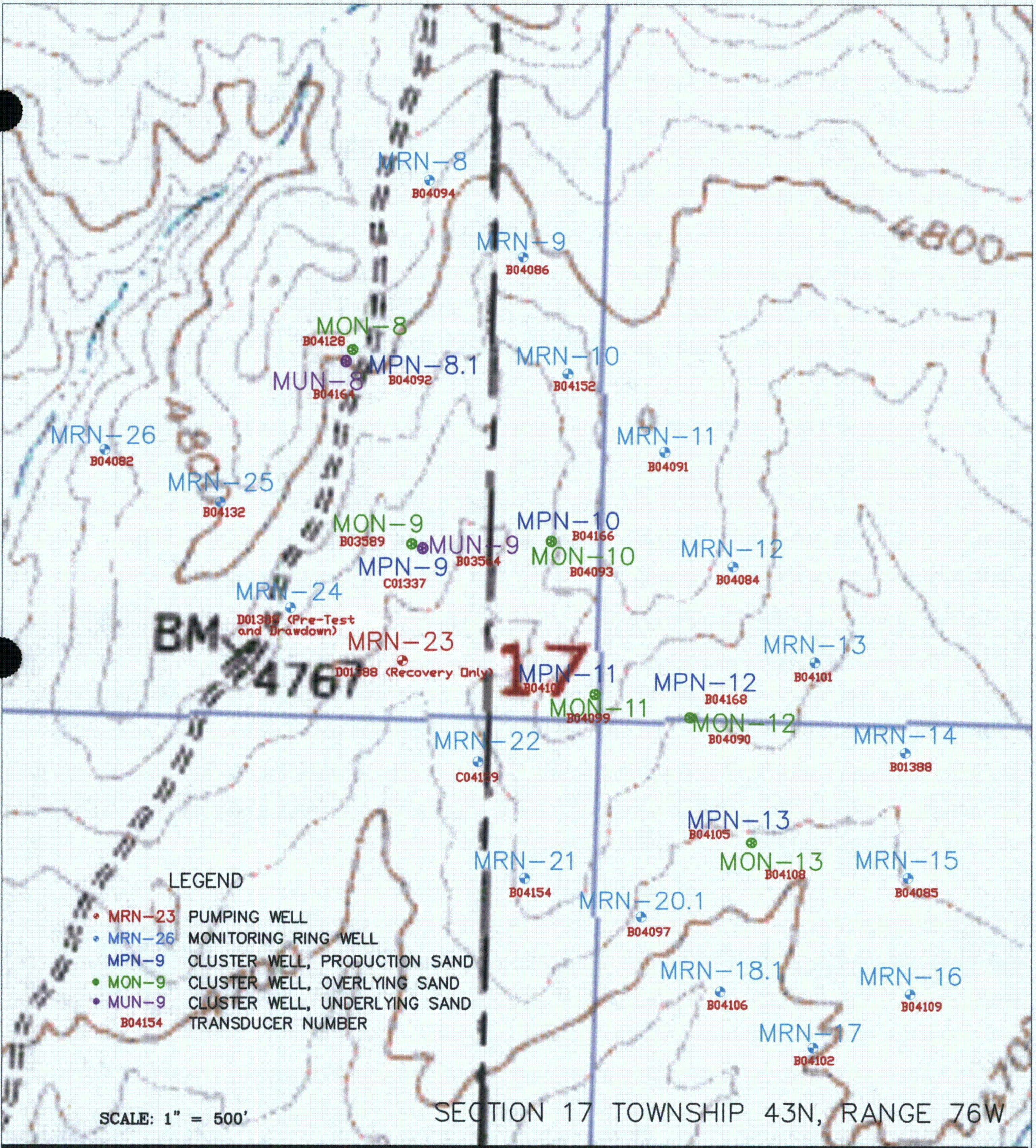
TABLE 4-2.
DATA LOGGER AND TRANSDUCER EQUIPMENT FOR MONITORING WELLS FOR THE MRN-23 TEST

	Well Name	Transducer Number
Monitoring Wells		
	MRN-23	D01388 (Recovery Only)
Ore Zone Completions		
	MPN-8.1	B04092
	MPN-9	C01337
	MPN-10	B04166
	MPN-11	B04104
	MPN-12	B04168
	MPN-13	B04105
	MRN-8	B04094
	MRN-9	B04086
	MRN-10	B04152
	MRN-11	B04091
	MRN-12	B04084
	MRN-13	B04101
	MRN-14	B01338
	MRN-15	B04085
	MRN-16	B04109
	MRN-17	B04102
	MRN-18.1	B04106
	MRN-20.1	B04097
	MRN-21	B04154
	MRN-22	C04159
	MRN-24	D01388 (Pre-Test and Drawdown)
	MRN-25	B04132
	MRN-26	B04082
Overlying Completions		
	MON-8	B04128
	MON-9	B03589
	MON-10	B04093
	MON-11	B04099
	MON-12	B04090
	MON-13	B04108
Underlying Completions		
	MUN-8	B04164
	MUN-9	B03564

Note: Transducers have a max depth of measuring
B series = max of 35ft
C series = max of 100ft
D series = max of 200ft

Table 4-3.
PUMPING RATE AND FIELD SAMPLING VERSUS TIME FOR PUMPING WELL MRN-23

DATE/TIME	TOTALIZER (GAL)	METER (GPM)	FIELD SAMPLING		
			pH	CONDUCTIVITY (µS)	Temp (C°)
12/6/11 10:40 AM	PUMP ON				
12/6/11 10:40 AM	57896				
12/6/11 10:48 AM		35			
12/6/11 10:54 AM		33			
12/6/11 11:06 AM		37			
12/6/11 11:10 AM		35			
12/6/11 11:15 AM		34.8			
12/6/11 11:36 AM		34.6			
12/6/11 11:41 AM		34.8			
12/6/11 12:00 PM		34.6			
12/6/11 12:24 PM		34.6			
12/6/11 12:47 PM	62200				
12/6/11 1:19 PM		34.8			
12/6/11 4:10 PM		34.6			
12/6/11 4:12 PM	69310				
12/6/11 4:24 PM			6.55	568	9.8
12/7/11 7:53 AM	102110	34.8			
12/7/11 1:00 PM		34.2			
12/7/11 2:23 PM	115500		8.43	557	12.3
12/8/11 8:29 AM	152770	34.2			
12/8/11 12:40 PM		34.5			
12/8/11 2:27 PM		34.5			
12/8/11 2:50 PM			8.38	554	13.4
12/9/11 8:42 AM	202100	34.1			
12/9/11 10:45 AM		34.1			
12/9/11 1:02 PM		34.1			
12/9/11 1:05 PM	210820		8.57	567	12.8
12/9/11 1:05 PM	PUMP OFF				



REVISIONS No.	DATE	MADE BY	DESCRIPTION
1			
2			
3			
4			

DATE	DRAWN BY	CHECKED	APPROVED
3-2012	RTS		

HYDRO-ENGINEERING L.L.C.

HYDRO-ENGINEERING L.L.C.
4685 EAST MAGNOLIA
CASPER, WYOMING, 82604

FILE: C:\PROJECTS\2012-14\nrwellfield

Uranerz ENERGY CORPORATION
1701 East "E" Street
P.O. Box 50850
Casper, Wyoming
USA 82605-0850

Figure 4-1

MONITORING WELL LOCATIONS AND TRANSDUCER LAYOUT FOR THE MRN-23 TEST

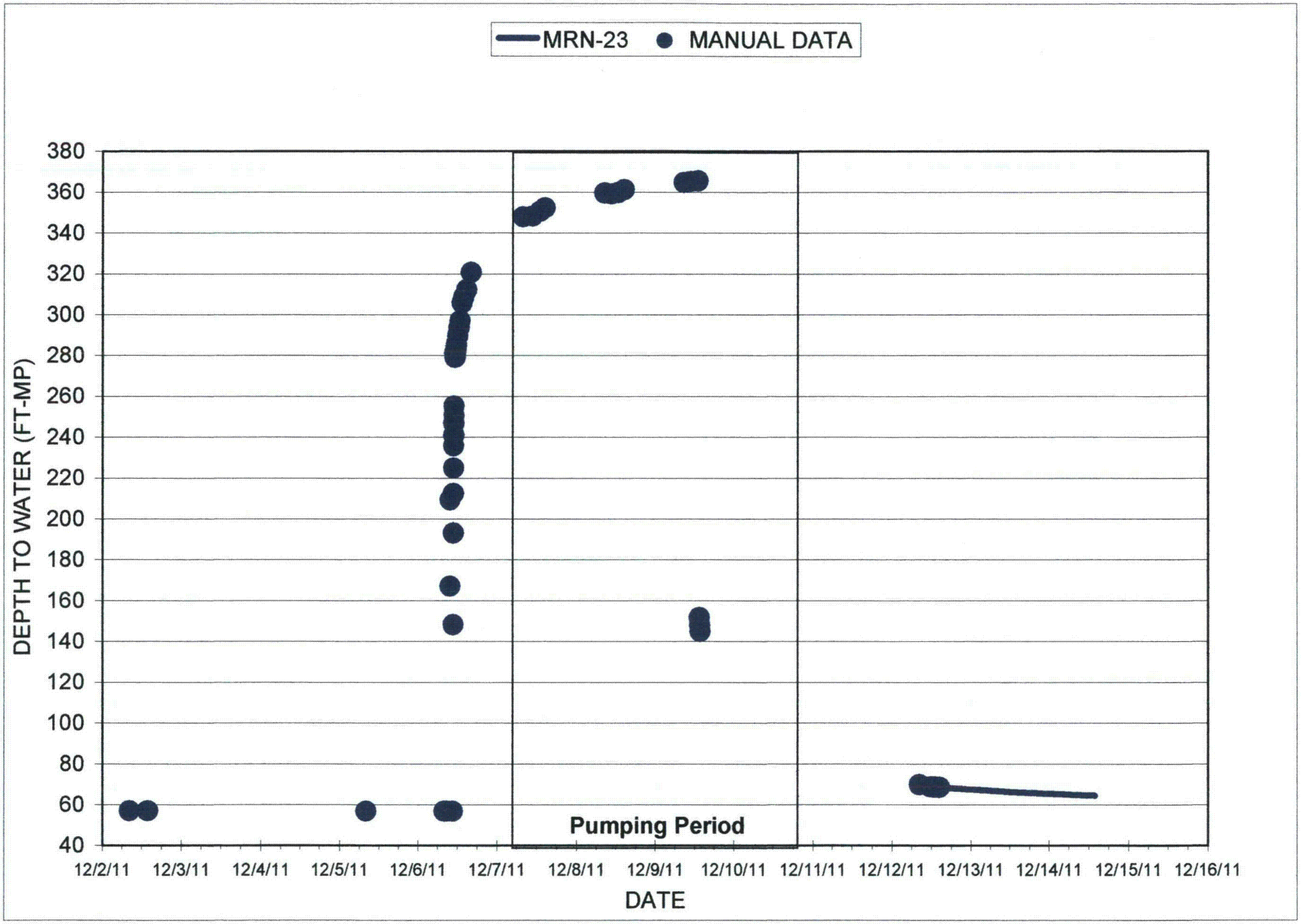


FIGURE 4-2. DEPTH TO WATER VERSUS TIME FOR PUMPING WELL MRN-23

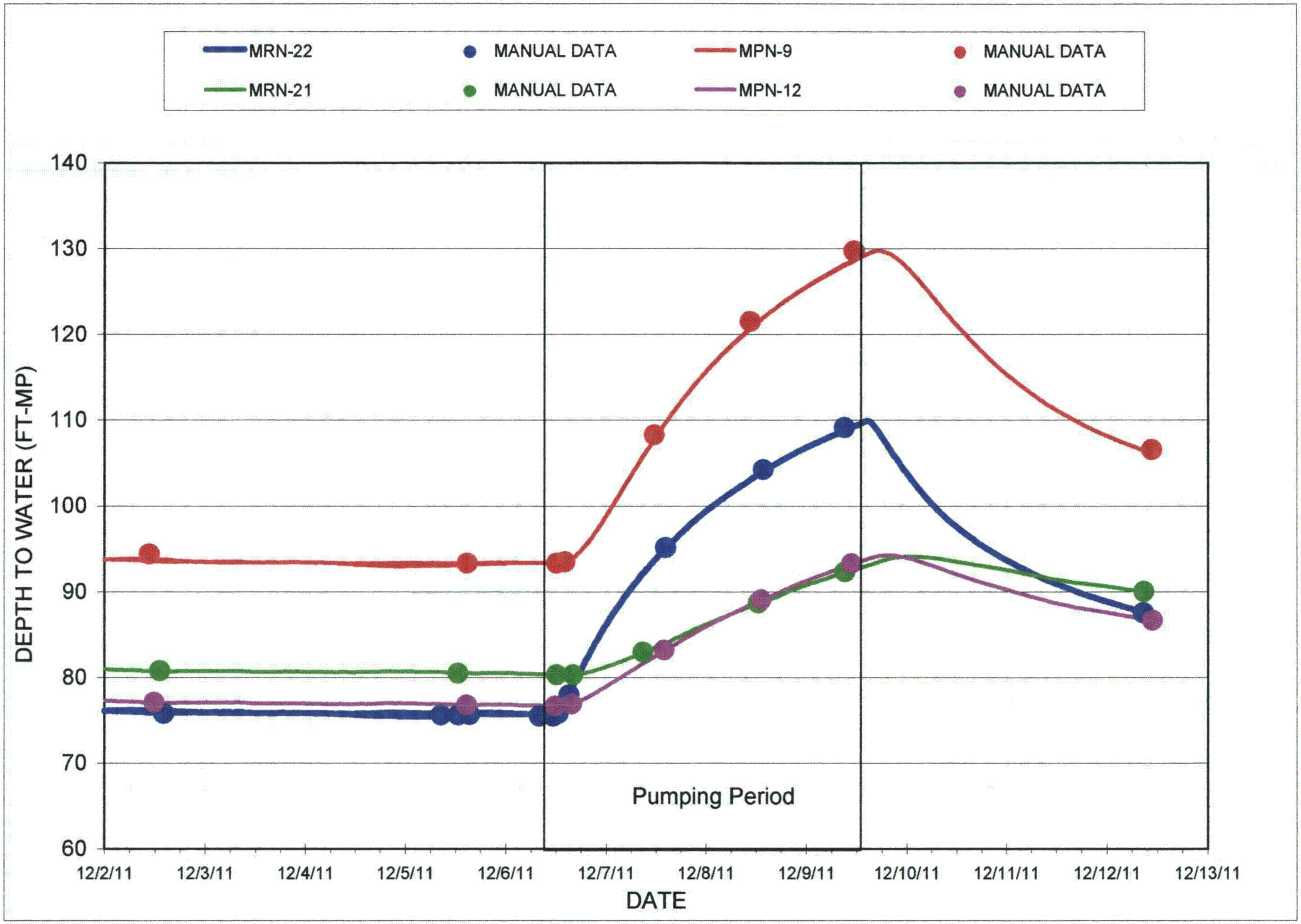


FIGURE 4-3. DEPTH TO WATER VERSUS TIME FOR OBSERVATION WELLS MRN-22, MPN-9, MRN-21 AND MPN-12

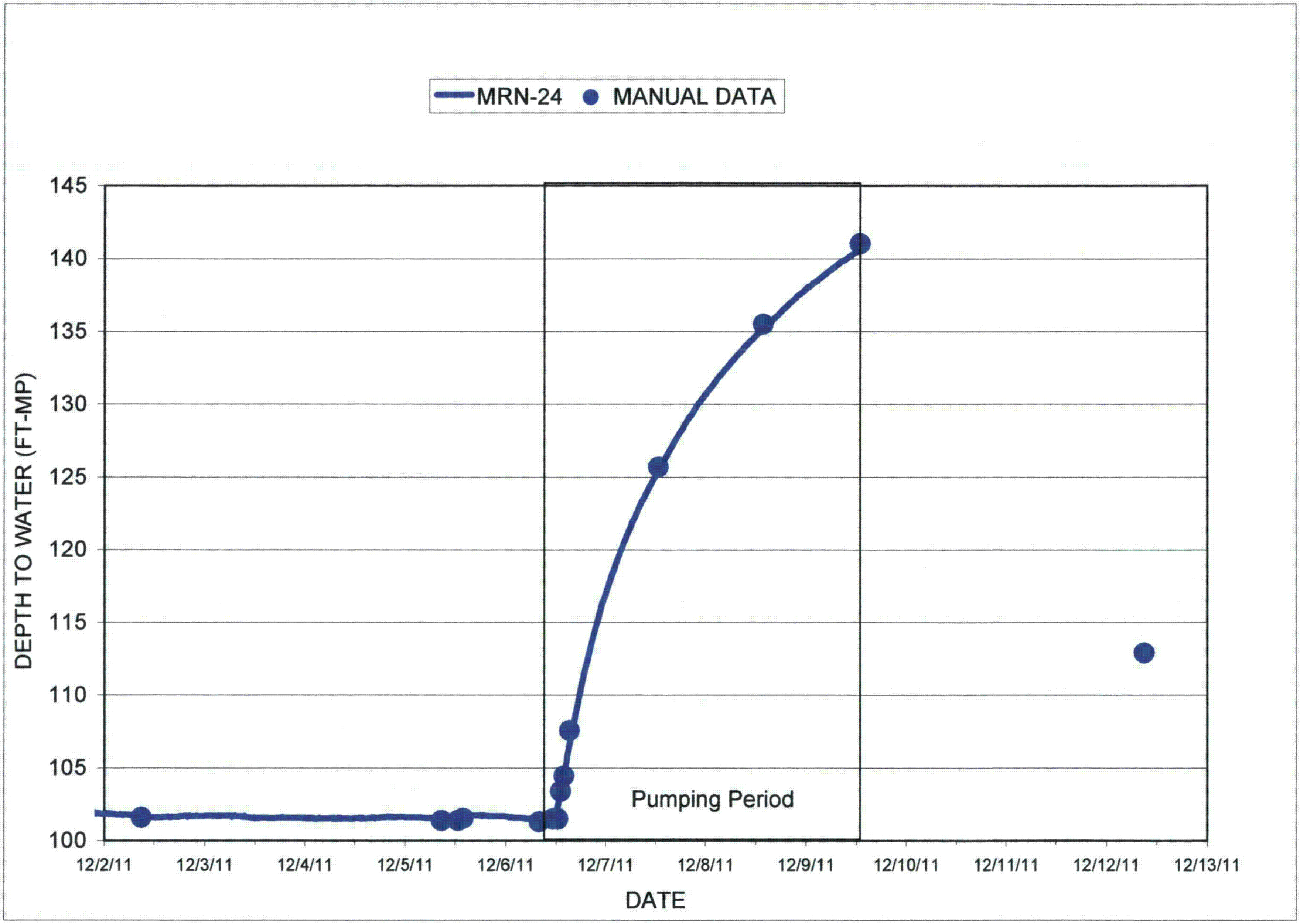


FIGURE 4-4. DEPTH TO WATER VERSUS TIME FOR OBSERVATION WELL MRN-24

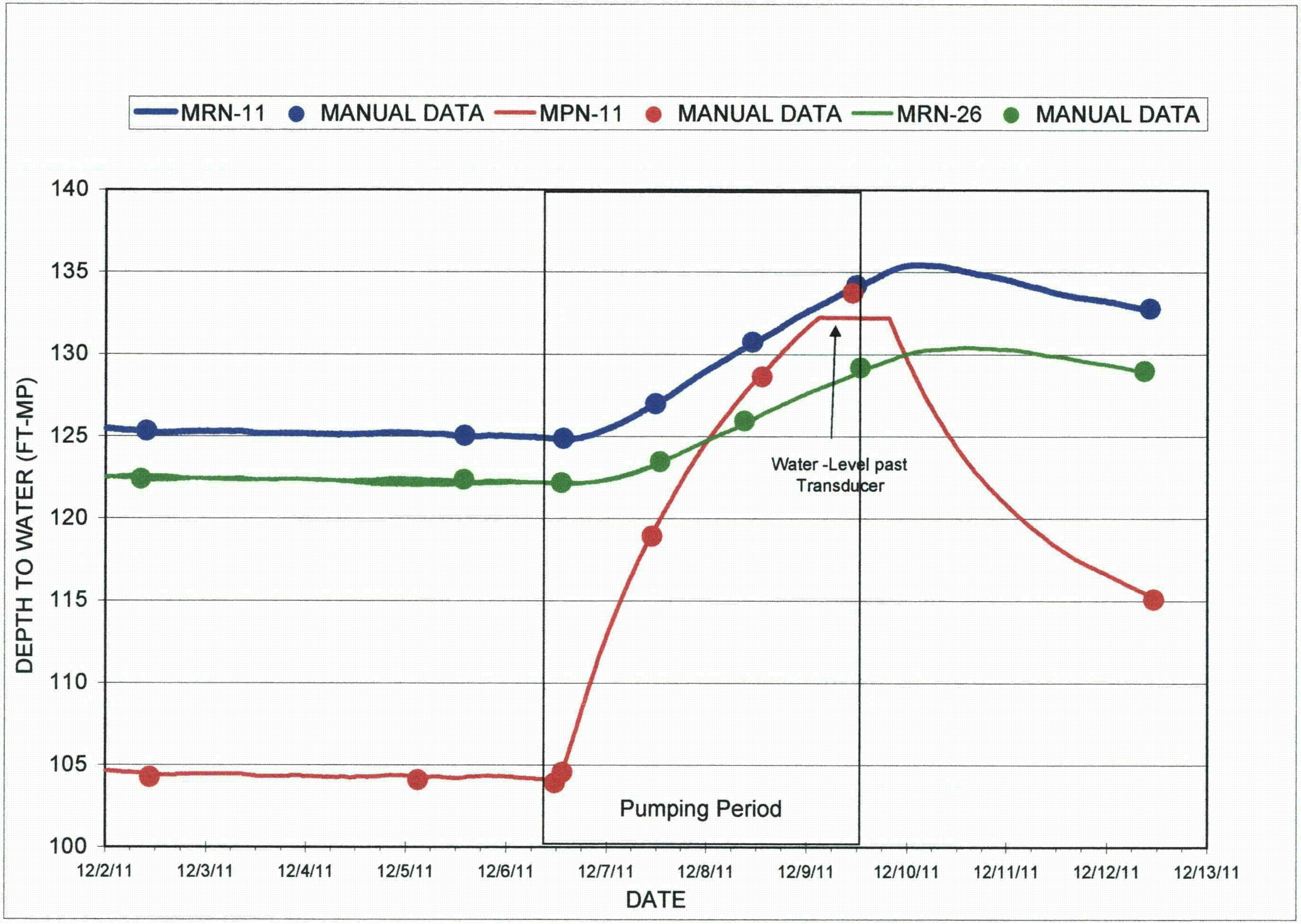


FIGURE 4-5. DEPTH TO WATER VERSUS TIME FOR OBSERVATION WELLS MRN-11, MPN-11 AND MRN-26

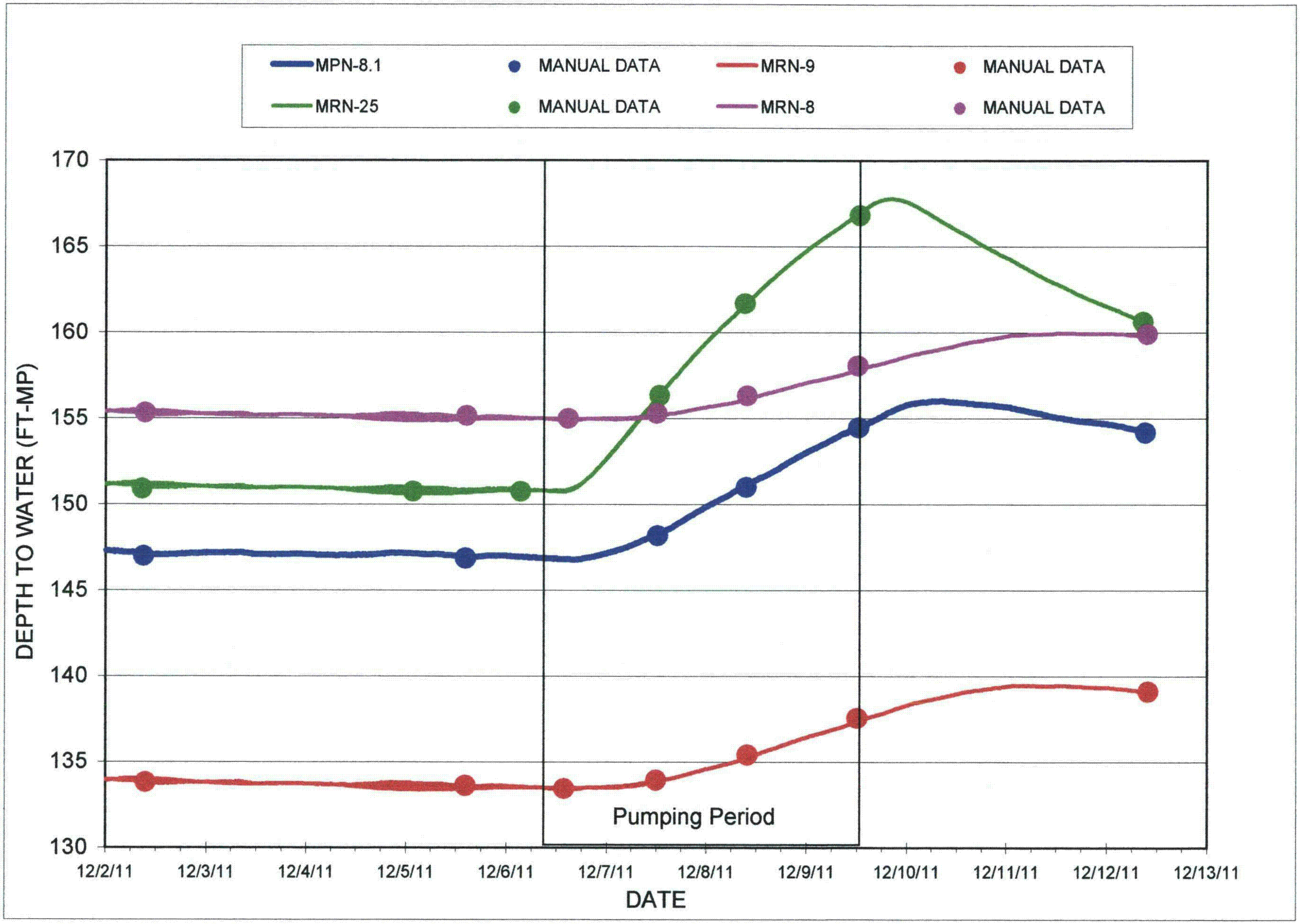


FIGURE 4-6. DEPTH TO WATER VERSUS TIME FOR OBSERVATION WELLS MPN-8.1, MRN-9, MRN-25 AND MRN-8

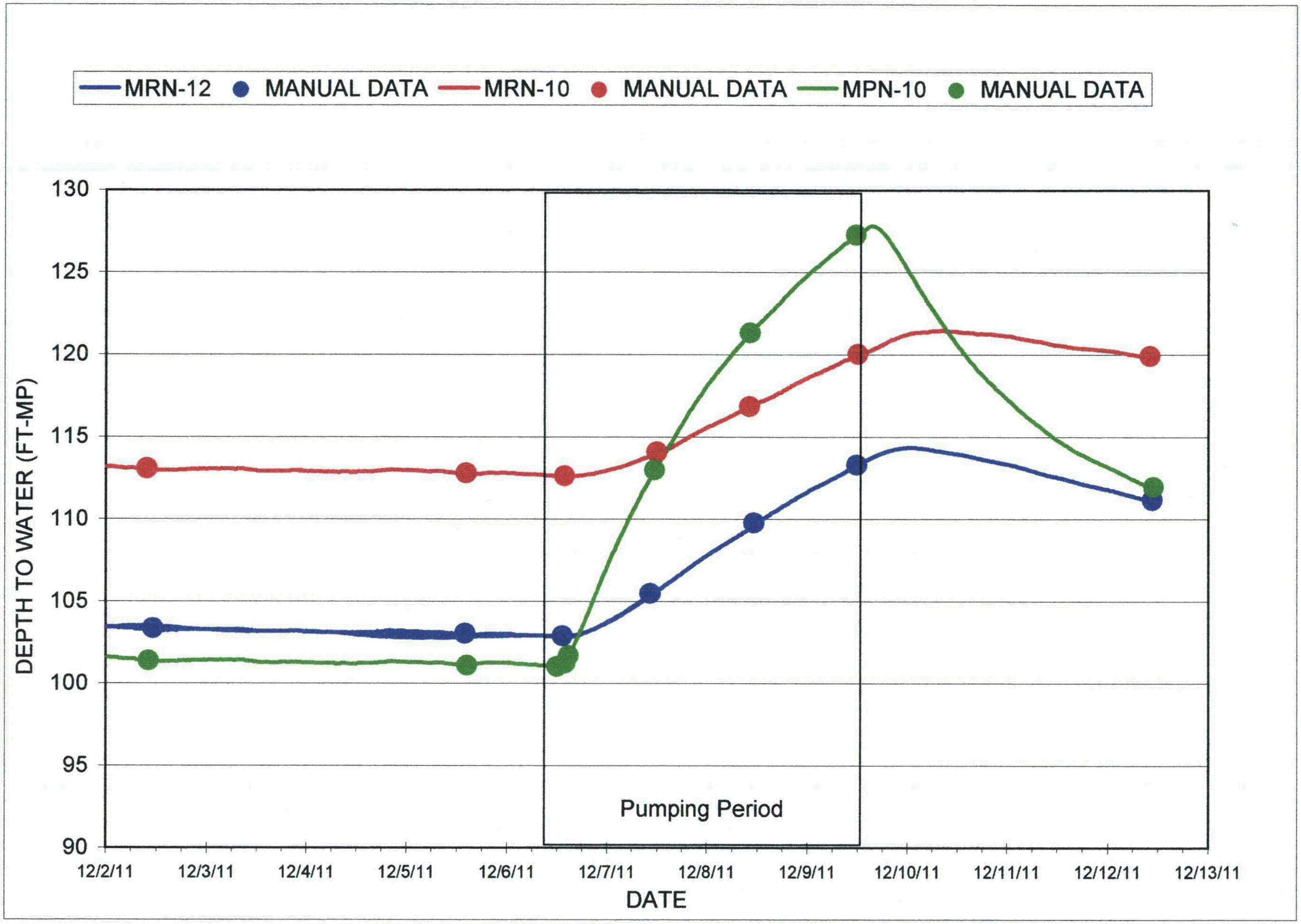


FIGURE 4-7. DEPTH TO WATER VERSUS TIME FOR OBSERVATION WELLS MRN-12, MRN-10 AND MPN-10

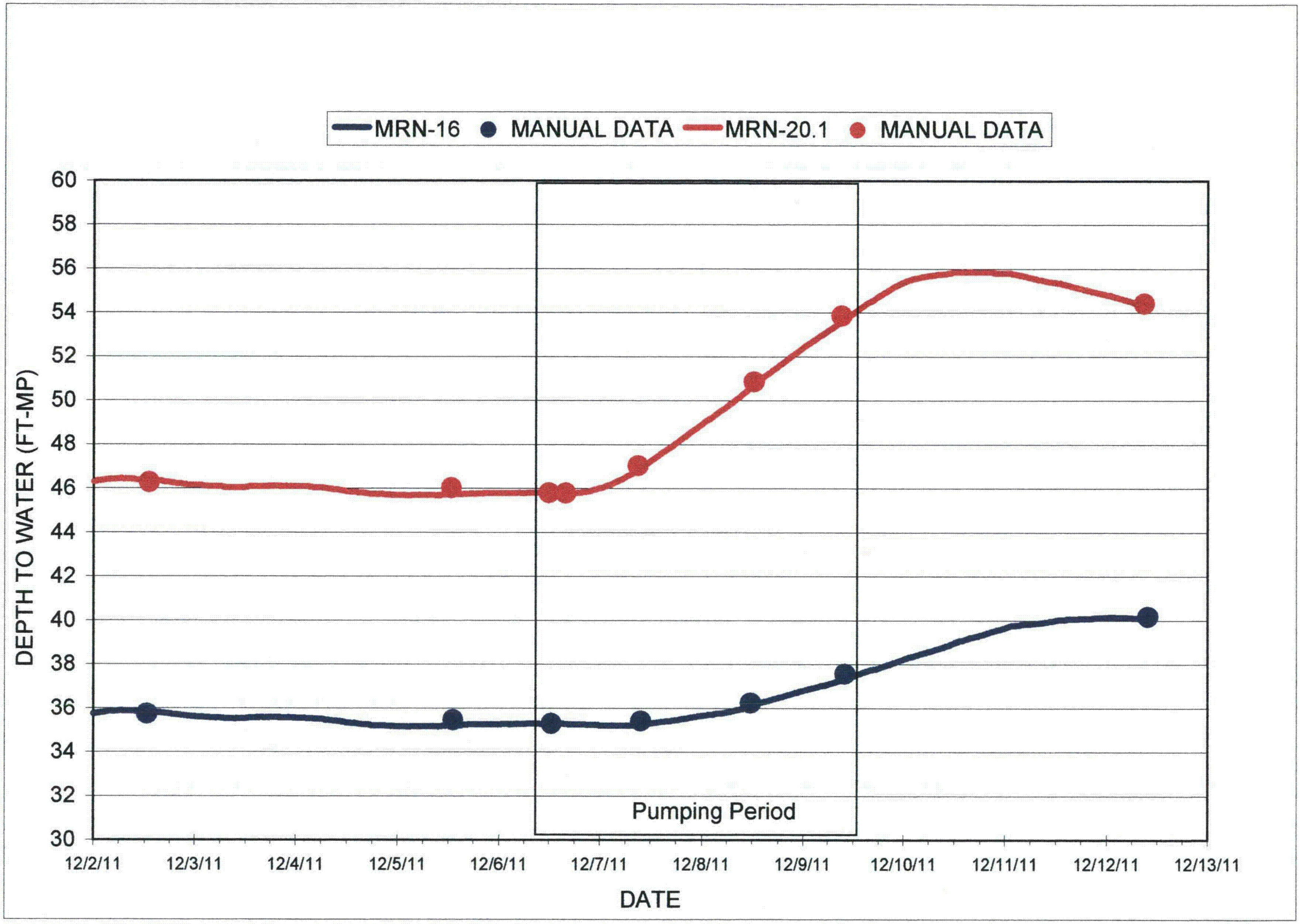


FIGURE 4-8. DEPTH TO WATER VERSUS TIME FOR OBSERVATION WELLS MRN-16 AND MPN-20.1

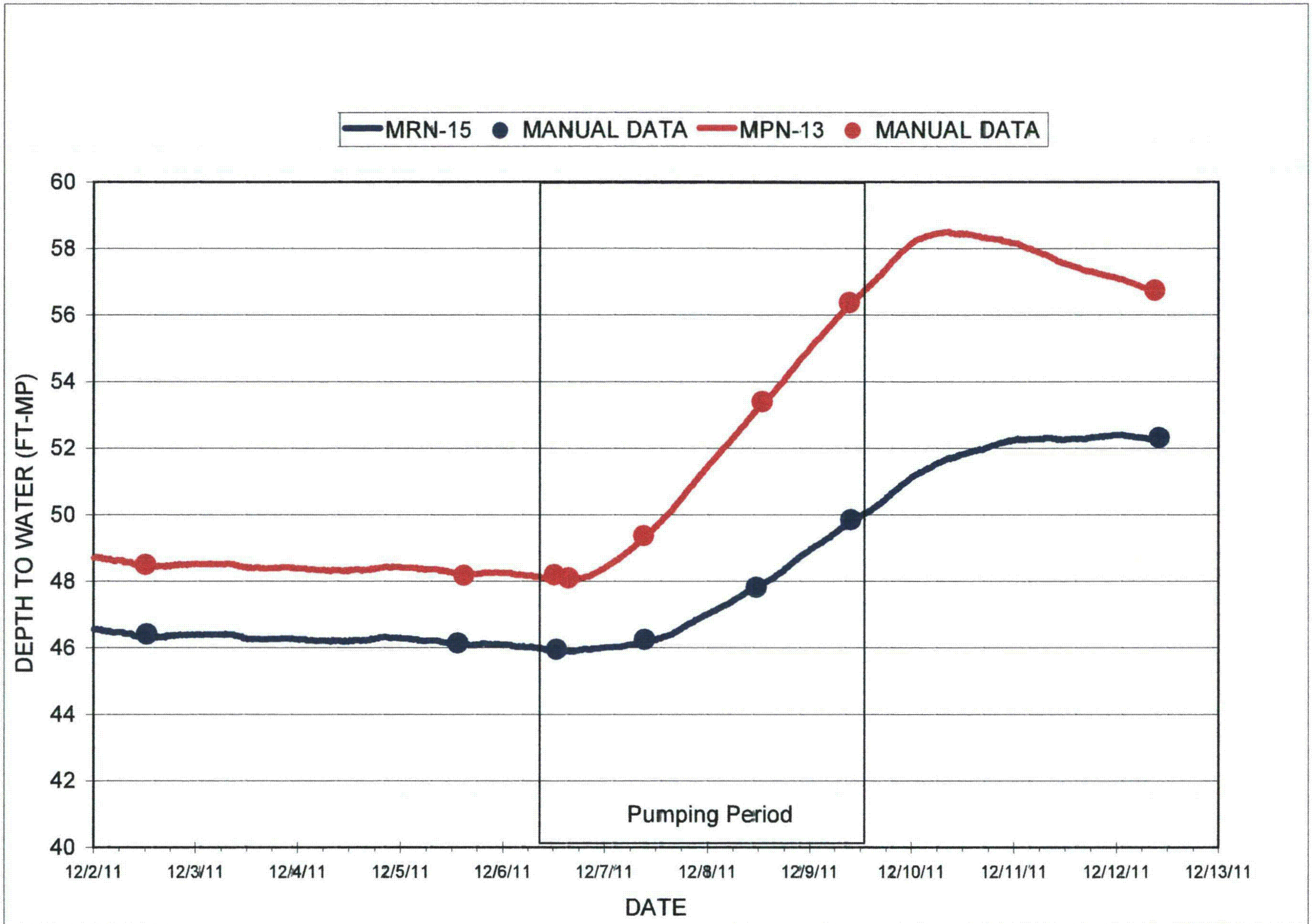


FIGURE 4-9. DEPTH TO WATER VERSUS TIME FOR OBSERVATION WELLS MRN-15 AND MPN-13

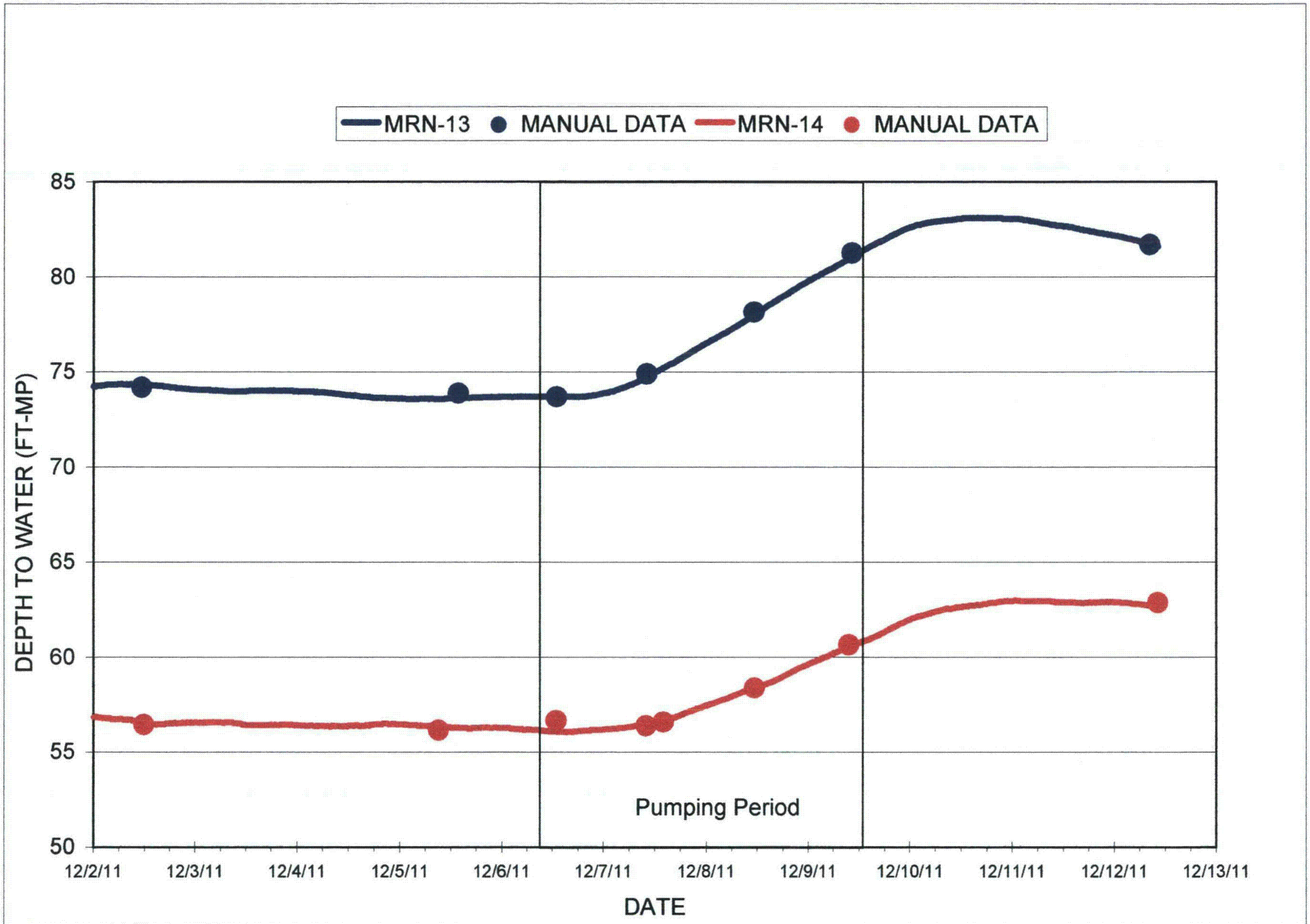


FIGURE 4-10. DEPTH TO WATER VERSUS TIME FOR OBSERVATION WELLS MRN-13 AND MRN-14

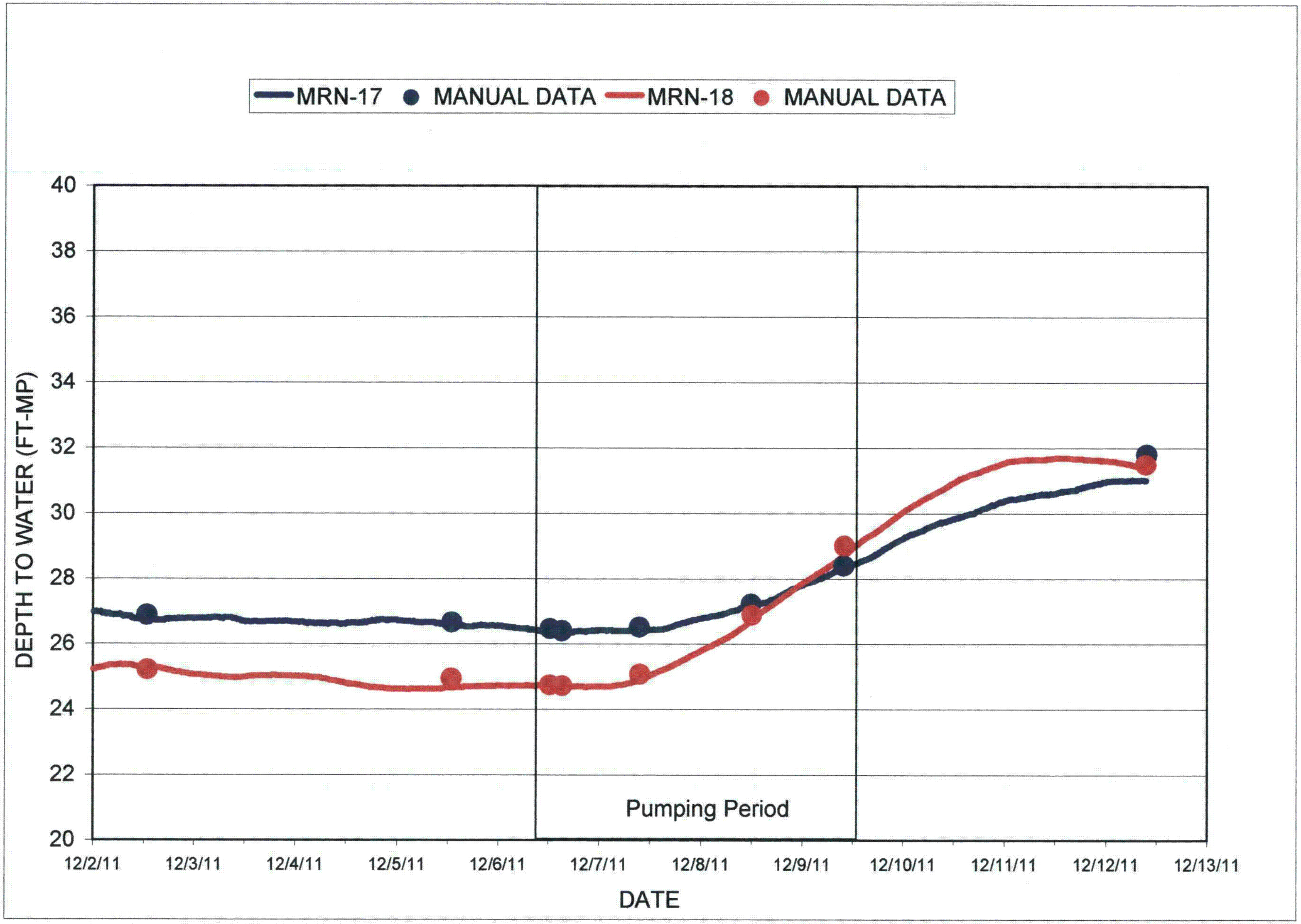


FIGURE 4-11. DEPTH TO WATER VERSUS TIME FOR OBSERVATION WELLS MRN-17 AND MRN-18.1

5.0 ANAYTICAL METHODS AND TEST RESULTS – PRODUCTION ZONE FOR MRN-23 TEST

5.1 ANALYTICAL METHODS

Drawdown data collected from the monitor wells were graphically analyzed to determine transmissivity and storativity. The primary analysis method used was the Theis (1935) log-log method. The Cooper & Jacob (Jacob) (1946) straight-line method was used in only five monitoring wells for this pump test due to the limitation of not meeting the 'u' criterion. Cooper & Jacob recommended the 'u' value to be <0.01 for usage of the straight line fit. Kruseman and de Rider (1991) suggest that a 'u' value of less than 0.1 is appropriate which can be seen from a plot of the Theis well function versus u on semi-log plot. With the use of the less than 0.1 criterion, the straight line method is appropriate for only five of the A Sand wells.

The test data were analyzed primarily using the Theis method (see Section 10 for a discussion of the aquifer test theories). Ferris and others (1962) present the Theis and Jacob equations in the gallon per foot per day units used in these calculations in this section. The significant assumptions inherent in these two methods include:

- The aquifer is confined and has apparent infinite extent
- The aquifer is homogenous and isotropic, and of uniform 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 penetrated
- Well diameter is small, so well storage is negligible

These assumptions are reasonably satisfied. Obviously, the A Sand is not homogenous and isotropic; however, over the scale of the pump tests, it can be treated in this manner. Observation wells respond to the average conditions in the area and are reflective of large area for a long pumping period.

Leaky aquifer solutions such as Hantush (1960) were not applicable to the data from the A Sand. Likewise, because none of the monitor wells were completed within the confining units, a Neuman-Witherspoon (1972) analysis was not performed.

5.2 BACKGROUND TRENDS

Water level stability data were collected prior to the start of the test. Plots of the background data for the pumping, MRN and MPN wells are shown in Figures 4-2 through 4-11. 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 MRN-23 pump test wells even though a gradual rising trend did exist in the A Sand wells prior to the start of the pump test. Correction for this trend would have been only a few tenths of a

foot over the three days of pumping and therefore not significant compared to the observed drawdowns. The barometric change during the pumping phase of the test was approximately 0.3 inches of Hg (see Section 6 plots for barometric pressure data) which did not require any adjustments in the A Sand water levels for barometric changes.

5.3 TEST RESULTS

5.3.1 DRAWDOWN

The drawdown achieved during the test is shown on Figure 5-1. A drawdown of 309 feet was developed in pumping wells MRN-23 while maximum drawdowns in the A Sand monitoring wells from this pumping were 4.6 to 39.1 feet. The five foot drawdown contour extended to roughly 2000 feet from the pumping well. Drawdown contours were fairly circular.

Theis type curves and Jacob matches are presented in Figures 5-2 through 5-37 for the A Sand wells. Semi-log plots are presented for each of the A Sand wells while fits are presented for only the five wells where the Jacob straight line fit is appropriate. Theis type curve fits are presented for each of the A Sand observation wells and drawdown data shows good fits to the Theis type curve. The type curve fits do not indicate leaky or boundary conditions in this area of the A Sand.

The tabulation of the water level data for the test is included in Appendix C.

The A Sand monitoring wells all showed adequate drawdown to prove communication between the Production Zone and the monitoring wells. Therefore adequate communication exists between the monitoring wells and the Production zone.

5.3.2 ANALYTICAL RESULTS

Transmissivity (T) results range from 18 to 46 ft^2/d (136 to 342 gpd/ft) from the Theis type curve matches. An average T value of 35 ft^2/d (261 gpd/ft) was obtained from the MRN-23 test. The Jacob results from wells were not used in calculating the average because the length of the test was not adequate to meet the requirement for the Jacob method except for the nearest five wells. The Theis results from 23 A Sand observation wells were used in the calculation of the average. Based on the average thickness of the A Sand at pumping well MRN-23 of 100 feet, the average hydraulic conductivity (K) is 0.35 ft/d (1.2E-4 cm/s). Assuming a water temperature of 50 degrees F, this equates to a permeability of approximately 167 millidarcies (md). Storativity (S) values ranged from 7.5E-5 to 2.0E-4. The average S value for the test was 1.2E-4.

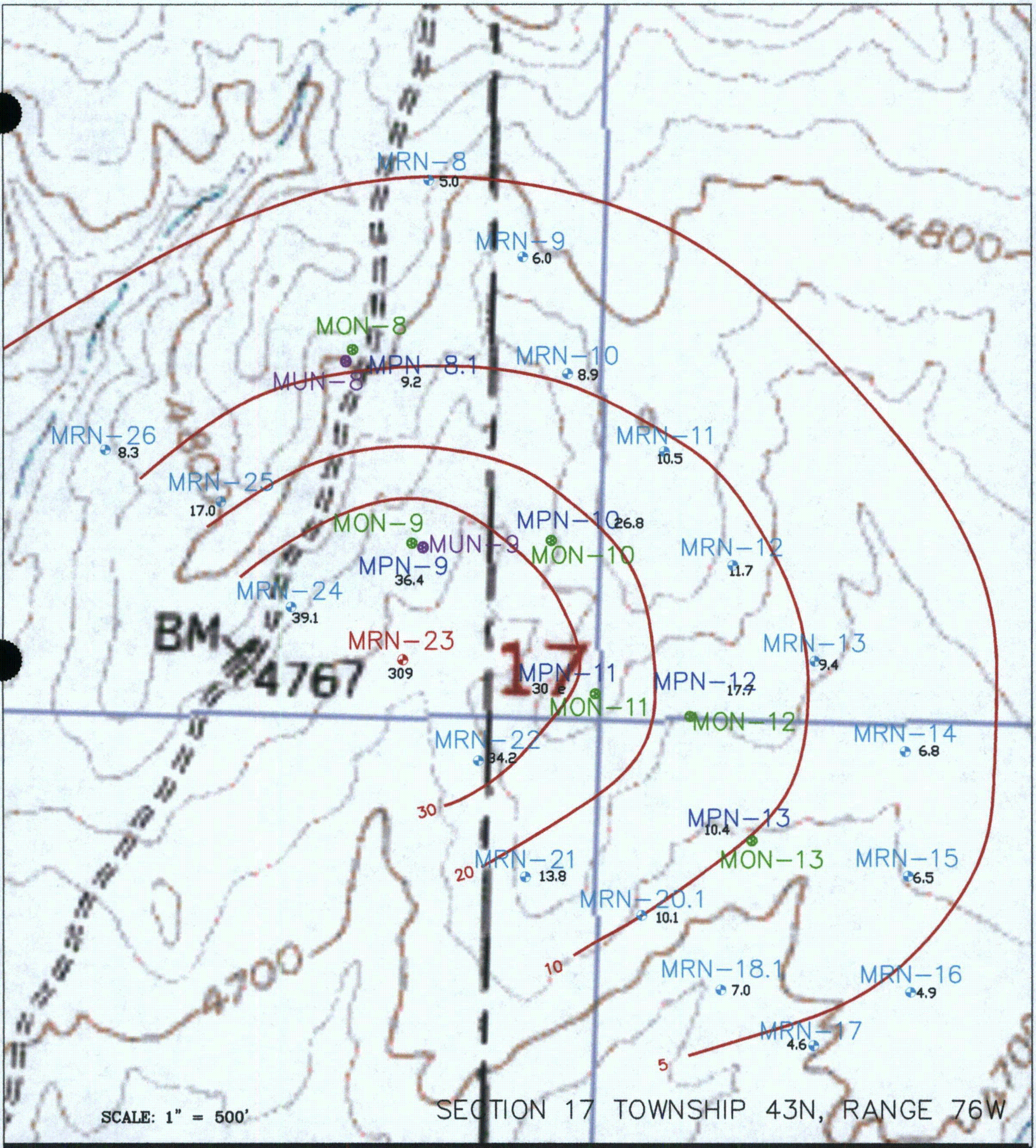
Recovery analysis of the pumping well data (MRN-23) results in a T value of 29 ft^2/d (214 gpd/ft).

5.4 DIRECTIONAL TRANSMISSIVITY

Drawdowns at the end of the MRN-23 pump test are presented in Figure 5-1 and show a fairly uniform circular pattern. The variation in drawdowns do not indicate a consistent directional transmissivity. These variations in drawdowns would greatly affect the result of the directional transmissivities calculated from the Papadopulos (1965) method. The directional transmissivities in the fluvial sands in the Powder River Basin vary greatly due to the combination of wells used in calculating the directional transmissivities. These fluvial channels were not formed in a consistent direction over any area such as PA #1; therefore no calculations of the directional transmissivities were made from MRN-23 pump test.

Table 5-1.
SUMMARY OF AQUIFER PROPERTIES FOR THE MRN-23 TEST

Well	Distance from Pumping Well	THEIS			COOPER & JACOB		
		Transmissivity		Storage Coefficient	Transmissivity		Storage Coefficient
	(ft)	*(gpd/ft)*	*(ft²/day)*		*(gpd/ft)*	*(ft²/day)*	
MRN-23	-	-	-	-	266	36	-
MRN-23 (REC)	-	-	-	-	214	29	-
MPN-8.1	1169	273	36	1.8E-04			
MPN-9	449	136	18	2.0E-04	204	27	1.5E-04
MPN-10	756	247	33	8.5E-05	279	37	6.9E-05
MPN-11	686	248	33	7.5E-05	293	39	6.2E-05
MPN-12	1113	271	36	7.9E-05			
MPN-13	1476	246	33	1.0E-04			
MRN-8	1859	288	39	1.4E-04			
MRN-9	1631	271	36	1.4E-04			
MRN-10	1278	289	39	1.4E-04			
MRN-11	1291	281	38	1.1E-04			
MRN-12	1326	307	41	9.4E-05			
MRN-13	1593	265	35	9.3E-05			
MRN-14	1978	246	33	8.6E-05			
MRN-15	2123	246	33	8.1E-05			
MRN-16	2351	266	36	9.8E-05			
MRN-17	2181	342	46	1.3E-04			
MRN-18.1	1770	246	33	1.2E-04			
MRN-20.1	1359	243	32	1.2E-04			
MRN-21	970	269	36	1.5E-04			
MRN-22	494	240	32	1.3E-04	272	36	9.8E-05
MRN-24	472	246	33	9.0E-05	267	36	7.7E-05
MRN-25	928	246	33	1.0E-04			
MRN-26	1399	281	38	1.3E-04			
	AVERAGE:	**261**	**35**	**1.2E-04**			



REVISIONS No.	DATE	MADE BY	DESCRIPTION
1			
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DATE	DRAWN BY	CHECKED	APPROVED
3-2012	RTS		

HYDRO-ENGINEERING L.L.C.

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4685 EAST MAGNOLIA
CASPER, WYOMING, 82604

FILE: C:\PROJECTS\2012-14\nrwellfield

Uranerz ENERGY CORPORATION
1701 East "E" Street
P.O. Box 50850
Casper, Wyoming
USA 82605-0850

Figure 5-1
Maximum Drawdown in the A Sand
For the MRN-23 Pump Test

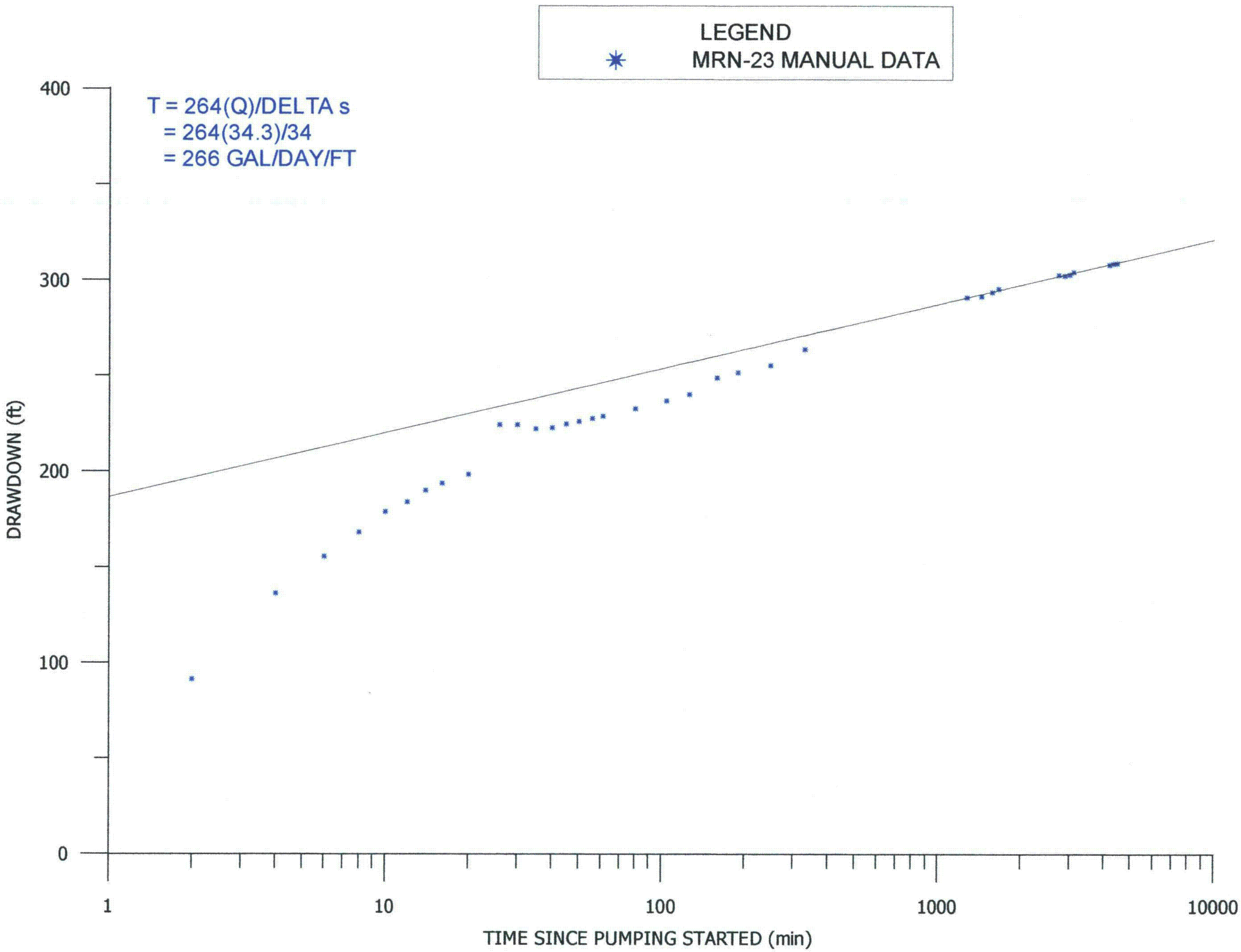

FIGURE 5-2. DRAWDOWN IN PUMPING WELL MRN-23

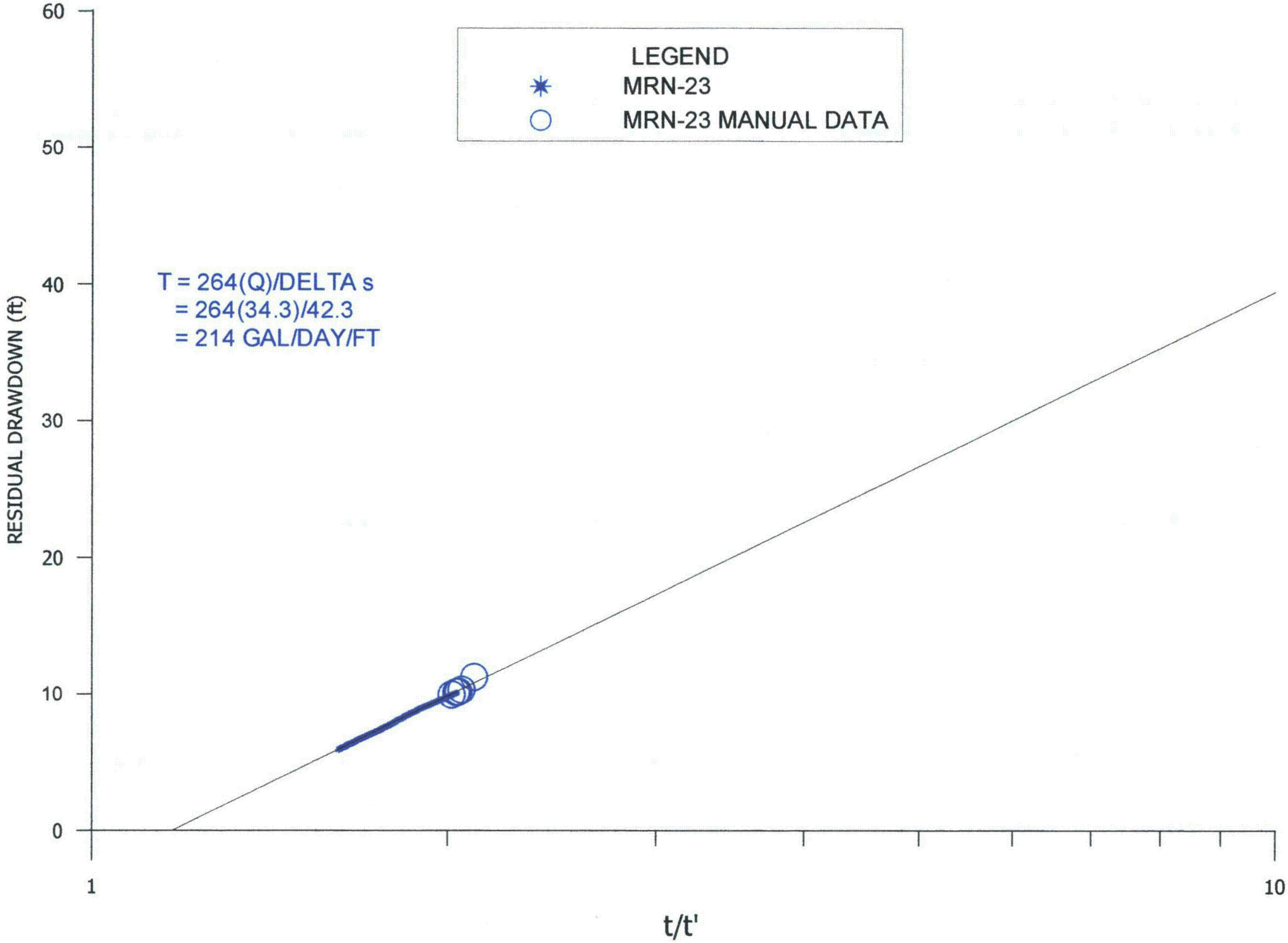

FIGURE 5-3. RECOVERY IN PUMPING WELL MRN-23

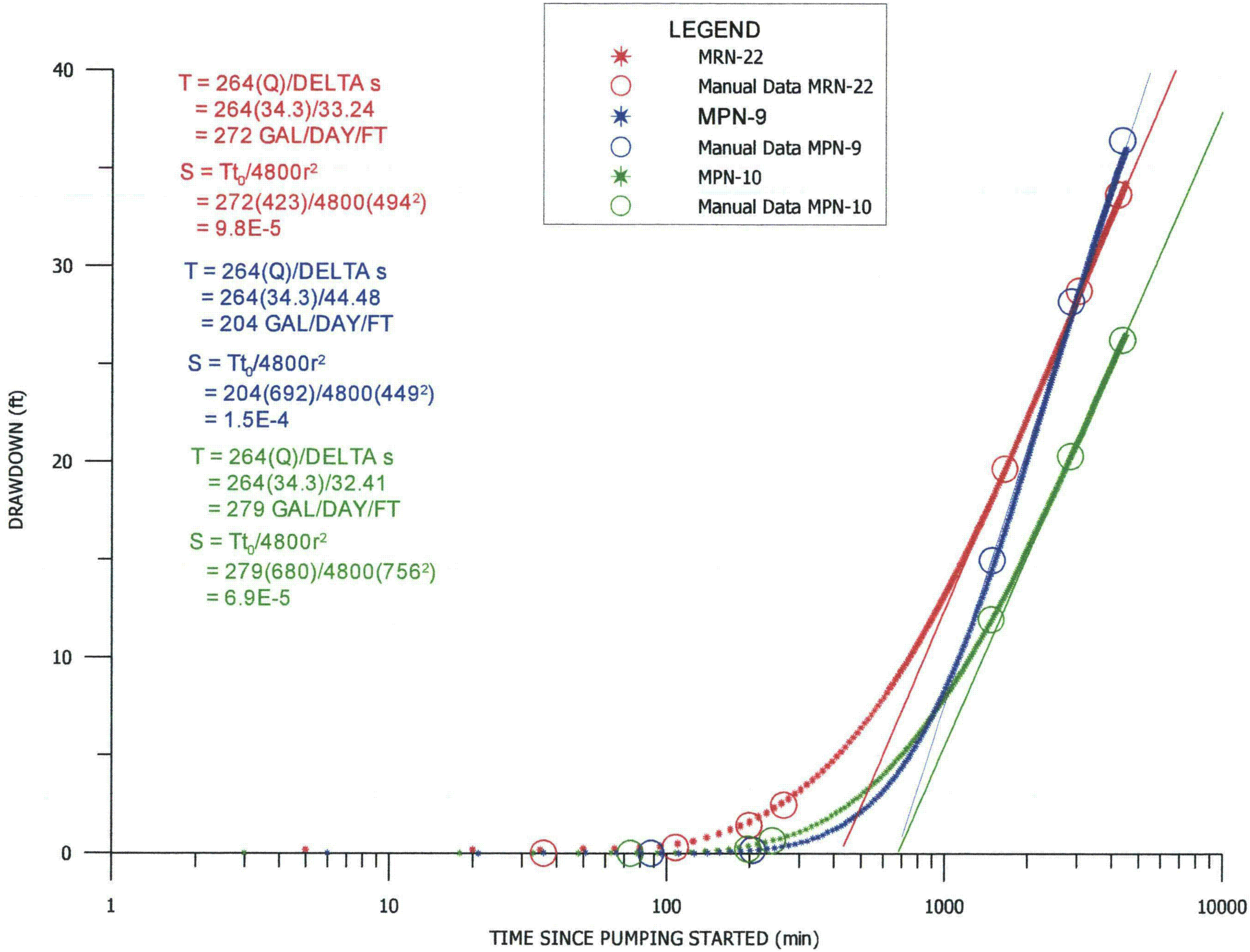

FIGURE 5-4. DRAWDOWN IN OBSERVATION WELL MRN-22, MPN-9 AND MPN-10

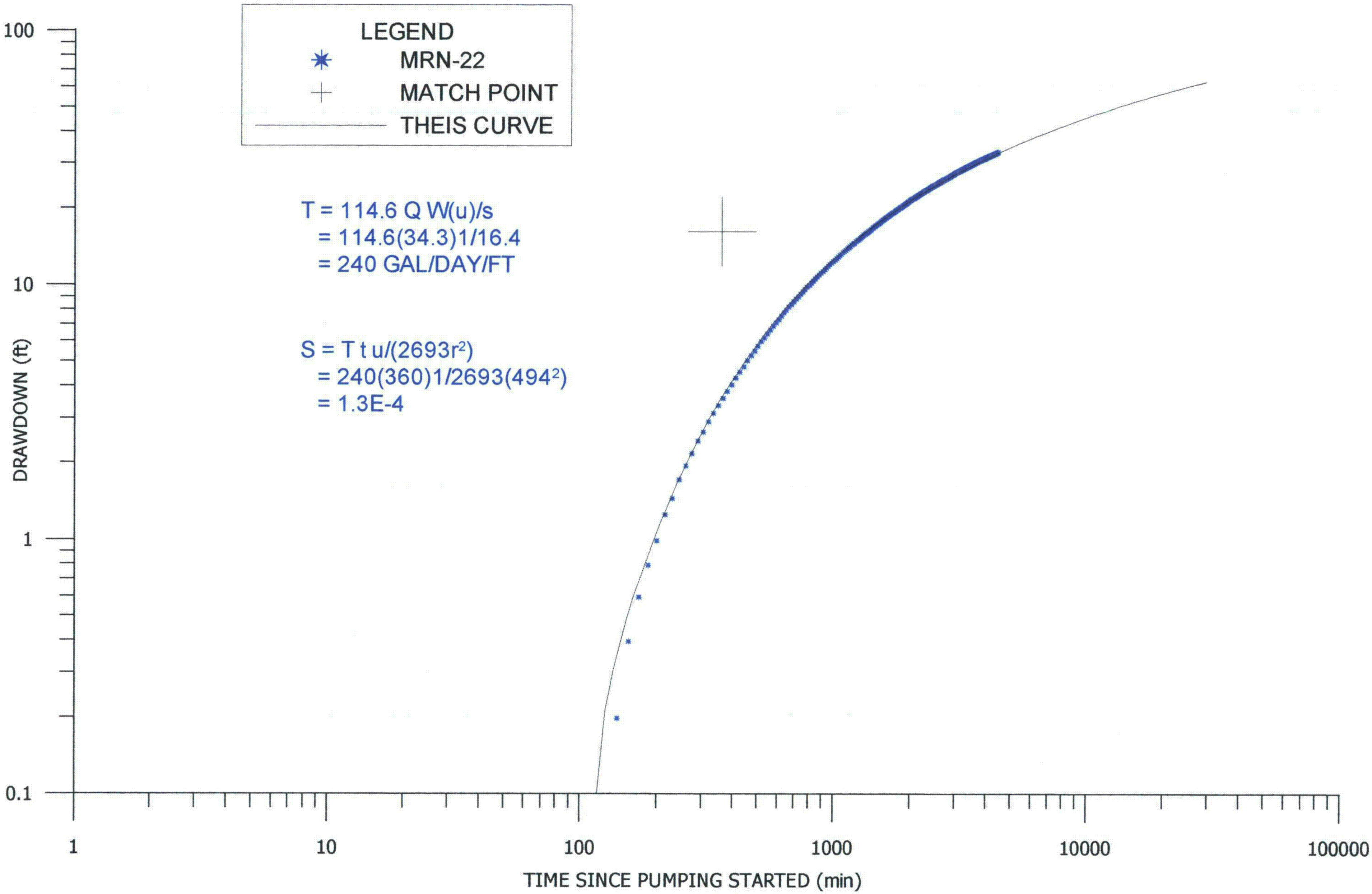

FIGURE 5-5. DRAWDOWN IN OBSERVATION WELL MRN-22, LOG-LOG

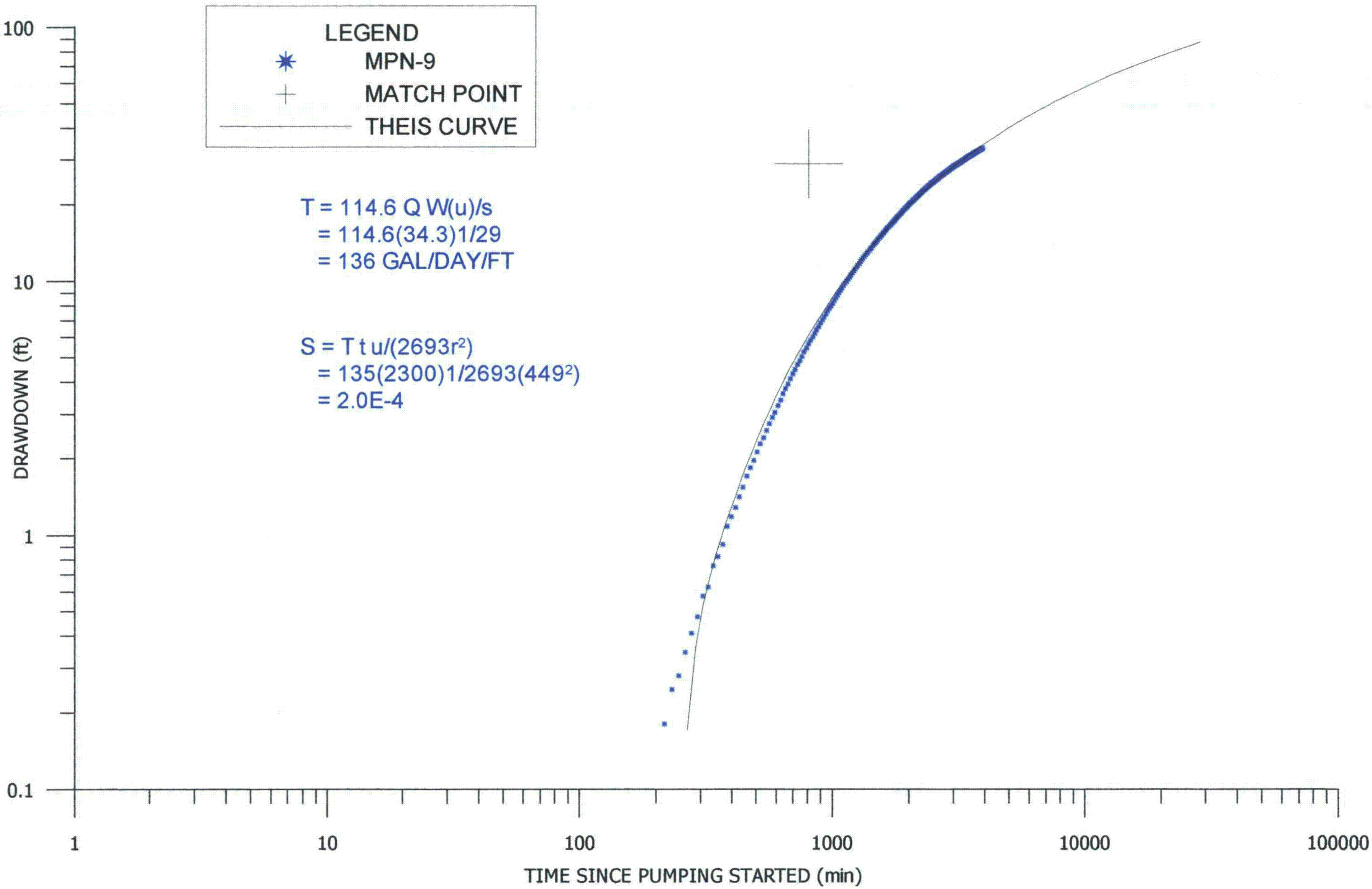

FIGURE 5-6. DRAWDOWN IN OBSERVATION WELL MPN-9, LOG-LOG

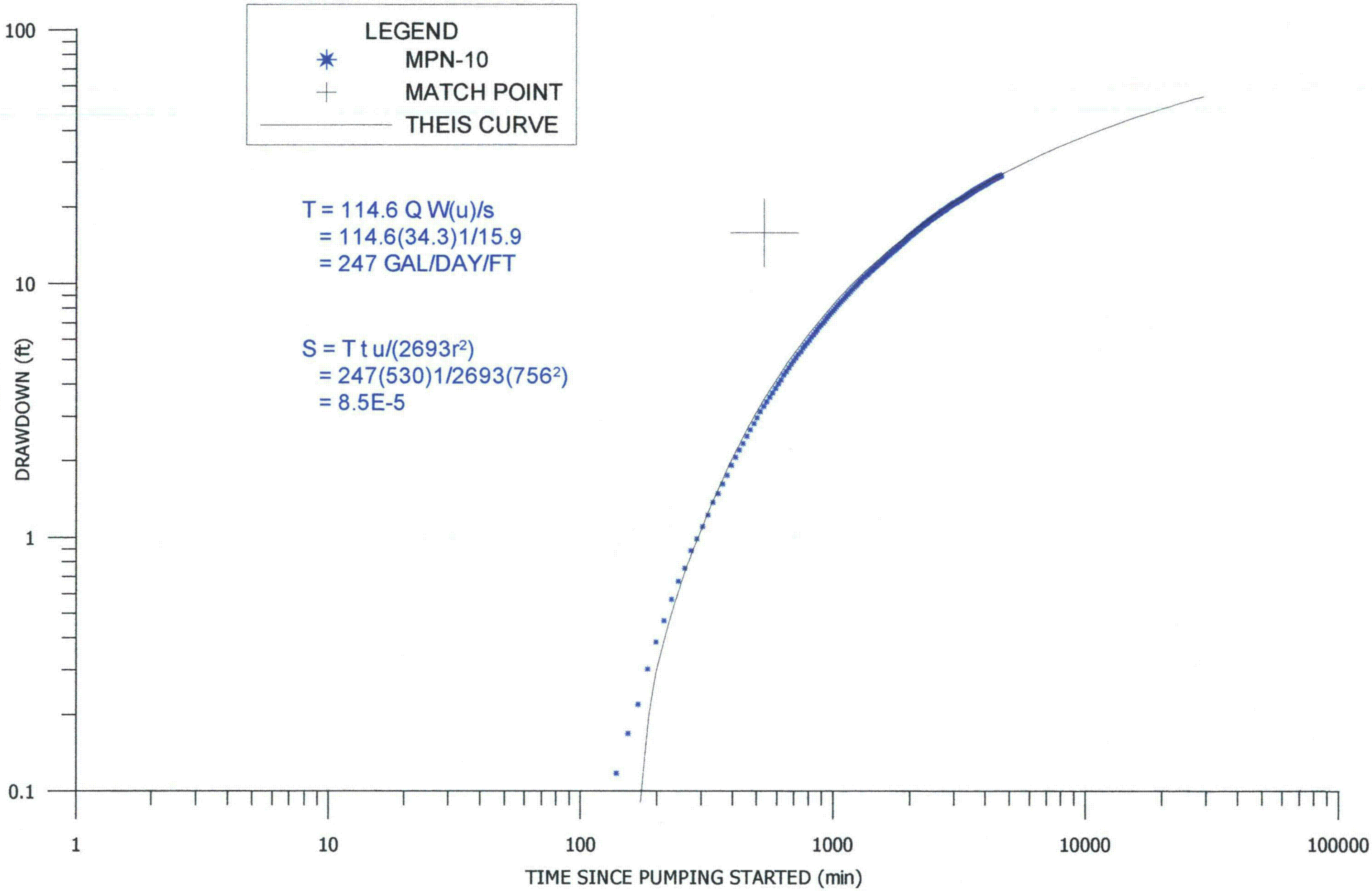

FIGURE 5-7. DRAWDOWN IN OBSERVATION WELL MPN-10, LOG-LOG

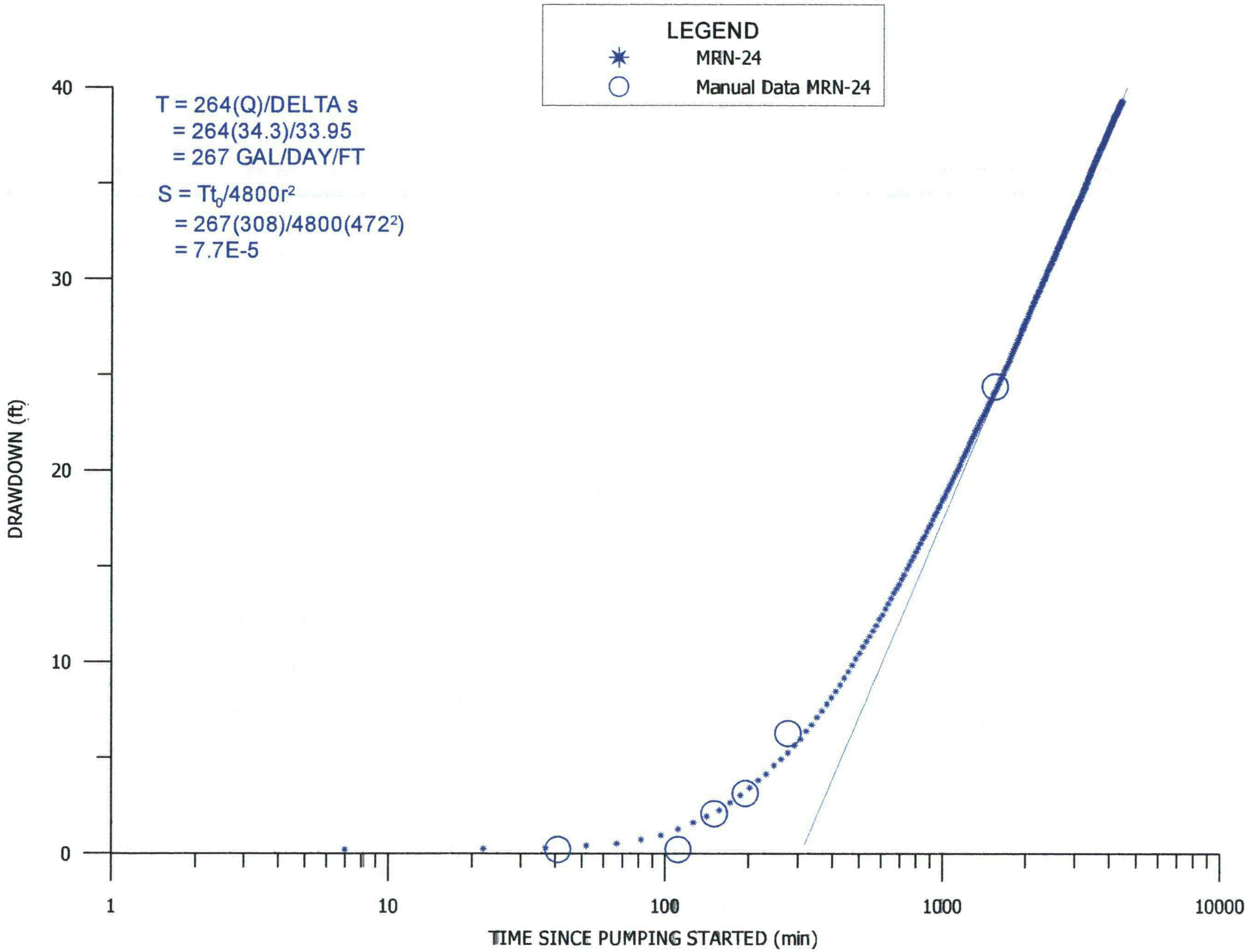

FIGURE 5-8. DRAWDOWN IN OBSERVATION WELL MRN-24

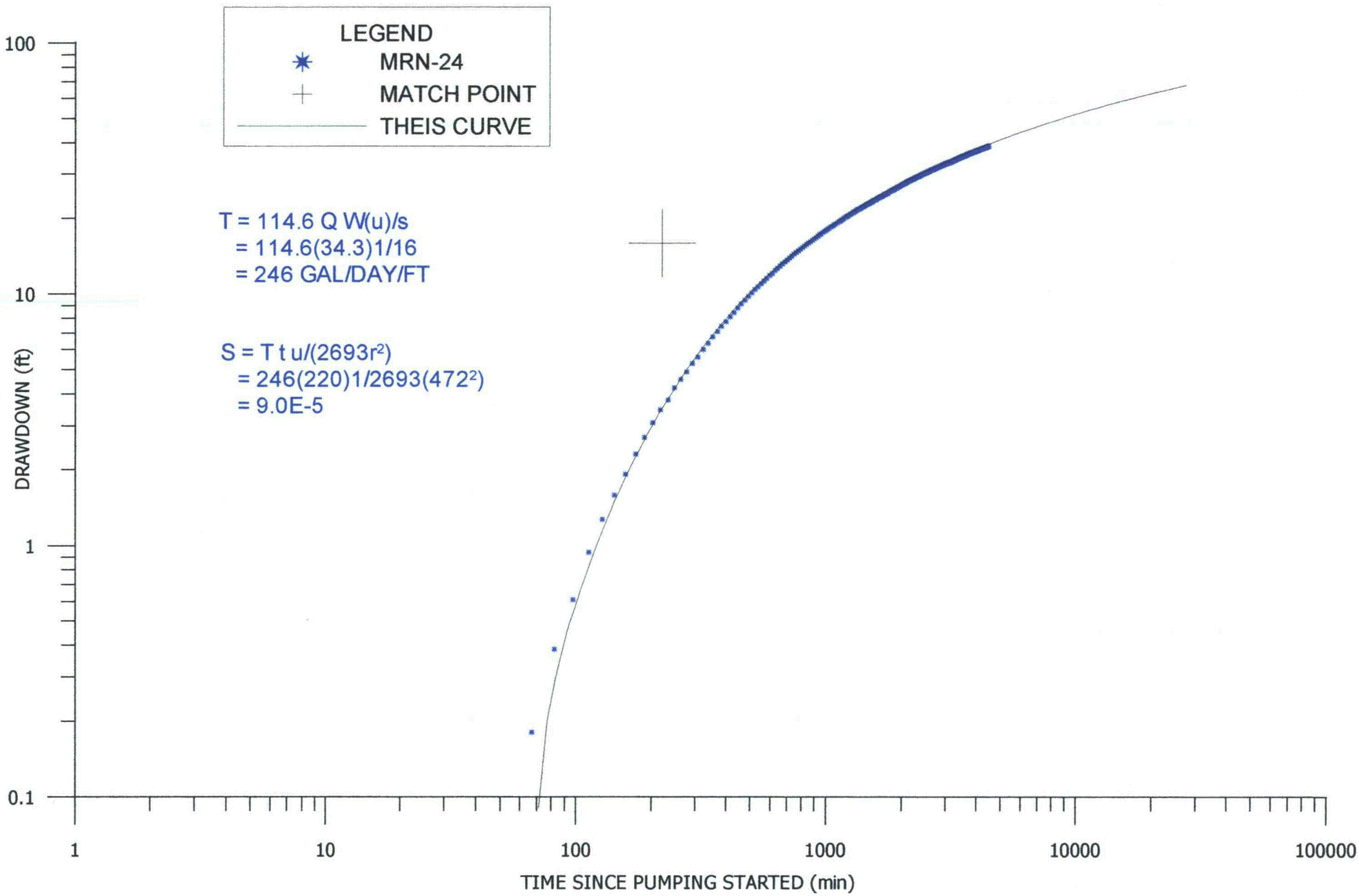

FIGURE 5-9. DRAWDOWN IN OBSERVATION WELL MRN-24, LOG-LOG

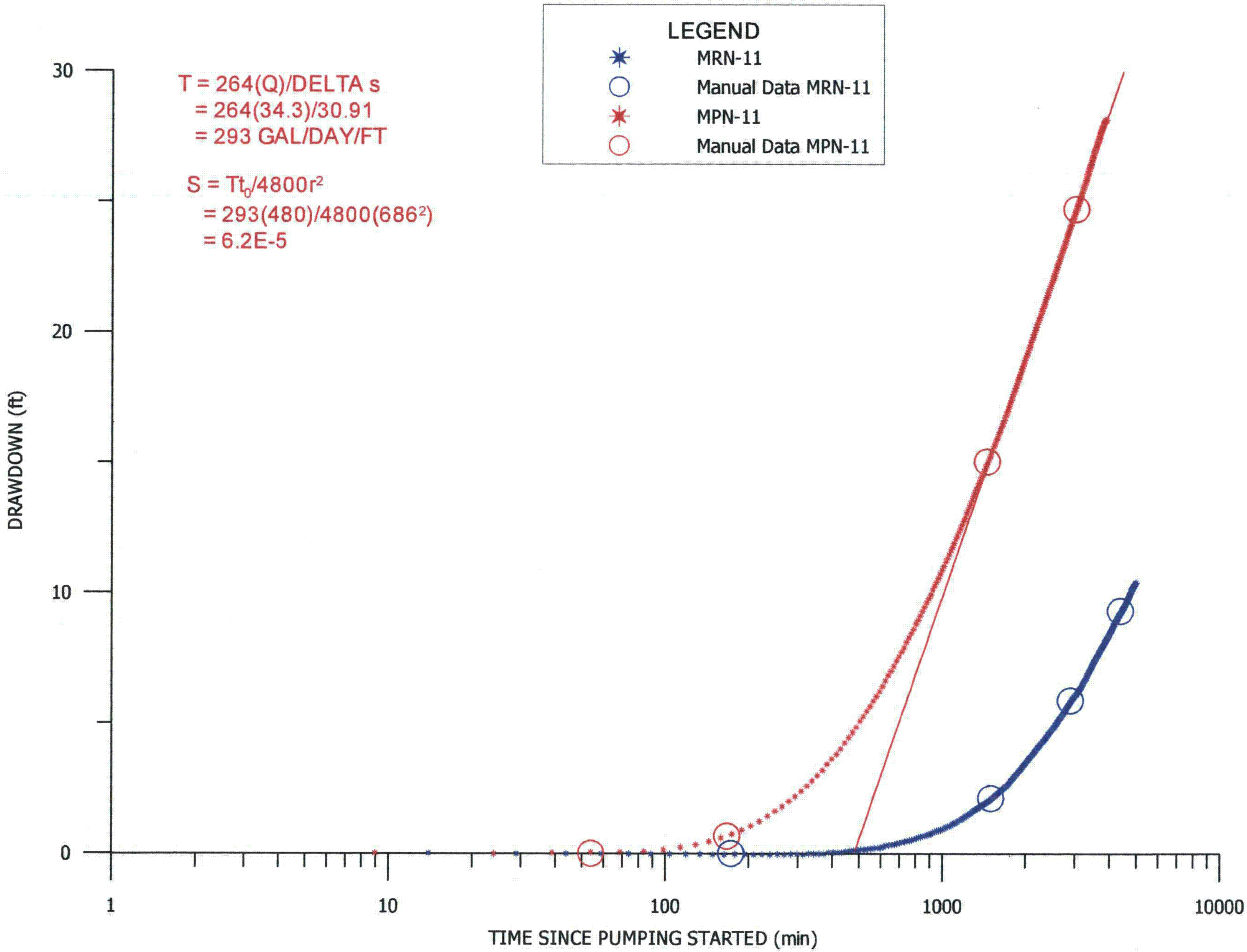

FIGURE 5-10. DRAWDOWN IN OBSERVATION WELL MRN-11 AND MPN-11

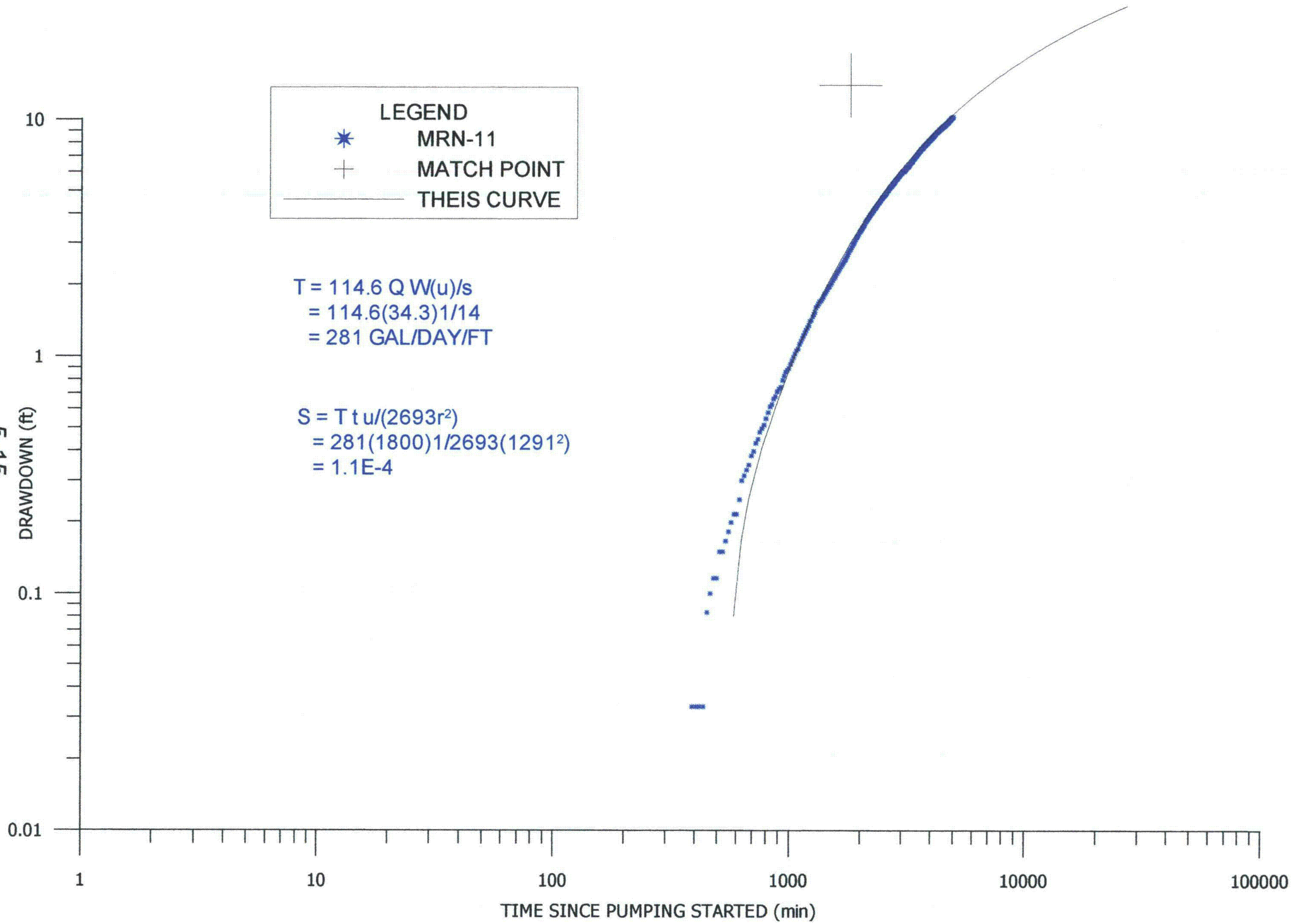

FIGURE 5-11. DRAWDOWN IN OBSERVATION WELL MRN-11, LOG-LOG

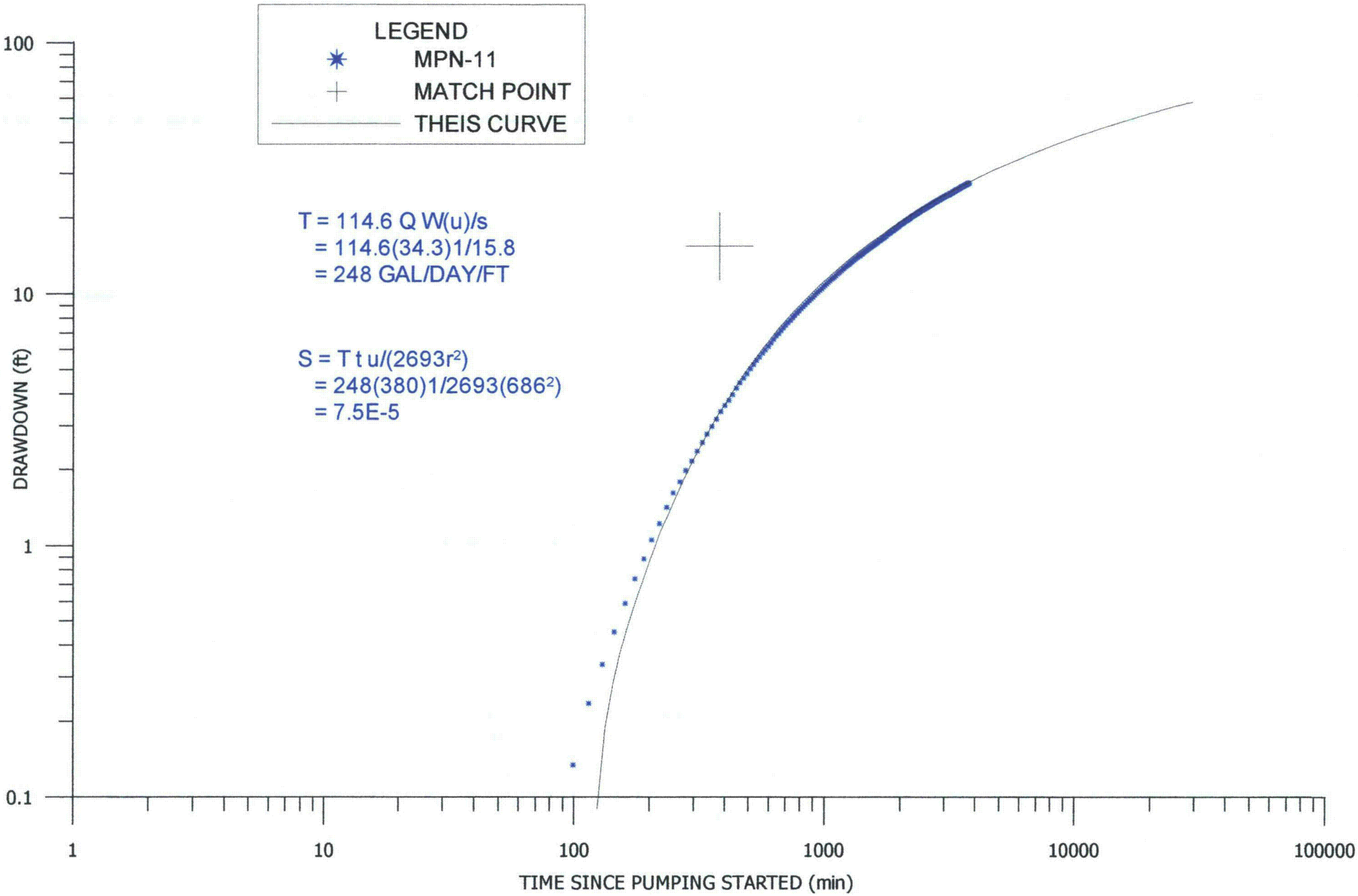

FIGURE 5-12. DRAWDOWN IN OBSERVATION WELL MPN-11, LOG-LOG

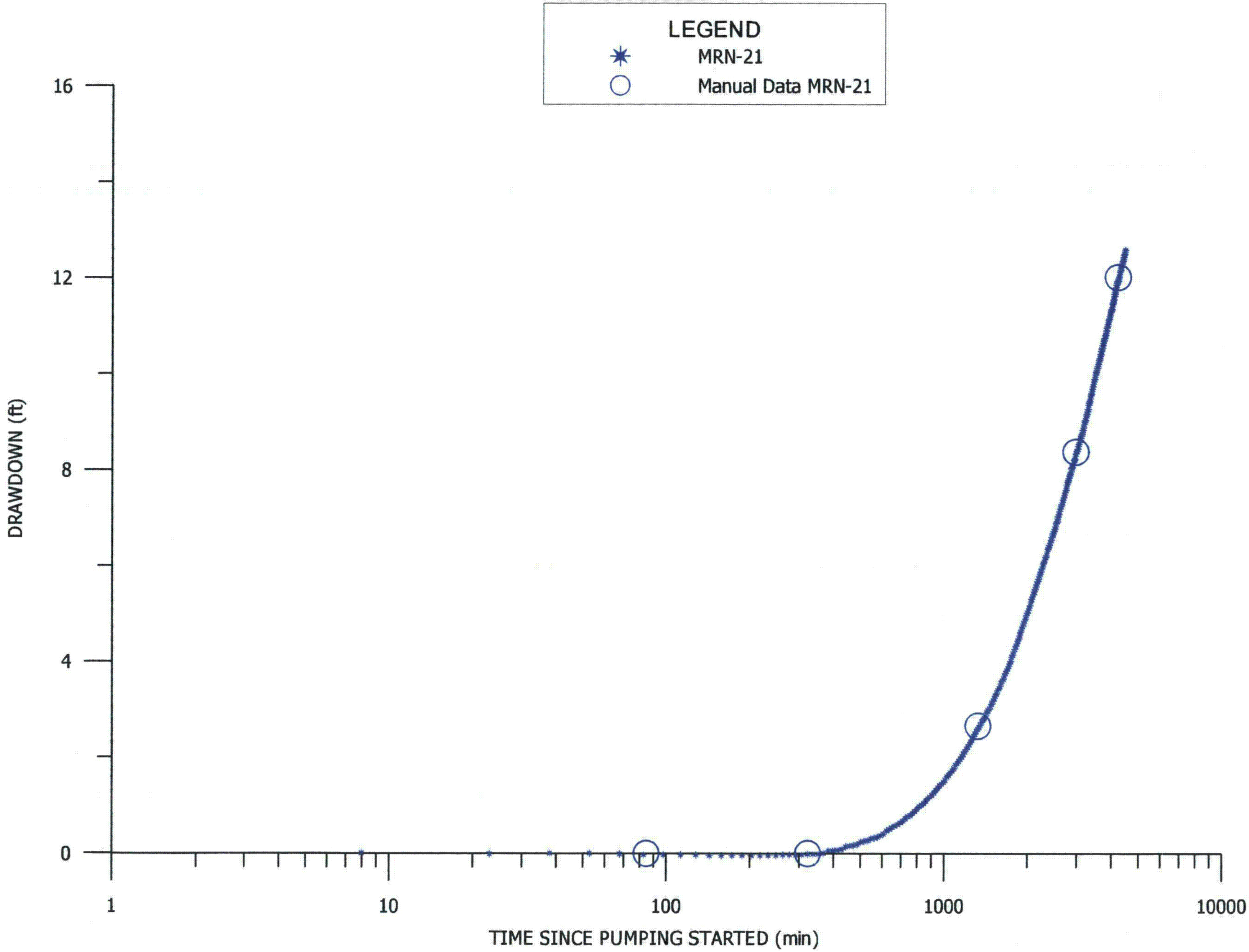

FIGURE 5-13. DRAWDOWN IN OBSERVATION WELL MRN-21

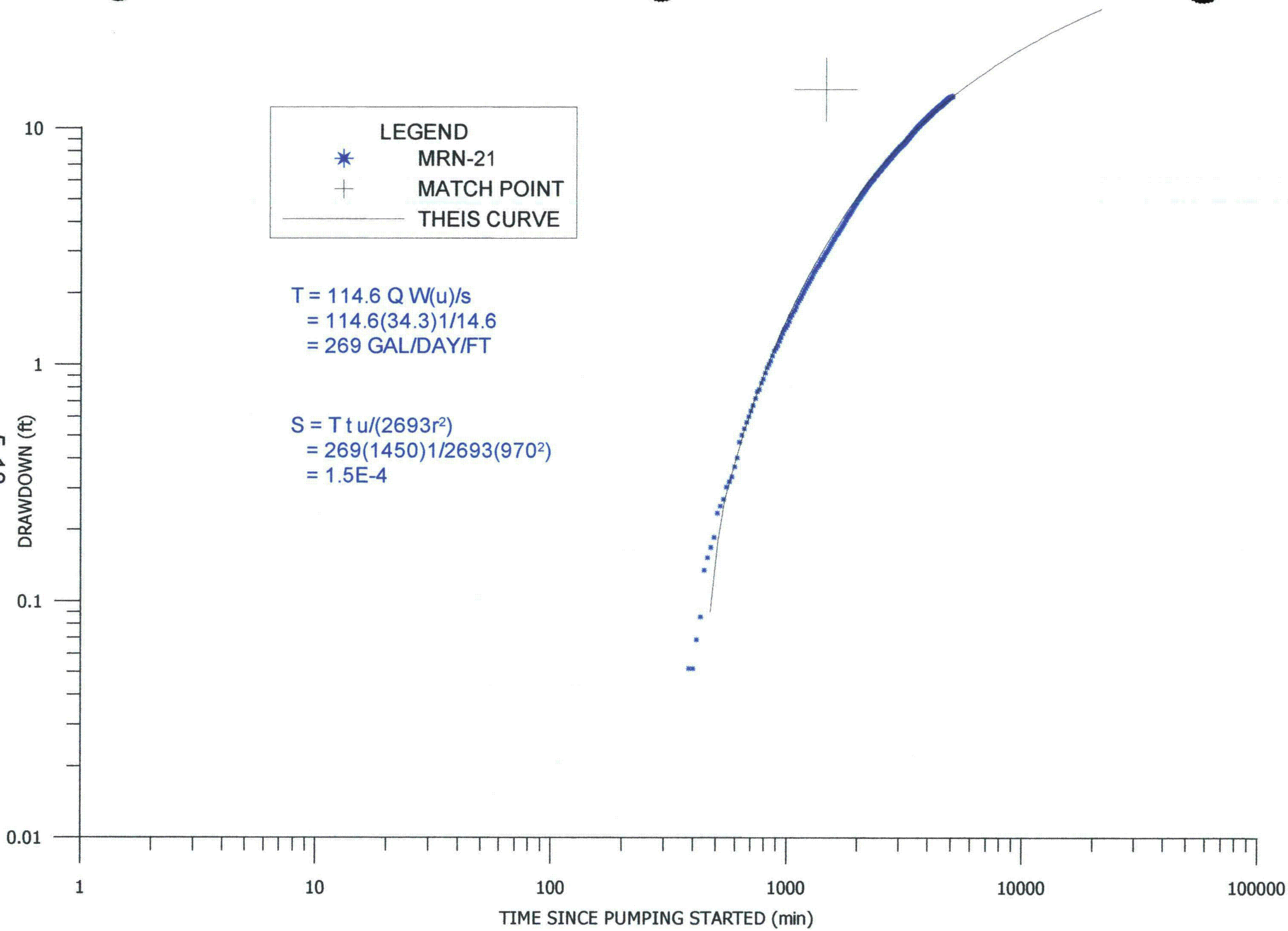

FIGURE 5-14. DRAWDOWN IN OBSERVATION WELL MRN-21, LOG-LOG

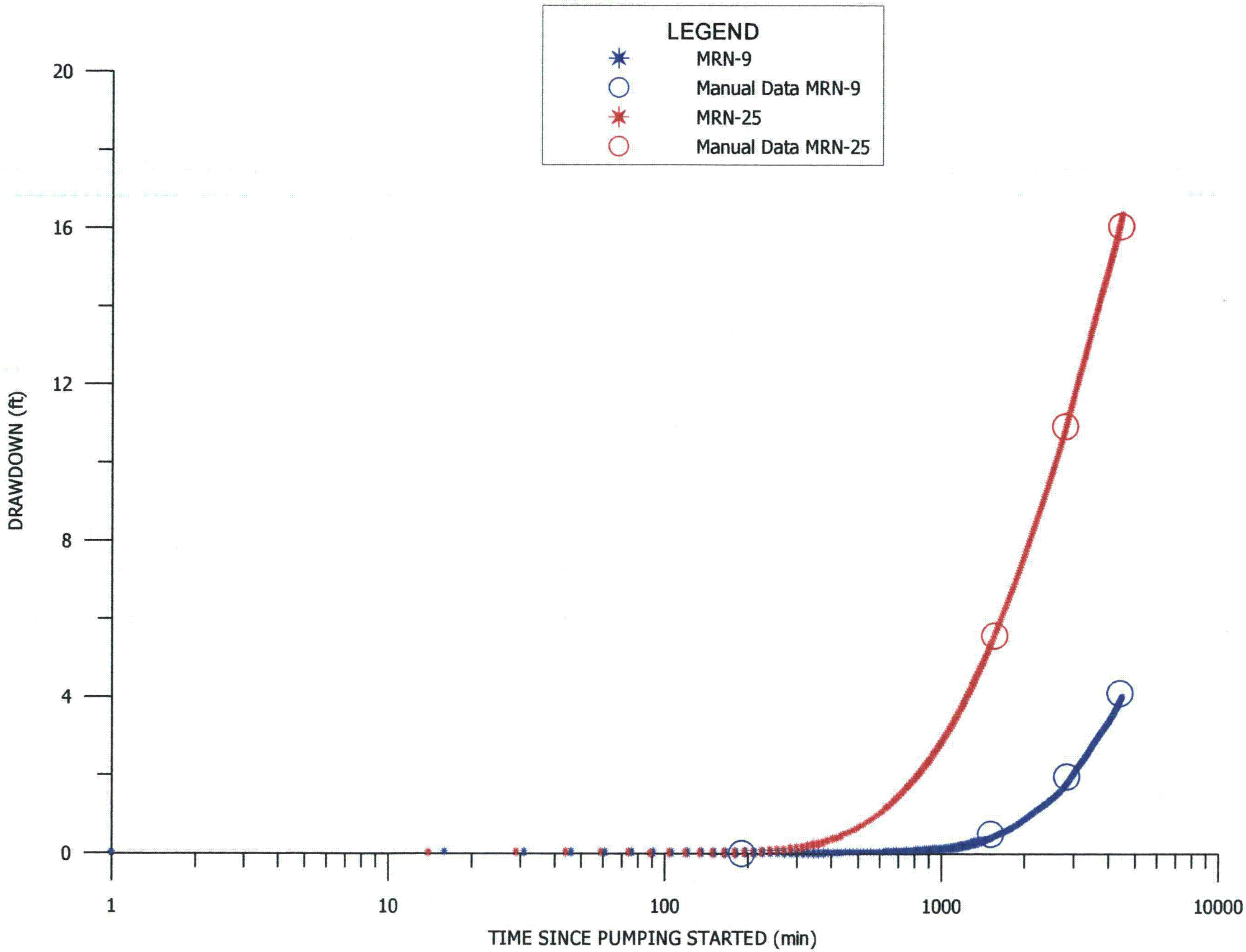

FIGURE 5-15. DRAWDOWN IN OBSERVATION WELL MRN-9 AND MRN-25

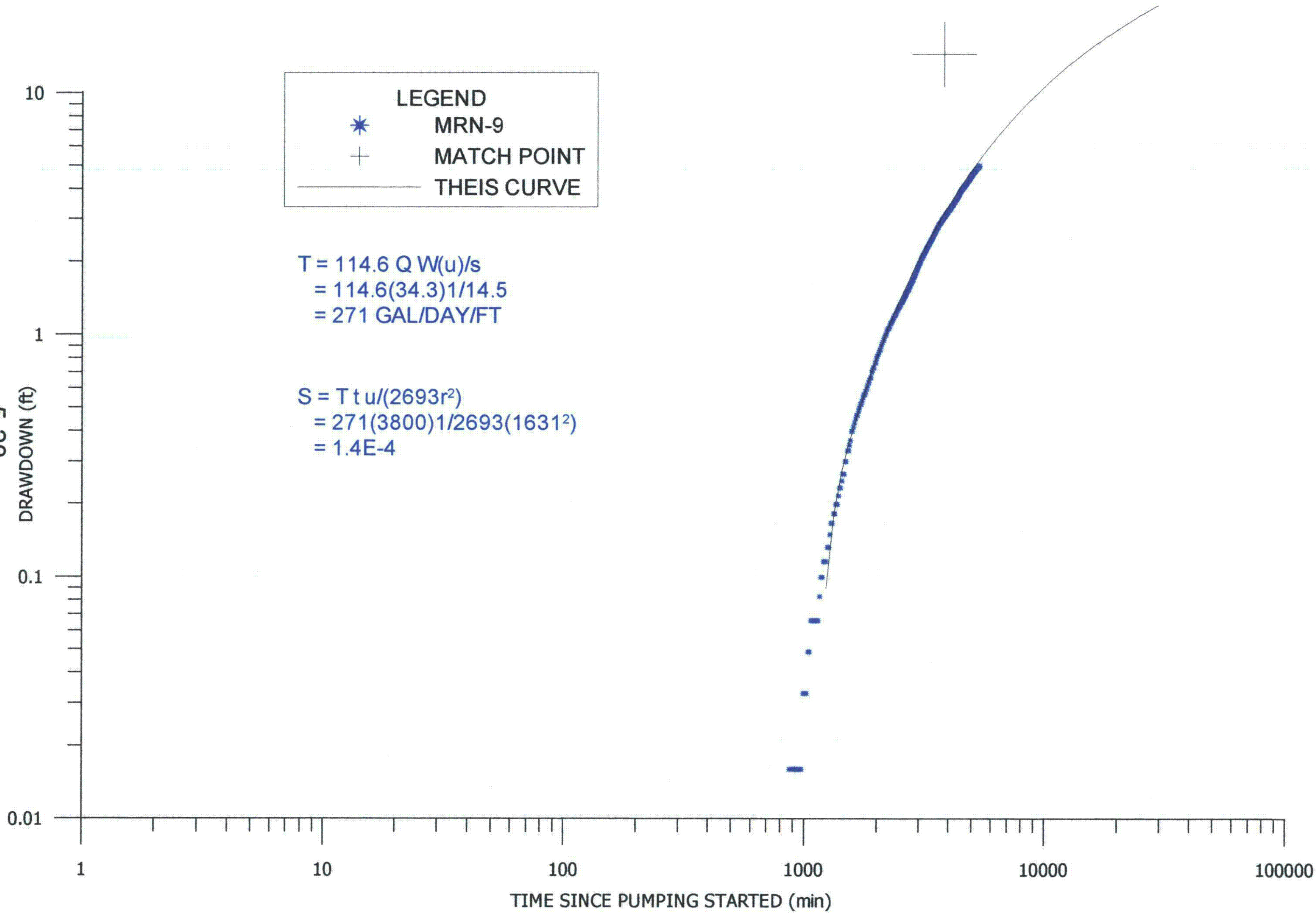

FIGURE 5-16. DRAWDOWN IN OBSERVATION WELL MRN-9, LOG-LOG

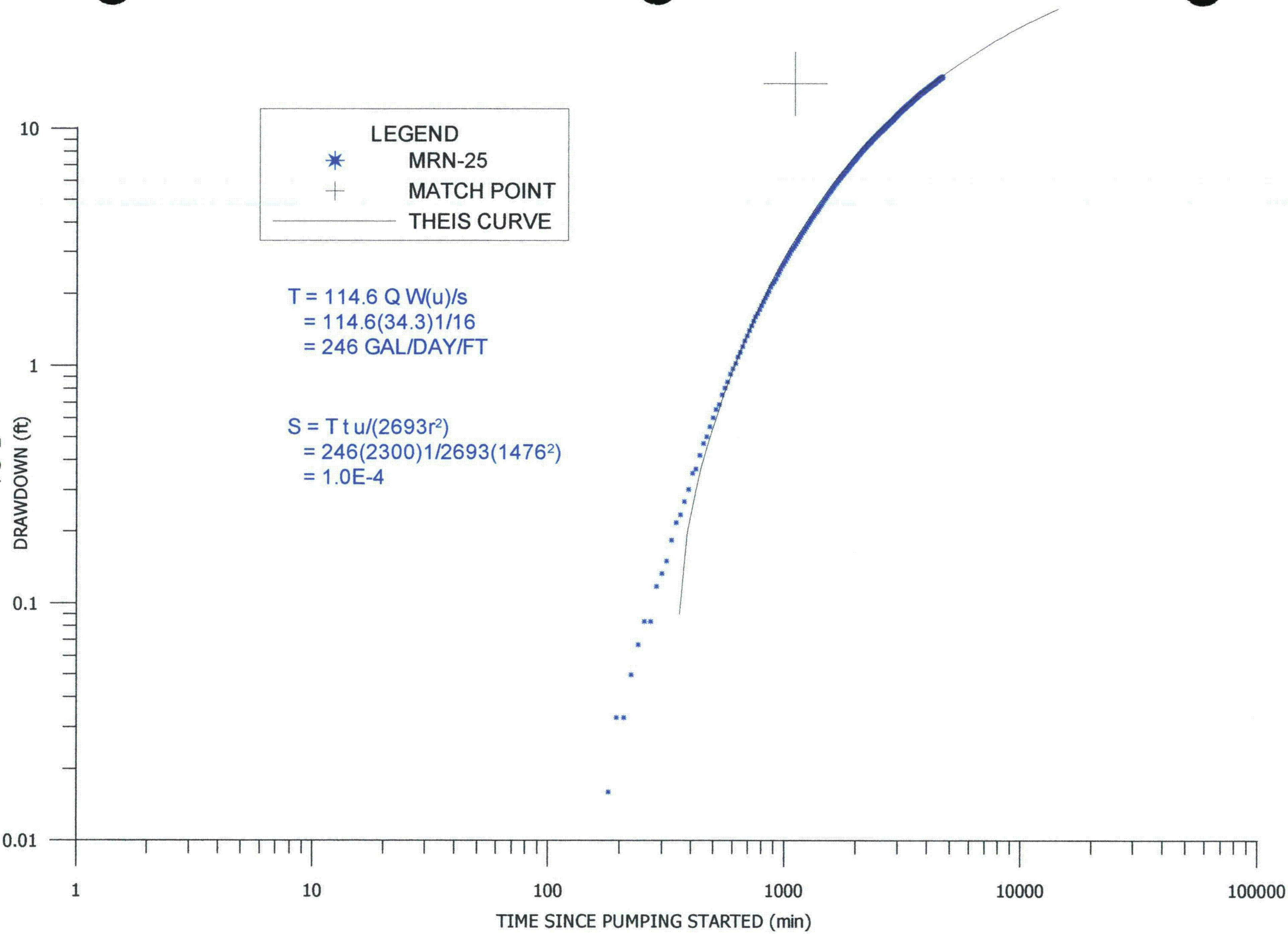

FIGURE 5-17. DRAWDOWN IN OBSERVATION WELL MRN-25, LOG-LOG

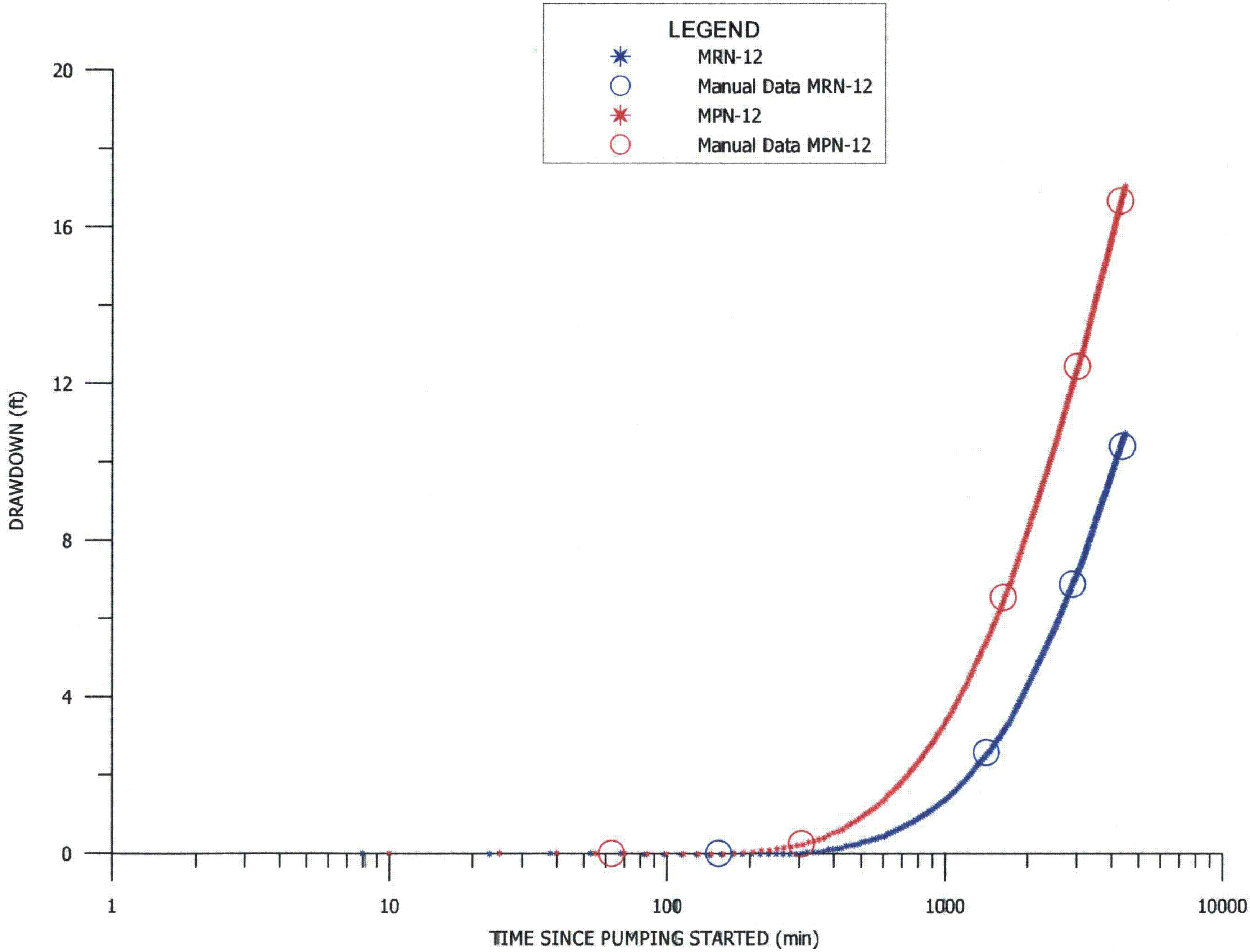

FIGURE 5-18. DRAWDOWN IN OBSERVATION WELL MRN-12 AND MPN-12

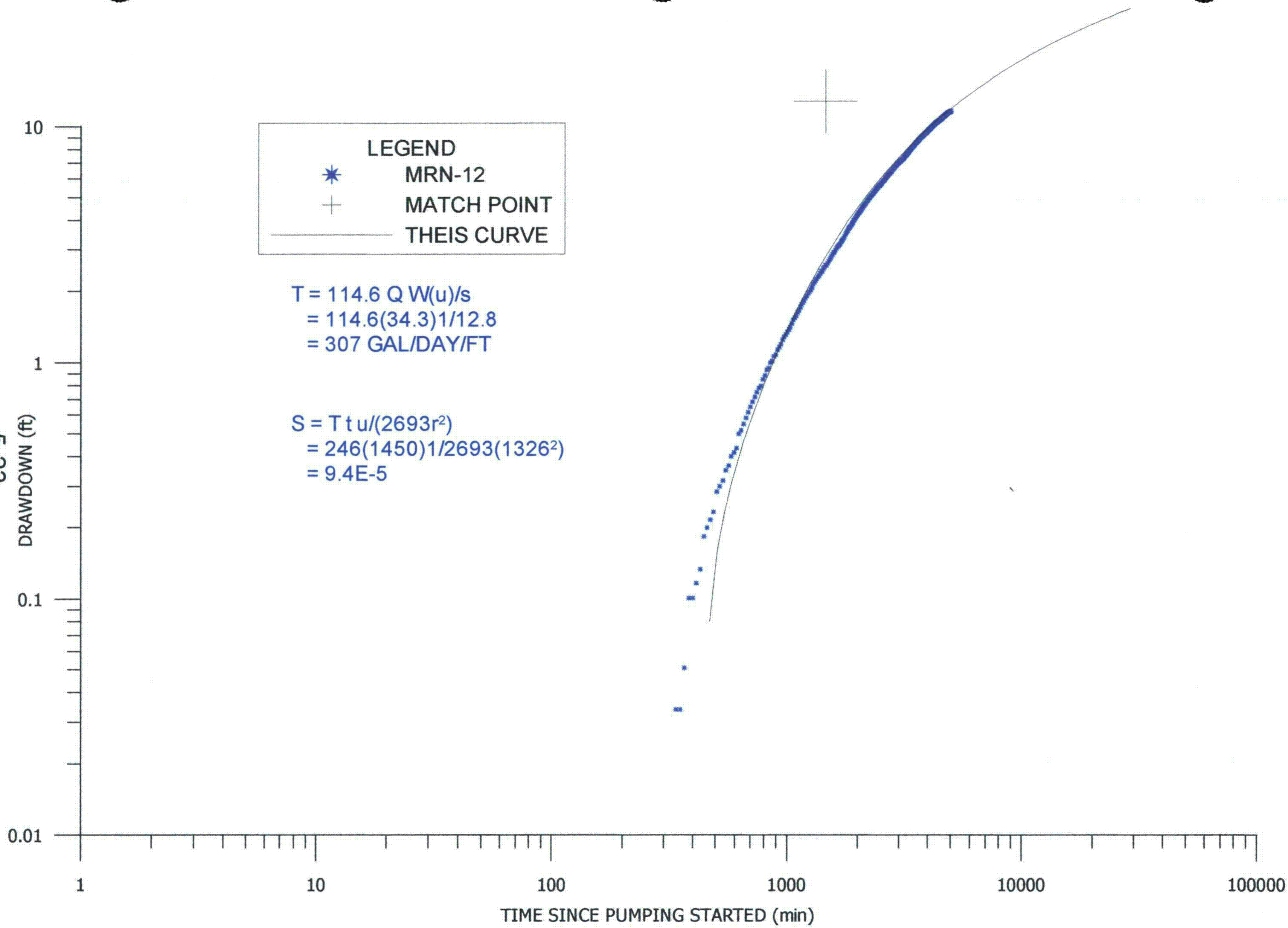

FIGURE 5-19. DRAWDOWN IN OBSERVATION WELL MRN-12, LOG-LOG

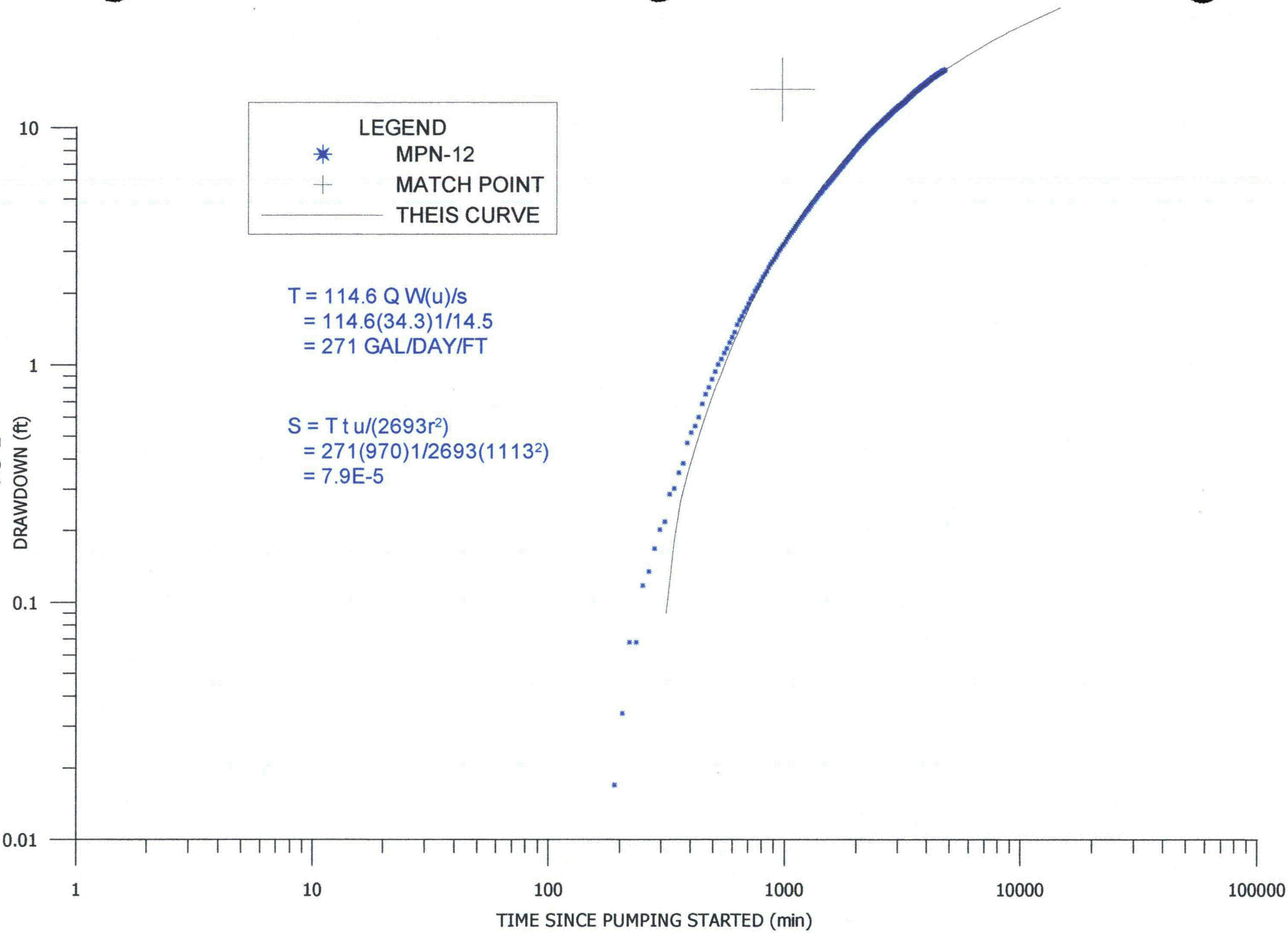

FIGURE 5-20. DRAWDOWN IN OBSERVATION WELL MPN-12, LOG-LOG

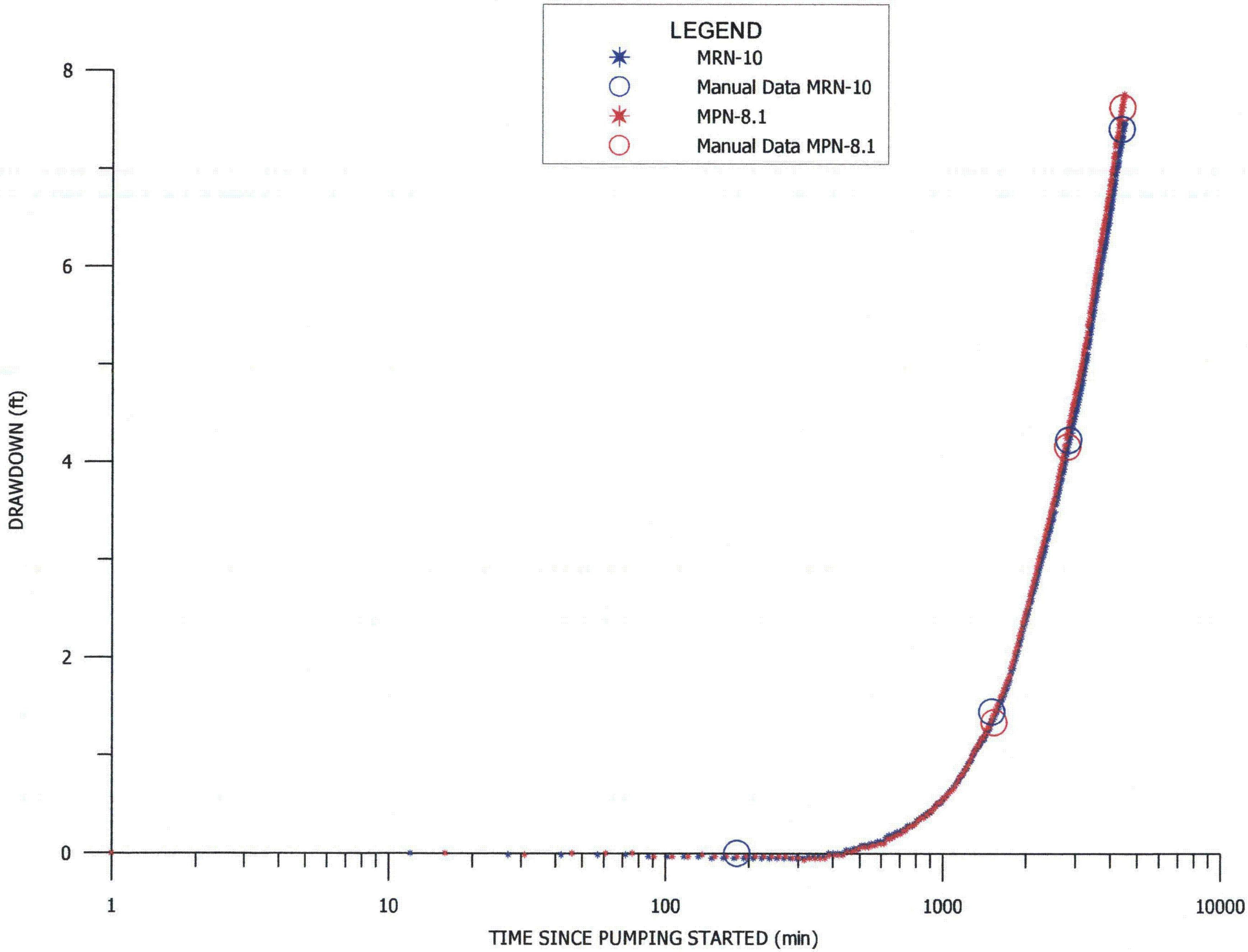

FIGURE 5-21. DRAWDOWN IN OBSERVATION WELL MRN-10 AND MPN-8.1

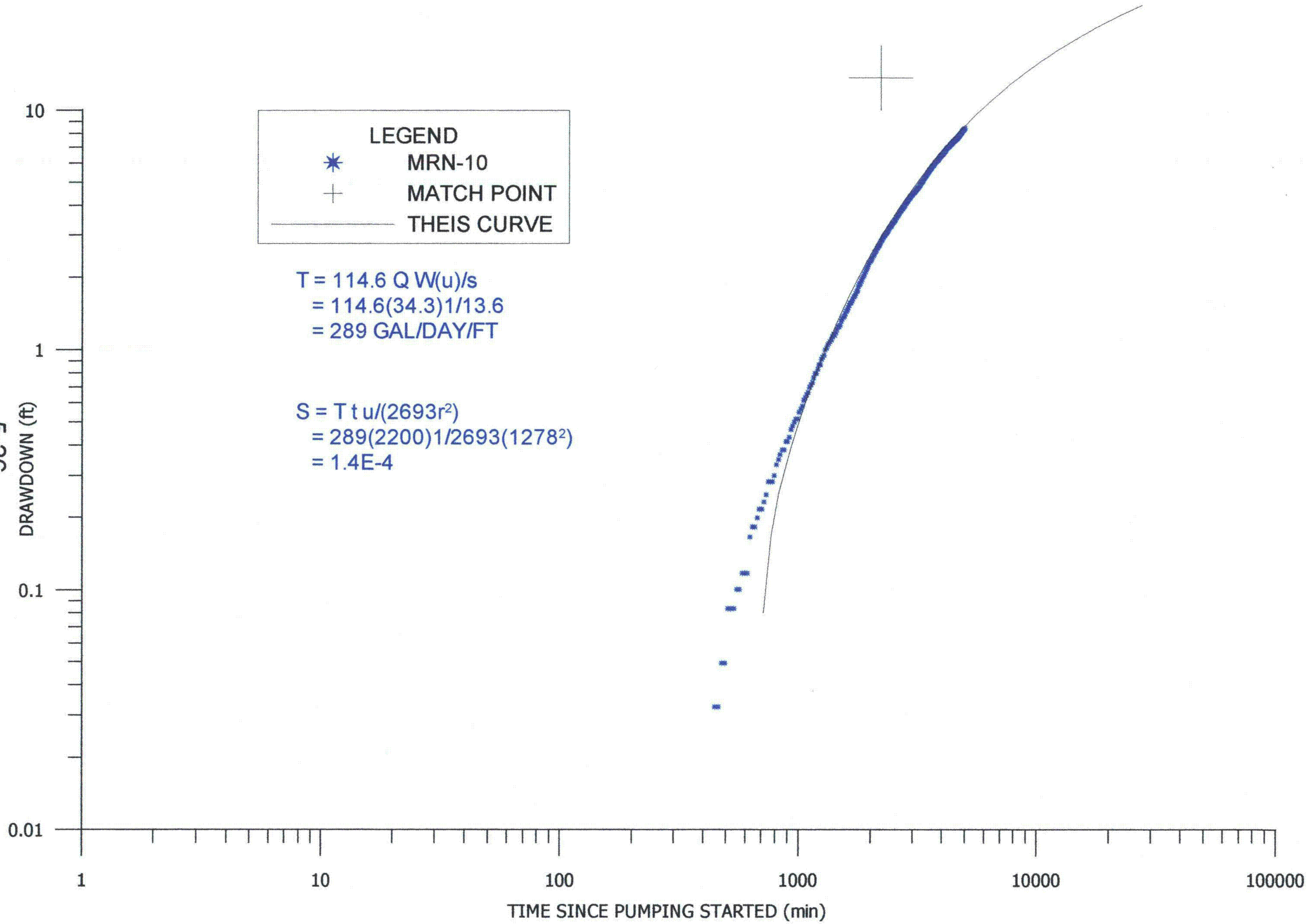

FIGURE 5-22. DRAWDOWN IN OBSERVATION WELL MRN-10, LOG-LOG

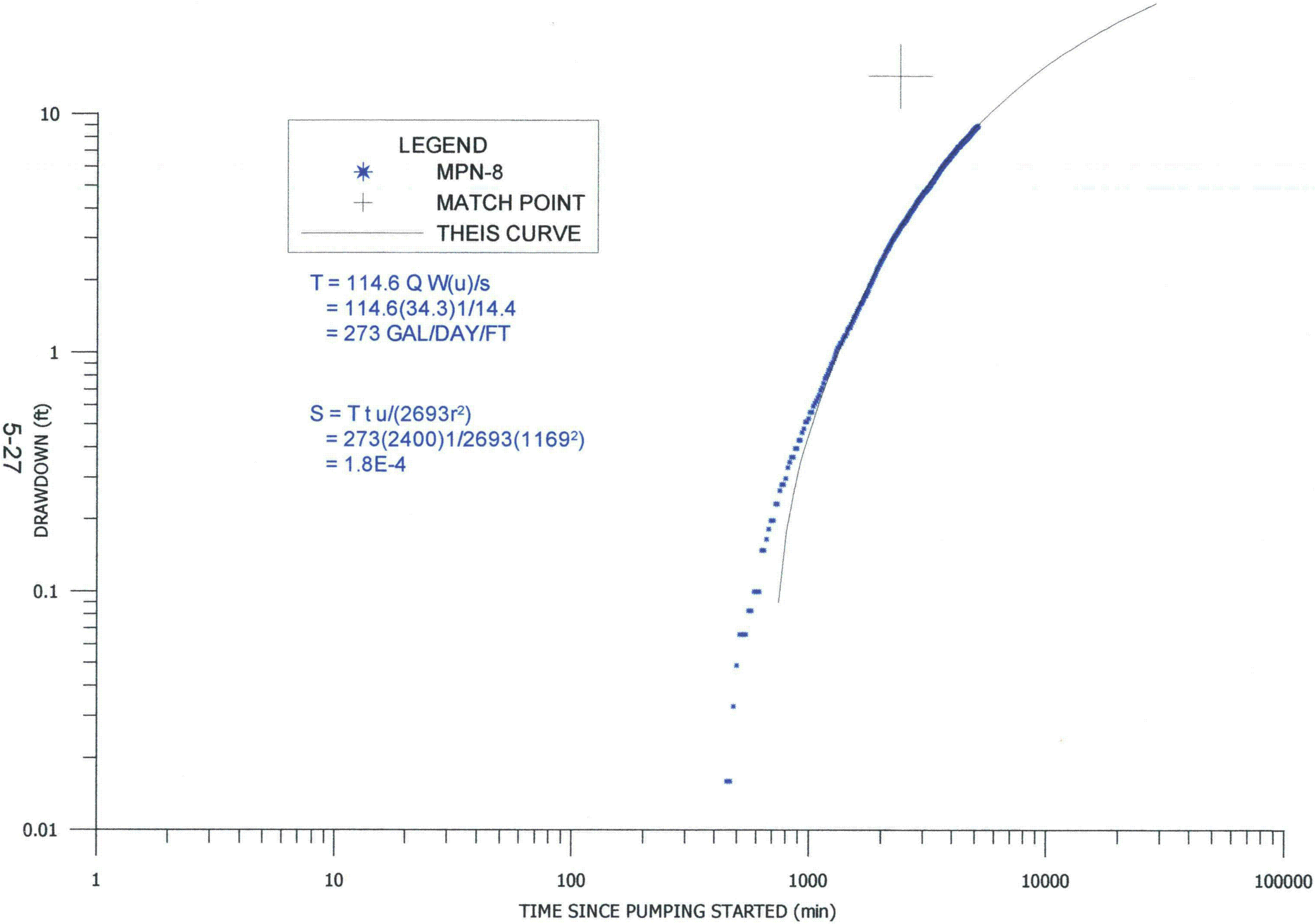

FIGURE 5-23. DRAWDOWN IN OBSERVATION WELL MPN-8.1, LOG-LOG

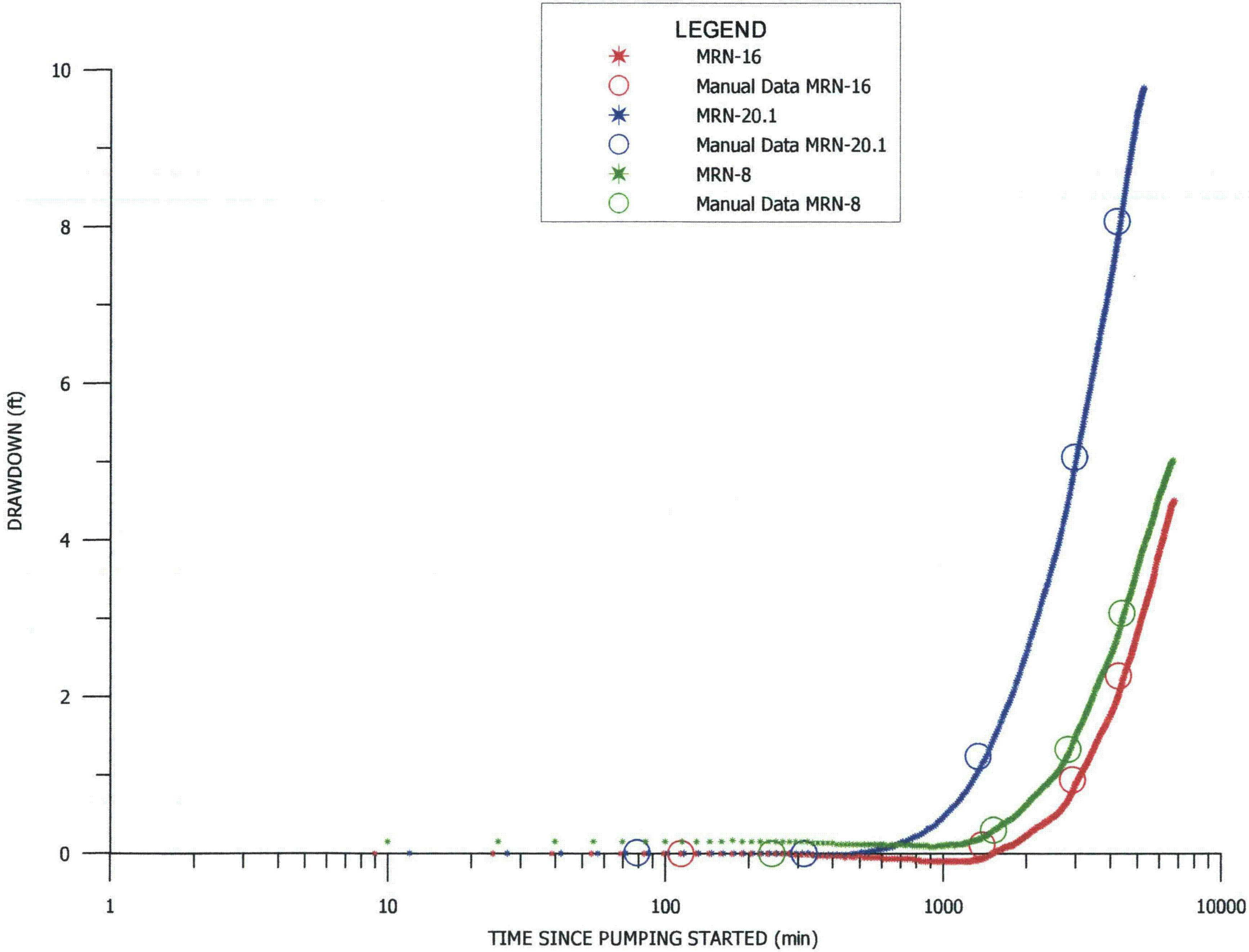

FIGURE 5-24. DRAWDOWN IN OBSERVATION WELL MRN-16, MRN-20.1 AND MRN-8

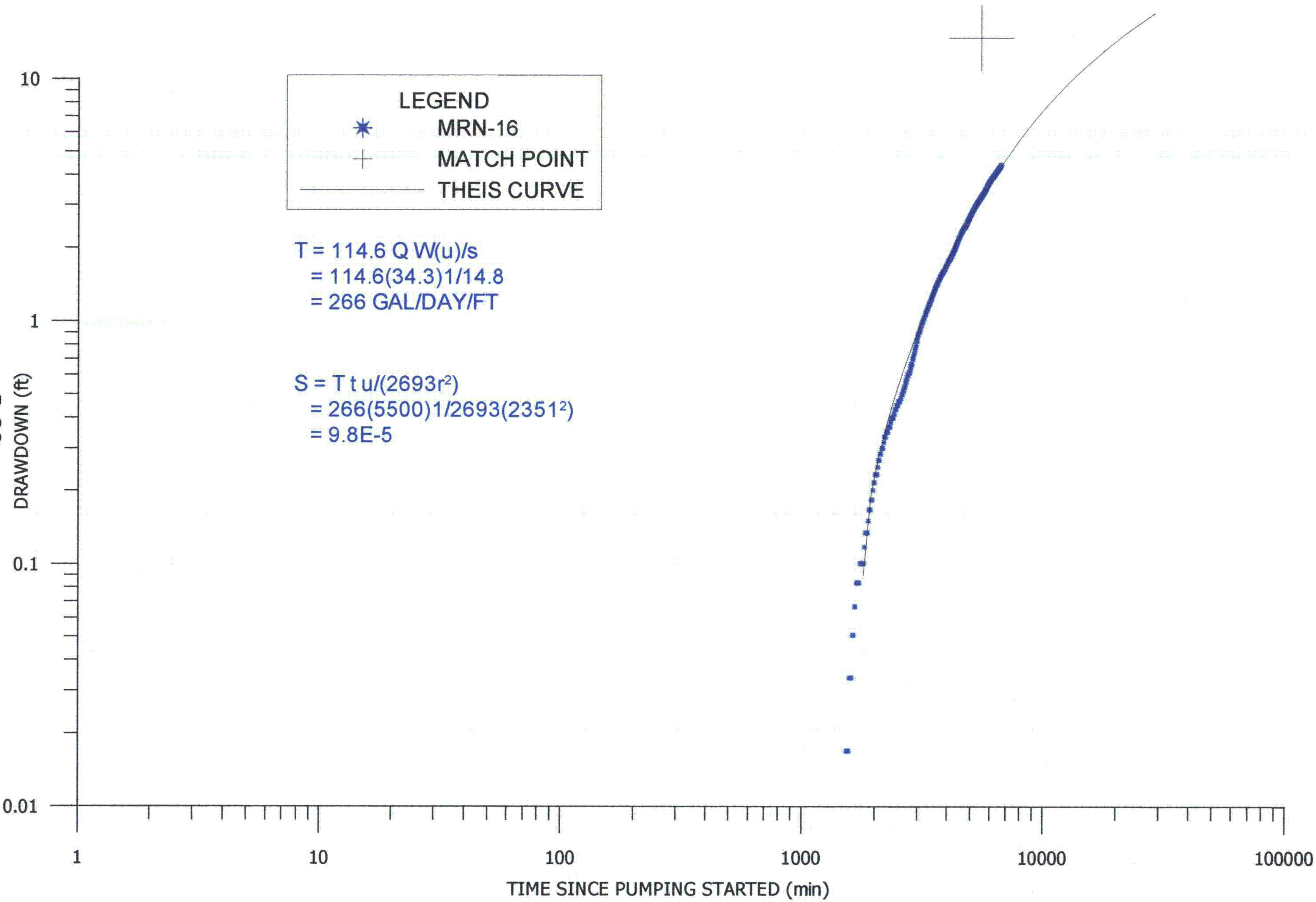

FIGURE 5-25. DRAWDOWN IN OBSERVATION WELL MRN-16, LOG-LOG

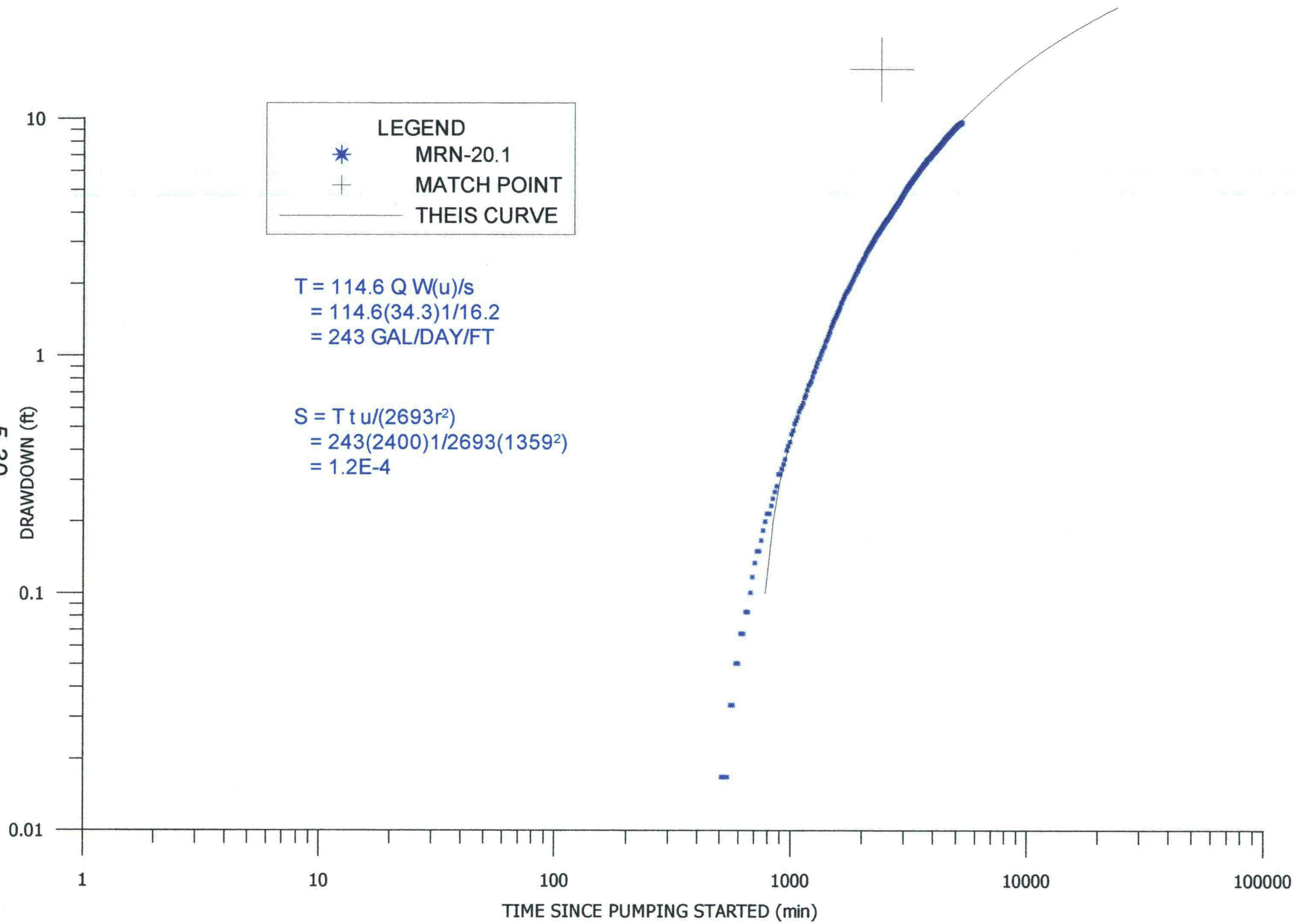

FIGURE 5-26. DRAWDOWN IN OBSERVATION WELL MRN-20.1, LOG-LOG

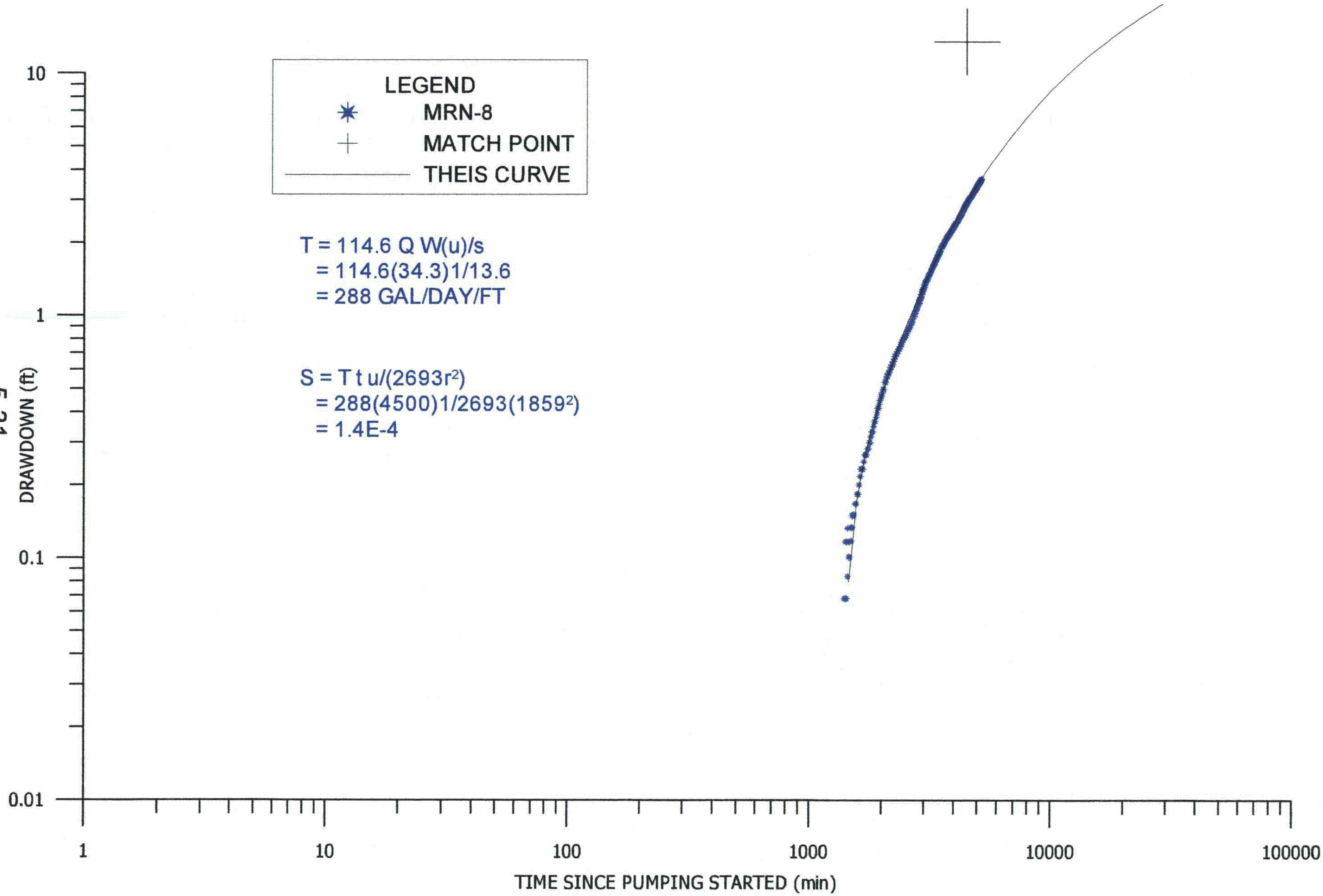

FIGURE 5-27. DRAWDOWN IN OBSERVATION WELL MRN-8, LOG-LOG

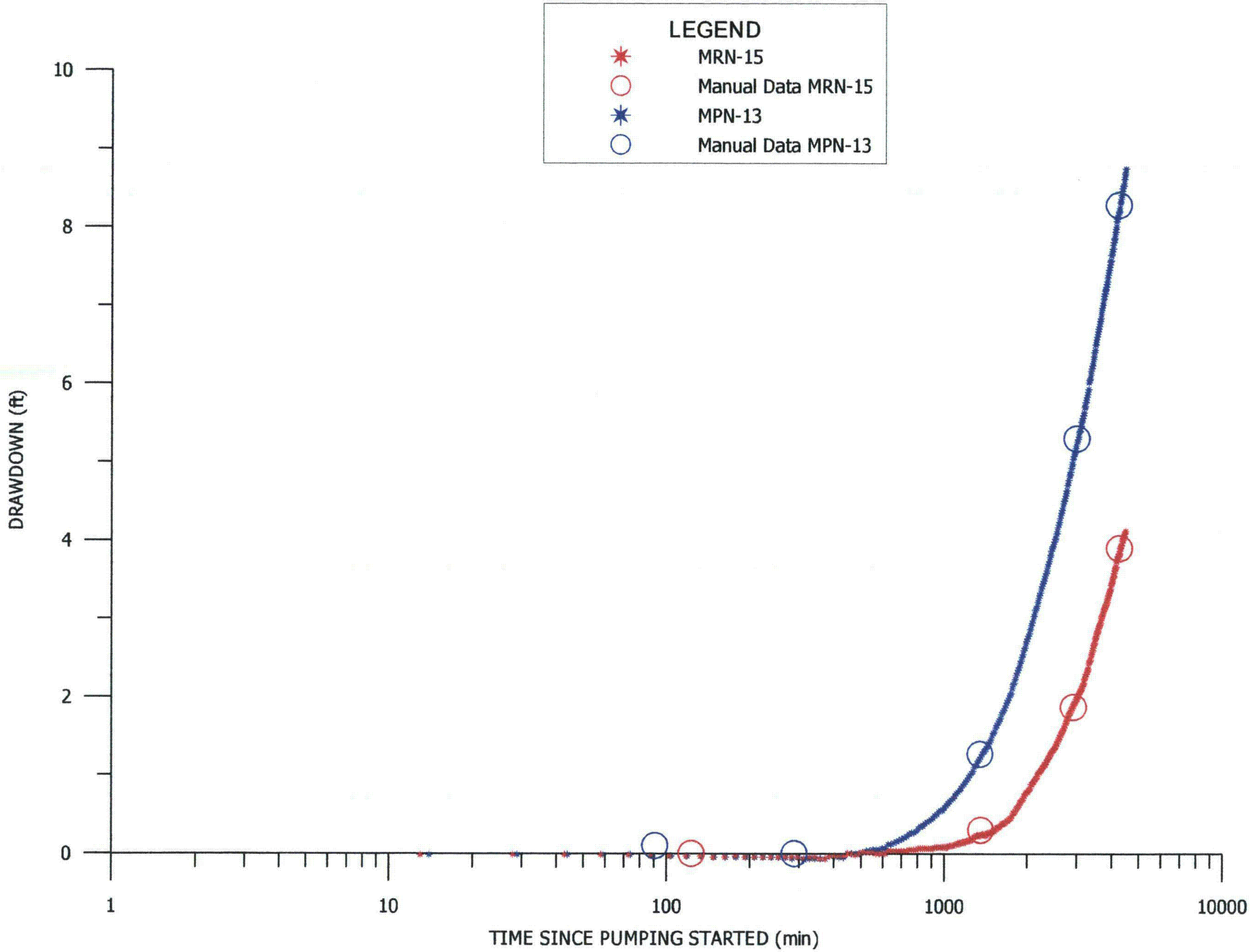

FIGURE 5-28. DRAWDOWN IN OBSERVATION WELL MRN-15 AND MPN-13

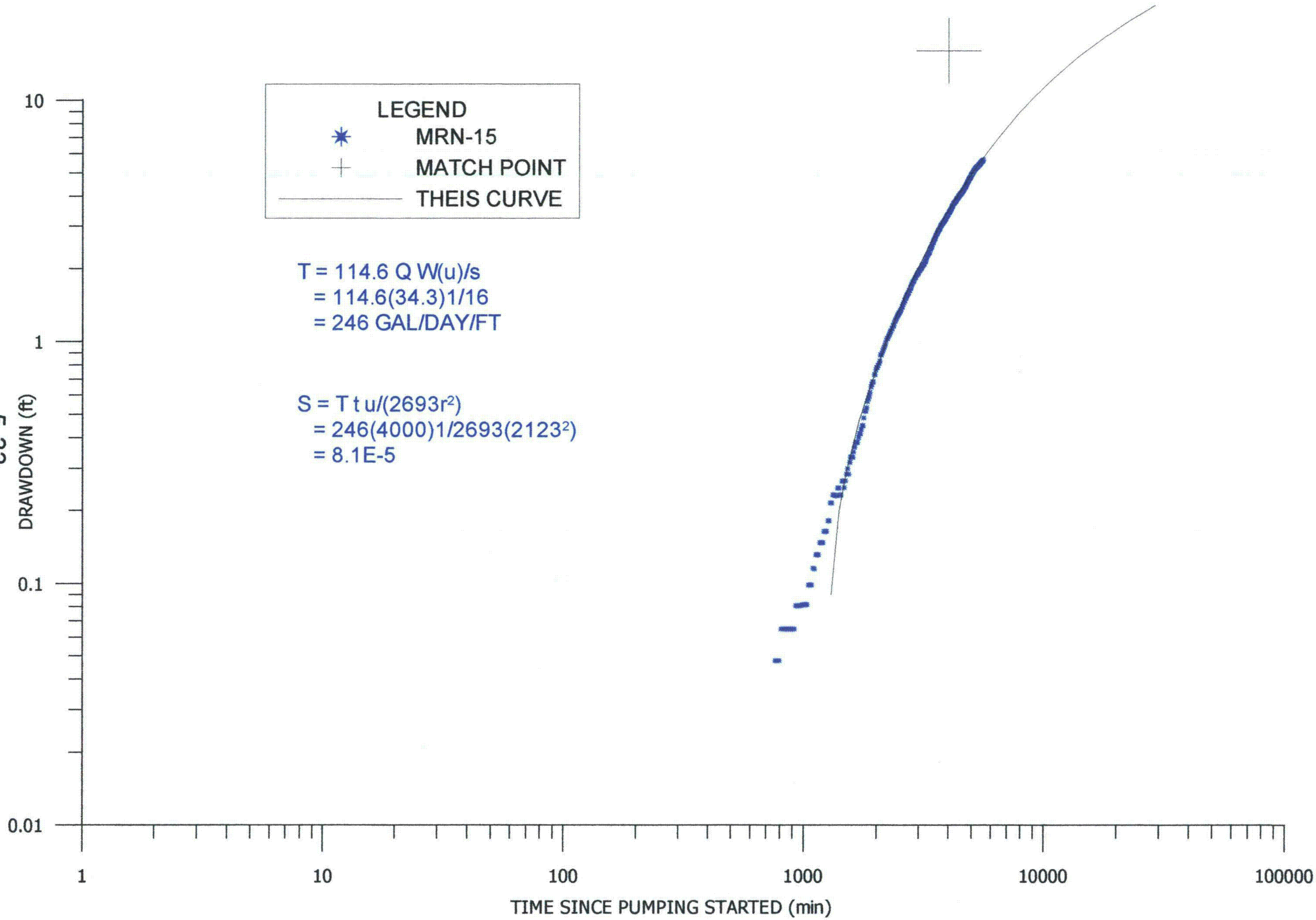

FIGURE 5-29. DRAWDOWN IN OBSERVATION WELL MRN-15, LOG-LOG

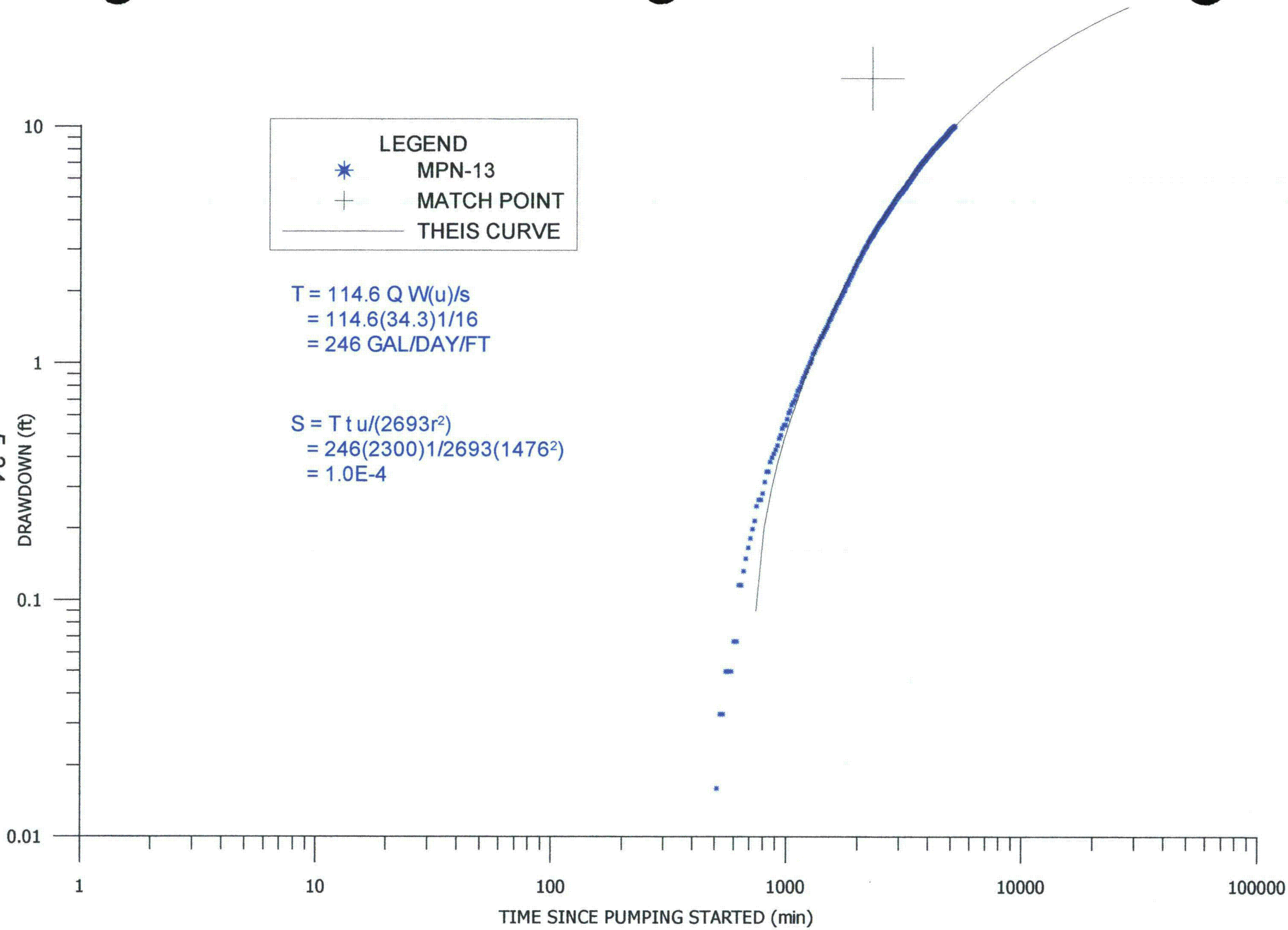

FIGURE 5-30. DRAWDOWN IN OBSERVATION WELL MPN-13, LOG-LOG

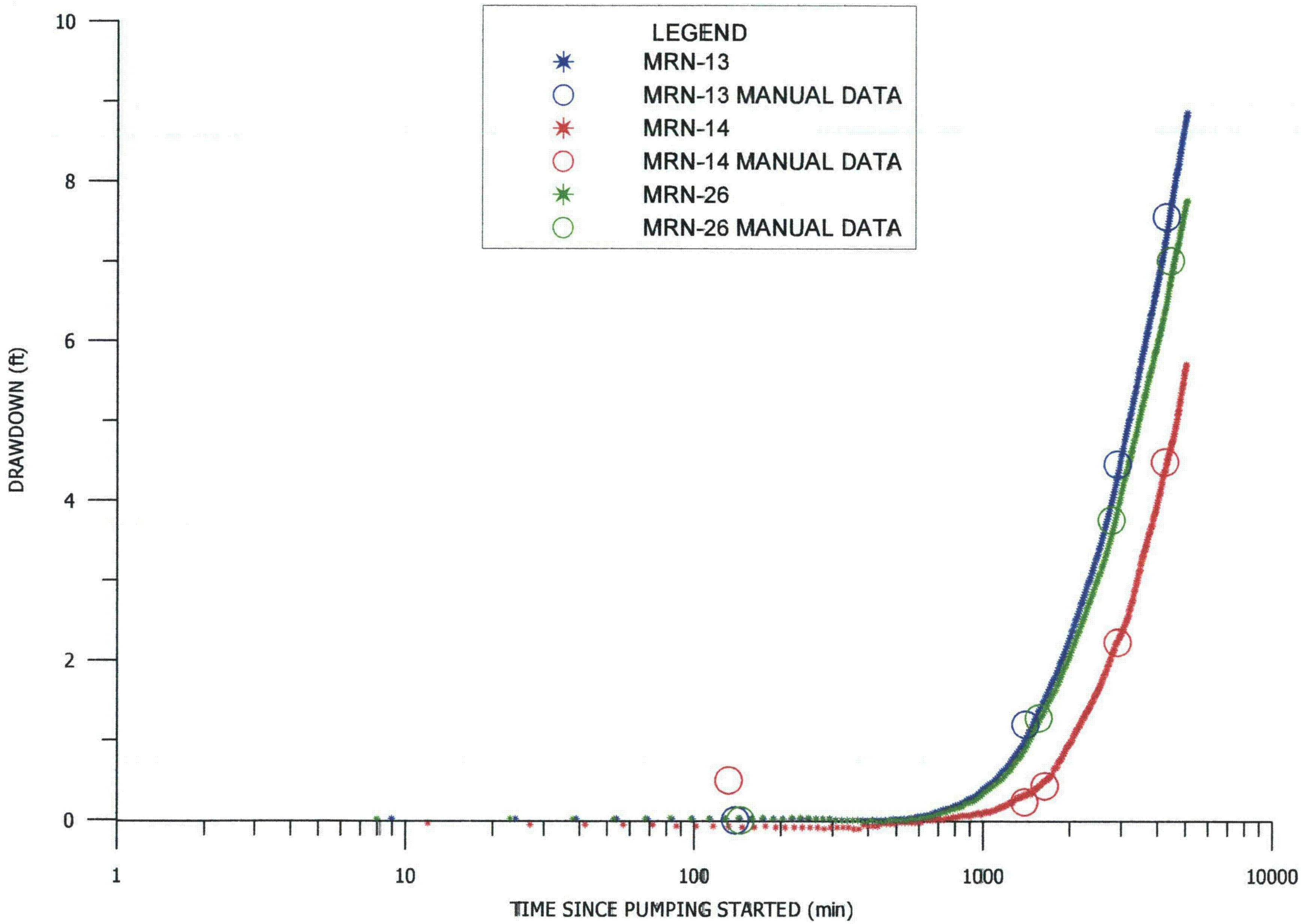

FIGURE 5-31. DRAWDOWN IN OBSERVATION WELLS MRN-13, MRN-14 AND MRN-26

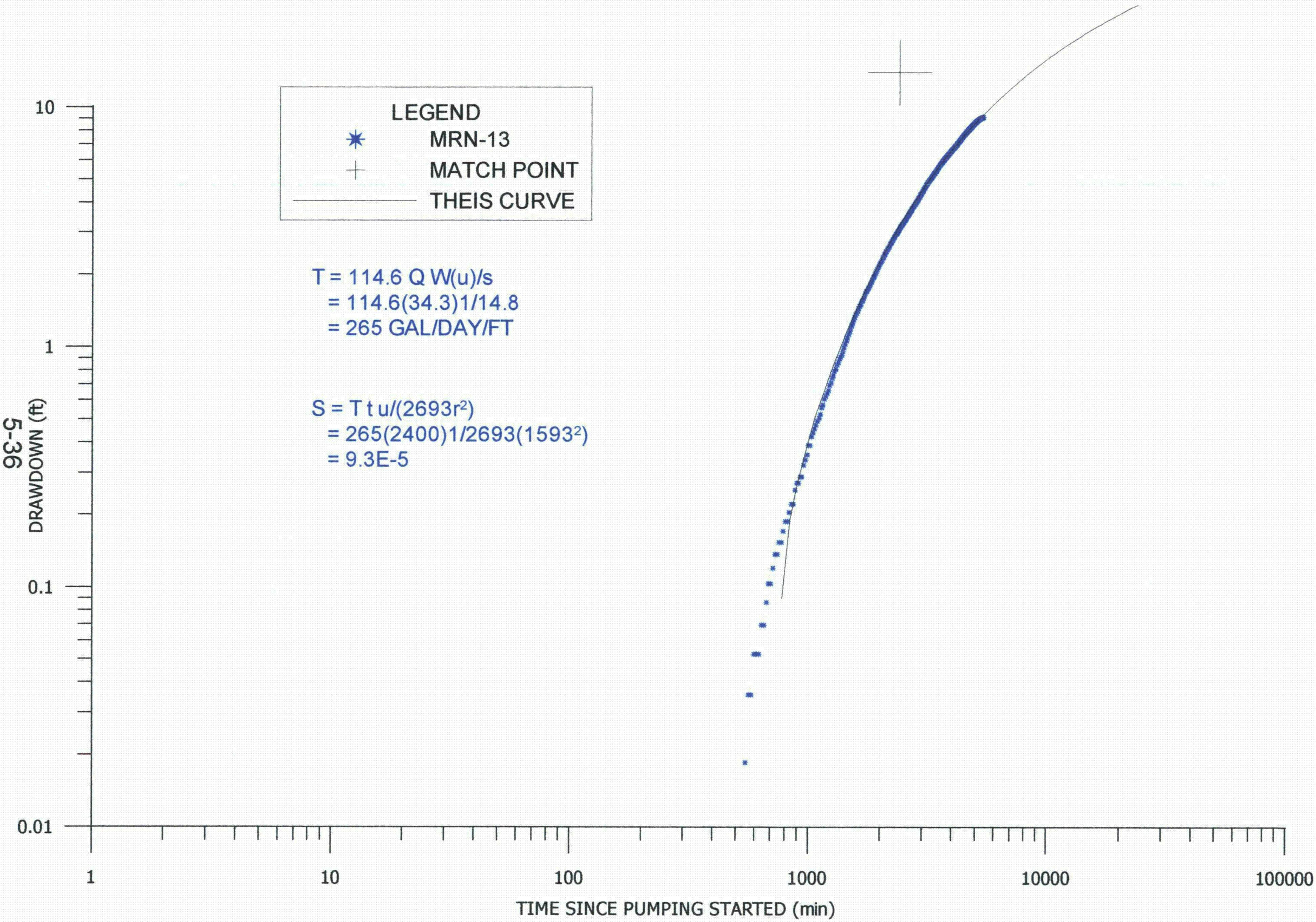

FIGURE 5-32. DRAWDOWN IN OBSERVATION WELL MRN-13, LOG-LOG

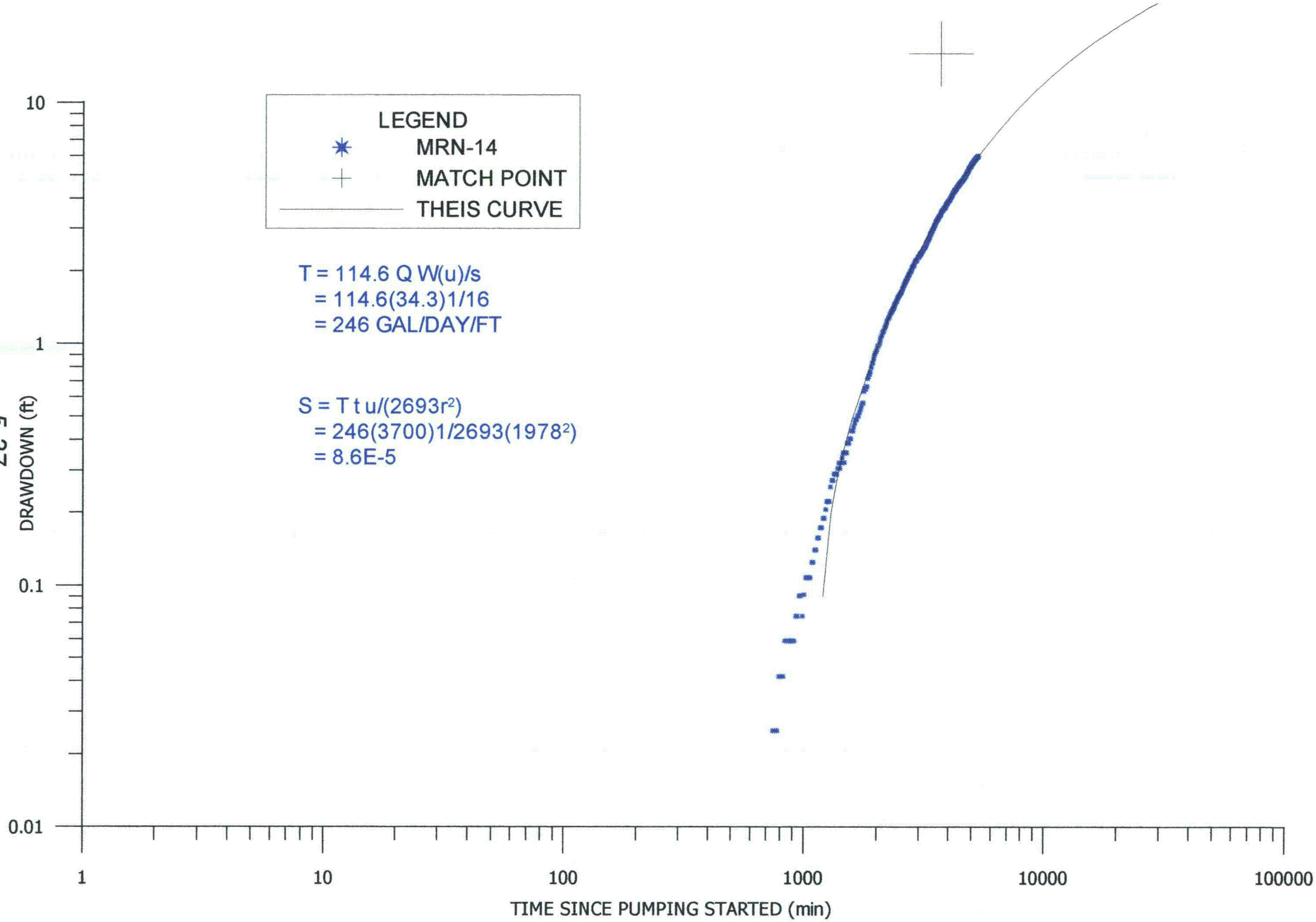

FIGURE 5-33. DRAWDOWN IN OBSERVATION WELL MRN-14, LOG-LOG

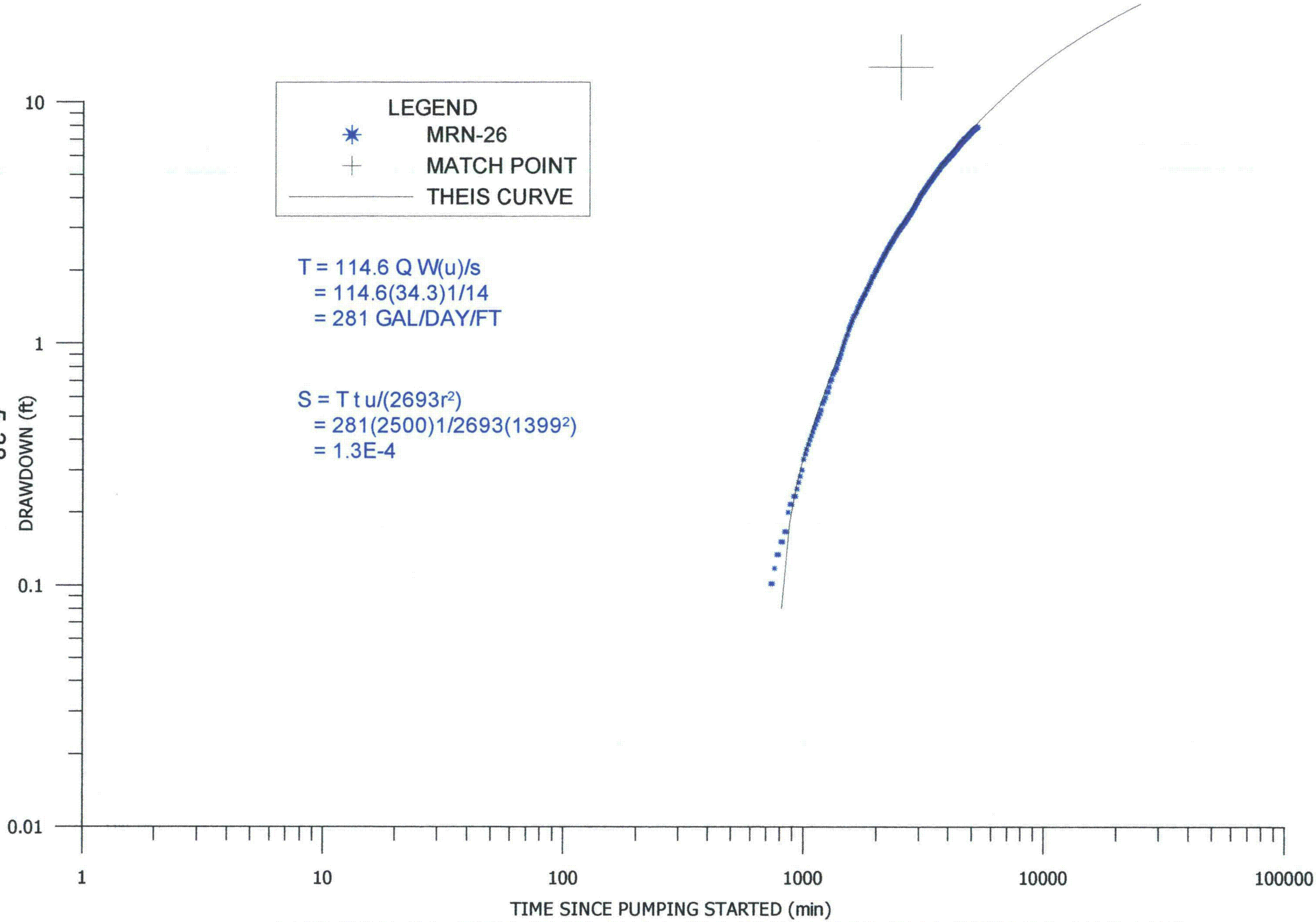

FIGURE 5-34. DRAWDOWN IN OBSERVATION WELL MRN-26, LOG-LOG

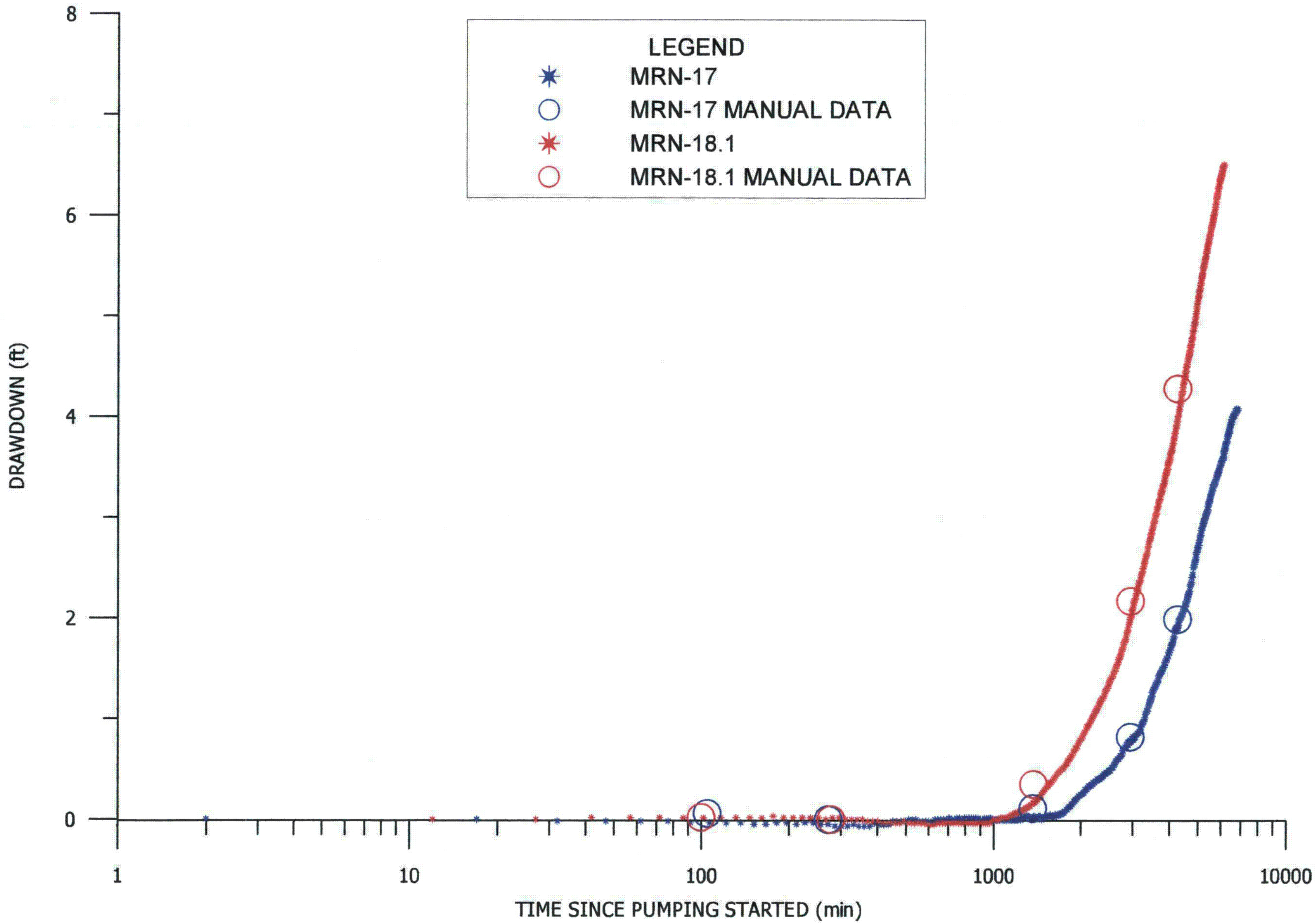

FIGURE 5-35. DRAWDOWN IN OBSERVATION WELLS MRN-17 AND MRN-18.1

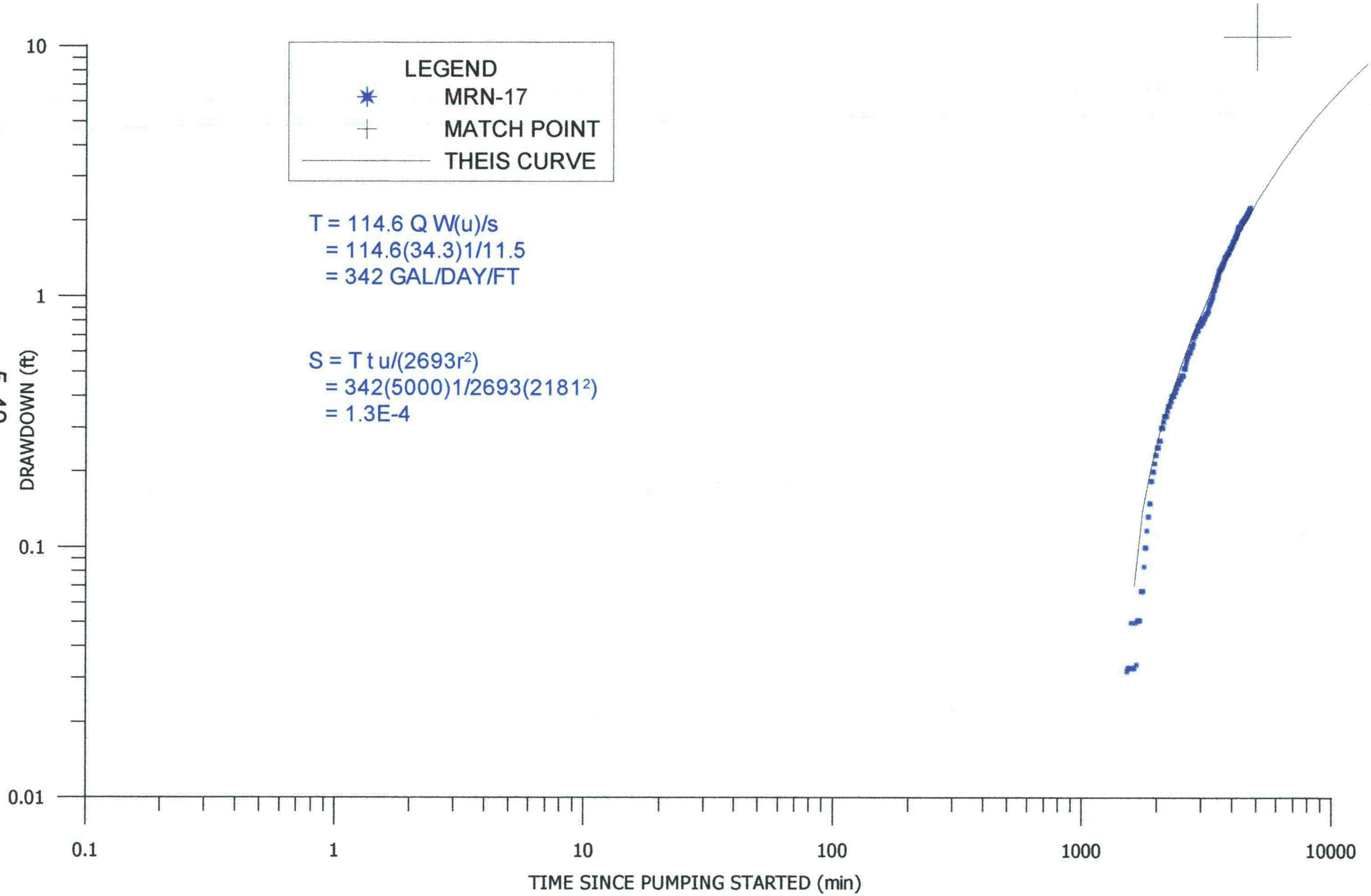

FIGURE 5-36. DRAWDOWN IN OBSERVATION WELL MRN-17, LOG-LOG

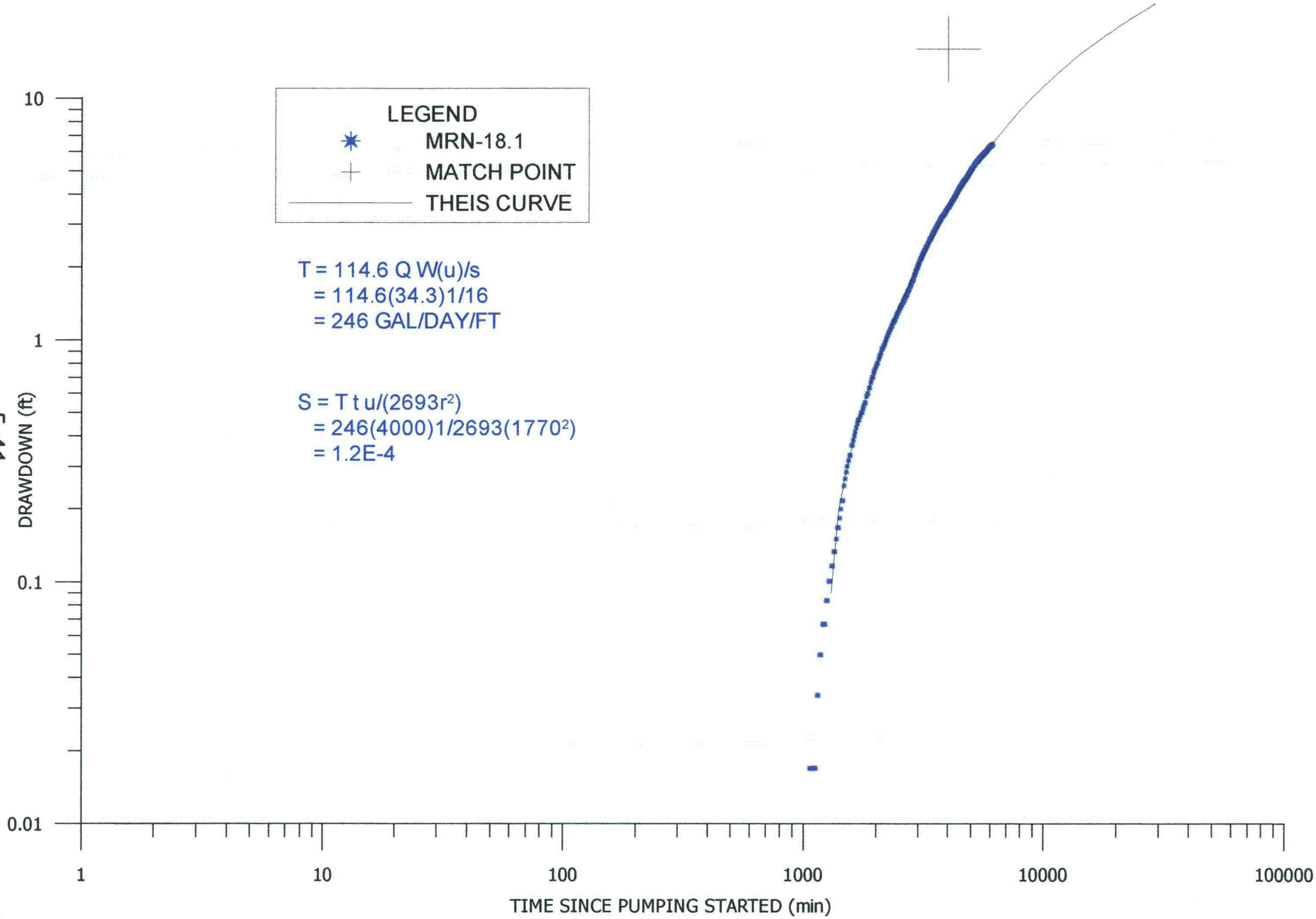

FIGURE 5-37. DRAWDOWN IN OBSERVATION WELL MRN-18.1, LOG-LOG

6.0 TEST RESULTS – CONFINING UNITS FOR MRN-23 TEST

6.1 HYDRAULIC CONDUCTIVITY OF CONFINING UNITS

Confining unit vertical hydraulic conductivities have been defined on some of the sites near Nichols Ranch in the Powder River Basin. Table D6-5a in the Nichols Ranch ISR Project Permit to Mine summarizes the test conducted on the confining units in this area.

The data indicate the vertical conductivities from core and pumping test results range from 1.5 x 10^{-9} cm/sec (4.3 x 10^{-6} ft/d) to 1.0 x 10^{-7} cm/sec (2.84 x 10^{-4} ft/d). Therefore the vertical conductivity of these confining units are considered to be more than adequate to retard connections between the Overlying and Underlying aquifers to the mining zone.

This test was conducted to define the adequacy of the continuity of the aquitards to separate the A Sand from the adjacent aquifers.

6.2 OVERLYING AQUIFERS

Plots of depths of water levels in the Overlying (MON) aquifers for the pre-test, pumping and recovery periods are presented in Figures 6-1 through 6-6 for wells MON-8, MON-9, MON-10, MON-11, MON-12 and MON-13. The water levels are compared to barometric pressure for the entire period. The barometric pressure changes were small during this test, with a change of less than 0.3 inches of mercury during the pumping phase of the test. Corrections for barometric pressure changes were not made due to the small change during this test. Typical barometric pressure coefficients of 0.3 to 0.4 feet of water per inch of mercury would only make small adjustments in the depths to water.

Figure 6-1 contains the depth to water versus time for overlying well MON-8. A very small water level rise occurred during the pumping phase of the test. The overall steady response indicates no connection with the overlying aquifer near well MON-8. Figure 6-2 shows that the water-level in well MON-9 was steady prior to the test. A small water level rise early in the pumping phase and small decline early after the pump was turned off in well MRN-23 were observed in this well. This does not indicate any connection between the overlying and A Production aquifers. This adjacent aquifer response is called the Noordbergum effect and is a pressure response from the adjacent aquifer pumping.

A similar response in overlying wells MON-10 and MON-11 was also observed during the pre-test, the pumping period and during the recovery period. Barometric pressure was not affecting the water level changes very much (see Figures 6-3 and 6-4). Similar steady water levels are shown for overlying wells MON-12 and MON-13 in Figures 6-5 and 6-6 with smaller Noorbergum effects due to less drawdown in the A Sand in the area of these two overlying monitoring wells.

The water level plots for the overlying wells do not indicate any connection between the A Sand production zone and the Overlying B Sand aquifer.

6.3 UNDERLYING AQUIFERS

The Underlying aquifer exists only at the MUN-8 and MUN-9 well clusters in the MRN-23 pump test. Plots of the water level versus time for the Underlying aquifer wells are presented in Figures 6-7 and 6-8 for wells MUN-8 and MUN-9 respectively. The water levels in the Underlying aquifer wells were very gradually declining prior to the start of the MRN-23 pump test. This response continued for Underlying well MUN-8 during the pumping and recovery phases of the test. A small increase in the water level decline occurred in Underlying well MUN-9 during the pumping phase of the test with fairly steady water level during the recovery portion of the test (see Figure 6-8). The pressure response in adjacent aquifers (Noordbergum effect) can also be a water level decline and this small decline that occurs at a similar time to the drawdowns in the A Sand in this area does not indicate connection between the 1 and A Sands.

The water level data collected on the Underlying wells indicates no connection between the A Sand and the Underlying aquifer in the southern half of PA #1 mine area.

6.4 INTERGRITY OF CONFINING UNITS

The MRN-23 test indicates that the southern half of PA #1 has adequate confinement above and below the A Sand such that mining in southern half of PA #1 can proceed in accordance with Permit To Mine No. 778 and License No. SUA-1597.

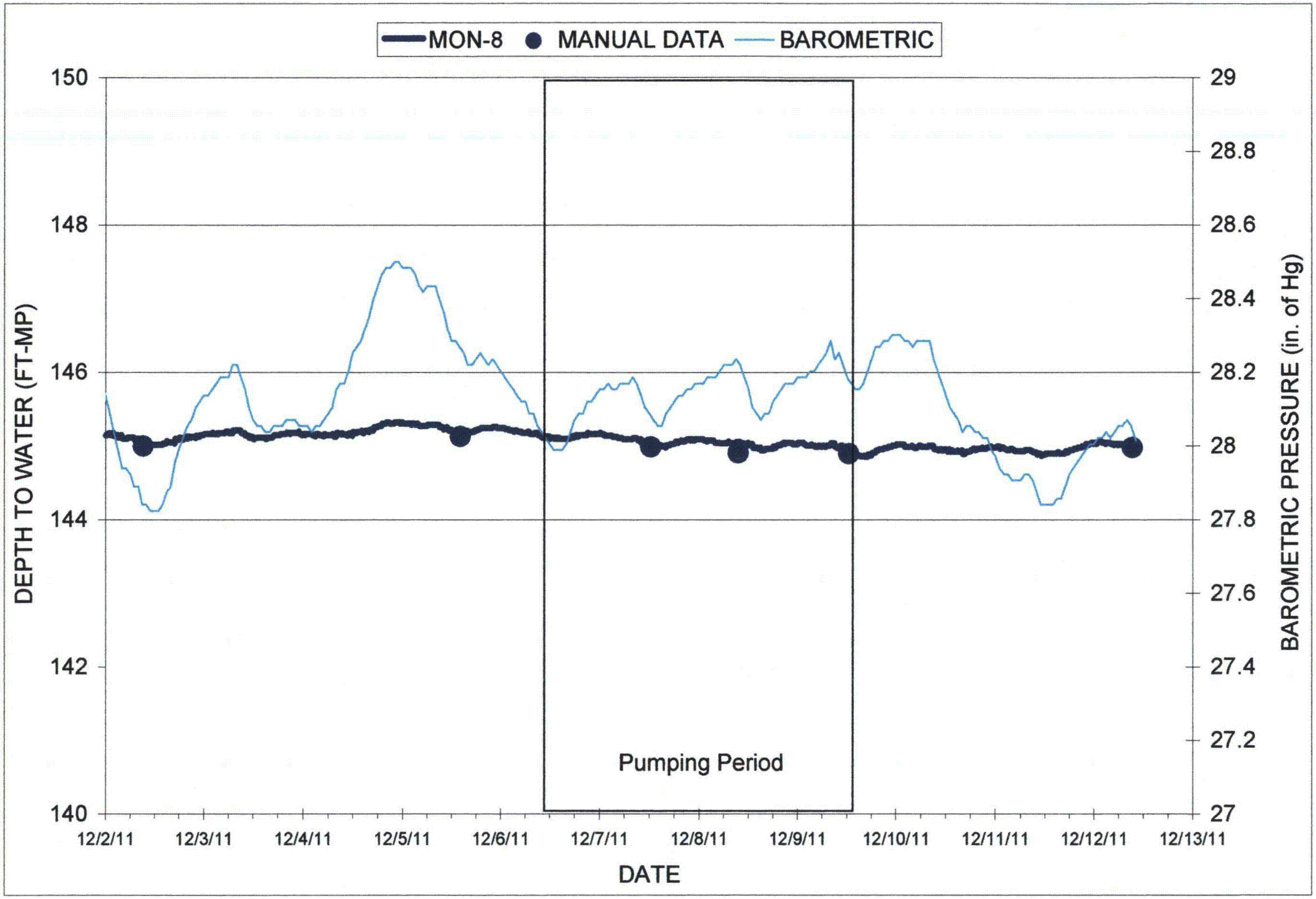

FIGURE 6-1DEPTH TO WATER VERSUS TIME FOR OVERLYING AQUIFER WELL MON-8

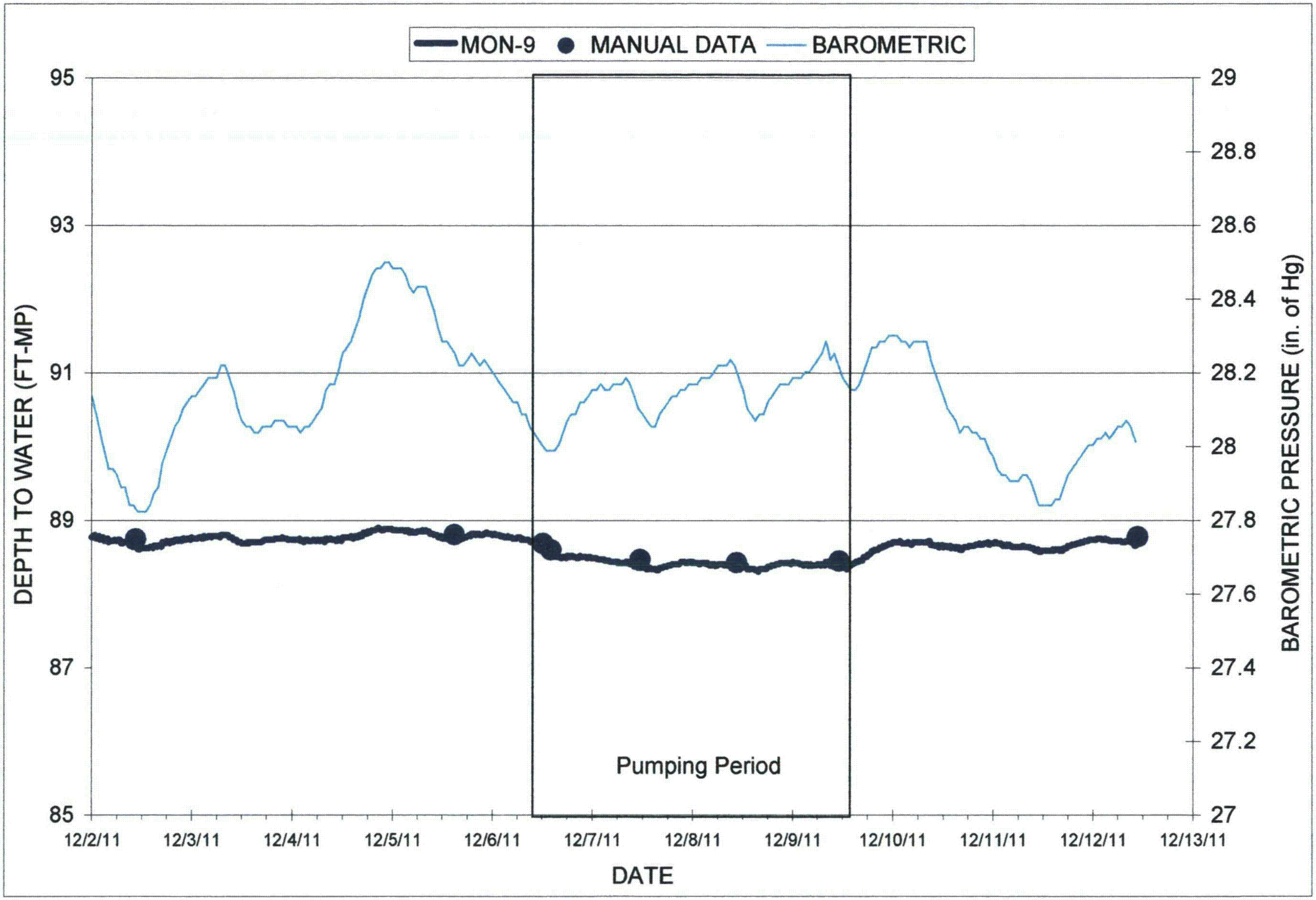

FIGURE 6-2 DEPTH TO WATER VERSUS TIME FOR OVERLYING AQUIFER WELL MON-9

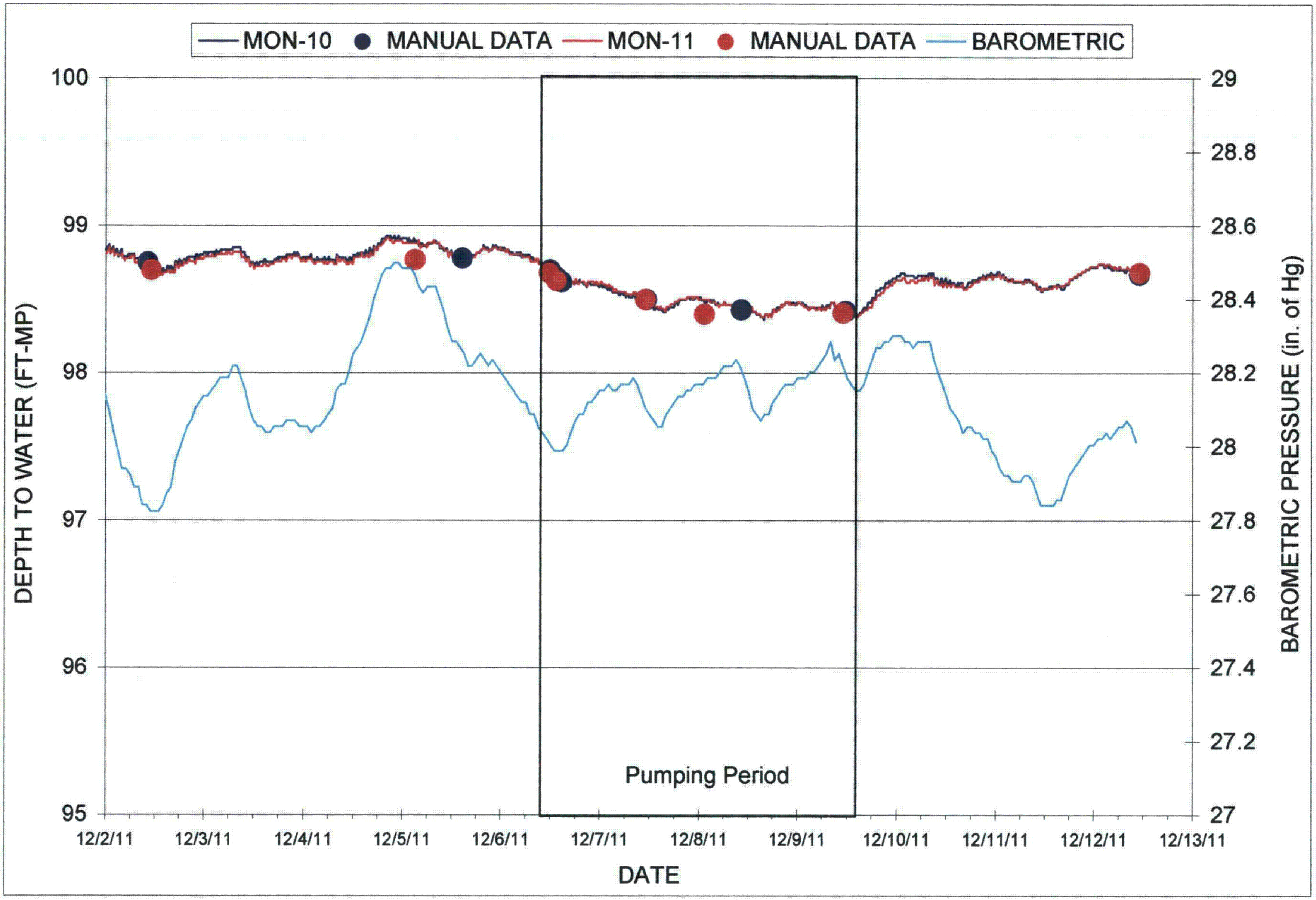

FIGURE 6-3. DEPTH TO WATER VERSUS TIME FOR OVERLYING AQUIFER WELLS MON-10 AND MON-11

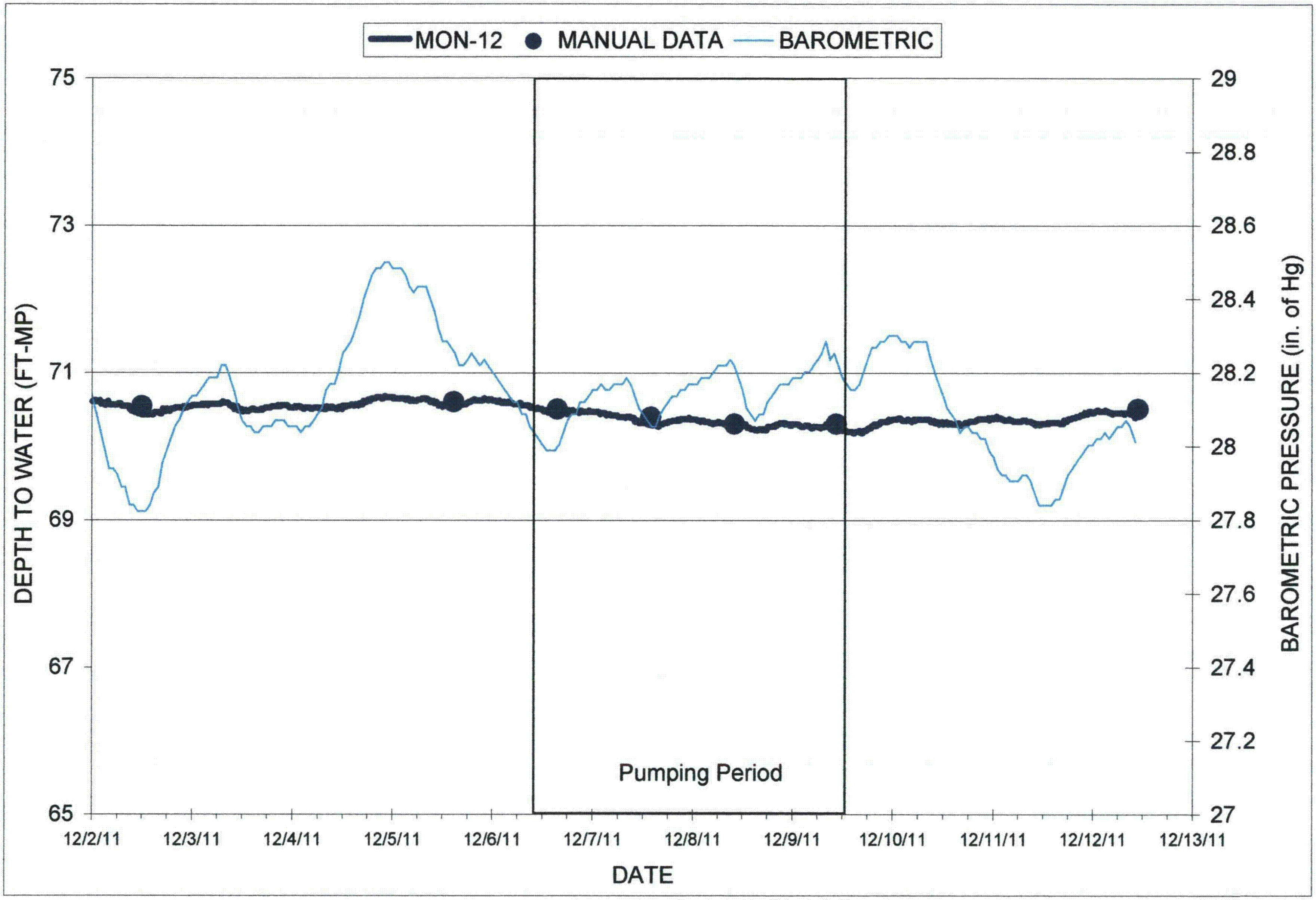

FIGURE 6-4DEPTH TO WATER VERSUS TIME FOR OVERLYING AQUIFER WELL MON-2

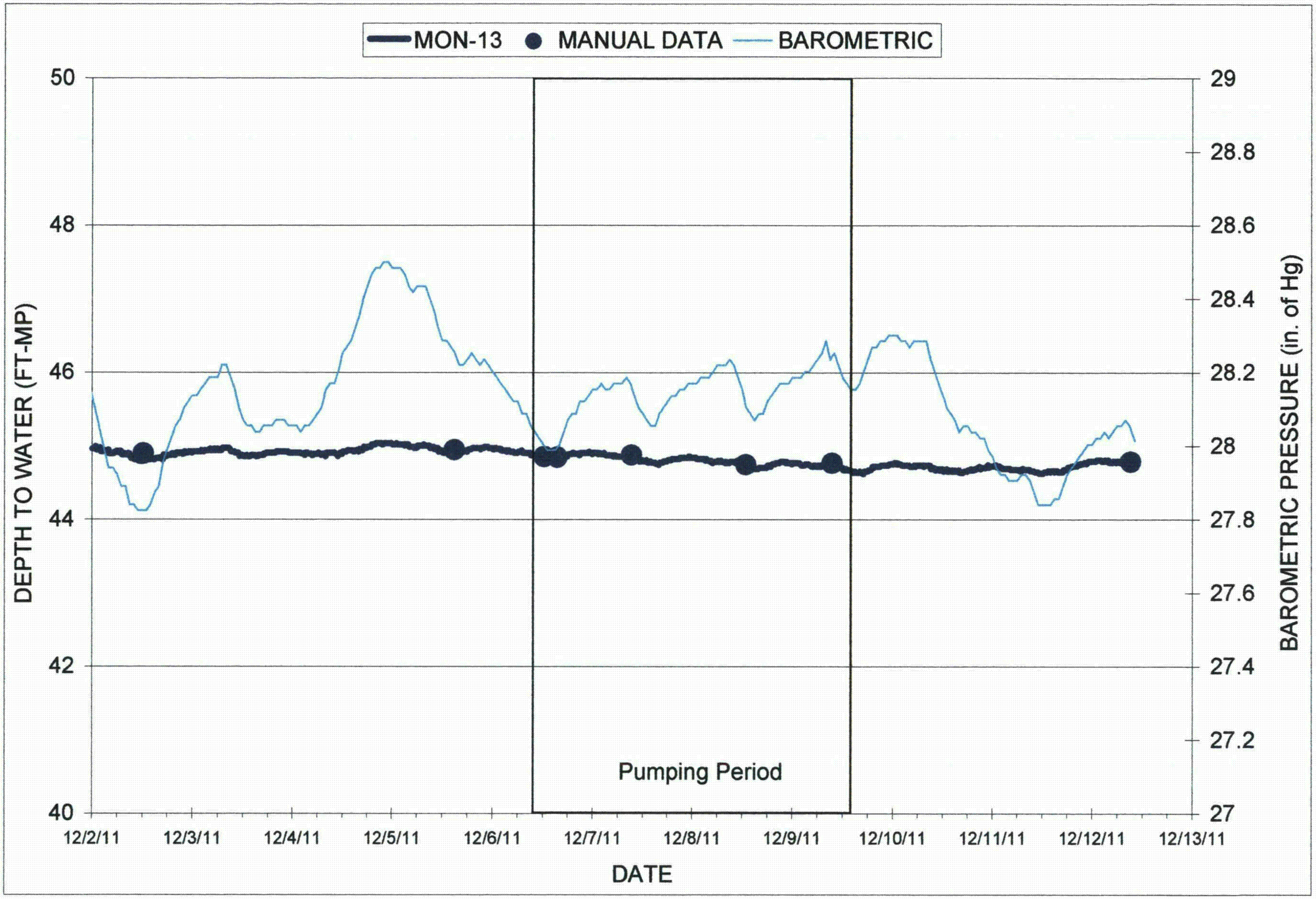

FIGURE 6-5. DEPTH TO WATER VERSUS TIME FOR OVERLYING AQUIFER WELL MON-13

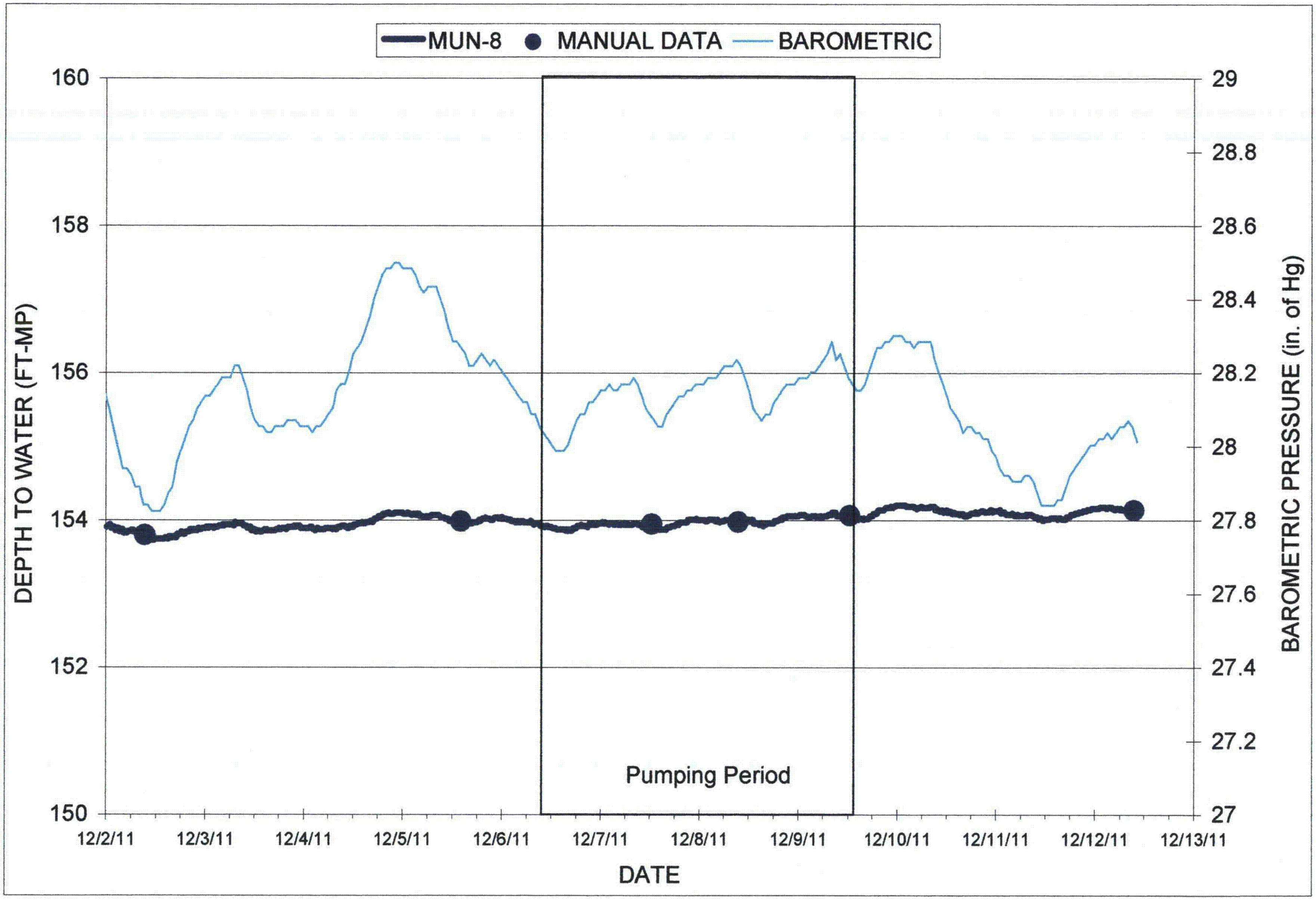

FIGURE 6-6. DEPTH TO WATER VERSUS TIME FOR UNDERLYING AQUIFER WELL MUN-8

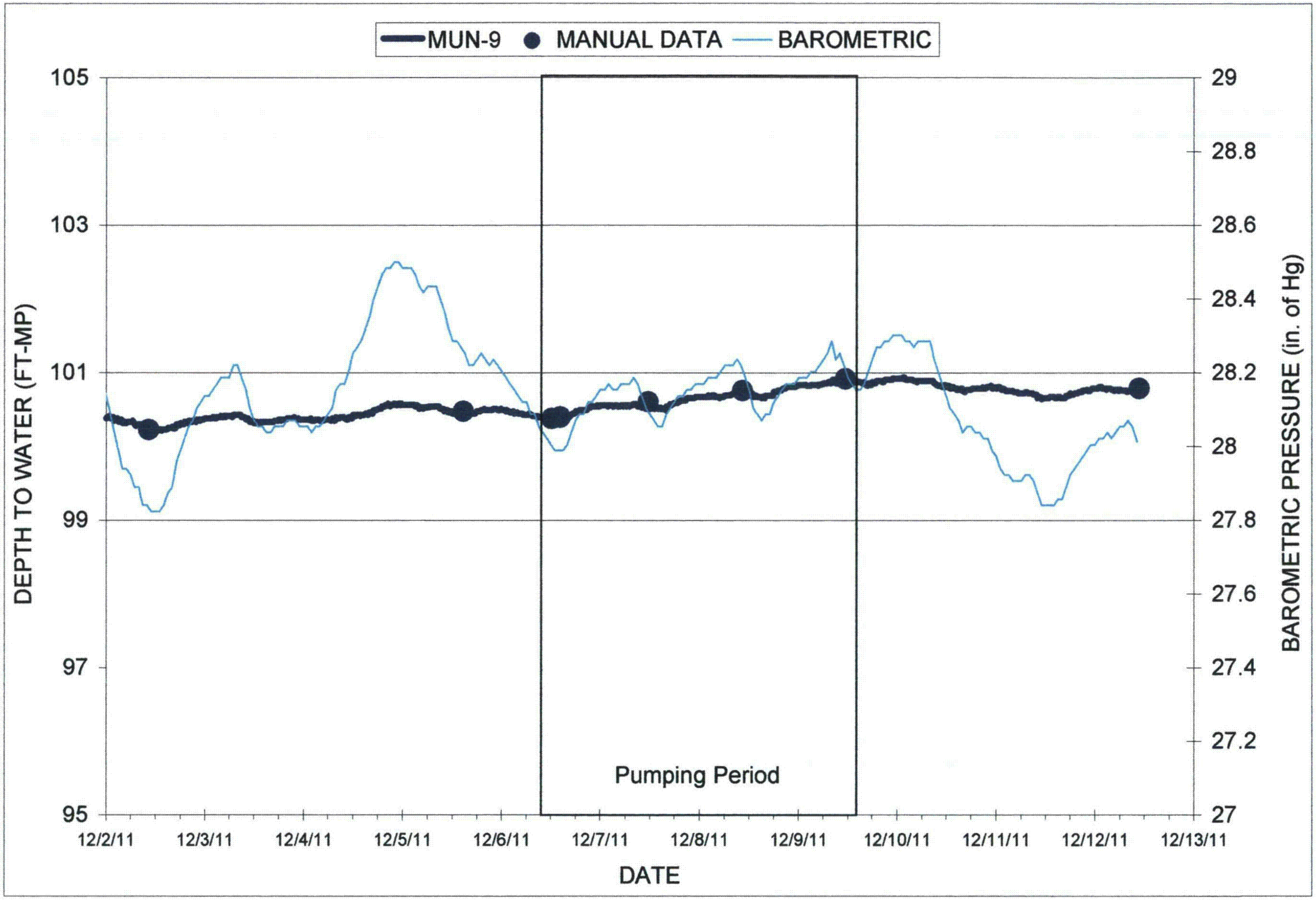

FIGURE 6-7. DEPTH TO WATER VERSUS TIME FOR UNDERLYING AQUIFER WELL MUN-9

7.0 PUMP TEST DESIGN AND WATER-LEVEL DATA FOR MRN-29 TEST

7.1 TEST DESIGN

The MRN-29 pump test was conducted with the following objectives for the northern half of PA #1:

- Demonstrate hydraulic communication between the Production Zone and the surrounding monitor well ring (MRN wells) for the northern half of PA #1;
- Determine the hydrologic characteristics of the Production Zone aquifer;
- Evaluate the presence or absence of hydrologic boundaries within the Production Zone; and,
- Demonstrate sufficient hydrologic isolation between the Production Zone and the Overlying and Underlying sands for the purposes of ISL mining.

The pump tests were designed to cause a minimum of one to two feet of water level drawdown in the A Sand at a radius of 2,500 feet from the pumping well.

Figure 7-1 presents the northern half of the PA #1 wellfield outline and the locations of the pumping and observation (monitoring) wells used during the MRN-29 hydrologic test. The pumping well (MRN-29) was screened across 90 feet of the A Production Sand (Table 3-1). The pump was installed to a depth of 400 feet without a check valve.

The general testing procedures were as follows:

- Install automated monitoring equipment in the wells selected to be used in the test. Verify setting depths and head reading with manual water level measurements.
- Measure and record background water levels at least every 12 hours for a minimum of 48 hours prior to the start of the test.
- Pump the Well MRN-29 at a constant rate (or as close as possible). Record water levels and barometric pressure throughout the background, pumping and recovery periods.

7.2 EQUIPMENT LAYOUT

Prior to the background monitoring period for the test, URZ installed a 35 gpm electric submersible pump. A totalizer meter was used to measure instantaneous flowrate and record total gallons pumped.

The monitoring equipment layout for the test is shown on Figure 7-1. All the monitor wells for the test were equipped with automated water level recorders, Heron Instruments data logger/transducers (see Table 7-2). Water levels were also measured periodically by hand to verify that the automated equipment was functioning properly. The pumping equipment performed as designed, except for a generator failure during the third day of the test. The generator was replaced and the pump test was continued through three days of pumping. For consistency, occasional erroneous data (e.g., inaccurate readings that resulted when the equipment tried to log data during a data download) were edited out of the database.

Prior to the test, HYDRO personnel selected the data logger/transducer layout. HYDRO personnel installed the monitoring equipment prior to testing and provided day-to-day downloads.

The monitor wells used for the test, distance from each monitor well to the pumping well, and the drawdown observed are presented in Table 7-1. The equipment layout and head ratings for each transducer, is shown on Table 7-2. Figure 7-1 shows the location of the data loggers/transducers. Appendix D presents the tabulation of water levels for all of the MRN-29 pump test wells.

7.3 BACKGROUND MONITORING, TEST PROCEDURES AND DATA COLLECTION

A potentiometric map for the A Sand, based on water levels prior to the start of each of the two tests, is shown in Figure 2-11. The water levels measured prior to the MRN-23 test are presented in orange while the water levels prior to the MRN-29 test are presented in black. These static water levels for December 2011 and February 2012 present similar water level elevations as those presented in the Nichols Ranch ISR Project permit. Pre-test water level monitoring data along with the pumping and recovery period data for the A Sand monitoring wells are shown on Figures 7-2 through 7-11. These plots present the depth to water versus time on a linear scale. A tabulation of the water level data is presented in Appendix D.

The pump test was performed by pumping MRN-29 at an average rate of 33.3 gpm from 10:40 on February 15, 2012 until 13:00 on February 18, 2012. The one hour and 34 minutes when the pump was off due to generator failure was not used calculating the average. The total pumping duration was over 74 hours (4,460 minutes). The drawdown achieved in the pumping well was 197.1 feet; drawdown in the A Sand monitoring wells ranged from 3.4 to 36.0 feet (Table 7-1). Water levels were automatically measured and recorded at a maximum interval of 15 minutes during the pumping and recovery periods. The pumping well transducer readings were recorded every 5 minutes. Pumping rate data for the test are shown on Table 7-3. Water level recovery was monitored for 69 hours. A list of A Sand monitoring wells, the distance of those wells from the pumping well, and the drawdown measured during the pumping period for all the wells are summarized in Table 7-1.

Table 7-1.
MONITORING WELL DISTANCE, STATIC WATER-LEVEL BEFORE TEST AND MAXIMUM DRAWDOWN DURING THE MRN-29 TEST

1st Start Date & Time	2/15/2012 10:40				
1st End Date & Time	2/17/2012 8:06				
2nd Start Date & Time	2/17/2012 9:40				
2nd End Date & Time	2/18/2012 13:00				
Duration	4366 min.				
Avg. Pumping Rate	33.3 G.P.M.				
Pumping Well	MRN-29	Distance from Pumping Well (ft)	Depth to Water Before Test (ft)	Water Elevation Before Test (ft)	Maximum Drawdown During Test (ft)
Monitoring Wells					
	MRN-29	0	165.70	4656.08	197.1
Ore Zone Completions	MPN-1.1	1190	151.54	4650.55	11.1
	MPN-2	1208	154.32	4651.71	11.9
	MPN-3	614	201.74	4651.04	20.3
	MPN-4	770	189.36	4656.37	20.4
	MPN-5	1148	147.74	4659.07	11.5
	MPN-6	1339	170.92	4661.34	7.0
	MPN-7	1510	190.73	4661.09	5.7
	MPN-8.1	1879	145.67	4662.63	3.4
	MRN-1	2038	125.86	4652.29	5.3
	MRN-2.1	1849	165.57	4653.95	6.2
	MRN-3.1	1534	193.46	4654.76	7.6
	MRN-4	1325	198.57	4655.02	9.2
	MRN-5	1294	208.32	4656.76	5.1
	MRN-6	1534	177.57	4658.39	9.1
	MRN-7	1724	166.55	4660.17	6.2
	MRN-8	2017	154.37	4661.63	3.8
	MRN-27	830	110.00	4658.59	18.2
	MRN-28	443	148.18	4654.29	36.0
	MRN-30	490	230.06	4655.39	27.4
	MRN-31	983	186.20	4654.94	14.3
	MRN-32	1434	158.79	4653.30	8.4
	MRN-33	1766	183.41	4653.21	5.9
	MRN-34.1	2042	138.05	4654.50	4.1
Overlying Completions	MON-1	1181	159.90	4649.99	*
	MON-2	1182	157.14	4654.63	*
	MON-3	808	192.44	4650.56	*
	MON-4	1280	190.38	4660.58	*
	MON-5	1119	144.18	4661.30	*
	MON-6	1280	162.15	4661.87	*
	MON-7	1476	191.56	4663.30	*
Underlying Completions	MUN-1.1	1136	155.40	4647.40	*
	MUN-2	1228	158.02	4647.39	*
	MUN-3	638	201.28	4647.35	*
	MUN-4	795	196.03	4647.49	*
	MUN-5.1	1127	159.96	4640.13	*
	MUN-6	1293	172.81	4647.93	*
	MUN-7	1545	202.16	4647.56	*

Note: * = No Drawdown Observed
e = estimated maximum drawdown because water level was

TABLE 7-2.
DATA LOGGER AND TRANSDUCER EQUIPMENT FOR MONITORING WELLS FOR THE MRN-29 TEST

	Well Name	Transducer Number
Monitoring Wells		
	MRN-29	D01388
Ore Zone Completions	MPN-1.1	B04093
	MPN-2	B04085
	MPN-3	C04159
	MPN-4	B04097
	MPN-5	B04192
	MPN-6	B04183
	MPN-7	B04108
	MPN-8.1	B04128
	MRN-1	B04132
	MRN-2.1	B04082
	MRN-3.1	B04086
	MRN-4	B04101
	MRN-5	B04209
	MRN-6	B04091
	MRN-7	B04473
	MRN-8	B04094
	MRN-27	B04104
	MRN-28	C01337
	MRN-30	C04167
	MRN-31	B04105
	MRN-32	B01388
	MRN-33	B01349
	MRN-34.1	B04102
Overlying Completions	MON-1	B04106
	MON-2	B04152
	MON-3	B04109
	MON-4	B04154
	MON-5	B04164
	MON-6	B04099
	MON-7	B04166
Underlying Completions	MUN-1	B01348
	MUN-2	B04092
	MUN-3	B04084
	MUN-4	B03589
	MUN-5.1	B03564
	MUN-6	B04090
	MUN-7	B04168

Note: Transducers have a max depth of measuring
B series = max of 35ft
C series = max of 100ft
D series = max of 200ft

Table 7-3.
PUMPING RATE AND FIELD SAMPLING VERSUS TIME FOR PUMPING WELL MRN-29

DATE/TIME	TOTALIZER (GAL)	METER (GPM)	FIELD SAMPLING		
			pH	CONDUCTIVITY (µS)	Temp (C°)
2/14/12 8:45 AM	238714				
2/14/12 8:50 AM	PUMP ON	35.3			
2/14/12 8:55 AM		34.6			
2/14/12 9:00 AM		34.3			
2/14/12 9:11 AM		34.3			
2/14/12 9:20 AM	239790				
2/14/12 9:21 AM	PUMP ON				
2/14/12 9:25 AM	PUMP OFF				
2/14/12 9:35 AM		34.0			
2/14/12 9:43 AM	PUMP OFF				
2/14/12 10:22 AM	240414				
2/14/12 10:22 AM	PUMP ON				
2/14/12 10:40 AM		34.0			
2/14/12 10:50 AM		33.6			
2/14/12 11:10 AM			8.82	540	15.6
2/14/12 12:15 PM		33.7			
2/14/12 12:20 PM	PUMP OFF				
2/14/12 12:20 PM	PUMP ON				
2/14/12 12:46 PM	245090				
2/14/12 12:55 PM	PUMP OFF				
2/15/12 8:00 AM	246358				
2/15/12 10:40 AM	***PUMP ON***				
2/15/12 11:00 AM		34.4			
2/15/12 11:30 AM		33.3			
2/15/12 2:57 PM	254098	34.2			
2/16/12 8:20 AM	289300	33.5			
2/16/12 8:40 AM			8.65	550	15.2
2/16/12 1:22 PM	299440	33.7			
2/17/12 8:06 AM	PUMP OFF	33.9			
2/17/12 8:10 AM	336858				
2/17/12 9:40 AM	PUMP ON				
2/17/12 2:46 PM			8.67	538	15.3
2/17/12 2:47 PM	346840				
2/18/12 8:20 AM	381300				
2/18/12 8:23 AM			8.77	541	15.4
2/18/12 12:58 PM	390180				
2/18/12 1:00 PM	***PUMP OFF***				

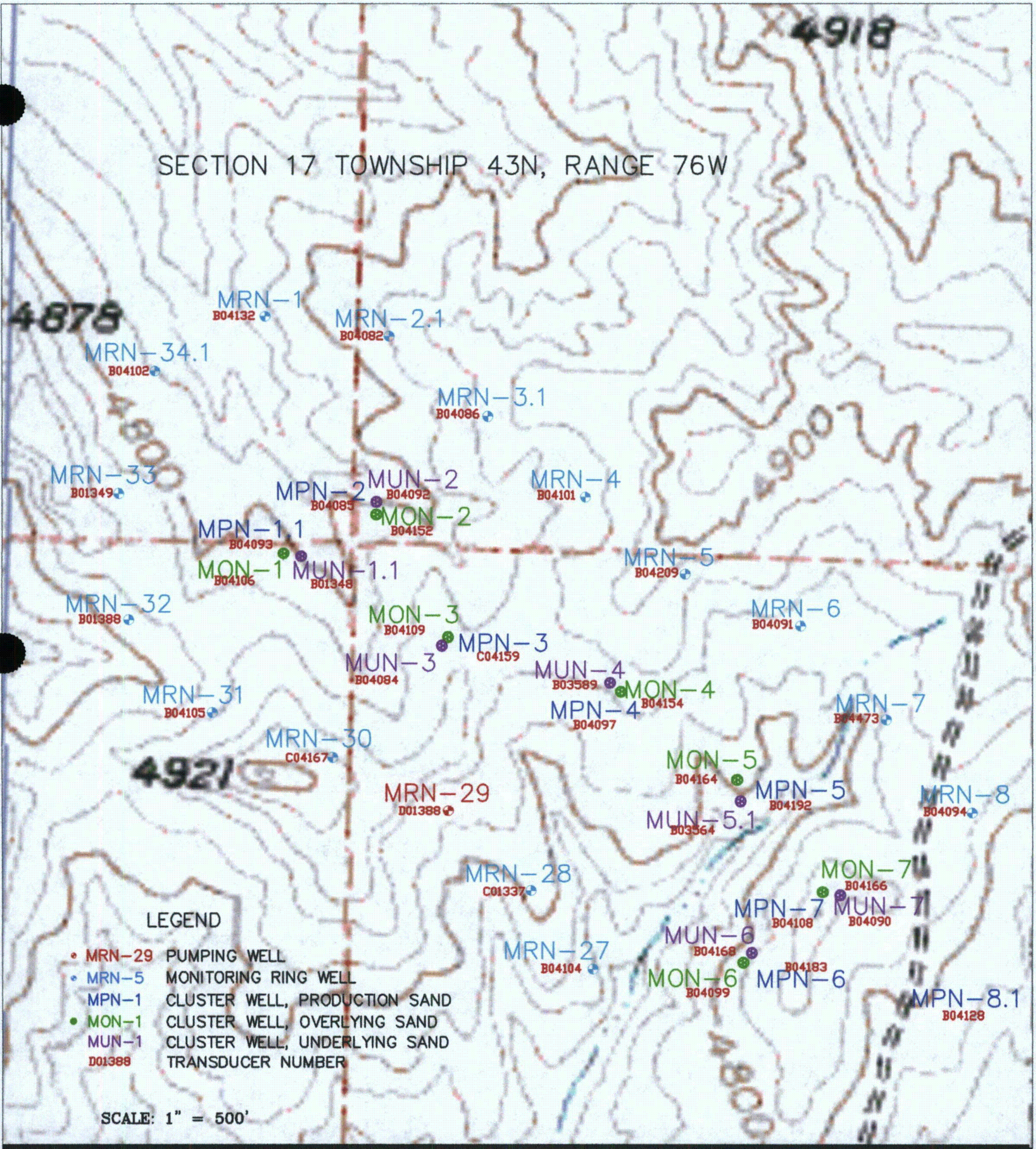

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Figure 7-1
Monitoring Well Locations and Transducer Equipment Layout for the MRN-29 Test

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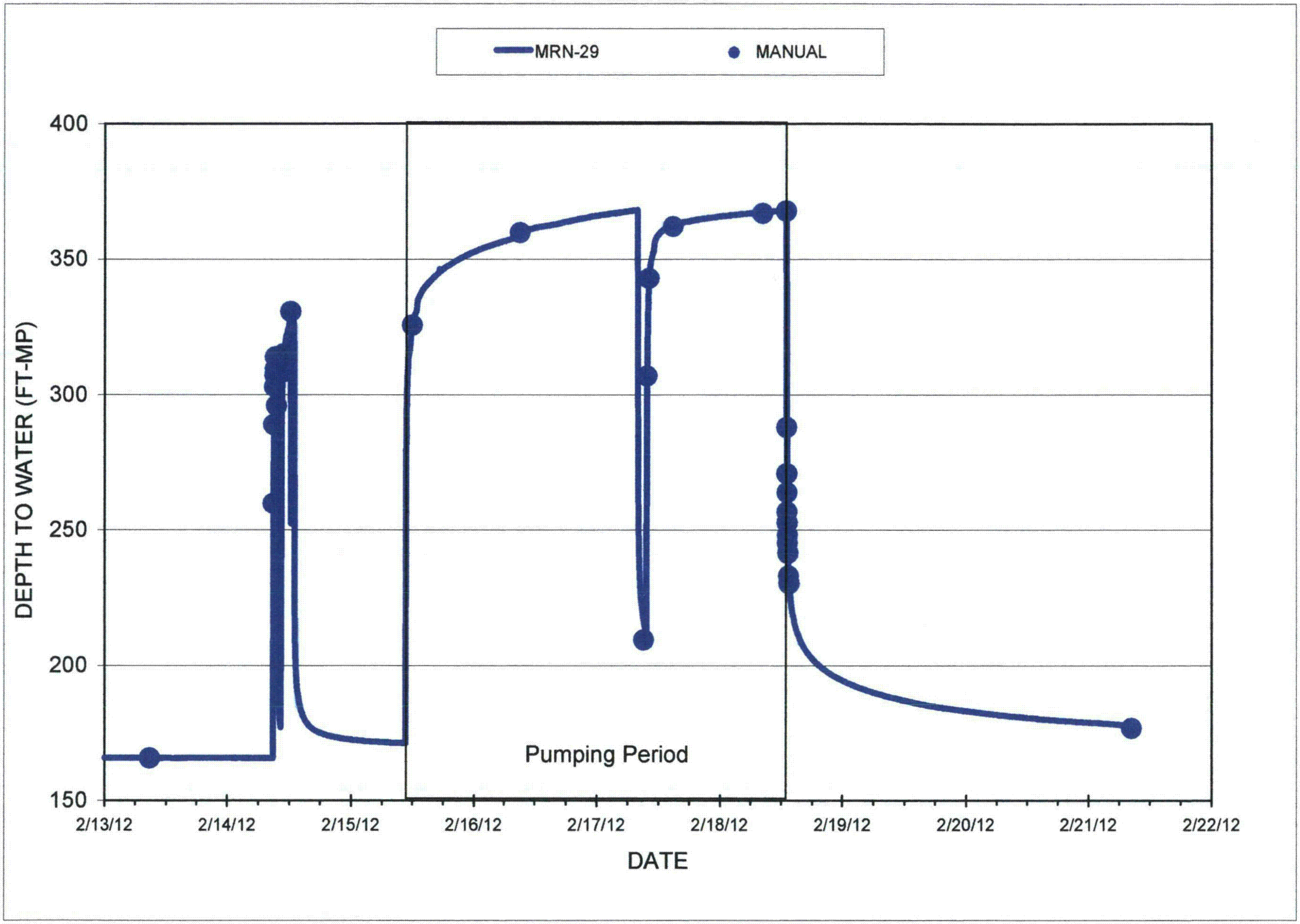


FIGURE 7-2. DEPTH TO WATER VERSUS TIME FOR PUMPING WELL MRN-29

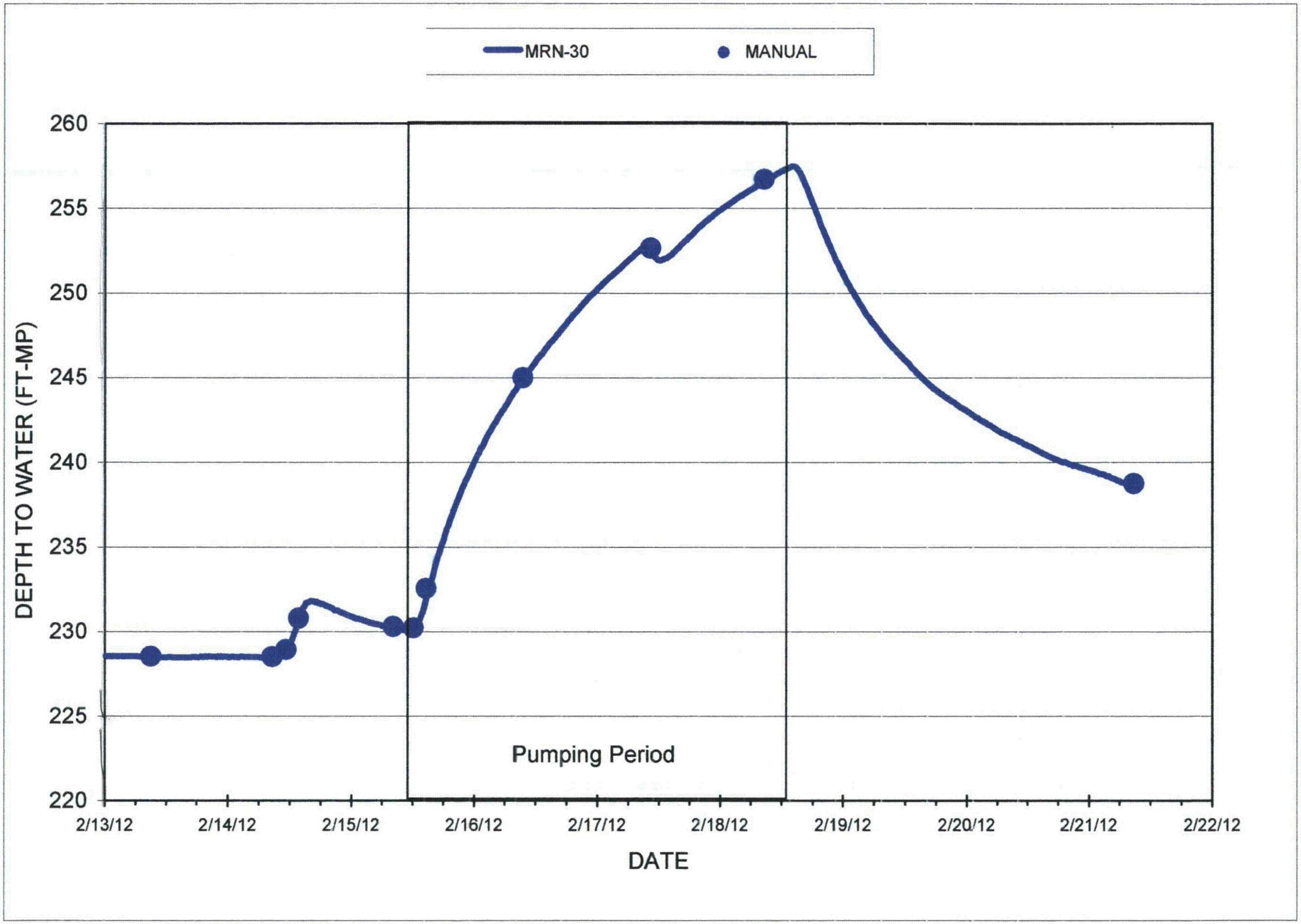


FIGURE 7-3. DEPTH TO WATER VERSUS TIME FOR OBSERVATION WELL MRN-30

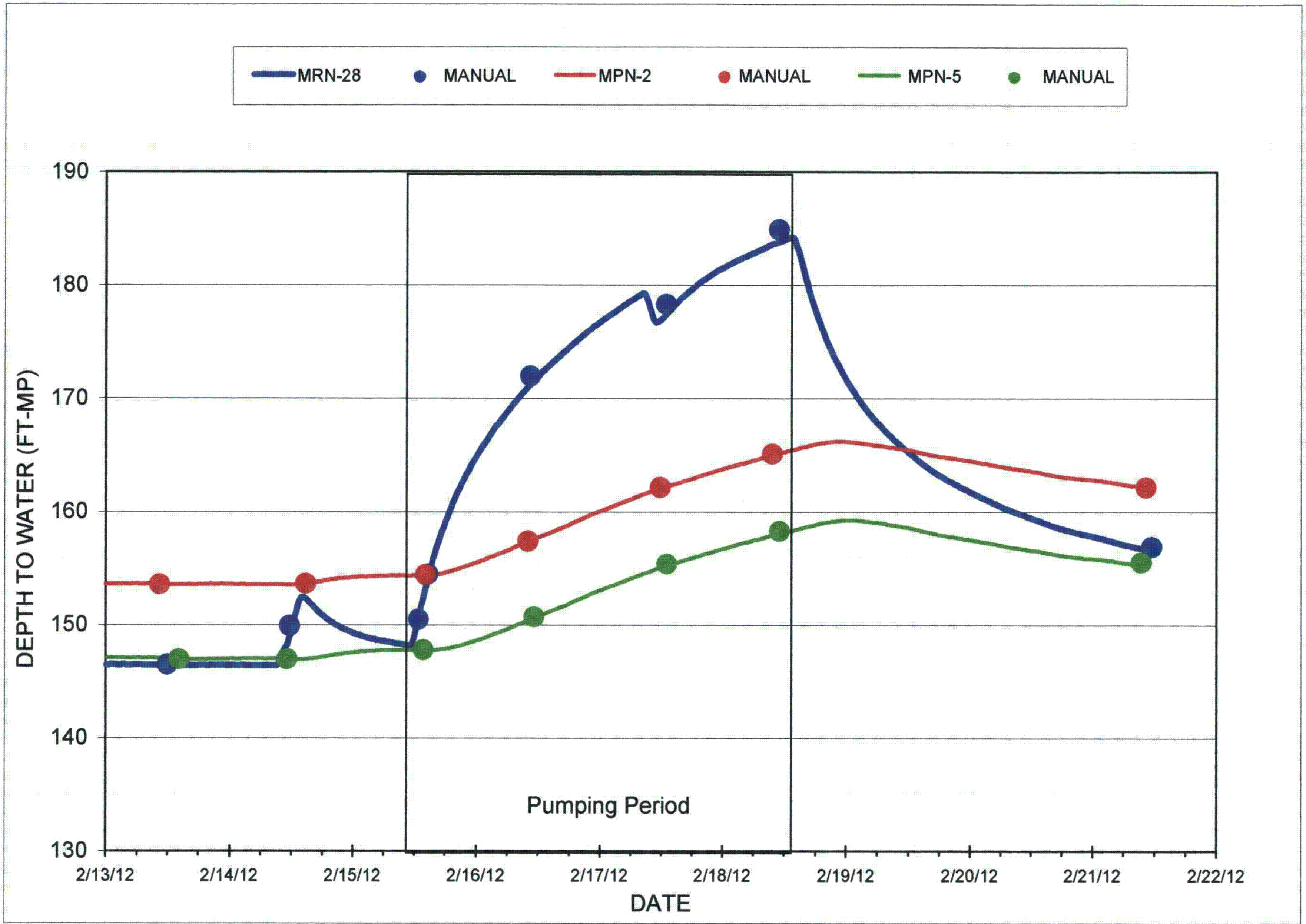


FIGURE 7-4. DEPTH TO WATER VERSUS TIME FOR OBSERVATION WELLS MRN-28, MPN-2 AND MPN-5

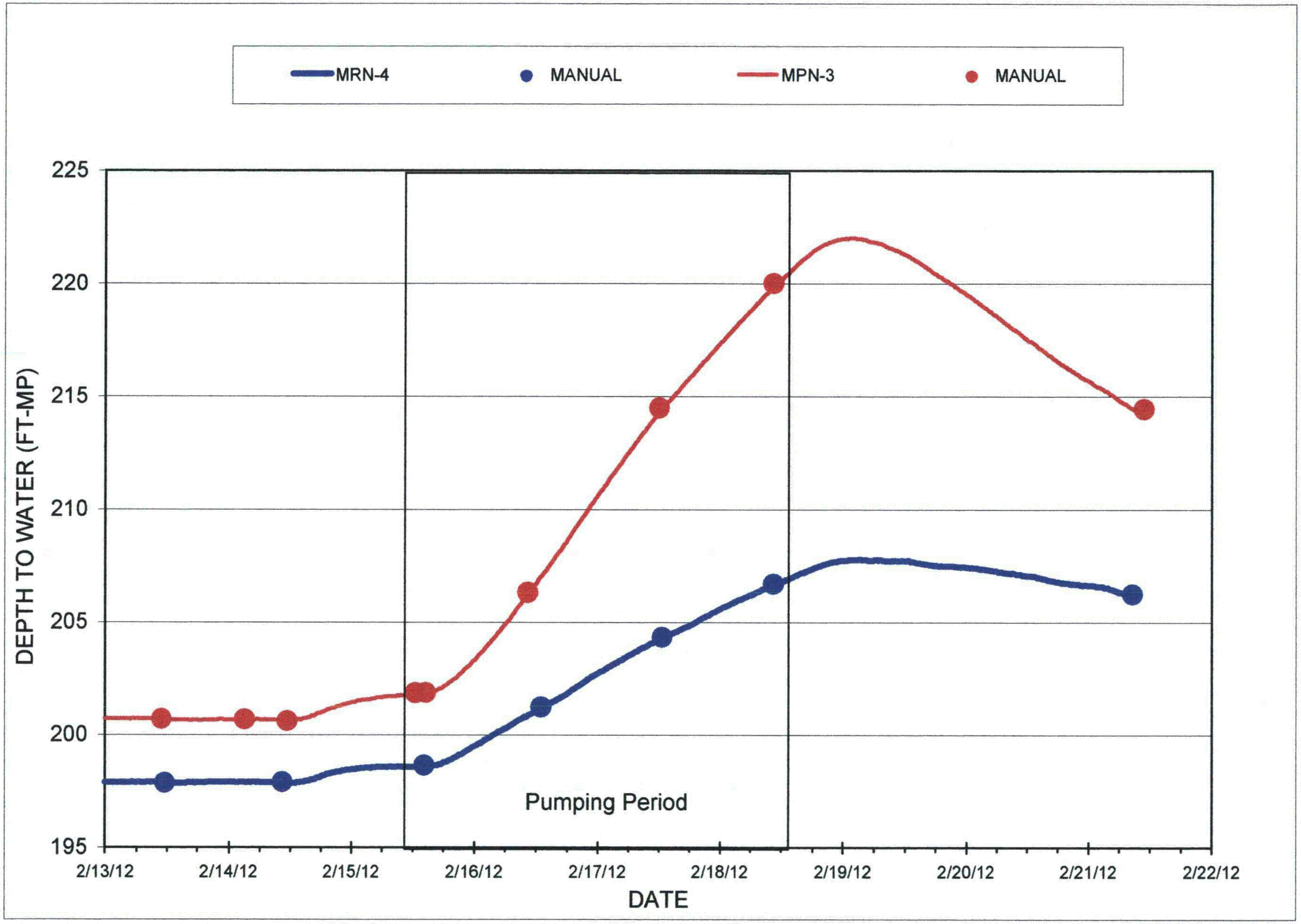


FIGURE 7-5. DEPTH TO WATER VERSUS TIME FOR OBSERVATION WELLS MRN-4 AND MPN-3

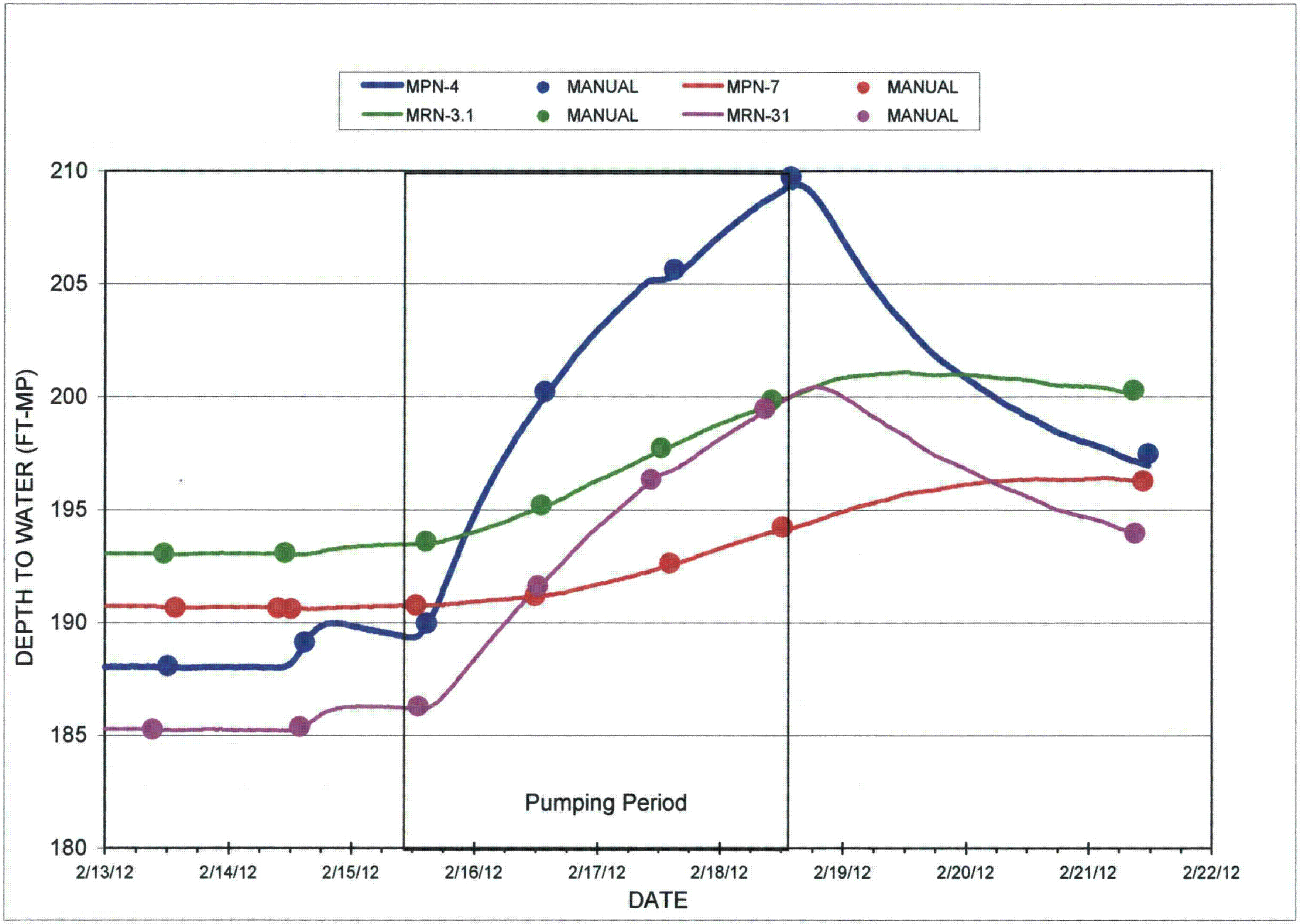


FIGURE 7-6. DEPTH TO WATER VERSUS TIME FOR OBSERVATION WELLS MPN-4, MPN-7, MRN-3.1 AND MRN-31

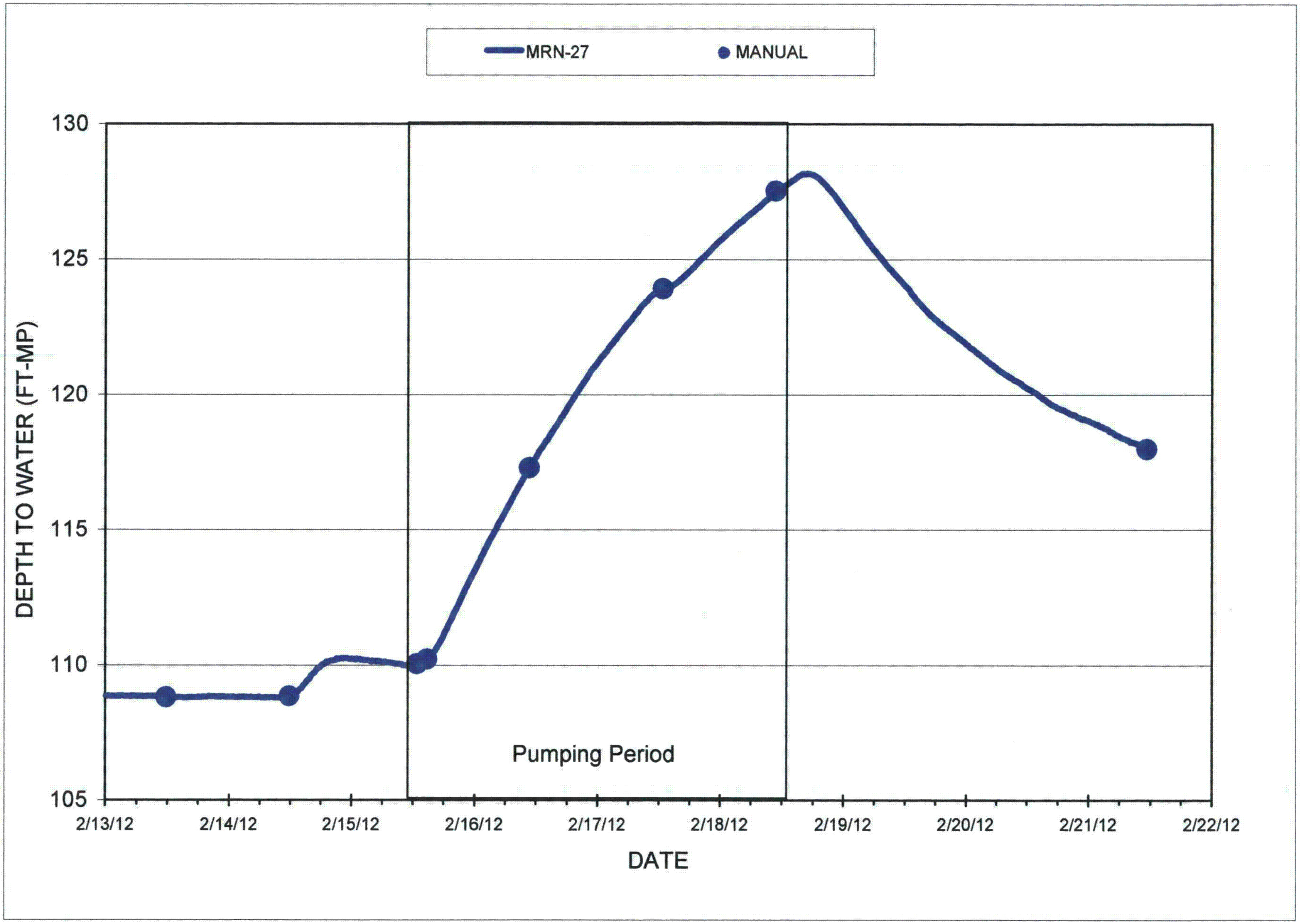


FIGURE 7-7. DEPTH TO WATER VERSUS TIME FOR OBSERVATION WELL MRN-27

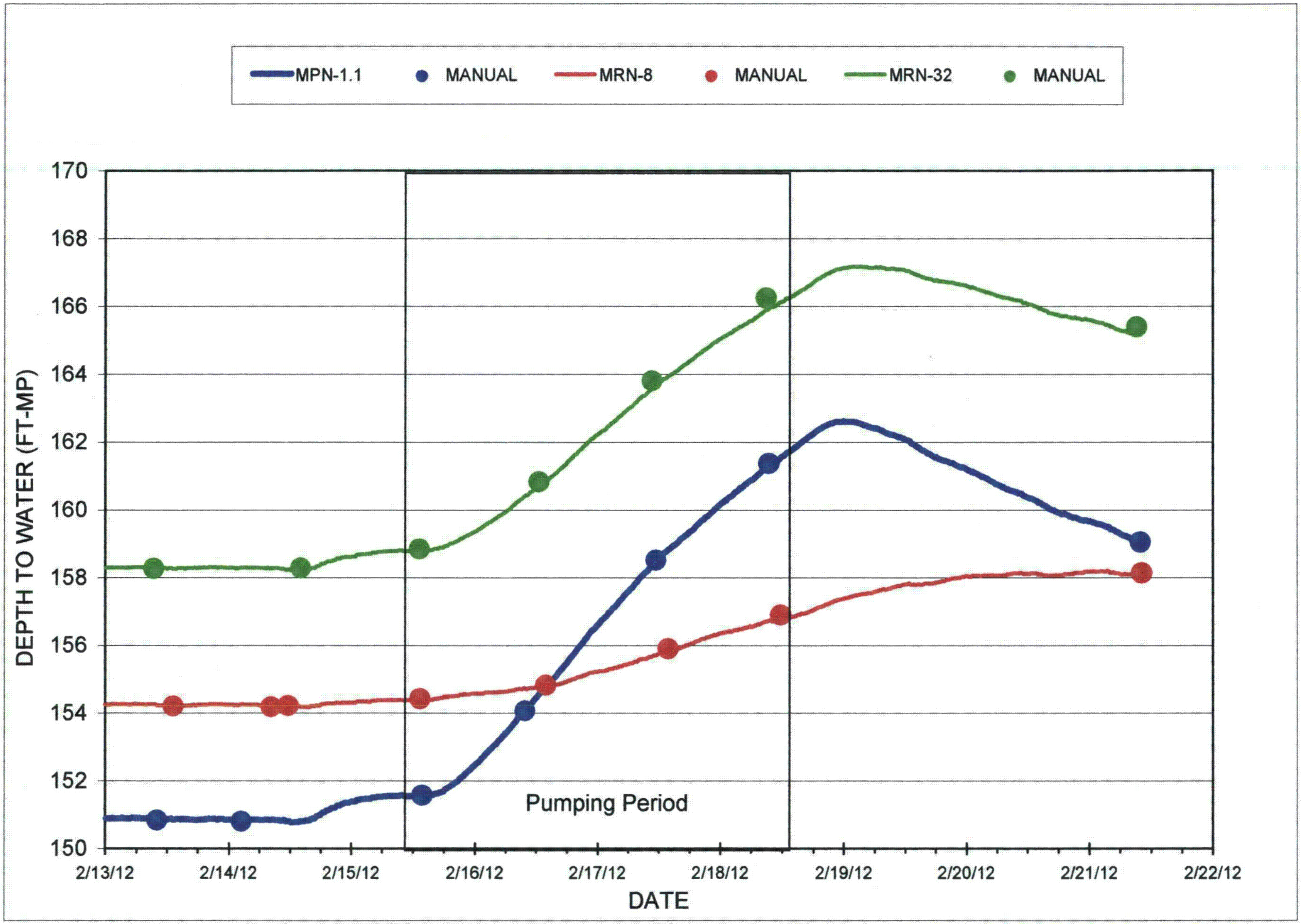


FIGURE 7-8. DEPTH TO WATER VERSUS TIME FOR OBSERVATION WELLS MPN-1.1, MRN-8 AND MRN-32

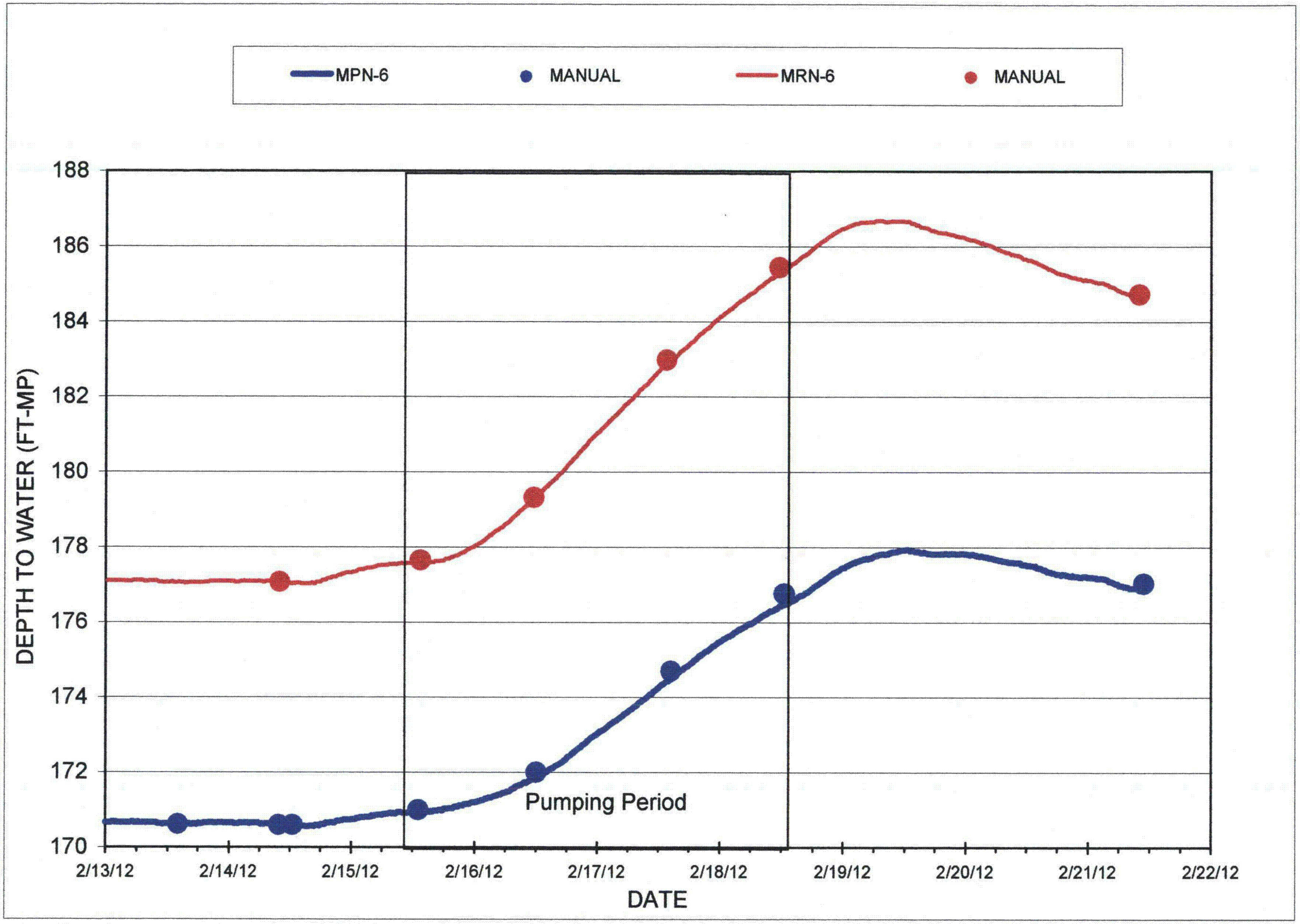


FIGURE 7-9. DEPTH TO WATER VERSUS TIME FOR OBSERVATION WELLS MPN-6 AND MRN-6

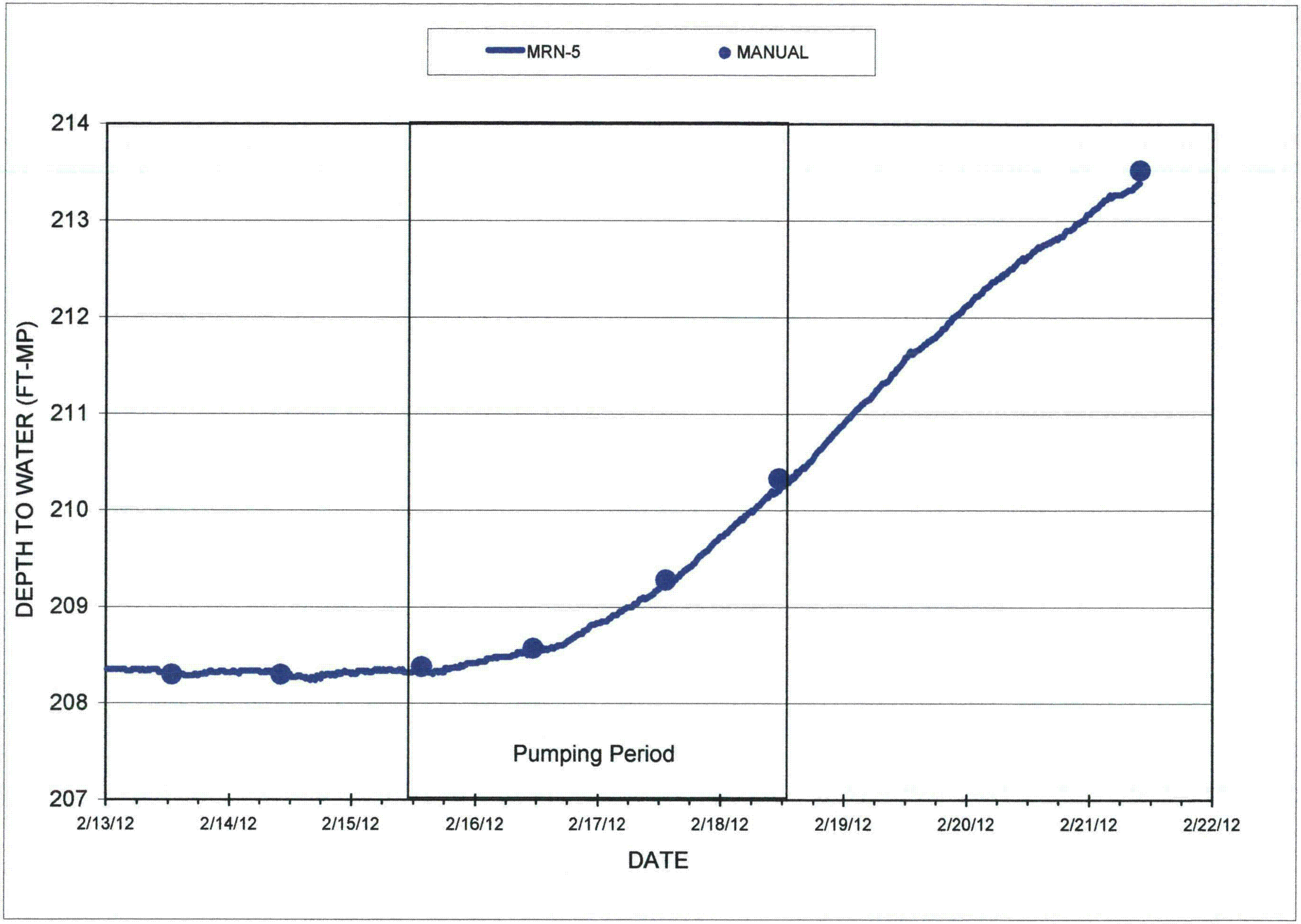


FIGURE 7-10. DEPTH TO WATER VERSUS TIME FOR OBSERVATION WELL MRN-5

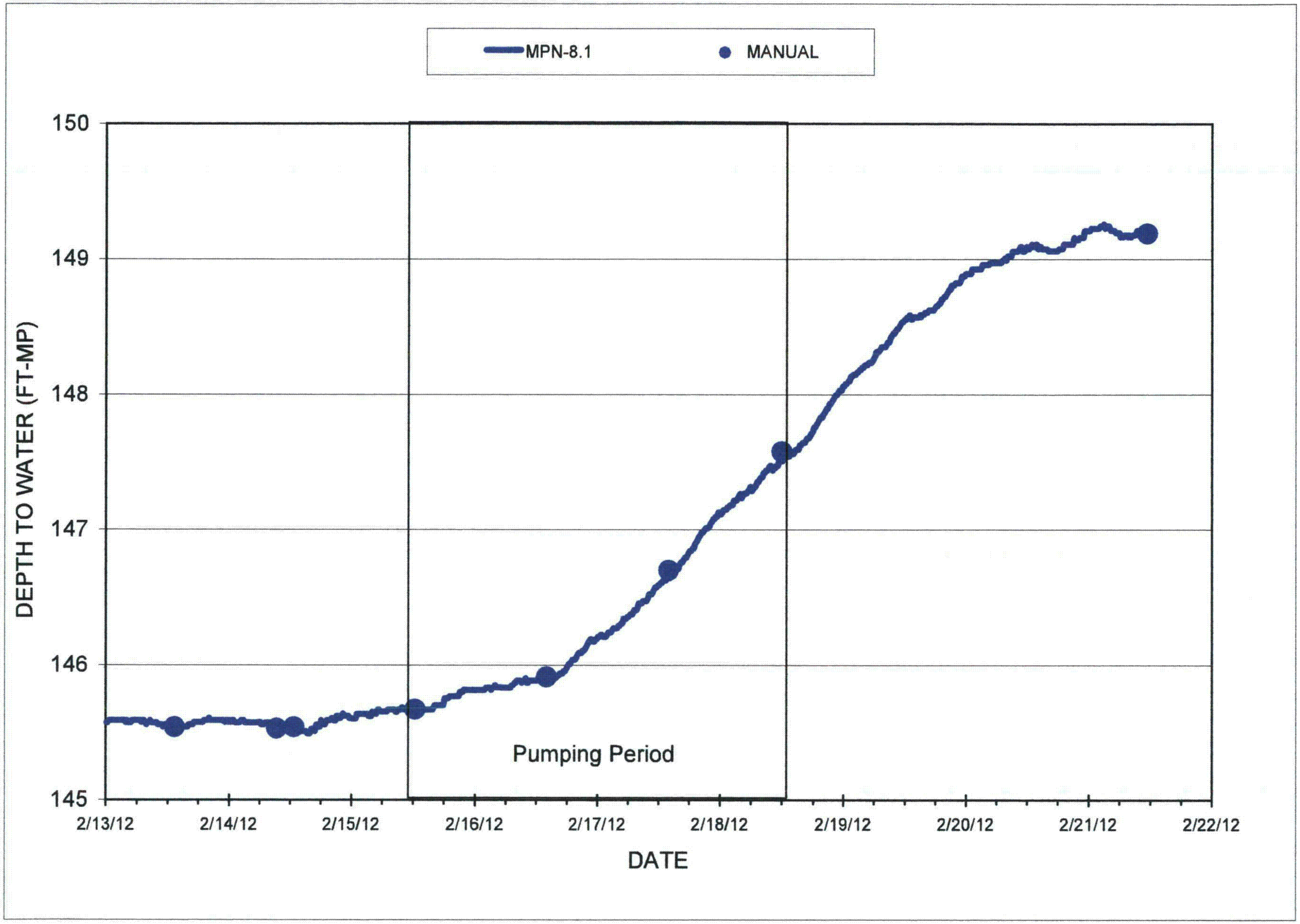


FIGURE 7-11. DEPTH TO WATER VERSUS TIME FOR OBSERVATION WELL MPN-8.1

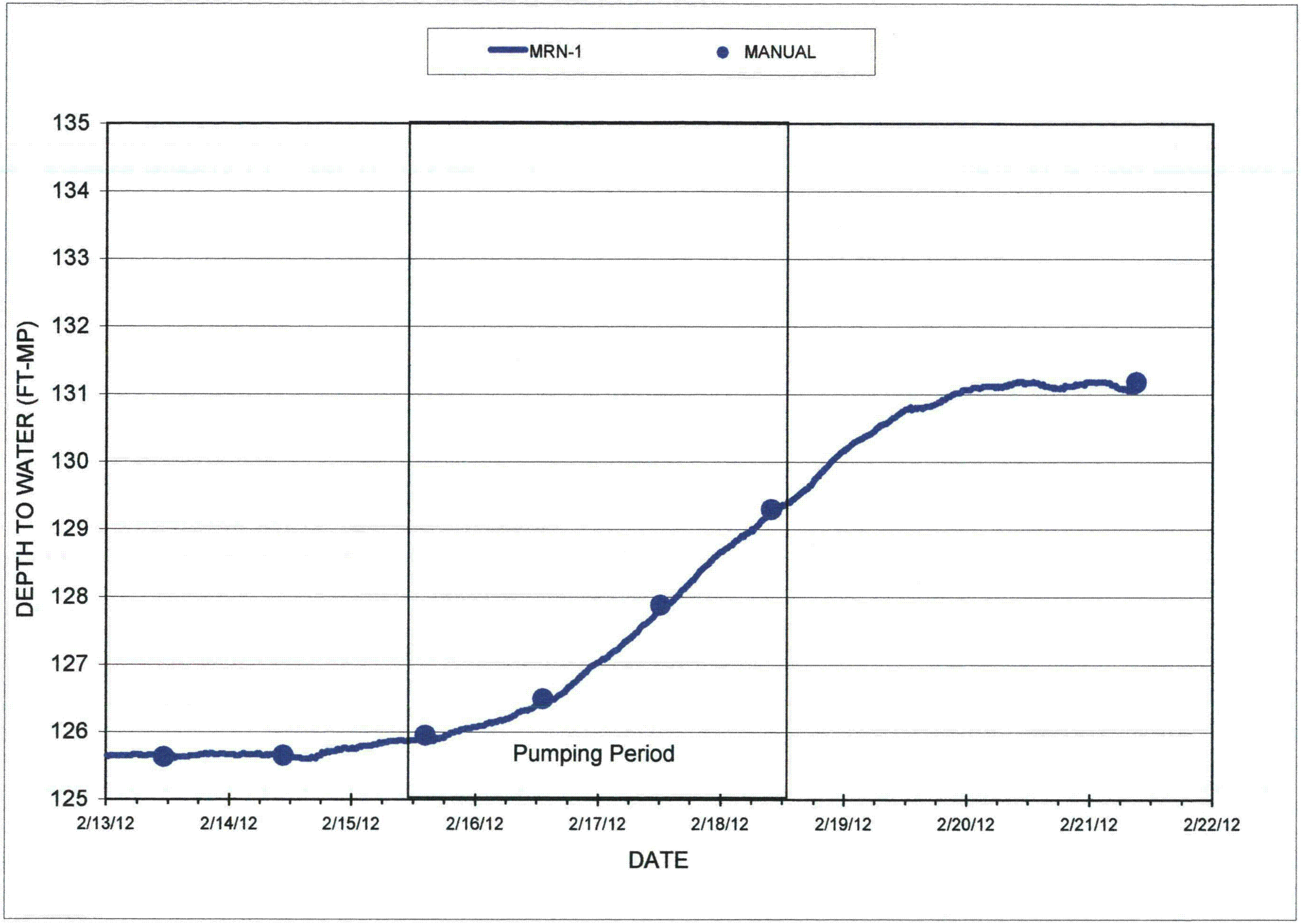


FIGURE 7-12. DEPTH TO WATER VERSUS TIME FOR OBSERVATION WELL MRN-1

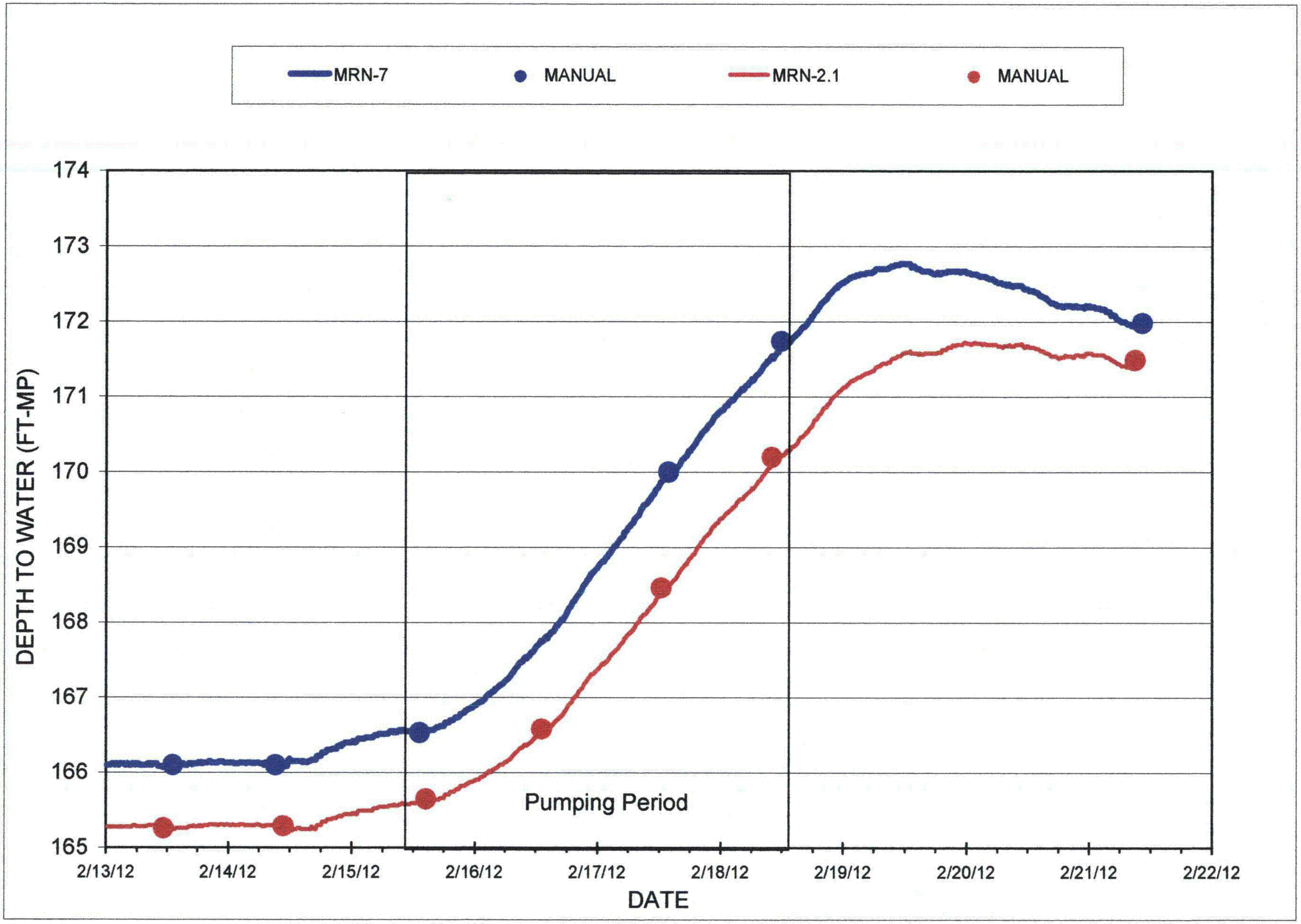


FIGURE 7-13. DEPTH TO WATER VERSUS TIME FOR OBSERVATION WELLS MRN-7 AND MRN-2.1

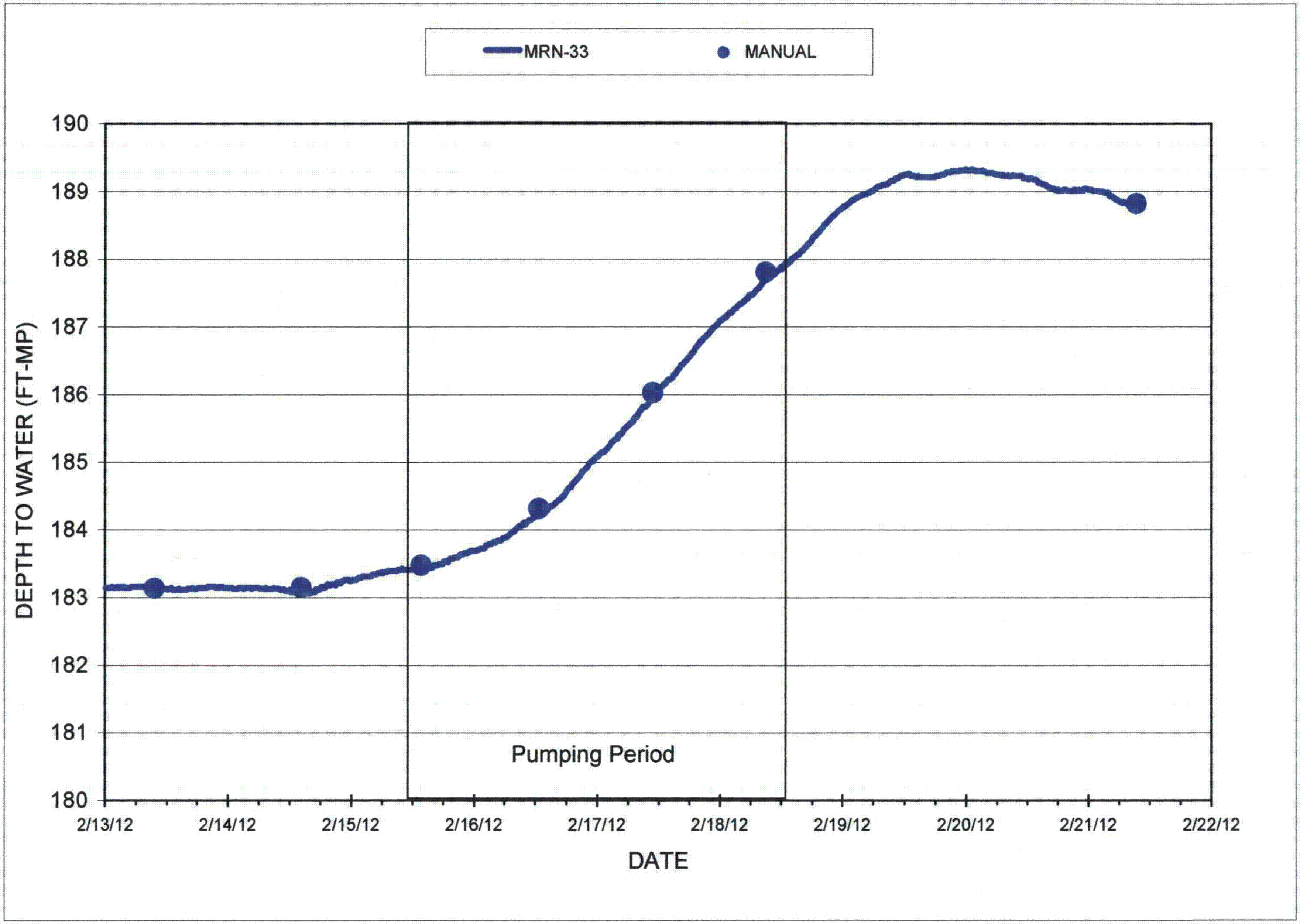


FIGURE 7-14DEPTH TO WATER VERSUS TIME FOR OBSERVATION WELL MRN-3

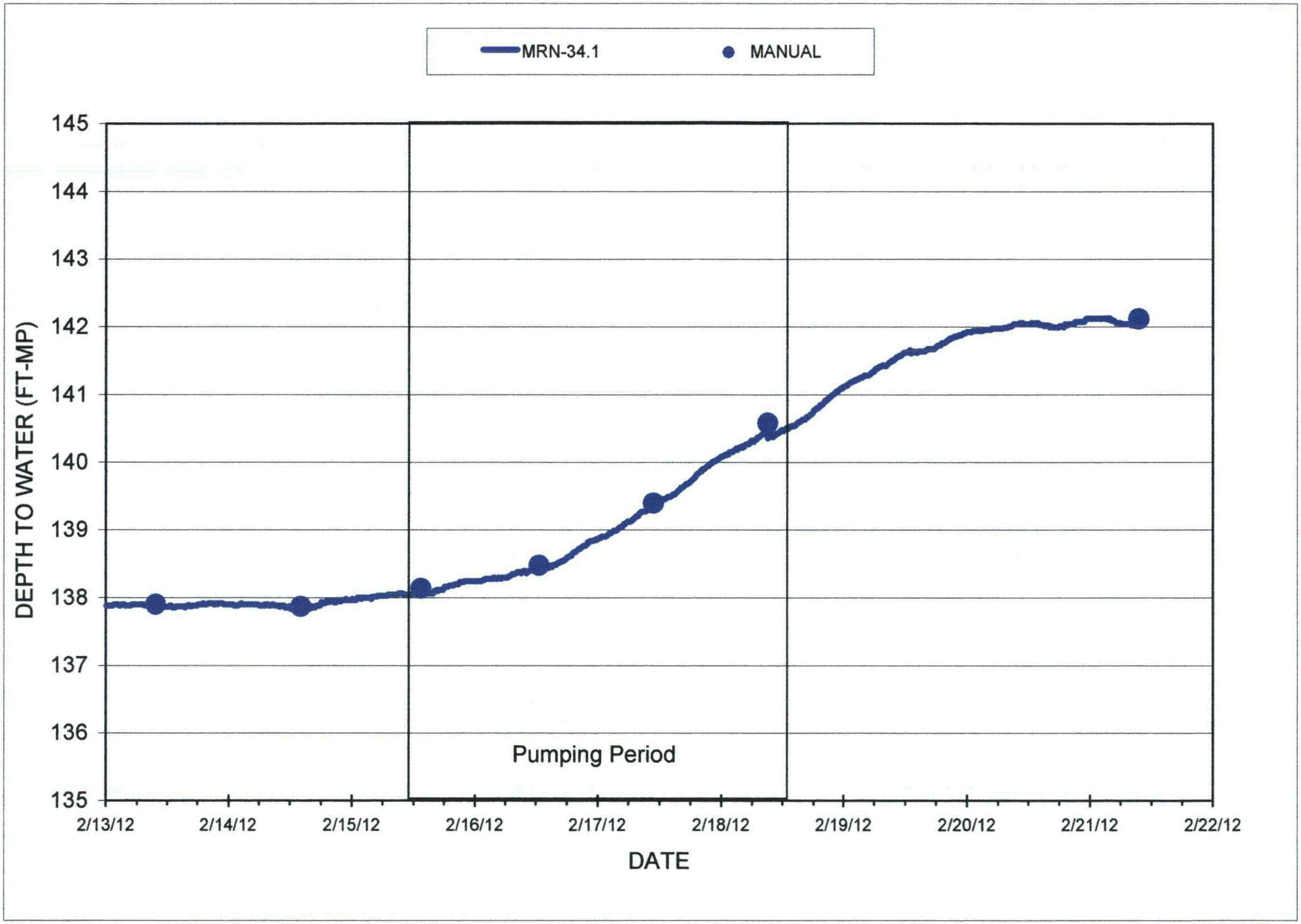


FIGURE 7-15. DEPTH TO WATER VERSUS TIME FOR OBSERVATION WELL MRN-34.1

8.0 ANAYTICAL METHODS AND TEST RESULTS – PRODUCTION ZONE FOR MRN-29 TEST

8.1 ANALYTICAL METHODS

Drawdown data collected from the monitor wells were graphically analyzed to determine transmissivity and storativity. The primary analysis method used was the Theis (1935) log-log method. The Cooper & Jacob (Jacob) (1946) straight-line method was used in only the pumping well MRN-29 due to the limitation on this method. Cooper & Jacob recommended the 'u' value to be <0.01 for usage of the straight line fit. Kruseman and de Rider (1991) suggest that a 'u' value of less than 0.1 is appropriate which can be seen from a plot of the Theis well function versus u on semi-log plot. With the use of the less than 0.1 criteria, the straight line method is appropriate for none the A Sand monitoring wells relative to the second time since pumping started.

The test data were analyzed using the Theis method for all of the observation wells because the Jacob method is not appropriate for this test. Ferris and others (1962) present the Theis and Jacob equation in the gallon per foot per day units used in calculations in this section. The pump was down for one hour and 34 minutes on February 17. Theis type curves which uses the well function summation to account for the down period were used in matching the log-log plot of the drawdown data (see Section 10 for the theory used to adjust the type curves). The significant assumptions inherent in these two methods include:

- The aquifer is confined and has apparent infinite extent
- The aquifer is homogenous and isotropic, and of uniform 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 penetrated
- Well diameter is small, so well storage is negligible

These assumptions are reasonably satisfied. Obviously, the A Sand is not homogenous and isotropic; however, over the scale of the pump tests, it can be treated in this manner. Observation wells respond to the average conditions in the area and are reflective of large area for a long pumping period.

Leaky aquifer solutions such as Hantush (1960) were not applicable to the data from the A Sand. Likewise, because none of the monitor wells were completed within the confining units, a Neumann-Witherspoon (1972) analysis was not performed.

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 MRN-29 wells.

8.2 BACKGROUND TRENDS

Water level stability data were collected prior to the start of the test. Plots of the background data for the pumping, MRN and MPN wells are shown in Figures 7-2 through 7-15. 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 MRN-29 pump test wells. The barometric change during the pumping phase of the test was approximately 0.3 inches of Hg (see Section 9 plots for barometric pressure data) which did not require any adjustments in the A Sand water levels for barometric changes.

8.3 TEST RESULTS

8.3.1 DRAWDOWN

The drawdown achieved during the test is shown on Figure 8-1. A drawdown of 197.1 feet was developed in pumping wells MRN-29 while maximum drawdowns in the A Sand monitoring wells from this pumping were 3.4 to 36.0 feet. The five foot drawdown contour extended to roughly 1800 feet from the pumping well. Drawdown contours were fairly circular. Drawdown in A Sand wells MPN-8.1 and MRN-8 from both test demonstrates continuity between the two multi-well tests.

Figure 8-2 presents the semi-log plot of the drawdown data for pumping well MRN-29. The red data points are drawdown values collected prior to the generator failure and plotted against time since the pump first started. The straight line fit of this data produced a transmissivity of 311 gal/day/ft (42 ft^2/d). The blue data points are data after the re-start of the pump and are plotted versus $t_1 * t_3 / t_2$ to account for the pump down time (see Section 10 for a discussion of the straight line adjusted theory). The straight line of the blue data was not used but would have produced a very similar transmissivity to the straight line of the red data. The pumping well recovery plot is presented in Figure 8-3 and the straight line fits yields a transmissivity of 286 gal/day/ft (38 ft^2/d).

Theis type curves matches and linear plots are presented in Figures 8-4 through 8-39 for the A Sand monitoring wells. Semi-log plots are presented for observation wells but a straight line fit was not used because they were not appropriate for these wells. A refined Theis type curve fit, which accounts for the off period, was used on the drawdown data of the observation wells. Each of these wells shows a good fit to the Theis type curve. The adjustment of the Theis type curve was minor for most of the observation wells and therefore non-adjusted type curve was used in most observation matches. The type curve fits do not indicate leaky or boundary conditions in this area of the A Sand.

The tabulation of the water level data for the test is included in Appendix D.

The A Sand monitoring wells all showed adequate drawdown to prove communication between the Production Zone and the monitoring wells. Therefore adequate communication exists between the monitoring wells and the Production zone.

8.3.2 ANALYTICAL RESULTS

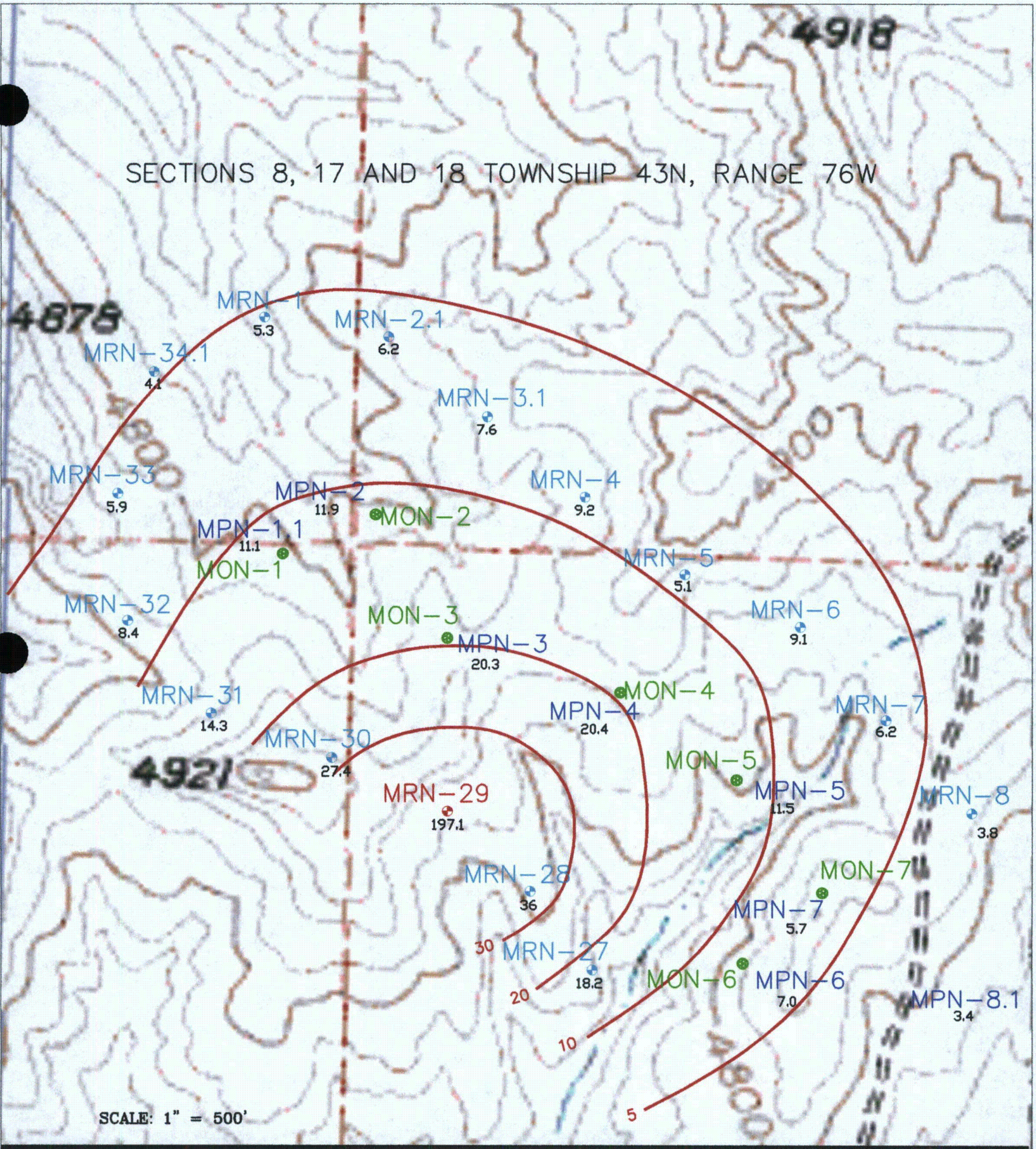
Transmissivity (T) results from 25 to 85 ft^2/d (185 to 636 gpd/ft) from the Theis type curve matches. An average T value of 50 ft^2/d (376 gpd/ft) was obtained from the MRN-29 test. Jacob results were not calculated for these observation wells because the length of the test was not adequate to meet the requirement for the Jacob method. The Theis results from 23 A Sand observation wells were used in the calculation of the average. Based on the average thickness of the A Sand at pumping well MRN-29 of 105 feet, the average hydraulic conductivity (K) is 0.48 ft/d (1.6E-4 cm/s). Assuming a water temperature of 50 degrees F, this equates to a permeability of approximately 229 millidarcies (md). Storativity (S) values ranged from 8.0E-5 to 3.7E-4. The average S value for the test was 1.4E-4.

8.4 DIRECTIONAL TRANSMISSIVITY

Drawdowns at the end of the MRN-29 pump test are presented in Figure 8-1 and show a fairly uniform circular pattern. The small variations in drawdowns do not indicate a consistent directional transmissivity. These variations in drawdowns would greatly affect the result of the directional transmissivities calculated from the Papadopulos (1965) method. The directional transmissivities in the fluvial sands in the Powder River Basin vary greatly due to the combination of wells used in calculating the directional transmissivities. These fluvial channels were not formed in a consistent direction over any area such as PA #1; therefore no calculations of the directional transmissivities were made from MRN-29 pump test.

Table 8-1.
SUMMARY OF AQUIFER PROPERTIES FOR THE MRN-29 TEST

Well	Distance from Pumping Well (ft)	THEIS			COOPER & JACOB		
		Transmissivity		Storage Coefficient	Transmissivity		Storage Coefficient
		(gpd/ft)	(ft^2/day)		(gpd/ft)	(ft^2/day)	
MRN-29	-	-	-	-	311	42	-
MRN-29 (REC)	-	-	-	-	286	38	-
MPN-1.1	1190	329	44	1.2E-04			
MPN-2	1208	347	46	1.0E-04			
MPN-3	614	185	25	2.5E-04			
MPN-4	770	313	42	1.0E-04			
MPN-5	1148	313	42	1.2E-04			
MPN-6	1339	347	46	1.7E-04			
MPN-7	1510	329	44	2.0E-04			
MPN-8.1	1879	477	64	2.1E-04			
MRN-1	2038	415	55	1.1E-04			
MRN-2.1	1849	424	57	1.1E-04			
MRN-3.1	1534	382	51	1.1E-04			
MRN-4	1325	460	61	1.1E-04			
MRN-5	1294	347	46	3.7E-04			
MRN-6	1534	334	45	9.0E-05			
MRN-7	1724	460	61	1.1E-04			
MRN-8	2017	636	85	1.6E-04			
MRN-27	830	294	39	1.1E-04			
MRN-28	443	303	41	8.0E-05			
MRN-30	490	267	36	1.3E-04			
MRN-31	983	341	46	1.2E-04			
MRN-32	1434	398	53	1.1E-04			
MRN-33	1766	398	53	1.1E-04			
MRN-34.1	2042	545	73	1.6E-04			
	AVERAGE:	**376**	**50**	**1.4E-04**			



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FILE: C:\PROJECTS\2012-14\nrwellfield

Uranerz ENERGY CORPORATION
1701 East "E" Street
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Casper, Wyoming
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Figure 8-1
Maximum Drawdown in the A Sand for the MRN-29 Pump Test

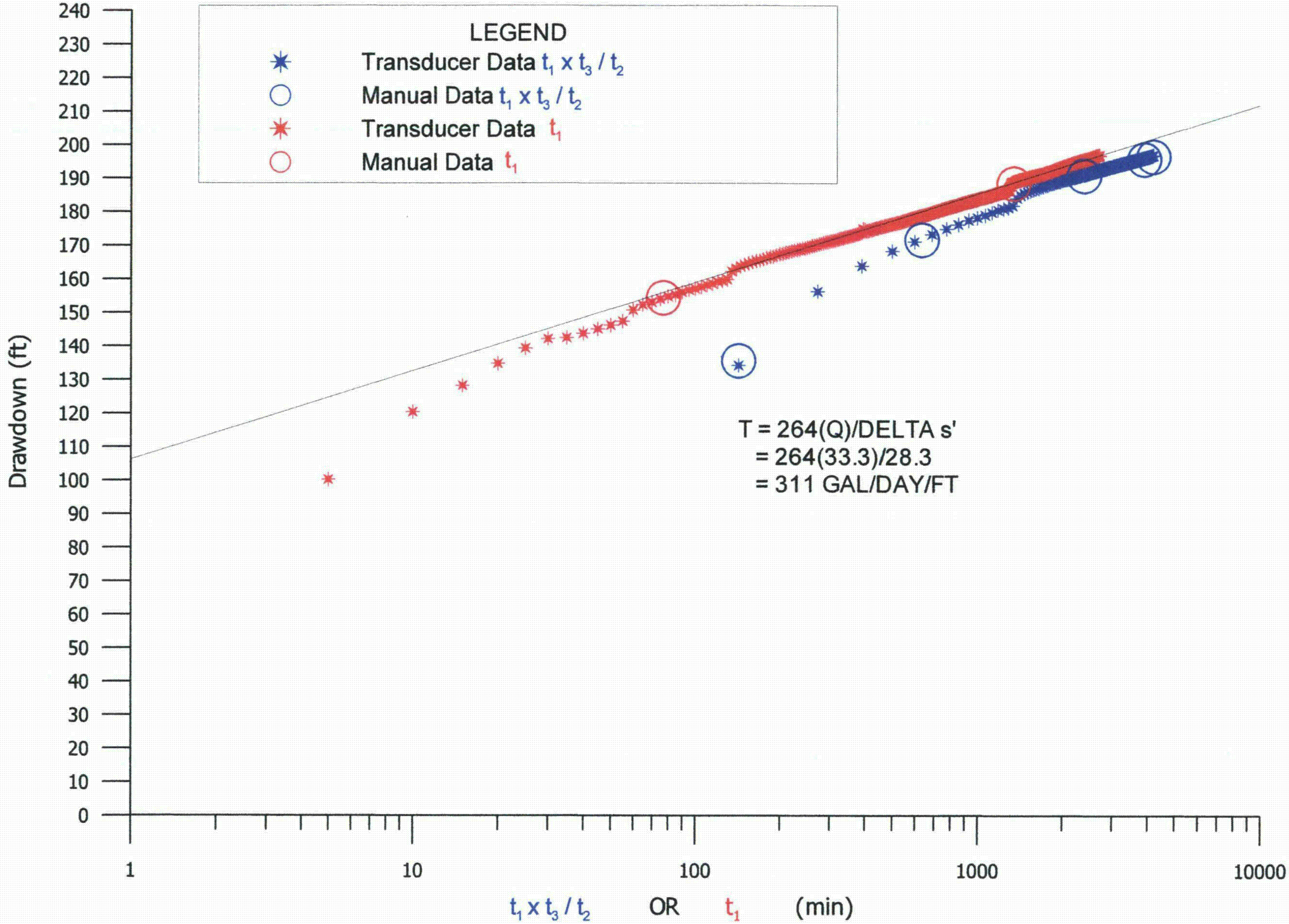


FIGURE 8-2. DRAWDOWN IN PUMPING WELL MRN-29

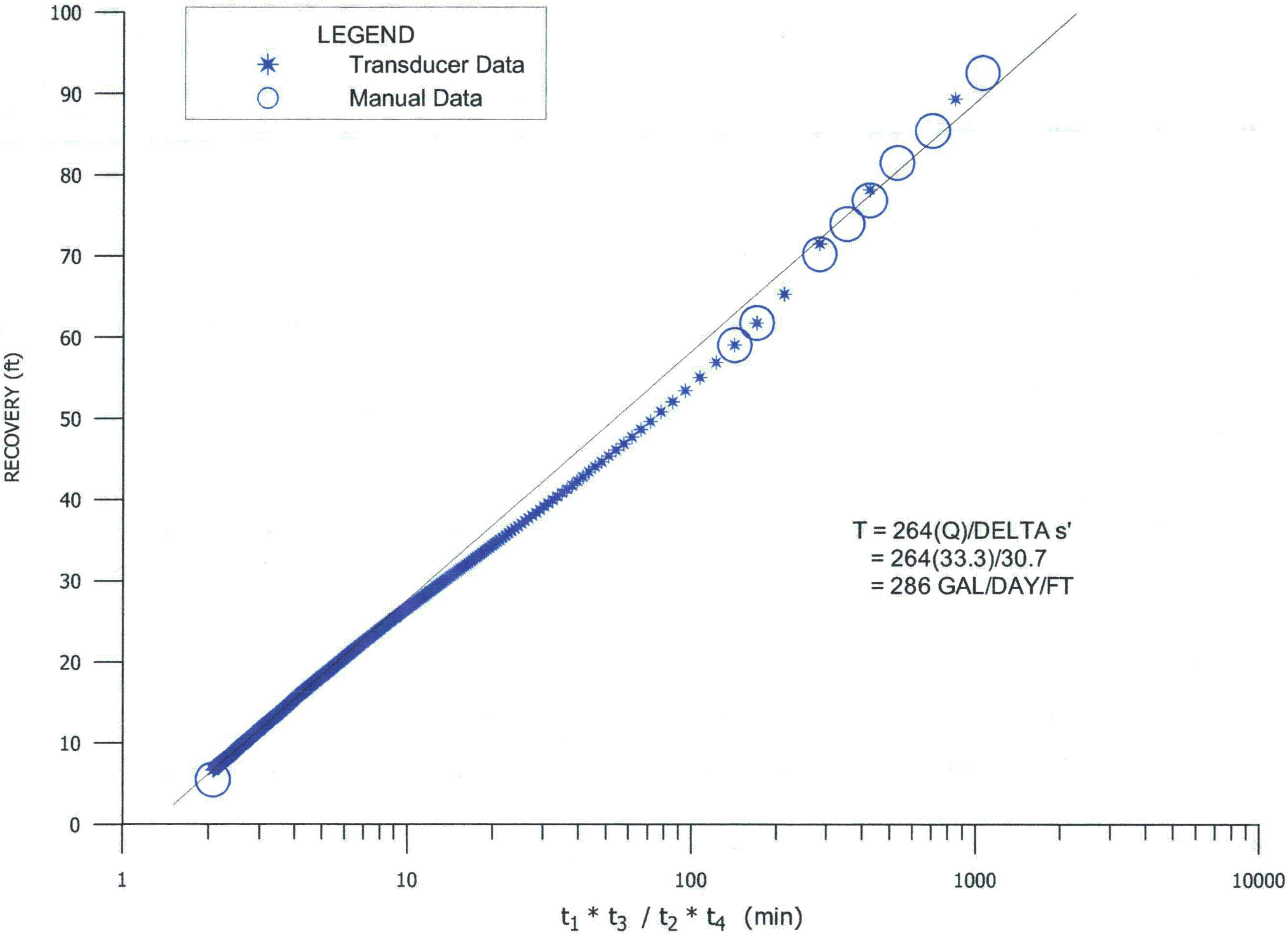


FIGURE 8-3. RECOVERY IN PUMPING WELL MRN-29

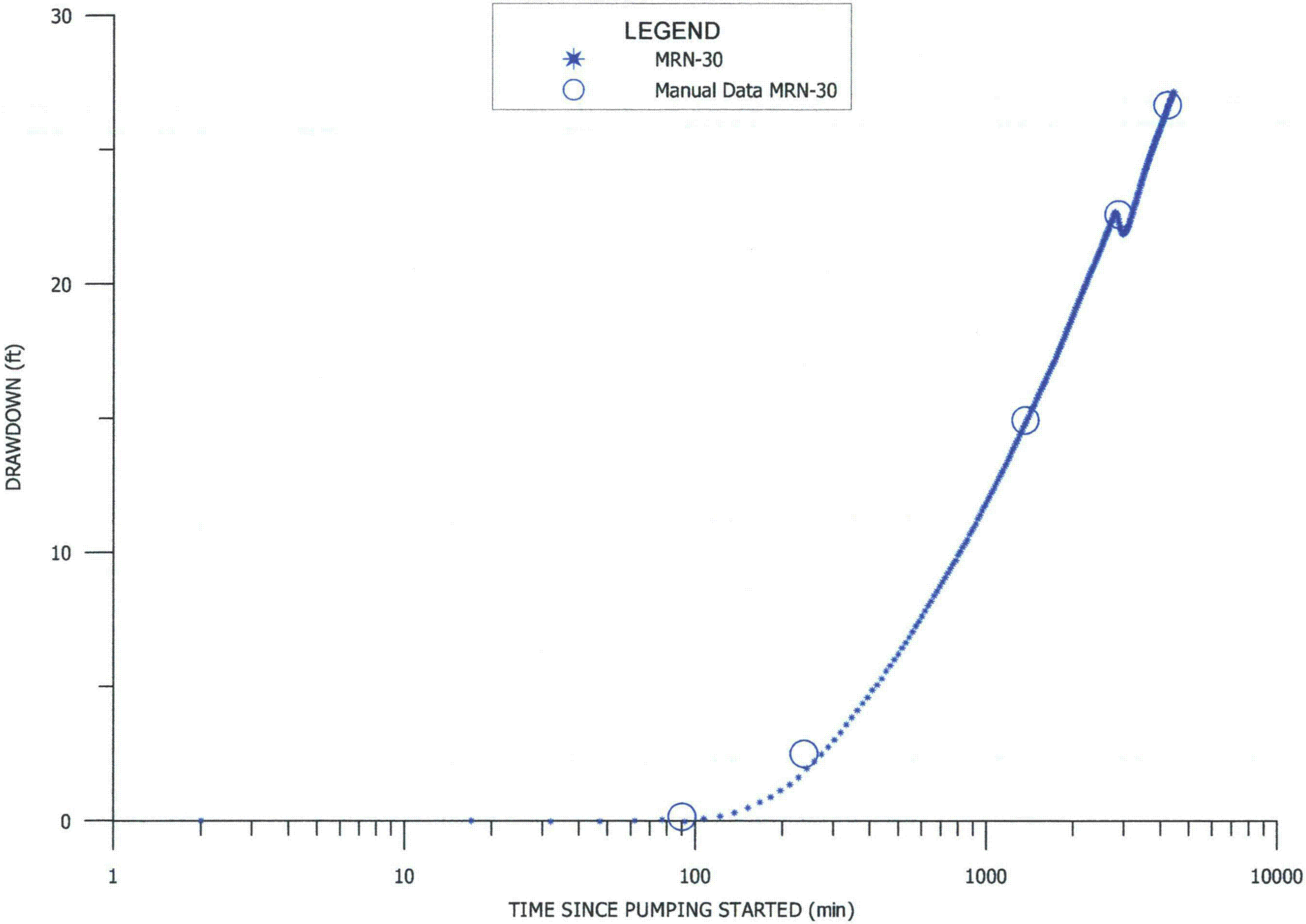
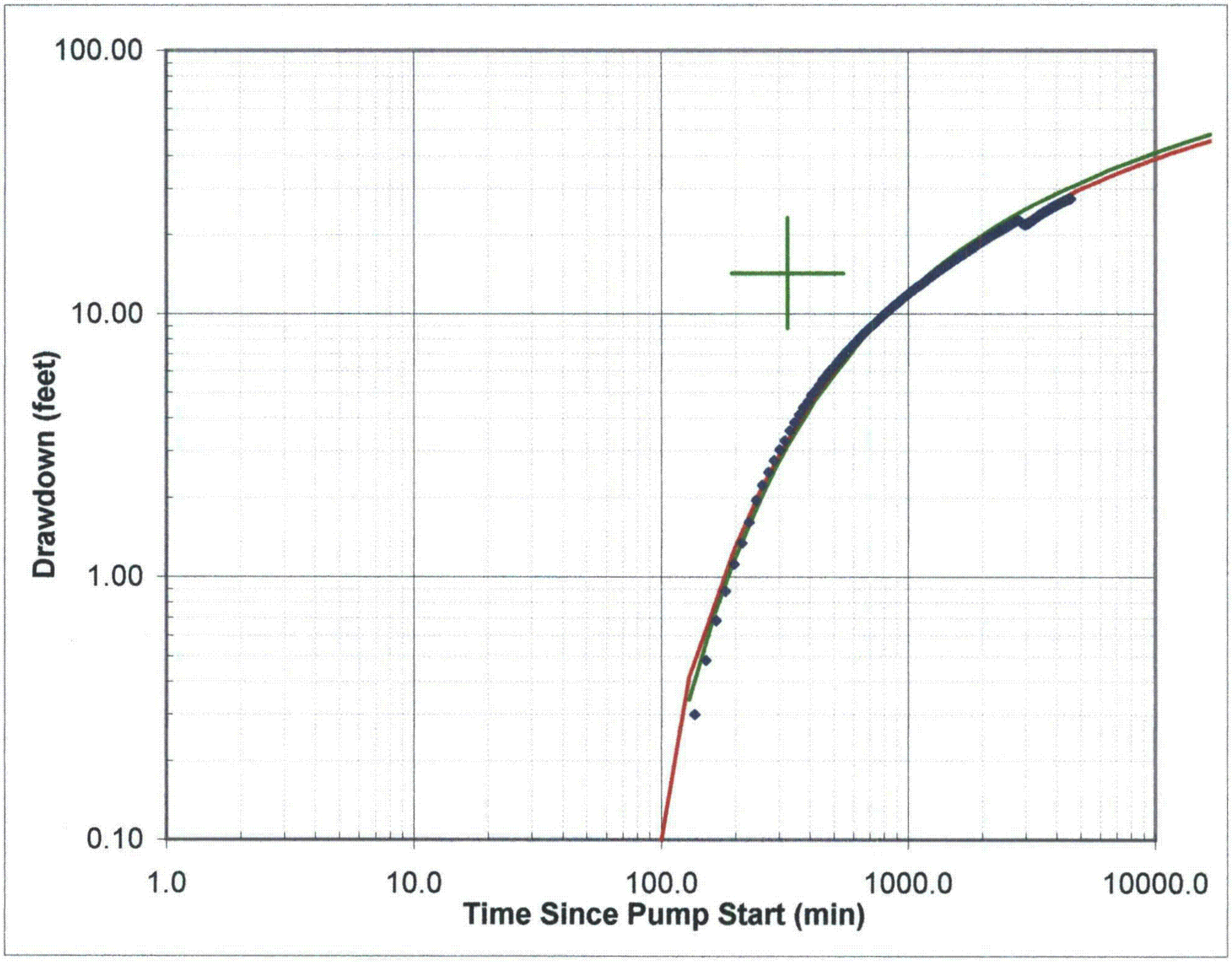


FIGURE 8-4. DRAWDOWN IN OBSERVATION WELL MRN-30



Theis Match Point

Intitial Discharge (gpm)	33.3
Radius to Pumping Well (ft) (<1 indicates pumping well)	490
Drawdown Match Point (ft)	14.30
Time Match Point (min)	325.0
Calculated Transmissivity (gal/day/ft)	267
Calculated Storage Coefficient (ft/ft)	1.34E-04
Refined Transmissivity Estimate (gal/day/ft)	273
Refined Storage Coefficient Estimate (ft/ft)	1.27E-04

Test Interruption Data

Pump Off Time (minutes after initial pump start)	2726
Pump Restart Time (minutes after initial pump start)	2820
Pump Restart Rate (gpm)	33.3

FIGURE 8-5. DRAWDOWN IN OBSERVATION WELL MRN-30, LOG-LOG

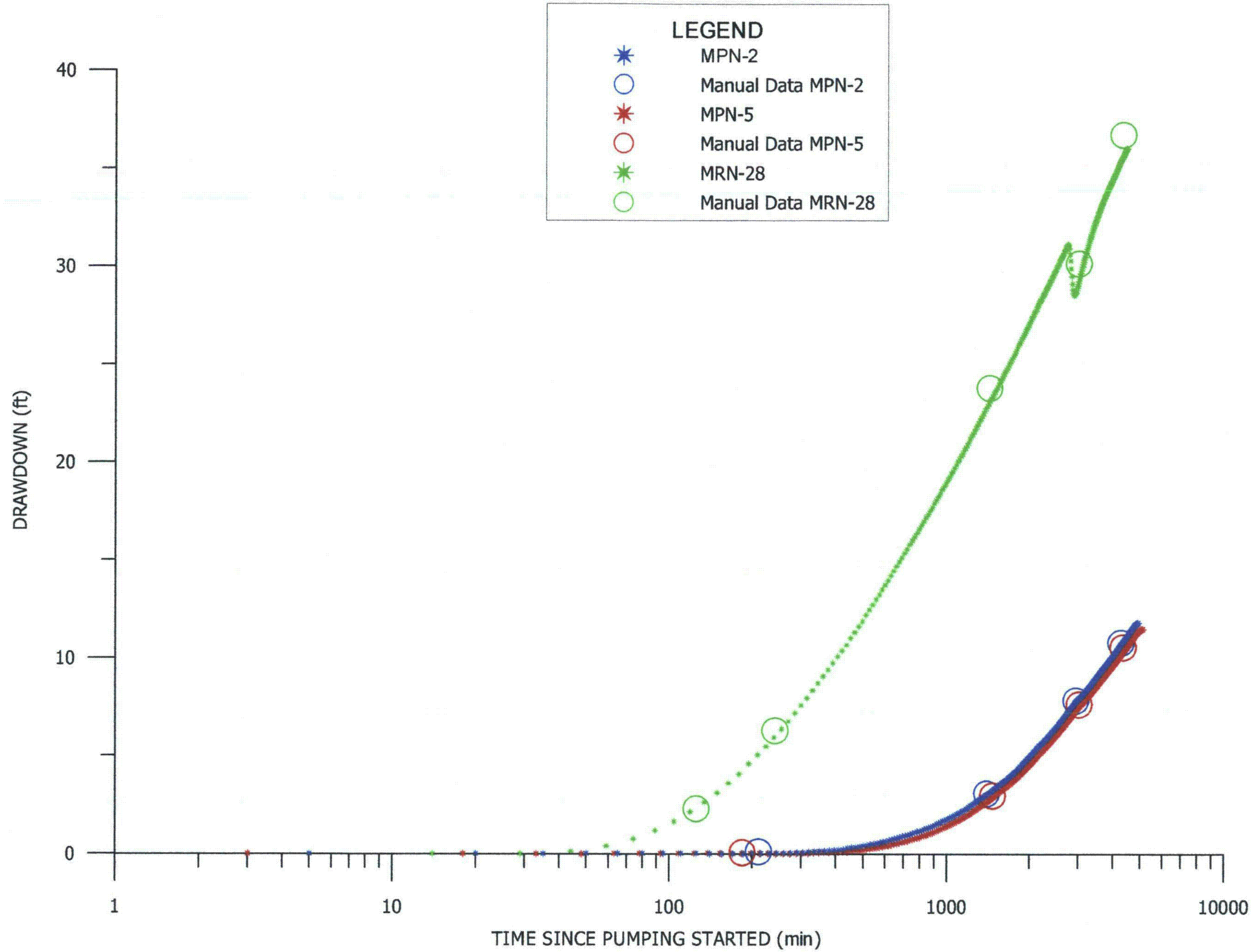
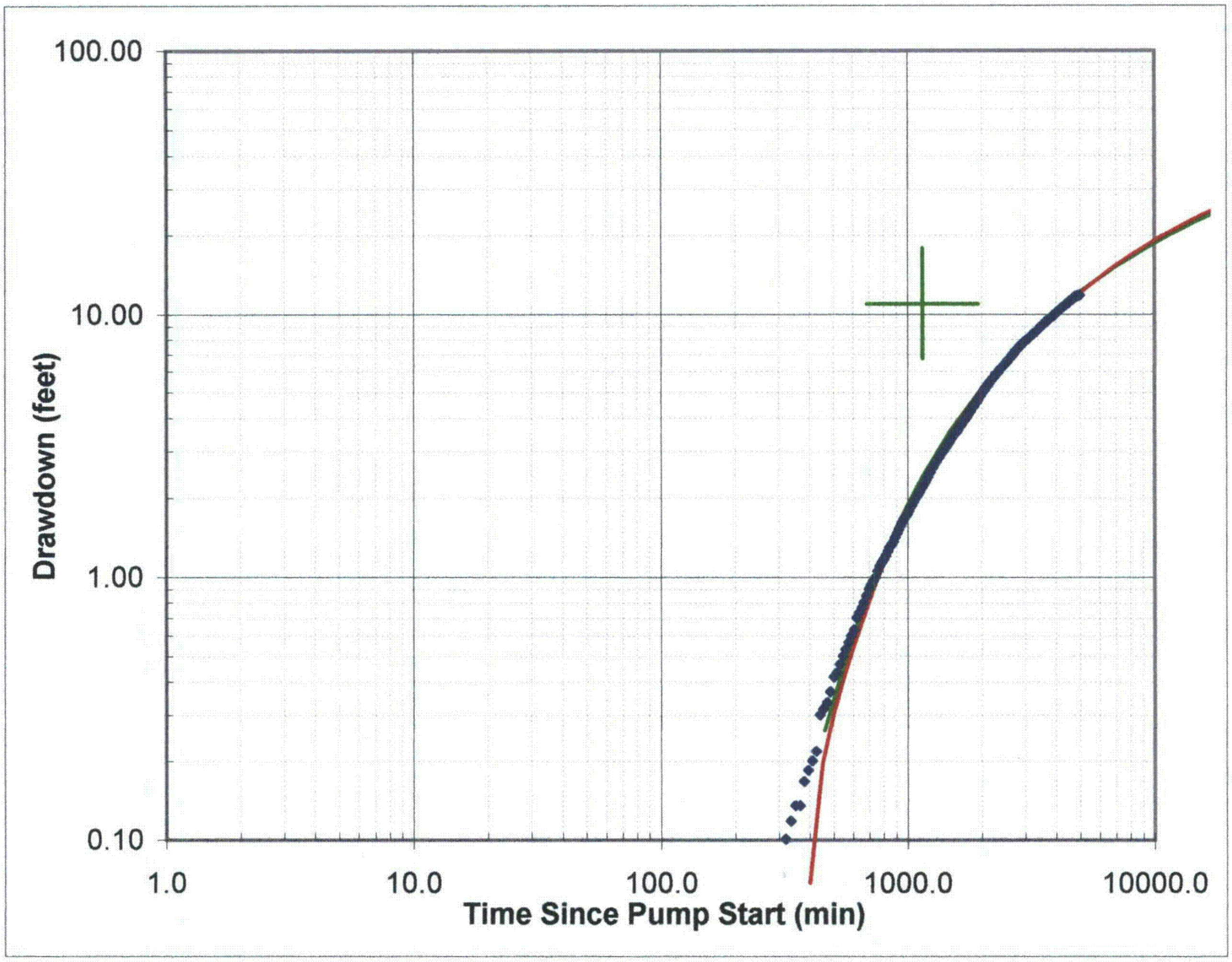


FIGURE 8-6. DRAWDOWN IN OBSERVATION WELL MPN-2, MPN-5 AND MRN-28



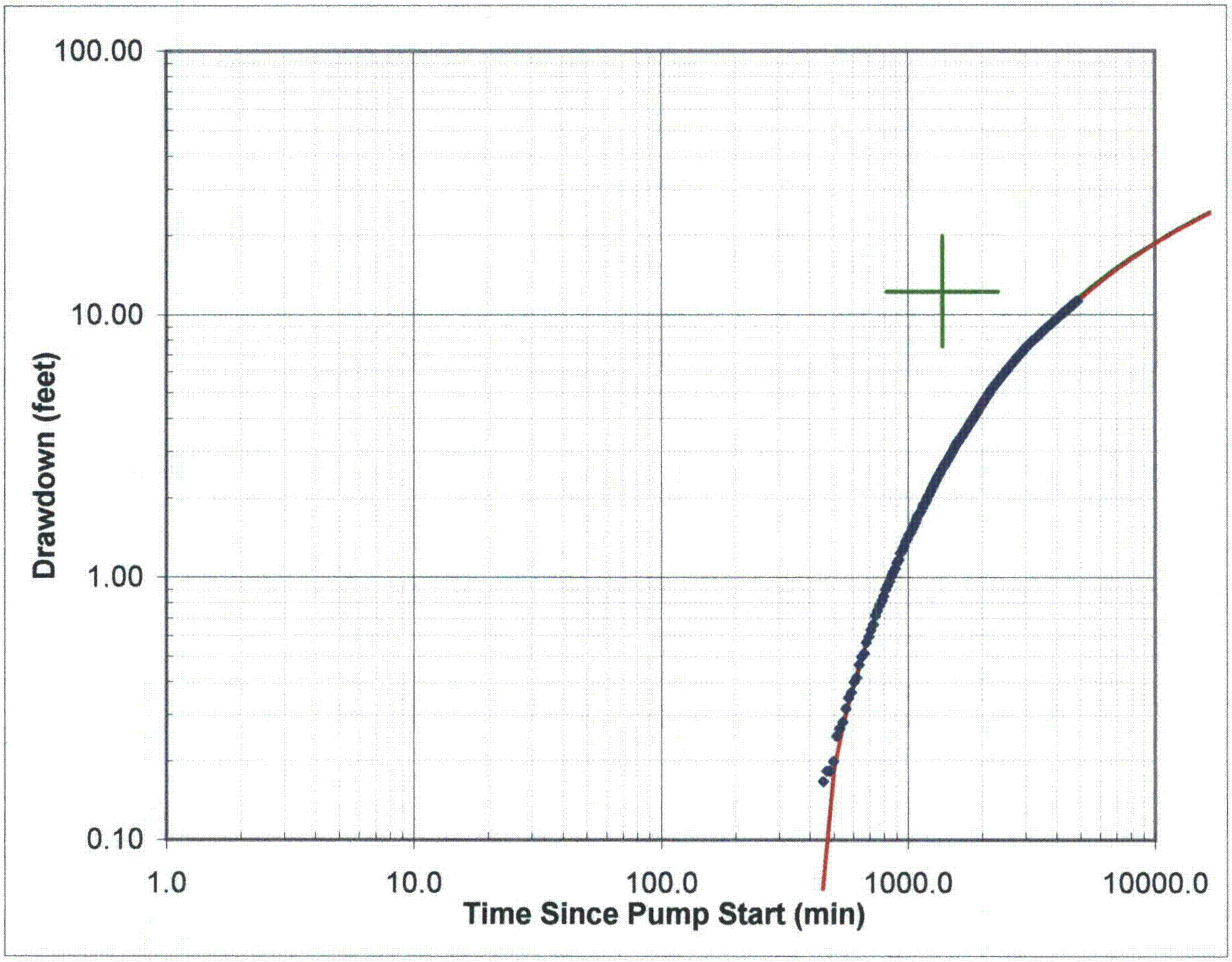
Theis Match Point

Intitial Discharge (gpm)	33.3
Radius to Pumping Well (ft) (<1 indicates pumping well)	1208
Drawdown Match Point (ft)	11.00
Time Match Point (min)	1150.0
Calculated Transmissivity (gal/day/ft)	347
Calculated Storage Coefficient (ft/ft)	1.02E-04
Refined Transmissivity Estimate (gal/day/ft)	327
Refined Storage Coefficient Estimate (ft/ft)	1.02E-04

Test Interruption Data

Pump Off Time (minutes after initial pump start)	2726
Pump Restart Time (minutes after initial pump start)	2820
Pump Restart Rate (gpm)	33.3

FIGURE 8-7. DRAWDOWN IN OBSERVATION WELL MPN-2, LOG-LOG



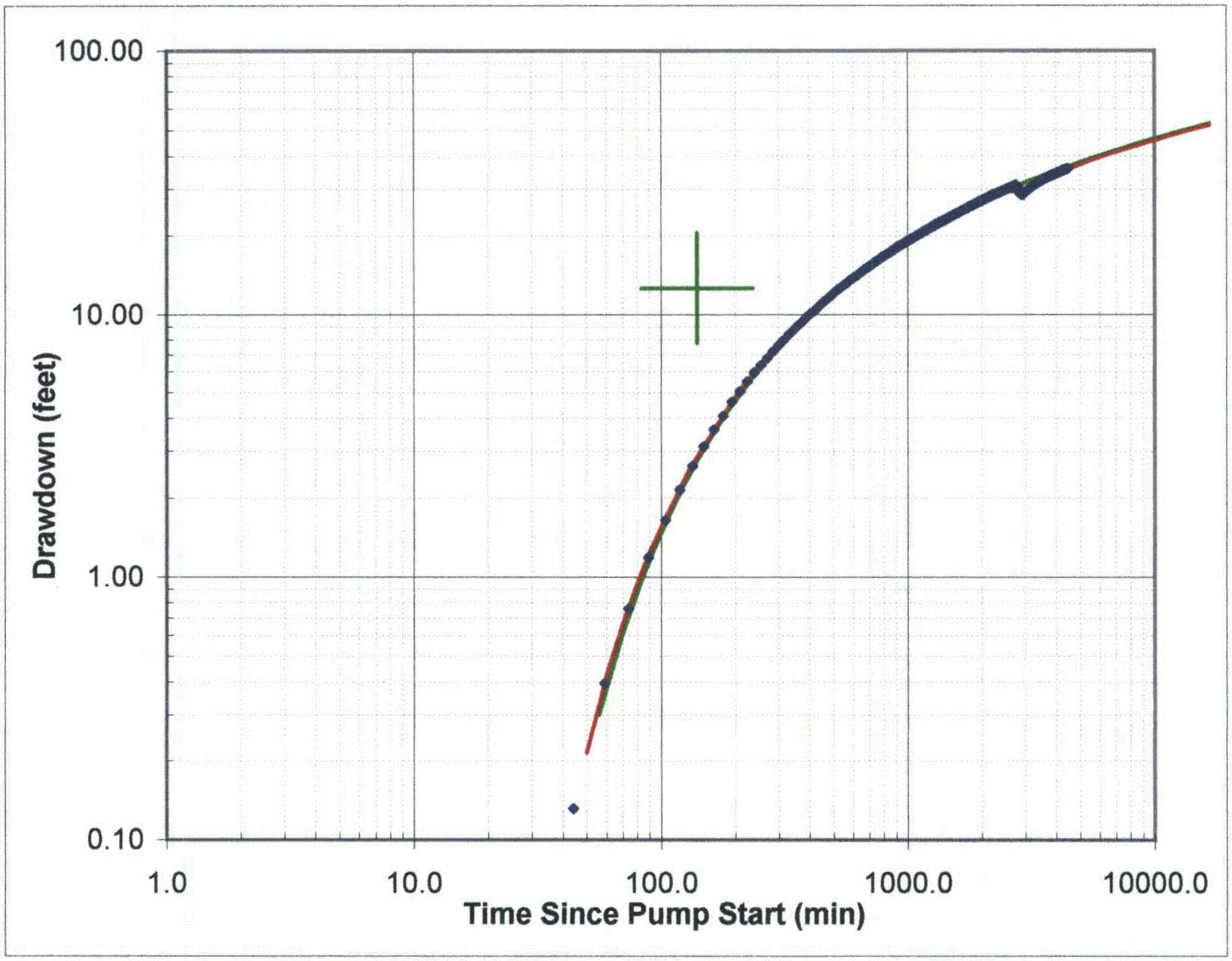
Theis Match Point

Intitial Discharge (gpm)	33.3
Radius to Pumping Well (ft) (<1 indicates pumping well)	1148
Drawdown Match Point (ft)	12.20
Time Match Point (min)	1380.0
Calculated Transmissivity (gal/day/ft)	313
Calculated Storage Coefficient (ft/ft)	1.22E-04
Refined Transmissivity Estimate (gal/day/ft)	313
Refined Storage Coefficient Estimate (ft/ft)	1.22E-04

Test Interruption Data

Pump Off Time (minutes after initial pump start)	2726
Pump Restart Time (minutes after initial pump start)	2820
Pump Restart Rate (gpm)	33.3

FIGURE 8-8. DRAWDOWN IN OBSERVATION WELL MPN-5, LOG-LOG



Theis Match Point

Intitial Discharge (gpm)	33.3
Radius to Pumping Well (ft) (<1 indicates pumping well)	443
Drawdown Match Point (ft)	12.60
Time Match Point (min)	140.0
Calculated Transmissivity (gal/day/ft)	303
Calculated Storage Coefficient (ft/ft)	8.02E-05
Refined Transmissivity Estimate (gal/day/ft)	309
Refined Storage Coefficient Estimate (ft/ft)	7.87E-05

Test Interruption Data

Pump Off Time (minutes after initial pump start)	2726
Pump Restart Time (minutes after initial pump start)	2820
Pump Restart Rate (gpm)	33.3

FIGURE 8-9. DRAWDOWN IN OBSERVATION WELL MRN-28, LOG-LOG

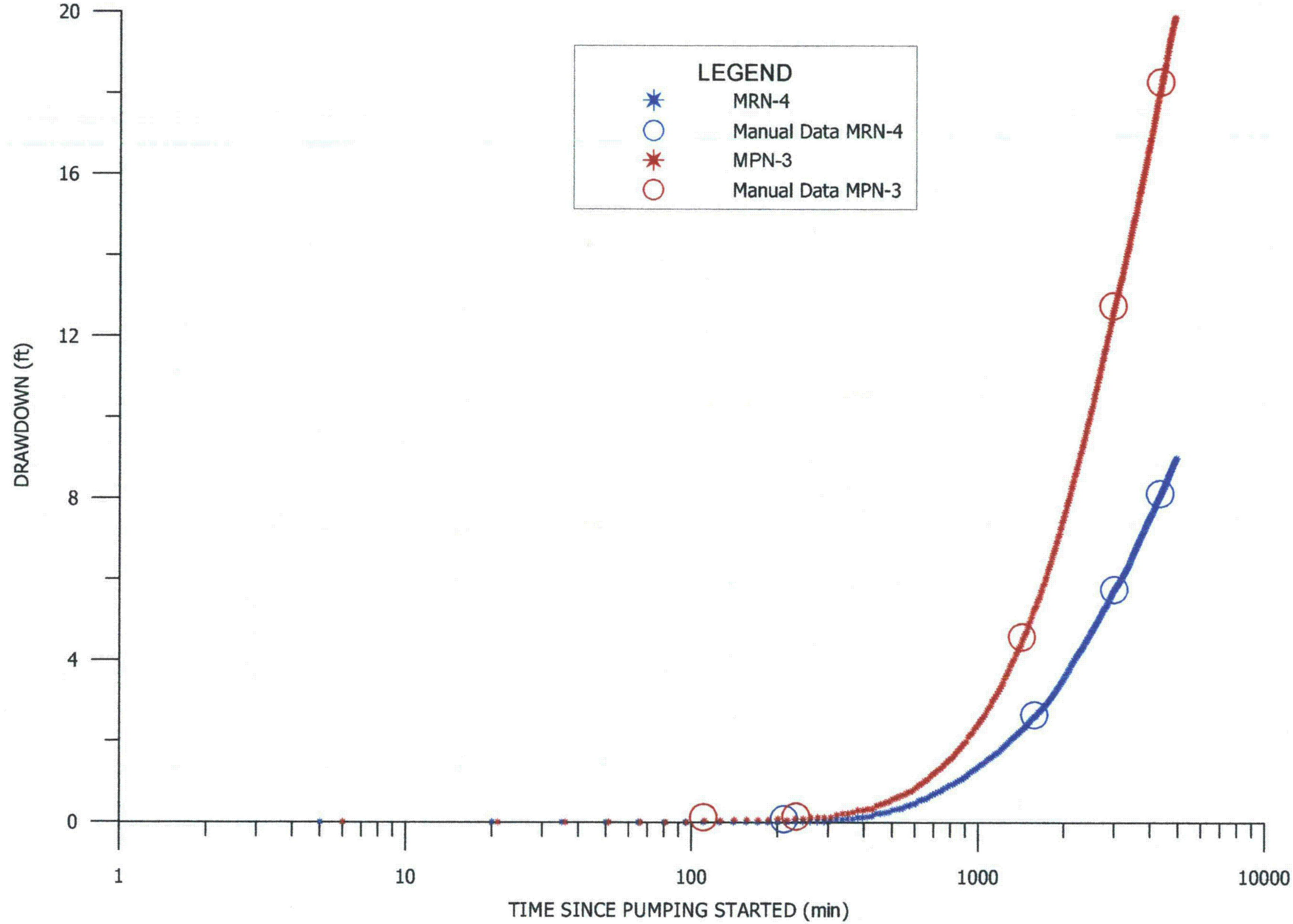
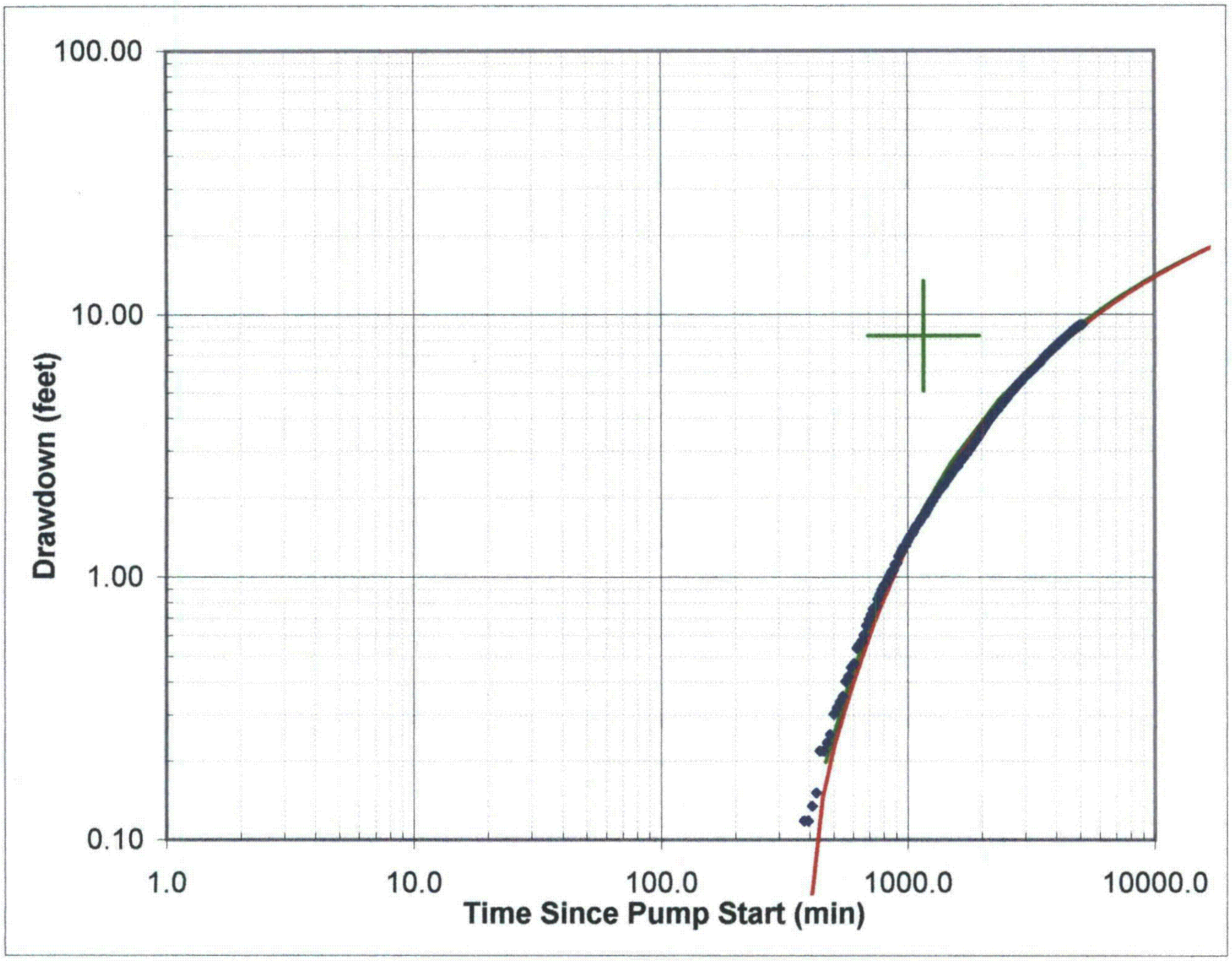


FIGURE 8-10. DRAWDOWN IN OBSERVATION WELL MRN-4 AND MPN-3



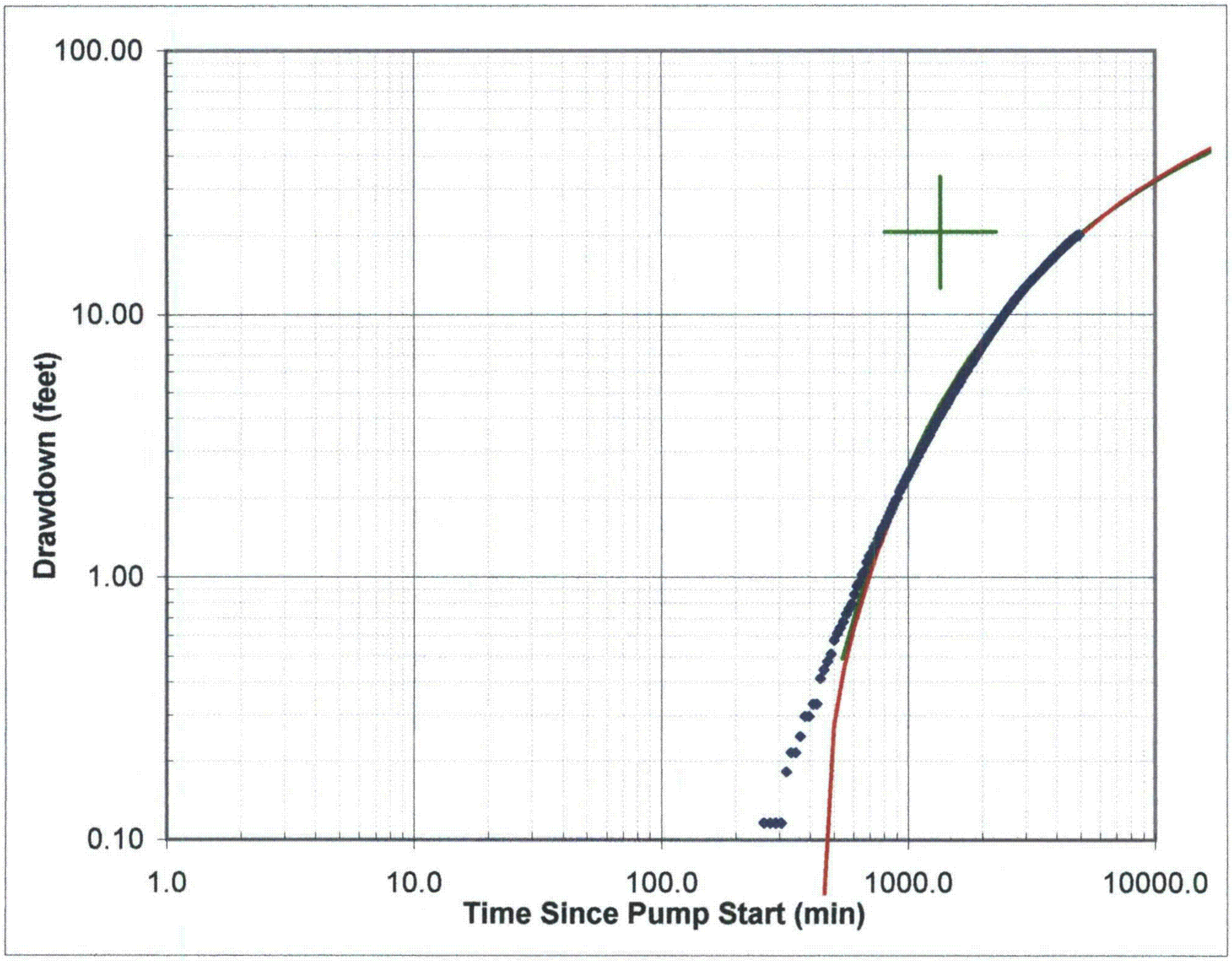
Theis Match Point

Intitial Discharge (gpm)	33.3
Radius to Pumping Well (ft) (<1 indicates pumping well)	1325
Drawdown Match Point (ft)	8.30
Time Match Point (min)	1160.0
Calculated Transmissivity (gal/day/ft)	460
Calculated Storage Coefficient (ft/ft)	1.13E-04
Refined Transmissivity Estimate (gal/day/ft)	449
Refined Storage Coefficient Estimate (ft/ft)	1.16E-04

Test Interruption Data

Pump Off Time (minutes after initial pump start)	2726
Pump Restart Time (minutes after initial pump start)	2820
Pump Restart Rate (gpm)	33.3

FIGURE 8-11. DRAWDOWN IN OBSERVATION WELL MRN-4, LOG-LOG



Theis Match Point

Intitial Discharge (gpm)	33.3
Radius to Pumping Well (ft) (<1 indicates pumping well)	614
Drawdown Match Point (ft)	20.60
Time Match Point (min)	1350.0
Calculated Transmissivity (gal/day/ft)	185
Calculated Storage Coefficient (ft/ft)	2.46E-04
Refined Transmissivity Estimate (gal/day/ft)	176
Refined Storage Coefficient Estimate (ft/ft)	2.46E-04

Test Interruption Data

Pump Off Time (minutes after initial pump start)	2726
Pump Restart Time (minutes after initial pump start)	2820
Pump Restart Rate (gpm)	33.3

FIGURE 8-12. DRAWDOWN IN OBSERVATION WELL MPN-3, LOG-LOG

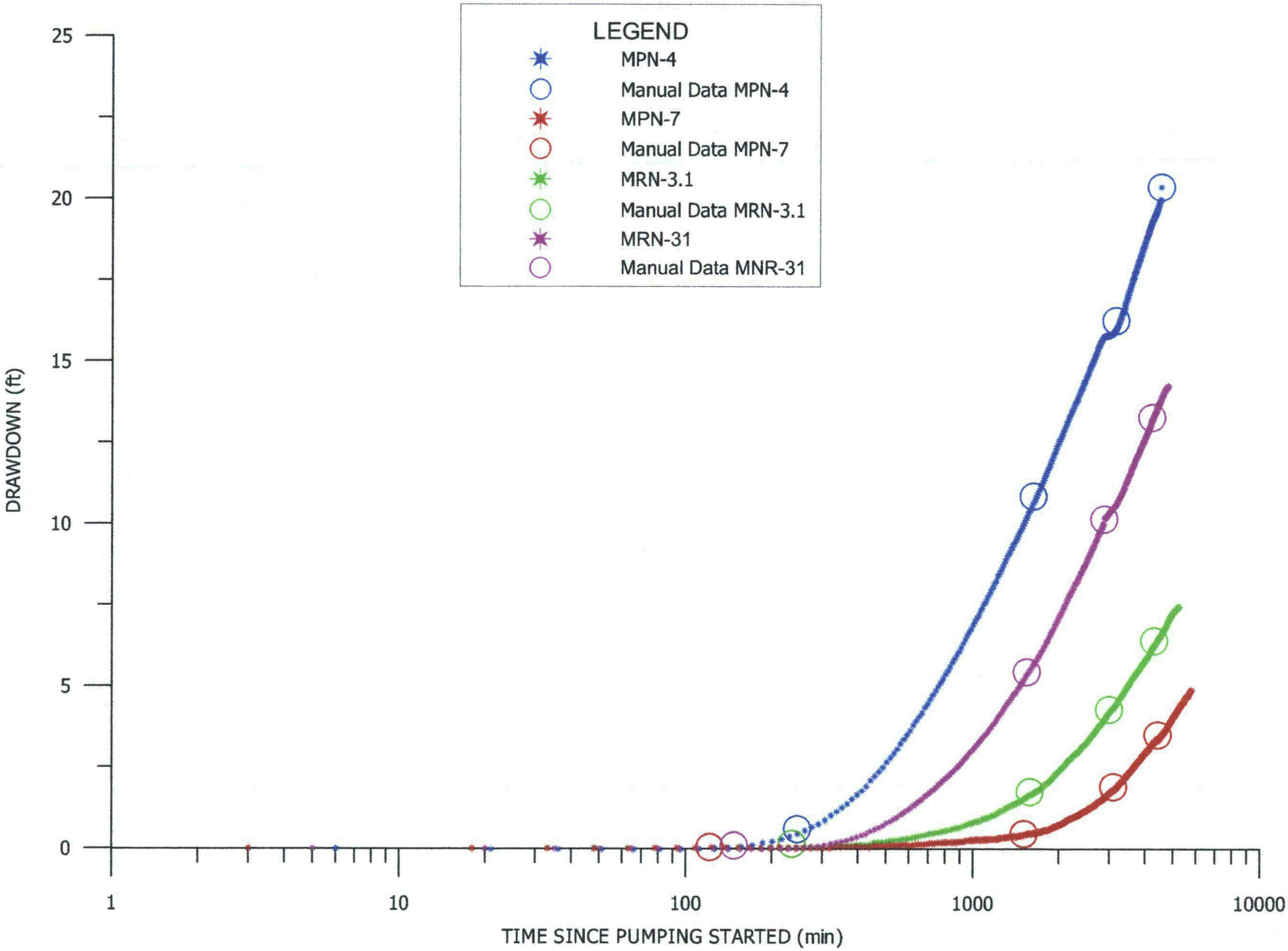
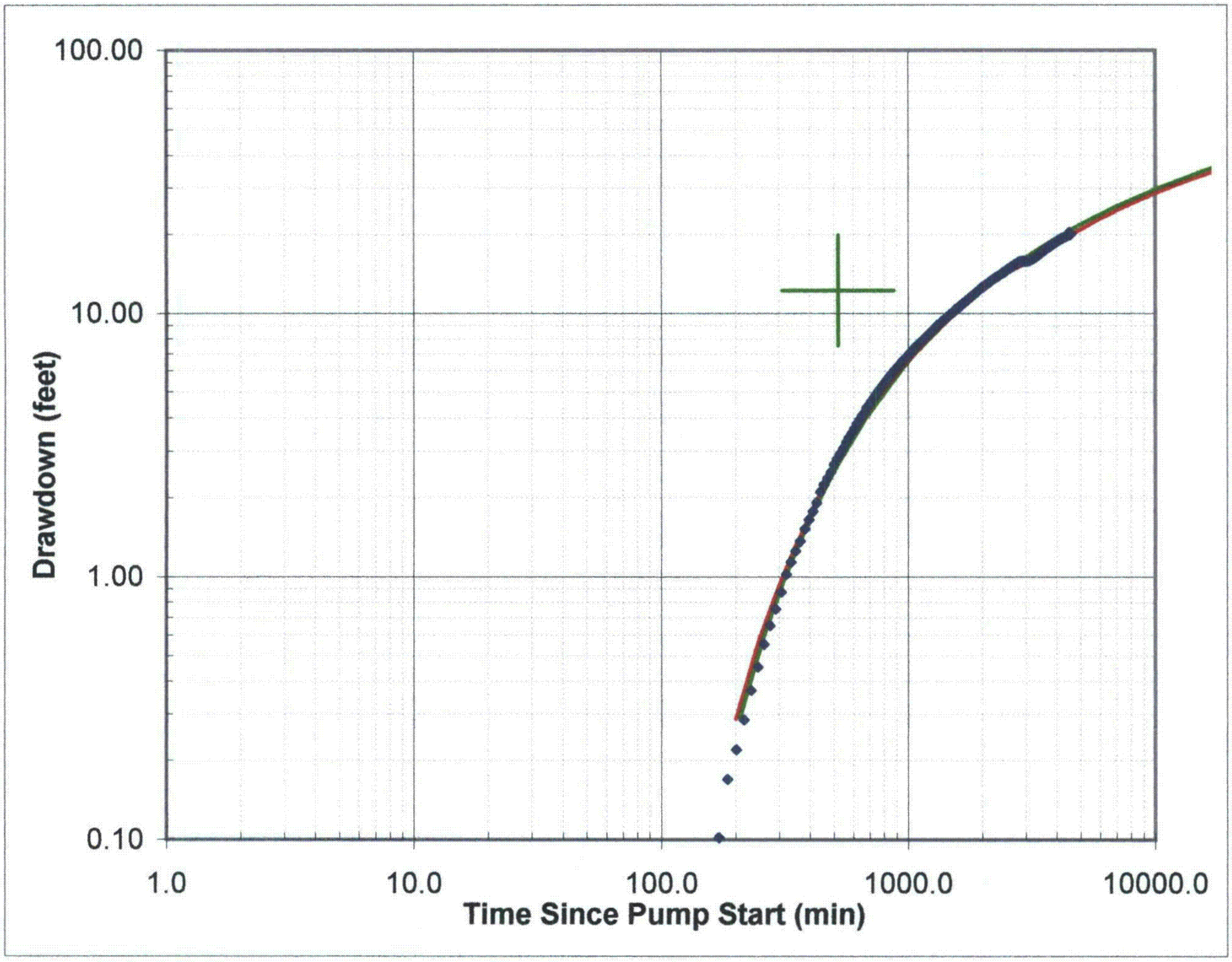


FIGURE 8-13. DRAWDOWN IN OBSERVATION WELL MPN-4, MPN-7, MRN-3.1 AND MRN-31



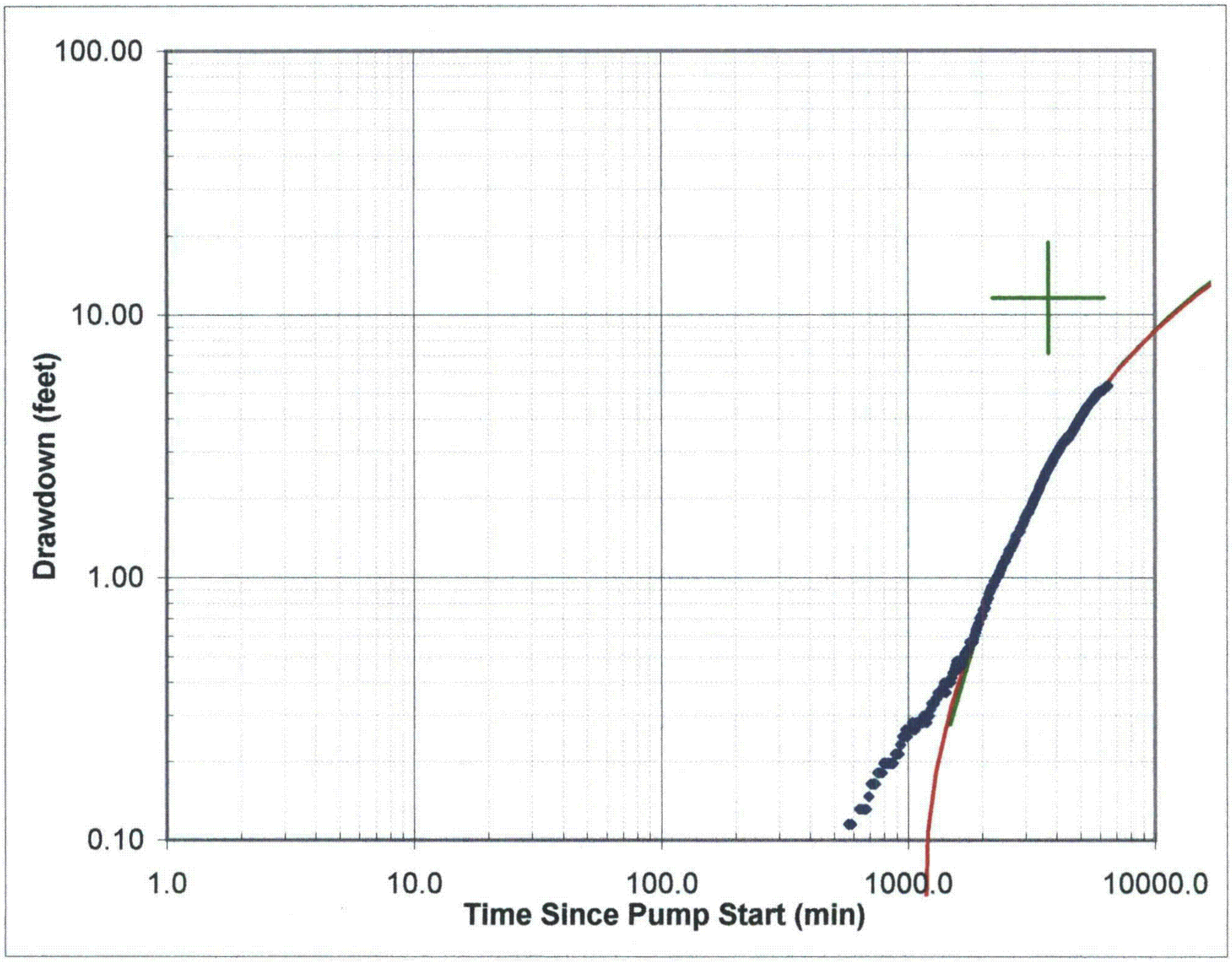
Theis Match Point

Intitial Discharge (gpm)	33.3
Radius to Pumping Well (ft) (<1 indicates pumping well)	770
Drawdown Match Point (ft)	12.20
Time Match Point (min)	520.0
Calculated Transmissivity (gal/day/ft)	313
Calculated Storage Coefficient (ft/ft)	1.02E-04
Refined Transmissivity Estimate (gal/day/ft)	328
Refined Storage Coefficient Estimate (ft/ft)	1.02E-04

Test Interruption Data

Pump Off Time (minutes after initial pump start)	2726
Pump Restart Time (minutes after initial pump start)	2820
Pump Restart Rate (gpm)	33.3

FIGURE 8-14. DRAWDOWN IN OBSERVATION WELL MPN-4, LOG-LOG



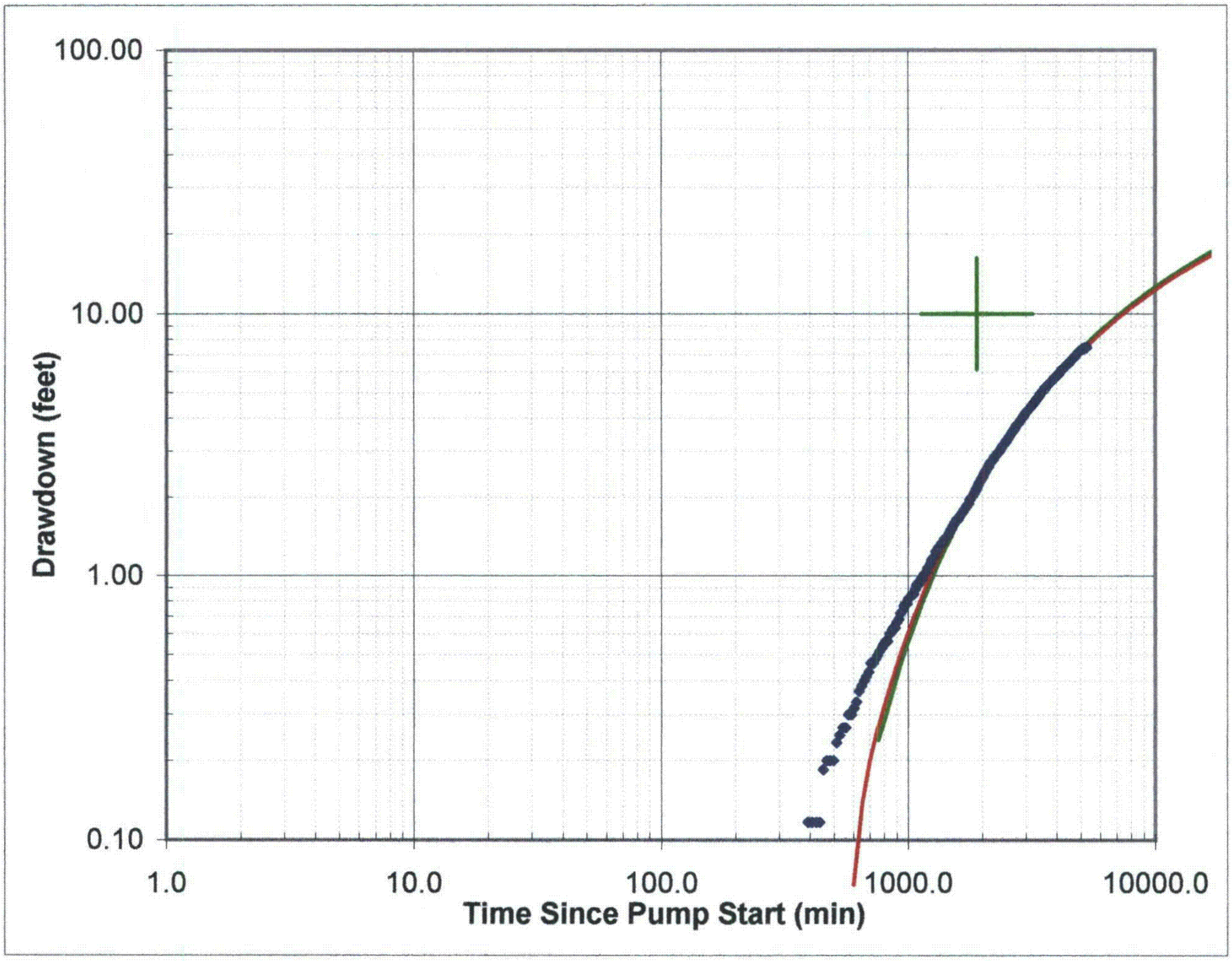
Theis Match Point

Intitial Discharge (gpm)	33.3
Radius to Pumping Well (ft) (<1 indicates pumping well)	1510
Drawdown Match Point (ft)	11.60
Time Match Point (min)	3700.00
Calculated Transmissivity (gal/day/ft)	329
Calculated Storage Coefficient (ft/ft)	1.98E-04
Refined Transmissivity Estimate (gal/day/ft)	345
Refined Storage Coefficient Estimate (ft/ft)	1.98E-04

Test Interruption Data

Pump Off Time (minutes after initial pump start)	2726
Pump Restart Time (minutes after initial pump start)	2820
Pump Restart Rate (gpm)	33.3

FIGURE 8-15. DRAWDOWN IN OBSERVATION WELL MPN-7, LOG-LOG



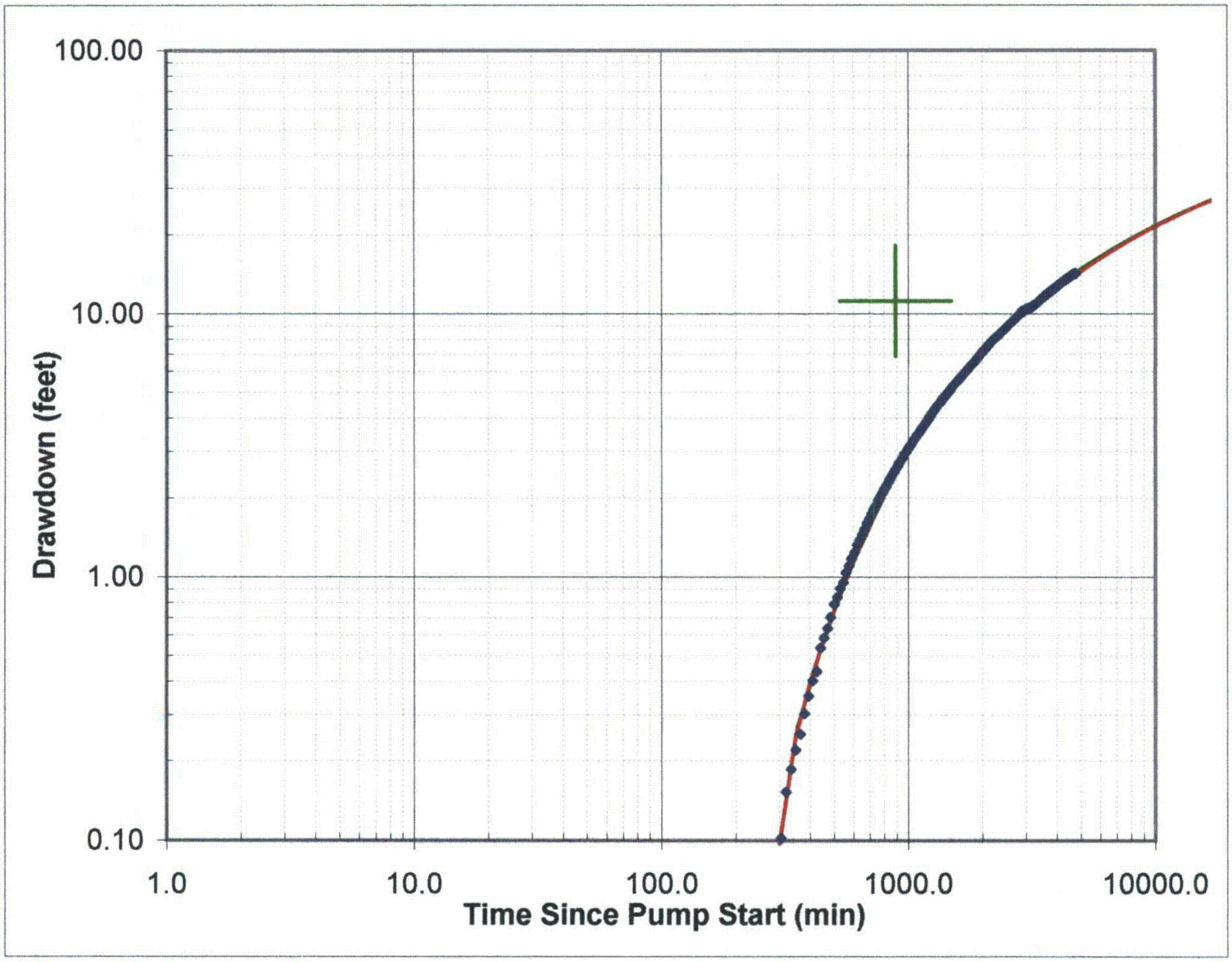
Theis Match Point

Intitial Discharge (gpm)	33.3
Radius to Pumping Well (ft) (<1 indicates pumping well)	1534
Drawdown Match Point (ft)	10.00
Time Match Point (min)	1900.0
Calculated Transmissivity (gal/day/ft)	382
Calculated Storage Coefficient (ft/ft)	1.14E-04
Refined Transmissivity Estimate (gal/day/ft)	401
Refined Storage Coefficient Estimate (ft/ft)	1.14E-04

Test Interruption Data

Pump Off Time (minutes after initial pump start)	2726
Pump Restart Time (minutes after initial pump start)	2820
Pump Restart Rate (gpm)	33.3

FIGURE 8-16. DRAWDOWN IN OBSERVATION WELL MRN-3.1, LOG-LOG



Theis Match Point

Intitial Discharge (gpm)	33.3
Radius to Pumping Well (ft) (<1 indicates pumping well)	983
Drawdown Match Point (ft)	11.20
Time Match Point (min)	890.0
Calculated Transmissivity (gal/day/ft)	341
Calculated Storage Coefficient (ft/ft)	1.17E-04
Refined Transmissivity Estimate (gal/day/ft)	341
Refined Storage Coefficient Estimate (ft/ft)	1.17E-04

Test Interruption Data

Pump Off Time (minutes after initial pump start)	2726
Pump Restart Time (minutes after initial pump start)	2820
Pump Restart Rate (gpm)	33.3

FIGURE 8-17. DRAWDOWN IN OBSERVATION WELL MRN-31, LOG-LOG

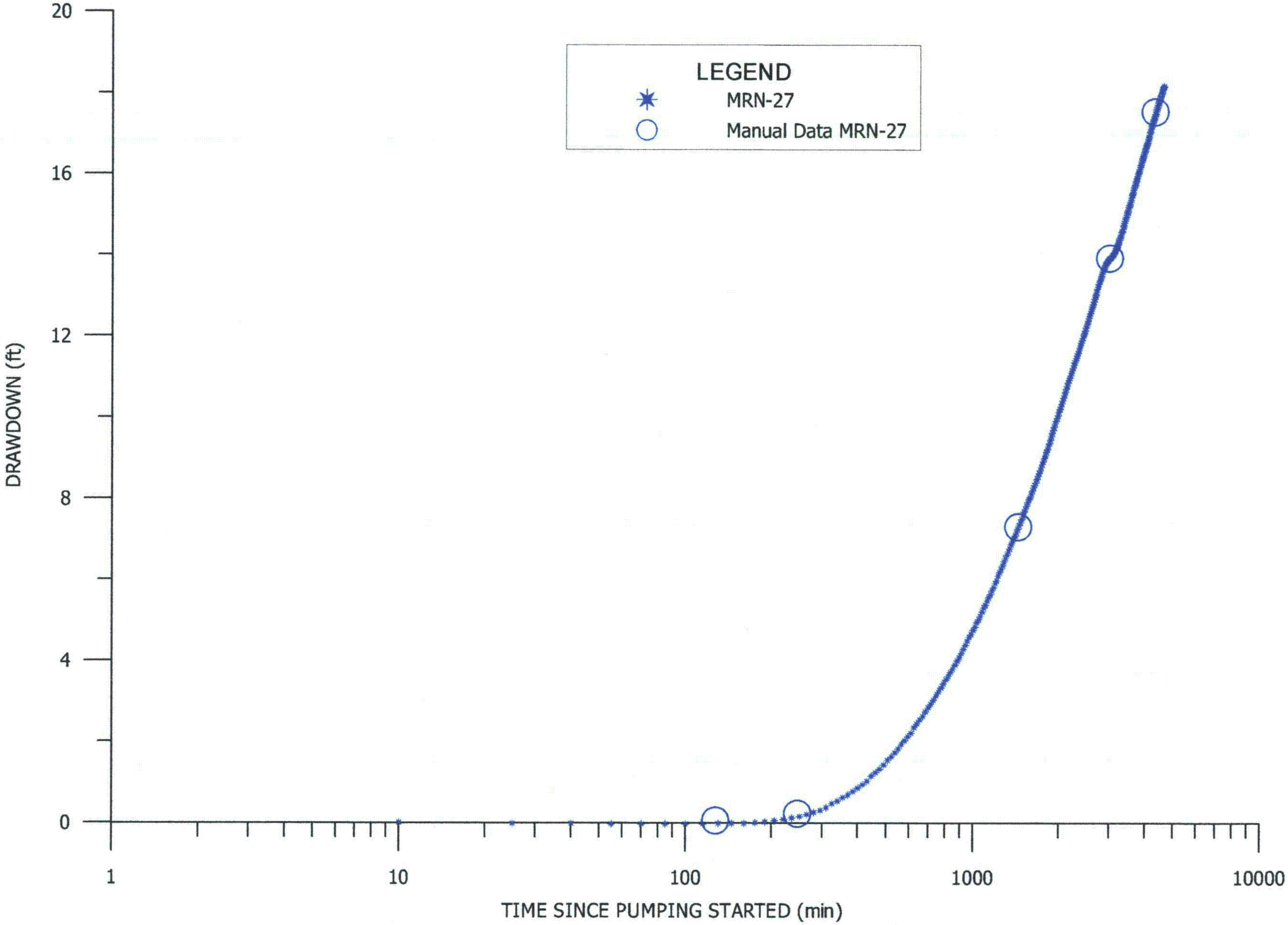
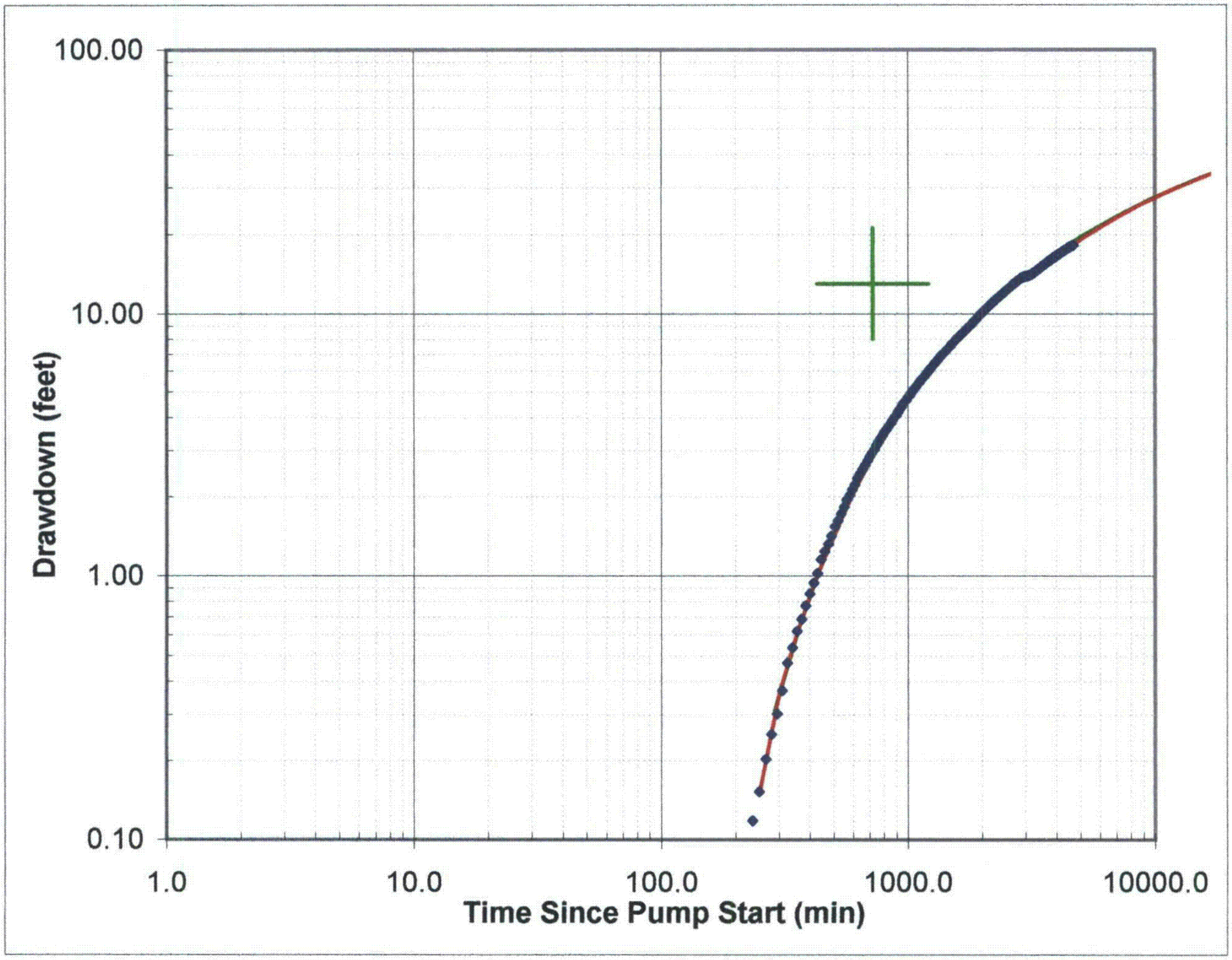


FIGURE 8-18. DRAWDOWN IN OBSERVATION WELL MRN-27



Theis Match Point

Intitial Discharge (gpm)	33.3
Radius to Pumping Well (ft) (<1 indicates pumping well)	830
Drawdown Match Point (ft)	13.00
Time Match Point (min)	720.0
Calculated Transmissivity (gal/day/ft)	294
Calculated Storage Coefficient (ft/ft)	1.14E-04
Refined Transmissivity Estimate (gal/day/ft)	294
Refined Storage Coefficient Estimate (ft/ft)	1.14E-04

Test Interruption Data

Pump Off Time (minutes after initial pump start)	2726
Pump Restart Time (minutes after initial pump start)	2820
Pump Restart Rate (gpm)	33.3

FIGURE 8-19. DRAWDOWN IN OBSERVATION WELL MRN-27, LOG-LOG

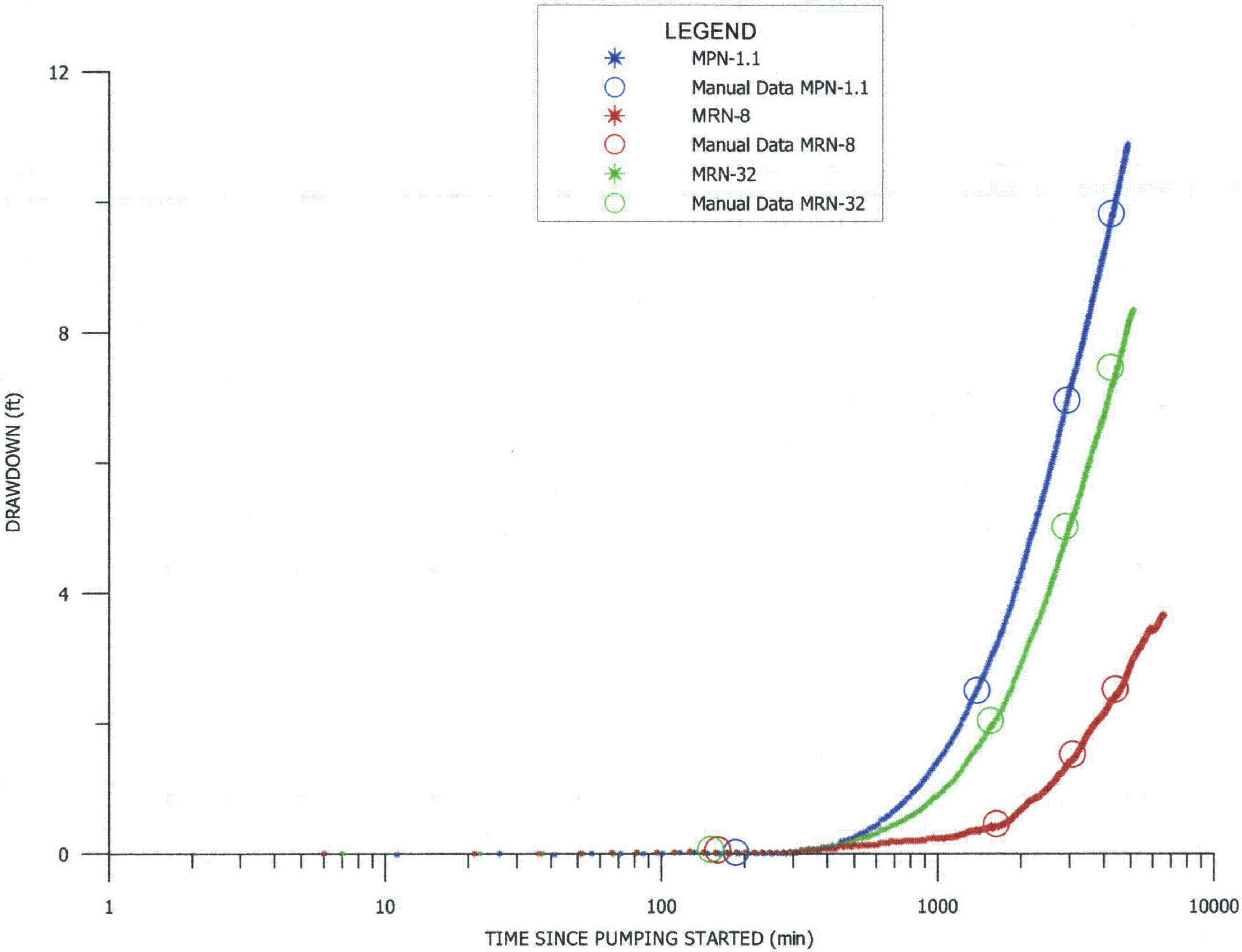
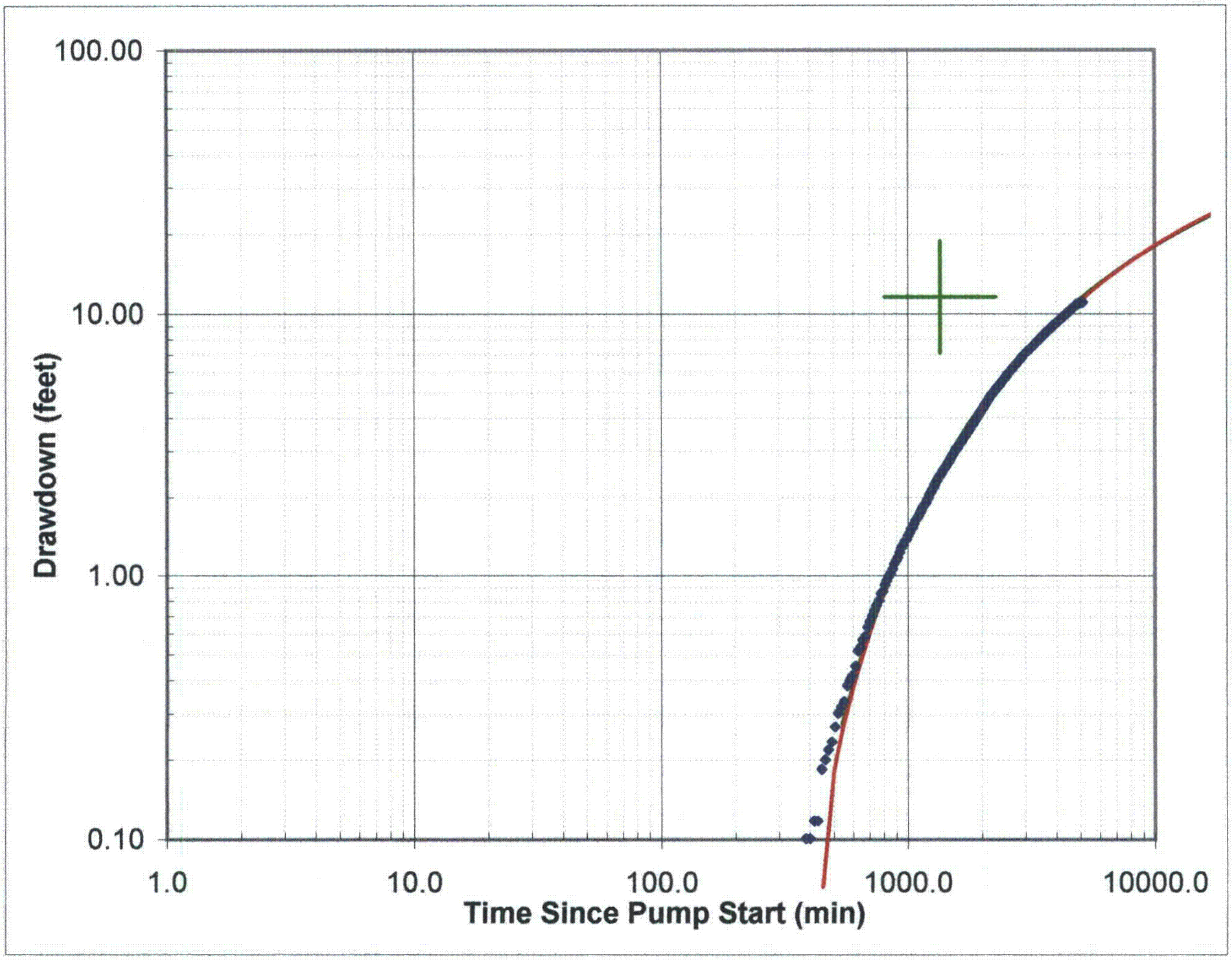


FIGURE 8-20. DRAWDOWN IN OBSERVATION WELL MPN-1.1, MRN-8 AND MRN-32



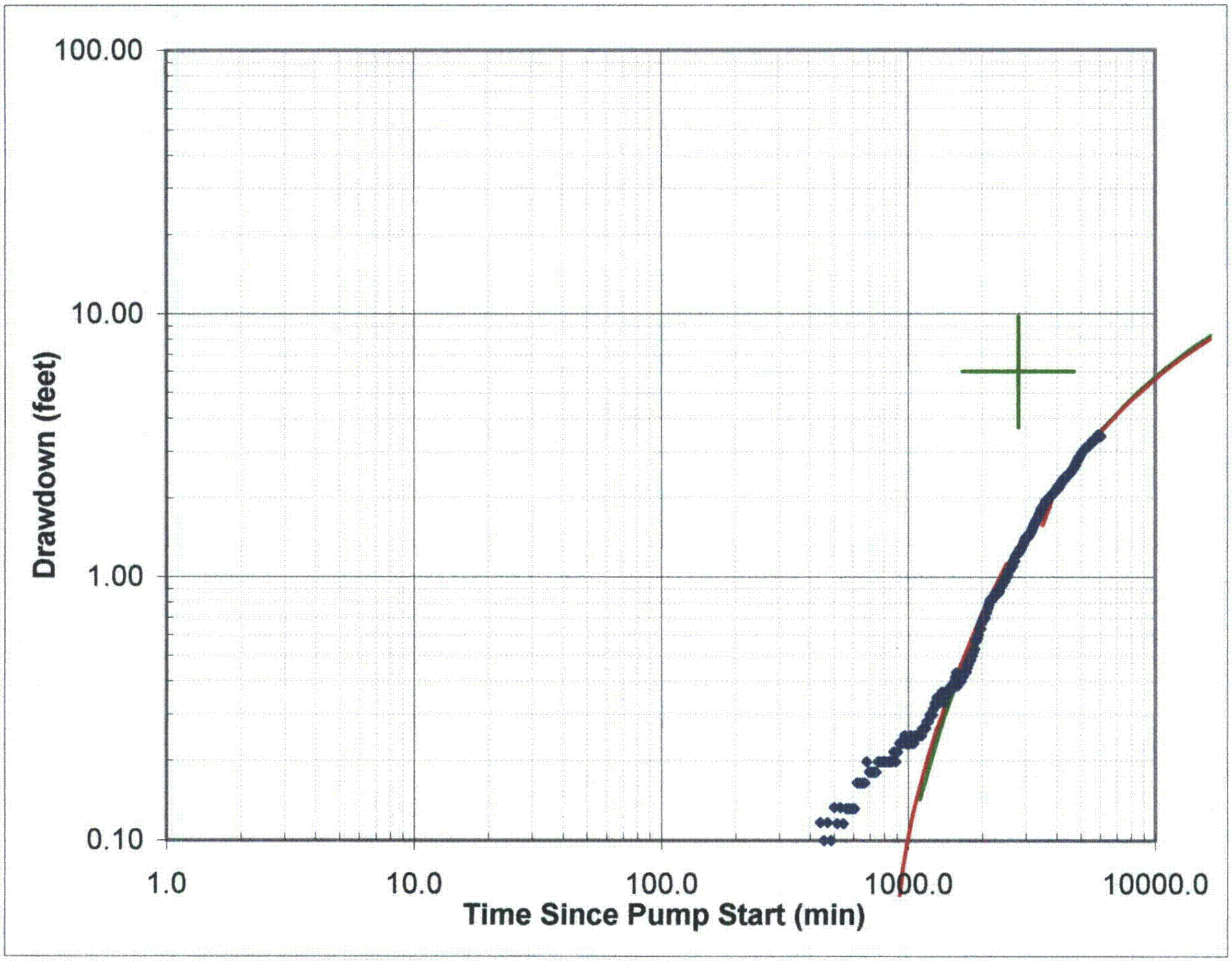
Theis Match Point

Intitial Discharge (gpm)	33.3
Radius to Pumping Well (ft) (<1 indicates pumping well)	1190
Drawdown Match Point (ft)	11.60
Time Match Point (min)	1350.0
Calculated Transmissivity (gal/day/ft)	329
Calculated Storage Coefficient (ft/ft)	1.16E-04
Refined Transmissivity Estimate (gal/day/ft)	323
Refined Storage Coefficient Estimate (ft/ft)	1.16E-04

Test Interruption Data

Pump Off Time (minutes after initial pump start)	2726
Pump Restart Time (minutes after initial pump start)	2820
Pump Restart Rate (gpm)	33.3

FIGURE 8-21. DRAWDOWN IN OBSERVATION WELL MPN-1.1, LOG-LOG



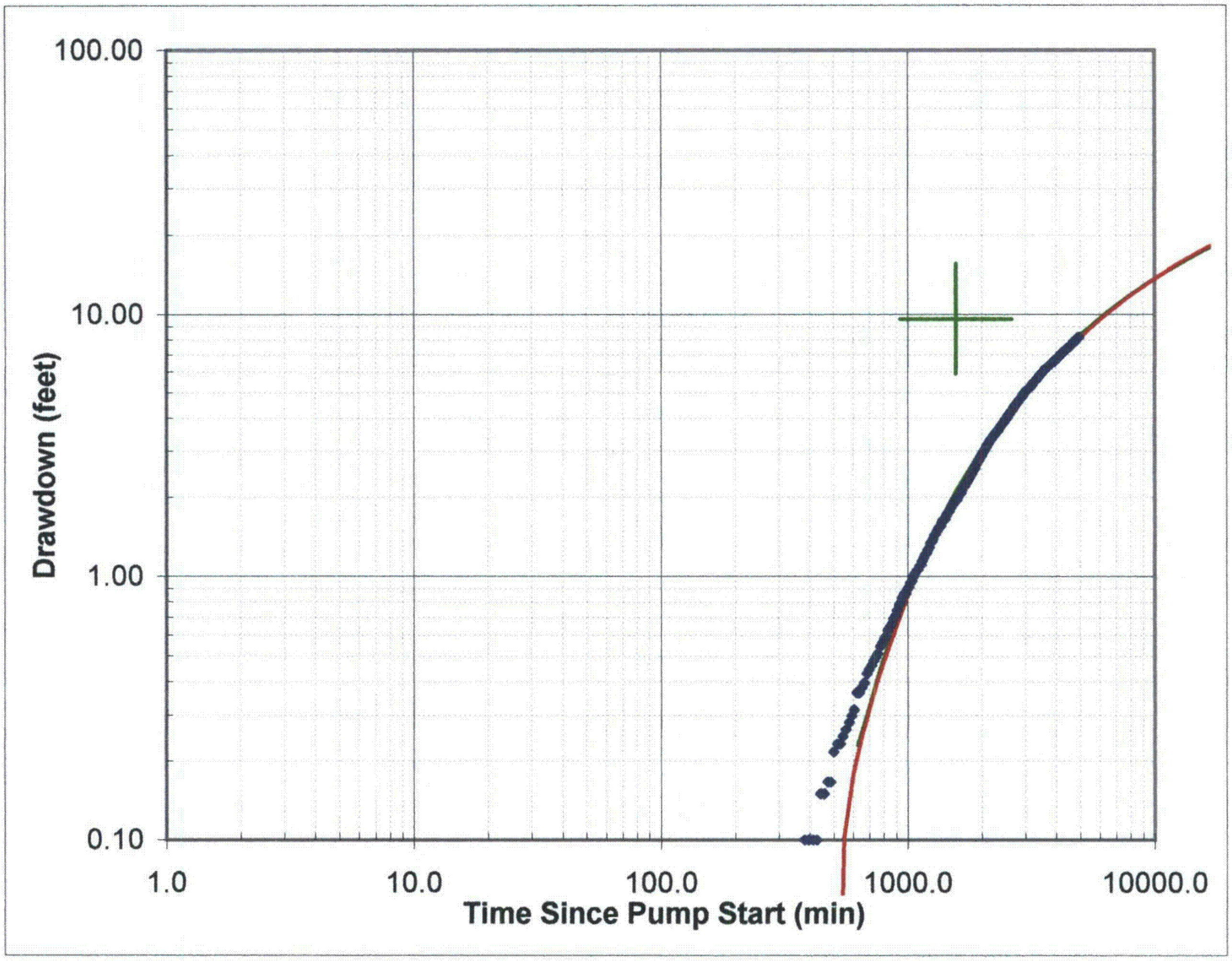
Theis Match Point

Intitial Discharge (gpm)	33.3
Radius to Pumping Well (ft) (<1 indicates pumping well)	2017
Drawdown Match Point (ft)	6.00
Time Match Point (min)	2800.0
Calculated Transmissivity (gal/day/ft)	636
Calculated Storage Coefficient (ft/ft)	1.63E-04
Refined Transmissivity Estimate (gal/day/ft)	668
Refined Storage Coefficient Estimate (ft/ft)	1.63E-04

Test Interruption Data

Pump Off Time (minutes after initial pump start)	2726
Pump Restart Time (minutes after initial pump start)	2820
Pump Restart Rate (gpm)	33.3

FIGURE 8-22. DRAWDOWN IN OBSERVATION WELL MRN-8, LOG-LOG



Theis Match Point

Intitial Discharge (gpm)	33.3
Radius to Pumping Well (ft) (<1 indicates pumping well)	1434
Drawdown Match Point (ft)	9.60
Time Match Point (min)	1570.0
Calculated Transmissivity (gal/day/ft)	398
Calculated Storage Coefficient (ft/ft)	1.13E-04
Refined Transmissivity Estimate (gal/day/ft)	390
Refined Storage Coefficient Estimate (ft/ft)	1.13E-04

Test Interruption Data

Pump Off Time (minutes after initial pump start)	2726
Pump Restart Time (minutes after initial pump start)	2820
Pump Restart Rate (gpm)	33.3

FIGURE 8-23. DRAWDOWN IN OBSERVATION WELL MRN-32, LOG-LOG

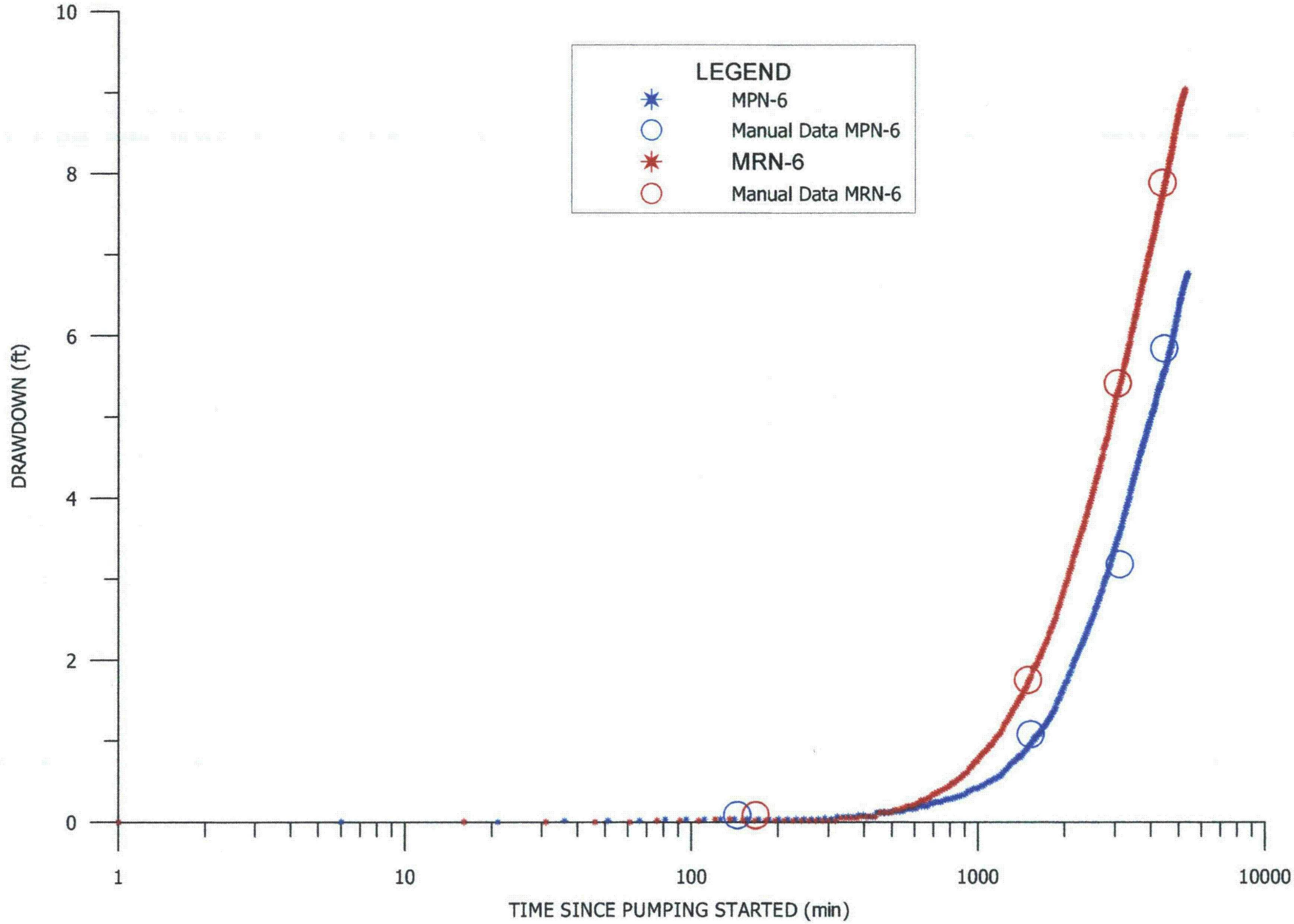
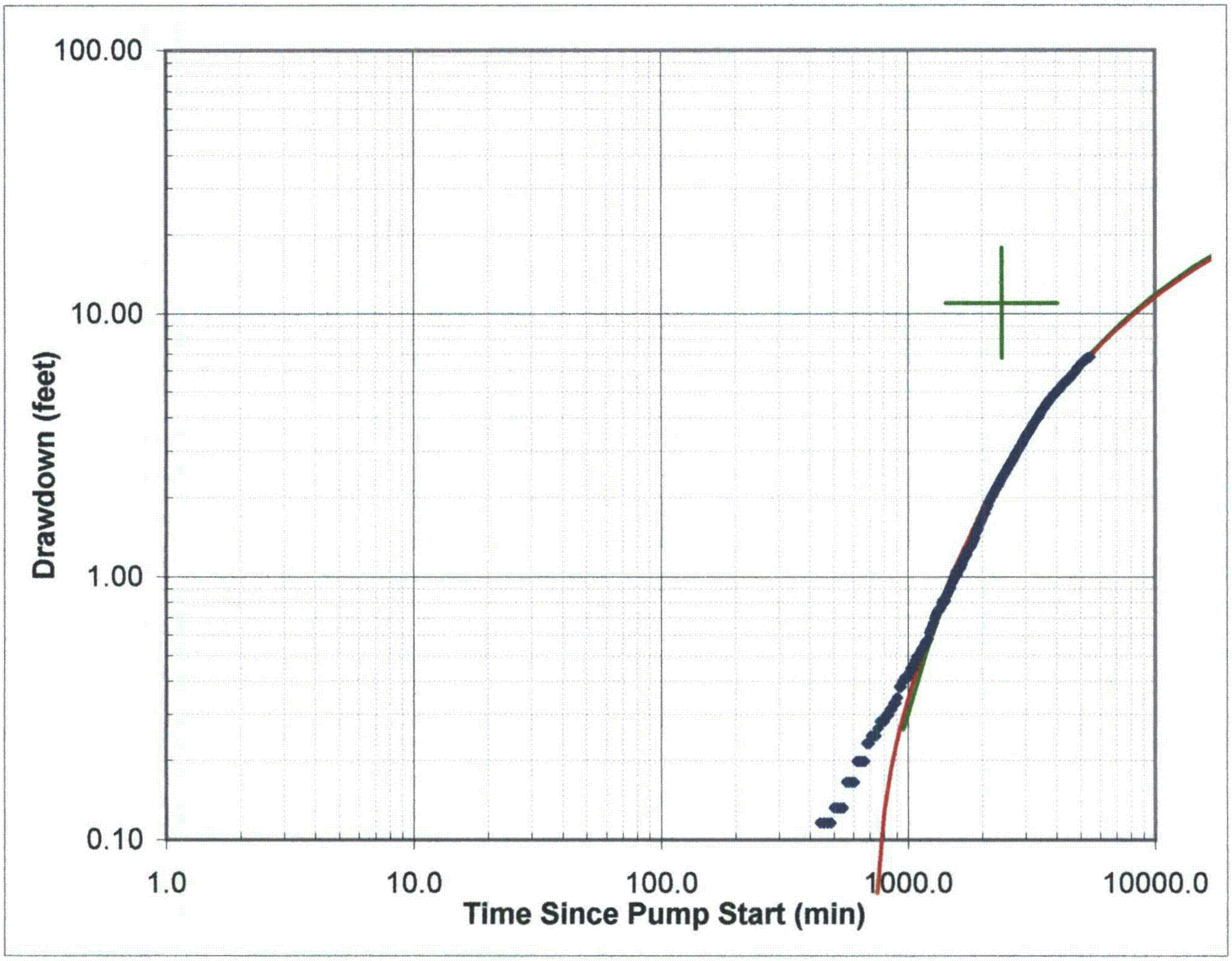


FIGURE 8-24. DRAWDOWN IN OBSERVATION WELL MPN-6 AND MRN-6



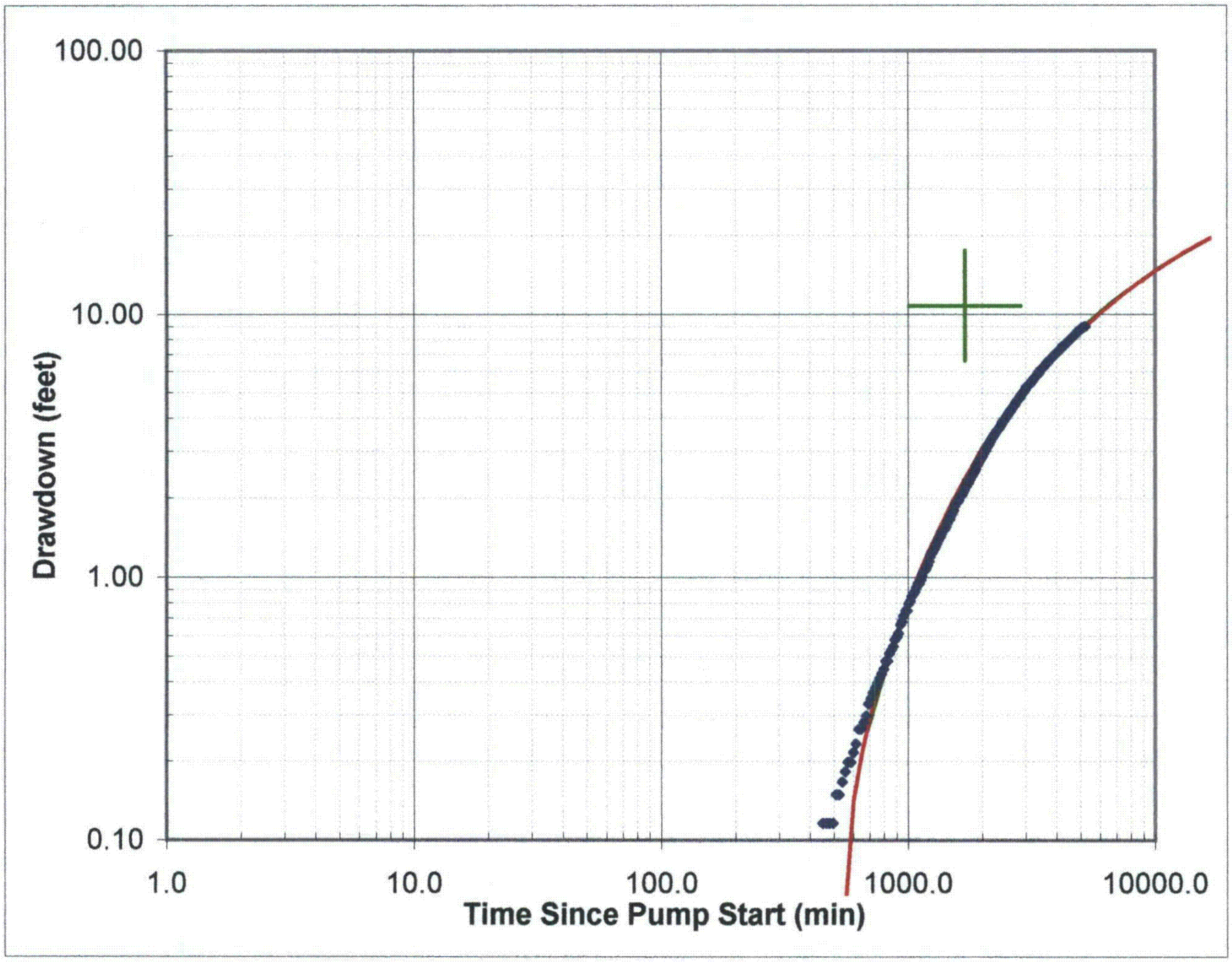
Theis Match Point

Intitial Discharge (gpm)	33.3
Radius to Pumping Well (ft) (<1 indicates pumping well)	1339
Drawdown Match Point (ft)	11.00
Time Match Point (min)	2400.0
Calculated Transmissivity (gal/day/ft)	347
Calculated Storage Coefficient (ft/ft)	1.72E-04
Refined Transmissivity Estimate (gal/day/ft)	364
Refined Storage Coefficient Estimate (ft/ft)	1.72E-04

Test Interruption Data

Pump Off Time (minutes after initial pump start)	2726
Pump Restart Time (minutes after initial pump start)	2820
Pump Restart Rate (gpm)	33.3

FIGURE 8-25. DRAWDOWN IN OBSERVATION WELL MPN-6, LOG-LOG



Theis Match Point

Initial Discharge (gpm)	33.3
Radius to Pumping Well (ft) (<1 indicates pumping well)	1534
Drawdown Match Point (ft)	10.80
Time Match Point (min)	1700.0
Calculated Transmissivity (gal/day/ft)	334
Calculated Storage Coefficient (ft/ft)	8.97E-05
Refined Transmissivity Estimate (gal/day/ft)	351
Refined Storage Coefficient Estimate (ft/ft)	9.42E-05

Test Interruption Data

Pump Off Time (minutes after initial pump start)	2726
Pump Restart Time (minutes after initial pump start)	2820
Pump Restart Rate (gpm)	33.3

FIGURE 8-26. DRAWDOWN IN OBSERVATION WELL MRN-6, LOG-LOG

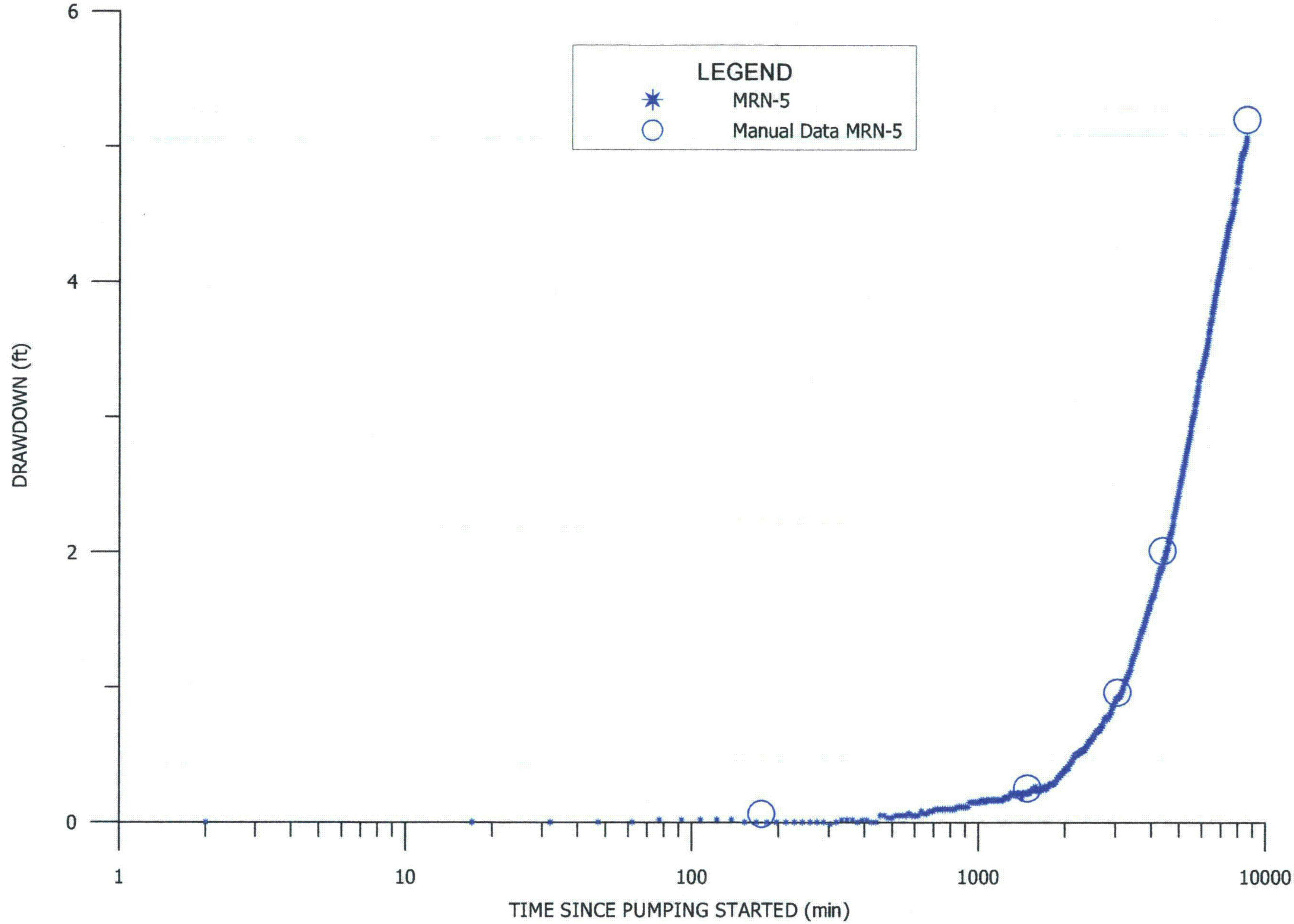
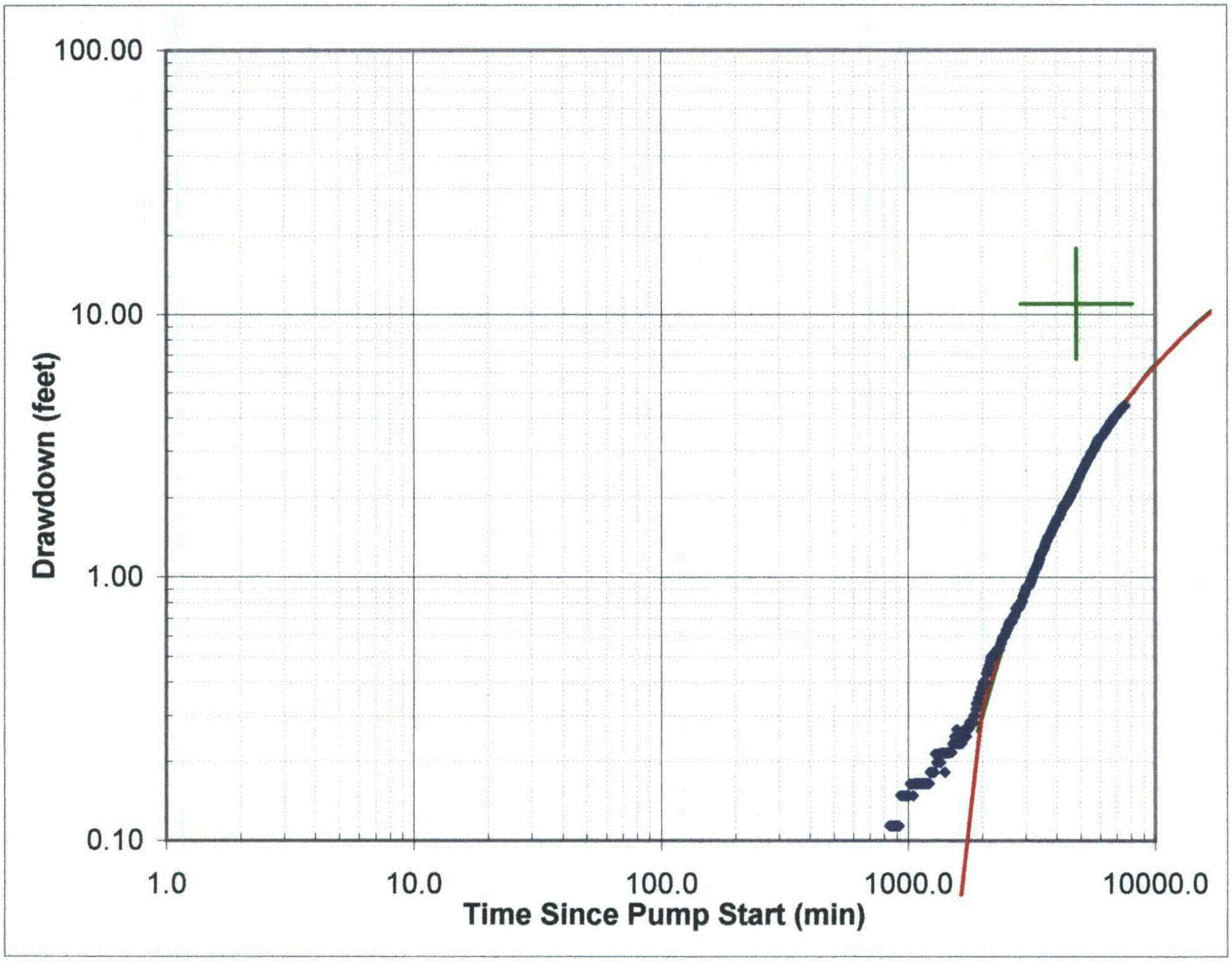


FIGURE 8-27. DRAWDOWN IN OBSERVATION WELL MRN-5



Theis Match Point

Intitial Discharge (gpm)	33.3
Radius to Pumping Well (ft) (<1 indicates pumping well)	1294
Drawdown Match Point (ft)	11.00
Time Match Point (min)	4800.0
Calculated Transmissivity (gal/day/ft)	347
Calculated Storage Coefficient (ft/ft)	3.69E-04
Refined Transmissivity Estimate (gal/day/ft)	354
Refined Storage Coefficient Estimate (ft/ft)	3.69E-04

Test Interruption Data

Pump Off Time (minutes after initial pump start)	2726
Pump Restart Time (minutes after initial pump start)	2820
Pump Restart Rate (gpm)	33.3

FIGURE 8-28. DRAWDOWN IN OBSERVATION WELL MRN-5, LOG-LOG

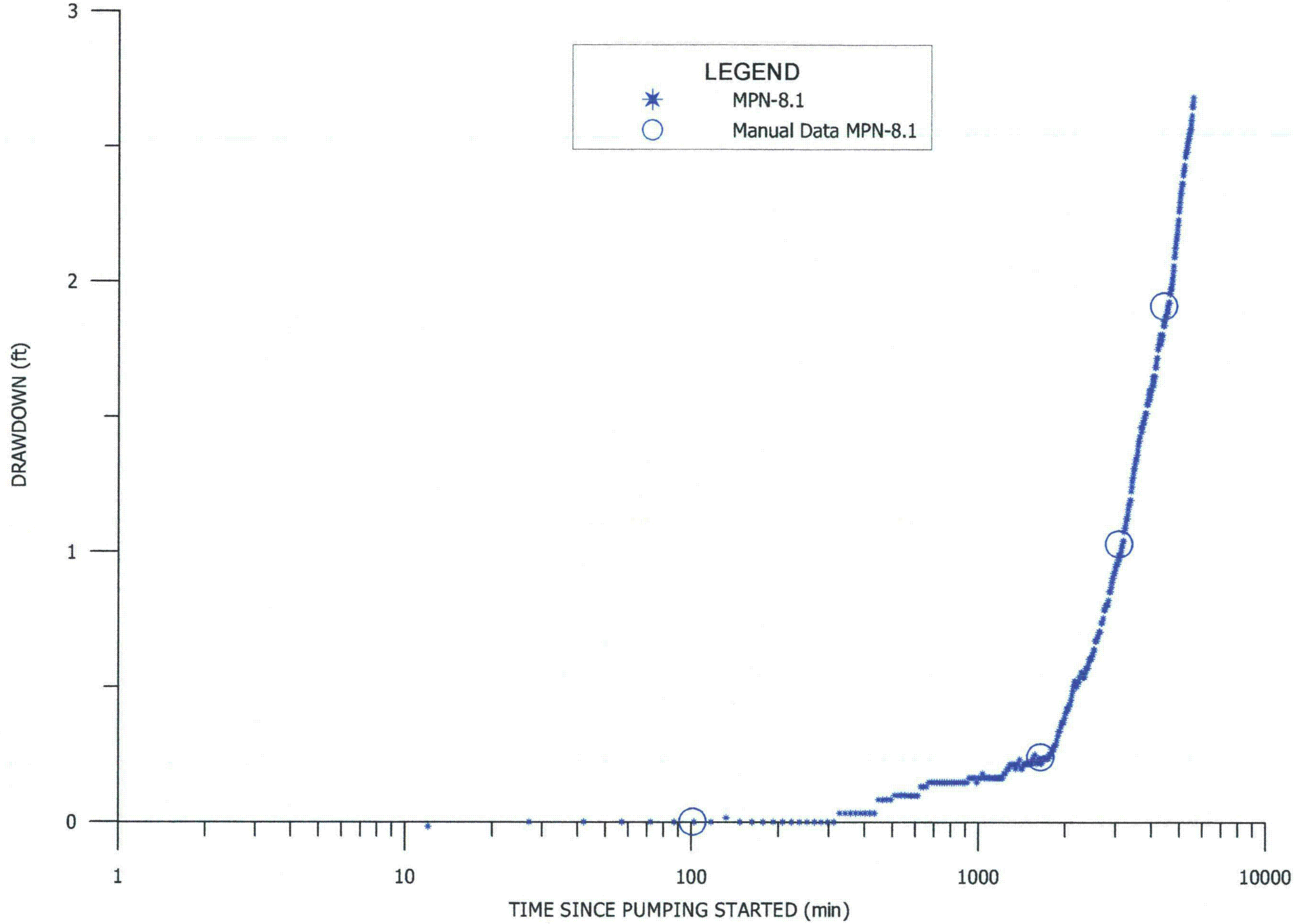
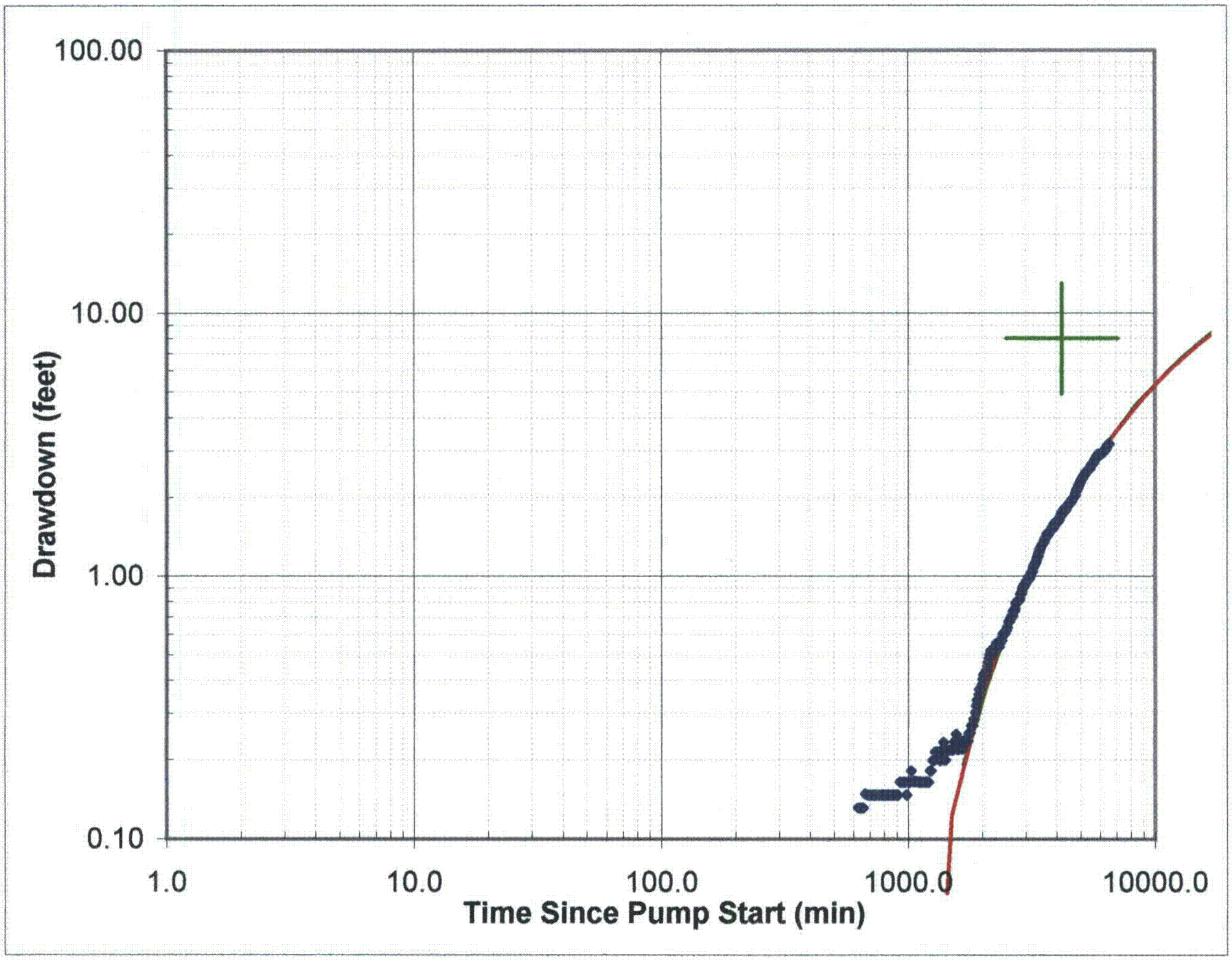


FIGURE 8-29. DRAWDOWN IN OBSERVATION WELL MPN-8.1



Theis Match Point

Initial Discharge (gpm)	33.3
Radius to Pumping Well (ft) (<1 indicates pumping well)	1879
Drawdown Match Point (ft)	8.00
Time Match Point (min)	4200.0
Calculated Transmissivity (gal/day/ft)	477
Calculated Storage Coefficient (ft/ft)	2.11E-04
Refined Transmissivity Estimate (gal/day/ft)	487
Refined Storage Coefficient Estimate (ft/ft)	2.11E-04

Test Interruption Data

Pump Off Time (minutes after initial pump start)	2726
Pump Restart Time (minutes after initial pump start)	2820
Pump Restart Rate (gpm)	33.3

FIGURE 8-30. DRAWDOWN IN OBSERVATION WELL MPN-8.1, LOG-LOG

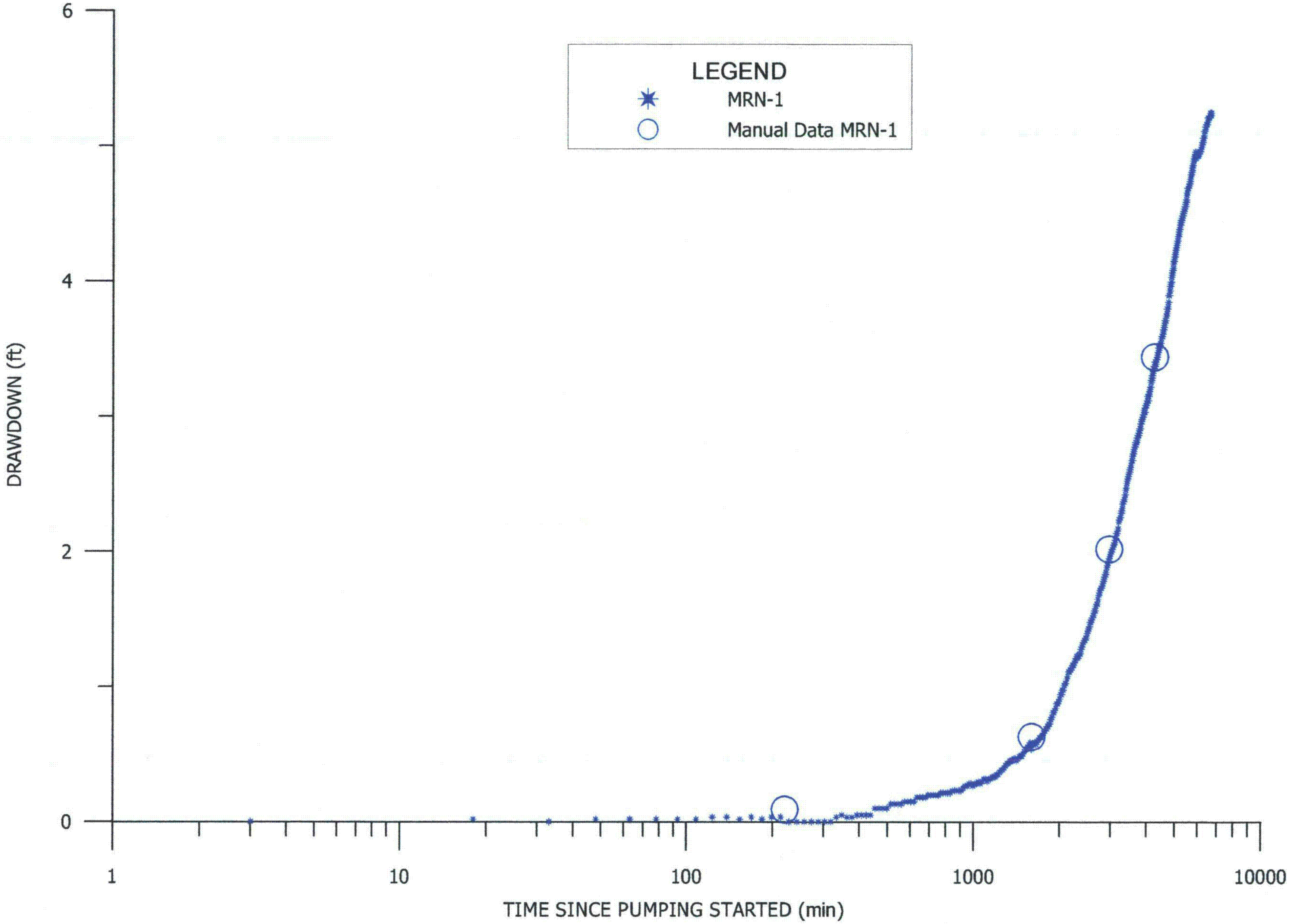
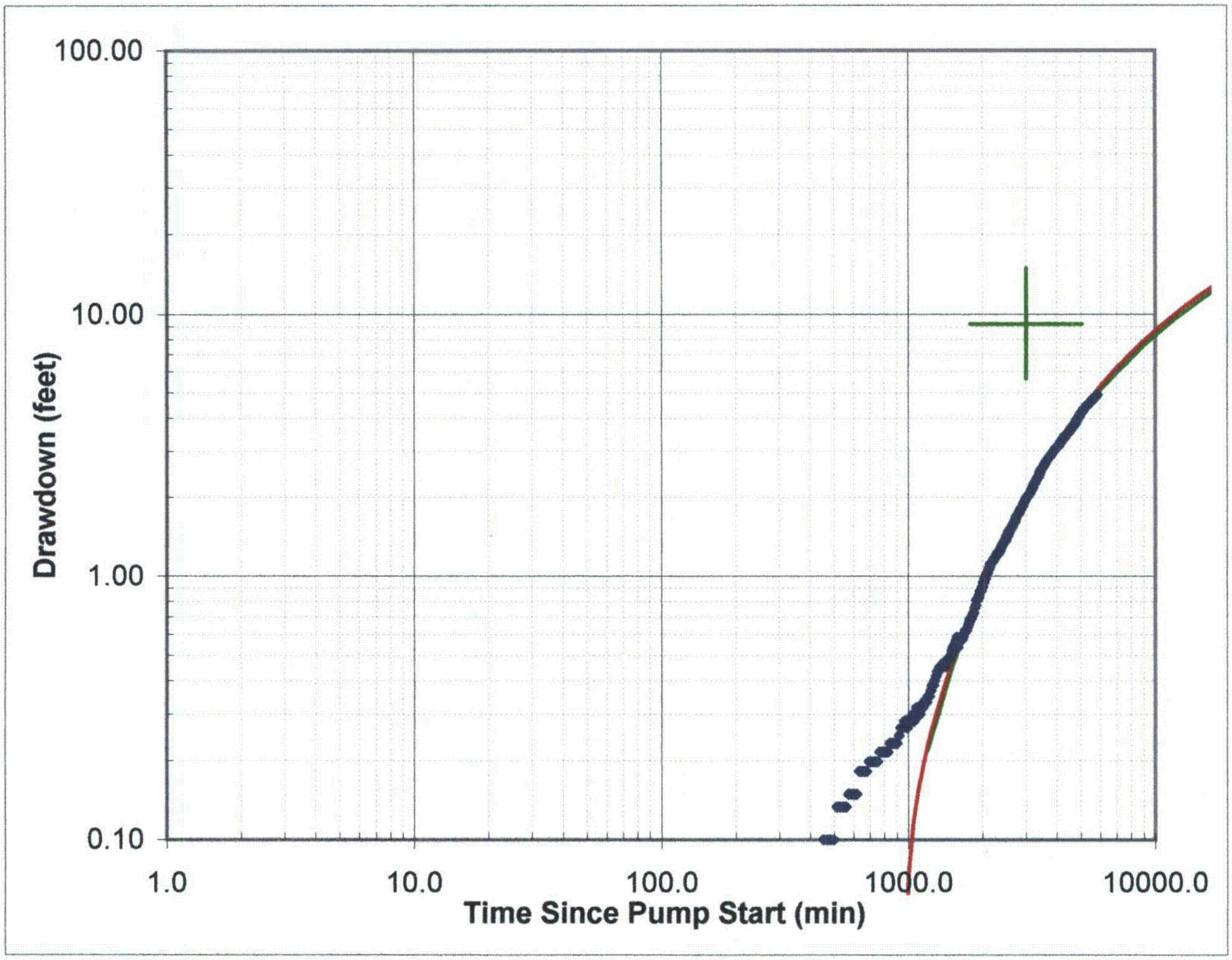


FIGURE 8-31. DRAWDOWN IN OBSERVATION WELL MRN-1



Theis Match Point

Intitial Discharge (gpm)	33.3
Radius to Pumping Well (ft) (<1 indicates pumping well)	2037
Drawdown Match Point (ft)	9.20
Time Match Point (min)	3000.0
Calculated Transmissivity (gal/day/ft)	415
Calculated Storage Coefficient (ft/ft)	1.11E-04
Refined Transmissivity Estimate (gal/day/ft)	395
Refined Storage Coefficient Estimate (ft/ft)	1.06E-04

Test Interruption Data

Pump Off Time (minutes after initial pump start)	2726
Pump Restart Time (minutes after initial pump start)	2820
Pump Restart Rate (gpm)	33.3

FIGURE 8-32. DRAWDOWN IN OBSERVATION WELL MRN-1, LOG-LOG

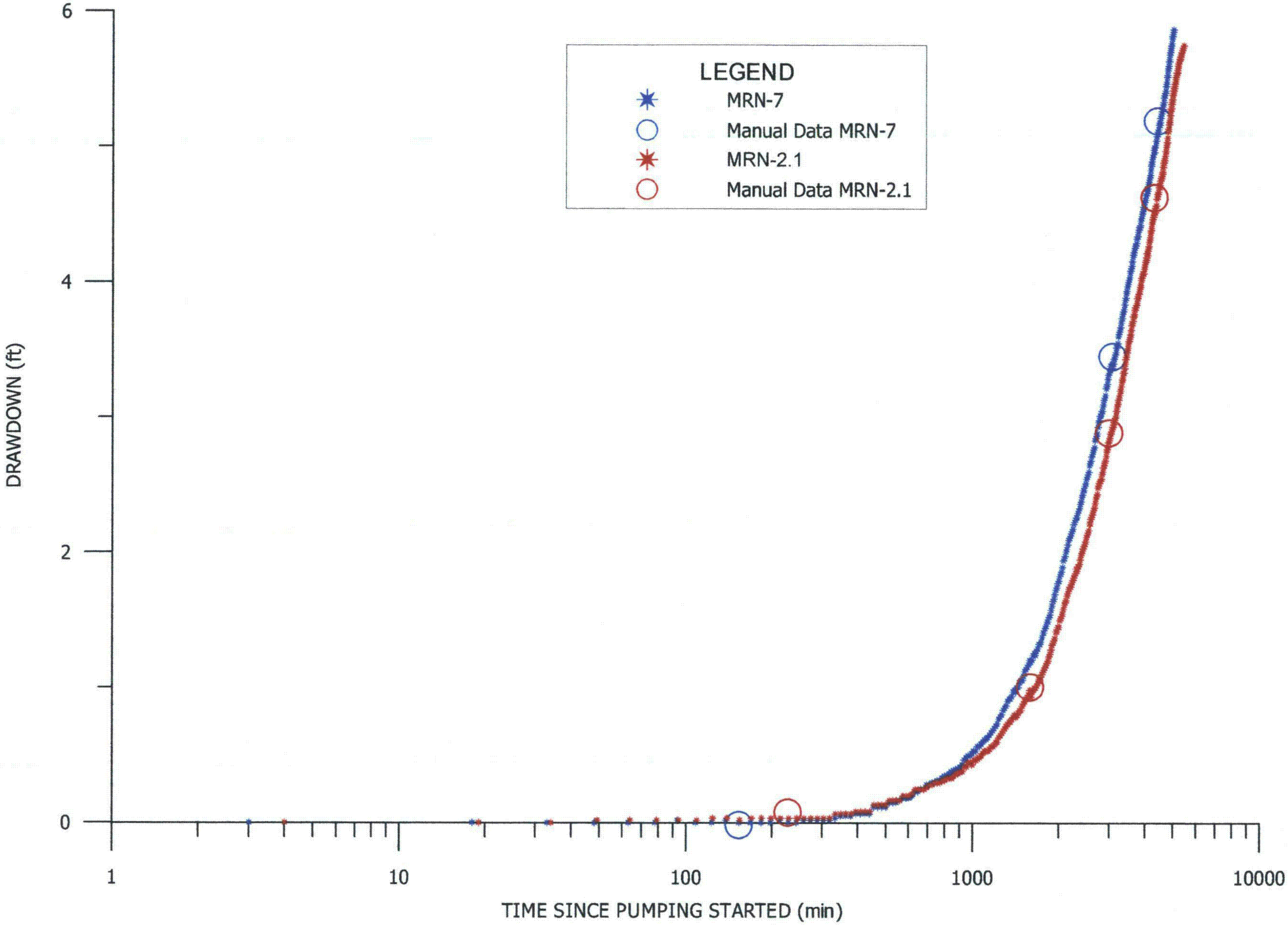
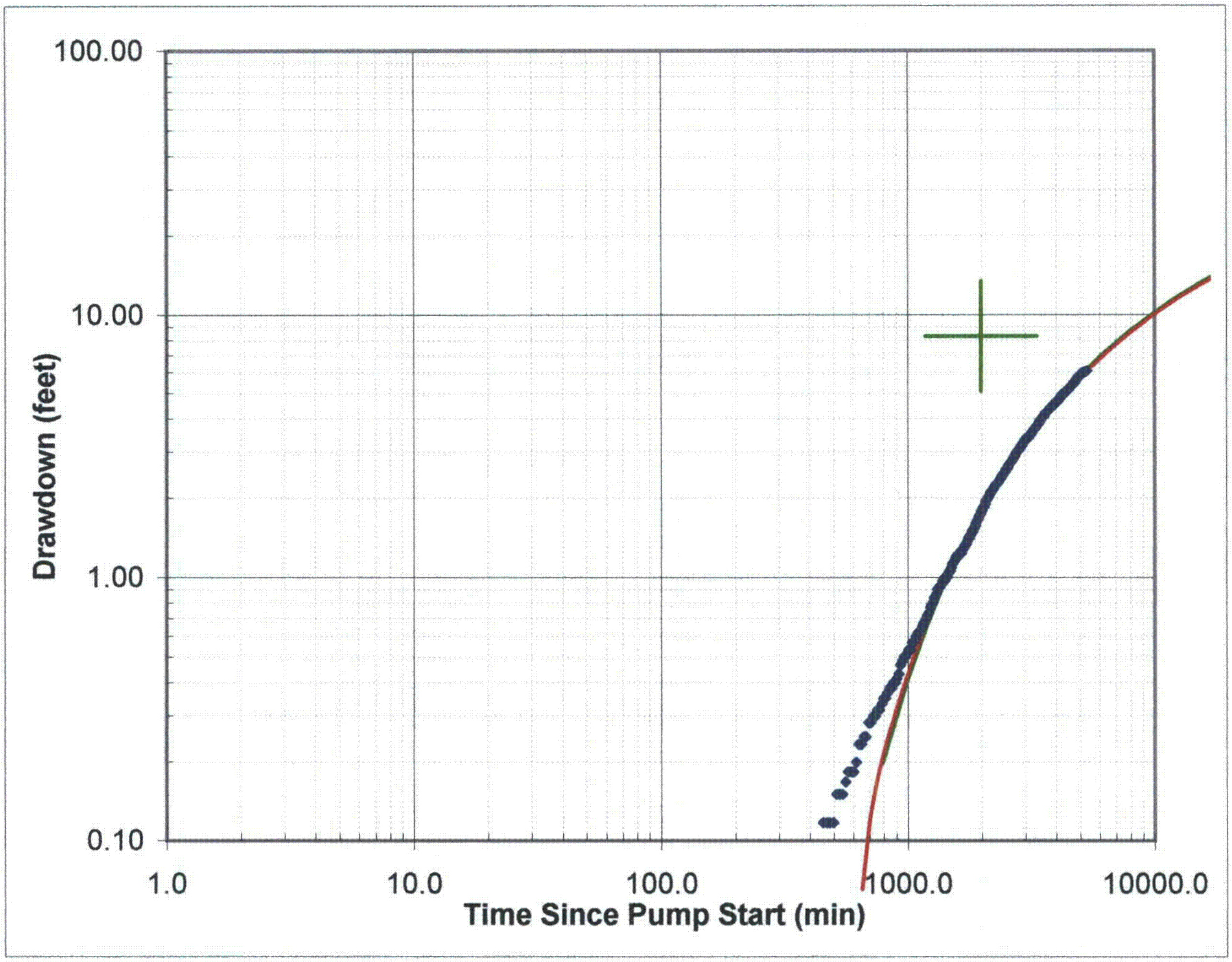


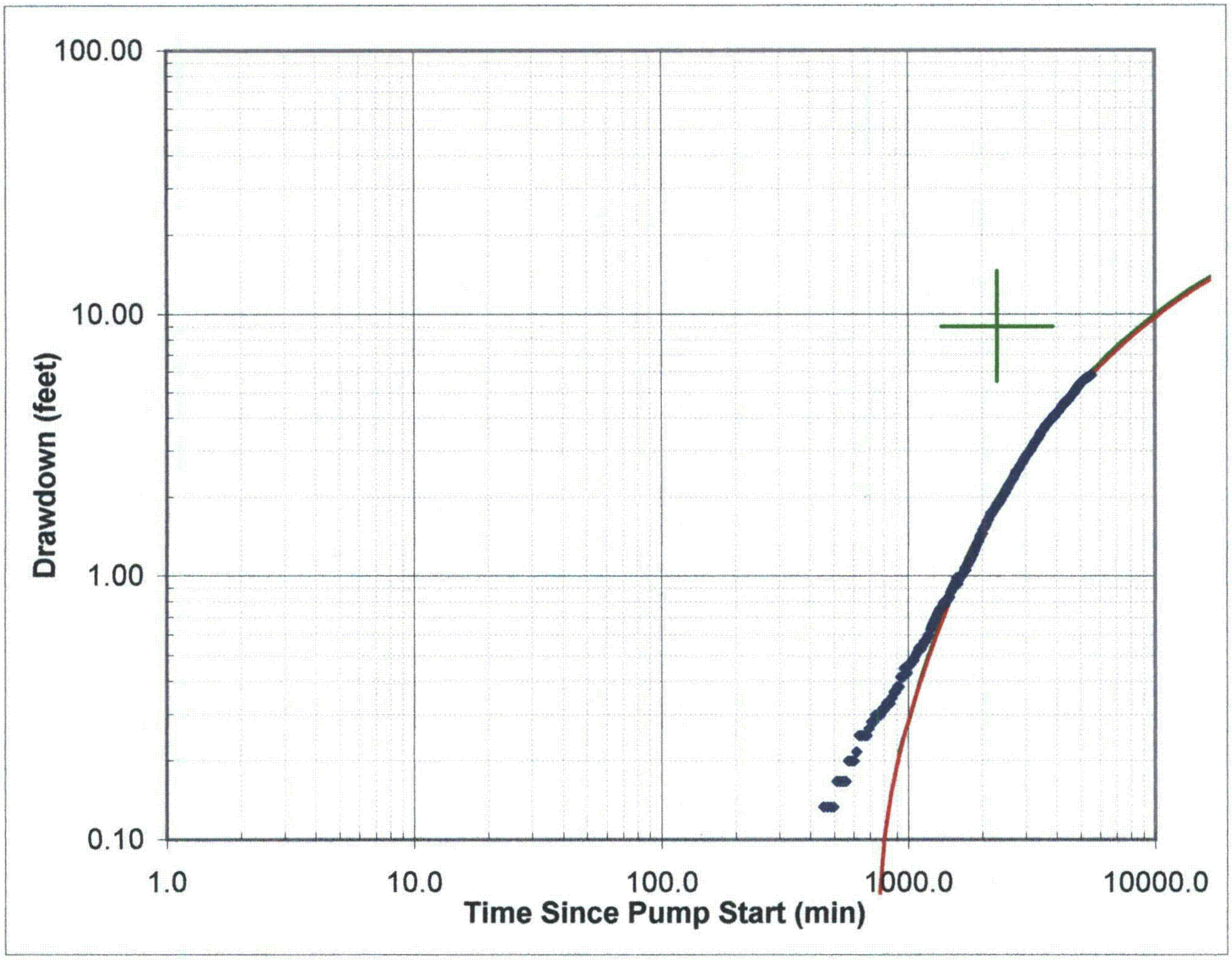
FIGURE 8-33. DRAWDOWN IN OBSERVATION WELL MRN-7 AND MRN-2.1



Theis Match Point	
Intitial Discharge (gpm)	33.3
Radius to Pumping Well (ft) (<1 indicates pumping well)	1724
Drawdown Match Point (ft)	8.30
Time Match Point (min)	1980.0
Calculated Transmissivity (gal/day/ft)	460
Calculated Storage Coefficient (ft/ft)	1.14E-04
Refined Transmissivity Estimate (gal/day/ft)	469
Refined Storage Coefficient Estimate (ft/ft)	1.14E-04

Test Interruption Data	
Pump Off Time (minutes after initial pump start)	2726
Pump Restart Time (minutes after initial pump start)	2820
Pump Restart Rate (gpm)	33.3

FIGURE 8-34. DRAWDOWN IN OBSERVATION WELL MRN-7, LOG-LOG



Theis Match Point

Intitial Discharge (gpm)	33.3
Radius to Pumping Well (ft) (<1 indicates pumping well)	1849
Drawdown Match Point (ft)	9.00
Time Match Point (min)	2300.0
Calculated Transmissivity (gal/day/ft)	424
Calculated Storage Coefficient (ft/ft)	1.06E-04
Refined Transmissivity Estimate (gal/day/ft)	433
Refined Storage Coefficient Estimate (ft/ft)	1.08E-04

Test Interruption Data

Pump Off Time (minutes after initial pump start)	2726
Pump Restart Time (minutes after initial pump start)	2820
Pump Restart Rate (gpm)	33.3

FIGURE 8-35. DRAWDOWN IN OBSERVATION WELL MRN-2.1, LOG-LOG

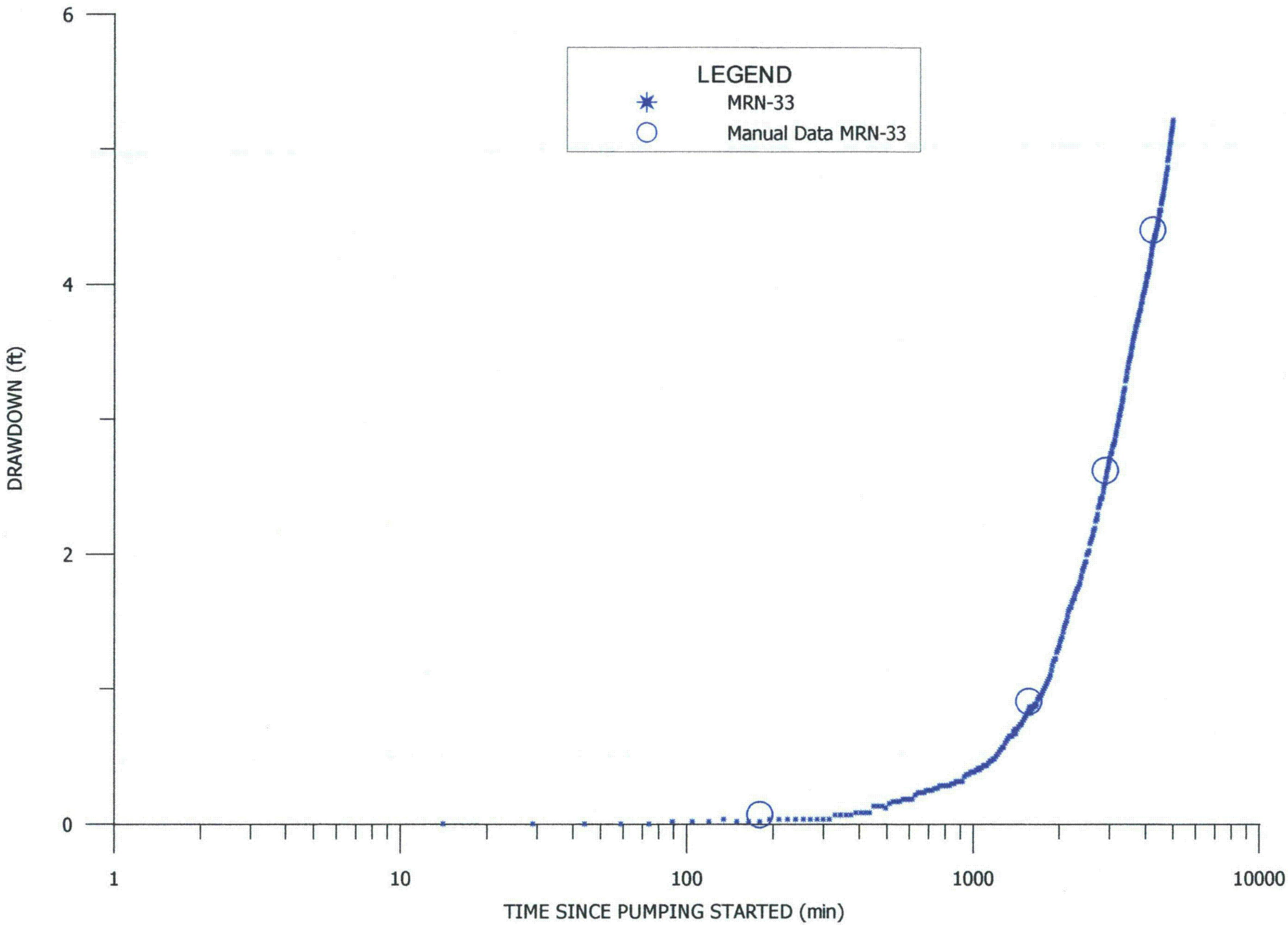
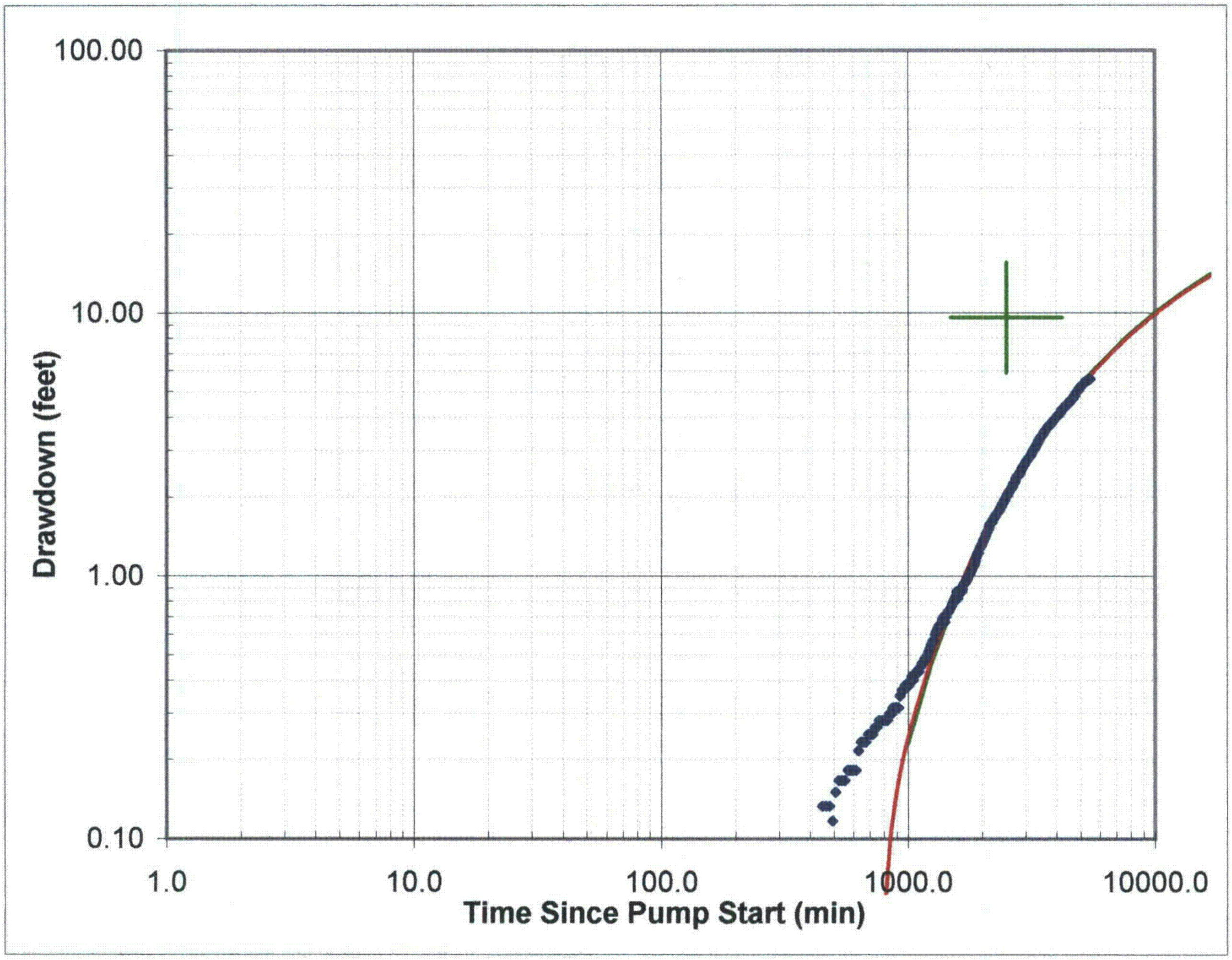


FIGURE 8-36. DRAWDOWN IN OBSERVATION WELL MRN-33



Theis Match Point

Initial Discharge (gpm)	33.3
Radius to Pumping Well (ft) (<1 indicates pumping well)	1849
Drawdown Match Point (ft)	9.60
Time Match Point (min)	2500.0
Calculated Transmissivity (gal/day/ft)	398
Calculated Storage Coefficient (ft/ft)	1.08E-04
Refined Transmissivity Estimate (gal/day/ft)	405
Refined Storage Coefficient Estimate (ft/ft)	1.08E-04

Test Interruption Data

Pump Off Time (minutes after initial pump start)	2726
Pump Restart Time (minutes after initial pump start)	2820
Pump Restart Rate (gpm)	33.3

FIGURE 8-37. DRAWDOWN IN OBSERVATION WELL MRN-33, LOG-LOG

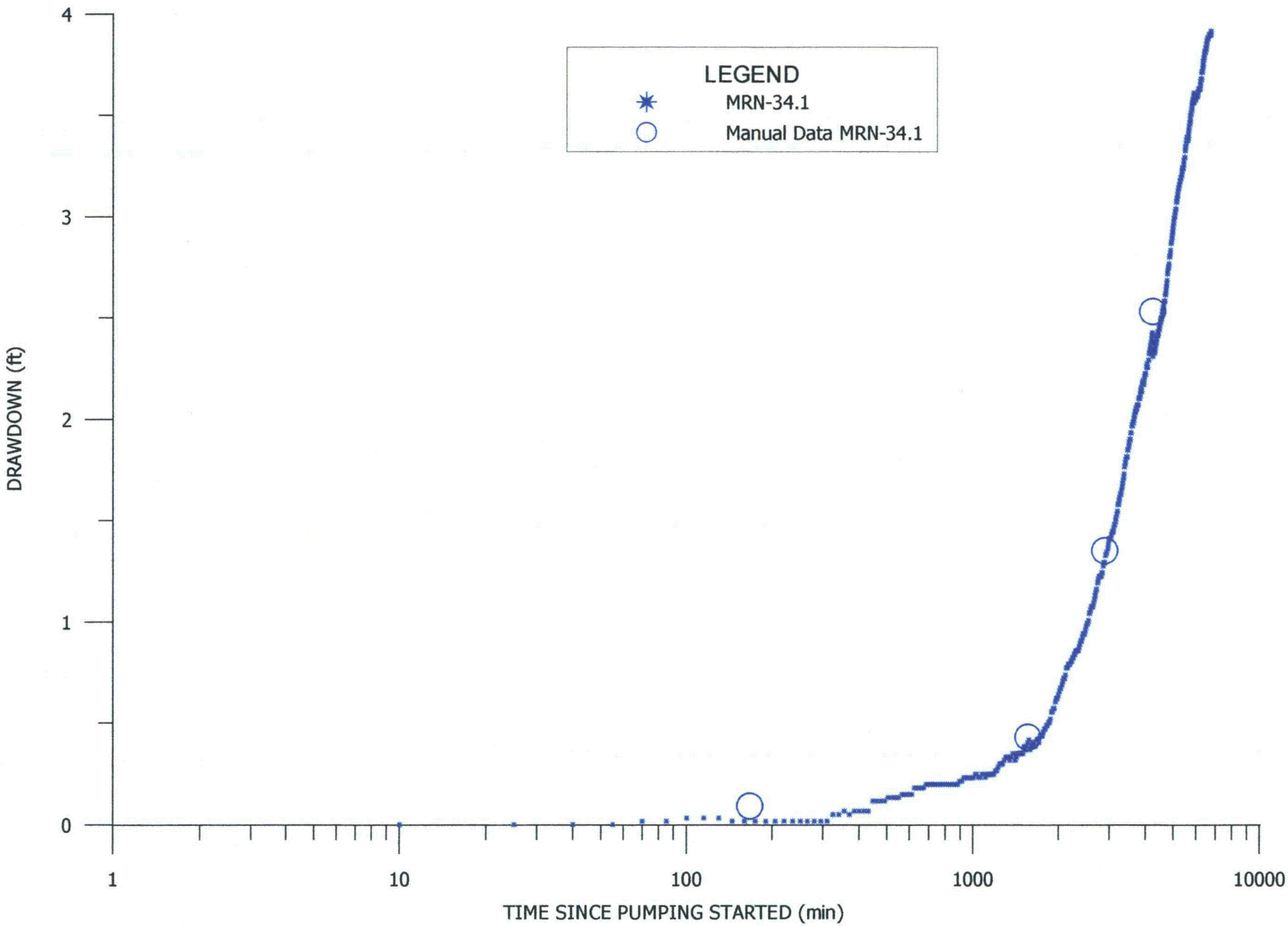
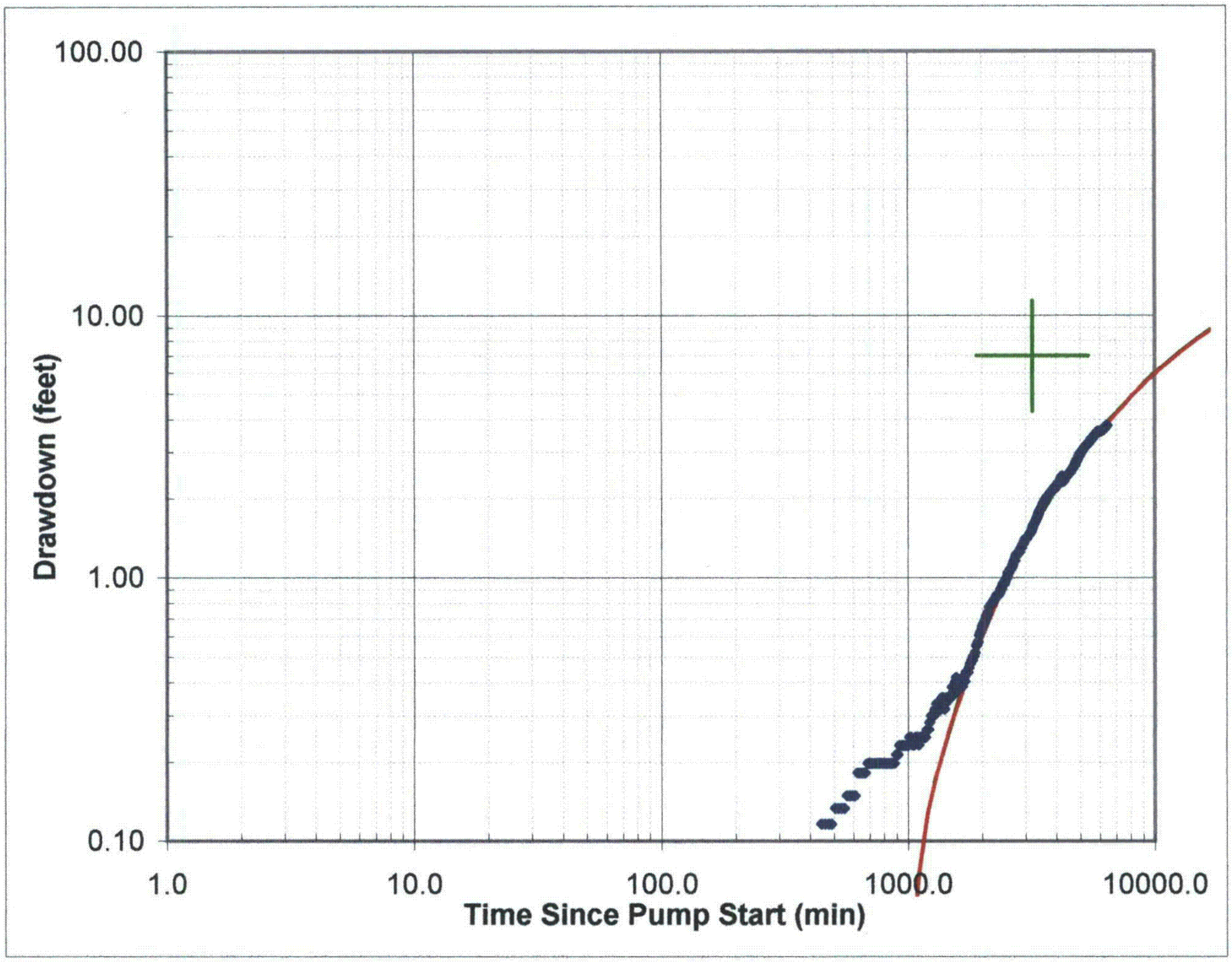


FIGURE 8-38. DRAWDOWN IN OBSERVATION WELL MRN-34.1



Theis Match Point

Intitial Discharge (gpm)	33.3
Radius to Pumping Well (ft) (<1 indicates pumping well)	2042
Drawdown Match Point (ft)	7.00
Time Match Point (min)	3200.0
Calculated Transmissivity (gal/day/ft)	545
Calculated Storage Coefficient (ft/ft)	1.55E-04
Refined Transmissivity Estimate (gal/day/ft)	545
Refined Storage Coefficient Estimate (ft/ft)	1.55E-04

Test Interruption Data

Pump Off Time (minutes after initial pump start)	2726
Pump Restart Time (minutes after initial pump start)	2820
Pump Restart Rate (gpm)	33.3

FIGURE 8-39. DRAWDOWN IN OBSERVATION WELL MRN-34.1, LOG-LOG

9.0 TEST RESULTS – CONFINING UNITS FOR MRN-29 TEST

9.1 HYDRAULIC CONDUCTIVITY OF CONFINING UNITS

Confining unit vertical hydraulic conductivities have been defined on some of the sites near Nichols Ranch in the Powder River Basin. Table D6-5a in the Nichols Ranch permit summarizes the test conducted on the confining units in this area.

The data indicate the vertical conductivities from core and pumping test results range from 1.5×10^{-9} cm/sec (4.3×10^{-6} ft/d) to 1.0×10^{-7} cm/sec (2.84×10^{-4} ft/d). Therefore the vertical conductivity of these confining units are considered to be more than adequate to retard connections between the Overlying and Underlying aquifers to the mining zone.

This test was conducted to define the adequacy of the continuity of the aquitard to separate the A Sand from the adjacent aquifers in the northern half of PA #1.

9.2 OVERLYING AQUIFERS

Plots of depths of water levels in the Overlying (MON) aquifers for the pre-test, pumping and recovery periods are presented in Figures 9-1 through 9-3 for wells MON-1, MON-2, MON-3, MON-4, MON-5, MON-6 and MON-7. The water levels are compared to barometric pressure for the entire period. The barometric pressure changes were small during this test, with a change of less than 0.3 inches of mercury during the pumping phase of the test. Corrections for barometric pressure changes were not made due to the small change during this test. Typical barometric pressure coefficients of 0.3 to 0.4 feet of water per inch of mercury would only make small adjustments in the depths to water.

Figure 9-1 contains the depth to water versus time for overlying wells MON-1, MON-2 and MON-6. Steady water levels occurred during this pumping test in these three overlying observation wells. The overall steady response indicates no connection with the overlying aquifer near these three wells. Figure 9-2 shows that the water-level in wells MON-3, MON-4 and MON-7 was steady prior to, during and after the test. A very small water level rise early in the pumping phase and small decline early after the pump was turned off in well MRN-29 were observed in closer monitoring wells, MON-3 and MON-4. This does not indicate any connection between the overlying and A Production aquifers. This adjacent aquifer response is called the Noordbergum effect and is a pressure response from the adjacent aquifer pumping.

Similar steady response in overlying well MON-5 was also observed during the pre-test, the pumping period and during the recovery period. Barometric pressure was not affecting the water level changes very much in this well (see Figure 9-3).

The water level plots for the overlying wells do not indicate any connection between the A Sand production zone and the Overlying B Sand aquifer.

9.3 UNDERLYING AQUIFERS

Plots of the water level versus time for the Underlying aquifer wells are presented in Figures 9-4 through 9-7.

The water levels in the Underlying aquifer wells are generally steady and show very little indication of a trend. Barometric pressure changes influence the water levels only slightly during this test and therefore the water levels were not corrected for barometric pressure changes.

The water level data collected from the Underlying wells indicates no connection between the A-Sand and the Underlying 1 Sand aquifer in the northern half of PA #1 mine area.

9.4 INTERGRITY OF CONFINING UNITS

The MRN-29 pump test indicates that adequate confinement is present between the A Sand and the underlying 1 Sand. Drawdown was not observed in the Overlying aquifer wells in the northern portion of PA #1 indicating adequate confinement is present between the A Sand and the Overlying aquifer, B Sand. This shows that adequate confinement exists in the northern portion of PA #1.

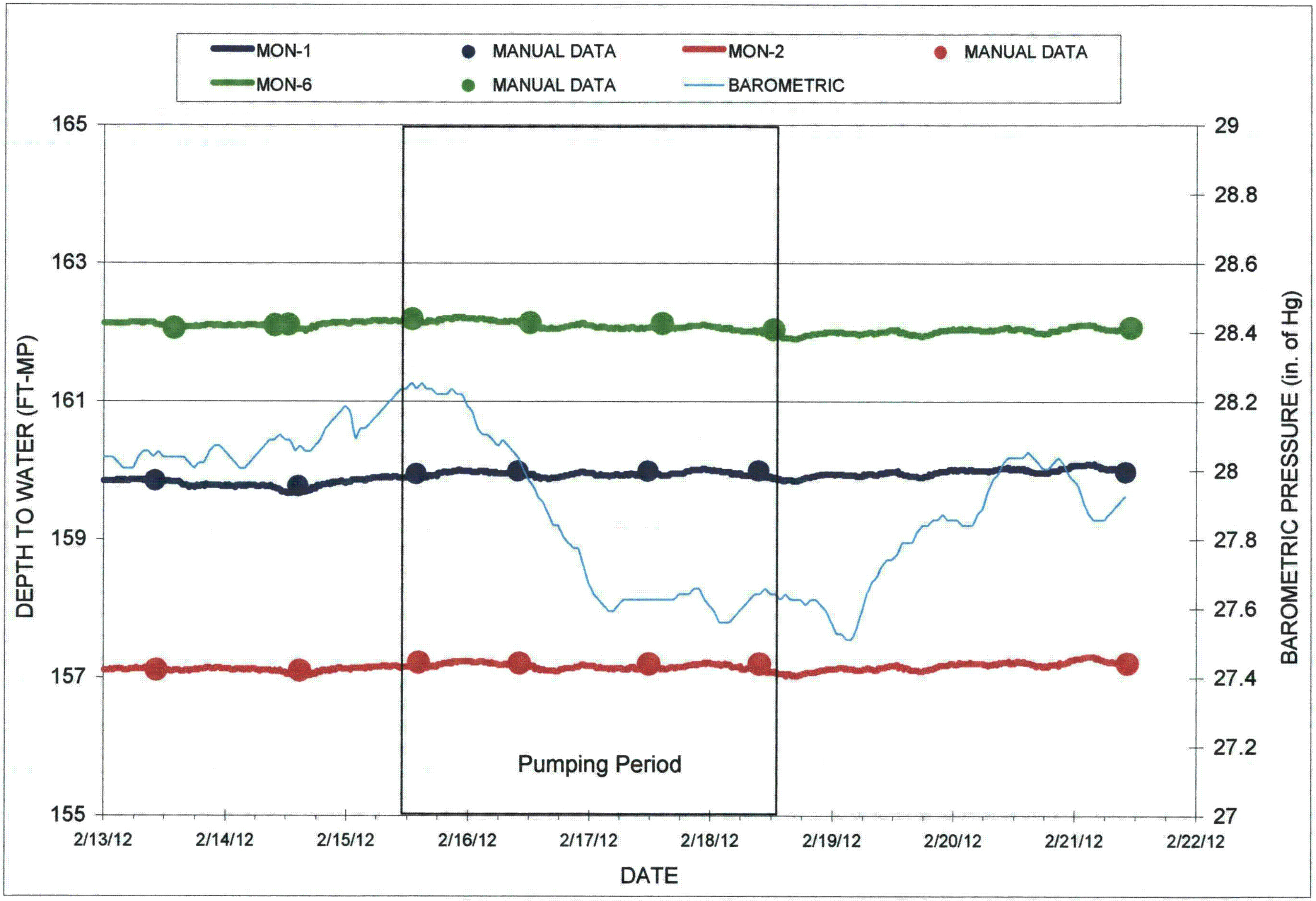


FIGURE 9-1. DEPTH TO WATER VERSUS TIME FOR OVERLYING AQUIFER WELLS MON-1, MON-2 AND MON-6

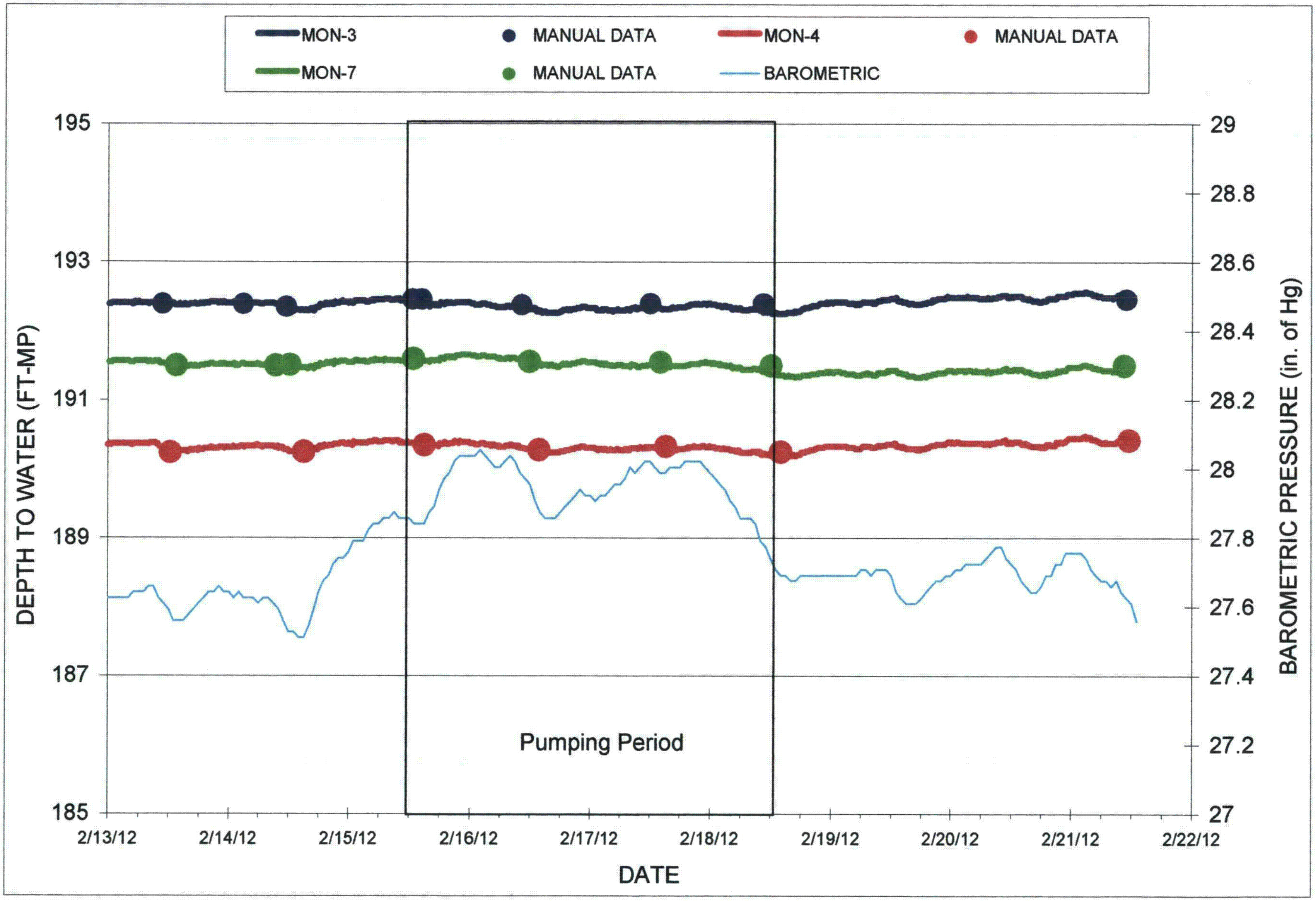


FIGURE 9-2. DEPTH TO WATER VERSUS TIME FOR OVERLYING AQUIFER WELLS MON-3, MON-4 AND MON-7

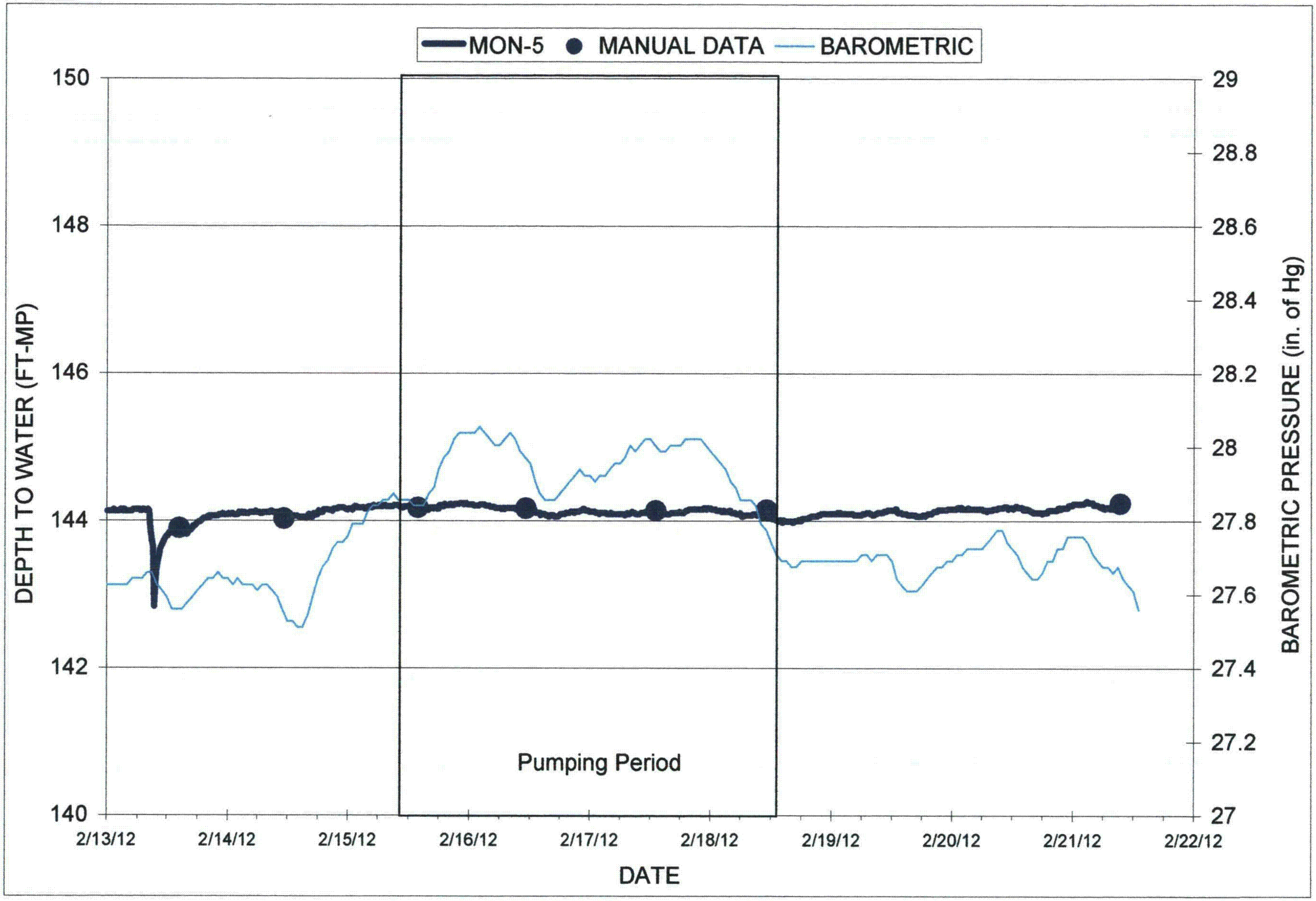


FIGURE 9-3. DEPTH TO WATER VERSUS TIME FOR OVERLYING AQUIFER WELL MON-5

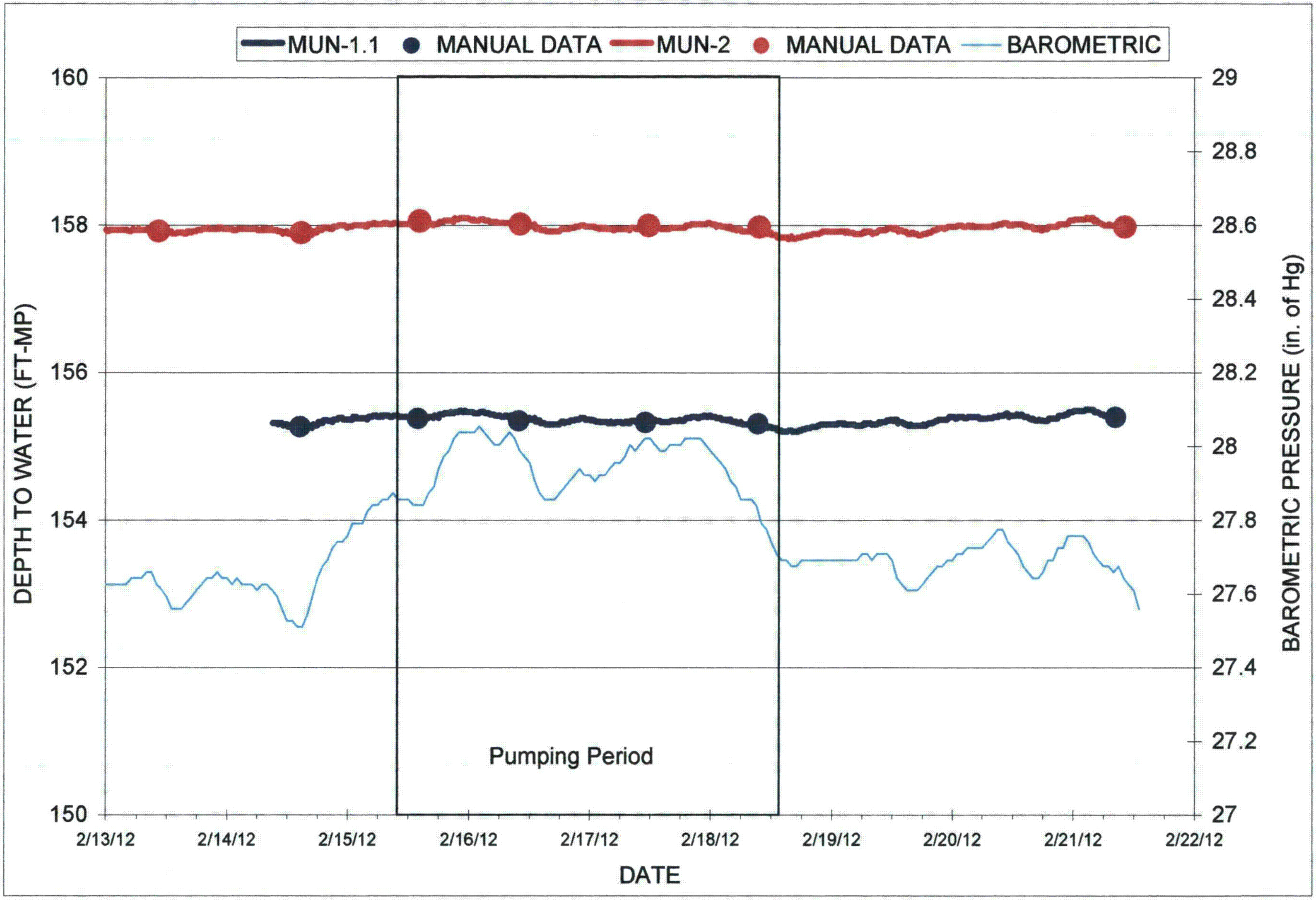


FIGURE 9-4. DEPTH TO WATER VERSUS TIME FOR UNDERLYING AQUIFER WELLS MUN-1.1 AND MUN-2

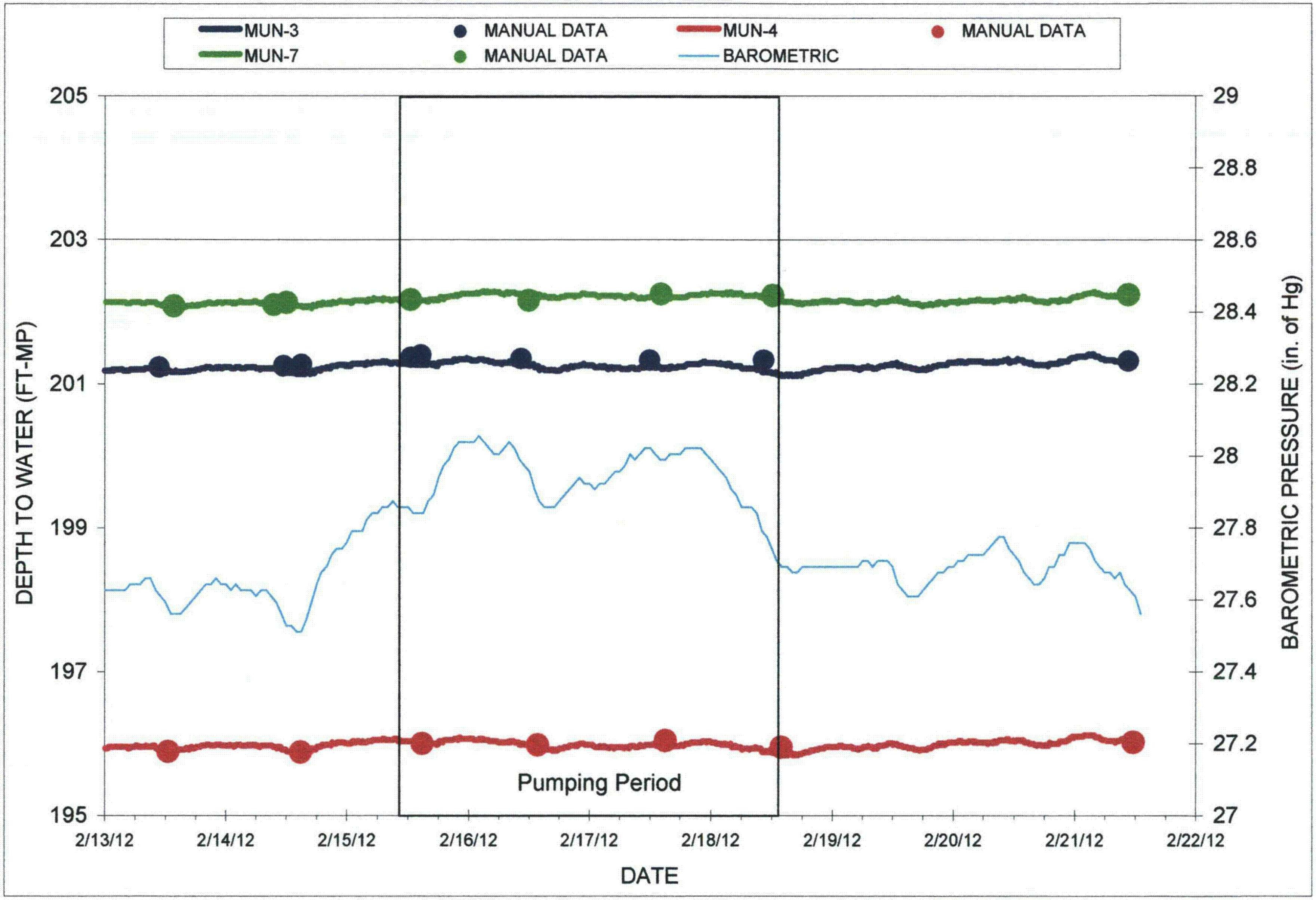


FIGURE 9-5. DEPTH TO WATER VERSUS TIME FOR UNDERLYING AQUIFER WELLS MUN-3, MUN-4 AND MUN-7

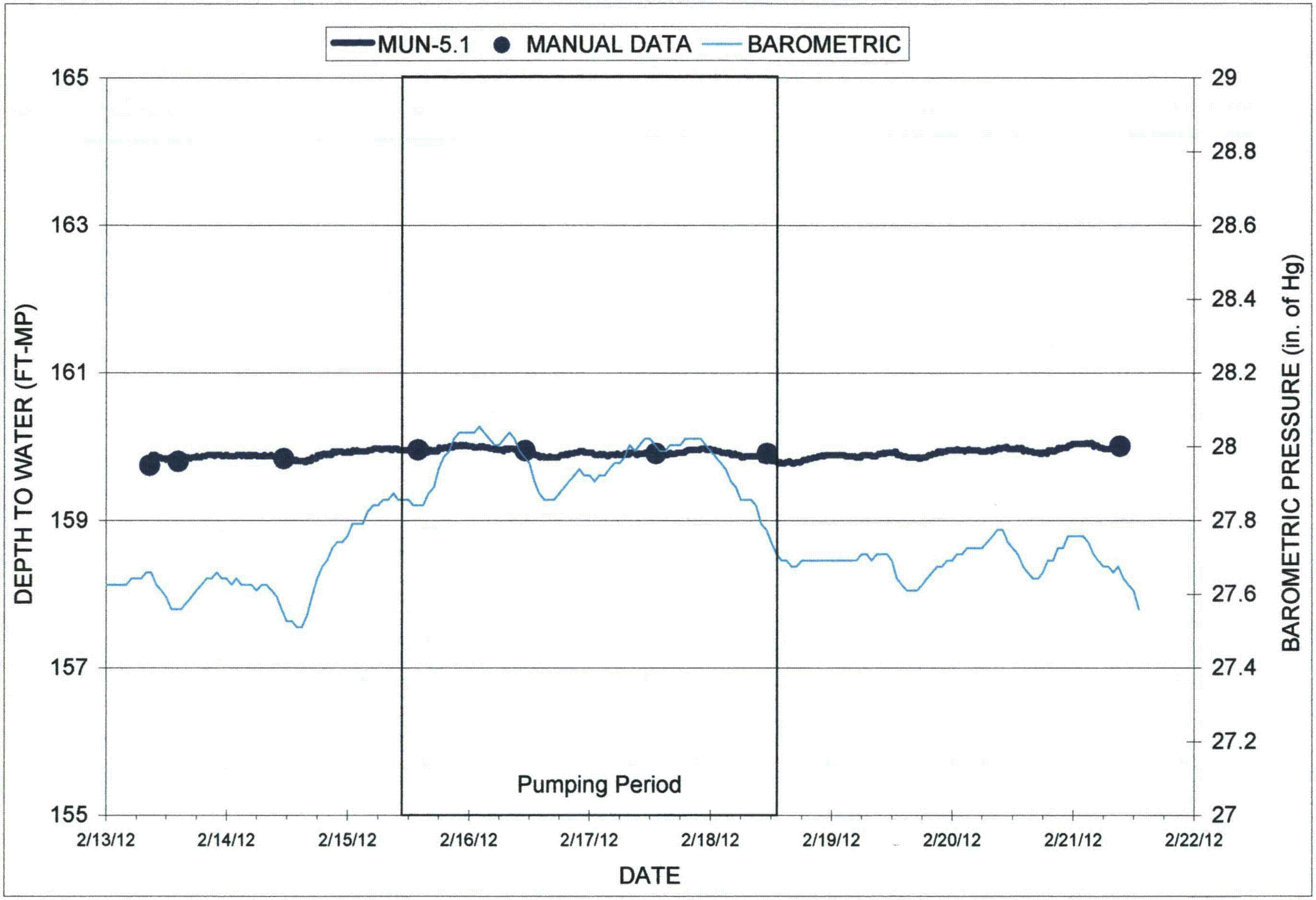


FIGURE 9-6. DEPTH TO WATER VERSUS TIME FOR UNDERLYING AQUIFER WELL MUN-5.1

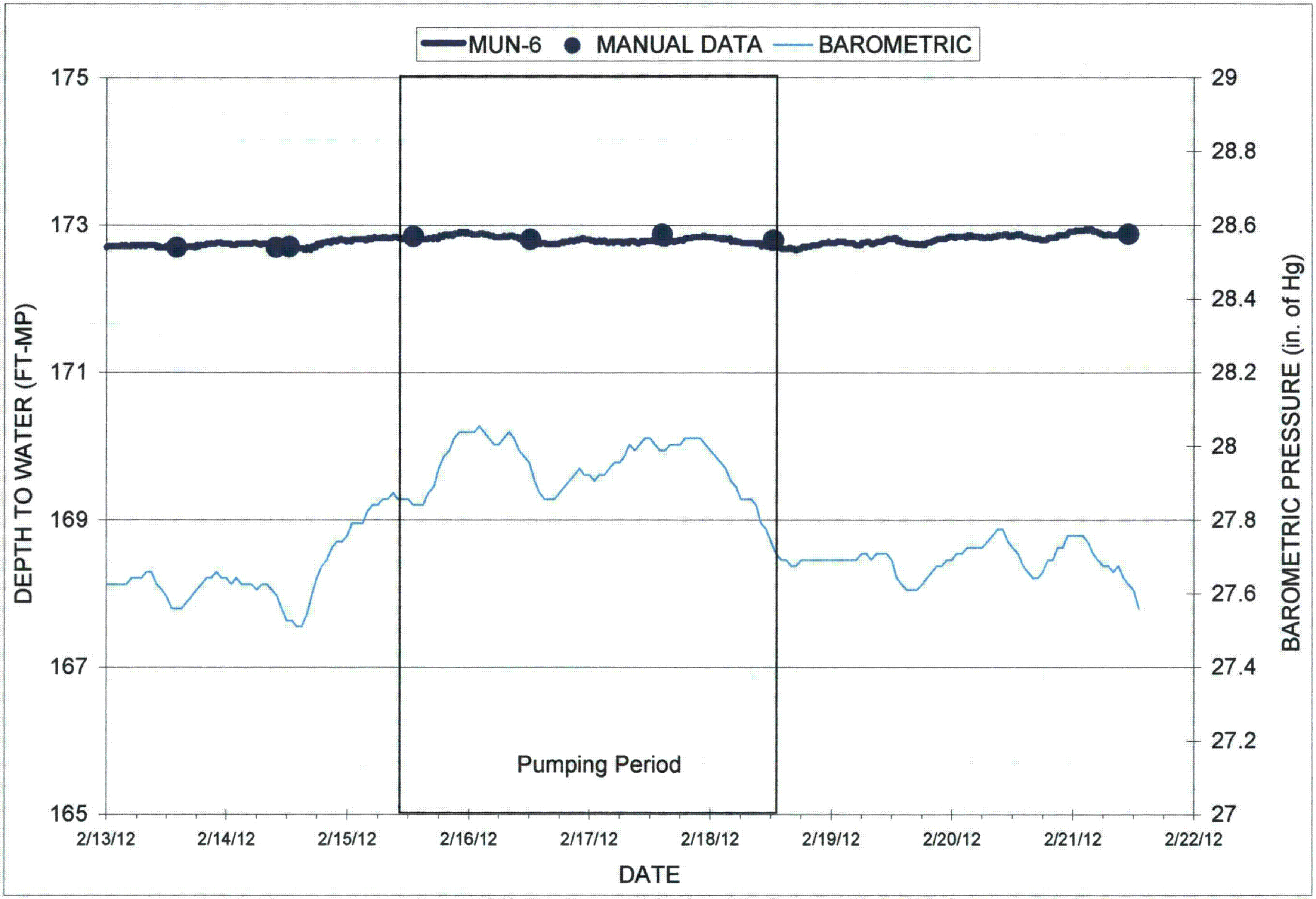


FIGURE 9-7. DEPTH TO WATER VERSUS TIME FOR UNDERLYING AQUIFER WELL MUN-6

10.0 AQUIFER-TEST THEORY

In order to quantify fluid movement through an aquifer, a number of characteristics must be taken into account. Transmissivity is defined as the ability of an aquifer to transmit water and is usually expressed as gallons per day per foot (gal/day/ft). Transmissivity, expressed in these units, is the rate at which water flows through a unit width of an aquifer under a unit hydraulic gradient. Transmissivity must be combined with the actual aquifer width and hydraulic gradient to determine actual aquifer flow rates.

Horizontal hydraulic conductivity commonly referred to as (permeability) of the aquifer is the transmissivity divided by the aquifer thickness. Permeability is the main property that governs the velocity of groundwater movement. Hydraulic gradient and effective porosity are also needed with permeability to determine the velocity.

The storage coefficient, as defined by Theis, is the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. The storage coefficient is dimensionless. Storage in a confined aquifer is derived from compression of the aquifer and a slight expansion of the water.

10.1 THEIS EQUATION

Theis, in 1935, introduced his equation to determine drawdowns in a non-leaky, confined aquifer. The following is a general definition of the Theis equation:

$$T = \frac{114.6Q\ W(u)}{s}$$

$$u = \frac{2693r^2S}{Tt}$$

where: s = drawdown, in feet
Q = discharge, in gallons per minute (gpm)
W(u) = well function, the integral from u to infinity of (e^{-u})/u du
T = Transmissivity, gal/day/ft
u = well function variable
r = observation well radius from pumping well, in feet
S = storage coefficient
and t = time since pumping started, in minutes

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 preceding equations to the match. The value of the integral expression for W(u) is given by the following series:

$$W(u) = -0.577216 - \ln u + u - \frac{u^2}{2.2!} + \frac{u^3}{3.3!} \ldots$$

where all terms are as previously defined.

10.1.1 STRIAGHT LINE EQUATION

Jacob developed a simplified form of Theis' drawdown equation by truncating the well function series after the first two terms. Assuming the truncation, the following equations were developed to analyze drawdown versus time data on semi-log plots and are called the straight-line or Jacob equation:

$$T = 264\ Q[\log (t_2/t_1)]/(s_2 - s_1)$$
$$T = 264\ Q/\Delta s$$
$$S = T\ t_0 / 4800 r^2$$

s_1 = drawdown, in feet, at time since pumping started, t_1, in minutes
s_2 = drawdown, in feet, at time since pumping started, t_2, in minutes
and $t_2 > t_1$
Δs = change in drawdown over one log cycle of time on a semi-log plot, in feet
S = storage coefficient
t_0 = straight-line intercept of zero drawdown, in minutes
r = radius of well, in feet

A straight line is fitted to the semi-log plot of drawdown versus time (log scale) to obtain transmissivity. Jacob suggested the u values less than 0.01 are needed before his straight-line method is useful. However, a plot of W(u) versus 1/u on semi-log paper indicates that this method should be applicable for values of u as large as 0.1. Kruseman and de Rider (1991) suggest the use of a u of less than 0.1 to meet the Jacob condition.

10.1.2 THEIS RECOVERY EQUATION

Theis' equation can be modified to handle recharge of a well or multiple pumping periods by summation of the well functions. The following equation is the solution of Theis' equation for one pumping and recharge cycle (Recovery equation) of a non-leaky confined aquifer using a log-log match format:

$$T = 114.6\ Q\ [W(u) - W(u')]s'$$
$$u' = 2693\ r^2\ S/Tt'$$
$$T = 114.6\ Q\ [W(u) - W(u) + (u')]\ sr$$
$$= 114.6\ Q\ W(u')/sr$$
$$s_r = s - s'$$

where: s_r = recovery, in feet

s' = residual drawdown (static water level – water level @ t'), in feet
$W(u')$ = recovery well function
u' = recovery well function variable
t' = time since pumping stopped, in minutes

The recovery data sets are analyzed by matching the log-log plot of the recovery versus time since pumping stopped to Theis' type curve. The type curve variables are $W(u')$ and $1/u'$ for the recovery match. The recovery is computed by estimating the drawdown which would have occurred if pumping had continued, and subtracting this predicted drawdown from the residual drawdown. For example, the recovery at 100 minutes after pumping has stopped is computed by estimating the drawdown had the pumping continued uninterrupted, and subtracting the estimated drawdown from the residual drawdown. The straight-line fit of the drawdown is normally extended to obtain these estimates of drawdown.

The well functions of the residual-drawdown form of Theis' equation were approximated by using the first two terms in the well function series. The following equations present the semi-log form of the Theis recovery equation:

$$T = 264\ Q\ [\log(t/t')]/s'$$

or

$$T = 264\ Q/\Delta s'$$

where: t = time since pumping started, in minutes
t' = time since pumping stopped, in minutes
s' = residual drawdown, in feet
and $\Delta s'$ = change in residual drawdown over one log cycle of t/t' on a semi-log plot, in feet

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.

10.1.3 MULTI-WELL THEIS EQUATION

The Theis equation can be modified to predict drawdown from more than one pumping period for one pumping well. Stallman used the well function summation theory to develop type curves for a variable discharge pump test (see Ferris & et al. 1962). HYDRO has used the well summation theory to analyze numerous pump tests with more than one pumping well. The sum of the $W(u)$ times Q values that are plotted versus $1/u_1$, on log-log paper to create the type curves. The following equations are for one pumping well that has three different discharges during the pump test:

$T = 114.6/s\ [W(u_1)Q_1 + W(u_2)Q_2 + W(u_3)Q_3]$
$W(u_1) = -0.577216 - \ln u_1 + u_1 - u_1^2/2.2! + u_1^3/3.3! - u_1^4/4.4!$
$u_1 = 1.87r^2S/Tt_1$

where: parameters are the same as before, plus:

u_1 = well function variable for the 1st pumping period
u_2 = well function variable for the 2nd pumping period
u_3 = well function variable for the 3rd pumping period
Q_1 = discharge for 1st pumping period in gpm
Q_2 = discharge for 2nd pumping period in gpm
Q_3 = discharge for 3rd pumping period in gpm

r = observation well radius from pumping well in ft.
t_1 = time since pumping started 1st pumping period
t_2 = time since pumping started 2nd pumping period
t_3 = time since pumping started 3rd pumping period

The summation of the product of the well functions and their corresponding discharge

$$\left(\sum_{i=1}[W(u_i)Q_i]\right)$$

have typically been plotted against the inverse of the well function variable for the first pumping period ($1/u_1$). If the discharge for each pumping period is the same, Q can be extracted from the summation term and taken as constant.

$$\frac{114.6Q}{s}\sum_{i=1}^{3}W(u_i)$$

The analysis of the multi-well Theis equation was done by selecting a match point for the first pumping period and computing a transmissivity and storage coefficient. This match point was evaluated as outlined in Section 10.1. The refined transmissivity and storage coefficient for the entire drawdown curve were computed from the above multi-well Theis equation by using the off and on periods for the second and third pumping phases and the aquifer properties from the match of the first phase of the pump test. The aquifer properties were then iteratively varied to refine the match of the predicted drawdown to the measured drawdown which produced refined transmissivity and storage coefficients based on the entire drawdown curve. Thus, the primary enhancement of the refined match is that it reflects fitting of the drawdown data over the entire pumping period. These refined transmissivity and storage coefficient values are the values from the entire log-log analysis of the pump test data fit.

10.1.4 MULTI-WELL STRAIGHT LINE EQUATION

The above Theis equation for three pumping periods can be modified using Jacob's approximation (see pp. 98-100 of Ferris, 1962) to obtain a straight-line (semi-log plot) for the drawdown data from three pumping periods. The u value for each of the pumping periods must meet the straight-line assumptions before the straight-line method is applicable for the combined drawdown. As with the single-well tests, u values should be less than 0.1 for t_3 before the use of the straight-line method. The following is the derivation of the straight-line equation that is equivalent to Jacob's equation for three pumping periods at the same pumping rate. The second pumping period is the first pump off period and therefore is at a negative rate of the first pumping rate:

$$s = \left(\frac{264Q}{T}\right)\left[\log\left(\frac{0.3Tt_1}{r^2S}\right) - \log\left(\frac{0.3Tt_2}{r^2S}\right) + \log\left(\frac{0.3Tt_3}{r^2S}\right)\right]$$

For drawdown at times of t_a and t_b:

$$s_b - s_a = \left(\frac{264Q}{T}\right)\left[\log\left(\frac{0.3Tt_{1b}}{r^2S}\right) - \log\left(\frac{0.3Tt_{2b}}{r^2S}\right) + \log\left(\frac{0.3Tt_{3b}}{r^2S}\right) - \log\left(\frac{0.3Tt_{1a}}{r^2S}\right) + \log\left(\frac{0.3Tt_{2a}}{r^2S}\right) - \log\left(\frac{0.3Tt_{3a}}{r^2S}\right)\right]$$

after multiplication and simplification of the log terms:

$$s_b - s_a = \frac{264Q}{T}\left[\log\left(\frac{t_{1b}t_{3b}t_{2a}}{t_{2b}t_{1a}t_{3a}}\right)\right]$$

$$T = \frac{264Q}{\Delta s} \text{ for } \Delta s = s_b - s_a \text{ for one log cycle over } \frac{t_1 t_3}{t_2}$$

The straight line equation is the same as the Jacob equation except the ratio of the three pumping periods is used in the place of t. The following is our derivation of the storage coefficient equation for the three pumping periods for the same well:

$$s = \left(\frac{Q}{4\pi T}\right)\left[\ln\left(\frac{2.25Tt_1}{r^2S}\right) - \ln\left(\frac{2.25Tt_2}{r^2S}\right) + \ln\left(\frac{2.25Tt_3}{r^2S}\right)\right]$$

$$s = \left(\frac{Q}{4\pi T}\right)\ln\left[\left(\frac{2.25Tt_1t_3}{r^2St_2}\right)\right]$$

$$0 = \ln\left(\frac{2.25Tt_o}{r^2S}\right)$$

$$1 = \left(\frac{2.25Tt_o}{r^2S}\right)$$

$$S = \left(\frac{2.25Tt_o}{r^2}\right)$$

or in the usual USGS units

$$S = \frac{(0.3Tt_o)}{(r^2)}$$

where: parameters are the same as before, and:

s_b = drawdown, in feet, at time since pumping started, t_b, in days
s_a = drawdown, in feet, at time since pumping started, t_a, in days
t_o = time when drawdown equals zero (extension of straight-line fit to s = 0), in days

The drawdown data for an observation well are plotted on semi-log paper against times since the ratio of t_1t_3/t_2. The slope of the straight-line fit is used with the discharge to compute the transmissivity, and the intercept of the straight line is used with the well radii to compute the storage coefficient.

10.2 HANTUSH'S MODIFIED METHOD

Hantush (1960) presents a modification of the theory of leaky confined aquifers which had previously been described by Hantush and Jacob (1955). The modification took into account the storage of water in the semipervious confining bed. Equations developed are as follows:

$$T = \frac{114.6Q}{s} H(u, BETA)$$

where: H(u, BETA) = the integral from u to infinity of $(e^{-y})/y$ [complementary error function of (BETA*Square Root u) / Square Root (y(y-u))]dy

$u = [(2693)r^2(S)]/Tt$

And $$BETA = \frac{r}{4b}\sqrt{\frac{K'Ss'}{KSs}}$$

The main parameters are as follows:

T = transmissivity, gal/day/ft.
Q = discharge, gpm
s = drawdown, ft.
y = variable of integration
r = radius, ft.
S = storage coefficient
t = time, min.
b = aquifer thickness, ft.
K = aquifer permeability, ft/day
K' = confining layer permeability, ft/day
Ss = aquifer specific storage, 1/ft.
and Ss' = confining layer specific storage, 1/ft.

This form of the beta equation assumes all leakage is coming from only one of the two confining layers. Hantush (1961) presented tabulations of H(u, BETA) for varying values of u and BETA, and subsequently, a family of type curves showing H(u, BETA) vs. 1/u has been developed. Main aquifer properties can be determined by matching plots of observed drawdown versus time data to one of Hantush's type curves and using the equations presented above. The specific storage of the confining layer can be determined from laboratory measurements of the coefficient of compressibility and void ratio on a core of the aquitard or the specific storage of the aquifer if the laboratory measurements are not available.

10.3 NEUMAN-WITHERSPOON METHOD

A method for determining aquitard vertical permeability has been described by Neuman and Witherspoon (1971) and Neuman and Witherspoon (1972). In this technique, referred to as the Ratio Method, the ratio of drawdown in the aquitard to the drawdown in the pumped aquifer at the same time distance is related to a dimensionless time parameter, t'D:

t'D = K't / Ss z^2

where: K' = aquitard vertical permeability
t = time for which drawdown ration was determined
Ss' = specific storage of the aquitard

= K' / ALPHA'
ALPHA = aquitard diffusivity,
and z = vertical distance from the center of the screened section of the well completed in the aquitard to the aquifer.

t'D is determined graphically. Therefore, aquitard diffusivity (ALPHA') can be calculated from ALPHA' = K' / Ss' = T'D Z^2 / t.

In order to determine aquitard specific storage, Ss', must be ascertained.

Ss' = avWw / (1 + e)
where: av = coefficient of compressibility
Ww = weight of water,
and e = void ratio

The values of av and e must be determined on samples of the aquitard in the laboratory or Ss' may be estimated based on published reports on similar sediments.

10.4 DIRECTIONAL TRANSMISSIVITY

Directional transmissivity of the aquifer was quantified using a method described by Papadopulos (1965). Papadopulos derived an equation for the drawdown distribution around a well discharging at a constant rate from an infinite horizontal anisotropic aquifer. Aquifer-test data from a minimum of three observation wells are analyzed to obtain principal transmissivities and the orientation of the principal axes.

The equations derived by Papadopulos for use in a type-curve matching technique are as follows:

$$s = \frac{114.6Q\ W(Uxy)}{\left[(Txx)(Tyy) - Txy^2\right]^{1/2}}$$

and

$$Uxy = \frac{(1.87S)}{(t)} \frac{\left[(Txx)(y^2) + (Tyy)(x^2) - (2Txy)(x)(y)\right]}{\left[(Txx)(Tyy) - Txy^2\right]}$$

where
s = drawdown, in feet
Q = discharge, in gpm
W(Uxy) = well function
Txx, Tyy & Txy = transmissivity components, in gal/day/ft
Uxy = well function variable
S = storage coefficient

t = elapsed time, in days
x = distance from pumping well of observation well along arbitrarily selected x-axis, in feet
and y = distance from pumping well of observation well along arbitrarily selected y-axis (orthogon 1 to x-axis), in feet

For each of the three wells analyzed, observed drawdown data are matched against type curves to determine values of s, t, W(Uxy) and U(xy). Three equations with three unknowns are then solved simultaneously to determine the transmissivity components Txx, Tyy and Txy. Then principal transmissivities, Tee and Tnn, are calculated from the following equations:

$$\mathrm{Tee} = \tfrac{1}{2}\left[(\mathrm{Txx}+\mathrm{Tyy})+(\mathrm{Txx}-\mathrm{Tyy})^2+4\mathrm{Txy}^2\right]$$

and

$$\mathrm{Tnn} = \tfrac{1}{2}\left[(\mathrm{Txx}+\mathrm{Tyy})^2+4\mathrm{Txy}^2\right]$$

where: Tee = maximum transmissivity
and Tnn = minimum transmissivity

The angle between the arbitrarily selected x-axis and the axis of maximum transmissivity (θ) is then determined by the following equation:

$$\theta = \arctan(\mathrm{Tee}-\mathrm{Txx})/\mathrm{Txy}$$

10.5 REFERENCES

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11.0 SUMMARY AND CONCLUSIONS

Two pump test were preformed for the area wellfield analysis for PA#1. The first by pumping well MRN-23 during December 6, 7, 8 and 9; the second by pumping MRN-29 during February 15, 16, 17 and 18. Greater than 300 feet of drawdown in the pumping well MRN-23 was observed in the first pump test and just under 200 feet of drawdown in the pumping well MRN-29 for the second test.

The Overlying aquifer monitor wells were fairly steady during the pre-pumping and pumping phases of the pump test. No measurable drawdown was observed in any of the Overlying aquifer wells during both pump test for the PA #1. Any small change in water-level can be attributed to barometric or Noordbergum effects. Therefore the PA #1 pump tests show that adequate confinement exists between the A Sand and the Overlying aquifer.

The Underlying aquifer monitoring wells were generally very steady during the PA #1 pump tests. Therefore the PA #1 pump tests show that adequate confinement exists between the A Sand and the Underlying aquifer.

Analysis of the water level data for the A Sand wells resulted in an average transmissivity of 50 ft^2/day for the northern half of PA #1 and 35 ft^2/day for the southern half of PA #1, and average hydraulic conductivity of 0.48 and 0.35 ft/day (1.6E-4 and 1.2E-4 cm/sec) and an average permeability (assuming a water temperature of 50 degrees F) of 229 and 167 millidarcies (md). The average storativity was 1.4E-4 and 1.2E-4. The analysis did not indicate the presence of significant geologic boundaries within the A Sand aquifer over the area evaluated by the testing.

In summary, the pump tests were performed in accordance with the Hydrologic Test Plan submitted by URZ in September 2011 to WDEQ/LQD. The testing objectives were met. The test results demonstrate:

- All A Sand monitoring wells are in communication with the A Sand Production Zone;
- Adequate confinement exists between the A Sand Production Zone and the Overlying and Underlying sands;
- The A Sand has been adequately characterized with respect to the hydrogeologic conditions within PA #1; and,
- Mining can proceed in accordance with Permit 778.