Aquifer-Test Report for Test Well MX-CSV-2

By Robert Graves
U.S. Geological Survey, Water Resources Division, Las Vegas, Nevada

INTRODUCTION

Numerous aquifer tests have been conducted in and around the Nevada Test Site. Many of these tests have been completed in a fractured rock medium. Methods used to analyze these aquifer tests have included the Theis and Cooper-Jacob solutions. Although both methods are used to estimate aquifer characteristics in fracture media, the results may be qualified because both methods were developed for porous rock media. Recently, GeoTrans Inc., working in cooperation with the U.S. Department of Energy (DOE), evaluated time/drawdown data collected in wells drilled for DOE in the Oasis Valley area (ER-EC wells, completed in fractured volcanic rock) using a fractured-rock, double-porosity model (Moench, 1984). Based on this evaluation, it was thought that analyzing aquifer-test results from these wells with a dual-porosity solution would yield a better transmissivity estimate in these wells. Subsequently, individuals from GeoTrans Inc. identified approximately 62 wells in the vicinity of the Nevada Test Site with aquifer test data that could potentially be reevaluated with a fractured-rock, double-porosity model. Transmissivity estimates from these aquifer tests will support ground-water flow models being developed for DOE.

The U.S. Geological Survey (USGS) proposed to DOE to work in cooperation with GeoTrans Inc. to review these aquifer tests for the availability of aquifer-test data that might be suitable for reevaluation. Well MX-CSV-2 was one of the wells selected by the USGS for reevaluation. Transmissivity in well MX-CSV-2 has been estimated to be 1,500 ft^2/d by Belcher and Elliott (2001, Appendix A, Hydraulic-Properties Database, Worksheet UCA&LCA, well NCAP-CSV-2) from an aquifer test conducted on June 7-8, 1986 (Berger and others, pg. 12-19, table 5). The aquifer-test data from this test were reanalyzed using the Cooper-Jacob solution (Cooper and Jacob, 1946) and Moench's dual-porosity spherical-shaped block and slab-shaped block solutions (Moench, 1984). Transmissivity estimates from each solution were compared.

TEST DESCRIPTION

On June 7, 1986, the USGS began a single-well aquifer test on well MX-CSV-2 which lasted approximately 21 hours (pump off on June 8, 1986) (Berger and others, 1988, p. 12-19). Well MX-CSV-2 is located in the Moapa Valley area of southeastern Nevada (fig. 1) and is completed in the Paleozoic carbonate rock aquifer.

Berger and others, (1988, p. 12) reported that prior to the June 7, 1986, aquifer test, the well was developed by pumping the well for 2 days at approximately 5,500 gallons per day. A 20-horsepower, 6-inch-diameter submersible pump with a 3-inch-diameter discharge pipe was used for the test. The pump intake was set at 430 feet below land surface. Discharge was piped 60 feet from the well to a small wash that transported flow from the site. The drawdown test

lasted approximately 21 hours with a constant discharge of about 101 gallons per minute. No adjustments to the drawdown data due to barometric, tidal, or temperature effects were made.

TEST SITE

Well MX-CVS-2 is located at 36 ° 46’ 50” N.; 114 ° 43’ 20” W., Moapa Valley, Clark County Nevada, approximately 3.2 miles north of the intersection of State Road 168 and Warm Springs Road. The well site is in an unnamed drainage on the south-western flank of the Meadow Valley Mountains and south of Farrier Wash (Berger and other, 1988, p. 12).

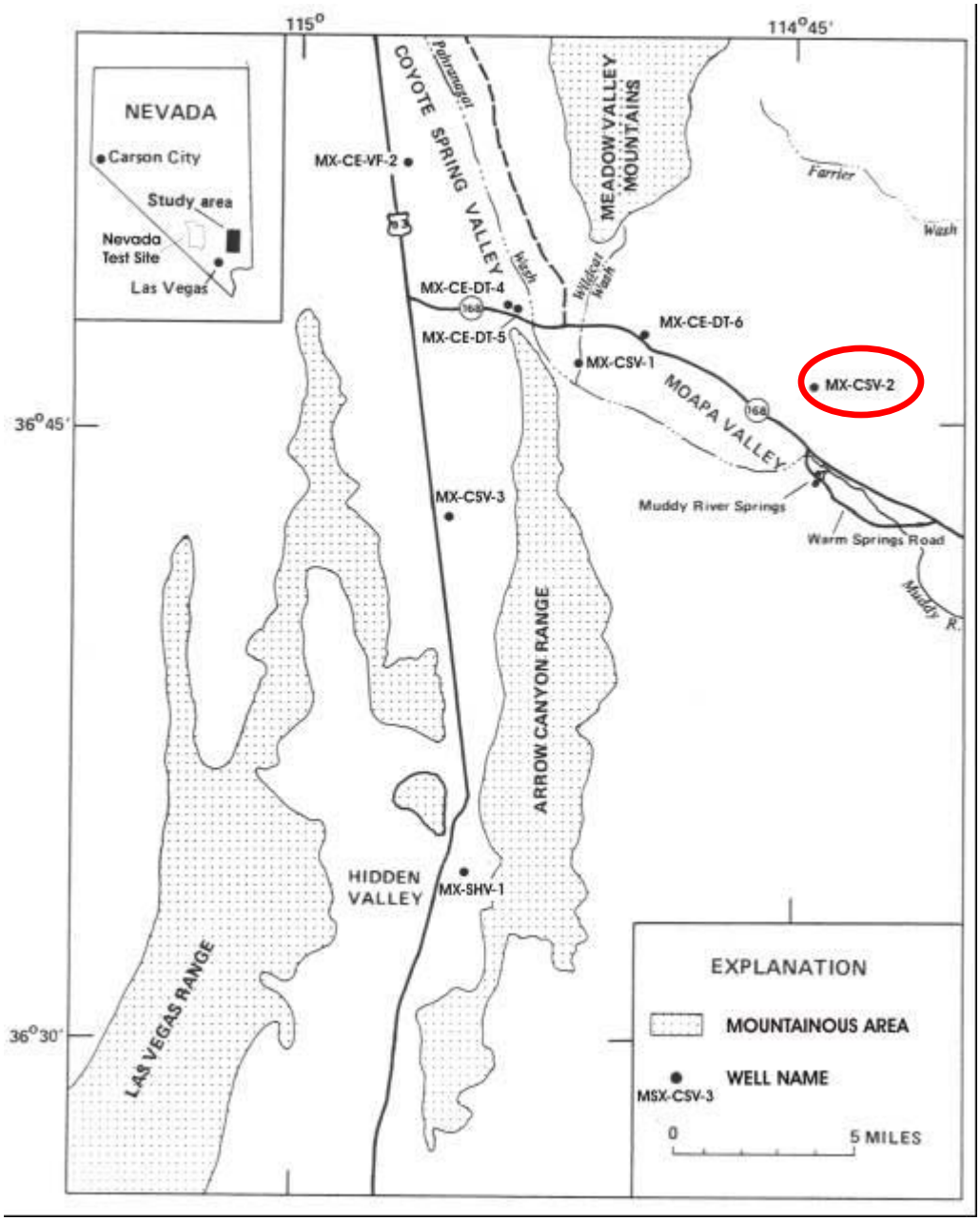

Figure 1 Location of well MX-CVS-2.

CONSTRUCTION

Well MX-CSV-2 was drilled as a test well by the USGS during October 1985. The well was completed on 10/26/85 to a depth of 478 feet below land surface. The well was drilled using hydraulic-rotary and air-foam methods and is cased from 0 to 95 feet below land surface with 10-inch PVC casing, and open hole from 95 to 478 feet below land surface with a 8.75 inch diameter borehole. The saturated thickness of aquifer tested is approximately 87 feet.

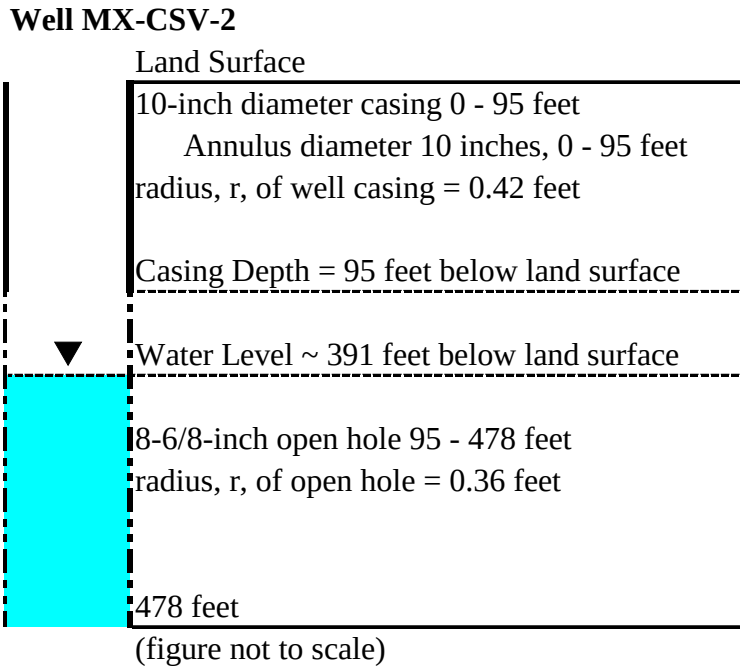

Figure 2 Construction of well MX-CSV-2.

HYDROGEOLOGIC CHARACTERISTICS

The saturated zone in well MX-CSV-2 is completed in Paleozoic carbonate rock which is predominantly a shaley limestone, fine grained, gray to pale reddish brown pink, with occasional calcite veins (Berger and others, 1988, p. 13) (table 1).

Table 1 Rock type in well MX-CSV-2 from 0 to 478 feet below land surface.

Depth interval, in feet below land surface [1/]	**Rock type**
0 - 19	Alluvium, gravel (80 percent), coarse sand (15 percent), silt and clay (5 percent)
19 - 76	Dolomite
76 - 118	Limestone
118 - 295	Silty limestone
295 - 465	Shaley limestone
465 - 478	Silty limestone

[1/] Depth interval interpolated from Berger and others (1988, p. 13, fig. 4)

COOPER-JACOB ANALYSIS

The Cooper-Jacob method (Cooper and Jacob, 1946), commonly referred to as the straight-line method, is a simplification of the Theis (1935) solution for flow to a fully penetrating well in a confined aquifer. Using the Cooper-Jacob method, a transmissivity was estimated to be 1,300 ft^2/d by fitting a straight line to late-time drawdown data (fig. 3). Lohman (1979, p. 22) states that the Cooper-Jacob method is only valid when the well function of u is less than or equal to 0.01 (u = r2 S/4 T t, where r = distance to observation well, S = aquifer storage, T = aquifer transmissivity and t = time of pumpage). Assuming an r of 1 foot and S of 0.001, the criteria of a value of u less than or equal to 0.01 was met after the first second of pumping.

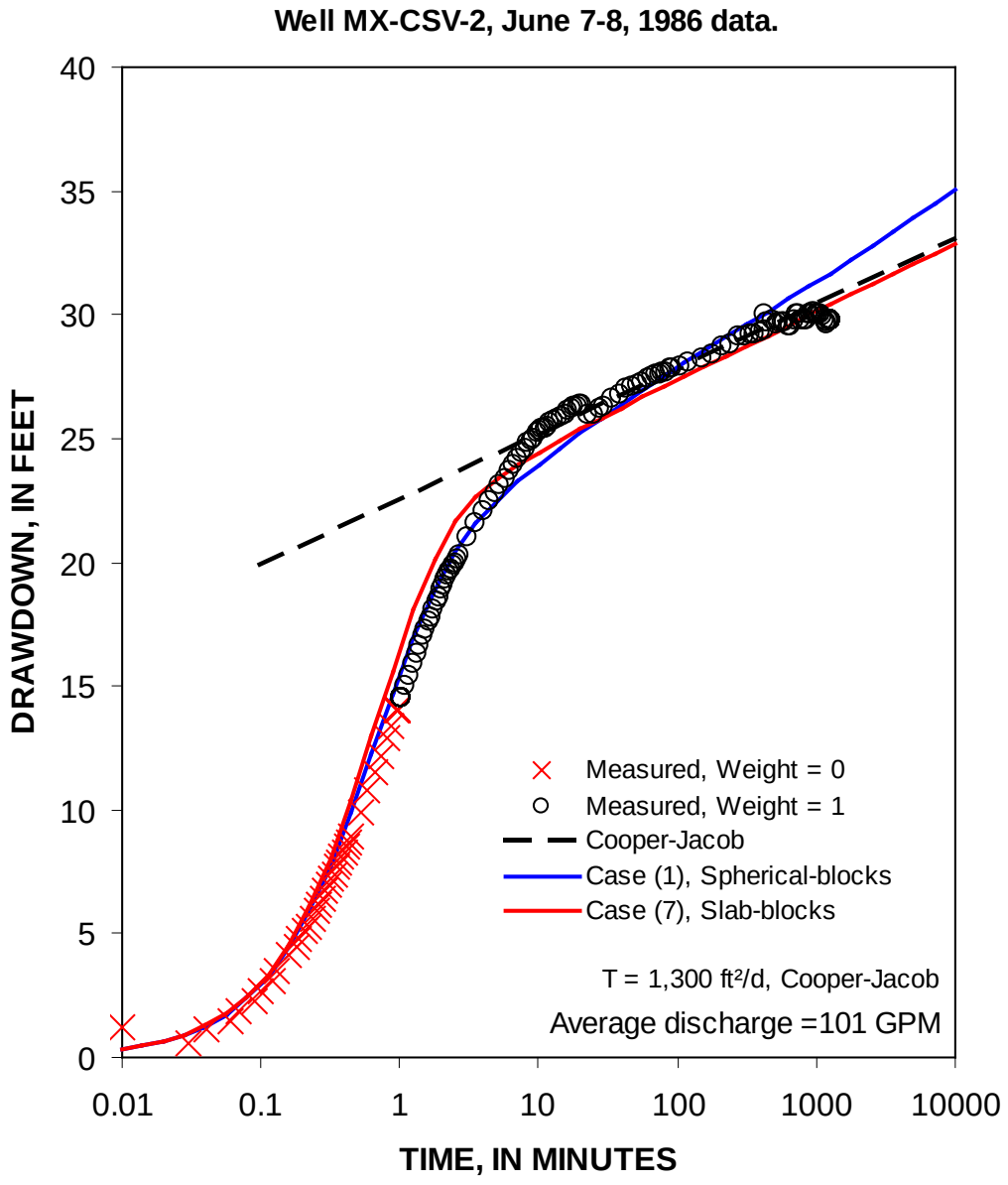

Figure 3 Measured, straight-line approximation, case (1) simulated, and case (7) simulated drawdowns for June 7-8, 1986, aquifer test conducted at well MX-CSV-2.

MOENCH ANALYSIS

General assumptions about aquifer geometry and hydraulic properties are similar for the Theis and Moench solutions. Common assumptions for both solutions are that aquifers are laterally infinite, have homogeneous and isotropic transmissivities, and are bounded by impermeable confining units. Production and observation wells are assumed to be fully penetrating so that all flow is horizontal. Transmissivity (T) and storage (S) are the same parameters in both solutions.

The Theis and Moench solutions differ in how the release of water from storage is simulated. Water is supplied from aquifer and water compressibility in the Theis solution, which is defined by a single parameter (S). Fractures and blocks of unfractured matrix provide two sources of water in the Moench solution. The first source is from fractures, which contribute water from aquifer and water compressibility in direct proportion to drawdown as defined by a single storage term (S). The second source of water is from the blocks of unfractured matrix that can release water at highly variable rates because the blocks are simulated as one-dimensional aquifers. The blocks of unfractured matrix are characterized by four parameters; slab thickness (2b'), (b' in table 2), fracture skin (Sf), matrix hydraulic conductivity (K'), and matrix specific storage (Ss') (fig. 4). The fracture network also can be conceptualized as spheres instead of slabs in the Moench solution where 2b' defines sphere diameter instead of slab thickness.

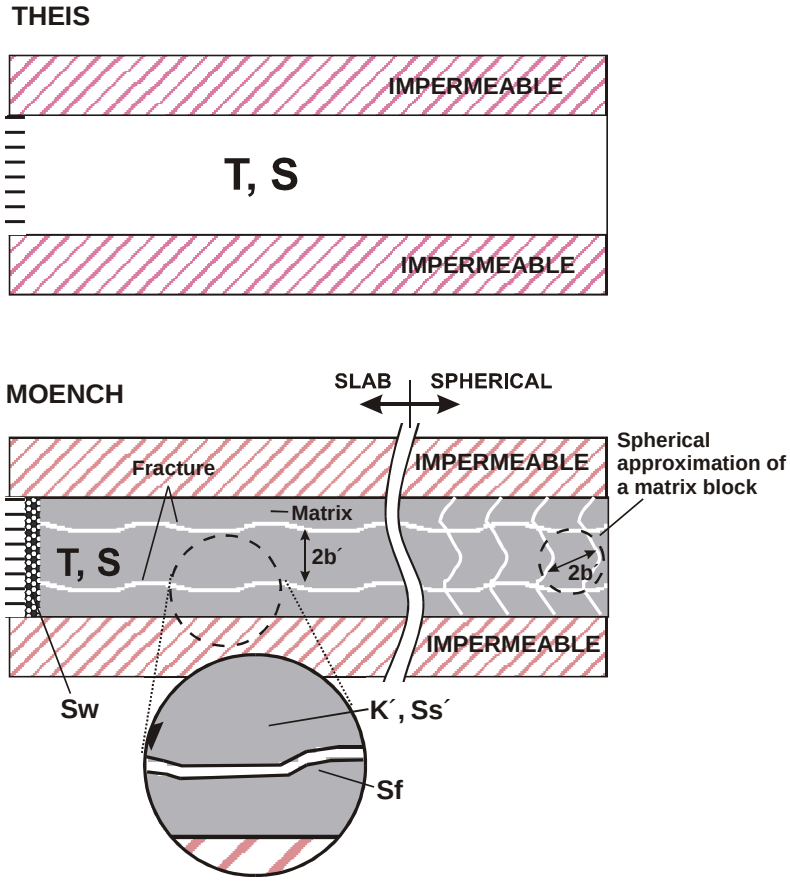

Figure 4 Schematic diagrams of Theis and Moench aquifers.

The range of hydraulic properties that is expected for matrix blocks or slabs is dependent on how the dual-porosity system is conceptualized. Fracture intervals in carbonates that are predominantly vertical and recur in intervals of 10 ft or less suggest a spherical approximation of matrix blocks is reasonable. Matrix permeability would be similar to estimates from cores and would have a relatively limited range of expected values if the dual-porosity system were pictured as spheres. Flow logging and packer testing in wells suggest interbeds that recur in intervals of 100 to 1,000 ft are the primary permeable zones. This would suggest that the dual-porosity system could be conceptualized as slabs of 100 to 1,000 ft thick. Matrix permeability in the slab conceptualization could be much greater than estimates from cores because the 'matrix' also would be fractured, albeit less well connected than the interbeds.

Multiple conceptualizations of the dual-porosity system around well MX-CSV-2 were tested to determine the uniqueness of hydraulic property estimates. Hydraulic properties were estimated by minimizing the sum-of-squares difference between simulated and observed drawdowns after the first minute of pumping. Drawdowns from the first minute of pumping were not used because wellbore storage greatly affected these measurements.

Aquifer geometry was specified and all hydraulic properties except for transmissivity were constrained to reasonable ranges (table 2). Matrix blocks were assumed to have 10-ft diameters for the spherical solutions. Because only 87 feet of saturated aquifer were tested matrix blocks were assumed to have 43-ft thickness for the slab solutions. Matrix specific storage coefficients were limited to range from 10^{-7} to 10^{-5} ft^{-1}. Matrix hydraulic conductivities were limited to range from 10^{-5} to 0.1 ft/d. The skin terms Sf and Sw were estimated, but were constrained to range from 0 to 100.

Estimates of S, b', Sf, K', and Ss' were not unique (table 2). Final estimates of the parameters that were estimated were highly dependent on initial estimates, except for transmissivity. Case 1 and Case 7 had RMS errors of 0.78 to 0.99 ft, respectively, which spans the range of RMS errors for all cases that were tested (table 2). Simulated drawdowns from all cases described the observed drawdowns equally well (fig. 3). Although some simulated drawdowns differed significantly for times later than when measurements existed.

Table 2 Parameter estimates and fitting error for multiple Moench solutions to the observed drawdowns in well MX-CSV-2.

[Aquifer thickness is 87 feet. A total of 114 points were used in the analyses. b' is slab thickness or sphere diameter. K is aquifer hydraulic conductivity. Ss is specific storage of fractures. K' is matrix hydraulic conductivity. Sw is wellbore skin. Sf is fracture skin. T is aquifer transmissivity. S is storage coefficient of aquifer. RMS is Root Mean Square.]

Hydraulic Property	CASE							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Slab Geometry[†]	Spherical	Spherical	Slab	Slab	Slab	Slab	Slab	Spherical
Slab, (b'), ft	10 [a]	10 [a]	43 [a]	43 [a]	43 [a]	43 [a]	43 [a]	10 [a]
K, ft/d	10.65	13.35	12.03	13.38	11.75	9.09	14.94 [a]	14.94 [a]
Ss, 1/ft	3.6E-06	1.0E-05	3.6E-06	7.5E-06	3.6E-06	3.6E-06	5.4E-06	1.5E-05
K', ft/d	1.0E-5 [a]	1.0E-1 [a]	1.0E-5 [a]	1.0E-1 [a]	1.0E-5 [a]	1.0E-1 [a]	1.0E-05	1.0E-05
Ss', 1/ft=	2.0E-6 [a]	2.0E-6 [a]	1.0E-7 [a]	1.0E-7 [a]	1.0E-5 [a]	1.0E-5 [a]	2.5E-07	1.0E-07
Sw	0.9	3.3	1.8	3.1	1.6	0.0	4.0	4.5
Sf	0.1	0.0	0.0	0.0	0.0	4.5	100.0	0.0
T, ft^2/d	**900**	**1,200**	**1,000**	**1,200**	**1,000**	**800**	**1,300 [a]**	**1,300 [a]**
S	3.E-04	9.E-04	3.E-04	7.E-04	3.E-04	3.E-04	5.E-04	1.E-03
RMS error, ft	0.78	0.86	0.81	0.86	0.80	0.57	0.99	0.99

[†] Geometry of matrix in Moench solution which is either slab or sperical.

[a] Values were specified.

CONCLUSIONS

Transmissivity could be reliably estimated around well MX-CSV-2 with either Cooper-Jacob or a Moench solution from aquifer-test results. Estimate of transmissivity determined for this report using the Cooper-Jacob solution was not significantly improved by using the Moench solution. Because the range of transmissivities determined using either the Moench or Cooper-Jacob solutions is only 800 to 1,300 ft^2/d, the best estimate of transmissivity is considered to be 1,000 ft^2/d. However, this best estimate of transmissivity will be biased above the actual value if the test was of insufficient duration to reach the final limb of a dual-porosity response.

Final estimates of parameters b', S, Ss, K', Ss', and Sf were dependent on initial estimates and could not be estimated uniquely. Estimates of matrix hydraulic conductivity (K') and fracture skin (Sf) could range over more than four orders of magnitude for models that matched the observed drawdowns equally well.

REFERENCES

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APPENDIX A –TIME/WATER LEVEL/DRAWDOWN RECORDS

Well MX-CSV-2, June 7 - 8, 1986, time/drawdown data.
Source of data, (Berger and others, 1988, pg. 15-17, table 5), exact time pump on not in literature.

Date	Depth to water, in feet	Elapsed time, in minutes	Drawdown, in feet

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Date	Depth to water, in feet	Elapsed time, in minutes	Drawdown, in feet
Pump on 06/07/86	390.76	0.00	0.00
	392.00	0.01	1.24
	391.40	0.03	0.64
	391.90	0.04	1.14
	392.30	0.06	1.54
	392.70	0.07	1.94
	393.10	0.09	2.34
	393.50	0.10	2.74
	393.90	0.12	3.14
	394.30	0.13	3.54
	394.90	0.16	4.14
	395.30	0.18	4.54
	395.60	0.19	4.84
	395.90	0.21	5.14
	396.10	0.22	5.34
	396.40	0.24	5.64
	396.70	0.25	5.94
	397.00	0.26	6.24
	397.20	0.28	6.44
	397.50	0.29	6.74
	397.80	0.31	7.04
	398.00	0.32	7.24
	398.20	0.34	7.44
	398.50	0.35	7.74
	398.70	0.37	7.94
	398.90	0.38	8.14
	399.10	0.40	8.34
	399.30	0.41	8.54
	399.50	0.43	8.74
	399.70	0.44	8.94
	400.70	0.52	9.94
	401.60	0.59	10.84
	402.30	0.66	11.54
	403.00	0.74	12.24
	403.70	0.81	12.94
	404.20	0.88	13.44
	404.80	0.96	14.04
	405.30	1.03	14.54
	405.80	1.11	15.04
	406.20	1.18	15.44

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Date	Depth to water, in feet	Elapsed time, in minutes	Drawdown, in feet
	406.70	1.25	15.94
	407.10	1.33	16.34
	407.40	1.40	16.64
	407.80	1.47	17.04
	408.10	1.55	17.34
	408.40	1.62	17.64
	408.60	1.70	17.84
	408.90	1.77	18.14
	409.20	1.84	18.44
	409.40	1.92	18.64
	409.70	1.99	18.94
	409.90	2.06	19.14
	410.10	2.14	19.34
	410.30	2.21	19.54
	410.40	2.29	19.64
	410.50	2.36	19.74
	410.70	2.43	19.94
	410.80	2.51	20.04
	410.90	2.58	20.14
	411.10	2.65	20.34
	411.80	3.10	21.04
	412.40	3.54	21.64
	412.90	3.98	22.14
	413.30	4.42	22.54
	413.60	4.87	22.84
	413.90	5.31	23.14
	414.20	5.75	23.44
	414.50	6.19	23.74
	414.70	6.64	23.94
	415.00	7.08	24.24
	415.20	7.52	24.44
	415.40	7.96	24.64
	415.60	8.41	24.84
	415.70	8.85	24.94
	415.80	9.29	25.04
	416.00	9.73	25.24
	416.10	10.18	25.34
	416.20	10.62	25.44
	416.20	11.06	25.44
	416.30	11.50	25.54
	416.40	11.89	25.64

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Date	Depth to water, in feet	Elapsed time, in minutes	Drawdown, in feet
	416.50	12.77	25.74
	416.60	13.66	25.84
	416.70	14.54	25.94
	416.80	15.43	26.04
	416.90	16.31	26.14
	417.00	17.20	26.24
	417.10	18.08	26.34
	417.10	18.97	26.34
	417.20	19.85	26.44
	417.20	20.74	26.44
	416.80	22.95	26.04
	416.80	25.16	26.04
	417.00	27.37	26.24
	417.10	29.59	26.34
	417.40	34.01	26.64
	417.60	38.44	26.84
	417.80	42.86	27.04
	417.90	47.29	27.14
	418.00	51.71	27.24
	418.10	56.14	27.34
	418.20	60.56	27.44
	418.30	64.98	27.54
	418.40	69.41	27.64
	418.40	73.83	27.64
	418.50	78.26	27.74
	418.50	82.68	27.74
	418.60	87.11	27.84
	418.60	91.53	27.84
	418.70	104.81	27.94
	418.90	118.08	28.14
	419.00	150.00	28.24
	419.20	180.00	28.44
	419.50	210.00	28.74
	419.60	240.00	28.84
	419.90	270.00	29.14
	419.90	300.00	29.14
	420.00	330.00	29.24
	420.00	360.00	29.24
	420.10	390.00	29.34
	420.20	420.00	29.44
	420.80	423.00	30.04

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Date	Depth to water, in feet	Elapsed time, in minutes	Drawdown, in feet
	420.50	440.00	29.74
	420.60	480.00	29.84
	420.40	510.00	29.64
	420.50	540.00	29.74
	420.50	570.00	29.74
	420.50	600.00	29.74
	420.30	630.00	29.54
	420.30	660.00	29.54
	420.60	690.00	29.84
	420.80	720.00	30.04
	420.80	750.00	30.04
	420.60	780.00	29.84
	420.60	810.00	29.84
	420.60	840.00	29.84
	420.80	870.00	30.04
	420.80	900.00	30.04
	420.90	930.00	30.14
	420.90	960.00	30.14
	420.80	990.00	30.04
	420.80	1020.00	30.04
	420.80	1050.00	30.04
	420.80	1080.00	30.04
	420.70	1110.00	29.94
	420.60	1140.00	29.84
	420.40	1170.00	29.64
	420.50	1200.00	29.74
	420.60	1230.00	29.84
	420.60	1260.00	29.84
Pump off 06/08/86	420.60	1290.00	29.84