Aquifer-Test Report for Test Well UE-19i

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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 UE-19i was one of the wells selected by the USGS for reevaluation. Transmissivity in well UE-19i has been estimated to be approximately 190 ft^2/d by Blankennagel and Weir (1973, p. B12, table 3), from an aquifer test conducted on September 2, 1965. 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

Well UE-19i is located in Area 19 of the Nevada Test Site (fig. 1). On September 2, 1965, at 4:21 am (Pacific Daylight Savings time, PDT) the USGS began a single-well aquifer test on well UE-19i which lasted approximately 16.6 hours (pump off at 9:01 pm, PDT, on September 2, 1965) (Weir and Blankennagel, 1966, p. 8). Average discharge during the test was 140 gallons per minute.

Weir and Blankennagel (1966, p. 9, footnote a/) reported that Several short pumping periods preceded the September 2, 1965 test. On September 1, 1965, the well was pumped for 75 minutes between 1615-1730 hours; for 4 to 45 minutes between 1735-2014 hours; for 116 minutes between 2024-2220 hours; and for 159 minutes between 2225-0134 hours on September 1-2, 1965. Prior to the short pumping periods, the depth to water was 2,363.6 feet, 11.8 feet above the level measured before the single-well aquifer test began. Weir and Blankennagel

(1966, p. 9, footnote b/) further reported that they were unable to maintain constant discharge rates when the water level dropped below 2,545 feet (at 250 minutes of pumping). Discharge measurements, based on meter readings dropped to 134 gpm after 255 minutes, 130 gpm after 460 minutes, 115 gpm after 600 minutes, and 105 gpm after 900 minutes.

Due to change in discharge with time only the first 250 minutes of drawdown data will be analyzed for this report to determine transmissivity. A discharge of 140 gallons per minute (Blankennagel and Weir, 1973, p. B12, table 3) will be used for this period of pumping. No adjustments to the drawdown data due to barometric, tidal, or temperature effects were made.

On page 2, Weir and Blankennagel (1966) reported that:

> *Water levels were measured with a deep-well electrical line that is capable of detecting relative changes in water level as small as 0.02 foot. The static-level measurements have not been corrected to a steel tape secondary standard and should not be used for water-level contouring.*
>
> *A Reda submersible pump was used in the test on well UE-19i. A positive displacement check value was placed immediately above the pump. Discharge measurements were made using Sparling water meters. In most tests the meter accuracy was checked with a 55 gallon barrel or a 10,000 gallon tank.*

TEST SITE

Well UE-19i is located at 37 ◦ 14’ 60” N.; 116 ◦ 20’ 49” W., in Area 19 of the Nevada Test Site (fig. 1).

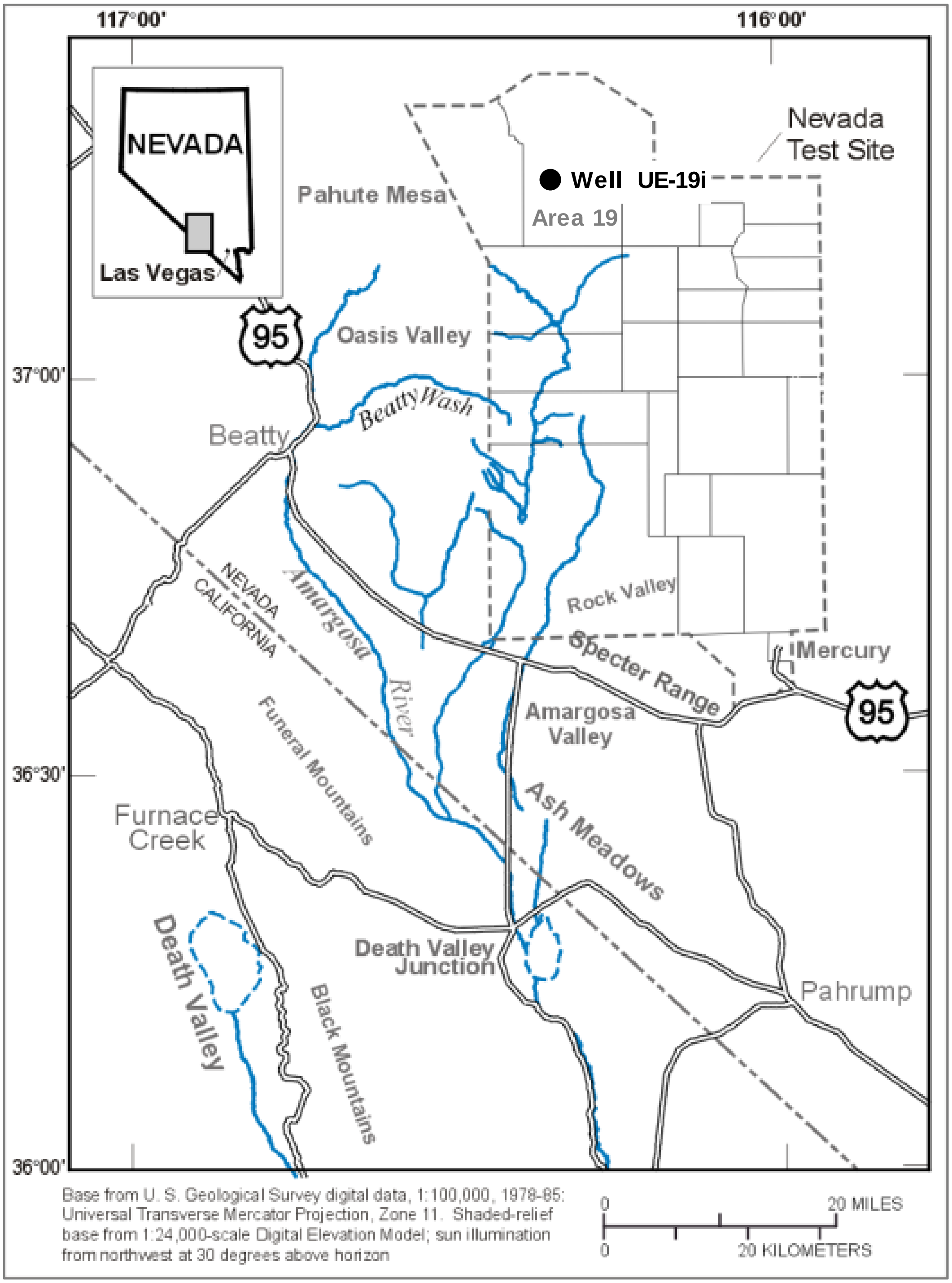

Figure 1 Location of well UE-19i on the Nevada Test Site.

CONSTRUCTION

Well UE-19i was drilled in the Pahute Mesa area to collect data for the evaluation of the subsurface geologic and hydrologic environment (Blankennagel and Weir, 1973, p. B1-B2). Well UE-19i was drilled to a depth of 8,000 feet below land surface and was completed with a 13 3/8-inch outside diameter casing from land surface to 2,896 feet below land surface, and a 12 1/4-inch diameter open hole from 2,896 to 4,566 feet below land surface, and a 9 7/8-inch diameter open hole from 4,566 to 8,000 feet below land surface. (fig. 2). The saturated thickness of aquifer tested was about 5,104 feet.

Well UE-19i

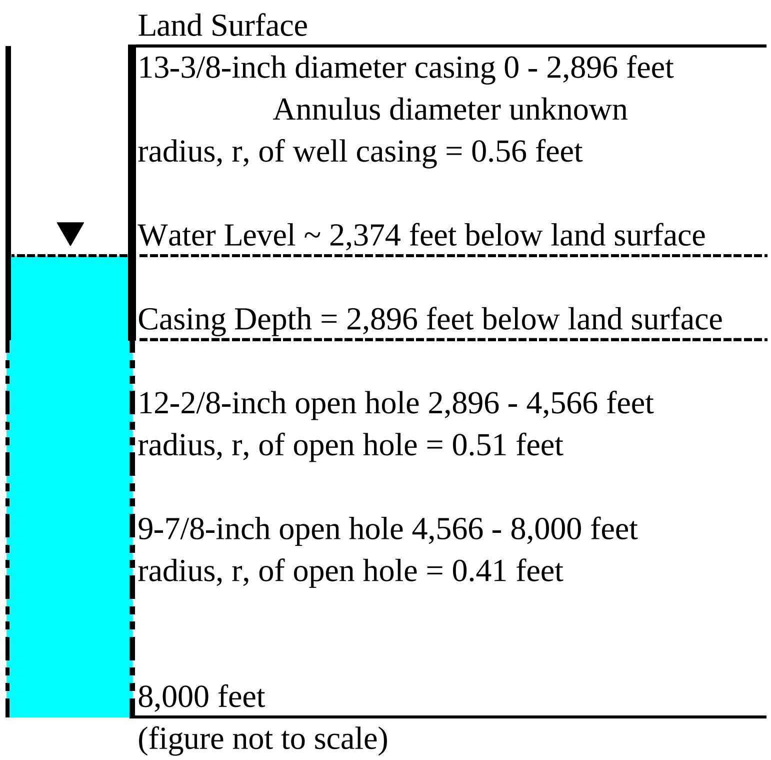

Figure 2 Construction of well UE-19i.

HYDROGEOLOGIC CHARACTERISTICS

Weir and Blankennagel (1966, p. 8), report that well UE-19i is completed in Rhyolite. Belcher and Elliott, (2001, Appendix A: Hydraulic-Properties Database, worksheet Tertiary Volcanics) report the well was completed in trachyte lava flows of the Belted Range Group/Dead Horse Flat Formation. Orkild and Jenkins, (1978, p. 41-42) present a detailed description of rock type and stratigraphic units for well UE-19i (table 1).

Table 1 Rock type in well UE-19i from 0 to 8,000 feet below land surface (adapted from Orkild and Jenkins (1978, p. 41-42)

Depth interval, in feet below land surface	**Rock type**
0 - 835	Partially to densely welded ash-flow tuff
835 - 840	Vitric ash-fall tuff
840 - 1,000	Moderately to densely welded ash-flow tuff
1,000 - 1,890	Rhyolitic lava flow
1,890 - 1,940	Fused tuff
1,940 - 2,100	Nonwelded to densely welded ash-flow tuff
2,100 - 2,460	Vitric ash-fall tuff
2,460 - 2,920	Zeolitized reworked tuff and volcanic sandstone and siltstone
2,920 - 3,270	Partially welded ash-flow tuff
3,270 - 3,370	Partially welded ash-flow tuff
3,370 - 3,805	Brecciated rhyolitic lava flow (phenocryst poor)
3,805 - 3,870	Partially welded ash-flow (?) tuff (possibly load compacted)
3,870 - 4,055	Moderately welded ash-flow tuff
4,055 - 4,110	Densely welded ash-flow tuff
4,110 - 4,885	Pyroclastic (?) or talus breccia
4,885 - 5,130	Densely welded ash-flow tuff
5,130 - 5,260	Welded (?) ash-flow tuff
5,260 - 6,430	Rhyolitic lava flow
6,430 - 6,815	Trachytic soda rhyolite
6,815 - 6,975	Welded tuff breccia
6,975 - 7,150	Tuff (?) or rhyolitic lava flow (?)
7,150 - 7,330	Lithic tuff breccia (argillized)
7,330 - 7,525	Rhyolitic lava flow (phenocryst poor)
7,525 - 8,000	Rhyolitic lava flow (phenocryst poor)

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 140 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.

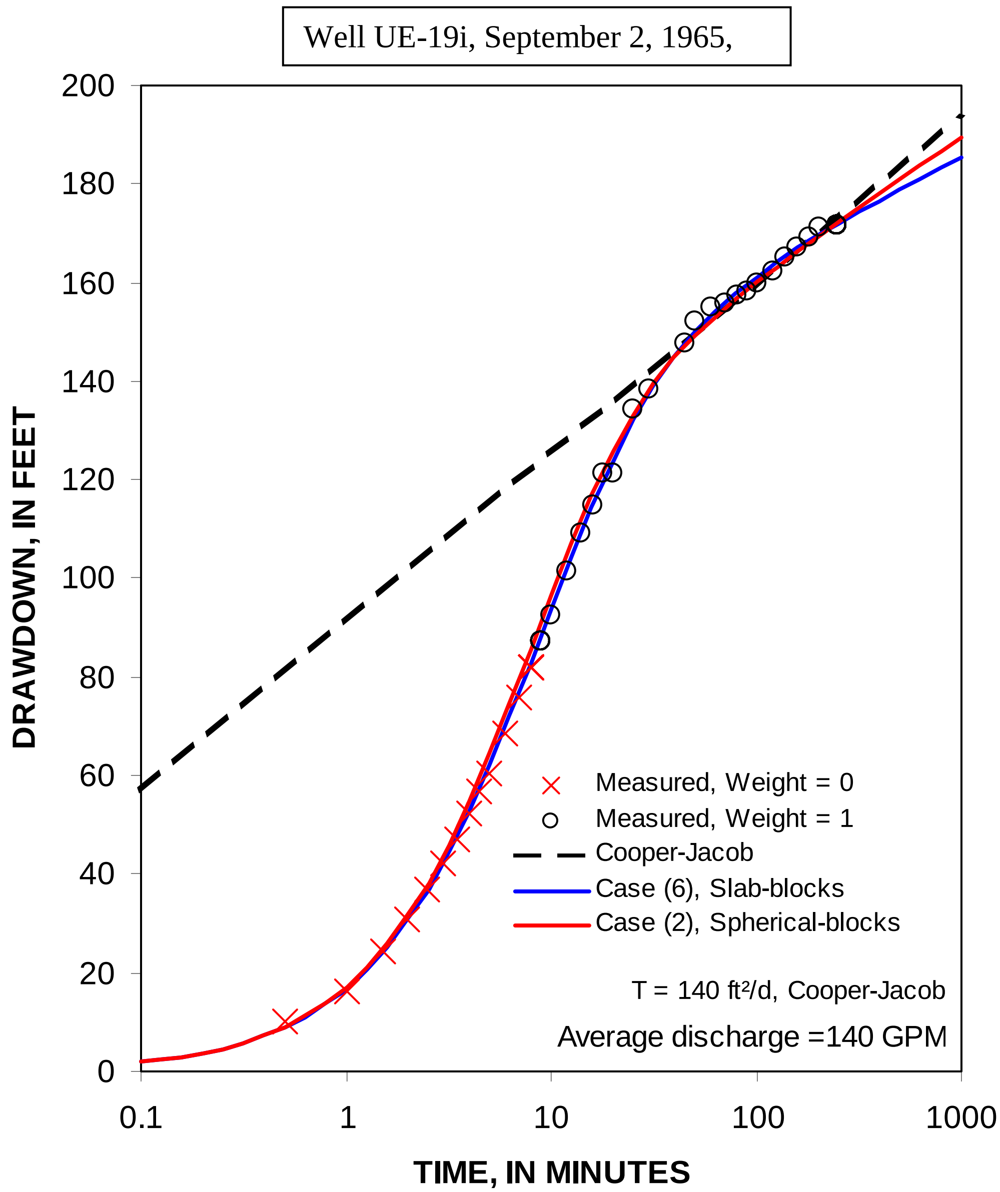

Figure 3 Measured, straight-line approximation, case (6) simulated, and case (2) simulated drawdowns for September 2, 1965, aquifer test conducted at well UE-19i.

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.

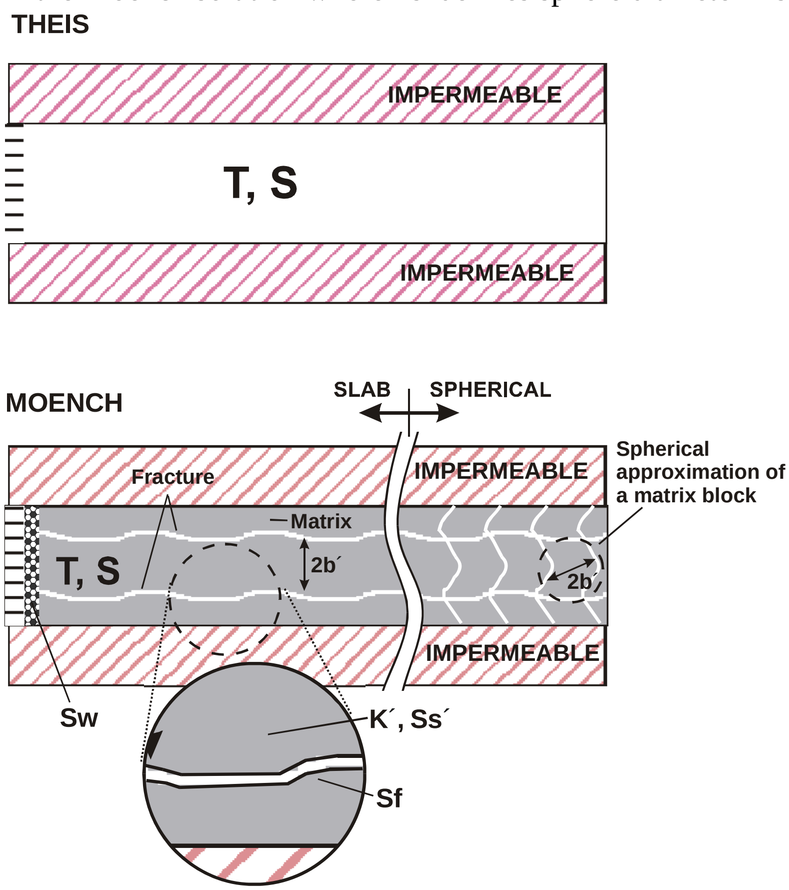

Figure 4 Schematic diagrams of Theis and Moench aquifers.

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 welded tuffs 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 at the Nevada Test Site suggest volcanic 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 UE-19i 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 8 minutes of pumping. Drawdowns from the first 8 minutes 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. Matrix blocks were assumed to have 500-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 6 and Case 2 had RMS errors of 1.26 to 2.17 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 UE-19i.

[Aquifer thickness is 5,104 feet. A total of 22 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]	500 [a]	500 [a]	500 [a]	500 [a]	500 [a]	10 [a]
K, ft/d	0.03	0.04	0.03	0.03	0.03	0.02	0.03 [a]	0.03 [a]
Ss, 1/ft	5.6E-07	6.0E-07	6.5E-07	1.8E-07	1.1E-07	7.9E-07	4.9E-07	2.5E-07
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-01	1.6E-04
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]	1.0E-05	1.0E-05
Sw	0.0	2.2	1.0	0.0	0.0	0.0	0.5	0.2
Sf	0.1	0.0	0.0	1.6	0.0	0.6	1.1	28.4
T, ft^2/d	**130**	**180**	**160**	**150**	**160**	**120**	**140 [a]**	**140 [a]**
S	3.E-03	3.E-03	3.E-03	9.E-04	6.E-04	4.E-03	2.E-03	1.E-03
RMS error, ft	1.30	2.17	1.75	1.52	1.68	1.26	1.50	1.50

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

[a] Values were specified.

CONCLUSIONS

Transmissivity could be reliably estimated around well UE-19i with either Cooper-Jacob or a Moench solution from aquifer-test results. An 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 120 to 180 ft^2/d, the best estimate of transmissivity is considered to be 160 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 UE-19i, September 2, 1965, time/drawdown data. Source of data, (Weir and Blankennagel, 1966, page 8, table 3). Data after 250 minutes not used for estimates of transmissivity. Table begins on next page.

DATE TIME	DEPTH TO WATER, IN FEET	ELAPSED TIME, IN MINUTES	DRAWDOWN, IN FEET
09/02/65 04:21:00	2,373.50	0.00	0.00
09/02/65 04:21:30	2,383.50	0.50	10.00
09/02/65 04:22:00	2,389.70	1.00	16.20
09/02/65 04:22:30	2,397.90	1.50	24.40
09/02/65 04:23:00	2,404.20	2.00	30.70
09/02/65 04:23:30	2,410.30	2.50	36.80
09/02/65 04:24:00	2,415.80	3.00	42.30
09/02/65 04:24:30	2,420.40	3.50	46.90
09/02/65 04:25:00	2,425.80	4.00	52.30
09/02/65 04:25:30	2,430.40	4.50	56.90
09/02/65 04:26:00	2,433.80	5.00	60.30
09/02/65 04:27:00	2,442.20	6.00	68.70
09/02/65 04:28:00	2,449.20	7.00	75.70
09/02/65 04:29:00	2,455.40	8.00	81.90
09/02/65 04:30:00	2,460.70	9.00	87.20
09/02/65 04:31:00	2,466.10	10.00	92.60
09/02/65 04:33:00	2,474.90	12.00	101.40
09/02/65 04:35:00	2,482.70	14.00	109.20
09/02/65 04:37:00	2,488.50	16.00	115.00
09/02/65 04:39:00	2,494.60	18.00	121.10
09/02/65 04:41:00	2,495.00	20.00	121.50
09/02/65 04:46:00	2,507.60	25.00	134.10
09/02/65 04:51:00	2,511.70	30.00	138.20
09/02/65 05:06:00	2,521.00	45.00	147.50
09/02/65 05:11:00	2,525.80	50.00	152.30
09/02/65 05:21:00	2,528.60	60.00	155.10
09/02/65 05:31:00	2,529.20	70.00	155.70
09/02/65 05:41:00	2,530.80	80.00	157.30
09/02/65 05:51:00	2,531.70	90.00	158.20
09/02/65 06:01:00	2,533.20	100.00	159.70
09/02/65 06:21:00	2,535.90	120.00	162.40
09/02/65 06:41:00	2,538.50	140.00	165.00
09/02/65 07:01:00	2,540.70	160.00	167.20
09/02/65 07:21:00	2,542.50	180.00	169.00
09/02/65 07:44:00	2,544.70	203.00	171.20
09/02/65 08:31:00	2,545.20	250.00	171.70
09/02/65 09:21:00	2,543.80	300.00	170.30
09/02/65 10:09:00	2,548.25	348.00	174.75
09/02/65 11:01:00	2,548.80	400.00	175.30
09/02/65 11:51:00	2,549.05	450.00	175.55
09/02/65 12:41:00	2,549.21	500.00	175.71
09/02/65 14:21:00	2,557.37	600.00	183.87
09/02/65 16:01:00	2,556.79	700.00	183.29
09/02/65 17:41:00	2,556.99	800.00	183.49
09/02/65 19:21:00	2,557.09	900.00	183.59
09/02/65 21:01:00	2,558.60	1,000.00	185.10

FIGURES

TABLES

APPENDIX A - TIME/WATER LEVEL/DRAWDOWN RECORDS
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