IMPACT OF THE PROPOSED UNION CAMP PAPER MILL

ON THE

LOCAL GROUND WATER USERS IN RICHLAND COUNTY, SOUTH CAROLINA

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Open-File Report 4

March 1982

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Introduction

The Union Camp Corporation, after having considered several candidate locations, decided in 1981 to develop a site in Richland County, South Carolina, for their new bleached Kraft paper mill. The site is located in the southeastern corner of Richland County, along the Wateree River, about 2 miles east of the Town of Eastover (figure 1).

The proposed plant will require approximately 35 to 40 Mgd (million gallons per day) for process water when it is completed. The present proposal is to withdraw 3 Mgd from wells completed in the Middendorf (Tuscaloosa) formation, and to withdraw the remainder from the Wateree River.

The purpose of this report is to evaluate the impact, in terms of water availability, of the proposed 3 Mgd pumpage on the local ground-water system.

I would like to acknowledge the help of the following: Terry Kingsmore, of J. E. Sirrine and Co., Engineers for providing me with copies of the three consulting reports concerning the ground water conditions; Carlos Lemos of Law Engineering Testing Co., for his assistance in obtaining some information on the site itself; and, most importantly, Mr. George E. Siple for his invaluable assistance in the interpretation of the geology and hydrology of the area.

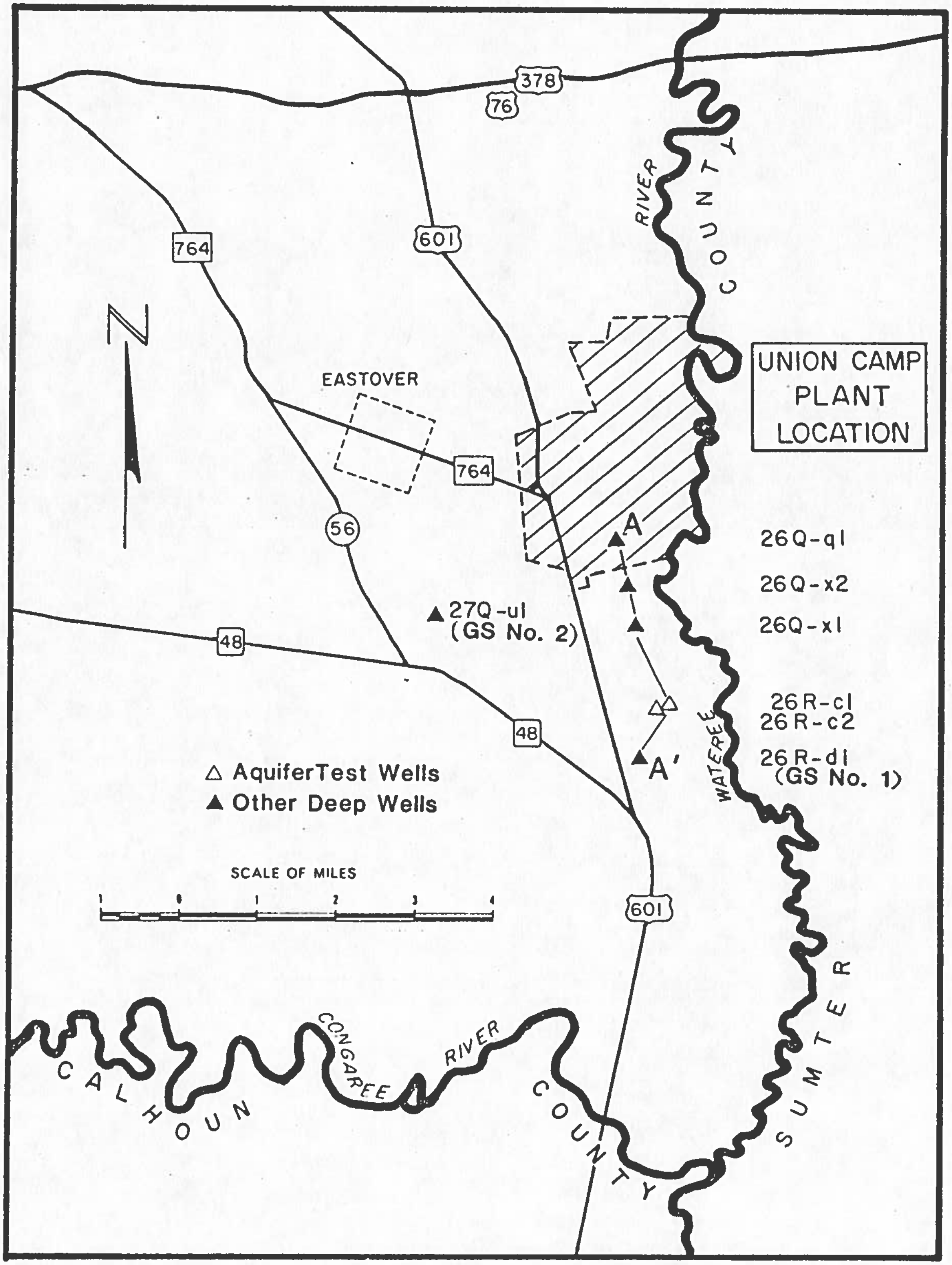


Figure 1 -- Map showing the location of the proposed Union Camp mill site, and its relationship to the Town of Eastover, the cross section A-A', and the other deep wells in the area

Geology of the Area

The study area is underlain by five geologic units: the crystalline basement complex of Precambrian age, the Middendorf (Tuscaloosa) and Black Creek formations of late Cretaceous age, the Black Mingo formation of Paleocene/Eocene age, and the shallow aquifer of Pleistocene (?) age (See figure 2).

The Precambrian rocks are probably composed of schist, gneiss and granite, similar to the rock units exposed in the Charlotte belt of the Piedmont province just to the northwest of Columbia, S. C. Overlying these crystalline rocks are the unconsolidated gray to white sands and white, brown, red and gray clays of the Middendorf (Tuscaloosa) formation. There may exist a zone of saprolite at the contact between the Middendorf (Tuscaloosa) sediments and the Precambrian rocks, but the information is inconclusive. The Black Creek formation overlies the Middendorf (Tuscaloosa), and is composed of dark gray sands and clays, some "pepper sand" and it can contain abundant fossilized wood fragments. Directly over the Black Creek lies the Black Mingo formation. These sediments strongly resemble the Middendorf (Tuscaloosa) in lithology and appearance but are of Paleocene or Eocene age. They contain yellow, brown, red, white and gray clays, interbedded with yellow, brown and white sands. No distinction has been made in this report between the shallow Pleistocene (?) formations and the Black Mingo formation. The lithologies appear to be quite similar and, without more intensive study, it would be impossible to differentiate between them. They have both been labelled "Black Mingo" for the purpose of this report.

The depth to bedrock was 640 feet at the Amoco test hole (SCWRC Well No. 26Q-ql), where "granite" was reported from 640 to 644 feet. This appears to be the only well on the cross section to have penetrated bedrock for certain. Several other wells have recorded "rock" or hard drilling as their final entry on the driller's log, but there is no indication as to the type of rock encountered.

The Middendorf (Tuscaloosa) formation here is about 300 feet thick and contains two aquifers which are recognizable on geophysical logs. The Black Creek formation is only 100 feet thick beneath the area and appears to be quite variable in character. The Black Mingo/Pleistocene deposits are about 250 feet thick and apparently contain a good aquifer, based upon geophysical data. This aquifer is becoming heavily developed farther to the south, near St. Matthews, where many irrigation systems are being installed with well-yields ranging from 300 to 750 gpm.

Hydrology of the Middendorf (Tuscaloosa) Aquifer System

In 1974, an aquifer test was conducted approximately three miles to the south of the proposed paper mill. The Hercules Corporation had drilled two wells (SCWRC no. 26R-cl, and 26R-c2) and had tested them on October 15 and 16 of that year, as part of their development of an industrial site. The test, conducted by Sydnor Hydrodynamics of Virginia, involved the pumping of well 26R-c2 at a rate of 2000 gallons per minute (gpm) for a period of just over one day, and measuring the water levels in the pumped well, and in the well (26R-cl) 1000 feet to the west. Both wells were screened throughout almost the entire thickness of the principal Middendorf (Tuscaloosa) aquifer. As far as is known, there were no problems encountered with the pump during the course of the test.

In all, five analytical graphical techniques were applied to the data, in order to determine the transmissivity(T) and storage coefficient(S) of the aquifer beneath the site. The results of the analyses are summarized in the table below. The diagrams that were constructed are contained in the Appendix.

Graphical Technique Used	Well Used	T	S
Log - Log Time-Drawdown	Pumped Well	66,400	-
	Obs. Well	67,400	1.28×10^{-4}
Log - Log Time-Recovery	Pumped Well	60,300	-
	Obs. Well	55,900	1.72×10^{-4}
Semi - Log Time-Drawdown	Pumped Well	78,200	-
	Obs. Well	70,400	1.17×10^{-4}
Semi - Log Time Recovery	Pumped Well	67,700	-
	Obs. Well	61,800	1.45×10^{-4}
Semi - Log Residual Drawdown	Pumped Well	63,600	-
	Obs. Well	62,100	-
	Mean	65,400	1.30×10^{-4}
	Median	65,000	1.36×10^{-4}

(techniques described in Ground Water and Wells, 1975, pp 108-144)

TABLE 1. Summary of Results of Graphical Techniques Used to Calculate the Transmissivity and Storage Coefficient.

Two aquifer-response models were selected to predict the drawdown effects of the proposed pumpage: the Theis non-leaky artesian model and the Hantush-Jacob leaky artesian model. Values of 65,000 gpd/ft and 1.3×10^{-4} were chosen for the transmissivity and storage coefficient, respectively. In addition to these two parameters, the Hantush-Jacob equations require values for the thickness (b') and vertical hydraulic conductivity (K') of the clays overlying the aquifer, in order to determine the amount of leakage occurring. On figure 2, the two clay layers separating the principal Middendorf (Tuscaloosa) aquifer from the Black Creek aquifer were measured, and found to be approximately 60 feet thick. The vertical permeability of these clays was not determined. However, published values for similar materials (Freeze and Cherry, 1979, p. 29) indicate the value to be within the range of 2×10^{-2} to 8×10^{-5} gallons per day per square foot.

The 3 tables below show the results of three sets of calculations based upon: (A) the Theis non-leaky model; (B) the Hantush-Jacob leaky model with a vertical hydraulic conductivity (K') of 0.001 gpd/ft^2; and (C) the Hantush-Jacob model with a vertical hydraulic conductivity of 0.005 gpd/ft^2.

Table 2.A. THEIS SOLUTION

Distance (r) (in feet)	W(u)	Drawdown (in feet)	
2,000	9.53	34.99	
5,000	7.69	28.26	
15,000	5.50	20.19	Q=3 Mgd
40,000	3.55	13.04	T=65,000 gpd/ft
100,000	1.82	6.69	$S=1.3 \times 10^{-4}$
200,000	0.701	2.57	t=365 days
300,000	0.250	0.92	
400,000	0.0817	0.30	
500,000	0.0230	0.09	

Table 2.B. HANTUSH-JACOB SOLUTION

Distance (r) (in feet)	r/B	W(u,r/B)	Drawdown (s) (in feet)	
250	0.004	11.2748	41.41	
937	0.015	8.6319	31.70	
4996	0.080	5.2950	19.45	Q=3 Mgd
15612	0.25	3.0830	11.32	T=65,000 gpd/ft
24980	0.40	2.2291	8.19	$S=1.3 \times 10^{-4}$
40592	0.65	1.4317	5.26	K'=0.001 gpd/ft^2
59327	0.95	0.9049	3.32	b'=60 feet
93675	1.5	0.4276	1.57	
124900	2.00	0.2278	0.84	
156125	2.50	0.1247	0.46	

Table 2.C. HANTUSH-JACOB SOLUTION

Distance (r) (in feet)	r/B	W(u,r/B)	Drawdown (s) (in feet)	
112	0.004	11.2748	41.41	
420	0.015	8.6319	31.70	
977	0.035	6.9394	25.48	Q=3 Mgd
4190	0.15	4.0601	14.91	T=65,000 gpd/ft
9775	0.35	2.4654	9.05	$S=1.3 \times 10^{-4}$
19550	0.70	1.3210	4.85	K'=0.005 gpd/ft^2
41890	1.50	0.4276	1.57	b'=60 feet
69820	2.50	0.1247	0.46	
97750	3.50	0.0392	0.14	

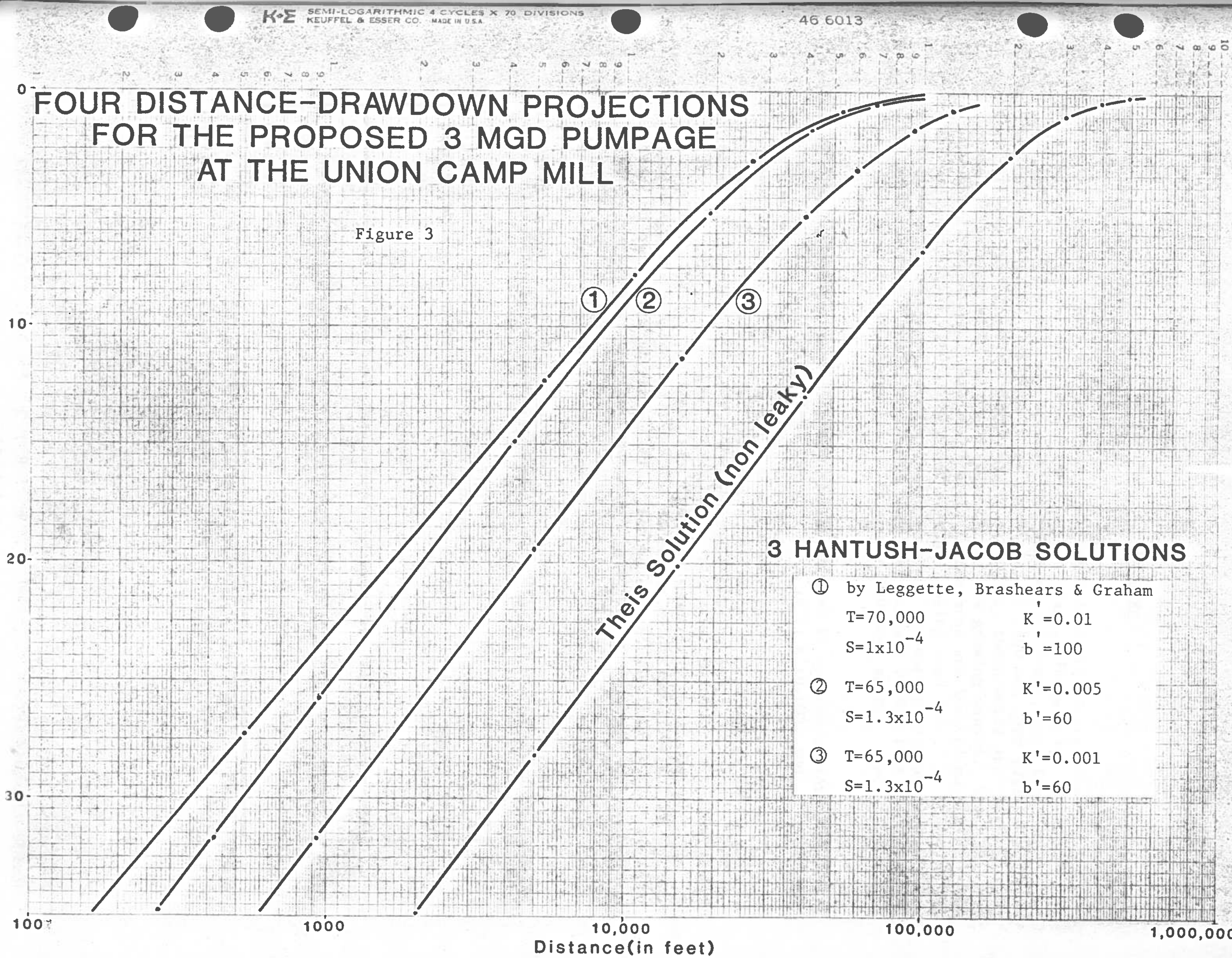
The preliminary consulting report by Leggette, Brashears, and Graham (Crum, 1979) used the Hantush-Jacob model with values for the aquifer and confining-bed characteristics which were different from those used in this report. In addition, the discharge rate was assumed to be 10 Mgd. For the purposes of comparison with Tables 2A, B and C, the drawdowns reported by Crum (1979) have herein been reduced in Table 2D to reflect a pumpage of 3 Mgd.

Table 2.D. HANTUSH-JACOB SOLUTION

Distance (r) (in feet)	Drawdown (s) (in feet)	Q=3 Mgd
5,280 (1 mi)	12.3	T=70,000 gpd/ft
10,560 (2 mi)	7.8	$S=1 \times 10^{-4}$
26,400 (5 mi)	3.0	$K'=0.01$ gpd/ft^2
52,800 (10 mi)	0.9	b'=100 feet

(modified from Crum, 1979)

The four distance-drawdown graphs, plotted from the data in Tables 2A, B, C and D are compared in figure 3.


K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 6013
FOUR DISTANCE-DRAWDOWN PROJECTIONS
FOR THE PROPOSED 3 MGD PUMPAGE
AT THE UNION CAMP MILL
Figure 3
①
②
③
Theis Solution (non leaky)
3 HANTUSH-JACOB SOLUTIONS
① by Leggette, Brashears & Graham
T=70,000
K'=0.01
S=1x10-4
b'=100
② T=65,000
K'=0.005
S=1.3x10-4
b'=60
③ T=65,000
K'=0.001
S=1.3x10-4
b'=60
0
10
20
30
100
1000
10,000
100,000
1,000,000
Distance(in feet)

Impact of the Proposed Pumpage

At present, there are only two producing Middendorf (Tuscaloosa) wells located in the vicinity of the proposed plant. These wells (SCWRC no. 26R-dl and 27Q-ul) have been drilled at Godspeed Farms, Inc. for irrigation purposes, and have rated capacities of 2500 and 2000 gallons per minute, respectively. According to the owner, these wells are pumped an average of 90 days each year during the growing season. The only other Middendorf (Tuscaloosa) wells in the area are located on the Hercules industrial site and are not presently being used for ground-water production. The distances from the proposed plant location to the two Godspeed wells are 24,000 feet (26R-dl) and 20,000 feet (27Q-ul), and the two irrigation wells are 16,500 feet apart. (See figure 1.)

The aquifer and confining-bed parameters used to construct plot number 3 on figure 3 (i.e., T=65,000; S= 1.3×10^{-4}; K'=0.001; and b'=60) have been used to construct distance-drawdown graphs for the two Godspeed Farms wells (figure 4). These parameters were selected because they gave a conservative, yet reasonable, estimate of the leakage to the Middendorf (Tuscaloosa) aquifer through the overlying clays.

The table below, compiled from figure 4, summarizes the mutual effect which the proposed well and the two existing Godspeed wells will produce on each other at the end of a growing season, when the irrigation wells will have been pumped for at least 90 days and the Union Camp well will have been pumping for about one year. The right-hand column reflects the expected increased drawdown experienced by each well when both of the other wells are being pumped. The three central columns reflect the expected increased drawdowns at each well when only the indicated well is pumping.

DRAWDOWN EXPERIENCED AT	INDIVIDUAL WELL BEING PUMPED TO PRODUCE THE INDICATED DRAWDOWN			COMBINED DRAWDOWN WITH BOTH OTHER WELLS PUMPING
	Union Camp	Godspeed No. 1.	Godspeed No. 2.	
Union Camp	---	9.5	9.0	18.5
Godspeed No.1.	8.5	---	10.0	18.5
Godspeed No.2.	9.5	13.0	---	22.5

Table 3. Summary of Well Interferences (in feet), between the Three Middendorf (Tuscaloosa) Wells.

Summary and Conclusions

There are five geologic formations beneath the proposed Union Camp mill site: the Precambrian crystalline bedrock complex, the late Cretaceous Middendorf (Tuscaloosa) and Black Creek formations, the Paleocene/Eocene Black Mingo formation, and the undifferentiated Pleistocene(?) deposits. The aquifers within the Middendorf (Tuscaloosa) formation appear to be the major water-producing zones beneath the site. An aquifer test 3 miles to the south has demonstrated that the principal aquifer of the Middendorf (Tuscaloosa) formation has a transmissivity and storage coefficient of 65,000 gpd/ft and 1.3×10^{-4}, respectively.

The only two production wells known to tap the Middendorf (Tuscaloosa) aquifer in the area are 24,000 feet to the south and 20,000 feet to the southwest of the proposed mill structures. They supply irrigation water to Godspeed Farms, Inc. and are rated to produce 2000 and 2500 gpm. The only other Middendorf (Tuscaloosa) wells known to exist in the area are on the Hercules industrial site and are not presently being used.

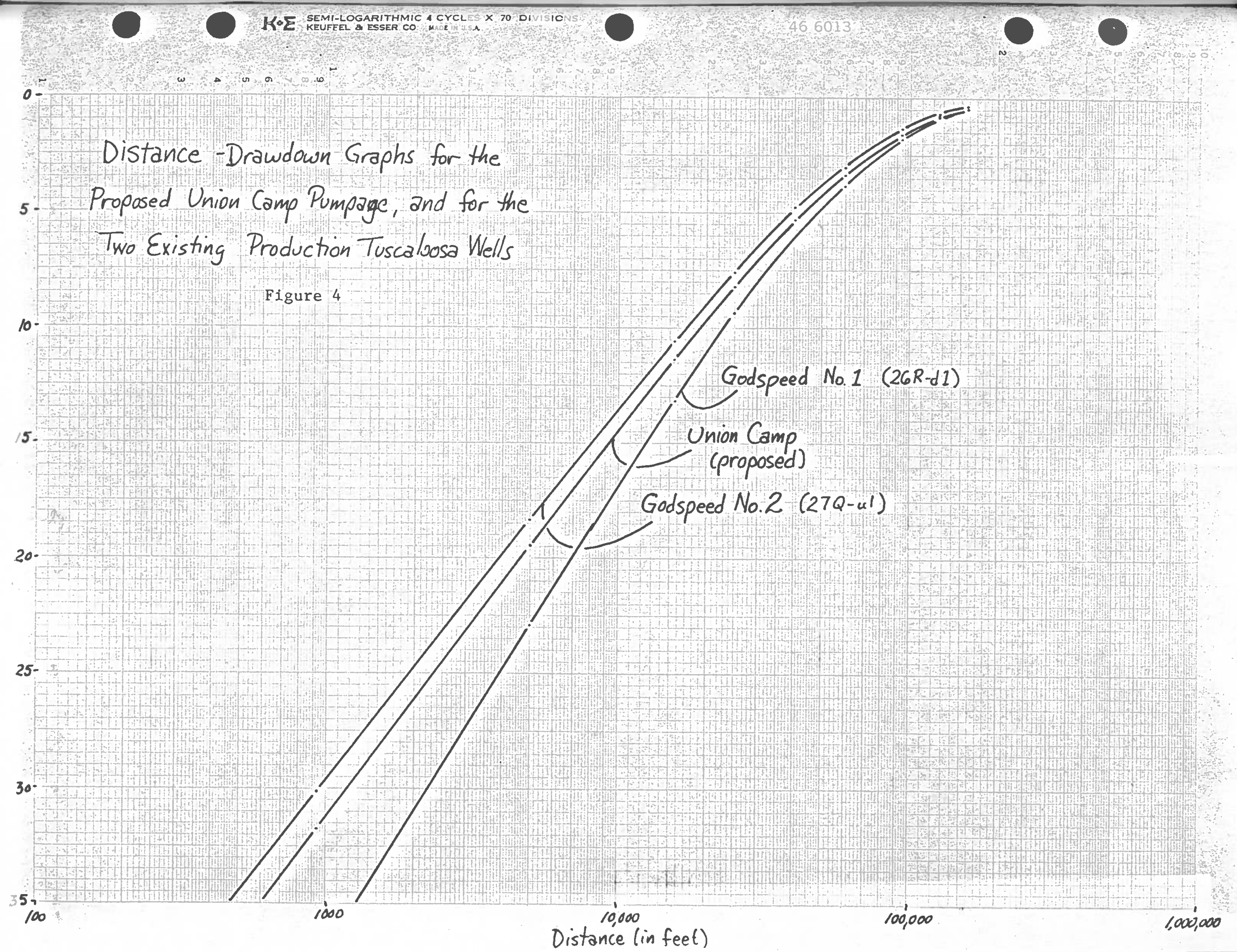
There are numerous wells, including wells for the Town of Eastover, which tap the Black Creek and Black Mingo aquifers. These generally supply water to private domestic water users.

The effect of the proposed Union Camp pumpage on the water levels in the Middendorf (Tuscaloosa) aquifer system has been calculated using the Hantush-Jacob leaky artesian model for aquifer response. The parameters used in the calculations were 65,000 gpd/ft for the transmissivity and 1.3×10^{-4} for the storage coefficient of the aquifer, and 0.001 gpd/ft^2 for the vertical hydraulic conductivity and 60 feet for the thickness of the confining beds. With these values, a single well, pumping 3 Mgd at the proposed site would lower the water level in the Middendorf (Tuscaloosa) aquifer system by approximately 20 feet at the northern plant boundary, 13 feet at the southern boundary, and approximately 10 feet at the Town of Eastover. The two Godspeed Farms wells would experience approximately 8.5 feet (26R-d1) and 9.5 feet (27Q-u1) of drawdown due solely to the pumpage of the proposed well. The drawdown effects within the Black Creek and Black Mingo aquifers, which overly the Middendorf (Tuscaloosa) are expected to be minor, but the impact cannot be estimated with the available data.

In conclusion, based upon the data available for this report, it appears that the impact on the existing ground-water users of the proposed 3 Mgd pumpage at the new Union Camp paper mill will be minor. The two existing irrigation wells tapping the Middendorf (Tuscaloosa) aquifer system will experience probably less than 10 feet of additional drawdown as a result of the new pumpage. The effects in the wells tapping the overlying Black Creek and Black Mingo aquifers are also expected to be minor, but no quantification of those effects can be given, due to an absence of the appropriate data.

The Town of Eastover is 18,000 feet west of the proposed mill, and 12,000 feet northwest of the closest Godspeed well. The town operates several wells completed in the Black Creek or Black Mingo aquifer systems. Although it is possible that pumpage from the Middendorf (Tuscaloosa) system would affect these aquifers, especially during the growing season, the effects at the town would probably be very minor. At present, however, there are no data to indicate the magnitude of any effect in the Black Creek or Black Mingo aquifers caused by pumpage from the Middendorf (Tuscaloosa) aquifer.

There are numerous wells in the vicinity of the Union Camp site used for private domestic purposes, which are completed in the Black Creek/Black Mingo aquifers. These wells would also probably experience only minor effect from the Union Camp pumpage.

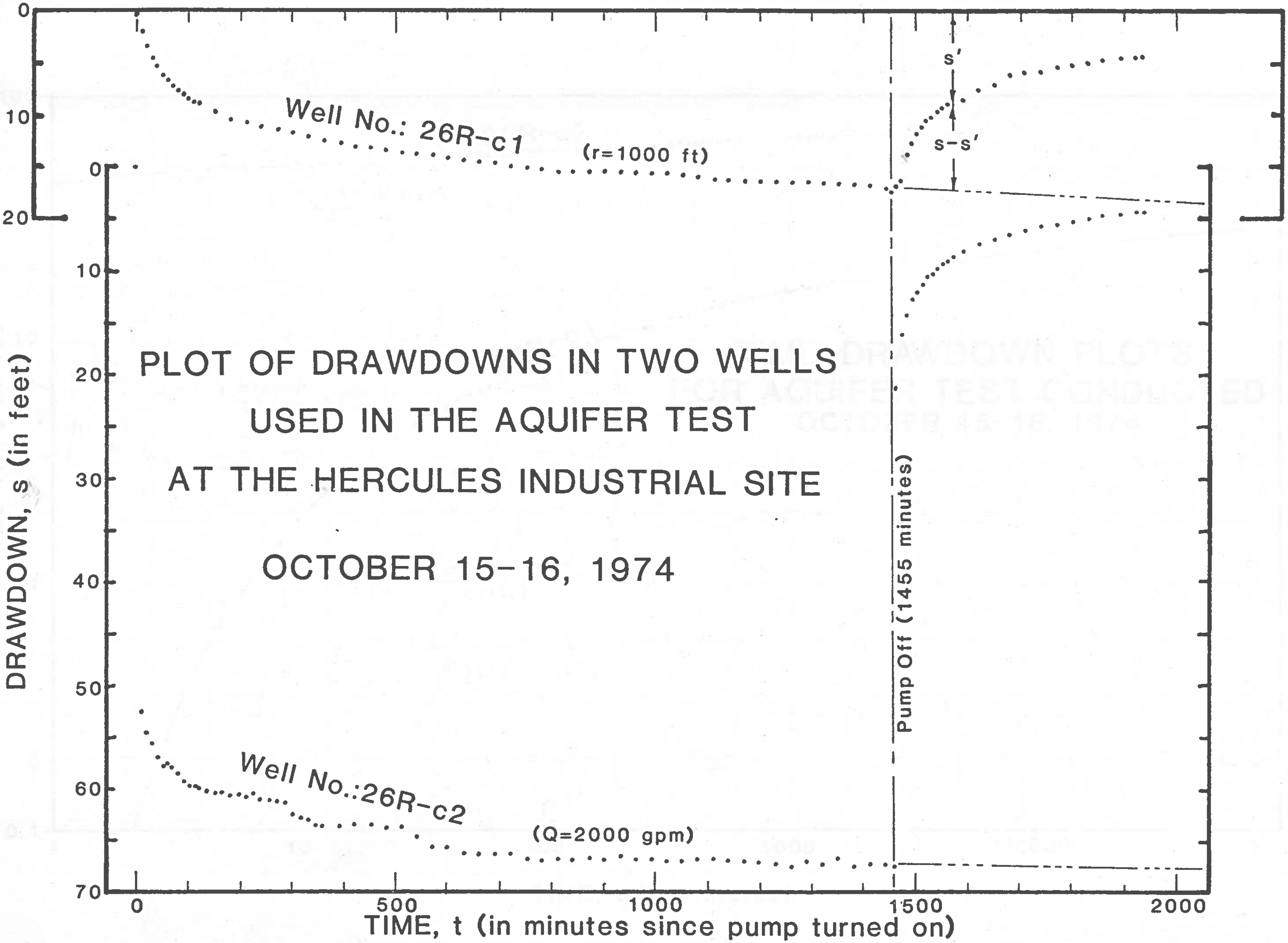


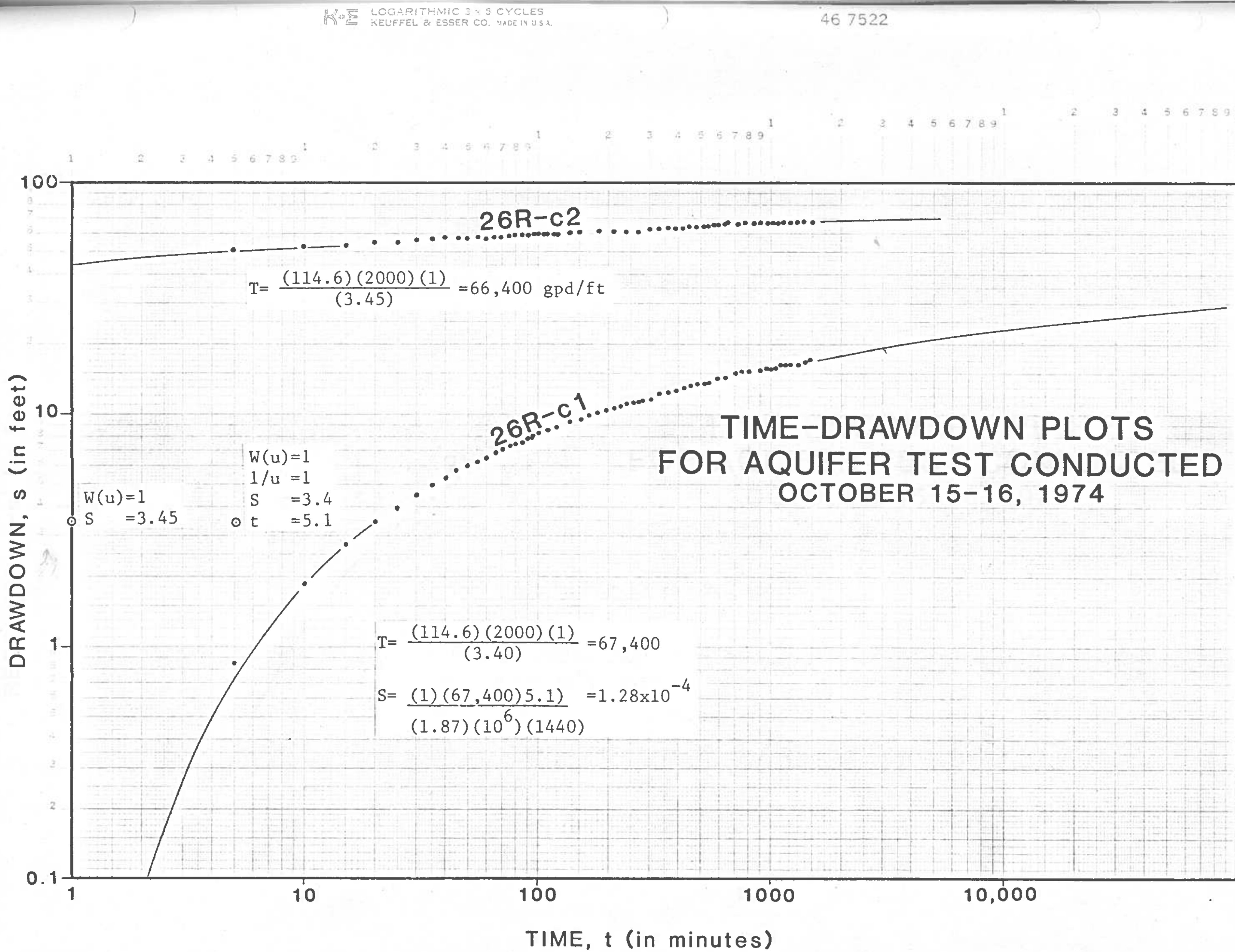
Distance-Drawdown Graphs for the Proposed Union Camp Pumpage, and for the Two Existing Production Tuscaloosa Wells

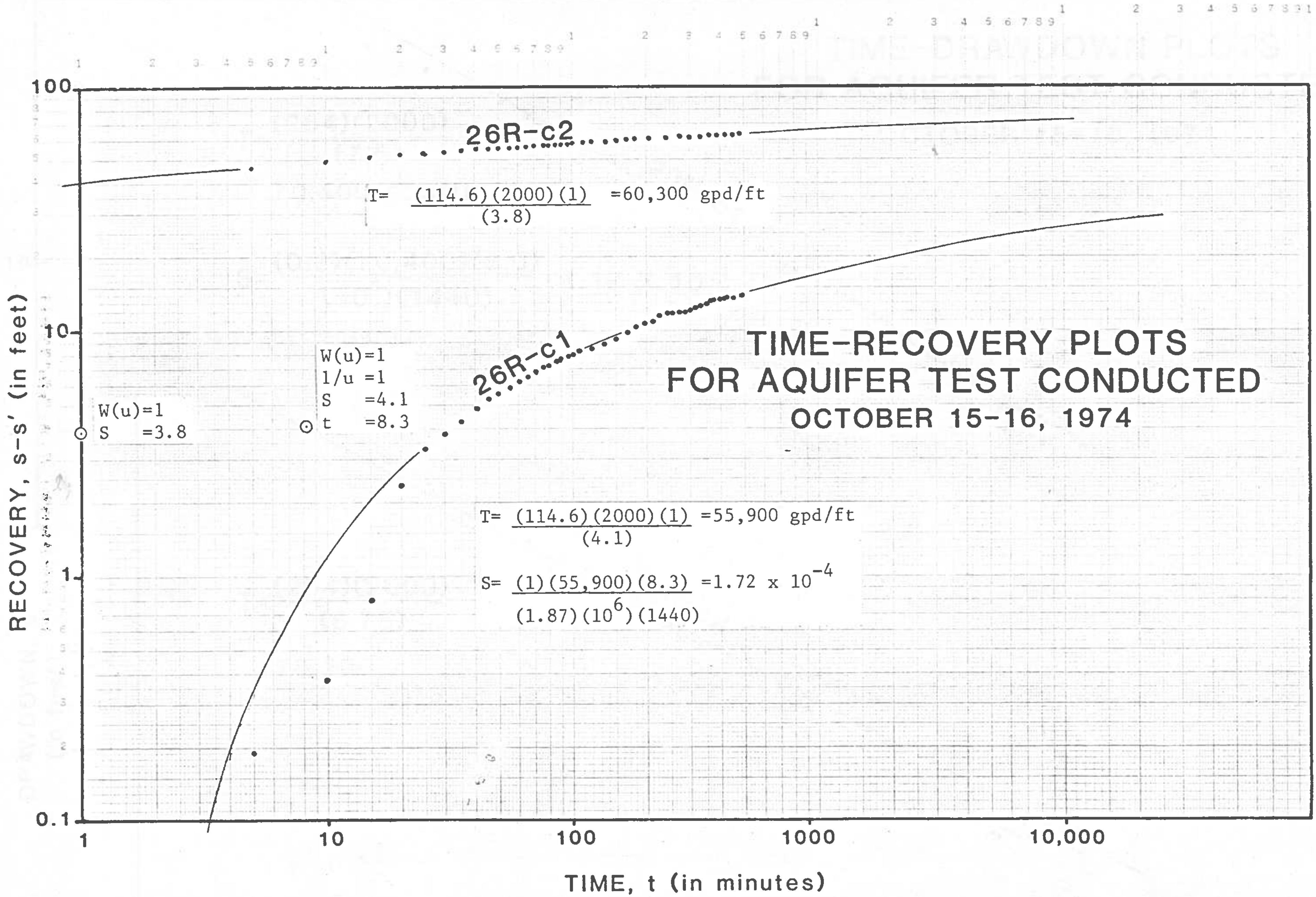
Figure 4

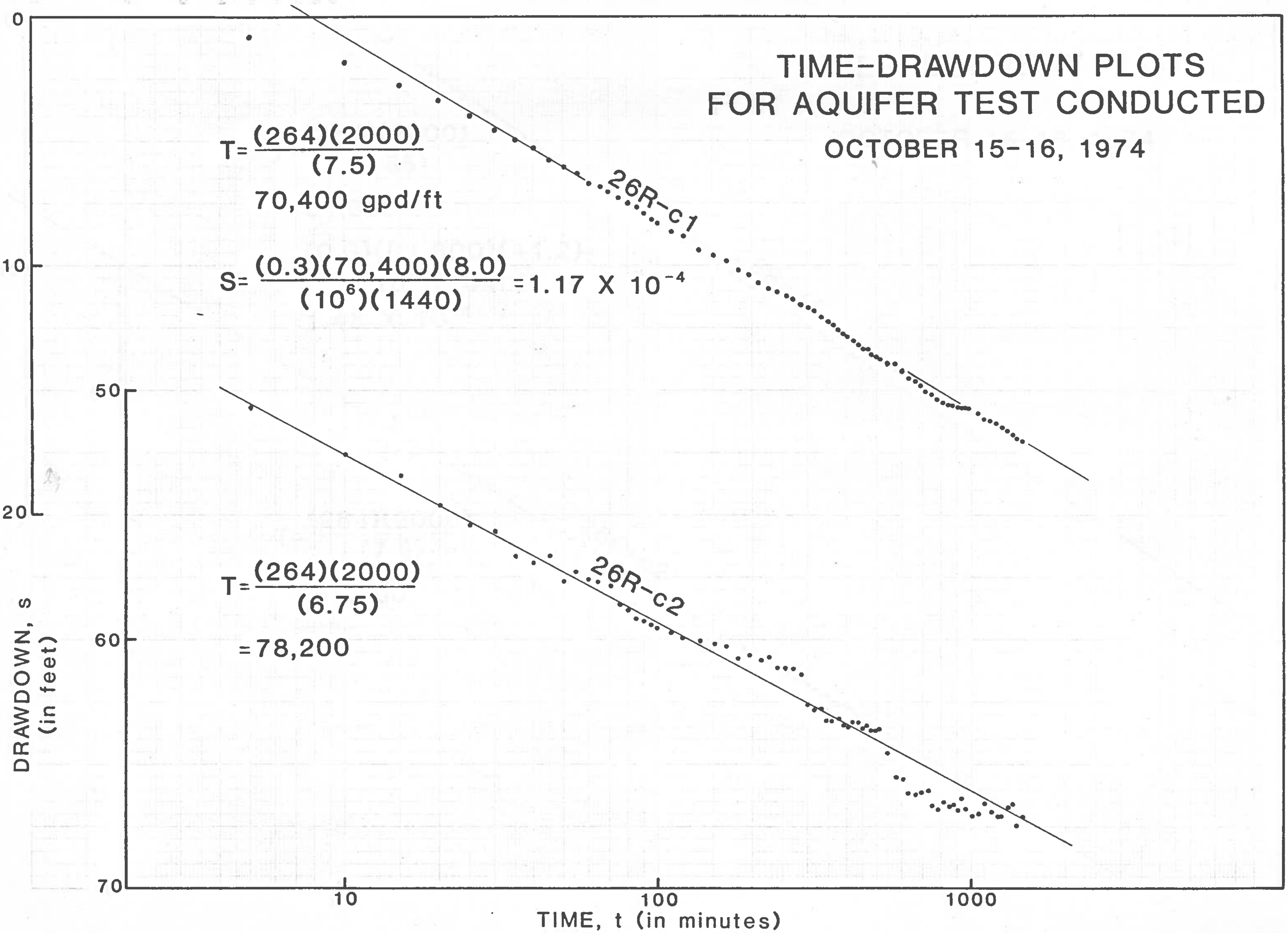
APPENDIX

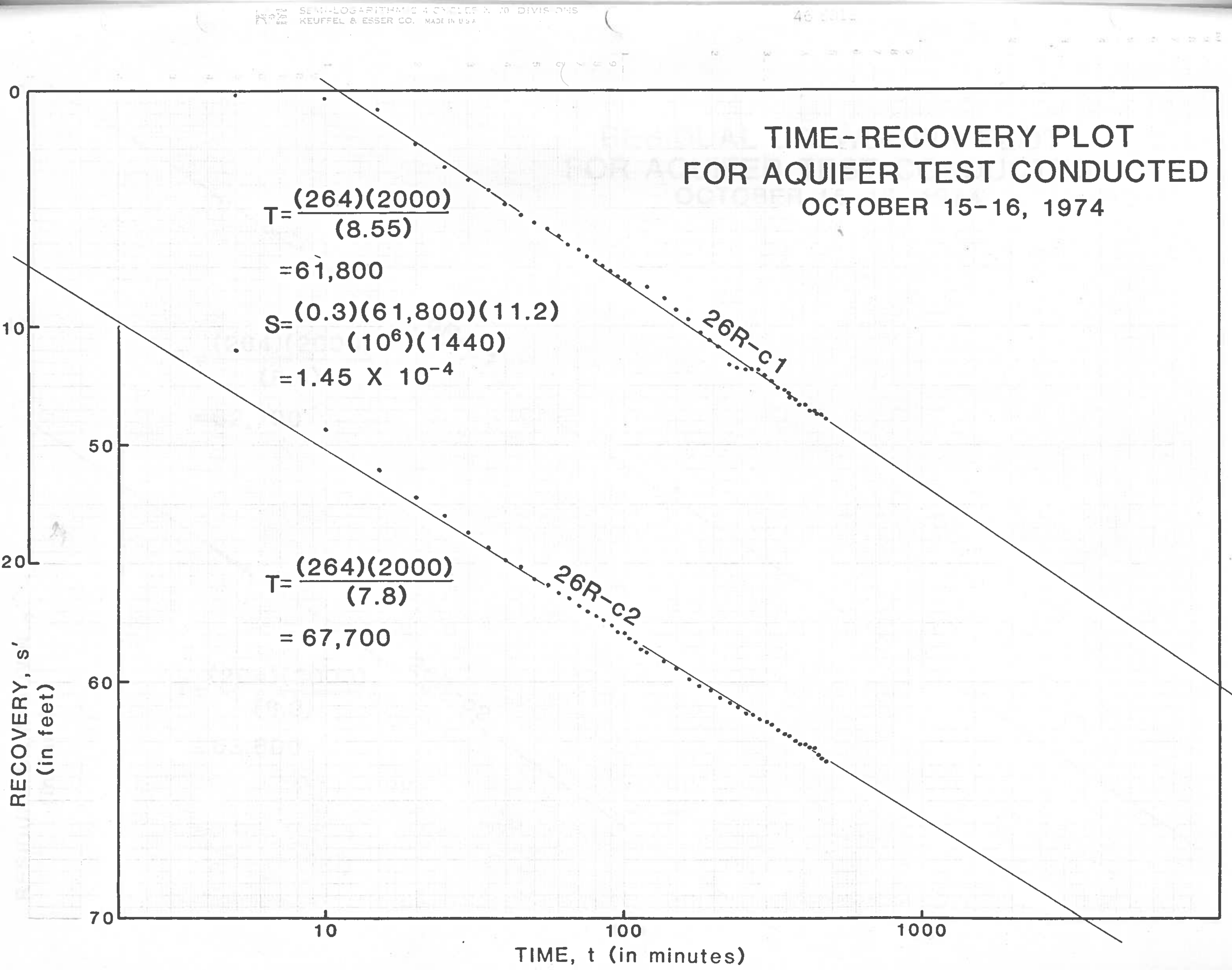
Plots used to evaluate the aquifer test conducted at the Hercules industrial site on October 15-16, 1974.

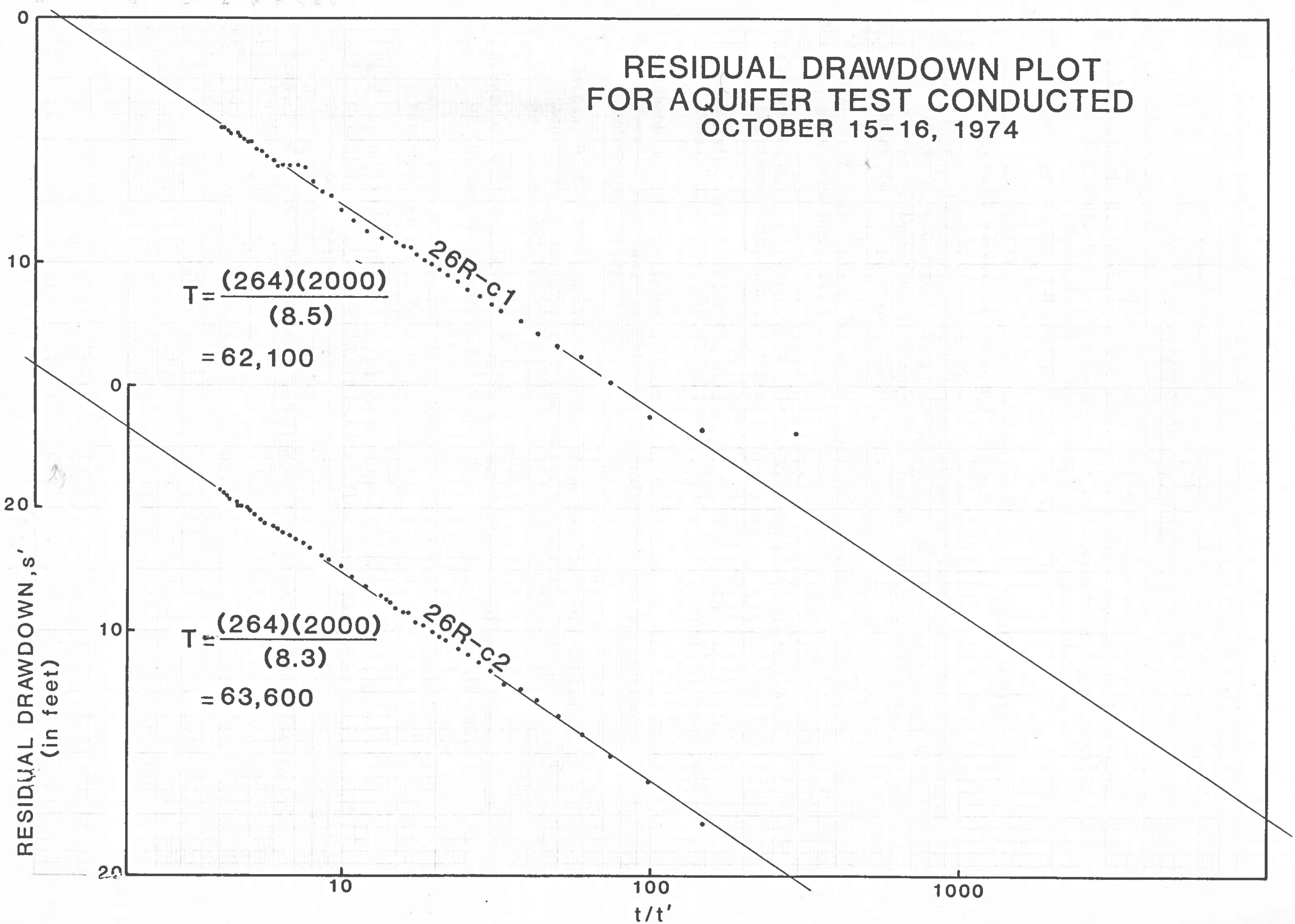

PLOT OF DRAWDOWNS IN TWO WELLS
USED IN THE AQUIFER TEST
AT THE HERCULES INDUSTRIAL SITE
OCTOBER 15-16, 1974
Well No.: 26R-c1
(r=1000 ft)
Well No.:26R-c2
(Q=2000 gpm)
s'
s-s'
Pump Off (1455 minutes)
DRAWDOWN, s (in feet)
TIME, t (in minutes since pump turned on)
0
10
20
0
10
20
30
40
50
60
70
0
500
1000
1500
2000


K+E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 7522
26R-c2
T= (114.6)(2000)(1) / (3.45) =66,400 gpd/ft
26R-c1
TIME-DRAWDOWN PLOTS
FOR AQUIFER TEST CONDUCTED
OCTOBER 15-16, 1974
W(u)=1
S =3.45
W(u)=1
1/u =1
S =3.4
t =5.1
T= (114.6)(2000)(1) / (3.40) =67,400
S= (1)(67,400)5.1) / (1.87)(10^6)(1440) =1.28x10^-4
DRAWDOWN, s (in feet)
TIME, t (in minutes)
100
10
1
0.1
1
10
100
1000
10,000


TIME-RECOVERY PLOTS
FOR AQUIFER TEST CONDUCTED
OCTOBER 15-16, 1974
26R-c2
26R-c1
T= (114.6)(2000)(1) / (3.8) =60,300 gpd/ft
W(u)=1
S =3.8
W(u)=1
1/u =1
S =4.1
t =8.3
T= (114.6)(2000)(1) / (4.1) =55,900 gpd/ft
S= (1)(55,900)(8.3) / (1.87)(10^6)(1440) =1.72 x 10^-4
RECOVERY, s-s' (in feet)
TIME, t (in minutes)
100
10
1
0.1
1
10
100
1000
10,000


TIME-DRAWDOWN PLOTS
FOR AQUIFER TEST CONDUCTED
OCTOBER 15-16, 1974
T= (264)(2000) / (7.5)
70,400 gpd/ft
S= (0.3)(70,400)(8.0) / (10^6)(1440) =1.17 X 10^-4
26R-c1
T= (264)(2000) / (6.75)
=78,200
26R-c2
0
10
20
50
60
70
DRAWDOWN, s
(in feet)
10
100
1000
TIME, t (in minutes)


TIME-RECOVERY PLOT
FOR AQUIFER TEST CONDUCTED
OCTOBER 15-16, 1974
T= (264)(2000) / (8.55)
=61,800
S= (0.3)(61,800)(11.2) / (10^6)(1440)
=1.45 X 10^-4
26R-c1
T= (264)(2000) / (7.8)
= 67,700
26R-c2
RECOVERY, s' (in feet)
TIME, t (in minutes)
0
10
20
50
60
70
10
100
1000
SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.



RESIDUAL DRAWDOWN PLOT
FOR AQUIFER TEST CONDUCTED
OCTOBER 15-16, 1974
26R-c1
T = (264)(2000) / (8.5)
= 62,100
26R-c2
T = (264)(2000) / (8.3)
= 63,600
0
10
20
0
10
20
10
100
1000
t/t'
RESIDUAL DRAWDOWN, s' (in feet)

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HYDROGEOLOGIC CROSS SECTION NEAR THE UNION CAMP SITE

Figure 2