RESULTS OF TESTS ON WELLS AT WACO, TEXAS

By

W. O. George and B. A. Barnes

Prepared in cooperation between the Geological Survey, U. S. Department of the Interior, and the Texas State Board of Water Engineers

August 1945

Reprinted December 1952

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INTRODUCTION

The investigation in the Waco area was made in connection with problems of water supplies for war purposes but the results are significant for the entire area. Three pumping tests were made, involving the well of the General Tire and Rubber Company, the well of the Missouri-Kansas-Texas R.R., and the wells of the City of Waco at the filtration plant. (For location of wells, see fig. 1.)

The investigation was conducted by the Geological Survey, U. S. Department of the Interior, in cooperation with the Texas State Board of Water Engineers, and was under the general direction of W. N. White, Principal Engineer in the Geological Survey, who is in charge of the ground-water investigations in Texas.

Acknowledgments

The writers wish to express their appreciation to Hubert Davis, Acting Superintendent of the Waco Water Department, and J. C. Allison, Filter Plant Superintendent, both of whom helped materially in conducting the pumping test at the Waco municipal wells; to Messrs. Quick, Payne, Ellison and Evans of the Missouri-Kansas-Texas R.R. who were especially helpful in making the necessary well adjustments and observing the fluctuations of pressure in the railroad well during the pumping of the General Tire and Rubber Company well; to H. T. Rochford of Giffels and Valley, Inc., and officials and employees of the General Tire and Rubber Company; to M. T. Rowland of the Layne-Texas Company, and Mr. Hynds of the Texas Power and Light Company.

Present use of well water in the Waco area

The municipal supply of Waco was formerly obtained from deep wells drawing water from sands of the Travis Peak formation, the basal member of the Trinity group. In 1930, upon the completion of a reservoir on Bosque River, the City changed to surface water for its general supply. However, it is still using deep wells to furnish water for the boilers at the filtration plant and for ornamental use in the park system. Other users of ground water from wells in basal sands of the Trinity include the Texas Water Company, which furnishes the public supply of a subdivision of Waco, the M-K-T-R.R., the Texas Public Service Company, and two office buildings.

The estimated average daily consumption of ground water by these different agencies is given below:

Table 1

Estimated withdrawals of ground water from basal Trinity sands at Waco, Texas

Well	Use of well water	Estimated consumption in gallons per day
City of Waco	Boiler feed and ornamental	300,000
Missouri-Kansas-Texas R.R.	Railroad	200,000
Texas Water Company	Public	500,000
Texas Public Service Co.	Power plant	200,000
Other industrial wells	Office buildings, laundries, ice plants, etc.	300,000
	TOTAL	1,500,000

Pumping tests

Two interference tests and one recovery test were conducted during the investigation from March 19 to 24, inclusive.

Since the pressure head in all of the wells involved in the tests was above the level of the ground all recovery and drawdown measurements were obtained by using pressure gages. These gages were equipped with dials calibrated at half-pound intervals from 0 to 15 pounds, and from them changes in pressures were estimated within one-tenth of a pound. The gages were tested on a dead-weight tester before, during, and after the pumping test.

Test No. 1, an interference test, was made on the two wells at the municipal infiltration plant by opening the check valve on the east well and permitting it to flow at a measured rate while the resulting changes in pressure were recorded in the second well about 435 feet to the west. In this test the discharge of the flowing well was computed by periodic measurements in an ornamental concrete tank.

In test 2, an interference test, there was recorded the decline in pressure in the Missouri-Kansas-Texas R.R. well caused by pumping the General Tire and Rubber Company well, approximately 4,400 feet distant.

In test 3, a recovery test, the well at the General Tire Plant was turned on and pumped for 45 hours while the yield of the well was recorded from hourly readings of a Layne orifice meter. Then the pump was shut-down and the amount and recovery of pressure in the well was observed for 48 hours. As the well began to flow in approximately four hours after it was shut-down, and in order to obtain accurate tape line measurements over a long recovery period a section of 3/4-inch pipe approximately 24 feet long was run from the shut-in well up the side of one of the cooling towers. The additional recovery;

above this 24-feet, was measured with a combination vacuum-pressure gage (0-15 pounds.)

Specific capacity

The specific capacity of a well is the yield-drawdown ratio or, as generally expressed, the number of gallons a minute that a well will yield for each foot of drawdown. In these computations the average yield for the first 24-hours of pumping divided by the drawdown occurring at the end of 24-hours were the values used to compute the specific capacity of the General Tire and Rubber Company well, and the east well at the City filtration plant. As shown in table 2, these specific capacities are 2.1 gpm per ft. and 3.7 gpm per ft., respectively.

Hydrologic characteristics computed from pumping tests

From the results of the tests values of "transmissibility" and "storage coefficients" were computed by the Theis formula. These coefficients are a measure of the ability of the aquifer to transmit and to store water, and in combination with the length of time of pumping, distance from pumped well, and the rate of pumping, they are the factors that determine the amount and rate of drawdown of the water levels caused by pumping from wells.

The "transmissibility" is defined as the volume of water that will flow in unit time through a vertical strip of the aquifer of unit width under unit hydraulic gradient. It may be measured in gallons per day per foot.

The coefficient of storage, or "storage coefficient", is the volume of water released from storage in a vertical prism of the aquifer of unit cross-section by a unit decline of head.

The formula 1/ for the drawdown produced by a well pumping at a steady rate from an infinite aquifer is

$$s = \frac{114.6\,Q}{T} \int_{\frac{1.87\,r^2 S}{Tt}}^{\infty} \frac{e^{-u}\,du}{u}$$

in which s is the drawdown, in feet, at any point a distance r, in feet, from the discharging well; Q is the discharge of the well, in gallons per minute; T is the transmissibility of the aquifer in gpd per foot; S is the coefficient of storage; and t is the time that the well has been pumped, in days.

The formula assumes that the aquifer has an infinite areal extent; that it is homogeneous and isotropic; that it is bounded by impermeable beds both above and below; and that the water is released from storage instantaneously with the decline in head.

Table 2 gives the coefficients of transmissibility and storage computed from the tests.

1/ Theis, C. V., American Geophysical Union, 1935. Opus. cit.

Table 2

Transmissibilities and storage coefficients computed from interference and recovery tests in the Waco, Texas area

Well used in test	Date of test	Pumped well	Observation well (idle)	Trans-missi-bility (gpd/ft)	Coeffi-cient of storage	Specific capacity (gpm/ft.)
Test 1						
City of Waco wells at filtration plant	Mar. 21 to Mar. 22, 1945	East well on	West well off	6,540	.000062	3.7
Test 2						
Wells of General Tire Co., and R.R.	Mar. 22 to Mar. 24, 1945	General Tire Co. well on	Missouri-Kansas-Texas R.R.	11,370	.00012	
Test 3						
General Tire and Rubber Co.well	Mar. 22, to Mar. 26, 1945	General Tire Co. well	General Tire off after pumping 45 hours.	4,480	--	2.1

As seen by the table, the transmissibility computed from the interference test on the wells at the city filtration plant (test 1), and that computed from the recovery test on the General Tire and Rubber Company well 1 (test 3), are not greatly different. But the transmissibility computed from test 2 (when using the M-K-T R.R. well for observation while pumping the General Tire and Rubber Company well) is approximately twice the average of the other two values. While this variation is large, it is not surprising in view of the fact that the Travis Peak formation varies materially in thickness and character from place to place and within short distances. Comparable variations were obtained in similar tests in Travis Peak wells at Camp Hood, and North Camp Hood, respectively 45 and 35 miles, an air line distance from Waco. Predictions of declines in water levels based on the tests at Camp Hood have proved to be only fairly accurate. After one year of pumping some of the predictions proved to be about 10 percent too high and others about 10 percent too low.

Theoretical decline in infinite aquifer

The curves in figures 2 and 3 were computed from two sets of values of the transmissibility and the storage coefficient and show the computed decline (drawdown) in water levels at the end of different periods of time at various distances from a well produced by pumping the well at the rate of 1,000 gallons a minute. The artesian aquifer is assumed to be ideal. The decline at any point is directly proportional to the rate of pumping. Therefore, to compute the decline produced by pumping 750 gallons a minute the decline indicated in the diagram should be multiplied by 0.75.

The curve in figure 2 is based on the average of the low values of transmissibility, 5,600 gpd per ft., computed from tests 1 and 3, and on the storage coefficient 0.000062 obtained from test 1. The curve in figure 3, is based on the high values of transmissibility and storage coefficient, 11,300 gpd per ft., and 0.00012, respectively, computed from test 2.

Table 3 gives the computed pumping levels after pumping continuously from one well for periods ranging from 3 months to 20 years, at the rate of 1,000 (gpm).

Table 4 gives the computed pumping levels, at the end of various periods of continuous pumping from wells 1 and 2 at the rate of 1,000 gpm each (2,000 gpm together).

Geologic factors and boundaries

The Travis Peak formation is composed of sands and gravels, sandy clay, and some limestone. The sands are lenticular and vary considerably in thickness and character. The formation is the lowest of the Trinity group and is at the base of the Cretaceous system. It lies unconformably upon an eroded surface of rocks of Carboniferous age.

The main body of the Travis Peak sand can be recognized both in drillers' logs and in electric logs but the exact position of the top of the formation can not be determined because of the occurrence of sands in the lower part of the overlying Glen Rose formation. These have been cased off in the General Tire and Rubber Company's well, but may contribute a small part of the water obtained from the M-K-T well, and to the city wells at the filtration plant.

The curves in figures 2 and 3 show the computed drawdown that will occur in an ideal aquifer, that is, one that is effectively infinite in extent, homogeneous and isotropic. Since this condition is seldom found in nature the lateral boundaries of the aquifer and their characteristics ordinarily must be determined. These boundaries can be structural such as faulting and folding; depositional such as the lensing out of a sand; or the cropping out of the aquifer at the surface. As the boundaries of an aquifer are within infinite distances they will eventually effect the amount and rate of decline of the water level caused by pumping from wells.

The nearer the boundary the sooner its effect will be felt at the wells and the greater will be the amount of the effect. Boundaries such as faults of large throw may retard the movement of ground water and thereby increase the rate of decline, while recharge at the outcrop tends to reduce the rate of decline.

It is believed that no faults exist in the Waco area of sufficient throw to retard the movement of the ground water. The nearest outcrop of the Travis Peak sands is about 75 miles west of Waco in Comanche County, a distance so great that the drawdown in the Waco area during the periods considered will be practically unaffected by the outcrop. Therefore, the figures given in the tables do not require modification to take care of effect of geologic structure or recharge at the outcrop.

Past and present decline or recovery in water levels in wells at Waco

No accurate information regarding water levels in wells in former years is available for comparison. It is known that the reduction in ground water withdrawals as a result of the abandonment of the municipal ground-water supply by the City of Waco about 1930 caused a general recovery of water levels. They may have continued until two or three years ago when an increase occurred in ground water withdrawals due to the war. Withdrawals of approximately 875,000 gallons per day for Army training fields in the Waco vicinity made up the largest known single increase in the area. However, the M-K-T- R.R., and the few industrial wells in the City (laundries, ice plants, etc.) have all increased their pumpage due to the war activities during the past several years. All reports indicate that this increase has caused some decline in the artesian pressure; therefore, it appears that at the present time the water levels in the Waco area have a downward trend. There is not sufficient data available to determine the amount of recovery after 1930 nor the rate of the present decline.

Quality of water

Table 5 gives the analyses of water from several of the wells that are believed to obtain water, either partly or entirely from the basal sands of the Trinity division of the Cretaceous.

Summary and conclusions

The main purpose of the Waco investigation was to obtain information from which to estimate future declines in artesian pressure and pumping levels in wells to be expected as a result of different rates of pumping at the General Tire and Rubber Company plant. Three sets of tests were made by the interference and recovery methods and from the results of those tests values of the transmissibility and storage coefficients were computed. The figures thus obtained vary greatly in magnitude for the three tests, but are typical of the coefficients obtained from pumping tests on other wells in this general region that draw from the highly variable basal sands of the Trinity group. The coefficients of transmissibility and storage may be used to compute future drawdown in water levels for considerable distances around a pumped well if geologic conditions are favorable. Usually the average of the coefficients obtained from several tests are used in such computations. In this case due to the rapidly changing hydrologic characteristics of the Travis Peak sands in the area it has been deemed advisable to use two sets of coefficients, one set with the larger coefficients obtained from test 2, and the other set with the smaller coefficients obtained from tests 1 and 3. It is assumed that the computed drawdowns based on the use of the first set (fig. 3) will be smallest that are likely to occur and those computed from the second set (fig. 2) will be the largest. In tables 3 and 4 the computed figures are given in separate columns under the headings minimum and maximum.

Some of the significant figures reached in these computations are as follows: If well 1 at the Tire Plant is pumped continuously at a rate between 600 and 800 gallons a minute the pump bowls in the well will have to be lowered. If a second well is put down, and each well is pumped at the rate of 1,000 gallons a minute representing a total draft of 2,000 gallons a minute, it is computed the pumping level in both wells at the end of three months will be between 552 and 679 feet below the surface if the wells are 1,000 feet apart, and between 524 and 622 feet if they are 4,000 feet apart. If the average rate of pumping from each well is 800 gallons a minute the pumping levels at the end of 3 months would be between 441 and 543 feet with spacing of 1,000 feet and between 419 and 497 feet with spacing of 4,000 feet. In considering these computations it should be noted that the low specific capacity of the well, which is characteristic of wells in the basal Trinity sands, is the greatest factor in causing the low pumping levels. For example the drawdown due to pumping the well itself is between 84 and 91 percent of the computed total drawdown at the end of 3 months, and between 62 and 84 percent of the computed total drawdown at the end of 20 years.

The factors limiting the allowable drawdown and pumping levels are cost and the physical construction of the wells. In well 1 at the General Tire and Rubber Company plant the top of the 8-3/8-inch casing is 675 feet below the surface thereby limiting to that depth the level to which the present 15-inch bowls can be lowered.

The computations show that if the pumpage at the General Tire and Rubber Company is of the order of one to one and one-half million gallons a day, the Waco City wells, M-K-T well, and the industrial wells all will cease flowing within about one year after the start of such pumping. It is recommended that the policy of electrical logging all new wells be continued.

Table 3

Theoretical drawdown in water levels and computed pumping levels in wells at Waco caused by continuous pumping of Tire plant well 1 at the rate of 1,000 gallons a minute.

	General Tire and Rubber Co. well		M-K-T R.R. well 1		City of Waco Filter plant wells		Texas Power and Light Co. well 1	
Observed highest water level above land surface during tests	+49		+45		+41		--	
Depth below surface to top of pump bowls as of April 4, 1945	410		--		--		--	
	Theoretical drawdown and pumping levels at end of three months, one year, 5 years, 10 years, and 20 years, in feet							
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Three months								
Drawdown	522	568	49	98	32	64	41	83
Pumping level below land surface	-473	-519	--	--	--	--	--	--
Static water level below land surface			-4	-43	+9	-23	--	--
One Year								
Drawdown	536	596	63	127	46	93	55	113
Pumping level below land surface	-487	-547	--	--	--	--	--	--
Static water level below land surface			-18	-82	-5	-52	--	--
Five Years								
Drawdown	553	629	80	161	63	125	72	145
Pumping level below land surface	-504	-580						
Static water level below land surface			-35	-116	-22	-84	--	--
Ten Years								
Drawdown	560	644	86	174	69	139	78	160
Pumping level below land surface	-511	-595						
Static water level below land surface	--	--	-41	-129	-28	-98	--	--
Twenty Years								
Drawdown	566	657	94	188	76	153	86	173
Pumping level below land surface	517	608						
Static water level below land surface	--	--	-49	143	35	92	--	--

Table 4

Theoretical drawdowns in water levels in feet and computed pumping levels in feet below land surface in well 1 and proposed well 2 at Tire Plant, caused by continuous pumping of each well at 1,000 gallons a minute with wells spaced 1,000 to 4,000 feet apart.

	Spacing 1,000 feet		Spacing 2,000 feet		Spacing 3,000 feet		Spacing 4,000 feet	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Three Months								
Drawdown due to interference between wells	79	160	65	131	57	115	51	103
Pumping level	552	679	538	650	530	634	524	622
One Year								
Drawdown due to interference between wells	94	188	79	160	71	143	66	132
Pumping level	581	735	566	707	558	690	553	679
Five Years								
Drawdown due to interference between wells	110	221	96	193	88	176	82	164
Pumping level	614	801	600	773	592	756	586	744
Ten Years								
Drawdown due to interference between wells	117	235	103	207	95	190	89	178
Pumping level	628	830	614	802	606	785	600	773
Twenty Years								
Drawdown due to interference between wells	124	247	110	221	102	205	96	193
Pumping level	641	855	627	829	619	813	613	801

Table 5

Analyses of water from deep wells at Waco, Texas

Owner	Depth of well (ft.)	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+ K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total hardness as $CaCO_3$	pH
1/ General Tire & Rubber Co. well 1	2,312	July 25, 1944	870	22.1	0.5	3.1	1.1	239.1	418.5	79.9	54	-	-	12	8.5
2/ City of Waco west well at filter plant (Adkins 3/ filter plant well)	2,046	Jan. 8, 1943	779	16	0.04	5.9	3.1	280	434	208	43	2.0	0.0	28	8.3
2/ City of Waco well at Jefferson and 4/ Riverside Street	--	do.	623	18	0.00	3.5	1.4	240	452	86	52	0.7	0.0	14	8.4
2/ Texas Light & Power Co. 4/	2,147	Jan. 9, 1943	633	17	0.01	3.3	1.3	237	445	86	52	0.7	0.2	14	8.4
2/ M-K-T R.R. well 1 (Bell Meads Roundhouse)	2,297	Apr. 17, 1945	952	--	--	2.1	8.6	321	430	320	68	1.2	0.5	88	8.2

1/ Analyses by Curtis Laboratories, Houston, Texas.

2/ Analyses by U. S. Geological Survey, Austin, Texas.

3/ Geology and Mineral Resources McLennan County, Texas, Univ. Tex. Bureau of Econ. Geology Bull. 2340, pp. 155, by W. S. Adkins, 1923.

4/ Op. cit., pp. 146-153.

Drillers' logs of wells at Waco, McLennan County, Texas

Well log at Defense Plant Corporation, Waco, Texas.

	Thickness (feet)	Depth (feet)
Clay, sandy	13	13
Sand and gravel	5	18
Gravel, thin shale breaks	4	22
Shale	101	123
Chalk and shale	123	246
Chalk	39	285
Shale and sandy shale	95	380
Shale	271	651
Shale and lime	40	691
Lime	317	1,008
Shale and sandy shale	123	1,131
Lime, hard	15	1,146
Shale and lime	130	1,276
Lime	50	1,326
Lime and shale	143	1,469
Shale, sandy, and lime	25	1,494
Shale, hard and lime	95	1,589
Lime and shale	290	1,879
Shale, sandy and lime	9	1,888
Sand	37	1,925
Shale, sandy, hard	16	1,941
Shale, hard	104	2,045
Shale, layers of sand	39	2,084
Shale, layers, and fine sand	30	2,114
Sand, layers of shale	26	2,140
Shale, hard	7	2,147
Sand, good	21	2,168
Sand, layers and shale	36	2,204
Sand and thin shale breaks	40	2,244
Shale, hard	13	2,257
Sand	8	2,265
Shale, hard	14	2,279
Sand, hard	8	2,287
Shale, hard	5	2,292
Sand	4	2,296
Shale, hard	16	2,312

Log of the Texas Light and Power Company's well No. 1, located about one-half mile in an easterly direction from the Waco, Texas, postoffice. Contractors R H. Dearing & Sons, Dallas, Texas. Driller H. H. Green. Well was begun March 28, 1912, completed July 27, 1914. Rotary rig was used. Surface elevation at well mouth was 384.7 feet, which refers to U. S. G. S. Bench Mark at east end of M. K. & T. bridge at East Waco. Diameter of well at mouth, 8 inches; at bottom 5-7/8 inches. 749 feet of 8-inch pipe; 1,230 feet of 6-inch pipe. Flows 800,000 gallons per day. Water rises 184 feet above surface.

	Thickness (feet)	Depth (feet)
Austin:		
Hard, white rock, mixed with layers of blue shale	232	232
Eagleford:		
Bluish shale, medium hard	186	418
Georgetown:		
Hard white rock, including lump of extra hard white rock found in layers	217	635
Hard white rock	245	880
Edwards to Walnut:		
Hard, white rock	20	900
Hard white rock	25	925
Hard white rock	30	955
Medium hard white rock	33	988
Medium hard light-bluish rock	12	1,000

(Continued on next page)

Drillers' logs of wells at Waco, McLennan County--Continued

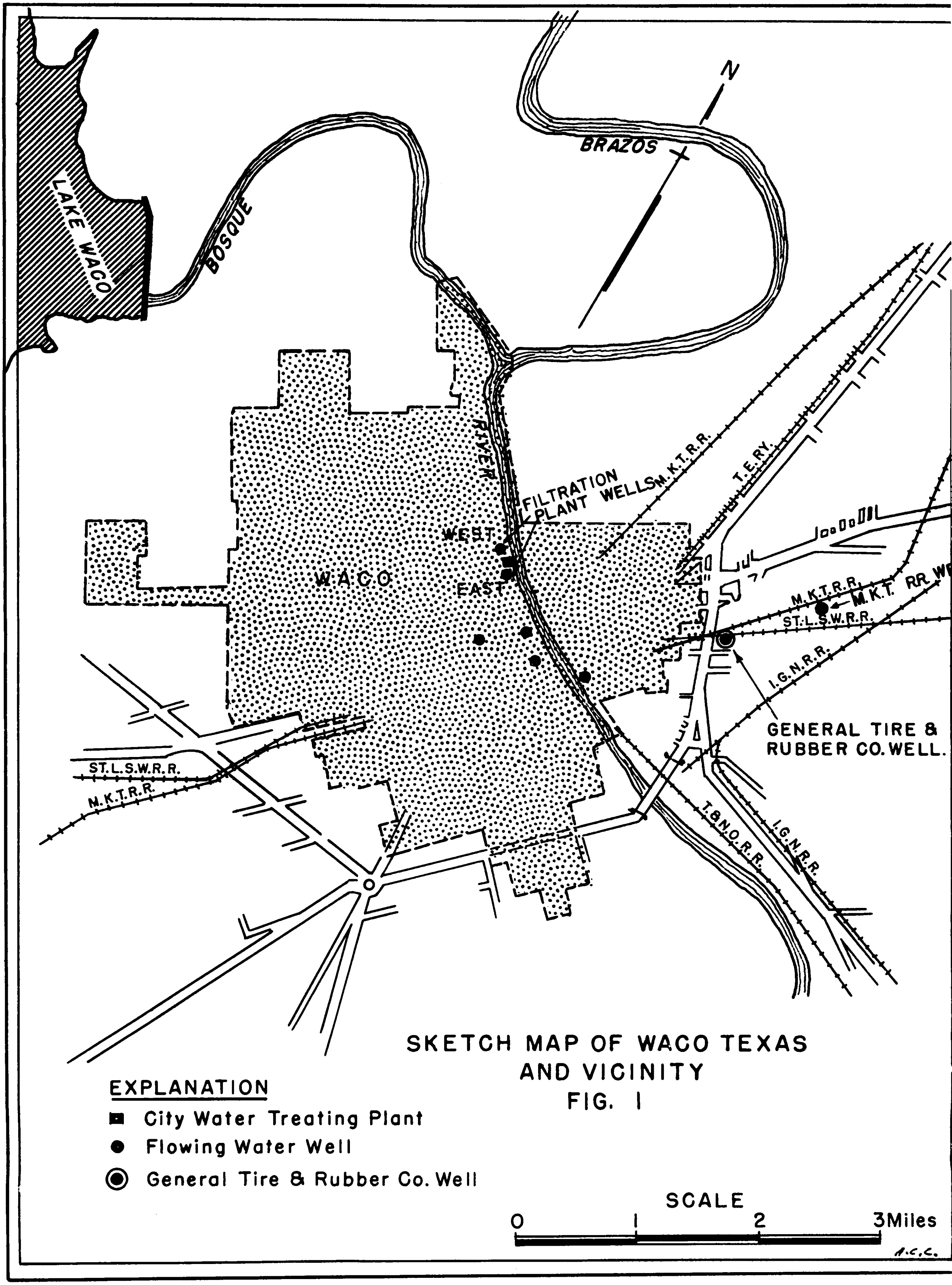
	Thickness (feet)	Depth (feet)
Texas Light and Power Company's well no. 1 -- Continued		
Edwards to Walnut:		
Blue shale, medium hard	35	1,035
Glenrose:		
Hard white rock	40	1,075
Medium hard rock and light blue shale	95	1,170
Medium hard blue shale	60	1,230
Hard rock	50	1,280
Hard white rock	35	1,315
Hard white rock, lump without cavings, was balled up on end of bit	45	1,360
Hard white rock	105	1,465
Medium hard white rock	32	1,497
Hard white rock	38	1,535
Rock, hard and white	35	1,570
Medium hard white rock, some water	25	1,595
Hard white rock	13	1,608
Medium hard white rock	50	1,658
Medium hard white rock, balled up on end of drill	6	1,664
Medium hard white rock	24	1,690
Basal sand:		
Medium hard white rock with small red particles	24	1,714
Medium hard white rock with small amount of water	26	1,740
Medium hard white rock with small amount of water, and some fairly hard particles. Traces of sand at 1,775-1,723	40	1,780
Began to run out of the white lime rock into sand rock	5	1,785
Sand rock, a bluish-gray and white marl	25	1,810
Gray sand with red specks. Water sand	30	1,840
Light gray water sand with layers of hard sand rock, bluish-gray, 1 to 6 inches	6	1,846
Shale, close and sticky	84	1,930
Alternate layers of a dingy white lime rock and a light blue shale. The lime and shale had some fine grit. It cut the bits off some, more than the white lime above the first Trinity reservoir	8	1,938
A blue marl that was sticky and hard to cut; had sand in it	2	1,940
Hard bluish-gray sand rock, very hard	8	1,948
Red shale, fine red sand, a little water. Set 6-inch pipe at 1,948, lapping into 8-inch pipe 30 or 40 feet size of well hole from bottom of 6-inch to bottom of hole 5-7/8-inch	10	1,958
Red water sand, very fine, and mixed with a red and blue shale. Well went to flowing at that depth and was cleared of the muddy water used in drilling. At that depth the sand continued to be dirty and fine for 70 to 80 feet, mixed with red, blue and green shale and hard layers of gray sand or a lime rock	76	2,034
Flow of about 150,000 gallons per 24 hours	14	2,048
Water sand of a better quality but mixed with red and blue shale and thin layers of sand rock. At this depth the well was flowing about 450,000 gallons per 24 hours	52	2,100
Layers of a dingy white lime and red shale with some blue shale	8	2,108

Drillers' logs of wells at Waco, McLennan County--Continued

	Thickness (feet)	Depth (feet)
Texas Light and Power Company's well no. 1 -- Continued		
Basal sand:		
Coarse water sand. Well flowed about 800,000 -------------------	30	2,138
A fine water sand, mixed with a little gray shale, well has 82 pound pressure at surface .		
Altitude, 387 feet --	9	2,147

It looks like we went through four of the Trinity strata of water with the one that I cased out, when I set the 6-inch pipe at 1,948 feet. I struck this strata of water at about 1,770 feet. We did not have a correct measurement on our drill line of pipe at about this depth. H. H. Green.

Bureau of Economic Geology, University of Texas, Bulletin No. 2340, page 118.



SKETCH MAP OF WACO TEXAS
AND VICINITY
FIG. 1

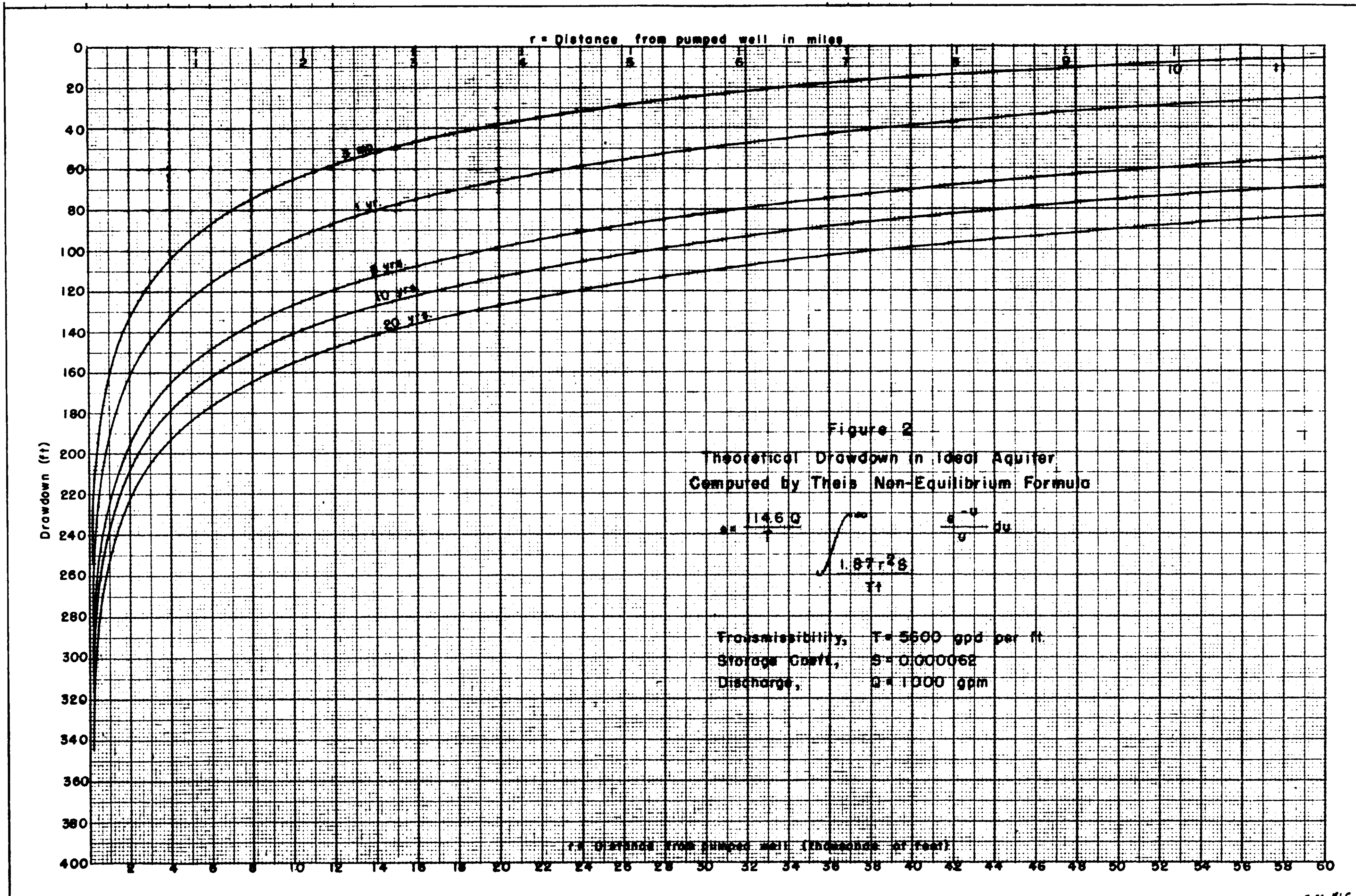


Figure 2

Theoretical Drawdown in Ideal Aquifer

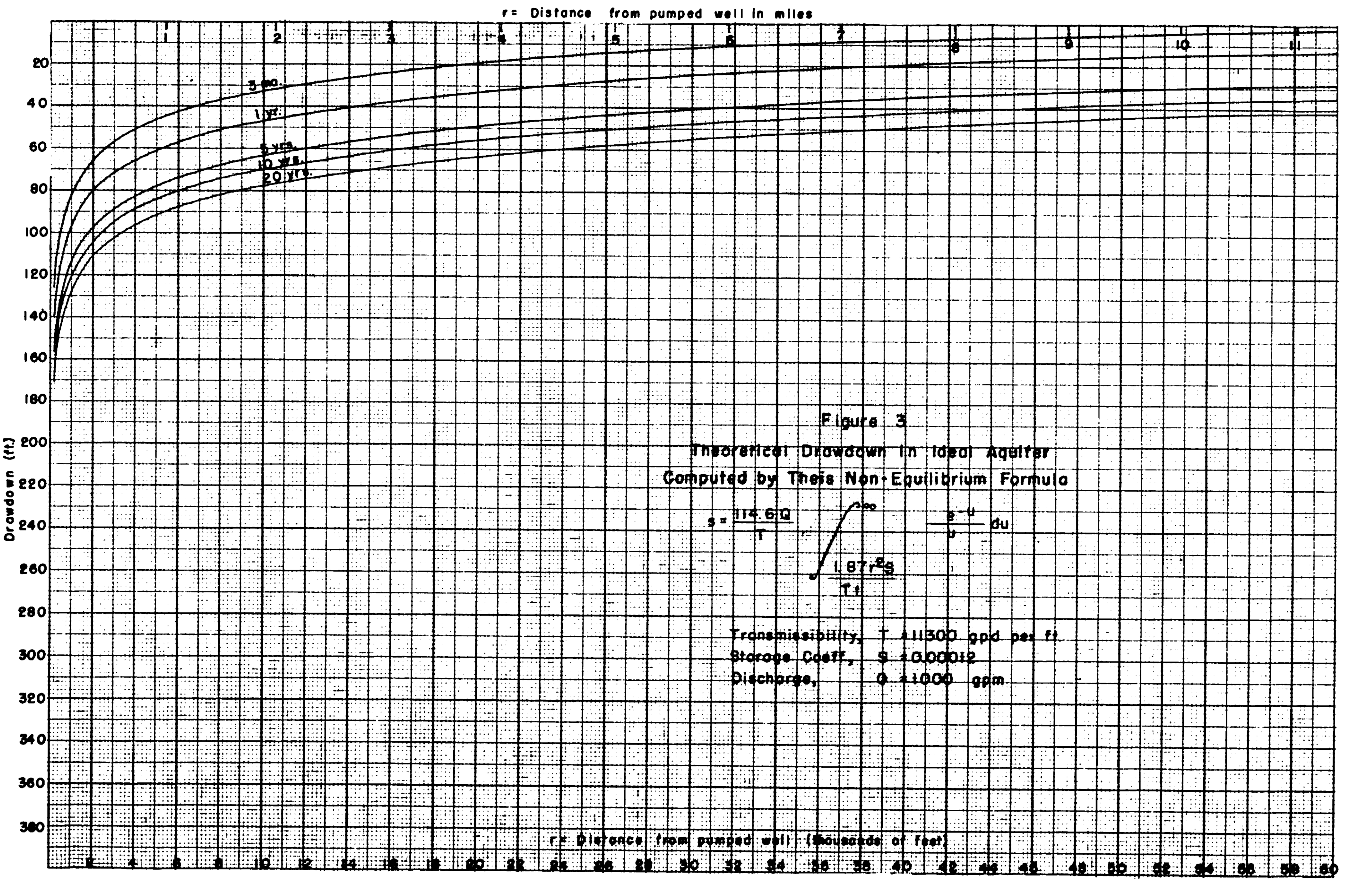
Computed by Theis Non-Equilibrium Formula

$$s = \frac{114.6\,Q}{T} \int_{\frac{1.87 r^2 S}{Tt}}^{\infty} \frac{e^{-u}}{u}\,du$$

Transmissibility, T = 5600 gpd per ft.

Storage Coeff., S = 0.000062

Discharge, Q = 1000 gpm



r= Distance from pumped well in miles
Drawdown (ft.)
r= Distance from pumped well (thousands of feet)
3 mo.
1 yr.
5 yrs.
10 yrs.
20 yrs.
Figure 3
Theoretical Drawdown in Ideal Aquifer
Computed by Theis Non-Equilibrium Formula
$s = \frac{114.6Q}{T} \int_{\frac{1.87r^2S}{Tt}}^{\infty} \frac{e^{-u}}{u}\,du$
Transmissibility, T = 11300 gpd per ft.
Storage Coeff., S = 0.00012
Discharge, Q = 1000 gpm

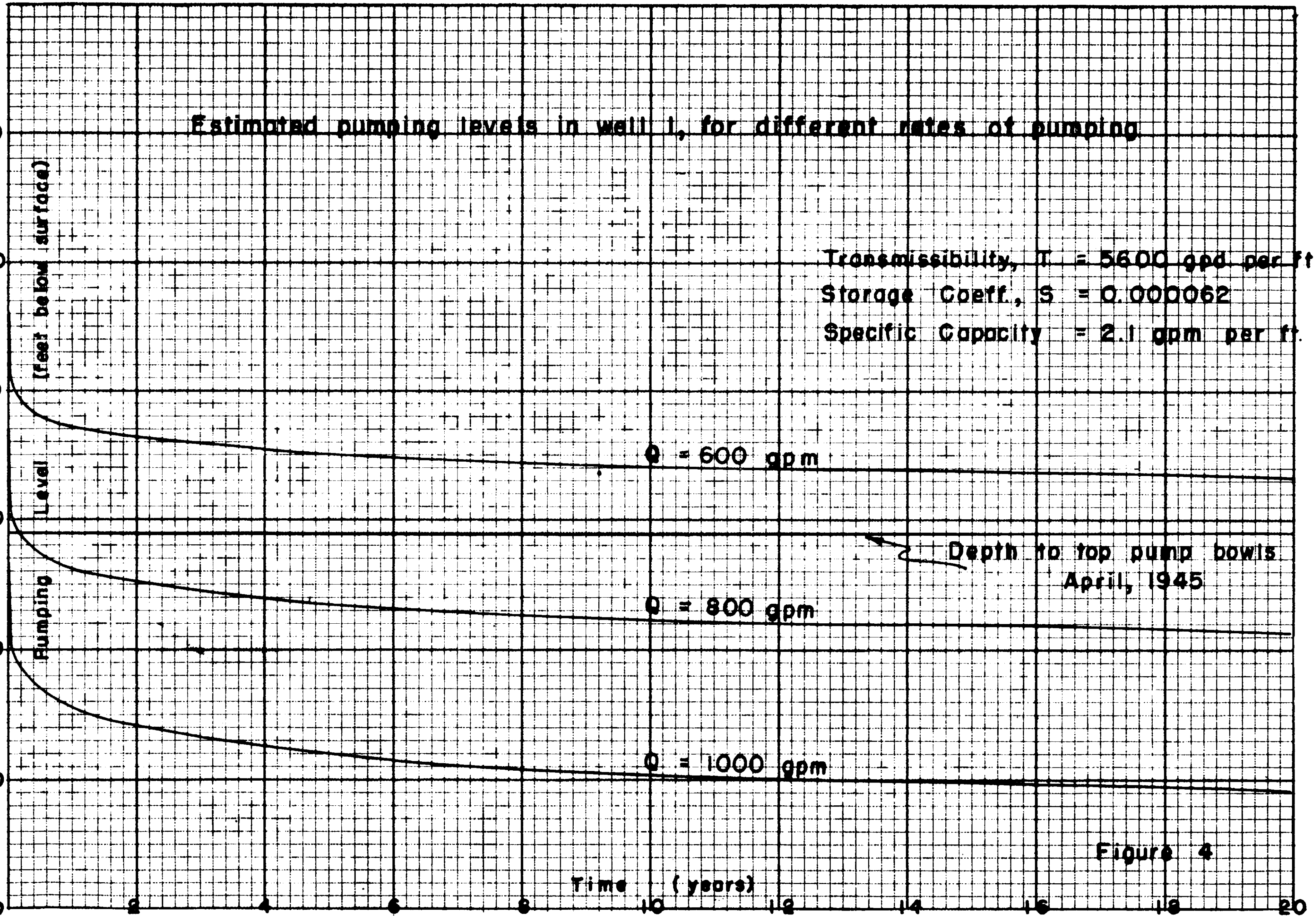


Figure 4

MLC-746