GROUND-WATER RESOURCES AT SHERMAN, TEXAS

By

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

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Purpose of investigation

In formulating a post-war policy for a water supply to meet the needs of industrial expansion and increased population, the city of Sherman has three general plans under consideration as follows: (1) continued use of ground-water; (2) use of water from Red River impounded in Lake Texoma above the Denison Dam about 10 miles from Sherman; and (3) use of impounded flood waters from several small streams in the immediate vicinity of Sherman.

A request was made by the city authorities to the Texas Board of Water Engineers and the U. S. Geological Survey, with which the Board is cooperating, for a report regarding the supply of ground water. Several pumping tests on the city wells were made in July 1945. The purpose of these tests was to obtain information as to the possibility of materially increasing the present rate of ground-water withdrawals in the Sherman area, and the effect of such increase on the ground-water reservoirs.

GEOLOGY

According to the U. S. Geological Survey map of Texas, Sherman is on the boundary between the outcrops of the Eagle Ford shale, and the Austin chalk of the Gulf series (Upper Cretaceous). Underlying the Eagle Ford shale is the Woodbine sand, the basal formation of the Gulf series. The Comanche series of Lower Cretaceous age which underlies the Woodbine sand consists in descending order of the Washita group, the Fredericksburg group, and the Trinity group. The latter is represented in this area only by the Paluxy sand and is underlain by rocks of Carboniferous age. Only the Woodbine and the upper and lower sands of the Paluxy yield water in sufficient quantities and of suitable quality for public and industrial supply. The Woodbine sand and the lower sand of the Paluxy are by far the most important. The reservoirs in these sands are replenished from rainfall on their outcrops.

The rocks of the Trinity group crop out in a broad band which crosses Montague County and the western part of Cooke County 60 miles west of Sherman in a north-south direction, and thence swing northeastward and eastward across southern Oklahoma into Arkansas. North of Sherman the outcrop occurs in places in the lowlands of Red River within 20 to 25 miles, but the main outcrop is about 40 miles from the city.

The Woodbine sand crops out in a belt roughly paralleling the outcrop of the Trinity group. West of Sherman the eastern edge of the outcrop is about 15 miles distant while north of Sherman it appears within about 6 miles of the city. The rocks dip generally in the southeast and south.

At Sherman the Woodbine sand is encountered in wells from about 550 to 800 feet beneath the surface, the Paluxy sand is encountered from 1,400 to 2,100 feet and contains an upper sand from about 1,400 to 1,500 feet, and a lower sand from about 1,550 to 2,100 feet. All these sands are fine-grained, relatively thin, and interbedded with shale, clay or limestone (see attached logs).

The underlying Carboniferous rocks presumably contain brackish or salty water. The contact between these rocks and the base of the Paluxy sand is not evident from an examination of the logs of the city wells but salty water has been reported below a depth of about 2,150 feet; and the electrical log of one well (T3) indicates the presence of highly mineralized water below about 2,130 feet. A well at Perrin Field six miles northwest of Sherman encountered salty water at a depth of about 1,600 feet, (see logs).

DEVELOPMENT OF GROUND WATER

(For location of wells see plate 1 and figures 1 and 2)

City wells

The first well put down by the City (well T4), 2,300 feet in depth, was drilled in 1889 at East and Epstein Streets, and developed in the lower sand of the Paluxy. During the period from 1909 through 1917, eight wells (W1 to W8) ranging from 776 to 800 feet in depth were drilled to the Woodbine sand in the present well field near Birge and Ricketts Streets. Two wells (T1 and T2) were drilled to the lower Paluxy sand in this field in 1921 and a fourth well in the lower Paluxy (T3) was drilled in 1944 about 1,400 feet northwest of the intersection of Hunt and Ricketts Streets, thereby completing the well development as of October 1945. Table 1, gives most of the pertinent information that is available concerning the city wells.

Table 1

Sherman City Wells

Location, depth, yield of wells, and formation from which they draw water

Well report	Number City	Year drilled	Location	Formation	Depth (ft.)	Yield (g.p.m.)
1	W1	1909	Birge and Ricketts Sts.	Woodbine sand	800	80
2	W2	1909	do.	do.	800	80
3	W3	1911	do.	do.	778	80
4	W4	1913	do.	do.	778	290
5	W5	1916	do.	do.	776	-
6	W6	1916	do.	do.	785	80
7	W7	1917	do.	do.	786	90
8	W8	1917	do.	do.	786	275
9	T1	1921	do.	Lower Paluxy sand	2,140	300
10	T2	1921	do.	do.	2,146	360
11	T3	1944	1,400 feet north of Hunt and Ricketts Sts.	Lower Paluxy sand (and upper (?) Paluxy sand)	2,169	540
12	T4	1889	East and Epstein Sts.	Lower Paluxy sand	2,300	200

Industrial wells

Two railroads, two ice plants, a laundry, a cotton oil and refining company, and one other industry are supplied by privately owned wells. These wells draw relatively small quantities of water from the Woodbine sand. The wells, numbered 13 to 20, inclusive, are briefly described in the following table and are shown under the same numbers on plate 1.

Table 2

Records of industrial wells at Sherman, Texas
(All wells draw water from the Woodbine sand)

Well	Owner	Location	Depth (ft.)	Diameter (in.)	Pump	Pump (gpm)	Estimated av. annual (gpm)	Remarks
13	St.L & S.F. R.R. Shops	City limits (north side)	805	10¾-6-5/8	Turbine	245	115	See log.
14	do.	do.	-	-	do.	-	-	Est.Aver. annual yield from both wells 115 gpm.
15	Interstate Cotton Oil and Ref. Co.	Pecan and Lee Sts.	-	-	do.	115	100	Also one unused well.
16	Southern Ice Co.	Houston and East Sts.	-	-	do.	40	15	Pump operated continuously June-Sept.
17	Southland Ice Co.	Houston and Montgomery Sts.		-	Plunger	10	-	
18	Sherman Steam Laundry	Lamar and Rusk Sts.	800	8-6	Turbine	90	30	Also an abandoned well.
19	Sherman Mfg. Co.	Park and Lincoln Sts.	776	8	do.	55	25	See log.
20	T & N O Ry.	Centennial St. and S. P. tracks	-	-	do.	70	12	

Pumpage

The following table which is based mainly on information furnished by the City Water Department and the St. Louis and San Francisco Railroad shows the estimated amount of water pumped from both city and industrial wells during 1933-44.

Table 3

Estimated pumpage from all wells at Sherman, Texas, 1933-1944

Year	City wells million gallons a year	Industrial million gallons a year	Total million gallons a year	Average in gallons a minute
1933	262	158	422	800
1934	296	158	454	860
1935	280	158	438	830
1936	288	158	446	850
1937	268	158	426	810
1938	284	158	442	840
1939	298	158	456	870
1940	286	158	444	840
1941	304	158	462	880
1942	342	158	500	950
1943	484	158	642	1,220
1944	436	158	594	1,130

Pumping tests

A series of pumping tests was run on the city wells from July 10 to 21, 1945, to determine the coefficients of transmissibility and the coefficients of storage of both the Woodbine sand and the lower sand of the Paluxy.

For the Woodbine sand the coefficients were determined by pumping well W8 and observing the resulting drawdown of water levels in wells W3, W4, W5, W6, and W7 for a period of about 23 hours after which well W8 was shut-down and the rate of recovery of the water levels in the same group of wells was observed for about 35 hours.

For the lower sand of the Paluxy the coefficients were determined by running three interference tests and one recovery test. In the interference tests the drawdowns in wells T1 and T3 caused by pumping well T2 were observed for a period of about 26½ hours. Then well T3 was started and pumped for 23 hours while the observations of drawdowns in well T1 were continued. In the recovery test the pump in well T3 was turned off at the end of the 23 hour period of pumping and the recovery of the water levels in T1 and T3 was recorded.

All water-level measurements were made with a weighted steel tape wherever such measurements were possible; otherwise the water level was determined by means of an air-line and pressure gage. The yields of the pumped wells were measured with a 2-foot sharp-crested weir.

<u>Results of test</u> - Table 4 shows the coefficients of transmissibility and storage computed by the Theis method from the pumping test data. These coefficients are a measure of the ability of the aquifer to transmit water and yield water from storage and can be used to compute the drawdown in wells which will occur as a result of increased pumping at varying distances from the point or points of increase.

The non-equilibrium formula developed by C. V. Theis 1/ of the U. S. Geological Survey is

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

Where s is the drawdown in feet at any point in the vicinity of a well discharging at a uniform rate; q is the discharge of the well in gallons per minute; T is the coefficient of transmissibility of the aquifer in gallons per day per foot; r is the distance from the discharge well to the point of observation in feet; S is the coefficient of storage; and t is the time the well has been pumped in days.

The transmissibility of an aquifer may be expressed as a coefficient which gives the volume of water, flowing in unit time through a vertical strip of the aquifer of unit width under unit hydraulic gradient. It is here used as the number of gallons that will flow in one day through a vertical strip of the aquifer one foot wide under an hydraulic gradient of 100 percent.

1/ Theis, C. V., The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: Trans. Amer. Geophys. Union, pp. 519-524, 1935.

The coefficient of storage is the volume of water released from storage in a vertical prism of the aquifer of unit cross section by a unit decline in head. As used here it is the volume of water measured in cubic feet that is released from storage in a vertical prism of the aquifer one foot square when the artesian head is lowered one foot.

The development and application of the Theis formula is based on the following assumptions: (1) the water-bearing formation is homogeneous and isotropic, (2) the formation has an infinite areal extent, (3) the discharge well penetrates the entire thickness of the formation, (4) the discharge well has an infinitesimal diameter and (5) the water is released from storage instantaneously with the drop in head.

Table 4

Coefficients of transmissibility and storage determined from tests on the Sherman City wells, Sherman, Texas

Date	Observation well	Coefficient of transmissibility T, gpd/ft	Coefficient of storage S	Remarks
		Wells in Woodbine sand		
July 13-15, 1945	W3	2,420	.000233	Well W8 in operation.
July 13-15, 1945	W4	2,080	.000060	Do.
	W5	2,190	.000095	Do.
	W6	2,320	.000189	Do.
	W7	2,340	.000178	Do.
July 15-16, 1945	W3	2.510	.000221	Well W8 idle.
July 15-16, 1945	W4	2,400	.000045	Do.
	W5	2,360	.000094	Do.
	W6	2,460	.000164	Do.
	W7	2,620	.000140	Do.
Average		2,370	.000142	
		Wells in lower Paluxy sand		
July 18-19, 1945	T1	2,220	.0000755	Well T2 in operation.
July 18-19, 1945	T3	3,200	.0000203	Do.
July 19-20, 1945	T1	3,660	.0000183	Well T2 and T3 in operation.
July 20-21, 1945	T1	2,830	.0000168	Well T3 idle, T2 in operation.
July 20-21, 1945	T3	2,550	-------	Do.
Average		2,900	.0000327	

It will be noted that the 10 values obtained for the coefficients of transmissibility and storage for the Woodbine sand agree rather well, the average being 2,370 gpd per ft. and 0.000142, respectively. These averages were used in computing the drawdowns to be expected from future pumpage.

The values of the coefficients obtained from tests on wells in the lower Paluxy sand, however, vary over a wider range. In view of the fact that a much better alignment of the data was obtained when using T3 for observation while T2 was pumped, more weight was given the transmissibility coefficient, (3,200 gpd per ft) which was computed for that test. Therefore, 3,000 gpd per foot has been used as a basis for computations. The value used for the coefficient of storage was 0.00003.

Future pumpage

In order to evaluate the results of the tests in terms of the effects of increasing the pumpage on the ground-water reservoirs, computations have been made on an assumed set-up with a rate of pumping approximately double the present draft. As the coefficients of transmissibility determined from the pumping tests are relatively low, the assumed new wells are placed far apart and as far as practicable from the main pumping station at Ricketts and Birge Street.

The plan calls for continued use of five of the present wells, including T3, which was drilled in 1944 and five new wells, one well in the lower Paluxy and one well in the Woodbine on the east side of the city at Colbert and Pacific Streets; one in each formation on the south side at Montgomery and Wilson Streets, and one Woodbine well in the down-town area at East and Epstein Streets. The object of the computations is not to arrive at any exact figures of drawdown at the various points but rather to arrive at results that will show the general order of magnitude of the drawdowns under some assumed conditions that approximate the largest draft that may reasonably be attained. The details of the plan are summarized in the following table:

Table 5

Assumed amount and distribution of pumpage under a plan in which the rate of pumping would be increased to 2,400 gpm or 3,456,000 gpd.

Well	Station	Location	Estimated present average yield (gpm)	Assumed future average yield (gpm)
		Present wells		
T4	Central	East and Epstein Sts.	100	200
T1 or T2[1/]	Ricketts St.	Birge and Ricketts Sts.	400	300
W4	do.	do.	200	200
W8	do.	do.	200	200
T3	Ricketts Sts. plant (Mc Gee Street)	(McGee Street)	-	500
		New wells		
	East side	Colbert and Pacific Sts.	-	200
	do.	do.	-	200
	South side	Montgomery and Wilson Sts.	-	200
	do.	do.	-	200
	Central	East and Epstein Sts.	-	200

1/ Considered as one well.

Effects of pumping

The boundary conditions of the aquifer must be known or assumed before estimates of the decline of water levels caused by pumping can be made. The boundaries may be produced by faulting, cropping out of the water-bearing beds at the surface, or lensing out of the beds. The boundaries will eventually affect the amount and rate of decline of the water level. Although it is realized that the water-bearing sands in this area are not constant in thickness over large areas and that local faulting may affect the movement of ground water, these conditions are not well known and their actual influence on the decline of the water cannot be determined. However, it is probable that their influence will be small in proportion to the total decline, and, therefore, these factors have not been taken into account in this report. The location of the outcrop of the water-bearing sands is more important, and this is known and is accounted for in the estimates.

The rate of decline of the water level in wells in the Woodbine wells will become less and less until at the end of about ten years water will move from the outcrop to the wells in sufficient quantity to replace the pumpage and the drawdown will practically cease. The recharge by rainfall on the outcrop, which is about 6 miles from Sherman, will prevent much unwatering of the sand in that area. Maintenance of the water level at the outcrop by recharge appears especially favorable as the outcrop is partially covered by Lake Texoma.

The pumping from wells in the Woodbine sand at Perrin Field probably has lowered the water levels in the Woodbine wells at Sherman less than 10 feet during the past two years. Pumping from these wells at Perrin Field will lower the water level at Sherman very little more if the pumping is continued at the present average rate.

The distance to the outcrop of the lower Paluxy sand is estimated to be about 40 miles, and a much longer time is required for unwatering of this sand in the outcrop to take place and for recharge on the outcrop to affect the decline of the water levels at Sherman. The computations for the lower Paluxy show that approximate equilibrium will not be established until after about 40 years of pumping.

Specific capacity - The non-equilibrium formula is likely to give results that are in error when used to determine the drawdown in a well caused by its own pumping. For this reason the observed specific capacity of a well is used to determine the drawdown in the well caused by its own pumping during the first day of operation. The specific capacity is the yield-drawdown ratio and is generally expressed as the yield of a well in gallons per minute for each foot of drawdown. There is very little information available concerning the specific capacity of lower Paluxy wells or Woodbine wells at Sherman, but the data that are available on wells T3 and W4 indicate that a value in the order of 2 gallons a minute per foot of drawdown after one day of pumping is not greatly in error for wells drawing water from either sand.

Drawdown in wells in the Woodbine sand - In estimating future drawdowns in wells in the Woodbine sand at Sherman due to increase in the pumpage it has been assumed that the water levels in the present Woodbine wells are in essential equilibrium and that practically all of the water is coming from the outcrop. This is not actually true because the rate of withdrawal from the Woodbine sand has been slightly increased since about 1940 as shown by the table of pumpage (see table 3), but the available pumpage data are not sufficiently detailed to allow a more accurate analysis. Therefore, the estimated drawdowns shown in table 6 should be considered as the minimum drawdowns that are likely to occur.

Table 6 gives an estimate of the drawdown that will occur in wells W4 or W8 at the Ricketts Street station and in assumed wells at the locations shown in table 5. According to these figures approximate equilibrium will be reached after about 10 years of constant pumpage and comparatively little additional drawdown will occur after 5 years. In estimating the future pumping levels to be expected it has been assumed that the static level obtained during the pumping tests at the Ricketts Street station, 265 feet below the surface, is applicable to the proposed new well locations. A specific capacity of 2 has been assumed for each well.

The table also shows that under the assumed pumping schedule the pumping levels will range from about 105 feet to 55 feet above the top of the sand after one year of continuous pumping and will range from about 84 to 32 feet above the top of the sand in the same wells after 10 years of continuous pumping.

Table 6

Wells in Woodbine sand

Computed drawdown and pumping levels in wells described, at end of periods shown if all wells are pumped continuously at the rates indicated.

	W4	W8	East side	South side	Central
Assumed rate of pumping (gpm)	200	200	200	200	200
One year					
Computed drawdown (ft.)	80	80	210	220	230
Computed pumping levels (ft.)	445	445	475	485	495
Height of pumping level above top sand (ft.)	105	105	75	65	55
Five years					
Computed drawdown (ft.)	101	101	232	242	250
Computed pumping levels (ft.)	466	466	497	507	515
Height of pumping level above top sand (ft.)	84	84	53	43	35
Ten years					
Computed drawdown (ft.)	101	101	234	248	253
Computed pumping levels (ft.)	466	466	499	513	518
Height of pumping level above top sand (ft.)	84	84	51	37	32
Twenty years					
Computed drawdown (ft.)	102	102	237	248	256
Computed pumping levels (ft.)	467	467	502	513	521
Height of pumping level above top sand (ft.)	83	83	48	37	29

The top of the Woodbine sand has been assumed as 550 feet below ground.

Computations have also been made of the effects on wells W4 and W8 that would be caused by pumping each of three new Woodbine wells at the rate of 200 gallons per minute continuously, all located within the Ricketts Street well field. The assumed locations are as follows: One well drilled beside T3, and two equally spaced between wells T3 and W8. Computations show that under this plan dewatering of the aquifer would start immediately which would result in a serious decline in the yield of the wells.

Drawdown in wells in lower Paluxy sand - In estimating the future drawdown of the water level of the wells screened in the lower Paluxy sand it has been assumed that the water level is in essential equilibrium at the present time although this is probably not exactly true because the rate of withdrawal of water from the sands has increased slightly since about 1940. As the effective distance of the lower Paluxy sand outcrop is estimated to be about 40 miles, a longer time is required for recharge on the outcrop to effect the drawdown in the lower Paluxy wells in Sherman. As can be seen from table 7, very little drawdown would occur after 30 years and the drawdown would practically cease after 40 years of constant pumping. In estimating the future pumping levels it is assumed that the static water level obtained during the tests, 240 feet, is applicable to the proposed new locations.

Table 7

Wells in lower Paluxy sand

Computed drawdown and pumping levels in wells described, at end of periods shown if all wells are pumped continuously at the rates indicated.

	T-1 or T-2 1/	T-3	East side station	South side station	Central station
Assumed rate of pumping (gpm)	300	500	200	200	200
One year					
Computed drawdown (ft.)	183	416	267	266	242
Computed pumping levels (ft.)	623	656	507	506	532
Height of pumping level above top of sand (ft.)	927	894	1,043	1,044	1,018
Five years					
Computed drawdown (ft.)	237	469	321	319	295
Computed pumping levels (ft.)	677	709	561	559	585
Height of pumping level above top of sand (ft.)	873	841	989	891	965
Ten years					
Computed drawdown (ft.)	253	484	336	335	310
Computed pumping levels (ft.)	693	724	576	575	600
Height of pumping levels above top of sand (ft.)	857	826	974	975	950
Twenty Years					
Computed drawdown (ft.)	265	498	349	347	323
Computed pumping levels (ft.)	705	738	589	587	613
Height of pumping levels above top of sand (ft.)	845	812	961	963	937
Thirty years					
Computed drawdown (ft.)	270	501	352	351	328
Computed pumping levels (ft.)	710	741	592	591	618
Height of pumping levels above top of sand (ft.)	840	809	958	959	932
Forty years					
Computed drawdown (ft.)					330
Computed pumping levels (ft.)					620
Height of pumping levels above top of sand (ft.)					930
Fifty years					
Computed drawdown (ft.)					330
Computed pumping levels (ft.)					620
Height of pumping levels above top of sand (ft.)					930

1/ The top of the lower Paluxy sand has been assumed as 1,550 feet below the ground surface. The static water level has been assumed as 240 feet below the ground surface.

Rate of movement of ground water

From assumptions made as to the thickness of the water-bearing sands, the porosity of the sands, and the present rate of pumping, estimates were made as to the rate of movement of the ground water. It was estimated that water moves from the outcrop of the Woodbine sand toward Sherman at the rate of about 50 feet a year, and more slowly from the outcrop of the lower Paluxy sand.

Quality of water

The chemical character of water from wells at Sherman is shown in the following table. The water from both Woodbine and lower Paluxy sands is exceptionally soft but has a fairly high content of sodium bicarbonate. The analysis of water from well W2 shows an iron content of 1.4 parts per million which is not only higher than is desirable but it is also much higher than in any of the other wells. It seems desirable to resample this well after it has been pumped for several hours to determine whether the iron is contained in the water before it leaves the water-bearing sand or whether it is derived from the casing and pumping equipment.

Table 8

Analyses of water from wells at Sherman, Texas

Well	Owner	Depth of well (ft.)	Date of collection	Total dis-solved solids	Silica (SiO_2)	Iron (Fe)	Cal-cium (Ca)	Magne-sium (Mg)	Sodium and Potas-sium (Na+K) (calc.)	Bicar-bonate (HCO_3)	Sul-fate (SO_4)	Chlo-ride (Cl)	Fluor-ide (F)	Ni trate (NO_3)	Total hard-ness as $CaCO_3$ (calc.)
a/T1	City of Sherman	2,100	Feb. 24, 1943	921	15	0.03	3.7	1.3	354	426	113	218	0.5	1.0	14
b/T1	do.	2,100	Feb. 22, 1945	976	20	.08	7	2	362	387	124	241	.6	.4	26
b/T2	do.	2,146	do.	815	19	.06	5	3	306	439	110	124	.2	.4	25
b/T3	do.	2,169	Mar. 23, 1945	856	20	.50	6	6	331	409	117	179	.7	.4	40
b/W2	do.	800	do.	402	21	1.4	4	.05	152	235	74	32	1.2	.4	35
a/W5	do.	770	Feb. 24, 1943	352	12	.11	0.9	0.5	127	269	42	12	1.0	.0	4
b/W8	do.	786	Feb. 22, 1945	340	16	.13	2	1	125	262	42	16	.8	.7	9

a/ Analyzed at The University of Texas under the direction of W. W. Hastings, Chemist, U. S. Department of the Interior, Geological Survey. Results are in parts per million.

b/ Analyzed by the Texas State Department of Health, Austin, Texas.

Summary and conclusions

The purpose of the tests on the wells at Sherman was to determine the coefficients of transmissibility and storage and to use these coefficients in making estimates of the decline of pumping levels that would results from future increased ground-water withdrawals.

The coefficients of transmissibility as computed from tests on the Woodbine sand and the lower Paluxy sand are 2,370 gpd per ft. and 3,000 gpd per ft., respectively. The coefficient of storage of the lower Paluxy sand at Sherman compares favorably with that found in other areas but comparable figures for the Woodbine sand are not available. The coefficients of storage used in the computations were .000142 for the Woodbine sand and .00003 for the lower Paluxy sand.

According to the summary of the computations given in table 6, withdrawal of water at the rate of 1,000 gpm from five wells in the Woodbine sand (W4, W8, East side, South side, and Central stations), pumping 200 gpm each, and located as shown on the map, is about the maximum practicable under the assumed conditions. In fact it is believed that the computed margin of safety of 30 to 80 feet before dewatering of the aquifer would begin is too small, especially in view of the prevailing low transmissibility and low specific capacity.

The other assumed plan of the development of three new wells with an average yield of 200 gpm each in the Woodbine sand in the Ricketts Street field would result in dewatering of the aquifer almost immediately.

Table 7 shows that with withdrawals amounting to 1,400 gpm from five lower Paluxy wells (T1 or T2, T3, East side, South side, and Central stations), according to the plan discussed previously, there still remains a large margin of safety before dewatering of the aquifer begins, and, therefore, from a strictly hydrologic viewpoint, more water could be developed from the lower Paluxy sand than that proposed under the plan discussed. Apparently the limiting factor restricting the development of water from the lower Paluxy sand is the economics of the pumping costs due to the large pumping lifts involved.

Drillers' logs of wells in and near Sherman, Texas

	Thickness (feet)	Depth (feet)
Well T1		
Owned by City of Sherman, drilled in 1921 at main pumping station, Ricketts and Birge Streets.		
Surface clay	28	28
Hard rock	4	32
Yellow water sand	2	34
Blue shale	457	491
Sand rock	2	493
Water sand	18	511
Blue shale	218	729
Water sand	23	752
Shale with thin strata rock	67	819
Blue shale with strata lime rock	93	912
Layers lime rock and shale	50	962
Blue shale with strata of lime rock every 20 feet	57	1019
Lime rock and shale in layers of 1 foot	75	1094
Lime rock with strata of blue marl	43	1137
Hard lime with breaks in it	19	1156
Hard lime with breaks	22	1178
Lime with shale	77	1255
Lime rock and shale	109	1364
Hard lime rock	23	1387
Hard lime rock with layers of marl	15	1402
Sand rock	6	1408
Sandy shale in layers	10	1418
Fine-grained sand	39	1457
Sand with white soft marl	10	1467
Sand and white marl	16	1483
Sand and marl in strata	33	1516
Hard lime rock	1	1517
Sharp fine-grained sand with streaks of marl	29	1546
White marl	4	1550
Fine-grained sand with red rock	18	1568
Water sand in 4 foot strata with marl	19	1587
Hard sand	8	1595
Red, blue and white marl	34	1629
Red blue and white marl with streaks of sand	24	1653
Red, blue and white marl	25	1678
Sand, lime rock	28	1706

	Thickness (feet)	Depth (feet)
Well T1 -- Continued		
Sand with red and blue marl mixed	21	1727
Hard sand rock	8	1735
Fine-grained sand	28	1763
Sand rock	9	1772
Fine-grained sand with thin layers marl	23	1795
Sand rock	4	1799
Marl	10	1809
Sand	9	1818
Sand with streaks of marl	22	1840
Red rock	13	1853
Hard sand	7	1860
Sand with streaks of red rock	25	1885
Red marl, sandy	3	1888
Fine hard sand	26	1914
Water sand, hard	8	1922
Red, blue, pink and white marl	7	1929
Red, blue, pink and white marl, sandy	37	1966
Sand rock, sand	14	1980
Sand	20	2000
Hard sand	2	2002
Sand rock, water	17	2019
Fine water sand, soft	8	2027
Fine water sand, hard	27	2054
Water sand, soft streaks	14	2068
Layers of rock, sand and marl, blue and red	26	2094
Hard sand and rock	4	2098
Sand rock and sand layers with marl	13	2111
Red marl with streaks of sand	22	2133
Water sand	10	2143
Hard sand rock	3	2146
Red gumbo	4	2150
Red marl	2	2152
Sand rock, red marl	13	2165
Red marl	2	2167
Sand rock, broken	8	2175
Red and blue shale, sandy	14	2189
Red marl	7	2196
Soft sand rock	4	2200
Hard rock	2	2202
Lime rock, hard	2	2204
Hard red shale	2	2206
Red, blue and white shale	9	2215
Hard lime	1	2216
Hard sand rock	3	2219

(Continued on next page)

Drillers' logs of wells in and near Sherman -- Continued

	Thickness (feet)	Depth (feet)
Well T1 -- Continued		
Red shale	1	2220
Red shale, some blue	28	2248
Red shale	18	2266
Sand rock	4	2270
Red shale	26	2296
Sand rock	1	2297
Red shale	4	2301
Sand rock	4	2305
Hard sand rock	3	2308
Red marl	2	2310
Rock, red shale	8	2318
Sand rock, red shale	8	2326
Red shale	3	2329
Red, white, and blue shale, hard	3	2332
Sand rock	4	2336
Layers of sand, and rock, red, white and blue shale	8	2344
Layers of sand rock and red shale, rock pretty hard	11	2355
Very hard sharp sand rock	1	2356
Hard shale	2	2358
Hard sharp sand rock	3	2361
Hard sand rock	5	2366

Well T2

Owned by City of Sherman, drilled in 1921 at main pumping station, Ricketts and Birge Streets.

	Thickness (feet)	Depth (feet)
Surface clay	15	15
Water sand	25	40
Sandy shale	22	62
Rock	1	63
Water sand	10	73
Sand rock	1	74
Shale	16	90
Sand rock	4	94
Shale	58	152
Sandy shale	10	162
Blue gumbo	20	182
Rock sand	20	202
Shale	10	212
Marl	28	240
Marl and sand	12	252
Blue marl	48	300
Marl	30	330
Hard sand rock	4	334
Marl	8	342
Gumbo	40	382
Well T2 -- Continued		
Marl, very tough	20	402
Marl	40	442
Hard lime rock	2	444
Marl and sand rock	18	462
Hard lime rock	2	464
Hard marl and sand rock	32	496
Hard lime rock	13	509
Hard sand rock	15	524
Sand rock	4	528
Blue gumbo	11	539
Tough gumbo	40	579
Sand rock	16	595
Blue gumbo	45	640
Hard sand rock	10	650
Gumbo	10	660
Sand rock	30	690
Rock, sand and boulders	20	710
Sand rock and boulders	10	720
Hard sand rock	10	730
Rock, sand and boulders	16	746
Rock sand	10	756
Sand rock and boulders	4	760
Rock sand	20	780
Water sand	60	840
Sand rock	20	860
Rock and and boulders	15	875
Water sand	25	900
Sand rock	10	910
Hard sand rock and boulders	20	930
Sand rock	8	938
Chalk rock	10	948
Hard lime rock	6	954
Hard chalk rock	2	956
Hard rock sand	26	982
Sand rock	7	989
Hard shale	11	1000
Rock sand	10	1010
Sand rock	9	1019
Hard sand rock	15	1034
Hard rock and boulders	2	1036
Hard lime rock	2	1038
Rock	2	1040
Hard rock	2	1042
Sand rock	4	1046
Gumbo	20	1066
Rock sand	6	1072
Sand rock	6	1078
Rock sand and boulders	22	1100
Rock sand and boulders	20	1120
Sand rock	30	1150
Hard rock	2	1152

(Continued on next page)

Drillers' logs of wells in and near Sherman -- Continued

	Thickness (feet)	Depth (feet)
Well T2 -- Continued		
Hard lime rock	4	1156
Hard lime rock and boulders	4	1160
Lime rock and boulders	12	1172
Hard lime rock	6	1178
Lime rock and boulders	12	1190
Gumbo and boulders	12	1202
Hard lime rock	10	1212
Gumbo and boulders	8	1220
Hard lime rock	4	1224
Lime rock and boulders	14	1238
Hard lime rock	12	1250
Lime rock and boulders	15	1265
Marl and boulders	10	1275
Gumbo and boulders	10	1285
Hard lime rock	6	1291
Hard lime rock and boulders	2	1293
Hard rock and boulders	3	1296
Hard lime rock	19	1315
Lime rock and boulders	10	1325
Hard lime rock	5	1330
Red and blue marl	22	1352
Hard lime rock	14	1366
Hard rock	1	1367
Hard lime rock	32	1399
Sand rock and marl	3	1402
Hard sand rock	3	1405
Sand rock and marl	50	1455
Rock sand and marl	40	1495
Fine water sand	15	1510
Blue gumbo	10	1520
Packsand and marl	25	1545
Hard sand rock	10	1555
Packsand soft	10	1565
Packsand and boulders	20	1585
Lime and shale	4	1589
Sand rock and marl	13	1602
Hard sand rock	8	1610
Hard lime rock	2	1612
Blue shale and boulders	33	1645
Blue shale	15	1660
Packsand and marl	35	1695
Lime, water sand	20	1715
Red, blue and white marl	20	1735
Hard sand rock	3	1738
Red marl	10	1748
Packsand and boulders	17	1765
Lime boulders	5	1770
Red, blue and white marl	15	1785
Lime, water sand	15	1800
Hard sand rock and boulders	72	1872

	Thickness (feet)	Depth (feet)
Well T2 -- Continued		
Hard sand rock	20	1892
Red marl	10	1902
Sand rock	10	1912
Red and blue marl	33	1945
Fine sand, soft	2	1947
Red marl and sand	25	1972
Packsand	25	1997
Hard sand rock	2	1999
Sand rock and water	6	2005
Tough blue gumbo	10	2015
Water sand	2	2017
Hard sand rock and water sand	18	2035
Tough blue gumbo	10	2045
Water sand	5	2050
Sand rock and boulders	5	2055
Water sand and boulders	50	2105
Water sand	25	2130
Hard sand rock	2	2132
Water sand	11	2143
Sand rock	3	2146

Well T3

Owned by City of Sherman, drilled in 1944. about 1,500 feet northwest of wells T1 and T2.

	Thickness (feet)	Depth (feet)
Surface soil	3	3
Clay	7	10
Sand	10	20
Blue shale	440	460
Sandy shale and sand	18	478
Shale	63	541
Sand and sandy shale	28	569
Shale	10	579
Shale, sandy shale	68	647
Sand	14	661
Shale, few sand breaks	34	695
Sandy shale	40	735
Sand	41	776
Blue and red shale	77	853
Hard sticky shale	6	859
Hard shale	52	911
Lime and shale	43	954
Hard shale	425	1379
Sand and breaks of shale and lime	50	1429
Hard shale	13	1442
Sand and sandy shale	45	1487

(Continued on next page)

Drillers' logs of wells in and near Sherman -- Continued

Well T3 -- Continued

	Thickness (feet)	Depth (feet)
White and blue shale	59	1546
Sandy shale and shale	25	1571
Hard shale	17	1588
Shale and breaks of hard sand	31	1619
Shale	28	1647
Sandy shale and sand	28	1675
Shale	10	1685
Sand and sandy shale	20	1705
Red and blue shale	12	1717
Shale and hard lime	15	1732
Shale	31	1763
Sandy shale and shale	32	1795
Tough shale	16	1811
Hard red and blue shale	39	1850
Sandy shale	10	1860
Hard red and blue shale	58	1918
Hard lime (2 hours work)	2	1920
Hard red and blue shale	19	1939
Sandy shale and sand	23	1962
Hard sandy shale	18	1980
Sand	35	2015
Sand and shale	16	2031
Sand	24	2055
Sand and shale breaks	61	2116
Hard shale	13	2129
Sand	13	2142
Sand and layers shale	13	2155
Sand	12	2167
Hard shale	2	2169

Well W4

Owned by City of Sherman, drilled in 1912-13.

	Thickness (feet)	Depth (feet)
Sandy soil	6	6
Yellow clay	14	20
Sand and gravel	14	34
Soapstone and shale	13	47
Gumbo, hard and tough	16	63
Sand rock	1	64
Blue shale	19	83
Shale with streaks of gumbo	57	140
Blue shale	60	200
Gumbo, very tough	23	223
Sand rock	3	226
Shells	19	245
Sand rock	2	247
Blue shale	63	310

Well W4 -- Continued

	Thickness (feet)	Depth (feet)
Black gumbo	13	323
Shale, light-colored	89	412
Sand rock	3	415
Blue shale	46	461
Black gumbo	9	470
Light-colored soapstone	15	485
Sand rock	3	488
Shale, light-colored	52	540
Black gumbo	14	554
Light-colored soapstone	21	575
Hard sandy formation	9	584
Sand rock, very hard	4	588
Hard fine sand, first Woodbine	26	614
Sand rock	4	618
Light-colored soapstone	8	626
Soapstone and shale	14	640
Blue gumbo, very sticky	25	665
Shale	18	683
Sand rock	2	685
Gumbo	17	702
Soapstone streaks shale	19	721
White sand, second Woodbine	57	778

Well 13

Owned by St. Louis, San Francisco and Texas Railway Company at Round House.

	Thickness (feet)	Depth (feet)
Clay	14	14
Shale and sand	13	27
Sticky shale	52	79
Rock	1	80
Shale	28	108
Rock	1	109
Shale	25	134
Sticky shale	11	145
Shale	13	158
Broken lime	1	159
Shale	55	214
Shale and sandy shale	25	239
Shale	61	300
Sandy shale	8	308
Sticky shale	8	316
Hard sand	4	320
Shale	19	339
Broken lime	2	341
Shale	22	363
Sandy shale	4	367
Shale	83	450

(Continued on next page)

Drillers' logs of wells in and near Sherman, Texas -- Continued

	Thickness (feet)	Depth (feet)
Well 13 -- Continued		
Sand and hard layers	10	460
Sandy shale	24	484
Rock broken	5	489
Sand	4	493
Shale	35	528
Sandy shale and shale	22	550
Sand, shale and shells	23	573
Hard sand	4	577
Sand with hard layers	43	620
Shale	32	652
Hard sand and shale	26	678
Shale and red beds	55	733
Sand	57	790
Shale and shells	15	805

Well 19

Owned by Sherman Manufacturing Company.

	Thickness (feet)	Depth (feet)
Yellow sand	32	32
White rock	39	71
Hard rock	1	72
Blue shale	139	211
Blue rock	9	220
Blue marl	140	360
Blue marl and shells	143	503
Blue gumbo	14	517
Hard rock	3	520
Blue gumbo	16	536
Hard rock	1	537
Hard blue gumbo	30	567
Hard sand rock	3	570
Hard blue shale	63	633
Soft sand (white) first water	25	658
Sandy shale	12	670
Hard sand rock	2	672
Extra hard shale	8	680
Hard blue gumbo	49	729
Soft white water sand second water	47	776

Perrin Field, U. S. Army.

	Thickness (feet)	Depth (feet)
Surface clay	10	10
Blue shale	59	69
Shale and chalk	41	110
Sand, shale and shells	185	295
Shale and shells	62	357
Perrin Field Well -- Continued		
Shale and lime shells	51	408
Sand and lime shells	30	438
Broken sand, shale and shells	130	568
Shale	17	585
Sand	25	610
Shale	41	651
Shale, blue and brown	24	675
Shale and lime streaks	7	682
Sand and lime streaks	23	705
Shale	12	717
Broken sand and lime	28	745
Shale and lime shells	63	808
Shale and lime streaks	22	830
Lime	5	835
Sand and lime streaks	67	902
Broken lime and shale	44	946
Shale and lime	44	990
Broken lime and shale	57	1047
Shale and lime streaks	52	1099
Broken lime and shale	131	1230
Sand, shale, and shells	28	1258
Lime	32	1290
Shale and lime shells	6	1296
Sand	5	1301
Sandy shale and lime shale	17	1318
Sand	8	1326
Sandy shale	76	1402
Sand	14	1416
Sandy shale	9	1425
Sand	2	1427
Broken sand and shale	13	1440
Hard sand, shale	32	1472
Sand	3	1475
Shale, sand, hard lime	35	1510
Sandy shale	8	1518
Sandy shale and lime shells	82	1600
Shale	2	1602
Sand, shale, lime shells	65	1667
Lime	9	1676
Sandy shale	9	1685
Hard lime	53	1738
Shale	27	1765
Sand	10	1775
Lime, broken shale	23	1798
Sand, shale and shells	9	1807
Shale and shells	27	1834
Broken lime	8	1842
Sandy shale and shells	30	1872
Sand and shale	12	1884
Sand	5	1889

(Continued on next page)

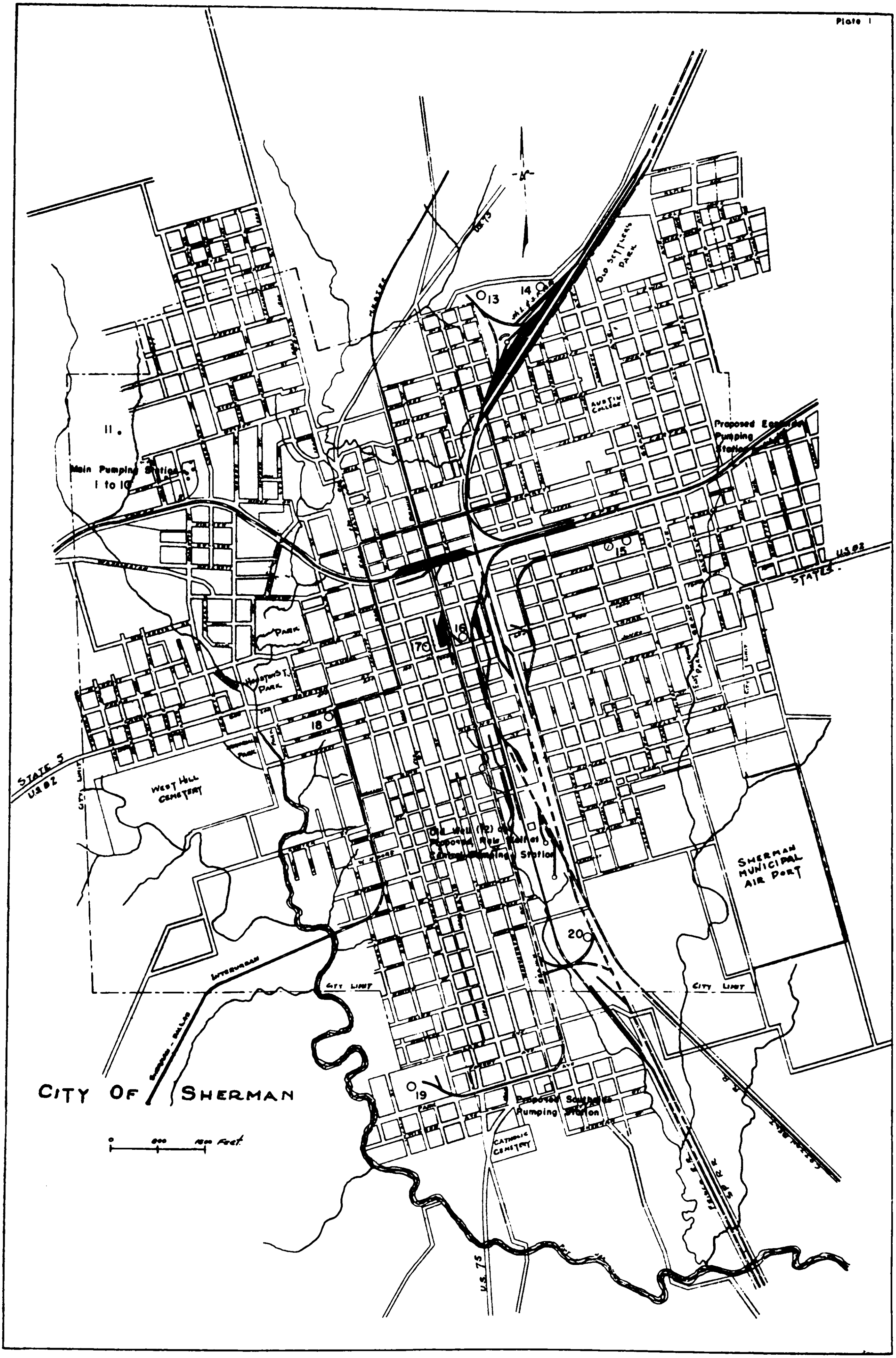
Drillers' logs of wells in and near Sherman, Texas -- Continued

	Thickness (feet)	Depth (feet)
Perrin Field Well -- Continued		
Hard sandy lime	12	1901
Sand, shale, shells	19	1920
Hard sandy lime and shale	9	1929
Broken sand and lime, hard	6	1935
Sandy shale and shells	25	1960
Hard sand	9	1969
Medium soft sand	7	1976
Broken sand and shale	5	1981
Sandy shale	8	1989
Soft sand	26	2015
Medium soft sand	16	2031
Soft sand	13	2044
Hard sand and medium lime	23	2067
Hard sand	15	2082
Sandy shale	9	2091
Hard sand and brown sticky shale	12	2103
Sand and brown shale	7	2110
Red shale and sand	8	2118
Hard sand and red shale	13	2131

Records of Sherman City wells

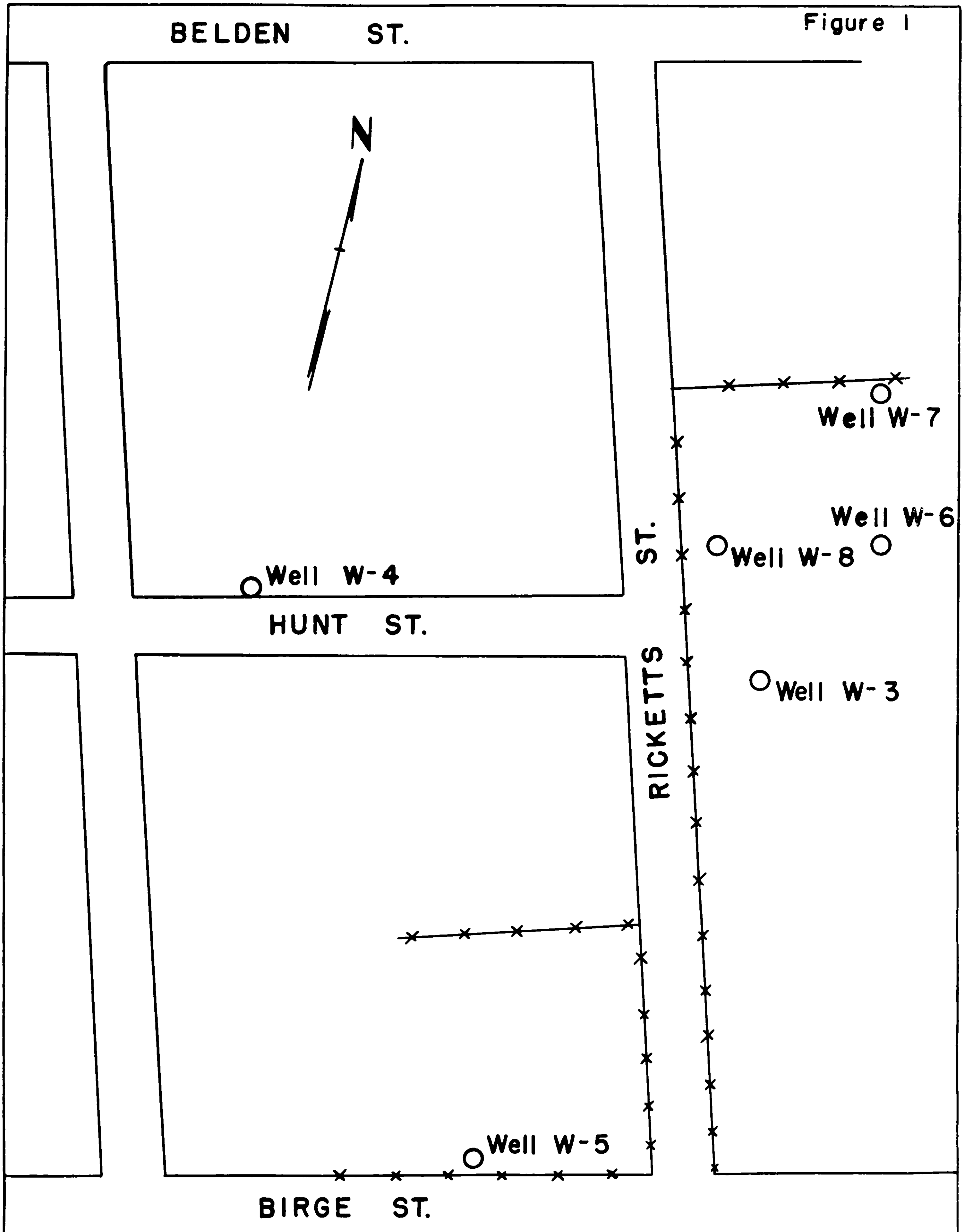
Well	Location	Date drilled	Depth of well (ft.)	Diameter of well (in.)	WATER LEVEL Below land surface (ft.)	Pump	Yield (gpm)	Remarks
W1	Birge and Ricketts Streets	1909	800±	8	-	Double action Cylinder	80 to 90	Not pumped during test of July 1945.
W2	do.	1909	800±	8	-	do.	80 to 90	Do.
W3	do.	1911	778	8	443.0	Air lift	80 to 90	103 feet southeast of well W8, not pumped during test of July 1945.
W4	do.	1913	778	8	444.5	Deep well turbine	300	348 feet west of well W8, not pumped during test of July 1945.
W5	do.	1916	775	8	444.2	None	-	477 feet southwest of well W8. Not used for several years.
W6	do.	1917	785	-	443.5	Air lift	90	117 feet east of well W8, not pumped during test of July 1945.
W7	do.	1917	786	-	444.3	do.	90	170 feet northeast of well W8, not pumped during test of July 1945.
W8	do.	1917	786	8	-	Deep well turbine	275	Pumped for test during July 1945.
T1	do.	1921	2,140	-	See remarks	do.	175	459 feet from well T2 and 529 feet from well T3. Water level 243 feet after shutdown of 14 hours. Pumping level 315 feet after three days of pumping.
T2	do.	1921	2,143	12 to 8	-	do.	360	
T3	Near Wharton and McGee Streets	1944	2,169	14	256.2	do.	540	Water level measured after wells T1, T2 and T3 were shutdown 39 hours. Pumping level 524 feet below land surface after 23 hours of pumping.

Plate 1



Main Pumping Station
1 to 10
11
13
14
Old Settlers Park
Austin College
Proposed Eastside Pumping Station
15
16
17
18
Park
Houston St. Park
West Hill Cemetery
State 5
U.S. 82
State 5
Sherman Municipal Air Port
20
City Limit
City Limit
19
Proposed Southside Pumping Station
Catholic Cemetery
U.S. 75
City of Sherman
0 900 1800 Feet

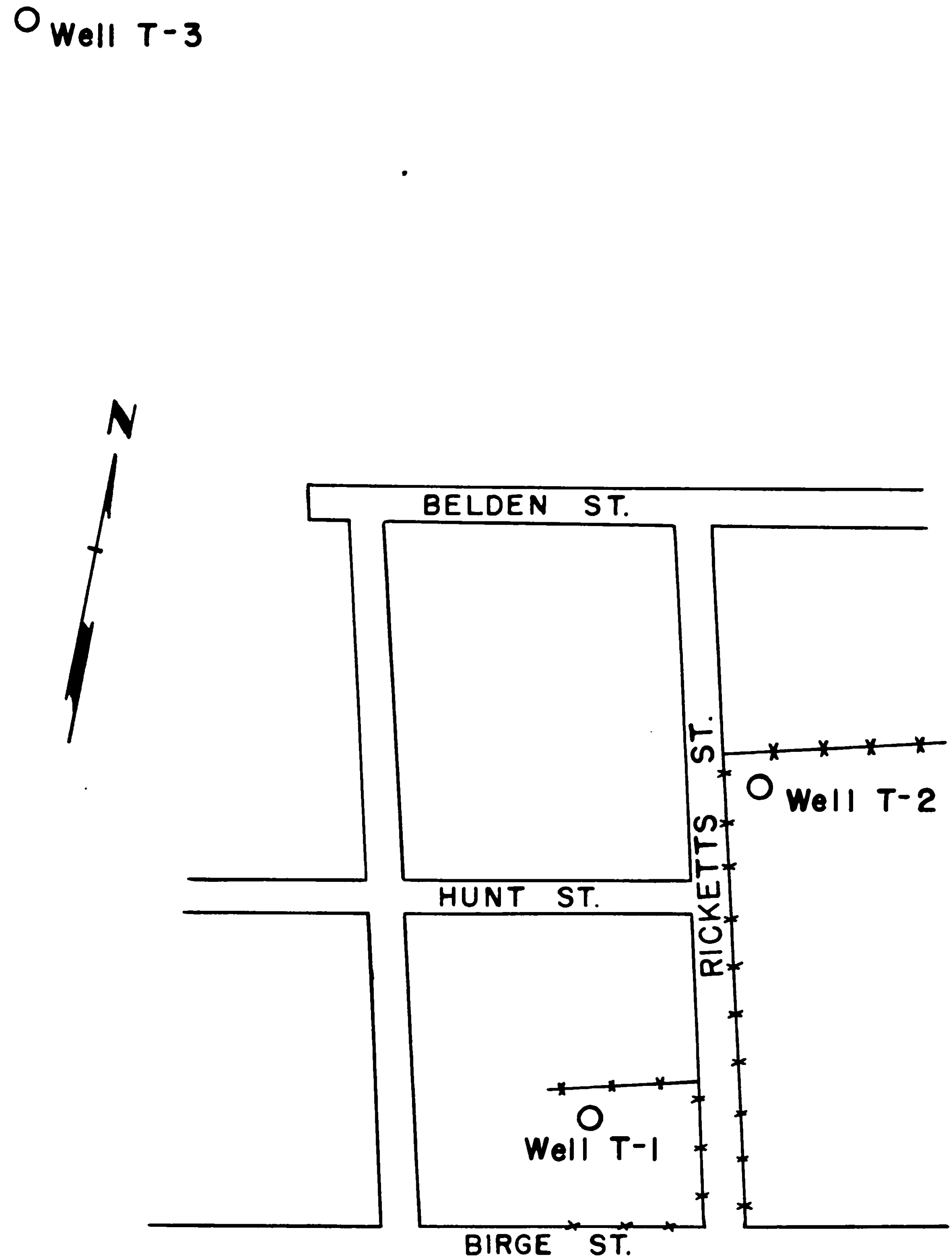
Figure 1



SKETCH SHOWING LOCATIONS OF CITY OWNED WELLS
DRAWING WATER FROM WOODBINE SAND, SHERMAN, TEXAS
1945
SCALE 1"= 100'

MLC-8-45

Figure 2



SKETCH SHOWING LOCATIONS OF CITY OWNED WELLS DRAWING WATER FROM LOWER PALUXY SAND, SHERMAN, TEXAS 1945

SCALE 1" = 200'

MLC-8-45