TEXAS STATE BOARD OF WATER ENGINEERS

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PROGRESS REPORT ON THE GROUND-WATER RESOURCES OF THE HOUSTON DISTRICT

January 1942

By

W. N. White, N. A. Rose and W. F. Guyton

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INTRODUCTION

History of investigation and previous reports

An investigation of the supply of ground-water available for the Houston district, comprising all of Harris County and parts of adjoining counties, has been in progress since December 1930, when funds have permitted, as part of a survey of the ground-water resources of Texas by the United States Department of the Interior, Geological Survey, in cooperation with the Texas State Board of Water Engineers. This investigation is under the general direction of O. E. Meinzer, geologist in charge of the division of ground-water in the Geological Survey. The results of the investigation have been summarized in six mimeographed progress reports, the first of which was released to the public in October 1932, and the last in November 1940. All periodic water-level measurements made before December 31, 1940, have been published by the Geological Survey.[1/]

The current phase of the investigation was begun in the fall of 1938 when $5,000 was allocated by the City of Houston for the investigation and was matched with Federal funds. Additional appropriations of $5,000 each were made in the springs of 1940 and 1941 and were also matched with Federal funds.

In addition to a discussion of the geology, pumpage and water-level fluctuations, the 1940 progress report included a summary of the results of a program of test well drilling made by the City in the summer of 1939. A detailed report of

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1/ Water levels and artesian pressure in observation wells in the United States: U. S. Geol. Survey, Water-Supply Papers 777, 840, 845, 886 and 909.

this exploratory drilling was released to the City in July 1940, and will be published by the Geological Survey.[2] The progress report also included the results of pumping tests made to determine the transmissibility and storage capacity of the water-bearing beds. Papers giving the results of the tests and their application in more detail were published in the American Geophysical Union Transactions of 1941.[3] [4]

The following is copied from the summary on pages 33 to 35 of the 1940 report:

> The aggregate annual pumpage in the Houston and Pasadena areas was nearly constant from 1930 to 1936, inclusive, but it increased about 60 percent between 1937 and 1940. In the Katy area the annual pumpage decreased slightly between 1930 and 1935, inclusive, but increased about 200 percent between 1936 and 1940. The total annual pumpage in the Houston district was nearly doubled in the five-year period.
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> From 1930 to 1937, inclusive, the water levels in the Houston and Pasadena areas remained practically constant, indicating that essential equilibrium in water levels had been reached for the amount of water pumped. As was to be expected, the increased pumpage in 1937 caused a marked decline in water levels, an increased hydraulic gradient, an expansion of the cone of depression, and the removal of water from artesian storage. Further increases in pumpage in 1939 and 1940 caused further decline and depletion. Since 1937 the head in the artesian aquifers has declined over a wide area perhaps to the outcrop area. A part of the water that is pumped is taken from artesian storage in the pumping areas, but most of it is being drawn into these areas through the aquifers. The water that is drawn into these areas is replenished in large part by recharge on the outcrop area, but a substantial part of it is also drawn from storage in the artesian aquifers outside of the pumping areas. The evidence obtained to date indicates that the pumping has not yet drawn water from storage in the outcrop area.

2/ N. A. Rose, W. N. White and Penn Livingston, Exploratory well drilling in the Houston district, Texas, manuscript, July 1940.

3/ C. E. Jacob, Coefficients of storage and transmissibility obtained from pumping tests in the Houston district, Texas, Trans. Amer. Geophys. Union, pp. 744-756, 1941.

4/ W. F. Guyton, Application of coefficients of transmissibility and storage to regional problems in the Houston district, Texas, Trans. Amer. Geophys. Union, pp. 756-770, 1941.

In the Katy area, the decline in water levels has been less than in the Houston and Pasadena areas, but it represents in part an unwatering of the beds, and hence a larger proportion of the water derived from storage. If the present rate of pumping in the Katy area is continued the local ground-water reservoir will be seriously depleted.

If pumping at the present rate of 79,000,000 [5/] gallons a day in the Houston and Pasadena areas is continued, the artesian head will continue to decline for some years, although at a diminishing rate. If the rate of pumping is substantially decreased, the water levels will rise, but they will probably not return to the altitudes at which they stood when a similar pumping rate was maintained at an earlier time. Any increase over the present rate of pumping will cause further decline in water levels, withdrawal of additional water from artesian storage, further steepening of the hydraulic gradient, and increased flow of ground water into the pumping areas. The question as to further increase in the rate of pumping is partly a question of the maximum depth from which water can be economically pumped, but it also involves the further depletion of the storage in the ground-water reservoir, the possibility of withdrawing water at a more rapid rate than it can be replaced from rainfall in the outcrop areas, and the possibility of increasing the danger of encroachment of salt water. If it is desired to maintain the water levels at or near their present altitudes the present rate of pumping should be reduced and a supplementary supply of water should be developed.

Analyses of water samples taken periodically since 1931 from selected wells have thus far not given any evidence of intrusion of salt water into the fresh water-bearing sands of the area from down dip or from underlying salt-water sands. However, this intrusion may be occurring beyond the limits of observation wells. Further lowering of the head in the fresh water-bearing beds will increase the possibility of the intrusion.

Previous reports have indicated that additional supplies for the City of Houston could be obtained from wells west of Houston in the direction of Clodine. To obtain an additional supply from this area is now less promising because of the large increase in pumpage during the last two years in the nearby Katy area, with the resulting large withdrawal of water from storage. Although the information at hand indicates that a supplementary supply of ground water may be obtained in the area north of Houston, including the Aldine-Westfield locality, from sands which lie stratigraphically deeper than the heavily-pumped sands of the Houston and Pasadena areas, the information is insufficient to allow estimates to be made of the quantity and quality of the water. Additional test drilling would serve to show the character and extent of these sands and the quality of the water in them.

5/ 1940 figure corrected.

Field operations and office studies in 1940 and 1941

During 1940 and 1941 records of about 600 important wells in Harris County and adjacent areas in Fort Bend and Waller Counties were obtained, and records of about 400 others, which were published in 1939, were brought up to date. The data included the depth of well, size of casing, position of screens, method of lift, reported yield, drillers' and electrical logs and other important information. Water samples were collected from many of the wells and analyzed for their chemical character. The well records and chemical analyses and a part of the logs were compiled and tabulated and will be released at an early date in mimeographed form. Records of the average daily pumpage from all of the important municipal, industrial, and irrigation wells were obtained and compiled during the latter part of 1941.

Measurements of water levels were made at intervals ranging from one to three months in about 220 observations wells, including 23 Houston municipal wells. A part of these wells are in the Houston and Pasadena pumping areas, a part in the Katy rice-growing area, and a part in the outcrop area of the water-bearing sands along the Houston-Hempstead and Houston-Conroe highways. The water levels in 52 shallow test wells, comprising 13 groups of two to six wells each at various places in the outcrop area, have been measured regularly in connection with studies of the recharge. Records of the water-level measurements in the Houston municipal wells from 1938 to 1941 were compiled and released in manuscript form to the City Water Department in the fall of 1941. The periodic analyses of water from about 60 selected wells throughout the area, made to determine whether the character of the water is changing, were continued.

RAINFALL

The rainfall in most of Texas was unusually heavy during the year ending November 1, 1941. According to the records of the U. S. Weather Bureau, the rainfall for this period at Houston amounted to 72.32 inches, or about 60 percent more than the average for 60 years. At Hempstead, about 50 miles northwest of Houston, it was 79.48 inches or about twice the average for 50 years. At Conroe, about 40 miles north of Houston, it was 87.06 inches or about 80 percent above the average for 23 years. The rainfall during the summer months, April to September inclusive, in 1941 was 37.02 inches at Houston, 29.98 inches at Hempstead, and 38.91 inches at Conroe. Because of the abnormally high rainfall the requirements for watering lawns and gardens and for industrial cooling during the summer were much less than usual and only about half as much water as usual was used for rice irrigation.

PUMPAGE

General Statement

Nearly all of the water pumped in the Houston district comes from approximately 350 wells, of which 255 are in the Houston and Pasadena areas, and 95 in the Katy rice-irrigation area. The estimated average quantities of water pumped in the Houston, Pasadena, and Katy areas in 1930, 1935, 1937, 1939, 1940, and 1941 are given in millions of gallons a day in the following table.

Estimated average daily pumpage in the Houston, Pasadena and Katy pumping areas (in millions of gallons a day) a/

	1930	1935	1937	1939	1940	1941
Houston Water Department (from city records)	25.8	24.5	25.2	27.2	b/28.8	27.2
Houston independent public water supplies and industrial wells	14	14	16	16	17	17
Pasadena industrial wells	10	10	29	29	b/33	34
Total in the Houston and Pasadena pumping areas	50	49	70	72	79	78
Katy pumping area	18	14	30	40	45	23
Total	68	63	100	112	124	101

a/ For convenience in compiling, all figures are given as daily averages throughout the year.

b/ Figures in 1940 report corrected.

Houston and Pasadena pumping areas

The Houston Water Department owns and operates 23 wells in seven groups widely spaced over the city. The average daily pumpage from these wells by months in 1930, 1935, and in the five years from 1937 to 1941 inclusive is given in the following table.

Average daily pumpage by the Houston Water Department (in millions of gallons a day)

	1930	1935	1937	1938	1939	1940	1941
January	24.5	22.9	22.2	22.3	21.9	28.2	23.6
February	24.6	22.9	22.2	22.4	21.8	24.9	23.3
March	24.0	24.0	21.9	23.6	24.1	27.0	23.8

Average daily pumpage by the Houston Water Department--Continued
(in millions of gallons a day)

	1930	1935	1937	1938	1939	1940	1941
April	25.9	23.7	23.6	23.8	26.9	27.1	26.3
May	25.0	24.2	29.2	25.4	29.4	29.7	27.6
June	27.9	25.8	27.7	26.9	30.7	29.2	28.0
July	28.5	27.0	28.1	27.9	32.1	31.1	31.5
August	28.2	27.5	27.8	27.8	32.2	36.1	32.2
September	27.7	24.8	27.4	26.9	29.9	33.8	29.5
October	26.0	24.2	25.5	26.6	27.5	28.8	28.0
November	24.5	22.6	23.9	23.5	25.2	24.7	26.5
December	23.7	22.5	22.7	22.2	24.2	23.6	26.4
Average	25.8	24.4	25.2	25.0	27.2	28.8	27.2

Most of the suburban communities obtain public supplies from their own wells and industrial requirements are met in large part from privately-owned wells. The following table gives the estimated average daily pumpage during 1941 for public water supply and for industrial use. The table is subdivided to show the pumpage by the City Water Department, the independent public water supply agencies and the nine classes of industrial activities using the most water.

Estimated average daily pumpage for public and industrial supply in the Houston and Pasadena areas in 1941

	Number of plants	Number of wells	Daily pumpage (million gallons a day)
Houston Water Department	7	23	27.2
Paper mill	1	9	21.0
Oil refineries	6	21	11.8
Railroads	10	21	3.0
Ice plants	18	24	3.0

Estimated average daily pumpage for public and industrial supply in the Houston and Pasadena areas in 1941--Continued

	Number of plants	Number of wells	Daily pumpage (million gallons a day)
Independent public water supplies	20	33	2.3
Office buildings, hotels and theatres	26	29	1.7
Meat packing plants	3	6	1.3
Tool companies	2	3	1.2
Laundries	13	13	0.9
Light and power plants	2	5	0.8
Miscellaneous industrial plants using more than 5,000 gallons a day	57	68	3.9
Total	165	255	78.1

During 1941 the total estimated average pumpage in the Houston and Pasadena areas was 78,000,000 gallons a day, or 1,000,000 gallons a day less than in 1940. The average daily consumption for public supply was about 2,000,000 gallons a day less than in 1940, although the number of consumers increased during the year. The unusually heavy rainfall and frequency of showers during the summer apparently was responsible for the decrease as comparatively little water was needed for lawns and gardens. The average daily pumpage by industries in 1941 was about 1,000 000 gallons more than in 1940. The average daily withdrawals for industrial use during the winter months of 1941 were materially greater than during the corresponding months of the preceding year, due to pumping by new industries and an increase in consumption by a number of others. Less water was used during the summer, however, as the demands for cooling purposes were less than usual. It follows that the total pumpage in the Houston-Pasadena area was more evenly distributed throughout the year than usual.

Katy rice-growing area

The following table shows the number of wells used for the irrigation of rice in the Katy area, the number of acres irrigated, the total amount of water pumped, in acre feet, and the amount of water, including rainfall, applied to the land per acre per season for 1930, 1935, 1937, 1938, 1939, 1940 and 1941.

Pumpage and rainfall in the Katy rice-growing area

	1930	1935	1937	1938	1939	1940	1941
Number of wells	45	40	61	71	78	88	95
Total number of acres irrigated	9,400	8,000	13,750	16,370	19,950	24,200	27,350
Total amount of water pumped, in acre-feet a/	20;200	15,700	33,600	28,000	44,900	50,400	25,800
Acre-feet of water pumped per acre	2.2	1.9	2.5	1.7	2.2	2.1	0.9
Rainfall, in feet (May to September) b/	0.9	1.9	0.9	1.9	1.6	1.4	2.6
Total amount of water applied to the land (irrigation + rainfall), in acre-feet per acre	3.1	3.8	3.4	3.6	3.8	3.5	3.5

a/ One-acre foot equals approximately 326,000 gallons.
b/ Average of rainfall recorded by U. S. Weather Bureau at Hempstead, Houston, Sealy and Sugarland. No record for Hempstead in 1938 or Sealy in 1939.

Records of the American Rice Growers Cooperative Association show that in the Katy area, which comprises approximately 300 square miles, about 27,350 acres of rice were planted during 1941 and irrigated with water pumped from 95 wells as compared with 24,200 acres planted and irrigated from 88 wells in 1940 (see figure 1, page 23). The total pumpage was about one-half that for 1940 or the equivalent

of about 23,000,000 gallons a day throughout the year, as compared with 45,000,000 gallons a day in 1940. However, the decrease in the use of irrigation water was compensated by the increase in rainfall during the growing season, and the total amount of water applied to the land per acre during the growing season remained about the same as it was in the six former years. This amount of water has been remarkably uniform throughout the seven years.

DECLINE OF WATER LEVELS IN WELLS

(See figures 1 and 2, pages 23 and 24 for location of observation wells)

Houston, Pasadena and adjacent localities

The general decline in water levels in the Houston and Pasadena areas, which began in 1937, continued during 1941, but at a somewhat slower rate.

In Pasadena and eastern Houston, the average decline between the spring of 1940 and the spring of 1941 was only slightly less than between the springs of 1939 and 1940. However, the rate of pumping throughout 1941 was unusually uniform, the decline in water levels during the summer was much smaller than usual, and the levels were only slightly lower in the early fall of 1941 than at the same time in 1940. The pumping was not decreased as much as usual after the summer months and most of the water levels showed a net decline for the year.

In northern Houston, the average decline in water levels between the springs of 1940 and 1941 was a little less than half that of 1939-40. The fall measurements in 1941 in general were no lower than those in 1940. A small rise in levels occurred late in 1941.

In central and western Houston, the average decline between the springs of 1940 and 1941 was approximately the same as during the previous year. Partly as a result of decreased pumping in the summer of 1941, however, a rise was shown between the

lowest measurements in the fall of 1940 and the lowest measurements in the fall of 1941. A normal rise also occurred after the 1941 low.

In the localities west and north of Houston, the average decline between the spring measurements of 1940 and 1941 was one-half to two-thirds as much as during the preceding year. A small rise was shown between the lowest measurements recorded in the falls of the two years.

The rate of pumping from wells screened opposite the comparatively shallow, lightly-pumped sands in the Houston and Pasadena areas increased during 1941. This increase resulted in declines between the spring and fall measurements of 1940 and 1941 which were about the same or slightly more than during the preceding year.

The decline of water levels between 1937 and 1941 in observation wells screened opposite the heavily-pumped sands in Houston, Pasadena and adjacent localities is shown in the following table.

Decline of water levels in wells screened opposite the heavily-pumped sands in the Houston, Pasadena and adjacent localities, in feet, 1937 to 1941

Well No.	Distance from Pasadena (miles)	Depth (feet)	Spring measurements					Fall measurements	
			1937-38	1938-39	1939-40	1940-41	1937-41	1939-40	1940-41
			Vicinity of Pasadena						
1182	½ W	685	--	--	--	20.88	--	12.90	1.92
1187	1 W	834	--	+0.13	18.93	7.6	--	15.8	--
1231	1 W	834	--	+1.47	19.34	6.0	--	11.14	--
1176	2 NW	1,134	28.99	2.90	+1.48	6.05	36.46	6.08	9.24
1170	2 W	836	31	+0.5	19.5	6.5	56.5	18.5	0.0
1161	2½ W	1,228	25	3.5	10	13.89	52	16.64	--
1150	2½ NW	680	--	--	--	13	50	13.10	3.14

Plus (+) indicates rise in the water levels.

Decline of water levels in wells screened opposite the heavily-pumped sands in the Houston, Pasadena and adjacent localities, in feet, 1937 to 1941--Continued

Well No.	Distance from Pasadena (miles)	Depth (feet)	Spring measurements					Fall measurements	
			1937-38	1938-39	1939-40	1940-41	1937-41	1939-40	1940-41
			Vicinity of Pasadena--Continued						
883	3⅓ W	841	--	--	11.24	12.36	--	13.96	0.29
1229	4 S	1,680	--	--	--	14.56	--	20.88	2.97
1230	4 S	1,419	--	--	--	12.95	--	12.14	6.08
890	4½ W	1,284	22.12	--	--	10.04	49	--	--
1302	6½ S	832	18	4.5	4.79	7.49	35	7.60	3.84
933	7 N	850	--	--	--	7.45	--	7.47	1.54
			Eastern Houston						
881	5 W	650	15.90	6.00	8.92	7.85	38.67	9.79	1.44
878	5 W	905	24.64	4.54	8.63	8.73	46.54	14.5	+2.2
913	5½ W	876	--	6.38	7.17	7.97	--	9.68	1.83
759	5½ NW	569	16.49	5.99	9.83	5.83	38.14	8.45	3.45
876	6½ W	--	--	--	5.57	9.63	5.80	--	7.58
757	6⅔ NW	676	13.2	6.57	9.91	4.2	33.9	9.7	+1.0
751	7 NW	540	12.56	6.62	9.88	6.24	35.30	9.58	0.55
748	7½ NW	721	--	--	--	6.06	--	9.26	0.32
			Northern Houston						
662	10 NW	834	12.20	7.21	15.65	+0.28	34.78	12.43	+4.13
663	10 NW	740	--	--	7.44	1.29	--	4.54	1.08
656	11½ NW	665	10.79	6.13	10.11	3.86	30.89	9.40	0.0
585	12⅔ NW	950	--	--	9.27	4.34	--	--	--

Plus (+) indicates rise in the water levels.

Decline of water levels in wells screened opposite the heavily-pumped sands in the Houston, Pasadena and adjacent localities, in feet, 1937 to 1941--Continued

Well No.	Distance from Pasadena (miles)	Depth (feet)	Spring measurements					Fall measurements	
			1937-38	1938-39	1939-40	1940-41	1937-41	1939-40	1940-41
			Central and western Houston						
680	9½ NW	1,280	13.20	+2.57	3.88	11.67	26.18	12.3	1.7
790	10½ W	606	+1.12	10.29	6.18	3.59	18.94	5.77	--
619	10½ NW	625	2.18	8.71	7.51	3.95	22.35	10.17	+4.42
788	11 W	1,416	--	--	3.90	9.06	--	4.54	--
623	11 NW	900±	--	--	5.97	3.51	--	5.20	3.20
620	11½ W	1,379	--	--	2.52	9.0	--	5.94	--
787	12 W	701	--	--	4.63	0.66	--	4.83	+1.57
779	12 W	584	--	--	4.82	3.58	--	--	--
780	12 W	732	--	--	4.57	4.30	--	9.07	--
606	12 NW	575	4.56	7.67	7.57	2.93	22.73	8.23	+2.06
609	12 NW	825	--	--	7.09	2.82	--	8.81	+3.40
602	13½ W	1,038	7.69	5.83	6.23	4.64	24.39	10.29	+2.80
			Locality west of Houston						
804	14½ W	650±	6.20	6.15	5.09	--	--	--	--
783	15½ W	350±	2.67	5.17	4.34	2.44	14.62	4.85	+0.40
809	16 W	1,100±	6.37	3.88	6.61	7.05	23.91	9.88	+1.43
840	16 W	827	--	--	5.07	3.70	--	3.15	0.29
473	18½ W	416	--	--	3.94	3.04	--	4.38	+1.31
498	19½ W	787	--	--	3.72	2.58	--	3.71	+0.97
472	20 W	365	--	--	3.68	1.27	--	4.11	+2.03
490	23½ W	1,272	--	--	--	2.57	--	3.35	1.40
489	25½ W	472	--	--	--	1.22	--	3.85	+1.56

Plus (+) indicates rise in the water levels.

Decline of water levels in wells screened opposite the heavily-pumped sands in the Houston, Pasadena and adjacent localities, in feet 1937 to 1941--Continued

Well No.	Distance from Pasadena (miles)	Depth (feet)	Spring measurements					Fall measurements	
			1937-38	1938-39	1939-40	1940-41	1937-41	1939-40	1940-41
			Locality north of Houston						
650	14 NW	468	--	--	5.84	3.74	--	5.83	0.15
649	16 NW	367	--	--	4.84	3.06	--	5.38	+1.05
648	16 NW	301	--	--	--	2.94	--	4.34	0.0
302	18 N	1,000-	--	--	2.66	2.44	--	2.70	1.42
256	21 NW	189	2.70	2.57	3.14	--	--	--	--
264	21 NW	900+	11.78	2.47	2.92	0.03	17.20	2.22	+1.50
225	23½ NW	616	--	--	2.54	0.29	--	4.85	+1.60
268	24½ N	815	--	--	--	1.3	--	2.0	+0.8
221	24½ NW	208	--	--	2.63	+2.73	--	4.42	+4.82

Plus (+) indicates rise in the water levels.

A summary of the more important declines from 1940 to 1941 and 1937 to 1941, based on spring measurements, is as follows:

Vicinity of Pasadena:-- In 13 observation wells near Pasadena, the decline in water levels between the springs of 1940 and 1941 ranged from 6.0 to 20.9 feet and averaged 10.7 feet. The decline between 1937 and 1941 in six wells, for which comparable records are available, ranged from 35.0 to 56.5 feet and averaged 46.5 feet (see figure 3, page 25).

Eastern Houston:-- In eight observation wells in eastern Houston the decline between the springs of 1940 and 1941 ranged from 4.2 to 8.7 feet and averaged 6.6 feet. The decline between 1937 and 1941 in five wells ranged from 33.9 to 46.5 feet and averaged 38.5 feet (see figure 4, page 26).

Northern Houston:-- In three wells in northern Houston, the decline ranged from 1.3 to 4.3 feet between the springs of 1940 and 1941 and averaged 3.2 feet. In one well there was a rise of 0.3 foot. In two wells, the decline was 30.9 and 34.8 feet between 1937 and 1941 (see figure 7, page 29).

Central and western Houston:-- Observations in central and western Houston in 12 wells showed a decline between the springs of 1940 and 1941 ranging from 0.7 to 11.7 feet and averaging 5.0 feet. The decline in five wells between 1937 and 1941 ranged from 18.9 to 26.2 feet and averaged 22.9 feet (see figure 5, page 27).

Locality west of Houston:-- West of Houston, the decline in eight wells between the springs of 1940 and 1941 ranged from 1.2 to 7.1 feet and averaged 3.0 feet. The decline in two wells between 1937 and 1941 was 14.6 and 23.9 feet (see figure 6, page 28).

Locality north of Houston:-- North of Houston, the decline in seven wells between the springs of 1940 and 1941 ranged from 0.1 to 3.7 feet and averaged 1.9 feet. In one well there was a rise of 2.7 feet. The decline in one well between 1937 and 1941 was 17.2 feet (see figure 7, page 29).

Records of the decline in water levels in observation wells that in general are considerably shallower than the wells listed in the preceding table and draw water from the more lightly-pumped sands are given in the following table.

Decline of water levels in wells screened opposite the lightly-pumped sands in the Houston, Pasadena and adjacent localities, in feet 1937 to 1941

Well No.	Distance from Pasadena (miles)	Depth (feet)	Spring measurements					Fall measurements	
			1937-38	1938-39	1939-40	1940-41	1937-41	1939-40	1940-41
1209	4½ S	650±	6.49	4.22	2.33	4.32	17.36	3.08	3.0
886	5 W	540	6.58	1.19	5.38	--	--	4.00	--

Decline of water levels in wells screened opposite the lightly-pumped sands in the Houston, Pasadena and adjacent localities, in feet, 1937 to 1941--Continued

Well No.	Distance from Pasadena (miles)	Depth (feet)	Spring measurements					Fall measurements	
			1937-38	1938-39	1939-40	1940-41	1937-41	1939-40	1940-41
738	8½ NW	205	3.03	0.40	2.06	3.39	8.88	2.6	4.4
778	11½ W	404	--	--	3.78	1.11	--	--	--
820	11½ W	310	0.60	3.89	2.43	2.89	9.81	3.05	--
608	12 NW	350	--	--	4.40	4.1	--	3.60	5.12
604	12½ NW	340	0.57	+1.02	4.93	2.22	6.70	2.63	7.15

Plus (+) indicates rise in the water levels.

The decline in six of these wells between 1940 and 1941 ranged from 1.1 to 4.3 feet and averaged 3.0 feet; the decline between 1937 and 1941 in four wells ranged from 6.7 to 17.4 feet and averaged 10.7 feet.

In the following table, the decline in water levels in the Houston municipal wells from 1939 to 1940 and from 1940 to 1941 are shown. With one exception the figures are based on winter and spring measurements. With each measurement recorded in 1940 and 1941, the time the pump on the well was idle before the measurement was made is given.

Decline of water levels recorded in Houston municipal wells, 1939 to 1941

Plant	Well	Decline from 1939 to 1940 1/	Date (1940)	Depth to water (feet)	Time of shut down 2/	Date (1941)	Depth to water (feet)	Time of shut down 2/	Decline from 1940 to 1941
Central	F-1	10.59	Feb. 27	103.89	30 min.	Mar. 4	101.74	1 week	+ 2.15
do.	F-5	7.83	Feb. 8	100.91	5⅔ days	do.	99.27	1 week	+ 1.64
do.	F-10	10.04	do.	93.26	8⅔ days	do.	94.02	1 week	0.76
do.	F-11	7.0	Feb. 27	93.0	30 min.	do.	100.0	29 min.	7.0
do.	F-12	11.60	do.	96.25	30 min.	do.	101.5	30 min.	5.25
do.	C-16	4.50	do.	102.33	30 min.	do.	102.42	28 min.	0.09
do.	D-17	13.53	do.	101.03	120 min.	do.	104.0	29 min.	2.97
East End	1	8.28	do.	109.32	30 min.	do.	116.81	30 min.	7.49
Heights	6	8.92	Feb. 28	87.41	29 days	do.	93.40	1 day+	5.99
do.	7	7.65	do.	96.96	30 min.	do.	98.92	30 min.	1.96
do.	8	6.08	Aug. 23	112.47	30 min.	Sept. 9	118.41	31 min.	5.94
Magnolia Park	2	6.92	Feb. 27	90.41	3 weeks	Mar. 4	92.10	3 months	1.69
Northeast	1	12.99	May 9	74.5	30 min.	May 20	84.69	30 min.	10.2
Scott Street	1	14.03	Feb. 27	116.54	90 days+	Mar. 4	124.32	90 days+	7.78
do.	2	17.54	do.	112.41	30 min.	do.	118.20	30 min.	5.79
do.	3	18.66	do.	116.97	30 min.	do.	125.75	30 min.	8.78
do.	4	14.20	do.	107.66	30 min.	do.	114.60	32 min.	6.94
do.	5	15.48	do.	112.84	22⅔ hrs.	do.	121.11	30 min.	8.27
South End	2	5.16	Feb. 28	87.23	35 min.	Mar. 4	93.47	30 min.	6.24
do.	4	3.12	do.	82.16	30 min.	do.	85.34	30 min.	3.18
do.	5	2.52	May 9	120.1	30 min.	May 21	127.03	30 min.	6.9

Plus indicates rise in water levels.

1/ From page 18 of the 1940 report.

2/ Time pump was idle before measurement was taken.

Most of the water-level measurements in the foregoing table do not reflect the true static levels because the wells were not allowed to remain unpumped long enough before the measurements were made to permit the water levels to become static, and because no control was exercised over the rates or times at which the other wells in the fields were pumped. Hence, the water levels measured in a single well at different times are not strictly comparable. However, if the measurements of all the wells at a plant are considered, the individual discrepancies tend to be ironed out and the average of the individual declines gives the approximate magnitude of the decline at that plant. The average decline recorded at each plant from 1939 to 1940 and from 1940 to 1941, respectively, was as follows: Central, 9.3 and 1.8 feet (a small rise is shown in two wells between 1940 and 1941); East End, 8.3 and 7.5 feet; Heights, 7.6 and 4.6 feet; Magnolia Park, 6.9 and 1.7 feet; Northeast, 11.1 and 10.2 feet; Scott Street, 15.8 and 7.5 feet; and South End, 3.6 and 5.4 feet.

Decline in Katy rice-growing area

The following table shows the decline in water levels in observation wells (see figure 1, page 23) in the Katy area between 1931 and 1941.

Decline of water levels in wells in the Katy rice-growing area, based on March measurements

Well No.	Depth of well (feet)	1931 to 1941	1939 to 1940	1940 to 1941	Well No.	Depth of well (feet)	1931 to 1941	1939 to 1940	1940 to 1941
	Harris County					Harris County--Continued			
134	274	--	3.8	2.5	146	250	--	4.0	2.8
136	138	17.1	4.7	3.1	182	239	--	2.8	--
139	134	a/12.8	4.0	2.6	183	284	6.4	2.2	+0.8
140	359	--	3.9	2.5	186	628	9.7	2.5	0.4

Plus (+) indicates rise in the water levels.

a/ Decline between 1933 and 1940.

Decline of water levels in wells in the Katy rice-growing area, based on March measurements--Continued

Well No.	Depth of well (feet)	1931 to 1941	1939 to 1940	1940 to 1941
	Harris County--Continued			
205	615	10.7	--	--
206	450+	5.1	3.6	+2.5
352	470	--	3.5	4.0
357	--	--	1.7	--
362	500	12.7	3.1	1.8
367	535	--	2.5	1.2
370	625	--	2.2	1.1
371	374	--	--	1.0
380	55+	--	0.5	0.3
381	95+	7.9	1.5	0.9
382	185	--	2.8	1.1
384	505	a/9.5	2.8	1.7
385	359	a/5.8	2.3	0.7
399	326	--	1.8	--
400	258	--	1.9	+0.5
	Waller County			
223	787	10.1	2.0	1.6
235	175	13.9	3.5	1.6
247	641	--	2.0	1.4
	Fort Bend County			
7	337	6.7	2.0	1.5
11	170	a/6.1	2.3	1.4
15	172	9.8	2.2	2.2
19	545	8.1	2.0	0.6
20	250	a/5.0	2.3	0.4
21	--	5.1	2.0	0.6
26	657	--	2.0	1.2
33	346	--	1.7	1.8

Plus (+) indicates rise in the water levels.

a/ Decline between 1933 and 1940.

Since a part of the water withdrawn in the Katy area in the last few years has been taken from storage, a net decline in water levels has resulted. The decline in the Katy area in 27 observation wells between March 1940 and March 1941 ranged from 0.3 foot to 4.0 feet and averaged 16 feet. In three of the wells there was a slight rise. The decline in 13 of the wells between March 1931 and March 1941 ranged from 5.1 to 17.1 feet and averaged 9.5 feet (see figure 6, well 205, page 28 and figure 8, page 30).

The decline between March 1940 and March 1941 was approximately one-half of the decline between March 1939 and March 1940. The smaller rate of decline in the latter year was due to (1) a slackening in the rate of yearly increase in the pumping, the increase between 1939 and 1940 being only about one-third of the increase from 1938 to 1939, (2) wider distribution of pumping attending the drilling of new wells, and (3) increased recharge resulting from the unusually heavy rainfall during the winter of 1940-41. In most of the observation wells of the Katy area, the water levels were slightly higher in December 1941 and January 1942 than they were during corresponding months in 1940 and 1941. This was to be expected, as the rainfall was unusually heavy in 1941 and the pumpage was only about half as great as in 1940. However, the decline of the past few years should continue with the occurrence of normal rainfall and the resumption of heavy pumping.

RISE IN WATER-TABLE WELLS ALONG THE HEMPSTEAD AND CONROE HIGHWAYS

Most of the water-table wells under observation along the Hempstead and Conroe highways showed a rise in water levels, the rise ranging from a fraction of a foot to about four feet. This indicates that the ground-water recharge resulting from the heavy rainfall in the outcrop area of the water-bearing sands during 1941 was unusually large.

CHEMICAL CHARACTER OF THE GROUND WATER

The chemical character of the ground water is discussed on pages 21 to 23 of the 1940 report. The possibility of salt-water encroachment has been discussed in that and several other progress reports. Since 1931 samples taken at regular

intervals from selected widely-spaced wells in the district have been analyzed primarily to determine whether there has been any increase in chloride content. According to these analyses, including the latest made in the spring of 1941, there has been no important change in the chemical character of the ground water.

SUMMARY

The results of the investigation in the latter part of 1940 and in 1941 are consistent with those recorded in former years, discussed in the 1940 report. the summary of which is repeated in part on pages two and three of this report.

The pumpage in the Houston and Pasadena areas during 1941 averaged about 78,000,000 gallons a day, about 1,000,000 gallons a day less than in 1940. The reduction was due to a marked decline in the demands for water during the summer, resulting from the abnormally heavy rainfall. Although the water levels in the observation wells were materially lower in the spring of 1941 than in the spring of 1940, the net decline during the calendar year 1941 was small as compared with the decline during each of the four calendar years 1937 to 1940, inclusive. The lessening in the rate of decline is attributed to the fact that the water levels were not lowered as much as usual during the summer of 1941.

In the Katy area the pumpage during 1941 was approximately one-half as much as in 1940, averaging about 23,000,000 gallons a day. Although there was a decline in the water levels between the spring of 1940 and the spring of 1941 there was a small average net rise during the calendar year 1941, due to the reduction in pumpage and to recharge from the heavy rains.

Most of the water table wells in the outcrop area of the water-bearing sands along the Hempstead and Conroe highways showed a rise in water levels in 1941. The area is too far away, however, for the rise to appreciably affect the water levels

in the Houston and Pasadena wells.

It is expected that with the return of normal rainfall the pumpage in the Houston, Pasadena and Katy areas will increase and will be accompanied by a further decline in water levels.

The periodic analyses of water samples from 60 selected observation wells in 1941, like those of former years, give no evidence of the intrusion of salt water into the fresh water-bearing sands of the Houston district.

The investigation of the ground-water resources of the Houston district should be continued. The need for watching the ground-water situation is as great as ever and the results are becoming increasingly valuable with increase in the length of the period of record. It is especially important to continue the pumpage inventories, periodic recording of water levels in wells, and periodic analyses of water from numerous selected wells as a means of promptly detecting any intrusion of salt water.

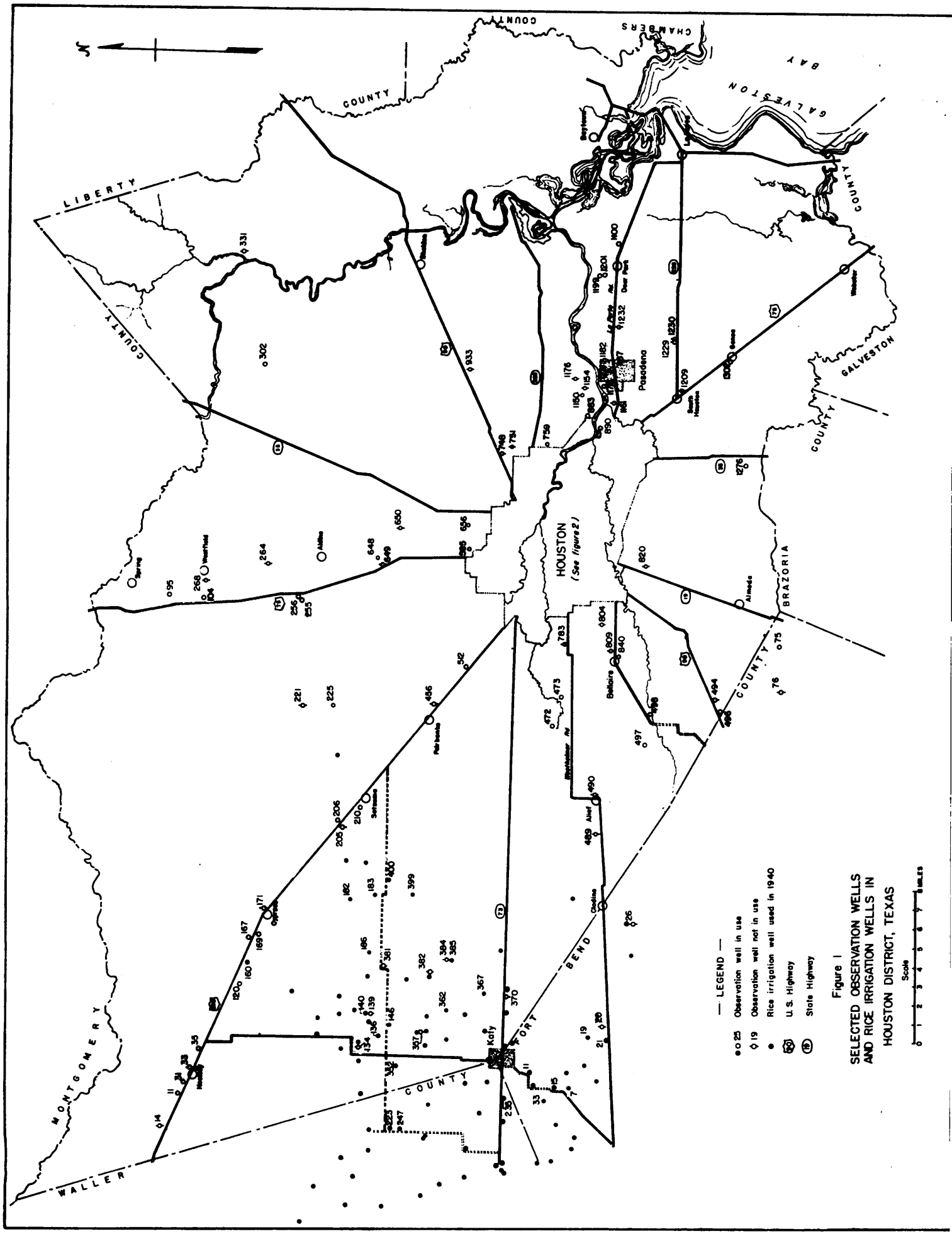


Figure 1
SELECTED OBSERVATION WELLS
AND RICE IRRIGATION WELLS IN
HOUSTON DISTRICT, TEXAS

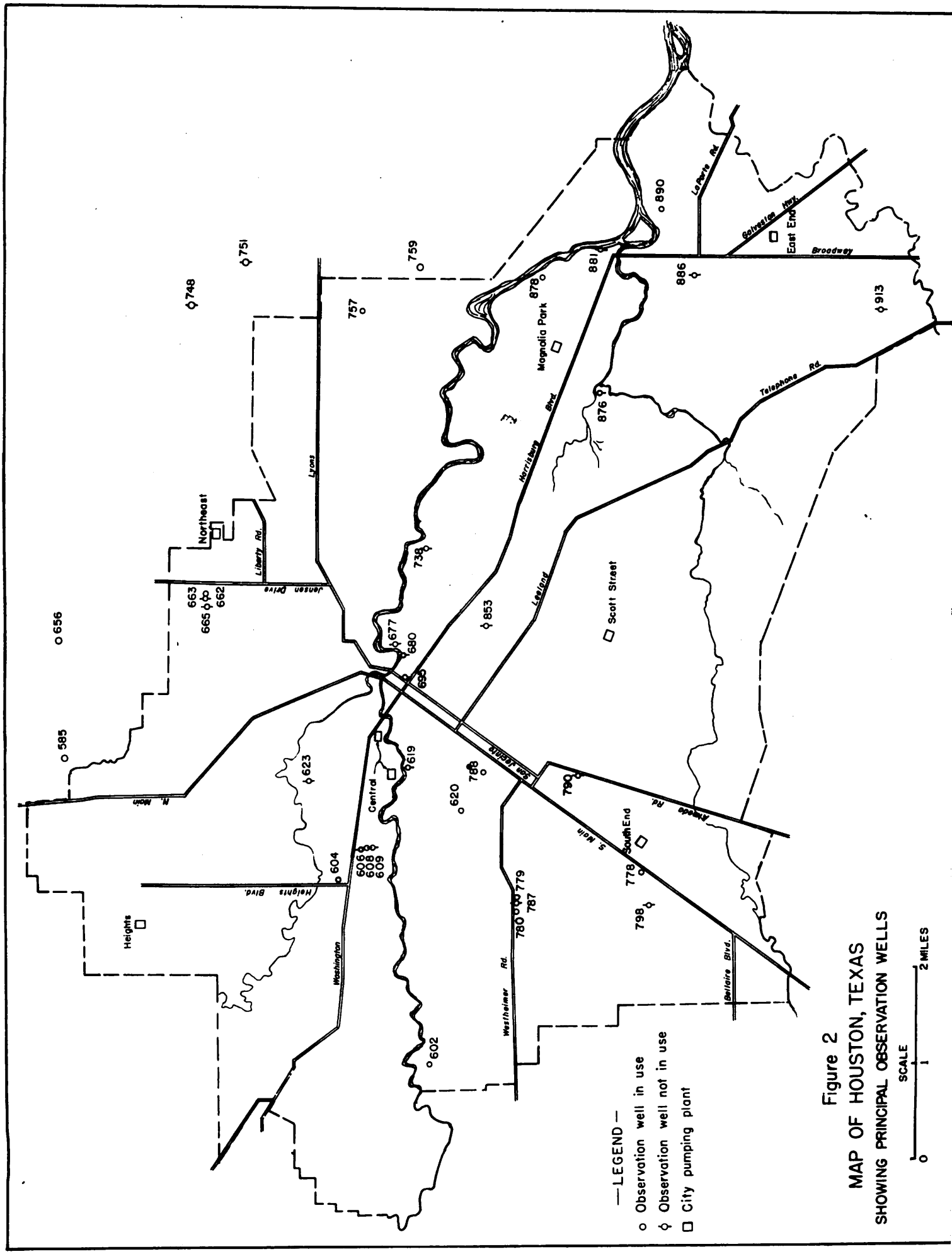
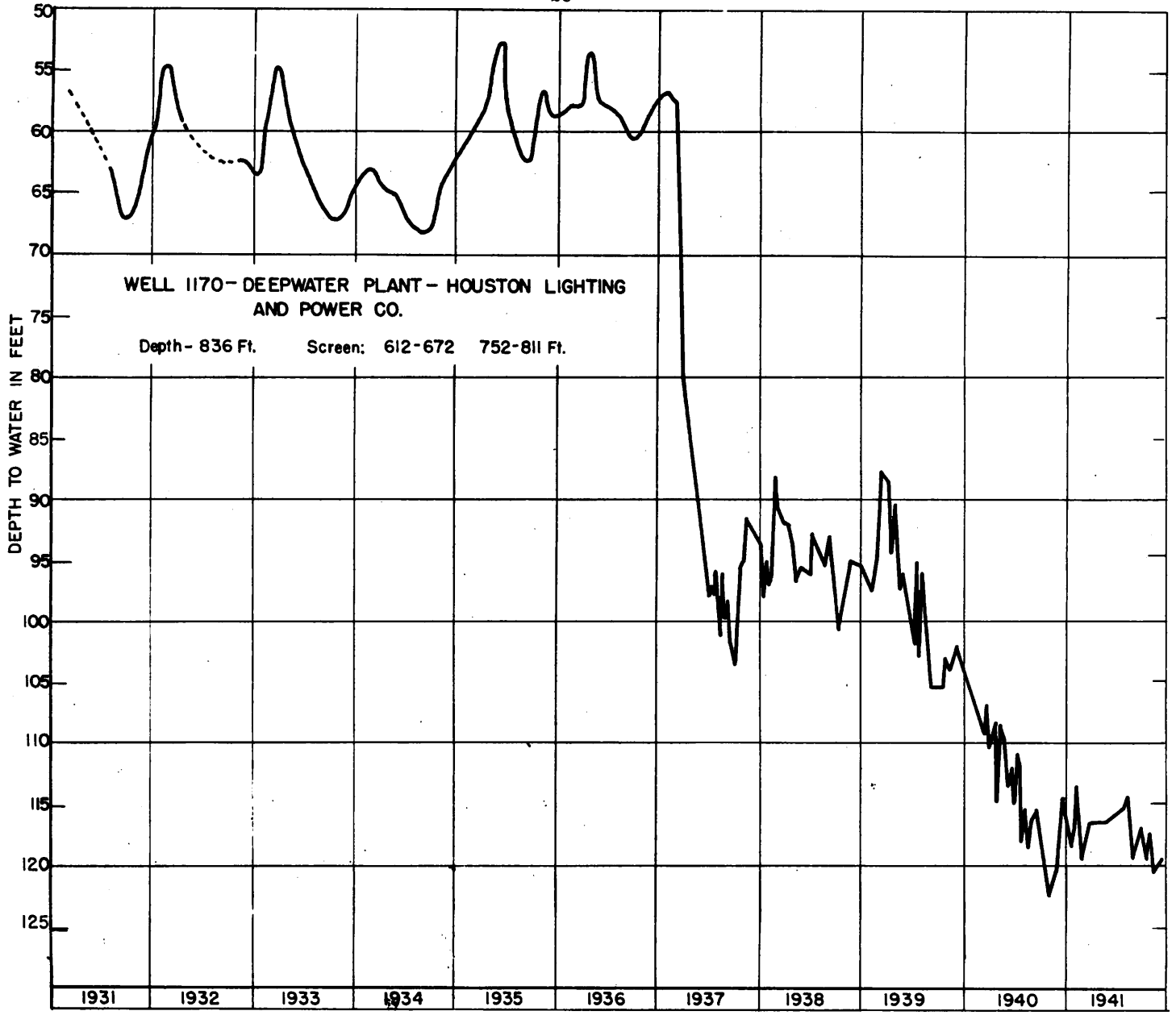
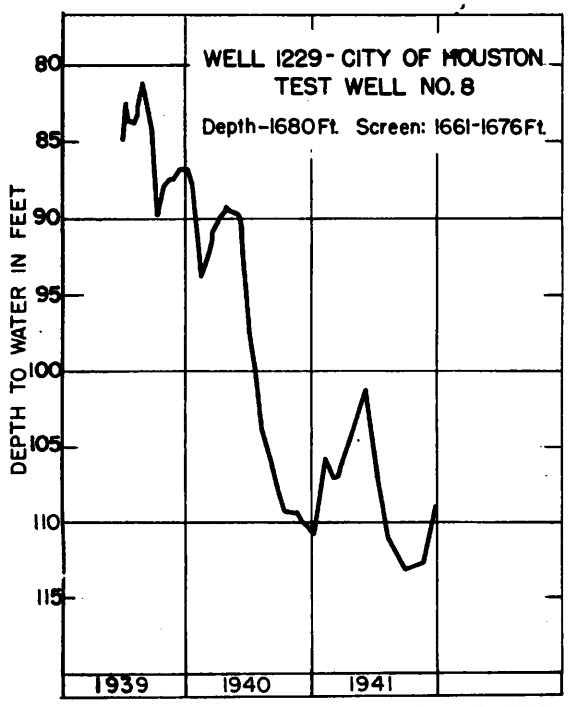


Figure 2
MAP OF HOUSTON, TEXAS
SHOWING PRINCIPAL OBSERVATION WELLS





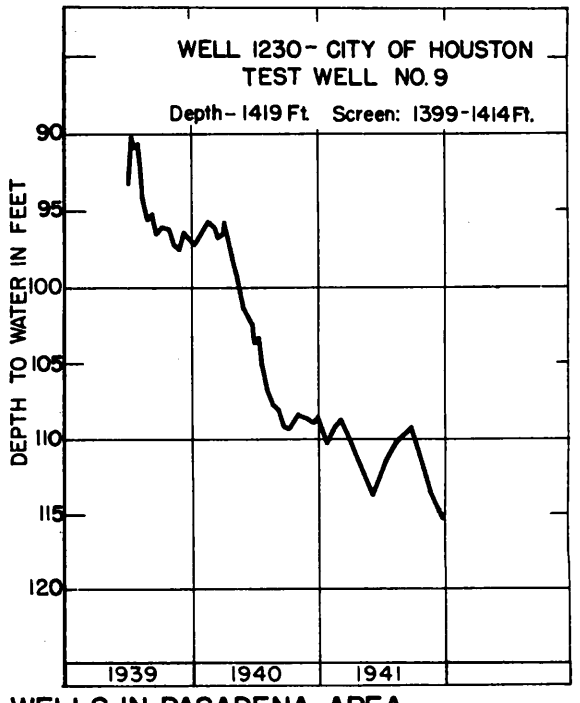


FIGURE 3. - FLUCTUATIONS OF WATER LEVELS IN WELLS IN PASADENA AREA

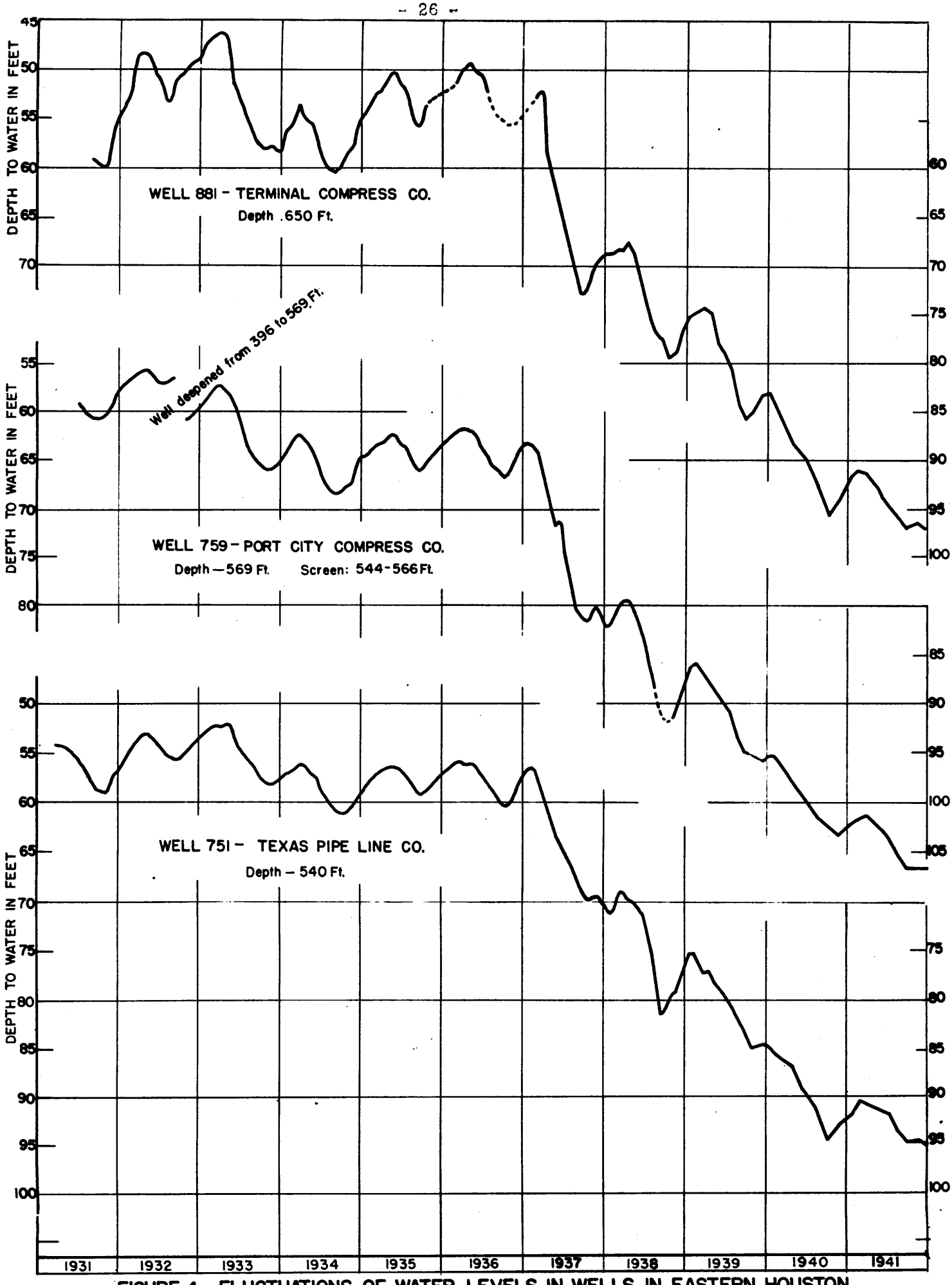


FIGURE 4. - FLUCTUATIONS OF WATER LEVELS IN WELLS IN EASTERN HOUSTON

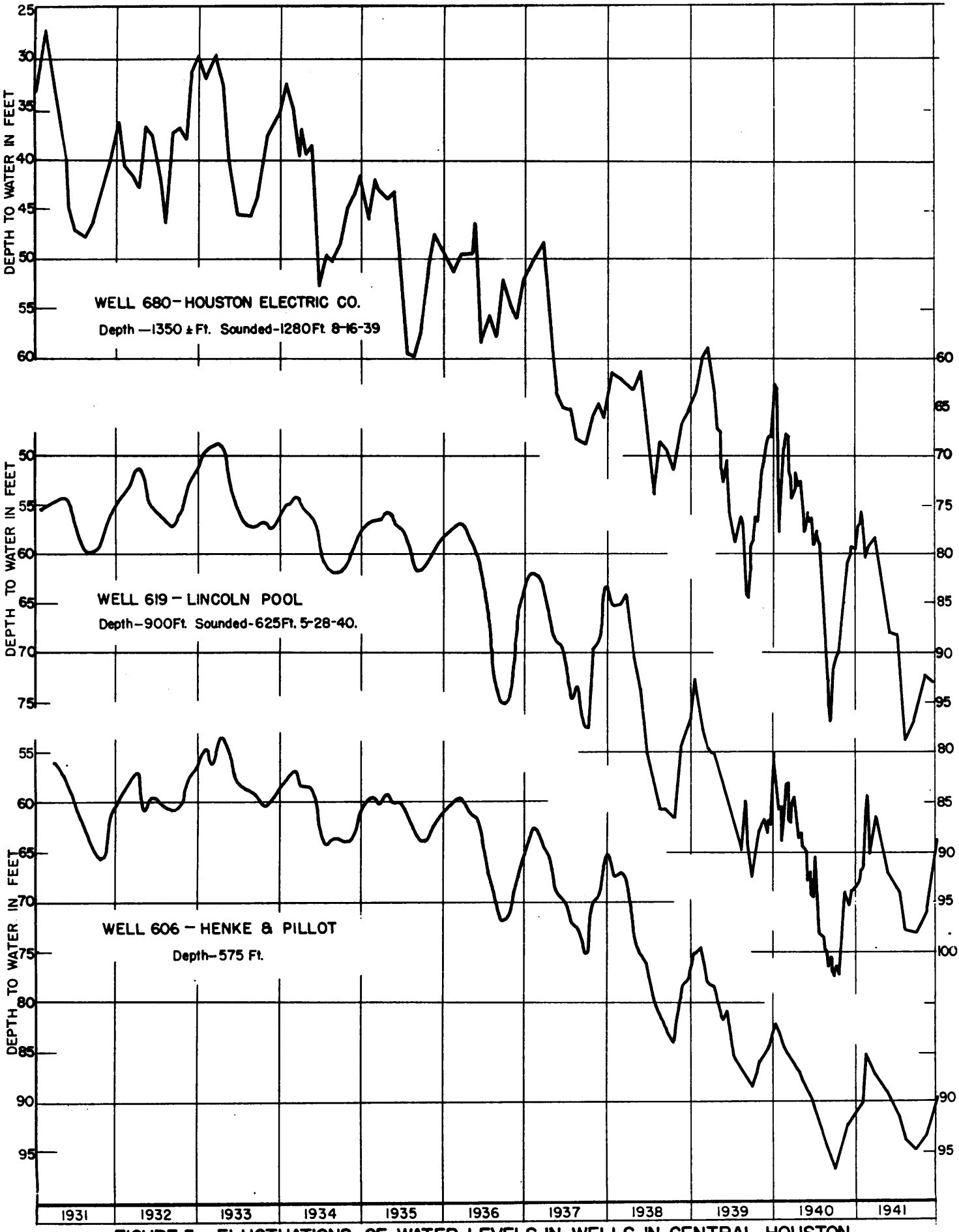
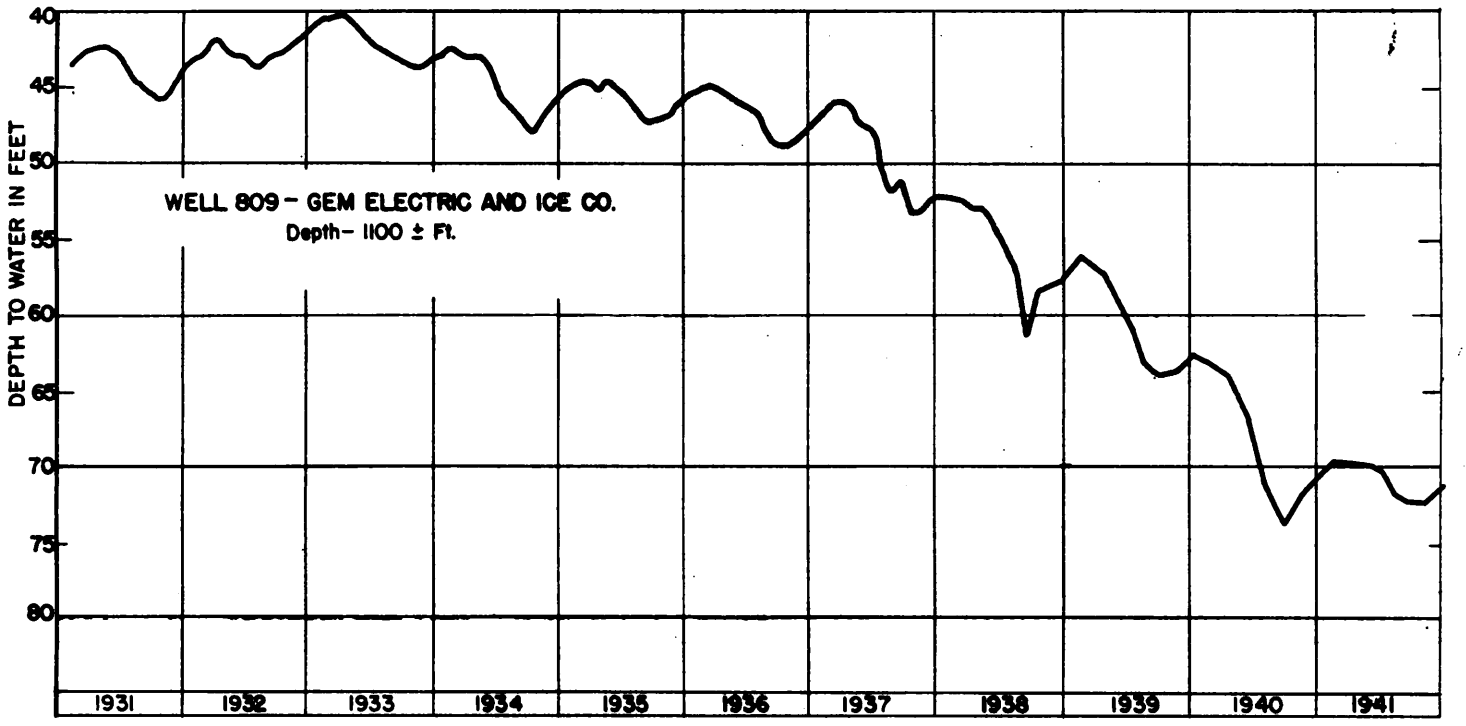
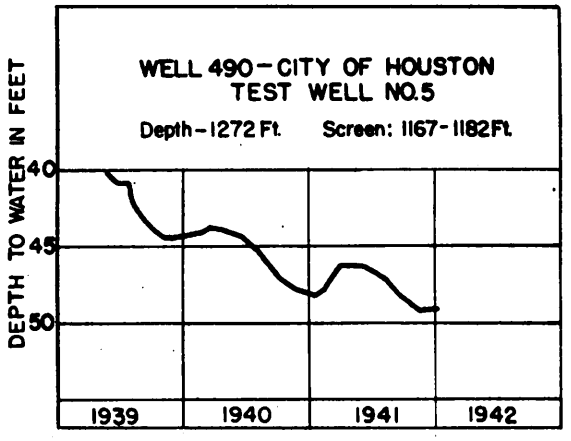
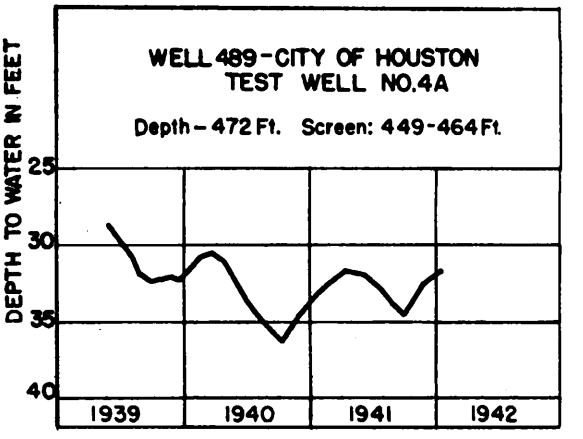


FIGURE 5.— FLUCTUATIONS OF WATER LEVELS IN WELLS IN CENTRAL HOUSTON







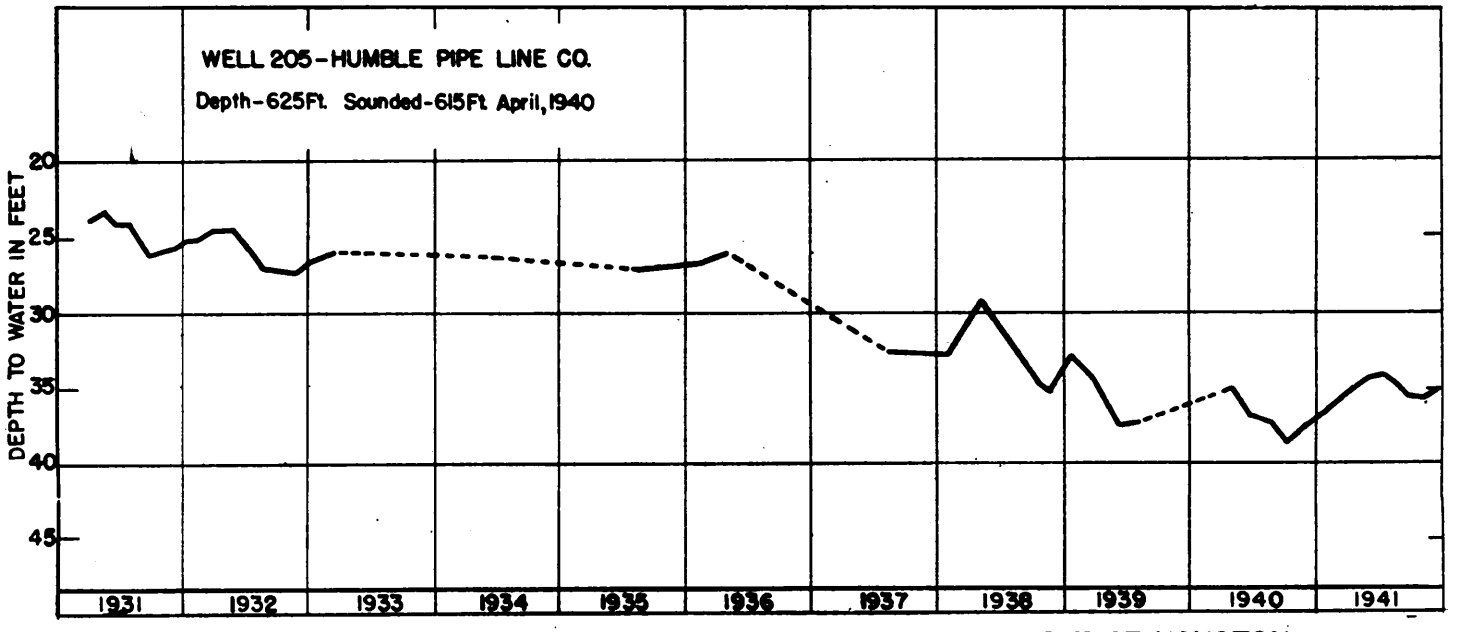


FIGURE 6. - FLUCTUATIONS OF WATER LEVELS IN WELLS WEST OF HOUSTON

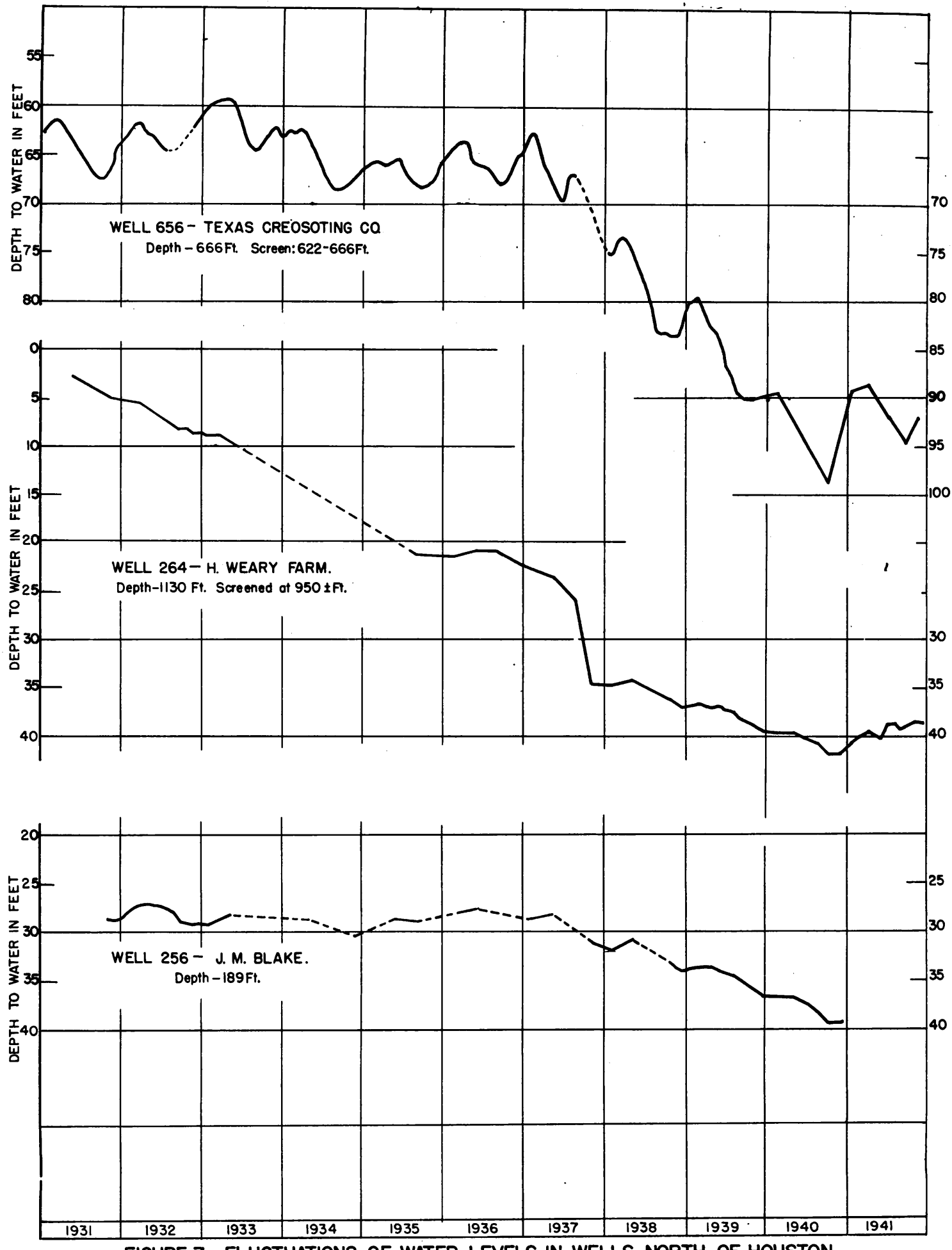


FIGURE 7. - FLUCTUATIONS OF WATER LEVELS IN WELLS NORTH OF HOUSTON

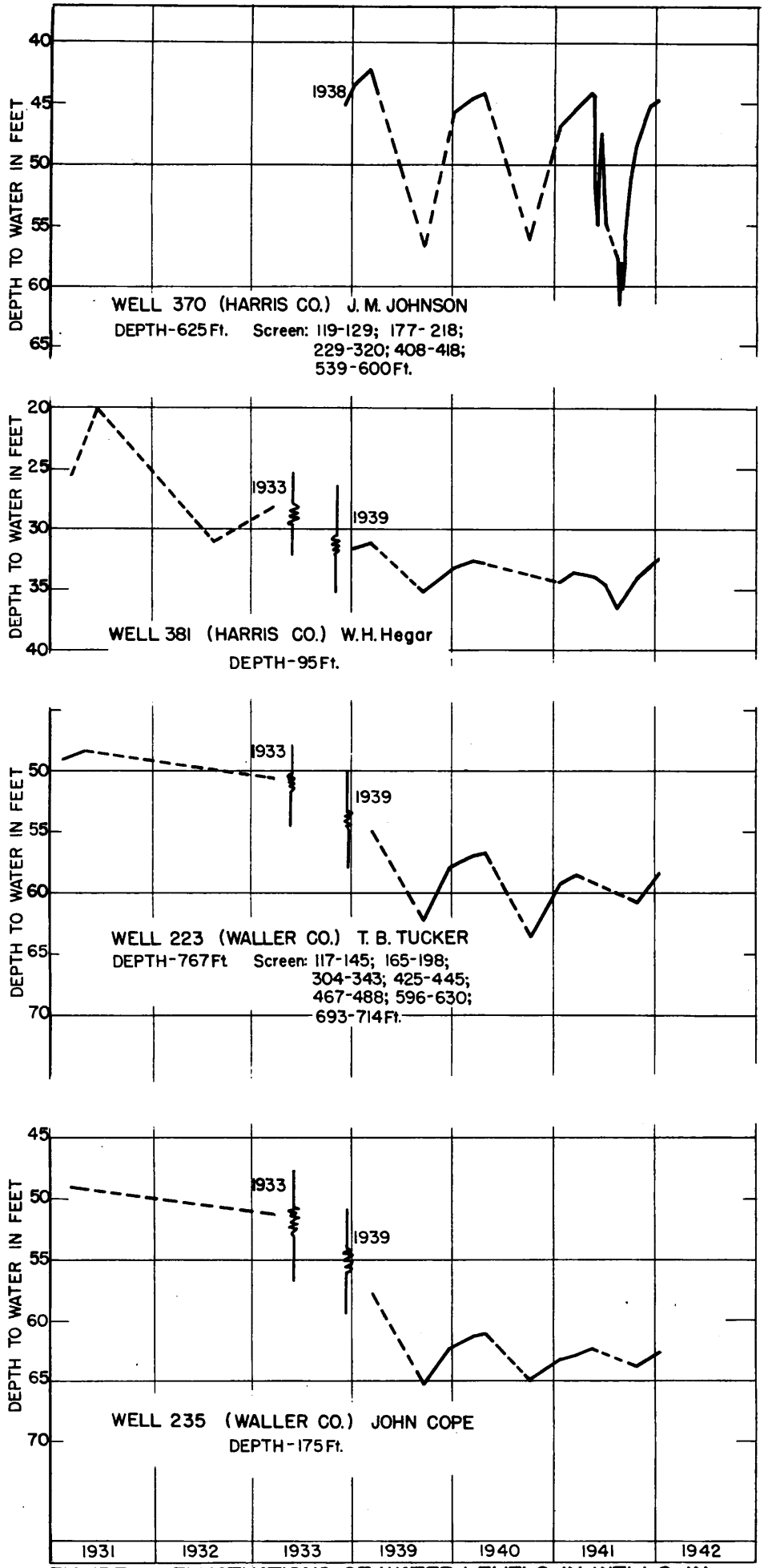


FIGURE 8.- FLUCTUATIONS OF WATER LEVELS IN WELLS IN KATY DISTRICT