TEXAS BOARD OF WATER ENGINEERS

H. A. Beckwith, Chairman
A. P. Rollins, Member
O. F. Dent, Member

BULLETIN 5402

SUMMARY OF GROUND-WATER DEVELOPMENT IN THE SOUTHERN HIGH PLAINS, TEXAS

By

Edward R. Leggat, Geologist
United States Geological Survey

Prepared cooperatively by the Geological Survey,
United States Department of the Interior

February 1954

CONTENTS

ILLUSTRATIONS

TABLES

SUMMARY OF GROUND-WATER DEVELOPMENT IN THE SOUTHERN HIGH PLAINS, TEXAS

By

Edward R. Leggat, Geologist
United States Geological Survey

February 1954

INTRODUCTION

LOCATION AND EXTENT OF AREA

The Texas High Plains consists of an area of about 35,000 square miles and extends from the Oklahoma Panhandle southward to Ector, Midland and Glasscock Counties, and from the New Mexico line eastward to the prominent escarpment. It is divided by the Canadian River into the North Plains or Panhandle and the Southern High Plains. Figure 1. The ground water development is largely concentrated in the principal irrigated region of the Southern High Plains which encompasses about 6,800,000 acres and extends from Amarillo southward to Tahoka in Lynn County.

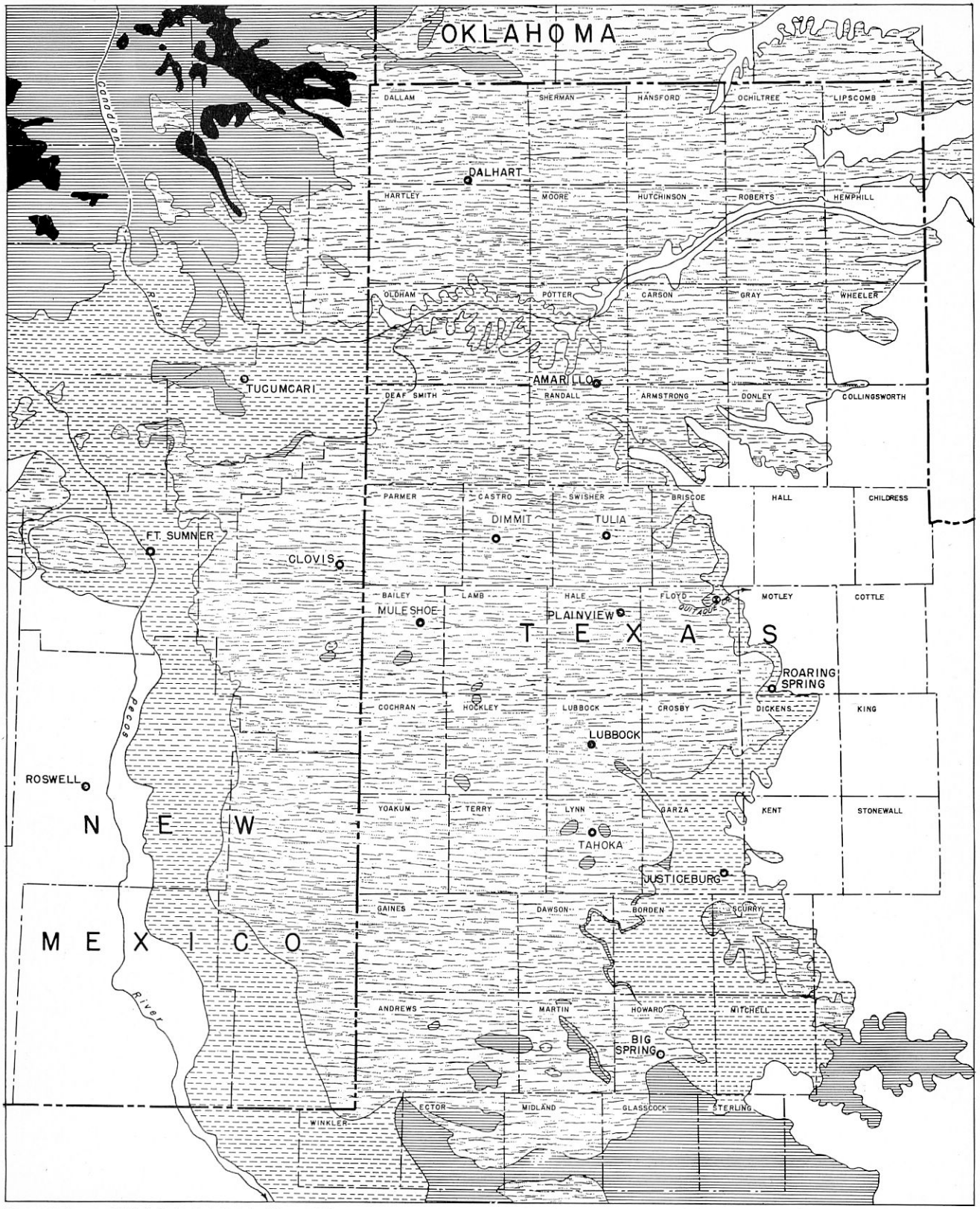
PURPOSE AND SCOPE OF THIS REPORT

The purposes of this report are (1) to bring up to date the available information on the increased use of ground water, (2) to discuss the fluctuations of water levels in wells during the period 1938-53, and (3) to summarize the effects of the ground-water development on the pumping levels and discharges of wells.

The investigation is a part of the Statewide cooperative program of the United States Geological Survey and the Texas Board of Water Engineers. The project is under the administrative direction of A. N. Sayre, Chief of the Ground Water Branch of the United States Geological Survey, and under the direct supervision of R. W. Sundstrom, District Engineer in charge of the cooperative work in Texas.

GROUND WATER DEVELOPMENT

The development of the ground-water resources of the Texas High Plains continued to expand during 1951 and 1952. During the 10-year period, 1943-52 more than 15,000 irrigation wells were drilled, of which about 4,000 wells were drilled during 1951-52 (fig. 2). During 1952 about 18,300 wells were used to irrigate 2,250,000 acres in the entire High Plains; of which approximately 17,700 wells were used to irrigate about 2,150,000 acres in the principal irrigated region of the Southern High Plains. The remainder of the wells and irrigated acreage are in the more southerly counties of the High Plains and in the North Plains north of the Canadian River.



From geologic map of United States, U. S. Geological Survey, 1932.

EXPLANATION

- Ogallala formation — TERTIARY
- Igneous rocks — TERTIARY
- Undifferentiated rocks — CRETACEOUS
- Dockum group — TRIASSIC
- Undifferentiated rocks — PERMIAN
- Stream-gaging station on Quitaque Creek

25 0 25 50 75 100 Miles

FIGURE 1.- Geologic map of the High Plains in Texas and adjacent territory.

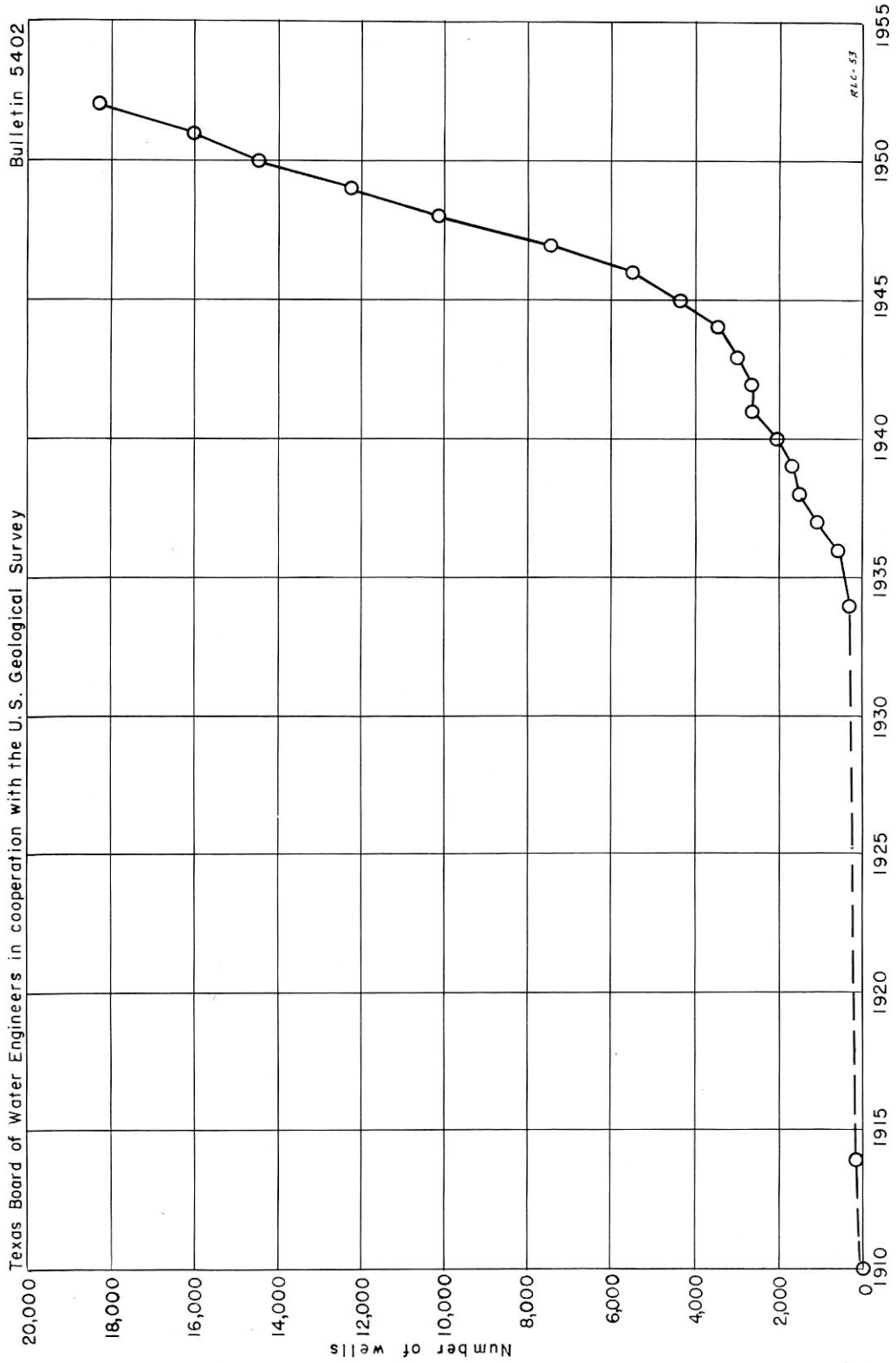


FIGURE 2.—Increase in number of irrigation wells in the Texas High Plains.

PRECIPITATION

Records of the United States Weather Bureau from stations at Dimmitt, Lubbock, Muleshoe, Plainview, and Tulia show that the average annual precipitation in the Southern High Plains is approximately 20 inches. Precipitation at the five stations in 1951 averaged 17.4 inches, of which 5.5 inches fell during the month of May. A large part of the precipitation that fell during May ran off into the depressions and streams because much of the soil-moisture deficiency had been made up by pre-planting irrigation which immediately preceded the heavy rainfall. During 1952 the precipitation averaged 11.8 inches, or less than 60 percent of normal. According to records of the U. S. Weather Bureau, the precipitation in 1952 at Muleshoe and Tulia was the lowest since records began. Table 1 shows the monthly rainfall during 1951 and 1952 at the above five stations.

Table 1.- Monthly rainfall, in inches, during 1951 and 1952 at five High Plains Weather Bureau Stations

1951

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Dimmitt	0.45	1.15	0.18	0.12	5.04	1.29	2.28	1.89	1.78	1.55	0.33	0.37	16.43
Lubbock	.32	.66	.78	.58	2.63	4.19	2.04	2.62	.70	.93	.06	.02	15.53
Muleshoe	.62	1.16	.21	.11	6.86	5.34	3.48	1.34	.06	1.51	.29	.36	21.34
Plainview	.34	1.04	.39	.51	6.91	1.59	2.88	1.35	3.40	1.47	.26	.18	20.32
Tulia	.22	.72	.23	.40	6.06	1.11	1.74	.79	.81	1.36	.22	.16	13.82

1952

Dimmitt	0.45	0.09	0.28	2.31	0.87	3.01	2.88	0.41	0.78	0.0	1.04	0.35	12.47
Lubbock	.98	.05	.04	2.30	1.39	1.94	3.24	1.88	.92	.0	.74	.06	13.54
Muleshoe	.80	.09	.26	1.74	.47	1.59	1.64	1.60	.87	.0	1.09	.29	10.44
Plainview	.96	.07	.07	3.53	1.01	.51	1.84	.81	1.03	.0	.89	.29	11.01
Tulia	.70	.10	.12	2.43	.75	2.05	2.16	1.02	.64	.0	1.37	.35	11.69

WITHDRAWALS OF GROUND WATER

The withdrawals of ground water from the Ogallala formation underlying the Southern High Plains for irrigation, municipal, and domestic supplies have increased each year since 1938, except during 1941, 1942, and 1949, when precipitation was above average and the demand for irrigation was relatively light. Although precipitation during 1950 and 1951 was approximately equal, the pumpage during 1951 was about 2,000,000 acre-feet, or an increase of 400,000 acre-feet over that of 1950. Owing to the near-drought conditions that prevailed during 1952, approximately 3,750,000 acre-feet of ground water was pumped, which represents an increase of 85 percent over 1951. Although a part of this large increase is attributed to the additional wells installed during 1952, a large part is due to the longer period of pumping per well. A study of the available data indicates that the average withdrawal increased from 125 acre-feet per well in 1951 to 200 acre-feet per well in 1952.

During the 15-year period March 1938 to January 1953, about 11,250,000 acre-feet of ground water was pumped, of which 5,750,000 acre-feet or about 50 percent was pumped during 1951 and 1952. Assuming a specific yield of 15 percent, it is calculated that the withdrawals of ground water in 1951 and 1952 unwatered 38,000,000 acre-feet of saturated material and that the withdrawal since 1938 unwatered about 75,000,000 acre-feet of material.

FLUCTUATION OF WATER LEVELS IN WELLS

During the years from 1911 until 1943, irrigation in the Southern High Plains was concentrated in relatively small areas, and the declines of the water levels in wells were greatest in those areas. Since 1943, in addition to continued development of those areas, irrigation has spread out to form one large district which in the principal irrigated region embraces all or parts of 20 counties. Prior to 1940, measurements of depths to water were made quarterly and even monthly in a large number of wells in the High Plains. Experience has shown that annual measurements made in January, February, or March, before pumping begins, provide the basis for the most accurate method of estimating the net loss or gain in storage for each year of operation. Water-stage recorders, which give continuous records of the rise or fall of the water table, were in operation during 1951-52 in 14 wells on the High Plains.

Figure 3 shows the highest daily water level in well 407a, which is 1,600 feet south of the White River (Running Water Draw) in Plainview. After a rain of 5.7 inches during May 15-17, 1951, the discharge of Running Water Draw reached a peak of about 1,400 second-feet at Plainview. The graph shows the rapid response to the infiltration of stream flow which caused the water level in well 407a to rise 3.12 feet from May 15 to July 10. The mound of water built up by recharge from the draw spread laterally and after July 10 the water level started to decline. The net decline in well 407a during the entire year of 1951 was 2.1 feet. During 1952 the water level continued to decline but at an accelerated rate and the total decline during the year was 5.1 feet.

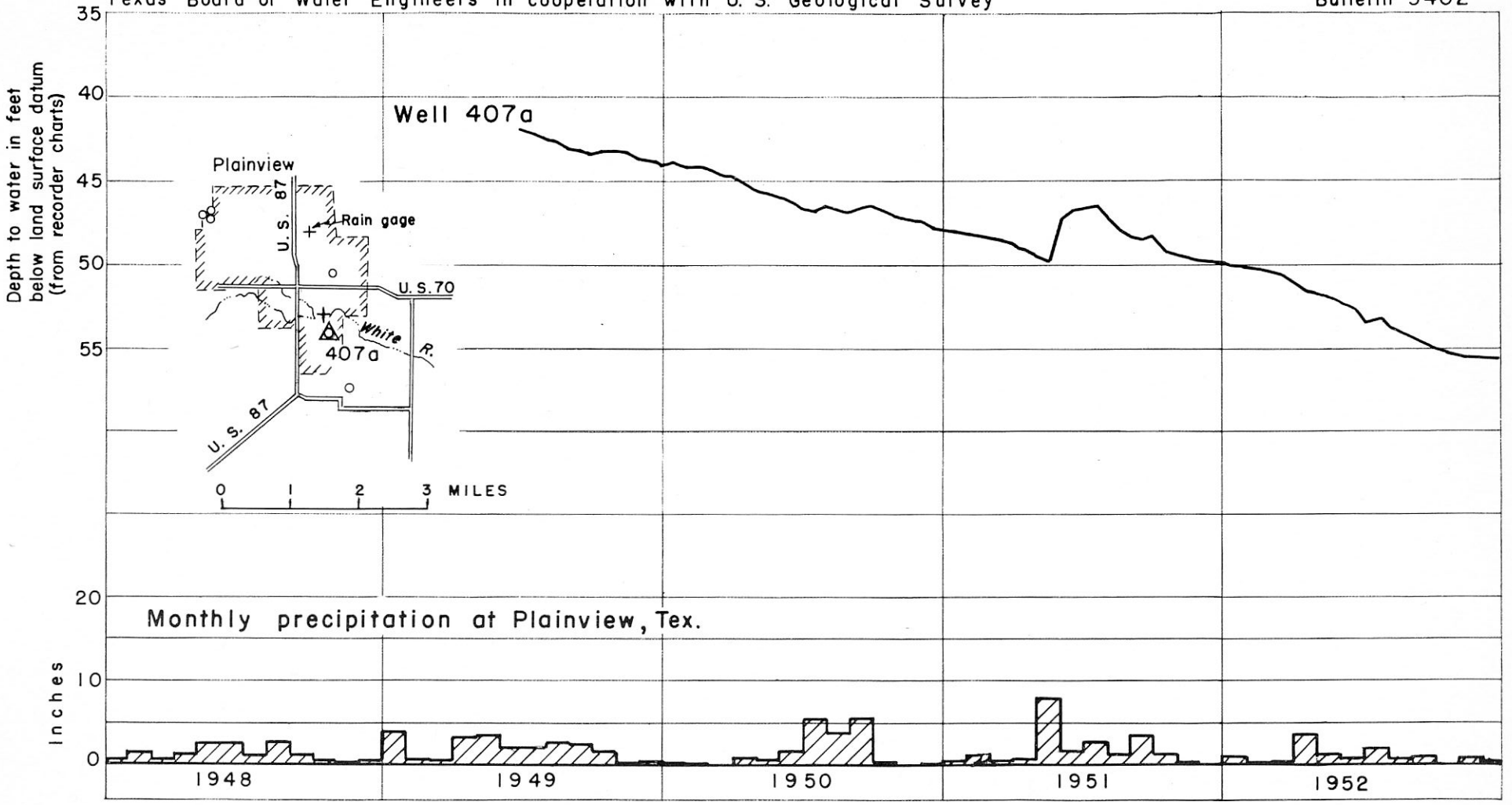


FIGURE 3.– Hydrograph for observation well 407a and monthly precipitation, 1948–52, Plainview, Tex.

The heavy rainfall in May 1951, however, did not cause a sharp rise in water levels in all parts of the Southern High Plains. Figure 4 shows the monthly rainfall and highest monthly water level recorded in well B-166 at the Southwestern Public Service Company Plant "X" in the sandhills in north-central Lamb County. The rain gage at Plant "X" was not installed until September 1951 but it was reported that rainfall at Plant "X" was heavy during May 1951.

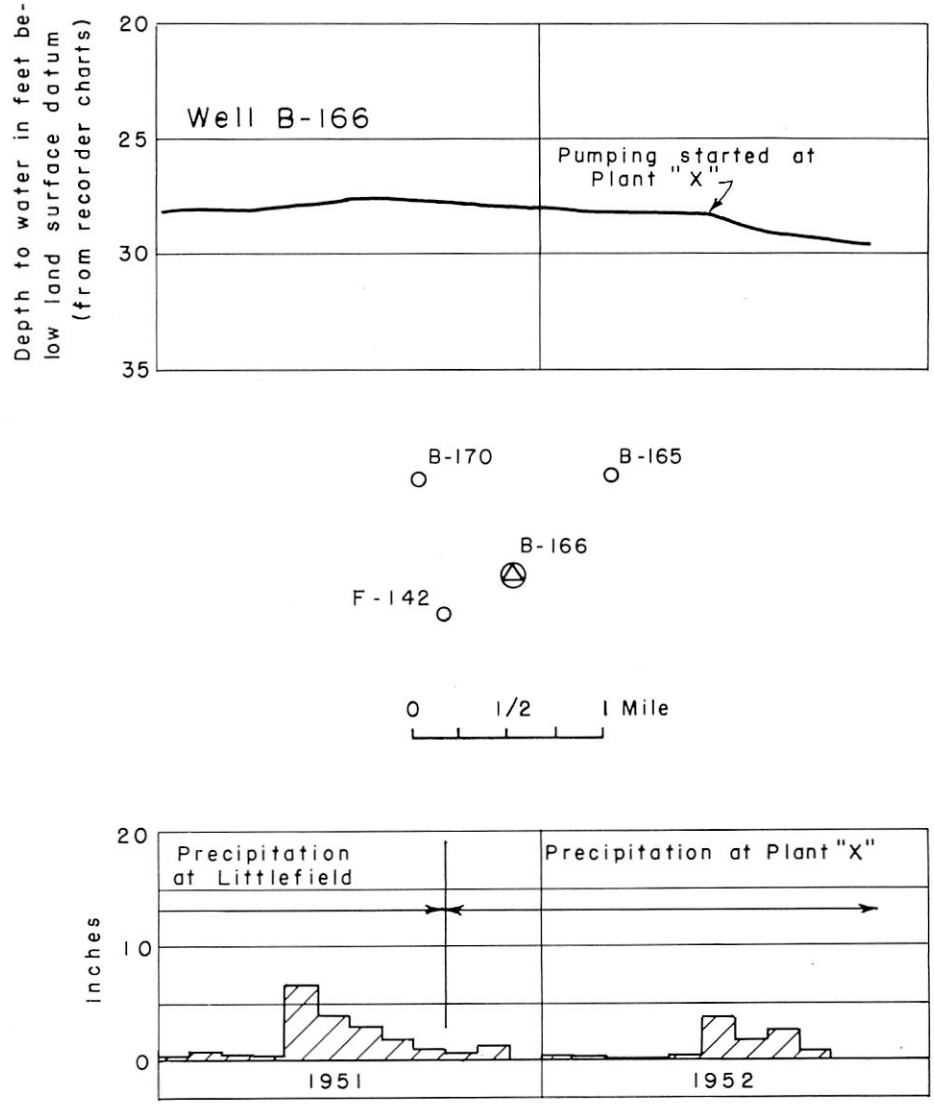


FIGURE 4.- Hydrograph for observation well B-166 and daily precipitation, 1951-52, Plant "X" Southwestern Public Service Co., Earth, Lamb County, Tex.

Owing to the permeable nature of the sand dunes covering the area and to the lack of well-defined surface drainage, conditions in the sandhills are especially favorable for the infiltration of rainfall. The water level in well B-166, however, shows no abrupt rise after the heavy rains of May 15-17, 1951. The relatively small response to the heavy rainfall is due in part to the low soil moisture, which had to be replenished before recharge could occur, partly to the loss of water by evaporation and transpiration, and partly to the slow downward movement of water through the clay subsoil and caliche which underlie the sandhills. The water level resumed a slow but steady decline from September 1951 to June 1952. Withdrawal of ground water for industrial use at Plant "X" began in June 1952, and during June and July about 48 million gallons was pumped from well F-142. The decline in the observation well (B-166) was accelerated at this time. From July 1952 to January 1953, however, 100 million gallons was pumped from three wells, B-165, B-170, and F-142, of which only 2 million gallons was pumped from F-142. The decline in well B-166 was retarded, therefore, because of its greater distance from the pumped wells. (See sketch, fig. 4.)

Figures 5, 6, and 7 show graphs based on data obtained from water-stage recorder charts for wells in Hale, Swisher, Deaf Smith, and Bailey Counties. These records indicate that the observation wells close to areas of heavy ground-water withdrawals show greater annual declines and a wider range in water-level fluctuations than those outside the heavily pumped areas. For example, well 428, near the west edge of the heavily pumped Lockney-Aiken area, east of Plainview, is 1,880 feet from the nearest pumped well; whereas, well 493a is more or less remote from the heavily pumped areas. The graph of well 428 shows large fluctuations in water level caused by nearby pumping, and during the year beginning March 1951 it showed a net decline of 6.0 feet; whereas, in well 493a the water level moved downward steadily but more slowly showing a net decline of 1.7 feet during 1951 and 1.8 feet during 1952, indicating that the movement of water from an area of light pumping into an area of heavy pumping continued after each irrigation season. The record of water levels in well 428 during the latter part of 1952 is not available, owing to the decline of the water table below an obstruction in the well; however, records of wells in the vicinity show a net decline of approximately 6 feet during 1952.

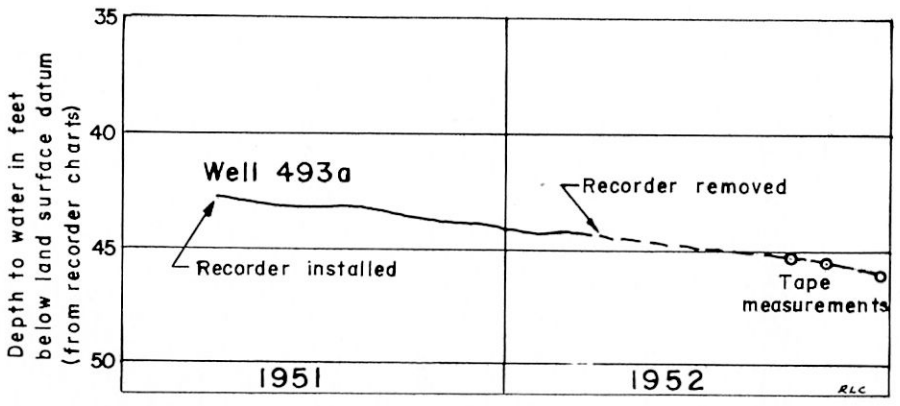


FIGURE 5.—Hydrograph for observation well 493a, Hale County, Tex.

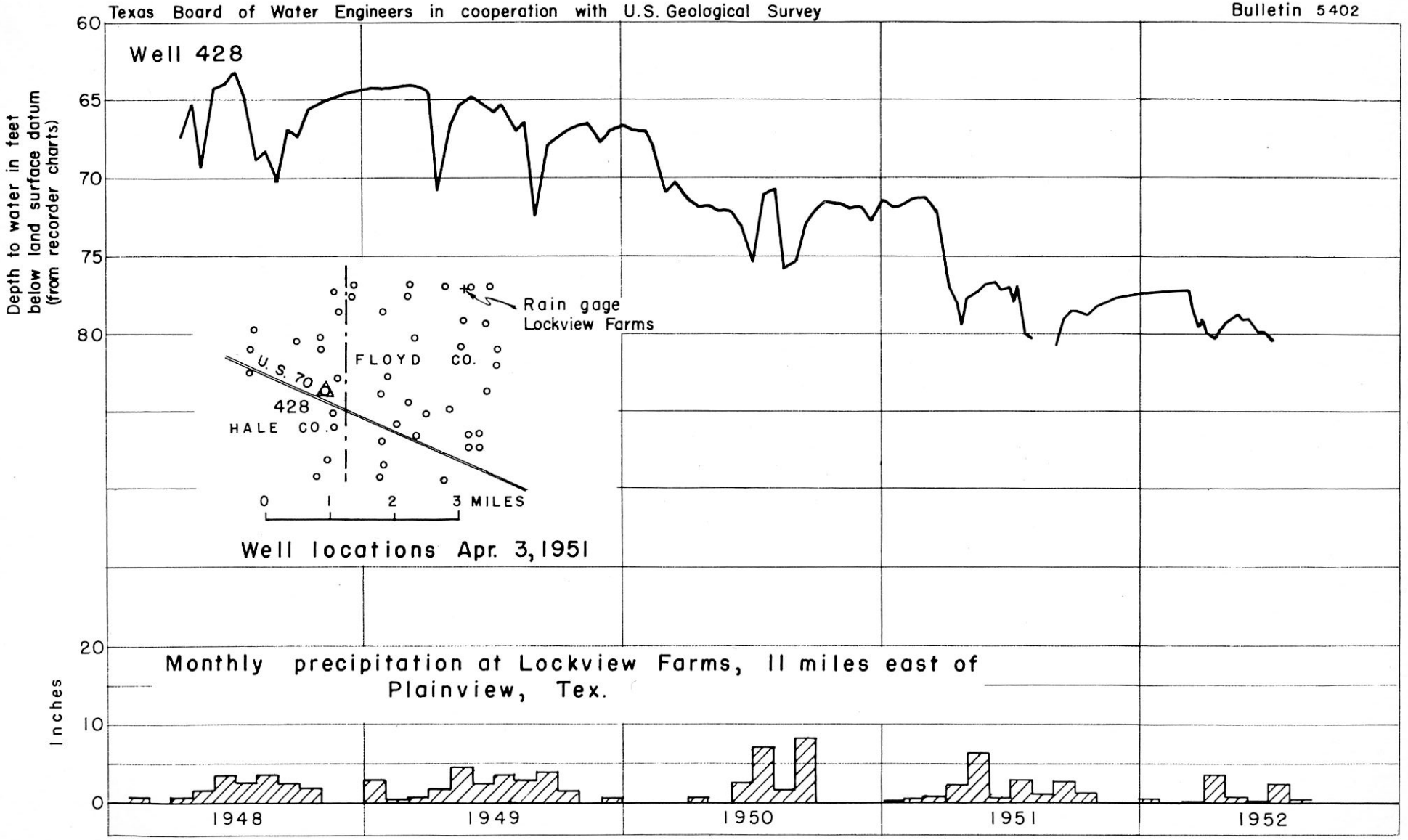


FIGURE 6.-Hydrograph for observation well 428 and monthly precipitation at Lockview Farms, 1948-52, Hale County, Tex.

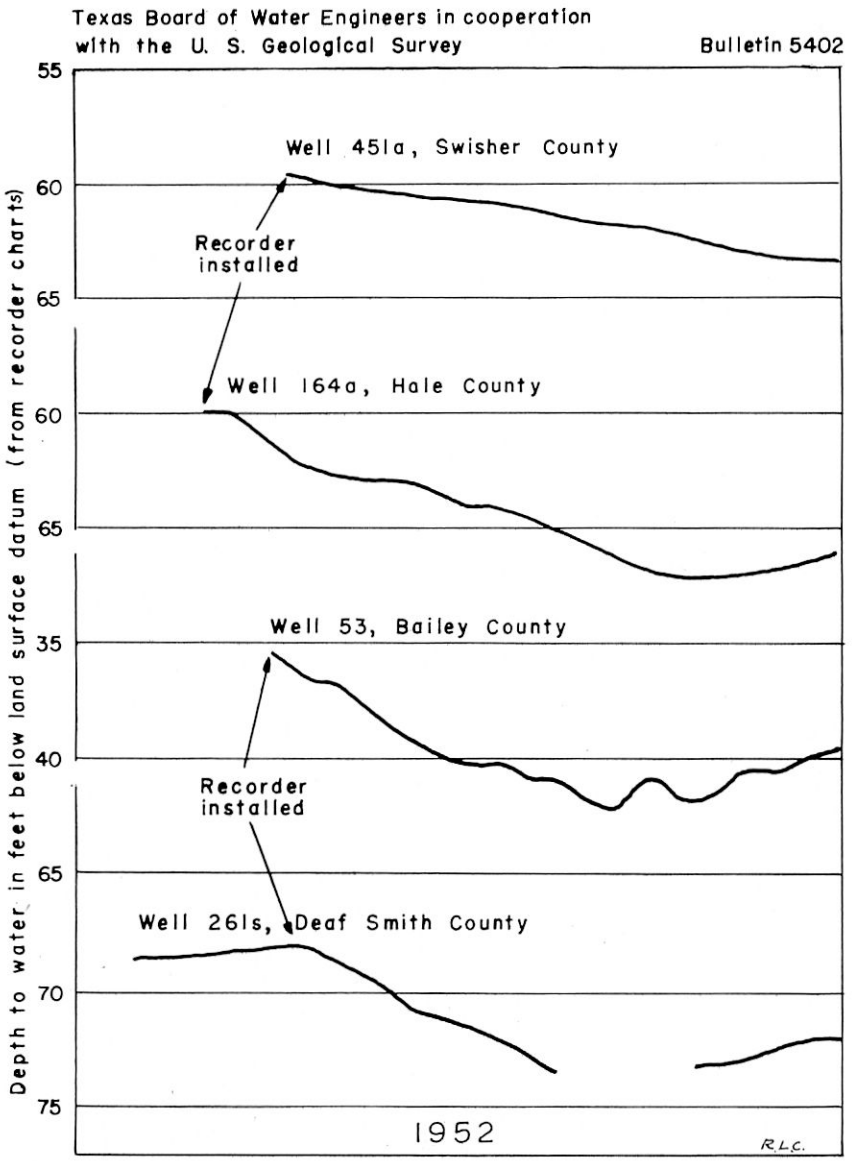


FIGURE 7.—Hydrographs for observation wells in Swisher, Hale, Bailey, and Deaf Smith Counties, 1952.

Figure 8 shows the steady decline of the water table in well A-2a near the center of Amarillo's West-Tex public-supply well field in Randall County. Although data on the pumpage from the West-Tex field are not available, the city of Amarillo pumped about 13,000 acre-feet of water in 1951 and 17,000 acre-feet in 1952 from a number of well fields of which the West-Tex field is the largest produced. The periodic changes in the rate of decline of the water table are the result of changes in the rate of pumping. During the winter and spring months the demand for ground water is considerably less than during the summer months and the rate of decline of the water table decreases. However, the relatively marked rise of the water level during the 3-month period from December 1951 to February 1952 was caused principally by the shutting down of wells 2 and 3 which are close to the observation well (A-2a) in the West-Tex field. The increase in ground-water withdrawals of approximately 30 percent in 1952 is reflected in the decline of water levels in A-2a. The graph shows that the water levels declined 4.7 feet in 1951 and 5.8 feet in 1952, an increase of about 25 percent.

Records of 426 widely distributed observation wells show that during 1951 the fluctuations of water levels ranged from a rise of 5.4 feet in eastern Bailey County to a decline of 8.3 feet in west-central Floyd County, and the numerical average net decline of water levels in all the observation wells was 2.1 feet. During 1952, when rainfall was greatly below normal, the water levels in 462 wells in the irrigated region declined an average of 3.9 feet. The records show that in 1952 the largest declines occurred in the heavily pumped area in west-central Floyd County and that, in general, the water table declined throughout the High Plains irrigated region. Contours of approximate water-level declines during 1952 are shown in figure 9.

Table 2.- Average declines of water table in Southern High Plains

County	1951 Average decline, (feet)	1952 Average decline, (feet)
Bailey	1.3	3.4
Briscoe	.9	2.6
Castro	1.5	2.4
Crosby	3.3	5.0
Deaf Smith	2.1	3.0
Floyd	3.0	5.3
Hale	2.0	4.7
Hockley	1.3	4.0
Lamb	3.2	3.5
Lubbock	2.6	4.6
Swisher	2.4	4.0

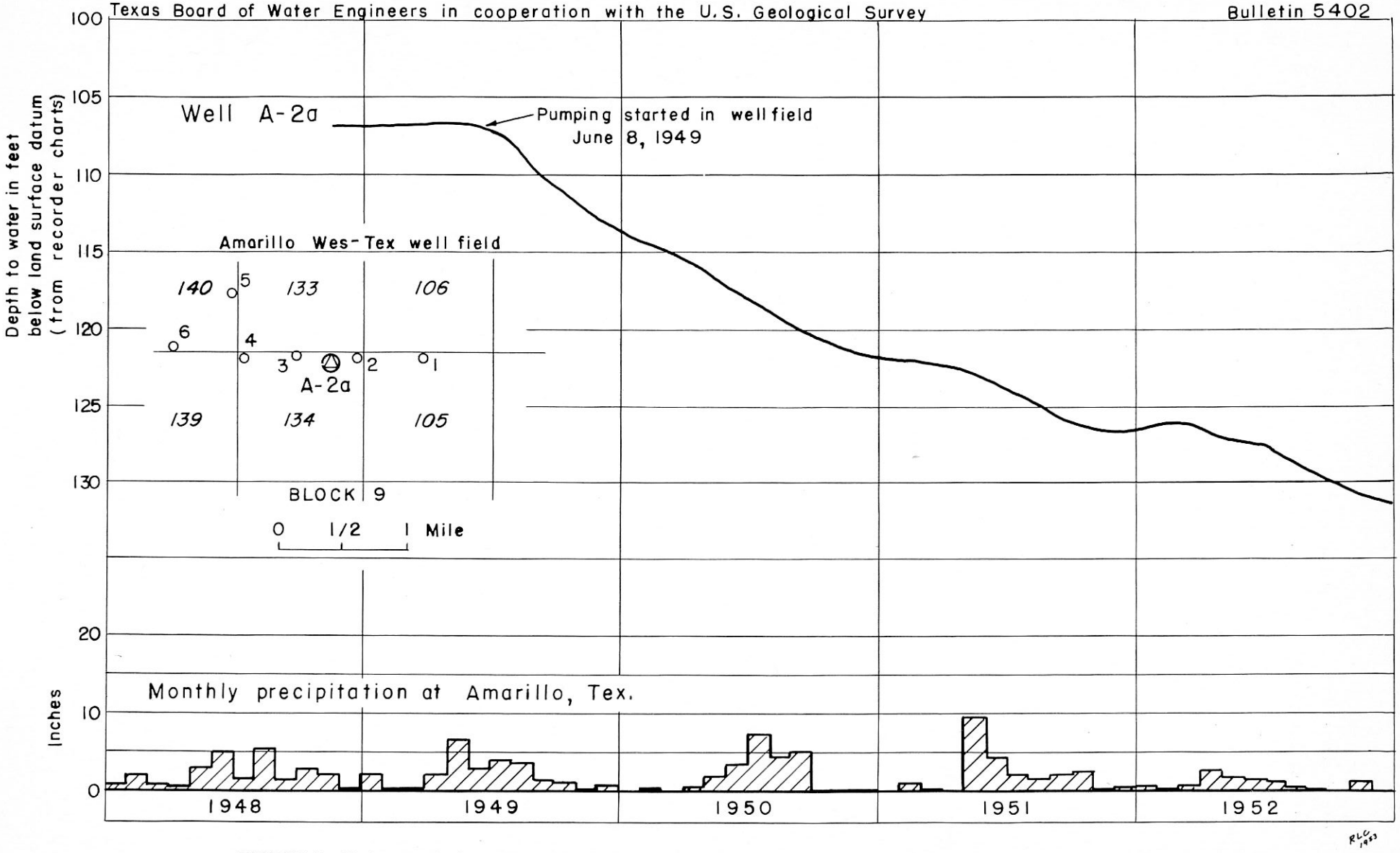


FIGURE 8.—Hydrograph for observation well A-2a and monthly precipitation, 1948-52, Amarillo, Tex.

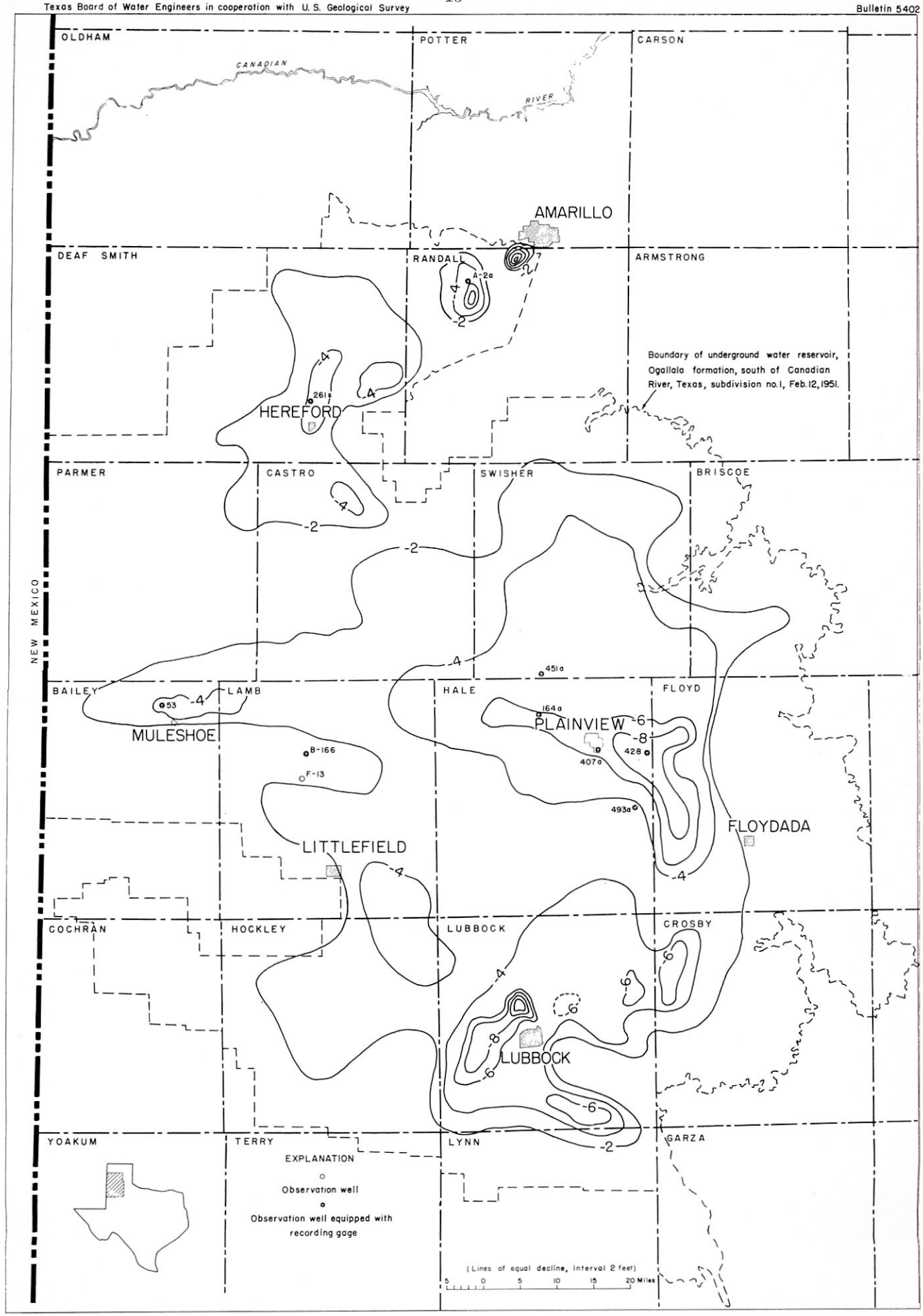


FIGURE 9.- Approximate decline of the water table in the Southern High Plains of Texas, February 1952 to January 1953.

A somewhat large proportion of the observation wells that were measured in 1952 and 1953 were in or near the heavily pumped areas. Had the observation wells been uniformly distributed throughout the irrigated region, the computed average decline of the water table would have been 1.8 feet in 1951 and 3.7 feet in 1952. If the unwatering of the saturated material caused by the withdrawal of 5¾ million acre-feet of water in 1951-52 had been uniformly distributed throughout the reservoir, and assuming that the unwatered material had a uniform specific yield of 15 percent, the water table would have declined 5.7 feet in the two-year period.

$$\frac{5{,}750{,}000 \text{ acre-feet pumped}}{6{,}800{,}000 \text{ acres} \times 0.15 \text{ specific yield}} = 5.7 \text{ feet decline}$$

Although the water levels in most wells in the sandhills and in other areas remote from heavy pumping declined during 1951 and 1952, they were at a higher stage in January 1953 than in 1937. For example, the water level in well F-13 in the sandhills in Lamb County declines 2.4 feet during the 2-year period 1951-52; however, since February 1937 the water level showed a net rise of 1.4 feet, indicating that the mound built up by recharge beneath the sandhills, mainly in 1941 and 1942, had not been completely dissipated.

Contours of water-level declines in the High Plains from the spring of 1938 to January 1953 are shown in figure 10. They show that the largest recorded declines occurred in the eastern part of the irrigated region in west-central Floyd County, where declines of 50 to 60 feet have been measured.

Although the decline of the water table since 1938 has locally reduced the natural discharge of ground water by evaporation and transpiration within the irrigated region, it has not materially affected either the flow of ground-water-fed Quitaque Creek (fig. 1) or the water levels in wells near the eastern edge of the escarpment in Floyd County. Records show that in January 1946 the flow of Quitaque Creek was 6.1 cubic feet per second or about 2,750 gallons a minute, and in January 1951 the flow was 6.3 cubic feet per second or 2,820 gallons a minute. Records of seven wells in the eastern part of Floyd County, and remote from irrigation, show that during the period 1938-53 the water levels in five wells rose by amounts ranging from 0.1 foot to 1.2 feet, whereas the water levels in two wells declined 0.5 foot and 2.2 feet. These data show that the pumping of ground water to date is essentially from storage except during those periods of recharge following abnormal rainfall, such as occurred in 1941 and 1942.

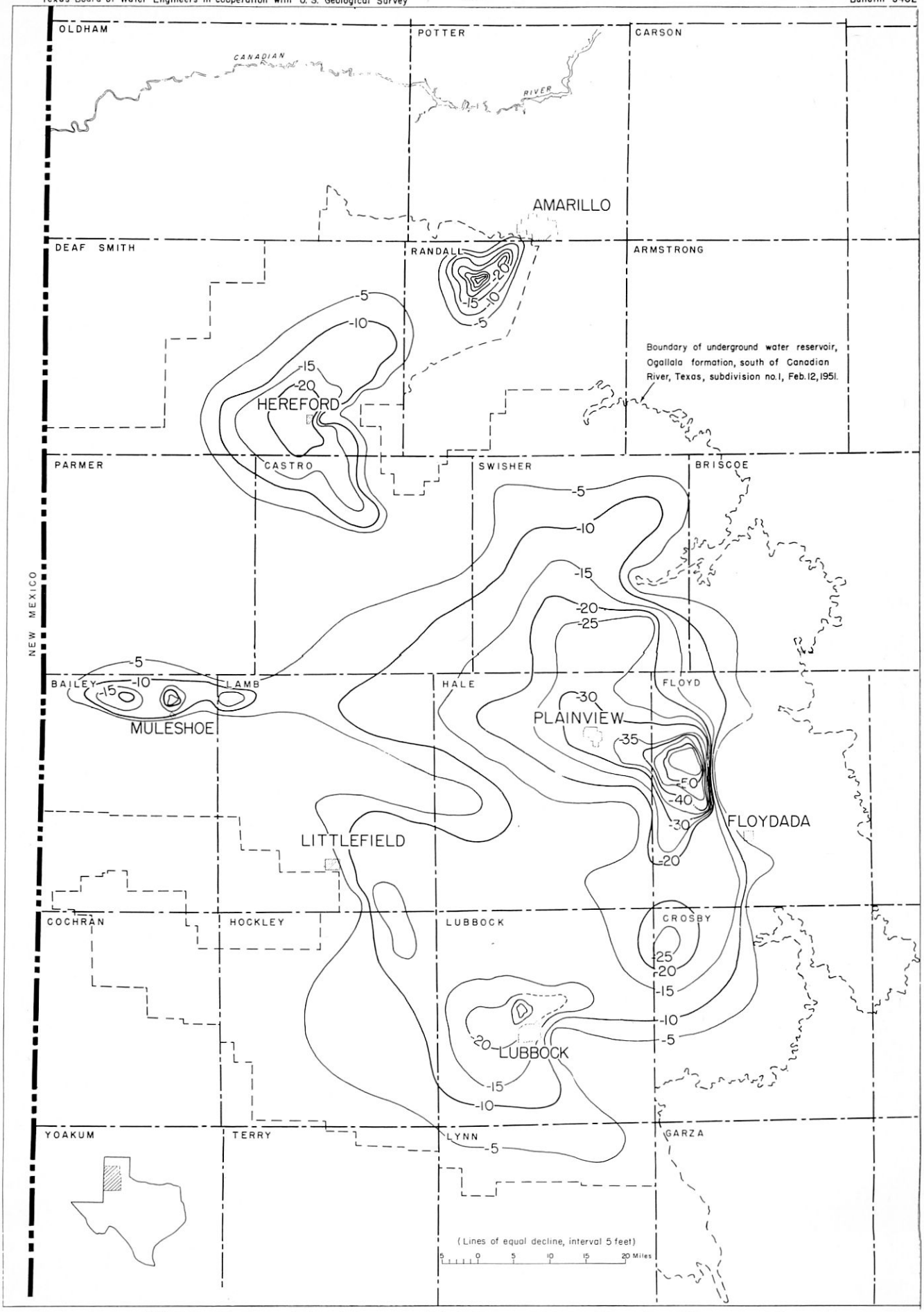


FIGURE 10.– Approximate decline of the water table in the Southern High Plains of Texas, March 1938 to January 1953.

EFFECTS OF DEVELOPMENT ON PUMPING LEVELS AND DISCHARGES OF WELLS

The phenomenal increase in the number of wells installed and the ever-increasing rate of ground-water withdrawal since 1938 have had a pronounced effect on the performance of wells in the Southern High Plains. Comparative performance data for 1938 and 1951 have been compiled for 51 wells in Deaf Smith, Floyd, Hale, and Swisher Counties, where wells were closely spaced and withdrawals were heavy. These data are shown in table 3.

Table 3.- Declines in water levels, pumping levels and discharges 1938 to 1951

Well	Water levels				Discharge	
	Nonpumping		Pumping			
	Feet below land surface					
	1938	1951	1938	1951	1938	1951
Deaf Smith County						
202	74	94	89	103	575	498
207	54	64	70	81	749	692
212	71	85	107	138	1,000	832
226	49	64	75	88	1,032	917
237	41	62	93	116	820	775
249	49	64	85	111	1,005	921
253	48	63	69	103	938	875
257	44	55	67	84	760	567
291	68	79	78	103	692	550
293	68	79	106	101	610	319
304	87	103	114	125	845	760
311	50	55	79	85	1,130	589
348	58	89	72	111	830	633
349	70	79	82	101	637	482
359	54	64	93	92	1,005	720
501	81	115	100	133	750	604
Average	60	76	86	105	836	671
Floyd County						
7	65	74	89	118	900	676
10	54	67	75	133	637	585
22	70	93	102	120	650	689
53	50	63	81	94	787	675
54	55	68	83	113	820	705
56	59	67	93	105	855	635
63	70	95	135	186	610	709
108	58	83	108	117	890	871
151	54	74	73	115	750	620
448	49	91	105	147	619	655
421	56	110	86	132	765	523
Average	58	80	94	125	753	668

Table 3.- Declines in water levels, pumping levels and discharges 1938 to 1951 -- continued

Well	Water level: Nonpumping 1938	Water level: Nonpumping 1951	Water level: Feet below land surface	Water level: Pumping 1938	Water level: Pumping 1951	Discharge 1938	Discharge 1951
			Hale County				
36	78	88		98	113	1,039	855
48	67	74		95	118	828	645
58	70	--		100	121	1,021	919
105	49	64		78	109	1,178	840
416	--	--		98	127	890	738
440	--	--		92	135	1,800	1,767
446	49	68		93	122	1,151	792
530	46	64		84	121	745	844
531	46	64		85	120	948	1,029
907	37	47		58	95	740	500
917	37	47		63	83	850	365
997	--	--		108	110	506	500
1409	--	--		73	98	1,222	729
1900	--	--		109	112	935	482
Average	53	65		88	113	989	786
			Swisher County				
1	90	90		165	162	550	450
40	60	64		98	104	900	494
59	114	120		167	181	900	854
201	41	51		79	101	950	776
235	51	70		65	102	950	800
370	72	91		90	133	844	750
372	72	91		91	117	525	410
376	68	87		100	126	857	884
413	86	95		115	143	800	615
888	65	80		80	95	1,000	771
Average	72	84		105	126	828	680

Table 3 presents only the comparative results and does not include such indeterminate factors as pump efficiencies, well construction, or pump installation, which also affect the changes in pumping levels and discharges. Although the records are incomplete in this respect, they do show the changes in the performance of the well due, in a large part, to the increase in the number of wells in operation, the increase in ground-water withdrawals, and the mutual interference between closely spaced wells during the irrigation seasons.

When a well is pumped the water table is lowered in the immediate vicinity of the well, the lowest point being at the well. Continued pumping gradually lowers the water in the formation, and the effects of pumping can be observed at increasingly greater distances from the pumped well. However, when closely spaced wells are pumped, the pumping level in each well is lowered as the result of interference caused by neighboring wells. Thus the decline in the pumping level in all the wells is much greater than that caused by the pumping of individual wells. (See fig. 11.)

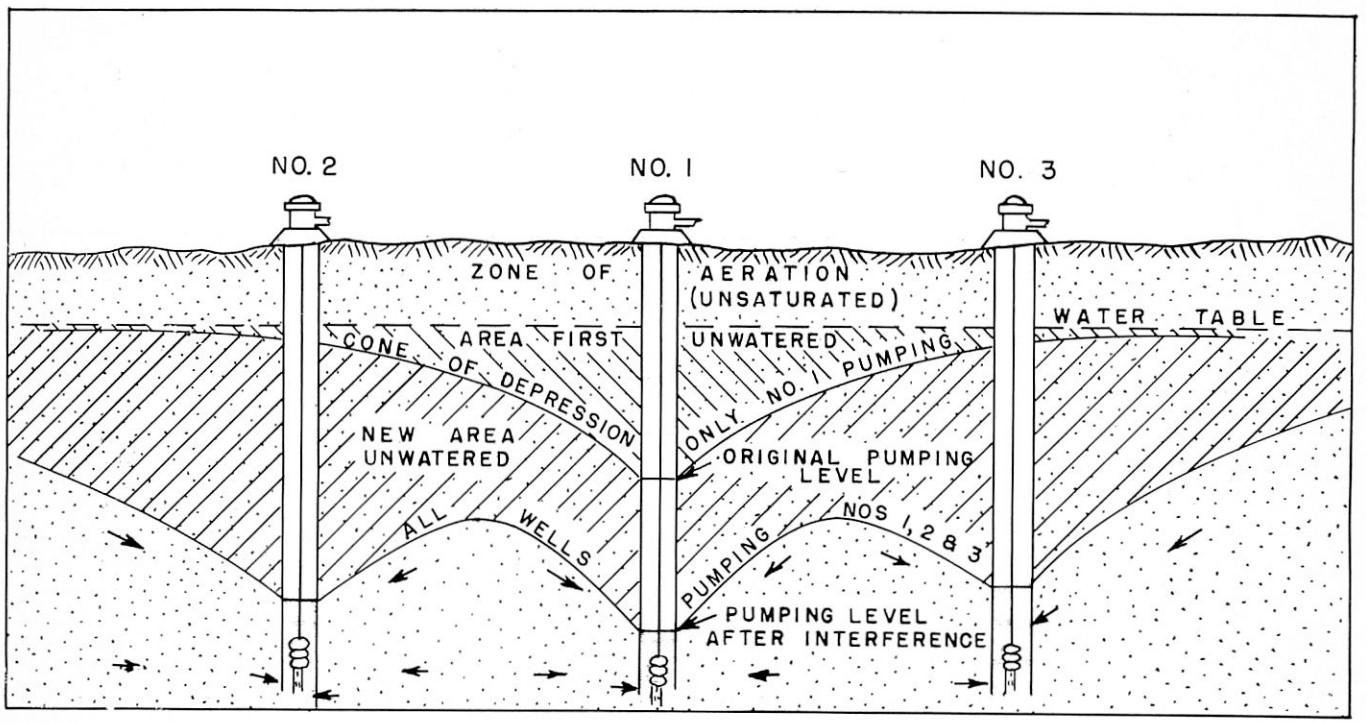


FIGURE 11. - Interference of water wells under water-table conditions.

Owing to the withdrawal of 11¼ million acre-feet of ground water since 1938, the saturated thickness of the Ogallala formation in the High Plains has been decreased. If this unwatering had been uniformly distributed, the water table would have declined about 10.2 feet and the saturated thickness decreased by about 5 percent, assuming an average saturated thickness of 200 feet. Inasmuch as the water-table decline has not been uniform and as the saturated thickness varies widely from place to place, the percentage decrease of the saturated thickness varies also. It is estimated that the water table declined an average of about 22 feet in the irrigated part of Floyd County and 12 feet in Lubbock County, however, the decrease in the saturated thickness was about 10 percent in both counties. However in the areas of maximum declines in these counties, excluding the areas of municipal well fields, the saturated thickness decreased nearly 30 percent in Floyd County and about 45 percent in Lubbock County.

The records for Floyd County show the largest decline in pumping levels (the greatest increase in pumping lift) but the smallest decline in discharge. A large number of wells in Floyd County have been reconditioned in order to maintain large yields. Wells have been cleaned or deepened, pump settings lowered, worn pumps replaced, and larger power units installed. Records maintained by the Southwestern Public Service Co. show that the size of the power units in more than 50 percent of the electrically operated pumps in Floyd County have been increased since 1947, by an average of about 20 percent.

Available data indicate that the discharge of 26 old municipal wells in Lubbock decreased from an average initial yield of 625 gallons a minute to 250 gallons a minute. The pumping levels as well as the pump settings in these wells are at or near the base of the water-bearing formation, thus precluding the possibility of increasing the discharge of the wells by the addition of larger pumping units.

SUMMARY AND CONCLUSIONS

From 1938 to 1952, inclusive, the number of irrigation wells in the Texas High Plains increased from 1,150 to 18,300, and during the same period the withdrawals of ground water totaled 11¼ million acre-feet, of which 5¾ million acre-feet was pumped in 1951 and 1952. Water levels declined correspondingly, the greatest declines occurring in the older irrigated areas. Despite the large withdrawals and the accompanying decline of the water table in the pumped areas, there has been little or no decline in the water levels in wells or the flow of Quitaque Creek near the eastern edge of Floyd County, remote from the irrigated region.

Data obtained during the summers of 1938 and 1951 indicate that, in most wells, the pumping levels declined and the discharges decreased as a result of the large withdrawals, the declining water table, and the mass interference between wells during the irrigation seasons.

The decline in pumping levels, as in water levels, has been greatest in the heavily pumped area in Floyd County. The average discharge of wells, however, has been relatively less in Floyd County than in Deaf Smith, Hale, and Swisher Counties owing to the large percentage of wells that have been reconditioned in Floyd County.

A continuation of the present trend in pumpage and water level declines will necessarily result in a further decline of the pumping levels and decrease in the discharges of wells. In those wells that completely penetrate the aquifer there can be little expectation of a substantial improvement in well performance by extensive reconditioning of the well installation or pumping unit.

BIBLIOGRAPHY

U. S. Geol. Survey Water-Supply Paper 889-F.

Geology and ground water in the irrigated region of the Southern High Plains in Texas, Progress report no. 7, Texas Board of Water Engineers, March 1949.

Records of water-level measurements in Hale County, Tex., Bulletin 5302, Texas Board of Water Engineers, 1953.

Records of water-level measurements in Lubbock County, Tex., Bulletin 5303, Texas Board of Water Engineers, 1953.

Records of water-level measurements in Floyd County, Tex., Bulletin 5304, Texas Board of Water Engineers, 1953.

Records of water-level measurements in Deaf Smith County, Tex., Bulletin 5305, Texas Board of Water Engineers, 1953.

Records of water-level measurements in Lamb County, Tex., Bulletin 5306, Texas Board of Water Engineers, 1953.

Records of water-level measurements in Swisher County, Tex., Bulletin 5307, Texas Board of Water Engineers, 1953.