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DEVELOPMENT OF GROUND WATER FROM THE CARRIZO SAND AND WILCOX GROUP IN DIMMIT, ZAVALA, MAVERICK, FRIO, ATASCOSA, MEDINA, BEXAR, LIVE OAK, McMULLEN, LA SALLE, AND WEBB COUNTIES, TEXAS

By

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United States Geological Survey

Prepared in cooperation with the United States Geological Survey and the Nueces River Conservation and Reclamation District.

May 1957

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INTRODUCTION

Purpose and Scope

The development of ground water for irrigation from the Carrizo sand south and southwest of San Antonio, Tex., has increased rapidly during the past few years. Declining pumping water levels in irrigation wells, caused by increased withdrawals, have caused considerable concern among the residents of the area. In response, the Nueces River Conservation and Reclamation District entered into a cooperative agreement with the Texas Board of Water Engineers and the United States Geological Survey to determine the extent of development and the rate of withdrawal that has caused the decline.

All wells that discharged more than 150 gallons per minute for extended periods of time in 1955 from either the Carrizo sand or sands of the Wilcox group were studied and are shown on plate 1. Estimates were made of the total withdrawals by county and are given in table 2. Similar estimates of withdrawals in some of the counties for the irrigation years 1929-30, 1938-39, 1944-45, and 1947-48 are presented for comparison in table 3. Although the Carrizo sand is the principal source of ground water pumped in the area, estimates of withdrawals of water from the Wilcox were included in this inven-

tory because (1) the formation appears to be hydraulically connected to the Carrizo sand, (2) the quality of water generally is good in the outcrop area of the Wilcox, and (3) appreciable withdrawals are being made from the Wilcox for irrigation in a few areas.

The investigation covered an area of about 7,500 square miles and included all or parts of the following counties: Dimmit, Zavala, Maverick, Frio, Atascosa, Medina, Bexar, Live Oak, McMullen, La Salle, and Webb (fig. 1).

Previous Investigations

Investigations of the ground-water resources of the Winter Garden district (Dimmit and Zavala Counties and part of Maverick County) began in 1929. Records and conclusions from these investigations were reported by White and Meinzer (1931), White and Livingston (1940), and Outlaw and others (1952). Lonsdale (1935) reported on the development of water from the Carrizo sand in Atascosa and Frio Counties for 1930. A later report by Sundstrom and Follett (1945) discussed development in Atascosa County through 1945. Ground-water development in Medina County was discussed by Sayre (1936) and Holt (1956). Lonsdale and Day (1937) stated that in 1932 the Carrizo had not been used as a source of irrigation water in Webb County. Some general statements were made by Deussen and Dole (1915) regarding the development of ground water from their Myrick formation (includes the Carrizo sand) in La Salle and McMullen Counties. Well records for Live Oak County (White, 1940) show no irrigation wells in the Carrizo prior to 1940.

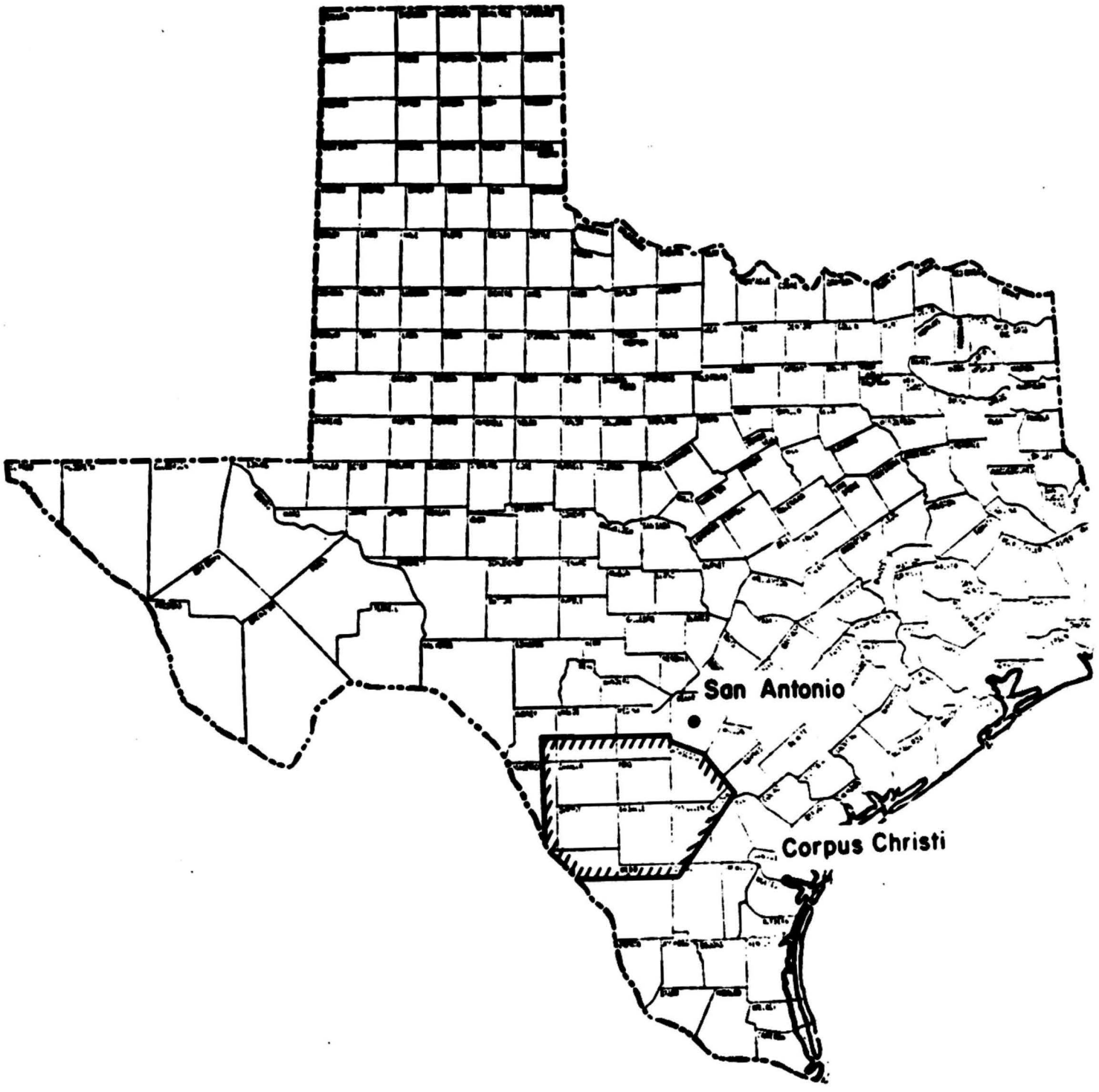

FIGURE 1.- Map of Texas showing location of area of investigation.

Method of Investigation

Records of power consumed for pumping water were obtained from the electric-power companies and natural-gas distributors serving the area. Estimates of irrigated acreage were obtained from field offices of government and local agencies and from individual well owners. The locations of wells were determined by Geological Survey personnel from maps and field inspection. Records of pumping equipment were furnished by the pump distributors serving the area and by the well owners.

Pump efficiencies, pumping rates, and rates of power consumption were determined by tests conducted at wells. Tests were made only at the wells that were readily suited for testing; as a result, wells selected for testing followed no statistical or geographic pattern.

Acknowledgments and Personnel

Excellent cooperation was received from individuals, agencies, and companies in the area of the report. Among those contributing information were Jay Myers and Alvin Morris, representatives of the Nueces River Conservation and Reclamation District; Fred Repper and numerous others of the Central Power and Light Co.; Frank Williams, assistant manager of the Medina Electric Co-Operative, Inc.; Mr. Hurd and others of the Rio Grande Electric Co-operative, Inc.; personnel of the Texas Gas Utilities Corp.; several butane and diesel-fuel distributors serving the area; representatives of pump-distributing companies, well drillers, Soil Conservation districts, local industries, and various agencies of the U. S. Department of Agriculture. Many farmers who allowed tests to be made at their wells deserve an expression of

thanks, as do numerous other individuals who gave material assistance during the investigation. Participating in the investigation were G. H. Shafer of the Texas Board of Water Engineers and O. C. Dale, Sergio Garza, and R. K. Gabrysch of the Geological Survey.

GEOGRAPHY AND GEOLOGY

The area investigated is in the Gulf Coastal Plain, which is a smoothly undulating to gently rolling plain extending southeast from the Edwards Plateau to the Gulf of Mexico. Fairly large areas with nearly flat surfaces ideally suited to irrigation farming are scattered throughout the Coastal Plain area. The principal streams have flood plains in broad, shallow valleys. Slopes rise smoothly and gently away from the valleys to the uplands. The area of the report is within the Nueces River basin, and the principal streams--the Nueces, Frio, and Atascosa Rivers--have their confluence near Three Rivers in Live Oak County. The altitude of the land surface ranges from about 100 feet in Live Oak County to 964 feet in Zavala County. The mean annual precipitation ranges from about 20 inches in the western part of the area to about 30 inches in the northeastern part. High to moderate temperatures and infrequent frosts make the area well suited to the production of winter truck crops. The economy of the area is based largely on irrigation farming.

The Carrizo sand is the principal water-bearing formation. It is underlain by the Wilcox group and overlain by the Mount Selman formation, both of which contain less permeable sands that generally yield more highly mineralized water. In some areas, however, the water in the Wilcox and Mount Selman is used for irrigation. Relatively impermeable beds of clay separate the water-bearing sands of the Mount Selman formation and the Carrizo sand, but the

sands of the Carrizo and the Wilcox are believed to be hydraulically connected to some extent. The Leona formation of Pleistocene age crops out along the stream valleys of the Leona and Nueces Rivers. It is the only other formation in the area that yields sufficient water for irrigation; however, it is limited to a small part of northern Zavala County. All the formations are recharged at their outcrops by precipitation.

The surface contact between the Wilcox group and the Carrizo sand is shown on plate 1. All the water-bearing formations in the area except the Leona are of Eocene age and dip toward the coast at a rate exceeding the slope of the land surface. South and east of their outcrops, the formations lie at increasingly greater depths below the land surface. Water of suitable quality and adequate quantity for irrigation is found in the Carrizo at depths considerably greater than 1,500 feet. Suitable water in sufficient quantities for irrigation is rarely found in the other formations at depths below 300 feet.

HISTORY OF IRRIGATION

Ground water from the Carrizo sand has been extensively developed for irrigation in the area of this investigation. The first recorded attempt at irrigation in the area, however, was with surface water near Batesville in 1876. The first flowing well was completed in 1884 at Carrizo Springs, and the water was used to irrigate about 4 acres of land. Irrigation increased slowly until about 1910 when surface reservoirs were built on the Nueces River and the newly built railroad to Crystal City increased the market potential. At this time surface supplies were the principal source of water for irrigation in the area. Successful crops and high profits led to the

rapid development of ground water to supplement surface-water supplies and to serve areas where surface water was not available. In addition to wells in the Carrizo sand, irrigation wells were drilled in the Leona formation near La Pryor and Batesville and in the sands of the Mount Selman near Pearsall and east of Pleasanton. These sources of water proved inadequate, and deeper wells were drilled to the Carrizo to obtain larger and more dependable supplies.

Irrigation developed most rapidly in Zavala, Dimmit, and La Salle Counties, and by 1920 the Carrizo sand was the principal source of water. Development continued in Dimmit and Zavala Counties after 1920, but it virtually ceased in La Salle County because of poor quality of water and the high cost of drilling deep wells. The same factors have restricted development in Webb, McMullen, and Live Oak Counties. The Carrizo sand and sands of the Wilcox age have not been extensively developed in Maverick, Medina, and Bexar Counties because only a small part of the area is underlain by the sands, yields from wells have been small, and the area having soils suitable for irrigation farming is relatively small.

Acreages irrigated by surface and ground water for some of the counties included in the report are shown in table 1 for several periods from 1929 to 1954. Table 1 cannot be compared exactly with tables 2 and 3, which are based on irrigation only from the Carrizo sand and sands of the Wilcox group. Only a small percentage of the acreage shown in table 1, however, was irrigated from sources of water other than the Carrizo sand. Zavala County led in development of new irrigation until 1949. The greatest increase in development in Dimmit County was from 1944 to 1949. During the period 1949-54 the acreage irrigated declined in Zavala and Dimmit Counties and increased in

Atascosa, Frio, and Live Oak Counties. Development in the latter two counties was exceptionally rapid. The present inventory of acreage for land irrigated with water from the Carrizo sand (table 2) suggests that Dimmit and Zavala Counties have had little or no additional development and that irrigated acreage during 1955 was nearly doubled in Atascosa and Frio Counties

Table 1.- Irrigated acreage in Zavala, Dimmit, Atascosa, Frio, La Salle, and Live Oak Counties, Tex. (reported by U. S. Department of Commerce, Agriculture Census) a/

Year	Zavala	Dimmit	Atascosa	Frio	La Salle	Live Oak
1929	13,126	13,694	1,452	1,101	2,419	--
1934	19,616	10,056	3,040	755	3,216	--
1939	23,384	14,305	2,321	761	3,094	--
1944	32,367	13,345	2,943	916	5,217	--
1949	46,287	21,898	4,106	2,323	1,812	90
1954	45,763	18,340	6,667	9,415	4,420	2,986

a/ Figures include acreage irrigated with surface water and ground water from the Carrizo sand, Wilcox group, and Mount Selman and Leona formations. No census figures available for McMullen County.

INVENTORY OF WITHDRAWALS

The present development of water for irrigation from the Carrizo sand and sands of the Wilcox group in the area of this study is greatest in Dimmit, Zavala, Frio, and Atascosa Counties. Table 2 indicates that about 94 percent of the total withdrawal in 1955 for the 10 counties surveyed was from wells in these 4 counties. The total withdrawal was about 145,000 acre-feet or 129 million gallons a day, of which about nine-tenths was used for irrigation.

In general, data on the quantity of water withdrawn for municipal and industrial wells were obtained from city or company records. Three different methods were used in calculating the withdrawals of ground water from irrigation or other wells where existing records of withdrawals were not available. Discharge for one group was calculated from annual power consumption and field ratings of pumping equipment; for a second group from power consumption and estimated ratings; and for the third group on the basis of average use per unit of irrigated area. The quantity of water pumped per unit of power consumed was determined for about 70 wells by field tests. The average overall efficiency was determined for pumping plants on 20 of the tested wells, and the average ratio of pumping lift to pump setting also was calculated. Using these averages and the reported pump setting, the quantity of water pumped per unit of power consumed was estimated for each nonrated well pump operated by electricity. Using figures of electric-power consumption obtained from the power companies, the measured and estimated power ratings were used to calculate the annual withdrawals. The ratio of withdrawals to irrigated acreage was calculated from selected data for about 400 electrically powered pumps. The average ratio of withdrawals to acreage irrigated for each county and the acreage figures were used to estimate the withdrawals for wells that were not rated.

Table 2.- Withdrawals of ground water from the Carrizo sand and Wilcox group in the Winter Garden and adjacent area, 1955. 1/

County	No. of active wells			Irrigated acreage	Withdrawals in acre-feet		
	Irrigation	Other	Total		Irrigation	Other	Total
Zavala	279	10	289	43,100	51,900	1,000	52,900
Dimmit	237	14	251	22,100	24,900	700	25,600
Maverick	11	0	11	1,000	1,200	0	1,200
La Salle	25	5	30	3,200	4,100	1,700	5,800
Frio	112	5	117	2/15,400	29,300	1,800	31,100
Medina	29	8	37	1,100	2,200	1,000	3,200
Bexar	3	0	3	50	70	0	70
Atascosa	181	9	190	13,800	16,700	7,800	24,500
McMullen	2	1	3	130	160	90	250
Live Oak	1	1	2	30	36	6	42
TOTAL 3/	880	53	933	100,000	131,000	14,000	145,000

1/ Includes figures for all wells which produced more than 150 gpm for extended periods throughout the calendar year 1955. There were no appreciable withdrawals from wells in Webb County. The quantity of water withdrawn from other wells in the area was probably less than 3 percent of the total.

2/ Includes only one crop. Total acreage for year may be as much as 20-25,000.

3/ Areas and volumes rounded off to nearest thousand.

The results of previous inventories of withdrawals are presented for comparison in table 3. Withdrawals from Dimmit, Zavala, and Maverick Counties were less for the 1937-38 irrigation year than for the 1929-30 irrigation year. Withdrawals for irrigation in these counties more than doubled in the period 1938-48, and by 1955 withdrawals had increased another 40 percent to a total of about 80,000 acre-feet or about 71 million gallons a day. Frio County ranked fourth in the development of ground water from the Carrizo sand in 1930, but by 1955 withdrawals for irrigation were greater than in any other county except Zavala. Withdrawals in Atascosa County increased 6,000 acre-feet from 1930 to 1945, and 9,000 acre-feet from 1945 to 1955. The withdrawals from La Salle County were considerably less in 1955 than in 1913.

Table 3. Withdrawals of ground water, in acre-feet, from the Carrizo sand in the Winter Garden district and nearby counties. a/

Irrigation Years	b/1913			1929-30			1937-38			1944-45			1947-48		
County	Irrigation	Other	Total	Irrigation	Other	Total	Irrigation	Other	Total	Irrigation	Other	Total	Irrigation	Other	Total
Zavala, Dimmit, and Maverick	-	-	-	27,000	-	-	22,000	-	-	-	-	-	52,000	2,800	54,800
Atascosa	-	-	-	3,200	c/6,300	9,500	-	-	-	7,900	c/7,600	15,500	-	-	-
Frio	-	-	-	2,060	c/4,440	6,500	-	-	-	-	-	-	-	-	-
La Salle	9,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-

a/ Data from Deussen and Dole (1915), Lonsdale (1935), Sundstrom and Follett (1945).

b/ Withdrawals for calendar year.

c/ Estimated waste from flowing wells.

EFFECTS OF WITHDRAWALS ON WATER LEVELS

Withdrawals for Irrigation

The withdrawal of ground water from the Carrizo sand for irrigation during a period of many years has caused continued declines of water levels throughout the Winter Garden and adjacent area. Prior to the development of ground water from the Carrizo, water levels in wells were above the land surface in many places and probably were nowhere more than 100 feet below the land surface. Present water levels in wells in several areas in Dimmit and Zavala Counties are between 300 and 400 feet below the land surface.

Periodic water-level measurements have been made in several wells since 1929. These and other water-level records have been published in reports by Swartz (1954) and Follett (1956 a, b, and c). Some of the longest records of water levels are shown on figures 2, 3, and 4, and the locations of the wells in which these observations were made are shown on plate 1. As the measurements were made in September, the month before the beginning of the winter irrigation season, the graphs generally show the highest water level for the year.

Prior to about 1943 most wells were used to irrigate one crop a year, but since that time most wells have been used to irrigate two or more crops a year. As a result of this changing practice and the trend toward larger capacity pumps, the annual withdrawal per well has increased.

Declines in water level have been comparatively small except in parts of Dimmit, Zavala, and Frio Counties (see figs. 2, 3, and 4 and pl. 1). If the rapid rate of irrigation development continues in Atascosa and Frio Counties, however, declines of water level similar to those experienced in Dimmit and Zavala Counties should be expected.

Ground water in the outcrop area of the Carrizo is unconfined. Downdip the water becomes confined beneath relatively impermeable clay of the Mount Selman formation. Declines of water levels in the outcrop area represent depletion of storage, whereas declines downdip represent a loss in artesian pressure. No dewatering occurs downdip from the outcrop except where the water levels may have declined below the upper confining bed.

Wells M3-7a, M6-19, and S1-18 (figs. 2 and 3) are in or near the outcrop area of the Carrizo. Sufficient data are not available to estimate the average rate of decline throughout the outcrop, but the available water-level records show a net decline since 1948 ranging from about 3 feet to more than 50 feet.

Increasing rates of withdrawal are responsible for the continued decline in water levels in the part of the ground-water reservoir that is under artesian conditions. Figures 2 and 3 show the relation of water levels to rates of withdrawal. Water levels generally were higher in 1938 than in 1930. The withdrawal of ground water for irrigation for these two periods was 22,000 and 27,000 acre-feet, respectively. (See table 3.)

Plate 1 shows a good example of the effects of concentrated development of ground water. In the late 1940's yields from wells in the Leona formation decreased appreciably in the Batesville area. The decrease prompted rapid development of water from the Carrizo sand, and during the period 1948-55, 55 to 60 wells were completed in the Carrizo in this area. This was about twice as many new wells as were completed elsewhere in the Carrizo in the Winter Garden district during the same period. The results of this concentrated withdrawal are shown by a large localized decline of water levels in the Batesville area.

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Other Withdrawals

Declines of water level caused by increased withdrawals for purposes other than irrigation are difficult to determine from existing data. Population increases and industrial development have not been great enough to cause a substantial increase in demands for water. Probably declines that are attributable to withdrawals for purposes other than irrigation are small except in the Campbellton area, Atascosa County. In that area withdrawal by the wells owned by the city of Corpus Christi is large compared to that for irrigation.

The city wells discharged 6,500 acre-feet of water by natural flow during 1955--an average rate of about 5.8 million gallons a day. Municipalities and food-processing plants used most of the remaining 7,500 acre-feet of ground water pumped for nonirrigation purposes (table 2). A comparatively small quantity of water was used for stock or wasted from flowing wells. A reduction in the number of flowing wells resulting from a decline in artesian head has reduced the waste of ground water from several thousand acre-feet in 1930 to practically nothing in 1955.

Pumping Lifts

Records of pump settings collected for this investigation are indicative of pumping lifts. The deepest pump settings are in Zavala County, where several pumps are set at 500 feet or more below the land surface and more than 60 percent of the active wells have pump settings exceeding 300 feet. About 10 percent of the pumps in Dimmit County are set below 400 feet, but most are set between 200 and 400 feet. Except for a few pumps in Frio County, the remainder of the pumps in the area are set at depths of 300 feet or less,

and most are not deeper than 200 feet. Less than 30 wells were reported flowing appreciable quantities of water; these were in Atascosa, Live Oak, and La Salle Counties. No large flowing wells were reported in the other seven counties.

SUMMARY

The Carrizo sand and sands of the Wilcox group are the source of water for more than 900 irrigation, municipal, and industrial wells in Dimmit, Zavala, Maverick, Frio, Atascosa, Medina, Bexar, McMullen, Live Oak, and La Salle Counties. About 90 percent of the 145,000 acre-feet of water withdrawn during 1955 was used for irrigation. The largest concentrated withdrawal of ground water for purposes other than irrigation was 6,500 acre-feet in 1955 from the wells at Campbellton owned by the city of Corpus Christi.

Zavala and Dimmit Counties have the greatest number of wells and until 1955 had the greatest withdrawals. In 1955, however, withdrawals in Frio County were second to those in Zavala County. Withdrawals in 1955 exceeded 5,000 acre-feet in each of 5 counties: Zavala County, 52,900 acre-feet; Frio County, 31,100 acre-feet; Dimmit County, 25,600 acre-feet; Atascosa County, 24,500 acre-feet; and La Salle County, 5,800 acre-feet.

Figures on irrigated acreage indicate that withdrawals of ground water remained essentially the same from 1954 to 1955 in Dimmit and Zavala Counties. During the same period the irrigated acreage nearly doubled in Frio and Atascosa Counties. Extensive development of ground water for irrigation in the rest of the counties in the area of this study is likely to be small by

comparison because of the poor quality and small quantity of ground water, the costs of drilling deep wells, the small areal extent underlain by the sands, and the unsuitability of much of the land for irrigation farming.

Records of water levels in wells show that artesian heads have declined in response to increasing rates of withdrawal. Many wells have ceased flowing, and pumping lifts of more than 300 feet are common in the western part of the area where declines have been greatest. Similar declines and subsequent deep pumping levels may be expected within a few years in Frio and Atascosa Counties if development of irrigation continues at its present rapid rate.

Declining water levels in wells observed in the outcrop area are evidence that the sands are being dewatered slowly. Sufficient records are not available to determine the average rate of dewatering.

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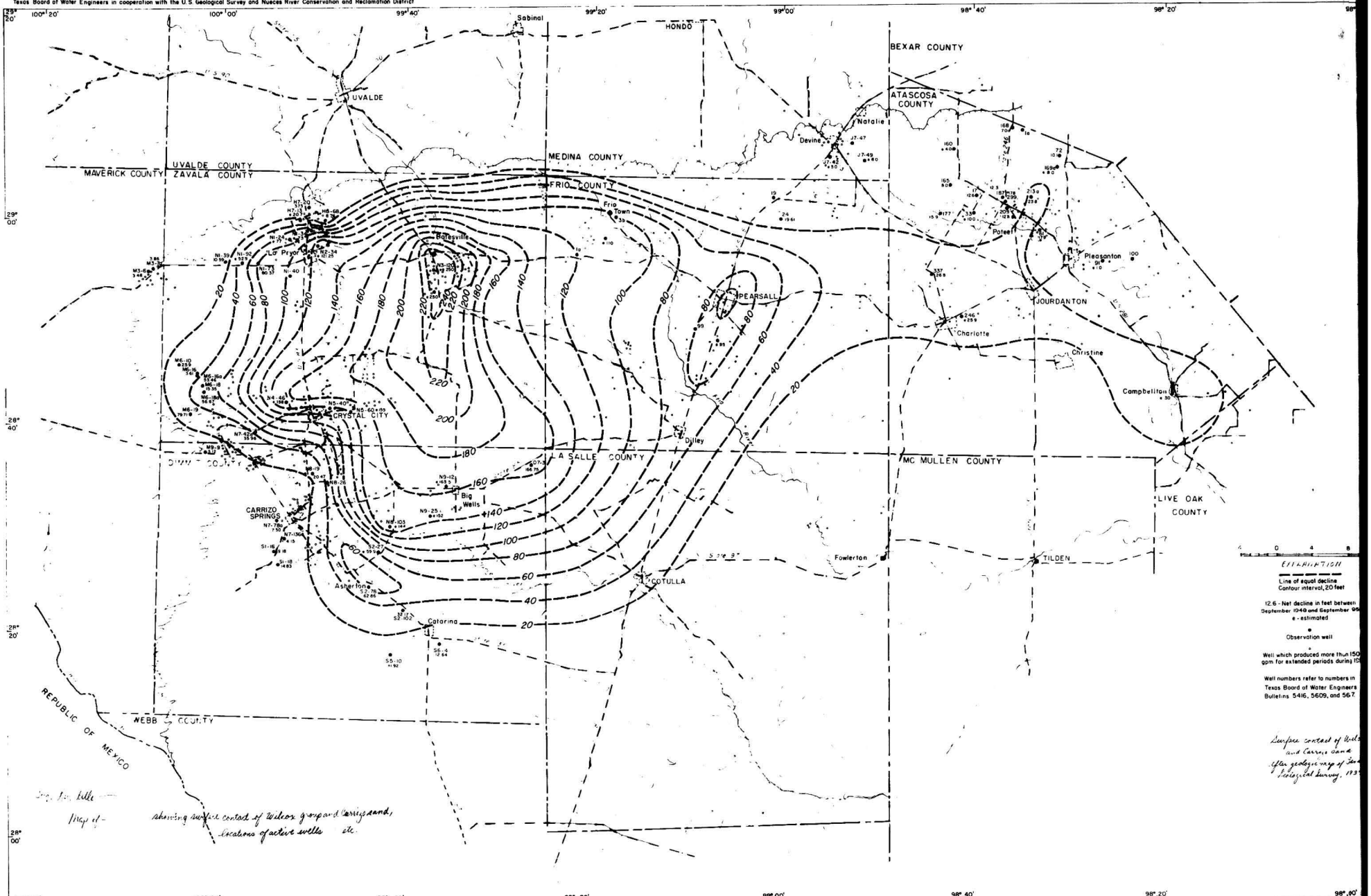
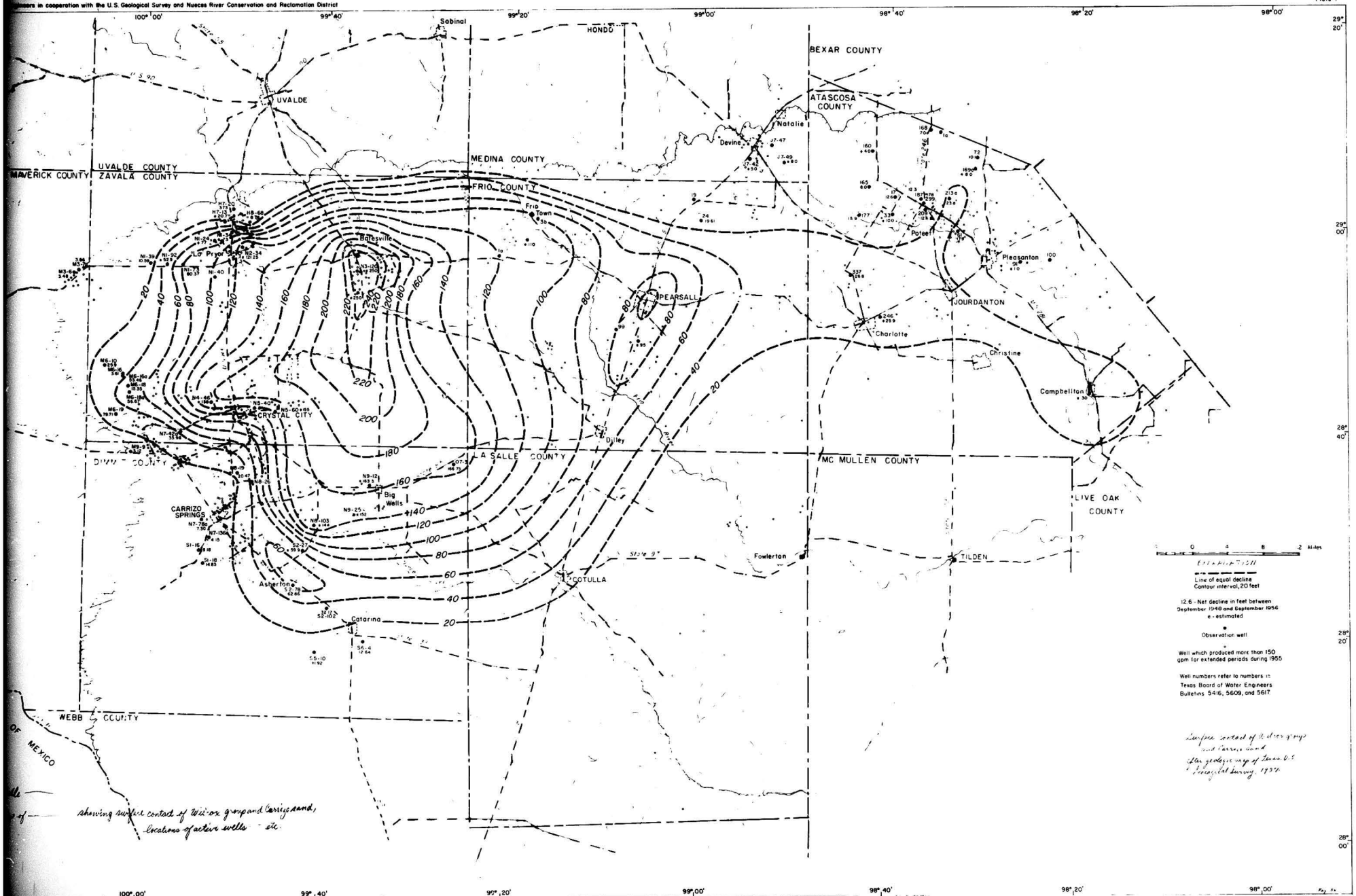


LOCATIONS OF ACTIVE WELLS, 1955, AND DECLINE OF WATER LEVELS ~~AND ARTESIAN PRESSURES~~, 1948-56, IN WELLS IN THE CARRIZO SAND AND WILCOX GROUP IN THE WINTER GARDEN AND ADJACENT AREA, TE



ACTIVE WELLS, 1955, AND DECLINE OF WATER LEVELS ~~AND ARTESIAN PRESSURES~~, 1948-56, IN WELLS IN THE CARRIZO SAND AND WILCOX GROUP IN THE WINTER GARDEN AND ADJACENT AREA, TEXAS.

Texas Board of Water Engineers in cooperation with the U.S. Geological Survey and Nueces River Conservation and Reclamation District

Fig. 2

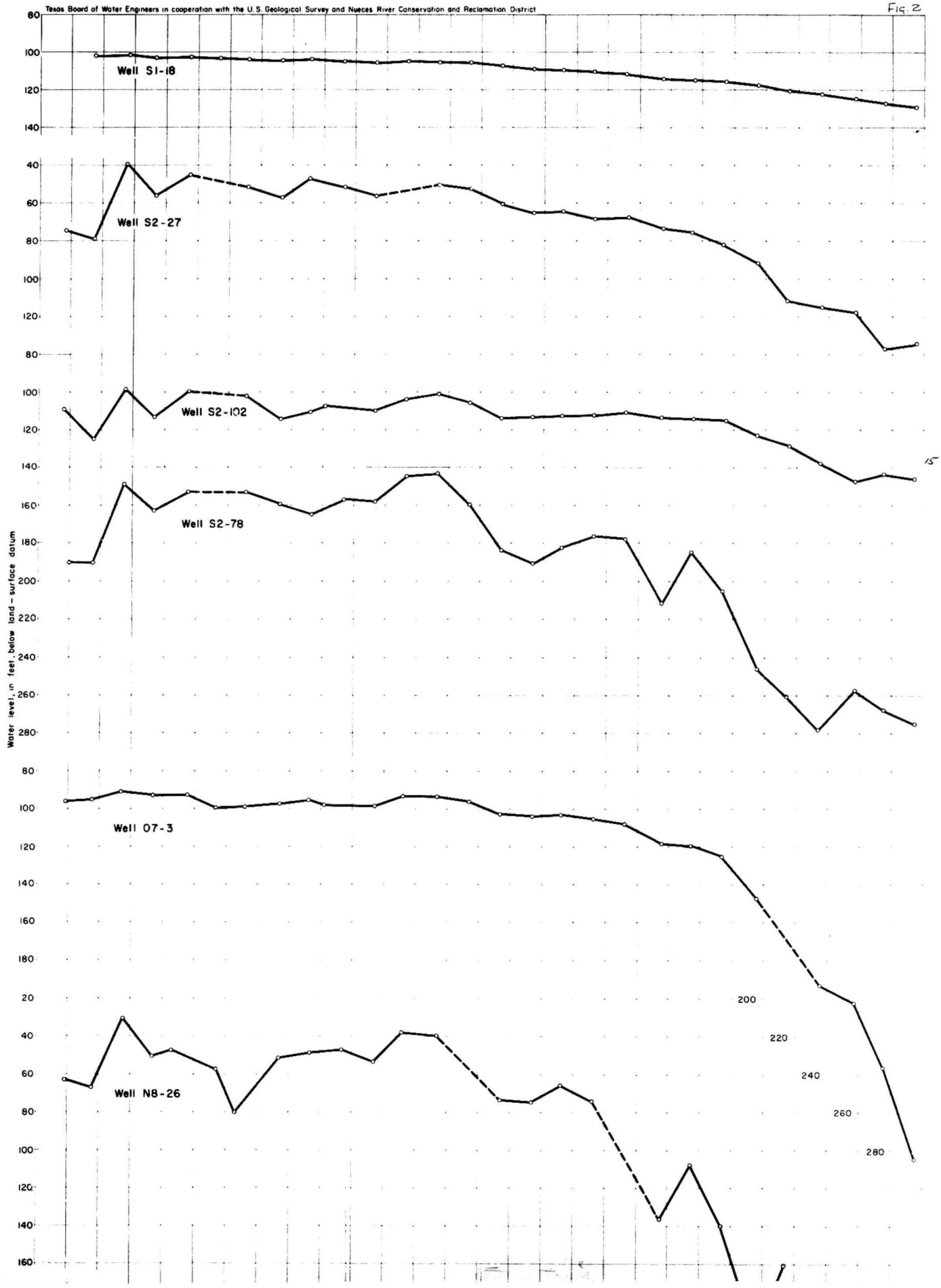
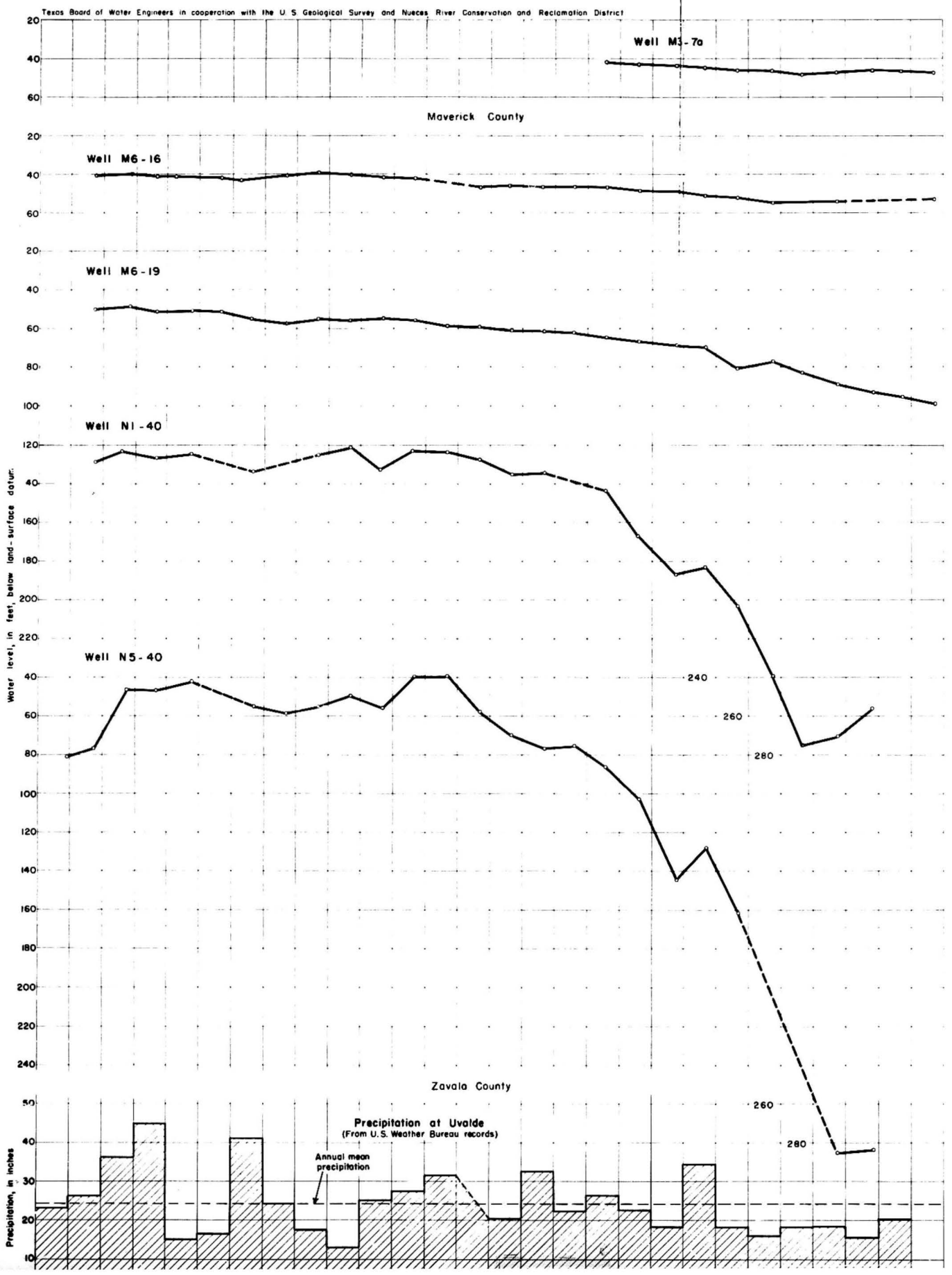


FIGURE 2.- Hydrographs showing fluctuations of water levels in wells in Dimmit County and precipitation at Carrizo Springs, Tex.

57-77 Fig. 3


Texas Board of Water Engineers in cooperation with the U. S. Geological Survey and Nueces River Conservation and Reclamation District
Well M3-7a
Maverick County
Well M6-16
Well M6-19
Well N1-40
Well N5-40
Water level, in feet, below land-surface datum
Zavala County
Precipitation at Uvalde
(From U. S. Weather Bureau records)
Annual mean precipitation
Precipitation, in inches

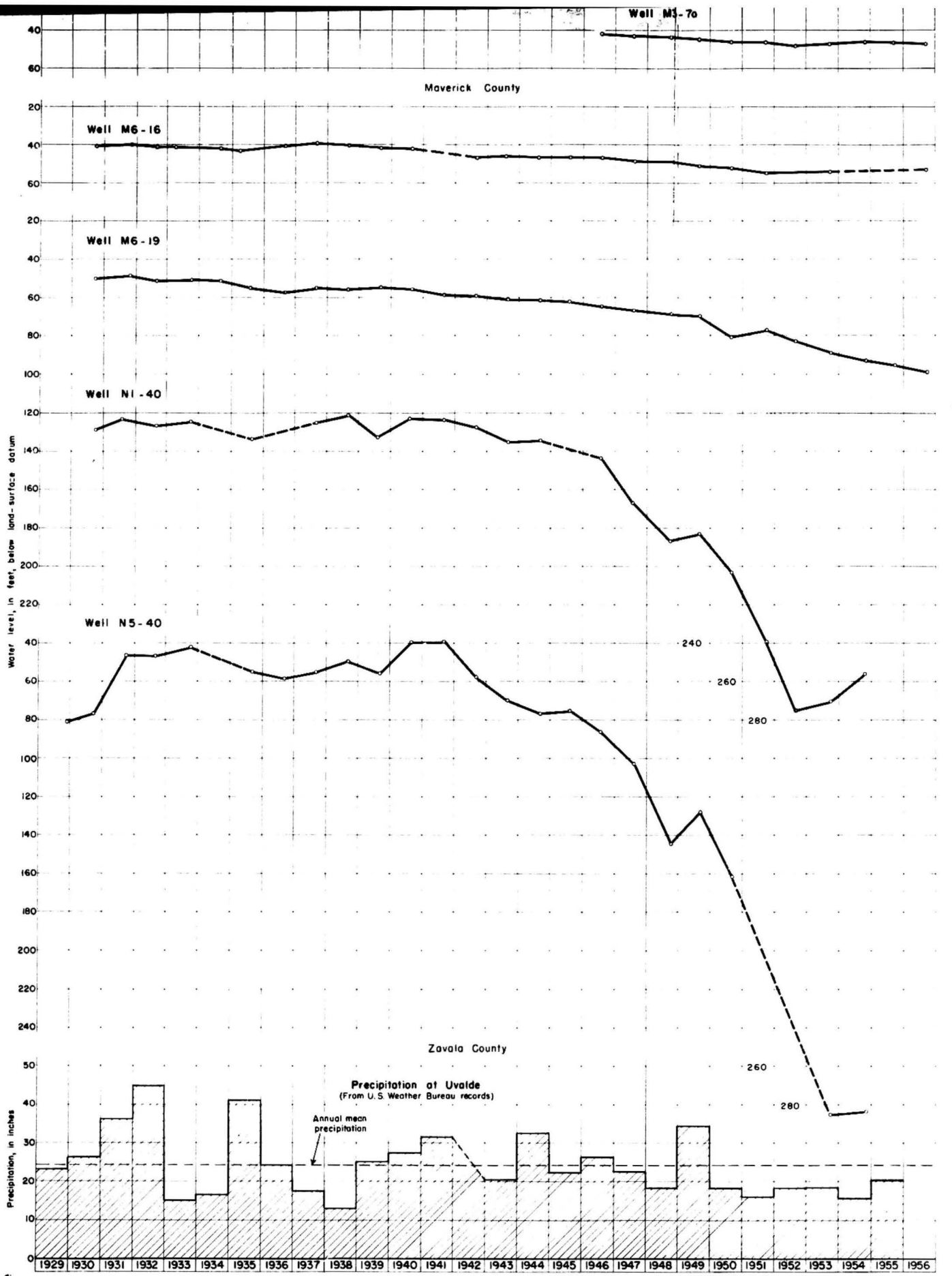


FIGURE 3.-Hydrographs showing fluctuations of water levels in wells in Maverick and Zavala Counties and precipitation at Uvalde, Tex.

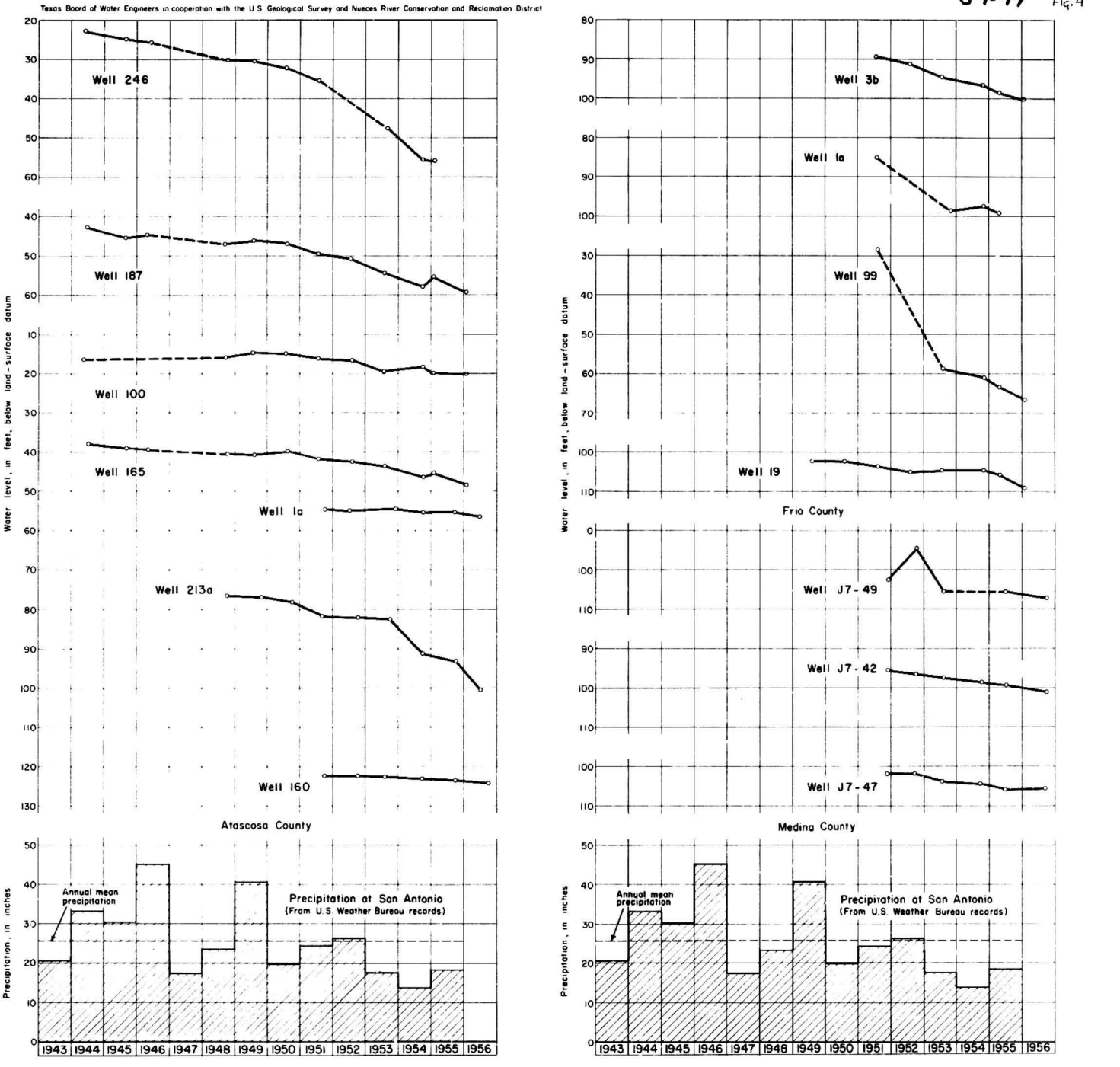


FIGURE 4.- Hydrographs showing fluctuations of water levels in wells in Atascosa, Frio, and Medina Counties and precipitation at San Antonio, Tex.