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BULLETIN 6402

GEOLOGY AND GROUND-WATER RESOURCES OF CARSON COUNTY AND PART OF GRAY COUNTY, TEXAS

PROGRESS REPORT NO. 2

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Prepared by the U. S. Geological Survey
in cooperation with the
Texas Water Commission
and the
Ground Water Conservation District No. 3
South of the Canadian River

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GEOLOGY AND GROUND-WATER RESOURCES OF CARSON COUNTY AND PART OF GRAY COUNTY, TEXAS

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ABSTRACT

Development of ground water in Carson and Gray Counties in the Panhandle of Texas continued to expand during the period 1960-62. During this period, 60 wells were drilled, 42 of which were drilled in 1962. By January 1, 1963 the total number of wells used or available for use was 431. During the period 1960-62, about 293,000 acre-feet of ground water was pumped, of which 259,000 acre-feet, or nearly 90 percent, was pumped by wells in Carson County, and of the total pumpage in the 2-county area nearly two-thirds was for irrigation. The withdrawal of ground water during the period 1960-62 amounted to only about 1 percent of the estimated total water in storage.

The continued development of the ground-water supplies in the Ogallala Formation has resulted in further decline of the water table. During the period 1960-62, the water level declined a maximum of 11.4 feet in the heavily irrigated part of Carson County as compared to a decline of only 2.7 feet in Gray County where the pumpage for irrigation is relatively small. Since 1954, when irrigation began, the water table has declined a maximum of 26.9 feet in Carson County; the maximum decline was only 3.4 feet in Gray County. In some wells remote from pumping for irrigation, the water levels have risen.

In a northeast-trending belt about 32 miles long and 2 to 3 miles wide, the ground water in the Ogallala Formation, the principal aquifer in the report area, is considerably higher in sulfate and chloride content than in other parts of the report area. Available data strongly indicate that relatively highly mineralized water in the northeastward-trending belt apparently is not related to the use of salt-water disposal pits. Elsewhere, evidence does indicate that contamination from surface pits is present, notably in a local area southeast of Pampa.

Because of the slow movement of ground water in the Ogallala Formation, the lack of large-scale development of the ground water in areas of salt-water disposal pits, and the wide spacing of existing wells, other areas of possible contamination resulting from surface disposal of oil-field brines in Carson and Gray Counties have not been detected.

GEOLOGY AND GROUND-WATER RESOURCES OF CARSON COUNTY AND PART OF GRAY COUNTY, TEXAS

PROGRESS REPORT NO. 2

INTRODUCTION

Location and Extent of Area

Carson and Gray Counties are in the approximate center of the Panhandle of Texas (Figure 1). The report area includes about 1,400 square miles, 1,300 of which lies within the boundary of the Ground Water Conservation District No. 3, South of the Canadian River. The 81 square miles in eastern Potter County added to the district in January 1963 is not included in this report.

Purpose

The purpose of this report is to present data on ground-water development, fluctuations of water levels, the chemical quality of the ground water, and related information compiled during the period 1960-62. This report is a progress report resulting from the current investigation that was begun in June 1957 by the U. S. Geological Survey in cooperation with the Ground Water Conservation District No. 3, South of the Canadian River, and the Texas Water Commission. One of the purposes of this investigation was to establish a network of observation wells to monitor possible future changes in chemical quality of ground water in the Ogallala Formation. The investigation was made under the immediate supervision of A. G. Winslow, district geologist in charge of ground-water investigations in Texas.

Acknowledgments

Appreciation is expressed for personal assistance given during the investigation by Mr. F. W. Ryals, manager, and other officials of the Ground Water Conservation District No. 3, South of the Canadian River; and for cooperation and information furnished by officials of cities, counties, industries, and the well owners and drillers; and for the assistance of the Soil Conservation Service of the U. S. Department of Agriculture and the County Agricultural Agents.

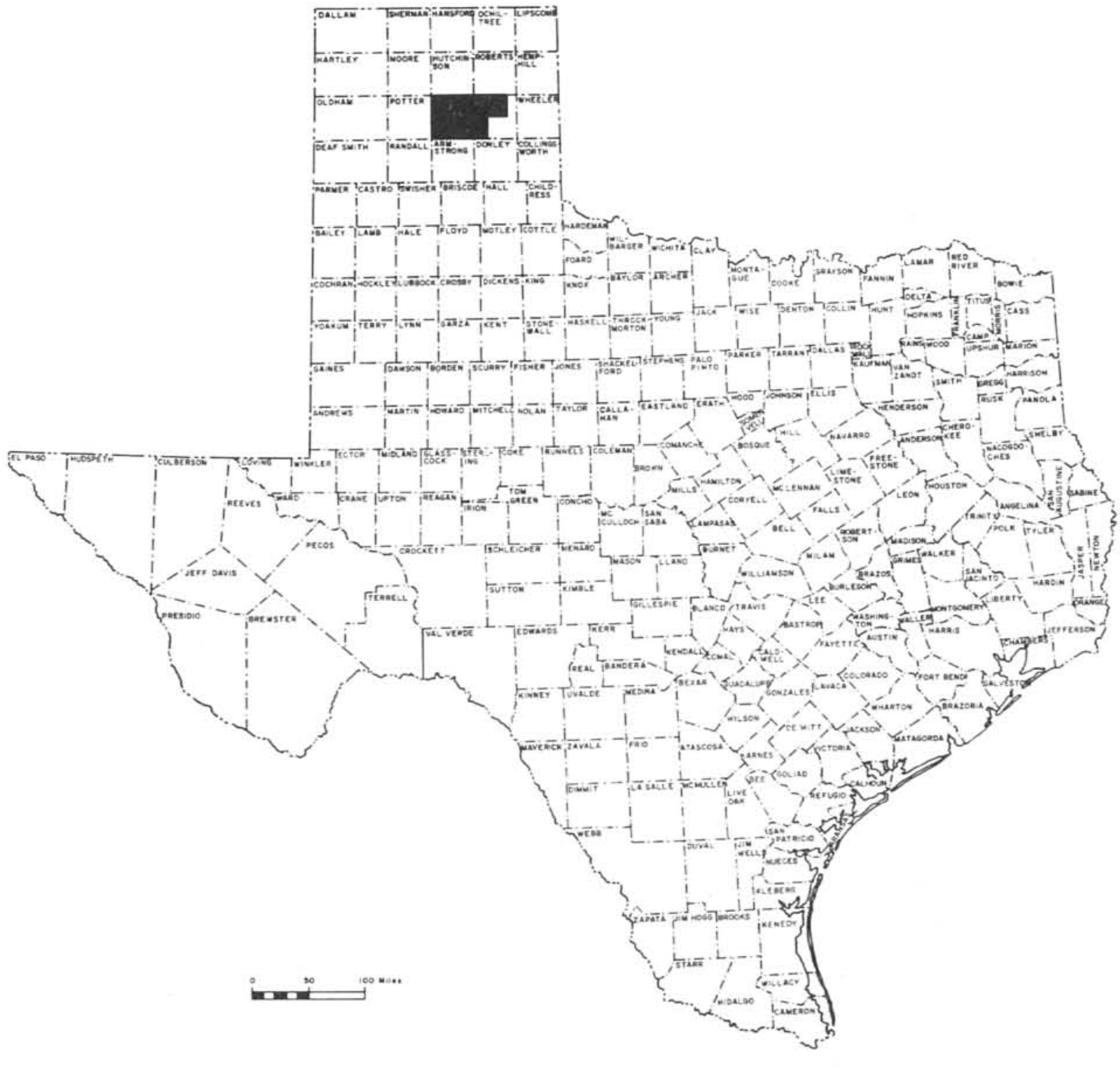


Figure 1

Index Map of Texas Showing Location of Area Discussed in this Report

U. S. Geological Survey in cooperation with the Texas Water Commission and the Ground Water Conservation District No. 3, South of the Canadian River

PRECIPITATION AND EVAPORATION

According to the records of the United States Weather Bureau, the annual precipitation at Amarillo averaged 29.62 inches during the period 1960-62 (Table 1), compared with the long-term mean of 21.12 inches. More than 60 percent of the annual precipitation falls during the period June to September as local thunderstorms of irregular areal distribution. Records show that in some years a few areas may have above-normal precipitation, while others may have several inches below normal. For example, in 1962 precipitation at Amarillo was 29.76 inches; whereas at Pampa the precipitation was only 17.22 inches. Residents in and near White Deer reported that rainfall during 1962 was below average because of the small amount of precipitation during June when 10.16 inches was recorded at Amarillo.

The evaporation from a free water surface, based on observations in a Young screen-type evaporation pan at Bushland near Amarillo, averaged 60.16 inches per year for the period 1960-62 (Table 2), in contrast to 86.00 inches per year for the previous 9-year period.

GROUND WATER IN THE OGALLALA FORMATION

Ground water in the Ogallala Formation, the principal aquifer in Carson and Gray Counties, occurs under water-table conditions except locally where it may be confined beneath less permeable material. The Ogallala Formation consists of sand and gravel, silt, clay, and caliche, and ranges in thickness from 0 where the red beds crop out to more than 900 feet in western Carson County. The thickness of the saturated material is a rough measure of the availability of water in the Ogallala Formation. However, the type of material below the water table may vary greatly over a short distance. A study of drillers' logs indicates that sand and gravel constitute about 50 percent of the total fresh-water-bearing sediments in the Ogallala Formation. The thickness and areal distribution of the saturated sand and gravel (excluding the silt, clay, and caliche) is shown in Figure 2. In some areas, the map shows abrupt changes in a short distance; for example, in the northwestern part of Carson County, the saturated sand and gravel ranges in thickness from 0 to as much as 155 feet in less than half a mile. In the vicinity of the Amarillo well field in the western part of Carson County, the maximum thickness is more than 400 feet. In a large area in the southwestern part of Carson County, the saturated sand and gravel is less than 50 feet thick and, in general, wells in this area yield insufficient quantities of water for irrigation. The map shows also that in several small areas in southeastern Carson County and western Gray County few wells have been drilled, although the thickness of the saturated sand and gravel is as much as 100 feet. However, the map should be used with caution in locating new wells because interpretation between control points may be substantially in error.

The Ogallala Formation rests on an irregular surface cut in Triassic and Permian rocks. The configuration of this buried surface is shown by means of contours on the base of the Ogallala Formation (Figure 3). The altitude of the base of the Ogallala ranges from about 3,200 feet above sea level in the northwestern and southwestern corners of Carson County to about 2,200 feet in

Table 1.--Precipitation, in inches, at Amarillo, 1960-62

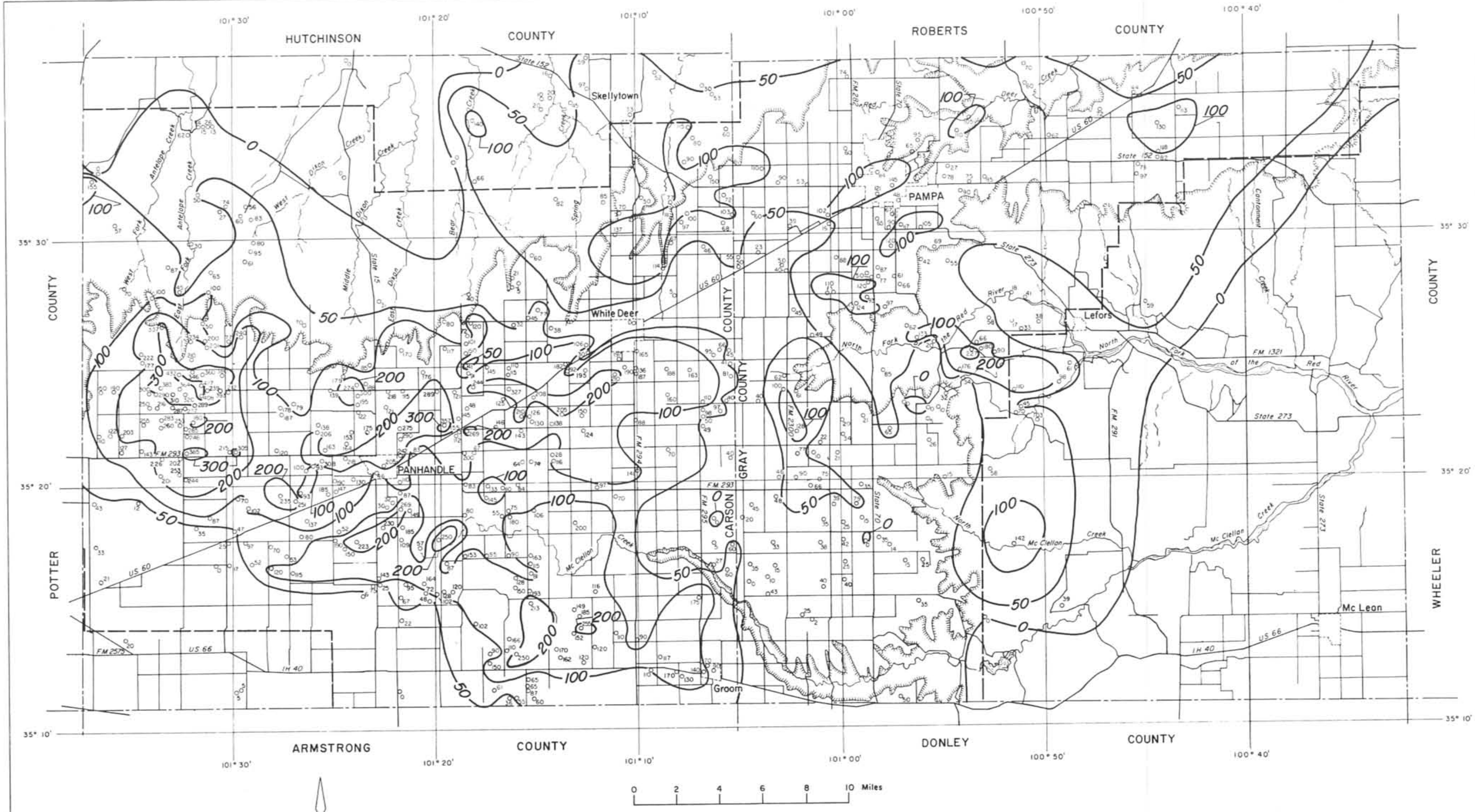
(Data from U. S. Weather Bureau)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1960	1.30	0.95	1.66	1.66	0.82	9.85	7.59	3.15	4.22	4.82	Trace	0.65	36.67
1961	.12	.27	2.55	.24	3.40	3.42	4.10	3.14	1.87	.91	2.26	.16	24.44
1962	.47	.39	.02	1.48	1.76	10.16	7.51	3.29	2.66	.85	.53	.64	29.76

Table 2.--Evaporation, in inches, at Bushland, near Amarillo, 1960-62

(Data from U. S. Department of Agriculture)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1960	0.22	0.52	3.56	7.15	8.34	8.85	6.19	7.59	5.82	4.72	4.00	1.32	58.28
1961	.91	1.29	3.97	6.25	8.29	7.78	8.21	8.73	7.06	6.23	2.27	1.34	62.33
1962	.85	2.94	5.39	5.45	8.70	7.13	7.27	7.73	4.62	5.36	2.99	1.43	59.86



EXPLANATION

Well used for control
Number indicates thickness of saturated sand and gravel, in feet

Line of equal thickness of saturated sand and gravel, in feet
Interval 100 feet; with 50 foot supplementary line

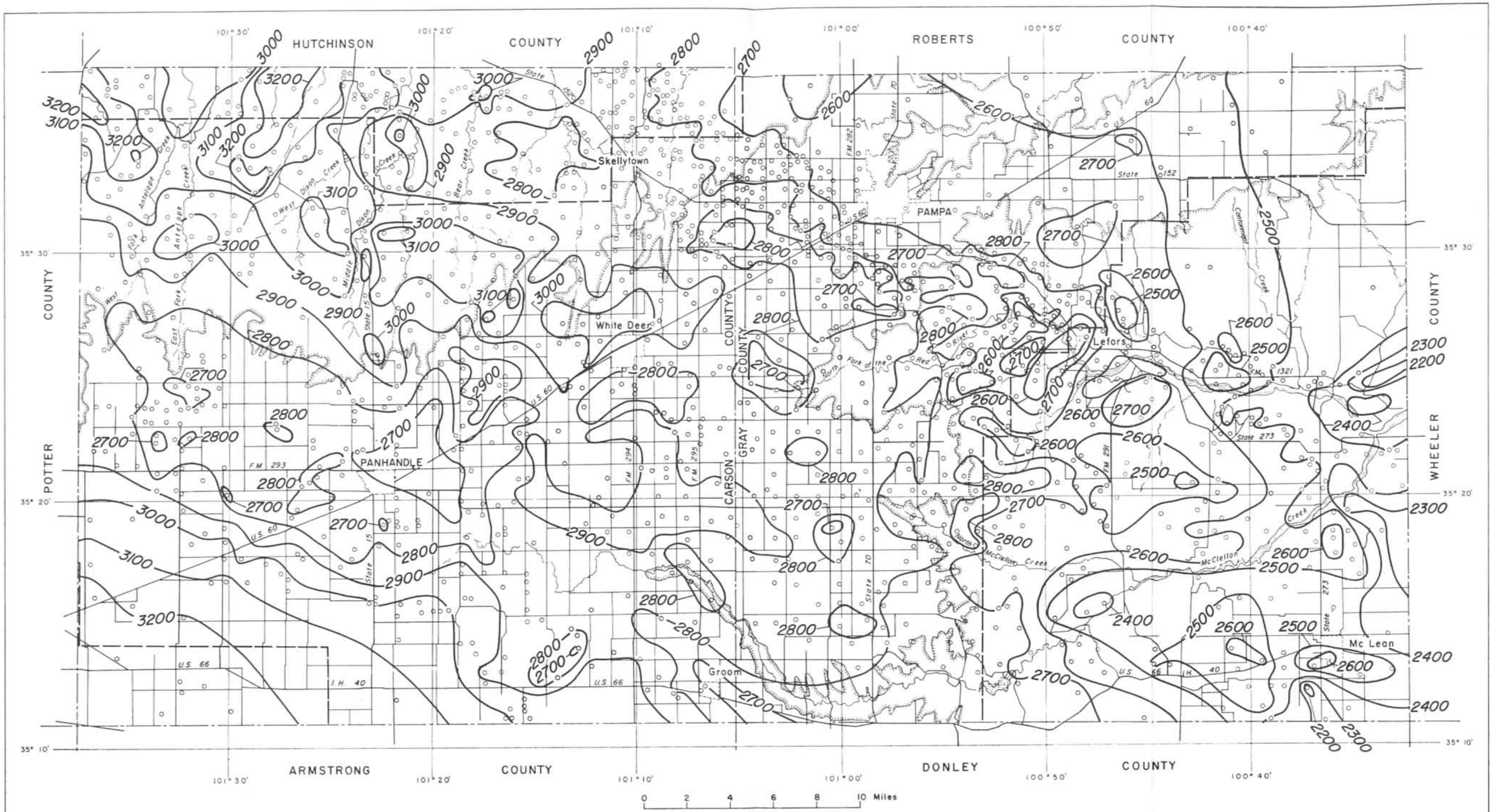
Boundary of Ground Water Conservation District No. 3, South of the Canadian River

Escarpment of the breaks

Figure 2
Approximate Thickness of Saturated Sand and Gravel in the Ogallala Formation, Carson and Gray Counties, 1962

U.S. Geological Survey in cooperation with the Texas Water Commission and the Ground Water Conservation District No. 3, South of the Canadian River

Base compiled from county maps of the Texas State Highway Department



EXPLANATION

o
Well used for control

—3000—
Structure contour

Drawn on base of the Ogallala Formation
Number shows approximate altitude.
Data for control points not shown
because of density of points.
Contour interval 100 feet
Datum is mean sea level

— — — —
Boundary of Ground Water Conservation District No. 3, South of the Canadian River

Escarpment of the breaks

Figure 3
Structure Contour Map Showing Approximate Altitude of the Base of the Ogallala Formation, Carson and Gray Counties

U. S. Geological Survey in cooperation with the Texas Water Commission and the Ground Water Conservation District No. 3, South of the Canadian River

Base compiled from county maps of the Texas State Highway Department

southeastern Gray County. The contours show an elongated basin trending southeastward through Panhandle and the flank of the adjoining red-bed ridge in the southwestern part of Carson County.

GROUND-WATER DEVELOPMENT

The development of ground water in Carson and Gray Counties continued to expand during the period 1960-62, and at the end of 1962, 431 wells were available for use. During the 3-year period, 60 wells were drilled, of which 55 were for irrigation (Table 3). The location of the wells is shown in Figure 4. Of the 55 wells, 42 were drilled in 1962 principally because of the reportedly below-average precipitation in Carson and Gray Counties.

In 1962, about 98,000 acres was irrigated in the report area, an increase of 34,000 acres since 1959. Slightly more than 90 percent of the irrigated acreage, or 90,000 acres, is in Carson County.

During the period 1960-62, the number of industrial wells was increased from 59 to 63, while the number of municipal wells increased from 57 to 58.

Withdrawals of Ground Water

The withdrawals of ground water from the Ogallala Formation underlying Carson and Gray Counties have increased each year since 1953, except during 1957, 1958, and 1960 when precipitation was above average, and the demand for irrigation was relatively light (Table 4).

During the period 1960-62, about 293,000 acre-feet of ground water was pumped, of which 259,000 acre-feet, or nearly 90 percent, was pumped from wells in Carson County, nearly two-thirds of the water being used for irrigation. The pumpage for irrigation in Gray County has remained fairly constant since 1960, ranging from 5,000 acre-feet in 1960 to 5,500 in 1962. In Carson County, however, irrigation pumpage in 1960 was about 36,000 acre-feet, a decrease of 19,000 below that of 1959. Because of the below-average precipitation in Carson County in 1961 and 1962, the pumpage for irrigation increased to about 55,000 acre-feet in 1961 and 90,000 in 1962.

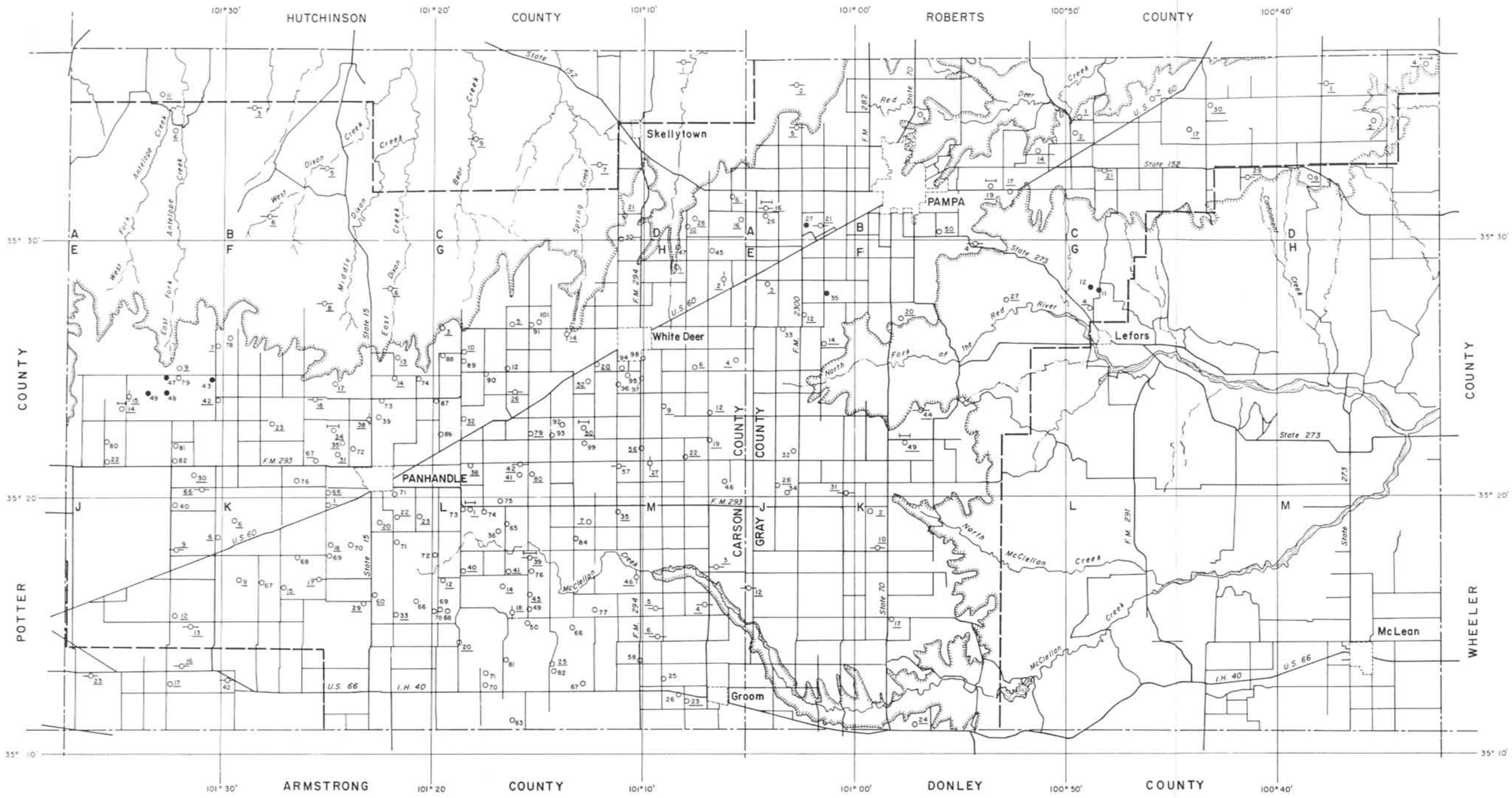
The withdrawals of ground water for municipal supplies during the period 1960-62 in the 2-county area ranged from about 17,000 acre-feet in 1960 to 21,000 in 1962, most of the water being pumped from the Amarillo well field in western Carson County.

The industrial pumpage, which has remained constant during the 3-year period, 1960-62, amounted to about 13,000 acre-feet per year, or less than 15 percent of the total pumpage.

Long (1961, p. 41) estimated that 26 million acre-feet of theoretically recoverable water was in storage in the Ogallala Formation in Carson and Gray Counties in 1958. Thus, the withdrawal of about 293,000 acre-feet of ground water during the period 1960-62 was only about 1 percent of the estimated total water in storage in 1958, and the withdrawal of about 383,000 acre-feet during

Table 3.--Irrigation, industrial, and municipal wells in Carson and Gray Counties, 1960-62

Year	Irrigation	Industrial	Municipal	Total
1960	255	59	57	371
1961	268	61	57	386
1962	310	63	58	431



EXPLANATION

Well symbols

Irrigation

Public supply or industrial

Domestic or stock

Abandoned or test

Symbol above well indicates hydrograph shown in Figure 5 or 6

Line under number indicates an observation well

Boundary of Ground Water Conservation District No. 3, South of the Canadian River

Escarpment of the breaks

Figure 4

Map of Carson and Gray Counties Showing Observation Wells and Locations of Wells Drilled 1960-62

U.S. Geological Survey in cooperation with the Texas Water Commission and the Ground Water Conservation District No. 3, South of the Canadian River

Base compiled from county maps of the Texas State Highway Department

Table 4.--Ground-water pumpage in Carson and Gray Counties, 1955-62
(acre-feet)

Year	Carson County				Gray County				Carson and Gray Counties			
	Irrigation	Industrial	Municipal	Total	Irrigation	Industrial	Municipal	Total	Irrigation	Industrial	Municipal	Total
1955	21,000	9,300	530	31,000	2,800	3,300	3,200	9,300	24,000	13,000	3,700	41,000
1956	51,000	11,000	3,400	65,000	3,600	3,500	4,600	12,000	55,000	15,000	8,000	77,000
1957	38,000	11,000	6,500	55,000	4,800	3,300	3,800	12,000	43,000	14,000	10,000	67,000
1958	34,000	10,000	10,000	54,000	4,800	3,200	3,300	11,000	39,000	13,000	13,000	65,000
1959	55,000	11,000	12,000	78,000	5,000	3,300	3,500	12,000	60,000	14,000	15,000	90,000
1960	36,000	10,000	13,000	59,000	5,000	3,200	3,700	12,000	41,000	13,000	17,000	71,000
1961	55,000	9,700	15,000	80,000	5,200	3,300	3,400	12,000	60,000	13,000	18,000	92,000
1962	90,000	9,800	17,000	120,000	5,500	3,300	3,700	13,000	95,000	13,000	21,000	130,000
Total	380,000	82,000	77,000	540,000	37,000	26,000	29,000	92,000	420,000	110,000	110,000	640,000

the period 1959-62 was only 1.5 percent. Actually, the depletion of the reservoir since 1958 was somewhat less than 1.5 percent because a part of the water pumped was supplied by recharge.

Fluctuations of Water Levels

The water table rises or declines depending on various factors. Changes in the water table represent changes in the amount of water in storage. If recharge exceeds discharge, the water table will rise; if discharge exceeds recharge, the water table will decline. The pumpage of ground water is, of course, the most important among the factors controlling the decline of the water table in Carson and Gray Counties.

Fluctuations of the water table in nine wells in Carson and Gray Counties are illustrated by the hydrographs shown in Figures 5 and 6. The locations of the wells are shown in Figure 4.

The hydrographs of wells in Carson County, except L-39, show a downward trend in water levels since 1956. The changes in the rates of decline of the water levels are related to the changes in the rates of withdrawal of ground water, principally for irrigation. The pattern of the fluctuation of the water table may be described generally as follows: water levels declined rapidly in 1956 owing to the large withdrawals during the drought which ended in early 1957. The rate of decline decreased during the period 1957-61 in response to near--or above--average precipitation, which caused a reduction in the rate of the withdrawal of ground water. The rate of decline increased in 1962, reflecting the increase in the withdrawals.

The hydrograph of well E-14 (Figure 5) in Carson County shows a nearly steady decline of water levels since 1956. The well, which is in the southwestern corner of the Amarillo well field, reflects the continuous pumpage of ground water for municipal use. Since 1956, the water level in this well has declined 26.5 feet, 9.2 feet of the decline occurring during the period 1960-62.

The hydrograph of well L-39 in Carson County (Figure 5) shows an almost continuous rise of water level since 1958, indicating recharge from nearby McClellan Creek.

The hydrographs of four wells in Gray County (Figure 6) show small changes in water level. The water levels in wells D-4 and F-49 show a rise, indicating that the effect of the heavy pumping in Carson County has not reached central and northeastern Gray County.

The net change in water levels in Carson and Gray Counties during the period 1960-63 is shown in Figure 7. During that period, the water table declined a maximum of 11.4 feet in the western part of Carson County where large volumes of water are pumped continuously for public supply and intermittently for irrigation. Several other centers of decline of smaller magnitude are shown near Panhandle and in an area south of White Deer. The map shows that the area influenced by pumping in Carson County has extended southward into Armstrong County and westward into Potter County. In Gray County, where the pumpage is relatively small, the water table declined an observed maximum of 2.7 feet, although in the extreme west-central part, the decline probably was greater.

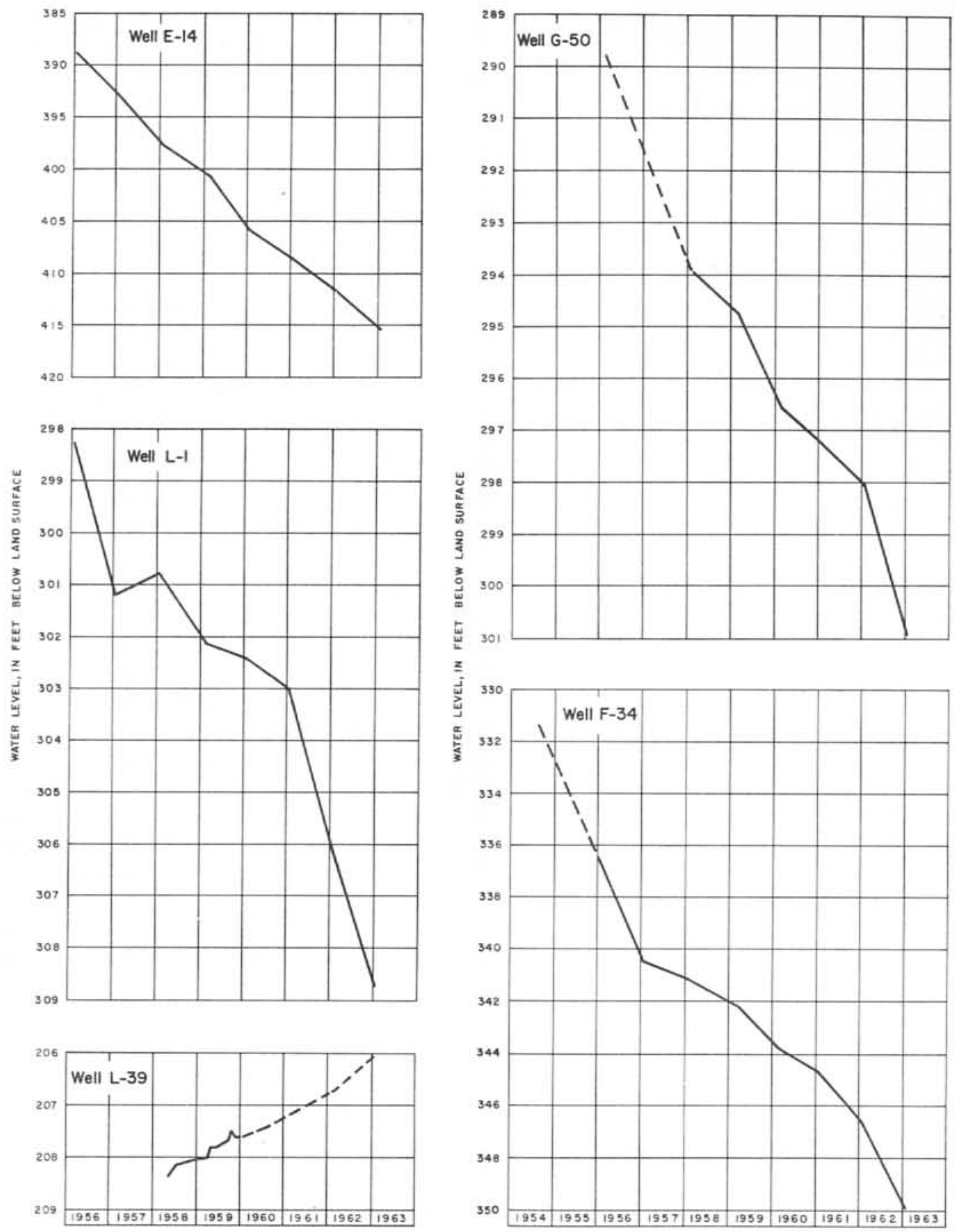


Figure 5

Hydrographs of Selected Wells in Carson County

U. S. Geological Survey in cooperation with the Texas Water Commission
and the Ground Water Conservation District No. 3,
South of the Canadian River

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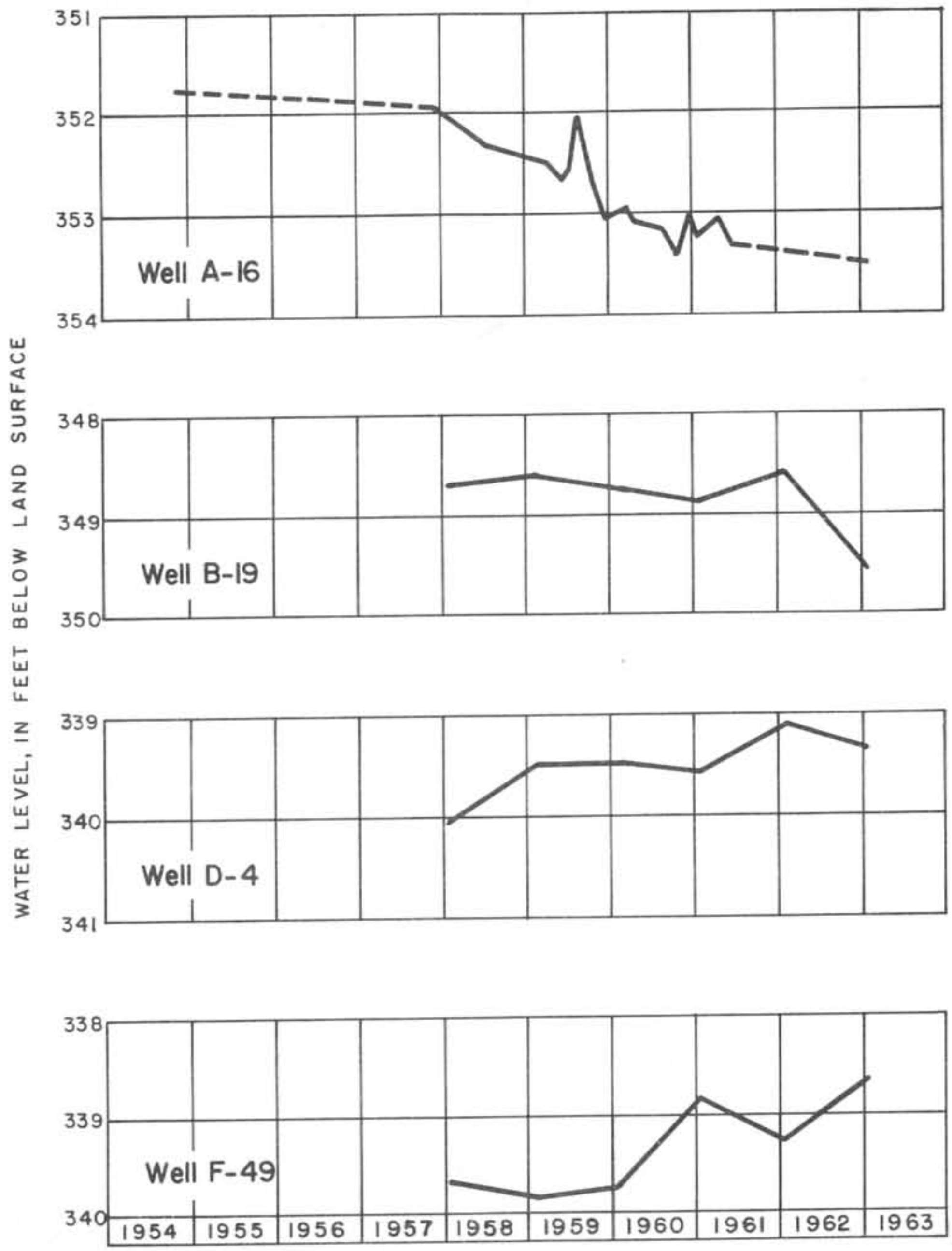

Figure 6

Hydrographs of Selected Wells in Gray County

U. S. Geological Survey in cooperation with the Texas Water Commission and the Ground Water Conservation District No. 3, South of the Canadian River

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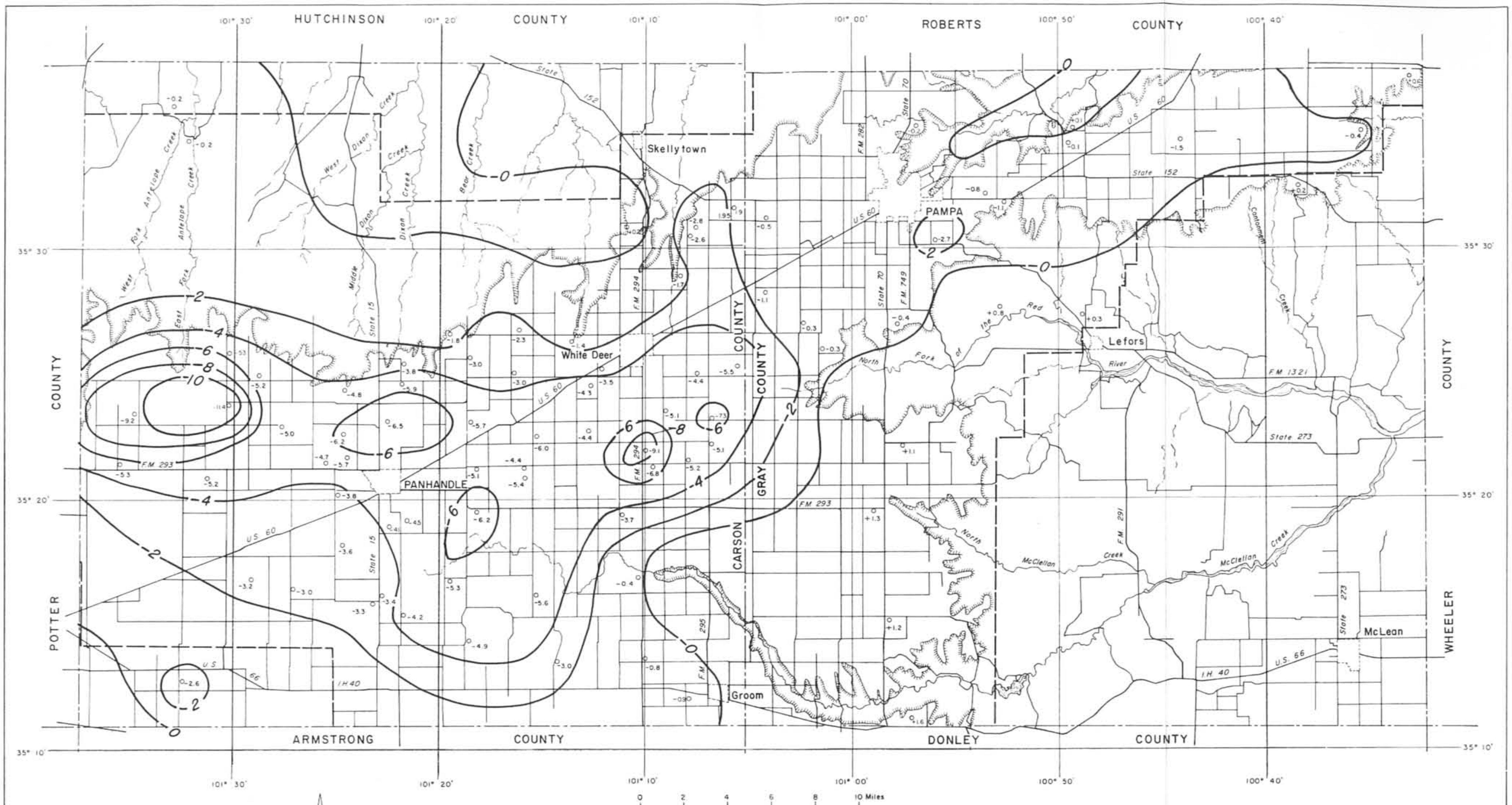


EXPLANATION

o-3.8

Well used for control. Number indicates change in water level, in feet

– Indicates a decline
+ Indicates a rise

—2—

Line showing approximate decline of water level, in feet

Interval, 2 feet

Boundary of Ground Water Conservation District No. 3, South of the Canadian River

Escarpment of the breaks

Figure 7

Approximate Change in Water Levels in Wells in Carson and Gray Counties, 1960-63

U.S. Geological Survey in cooperation with the Texas Water Commission and the Ground Water Conservation District No. 3, South of the Canadian River

Base compiled from county maps of the Texas State Highway Department

Table 5 shows the changes in water levels in selected wells in Carson and Gray Counties during the period 1954-63. The maximum observed decline in Carson County was 26.9 feet in well E-15 in the heavily pumped area in the western part of the county. A decline of 19.3 feet was observed in well G-56 about 3 miles south of White Deer. The maximum decline in Gray County was 3.4 feet in well C-21; in several wells the water level rose, the maximum rise being about 1.6 feet.

QUALITY OF GROUND WATER

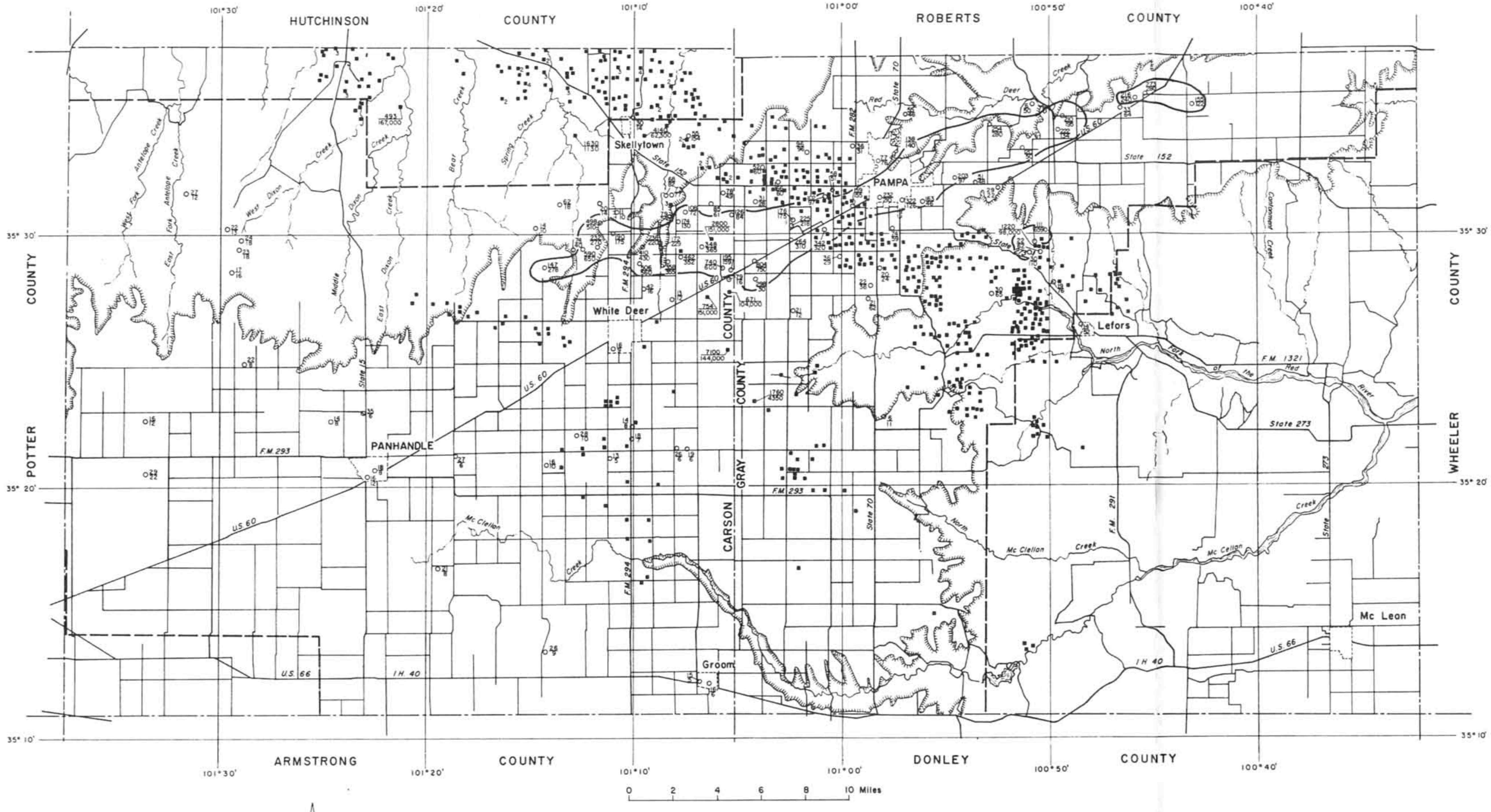
The mineral content of the ground water in the Ogallala Formation in Carson and Gray Counties is uniformly low (Long, 1961, p. 27, 35-38), except in a belt about 2 to 3 miles wide that trends northeastward, in the general direction of the regional hydraulic gradient (Long, 1961, p. 19), from a point about 4 miles northwest of White Deer to about 15 miles northeast of Pampa (Figure 8), where samples of the ground water commonly contain more than 100 ppm (parts per million) of sulfate or chloride, or both. This belt is about 32 miles long and includes Pampa, the largest city in the report area. In some wells in this belt, the sulfate and chloride content of the water is high enough to render the water unfit for industrial or municipal use.

Following the development of the Panhandle Oil Field in 1926, several industrial plants related to the petroleum industry were located in the belt of relatively highly mineralized water. As a consequence, the industries, which require water of good quality for cooling and the production of chemicals, obtained water from wells outside of the belt. Prior to 1950, the city of Pampa obtained its water supply from wells inside the city limits. However, as the rate of withdrawal of ground water increased to meet the needs of the growing city, the mineralization of the water increased also, and as a result the city developed a new well field in 1950 several miles south of Pampa. The water from the new field is of good quality and is mixed with water from the old wells at Pampa.

Prior to October 1, 1962, a substantial part of oil-field brine produced in the northern part of Carson and Gray Counties was disposed of through surface pits. The locations of the salt-water disposal pits are shown in Figure 8. The map shows that most of the disposal pits are in a belt about 3 to 4 miles wide trending southeastward from northeastern Carson County to central Gray County at an angle to the regional hydraulic gradient and the trend of the belt of relatively highly mineralized water. The chemical analyses of samples of brine from seven disposal pits in Carson County and two in Gray County (Figure 8) show that, with one exception, the chloride content greatly exceeds the sulfate content; whereas, water from the Ogallala Formation typically contains slightly more sulfate than chloride. These data strongly indicate that relatively highly mineralized water in the northeastward-trending belt apparently is not related to the use of surface-disposal pits. Local residents report that the ground water in the belt was highly mineralized prior to 1926 when drilling of oil wells began, indicating that the saline water is due to natural conditions, such as the upward movement of highly mineralized water from deeper formations along a fault, or to the contact of the ground water in the Ogallala with underlying Permian rocks, which contain gypsum and halite locally.

Table 5.--Changes in water levels in selected wells in Carson and Gray Counties, 1954-63

Well no.	Change, in feet	Well no.	Change, in feet
	Carson County		
B- 3	- 0.6	H-22	-14.9
B- 5	+ 1.5	J- 9	- 4.8
B- 6	- 5.2	J-12	- .1
C- 7	+ .1	J-13	- 1.5
C- 9	+ .3	J-16	- 5.9
E-15	-26.9	J-23	+ 1.1
E-66	- 8.4	K- 6	-20.2
F- 8	- 3.8	K-17	- 5.0
F-18	-13.0	K-42	+ 2.4
F-34	-18.6	L-18	- 8.3
G-14	- 5.6	M- 3	+ 1.7
G-26	-16.4	M- 4	+ 1.5
G-42	-10.2	M- 5	+ 1.8
G-56	-19.3	M- 6	- 1.9
H- 2	- 6.2		
	Gray County		
A- 2	- 0.2	D- 1	+ 1.1
A- 5	- 1.3	E-31	.0
A-21	+ 1.3	J-12	+ 1.6
C-21	- 3.4		



EXPLANATION

Approximate boundary of area where water contains more than 100 ppm of chloride or sulfate or both

o—Sample well
15—Sulfate (ppm)
20—Chloride (ppm)

Salt-water disposal pit; number indicates more than one

Boundary of Ground Water Conservation District No. 3, South of the Canadian River

Escarpment of the breaks

Figure 8

Map of Carson and Gray Counties Showing Locations of Salt-Water Disposal Pits and the Quality of Water from Selected Wells and Pits

U.S. Geological Survey in cooperation with the Texas Water Commission and the Ground Water Conservation District No. 3, South of the Canadian River

Base compiled from county maps of the Texas State Highway Department

Elsewhere, evidence does indicate local contamination from pits. This is shown 5 miles southeast of Pampa (Figure 8) in a small area which is in the breaks of the plains where the depth of water is relatively shallow and the soil is sandy. In one well in this area, the water contained 111 ppm of sulfate and 6,590 ppm of chloride, and in the other, 30 ppm of sulfate and 110 ppm chloride. The water in a nearby disposal pit contained 1,220 ppm of sulfate and 98,000 ppm of chloride. The ratios of sulfate to chloride, based on equivalents per million, are 1 to 80 and 1 to 5, respectively, for the wells, and 1 to 111 for the disposal pit. The increase of the sulfate to chloride ratio to considerably more than the approximate 1 to 1 ratio for the typical Ogallala water indicates the addition of high chloride water to the ground water in the Ogallala Formation in this area. In other similar areas, the sulfate-chloride ratio suggests possible changes in the quality of the ground water as a result of infiltration of oil-field brines from disposal pits; more detailed investigations will be necessary for verification.

In Carson and Gray Counties, areas of ground-water contamination would be expected to occur primarily downdip from the disposal pits, except possibly in areas of concentrated ground-water pumpage where the hydraulic gradient may be modified locally. Most of the wells in areas of surface-disposal pits are widely scattered and pump only small quantities of water for domestic or livestock use. Because of the slow movement of ground water in the Ogallala Formation and the gentle slope of the water table in most places, other areas of possible contamination resulting from surface disposal of oil-field brines in Carson and Gray Counties have not been detected.

Under the ruling by the Texas Railroad Commission effective October 1, 1962, the use of surface pits for the disposal of oil-field brines was discontinued in Carson and Gray Counties. Since then, the program of oil-field brine disposal has undergone a changeover to subsurface injection. Nevertheless, the salt water that has percolated from these pits represents a potential source of contamination. When these wastes eventually percolate to the water table, they will be diluted so slowly that the effects of contamination may be long lasting.

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