Ground-Water Resources of the Lower Rio Grande Valley Area, Texas

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GROUND-WATER RESOURCES OF THE LOWER RIO GRANDE VALLEY AREA, TEXAS

By Roger C. Baker and O. C. Dale

ABSTRACT

The report contains information about the occurrence, quality, and use of ground water in the Lower Rio Grande Valley area which consists of Cameron, Hidalgo, Starr, and Willacy Counties in southern Texas.

The principal use of water in the area is for irrigation. The principal irrigated crops are cotton, winter vegetables, and citrus fruits. In southeastern Starr County, southern Hidalgo County, and western Cameron County, the main source of water is the Rio Grande. The greatest development of ground water in this area was after 1948 when ground water was needed to supplement water from the river.

The Lower Rio Grande Valley area has four major ground-water reservoirs. Because of the uncertainty in mapping the stratigraphic units and because some of the ground-water reservoirs are composed of parts of two or more formations, three of the ground-water reservoirs have been given names in this report. The major ground-water reservoirs are: the Oakville sandstone, an important source of water for industrial use in northeastern Starr County; the Linn-Faysville ground-water reservoir, which supplies irrigation water in the Linn-Faysville area in central Hidalgo County; and the Rio Grande ground-water reservoir and the Mercedes-Sebastian shallow ground-water reservoir, both of which supply considerable irrigation water in southeastern Starr, southern Hidalgo, western Cameron, and southwestern Willacy Counties.

The quality of water differs considerably from place to place in the Lower Rio Grande Valley area. In most of the area, water is available that can be used for domestic or public supply, but it generally is slightly saline. In most of the area, the ground water is unsuitable for irrigation, particularly if used exclusively. Water of the best quality in the area is from the Rio Grande ground-water reservoir near the Rio Grande at depths of less than 75 feet in southeastern Starr County, between 50 and 250 feet in southern Hidalgo County, and between 100 and 300 feet in western Cameron County. At progressively greater distances from the Rio Grande, the ground water at these depths tends to be more mineralized. Also at some places at depths greater than those indicated, the water tends to be more mineralized. In the Linn-Faysville area the ground water from the Linn-Faysville ground-water reservoir is moderately mineralized and ranges from fair to unsuitable for irrigation.

In western Cameron County, water levels in some wells tapping the Rio Grande ground-water reservoir declined about 10 feet from 1954 to 1957. In 1959 the water levels stood higher than in 1954. The water levels in most wells tapping the Linn-Faysville ground-water reservoir declined 10 feet or more from 1948 to 1958. In some wells the decline was more than 15 feet.

The available information indicates that in some localities the Rio Grande ground-water reservoir may be nearly filled to capacity, and waterlogging will occur during periods of above-normal precipitation. During protracted periods of below-normal precipitation, the available water in the ground-water reservoir may be depleted.

Further studies should be made in the area to correct important deficiencies in available information. A continuing program is recommended because information such as fluctuations in water levels and the amount and distribution of pumping can be obtained only on a current basis.

INTRODUCTION

PURPOSE AND SCOPE

Water has made possible the transformation of a large part of the Lower Rio Grande Valley area from semiarid rangeland to highly productive orchards and gardenland. Most of the water for irrigation was taken initially from the Rio Grande, but during the period of drought in the late 1940's and the early 1950's, when water from the river was insufficient to satisfy all demands, ground water was developed extensively to meet the deficiency. The importance of ground water to the area and the need for basic information about the ground-water resources were recognized by the citizens of Cameron, Hidalgo, Starr, and Willacy Counties. An investigation of the ground-water resources of the Lower Rio Grande Valley area was begun in September 1956 by the U.S. Geological Survey in cooperation with the Texas Board of Water Engineers and Cameron, Hidalgo, Starr, and Willacy Counties as a part of the statewide program of ground-water investigations.

Fieldwork was in progress most of the time between September 1956 and August 1958. Most of the fieldwork was conducted by O. C. Dale of the Geological Survey and H. H. Ewing of the Texas Board of Water Engineers. Fieldwork consisted largely of (1) locating, describing, and tabulating data concerning 2,070 wells in the study area; (2) collecting data concerning the potential pumping capacity of the wells; (3) collecting data on the hydraulic characteristics of the ground-water reservoirs by means of pumping tests; (4) measuring water levels throughout the area to evaluate the stage of the ground-water reservoirs; (5) collecting 327 drillers' logs for interpretation and evaluation of the ground-water reservoirs and collecting and examining several hundred electric logs for the same purpose, for study of saline water problems, and for use in geological studies; (6) collecting samples of water for chemical analyses and tabulating data concerning the chemical quality of water from 924 wells in the area; and (7) making such field studies as were necessary to describe further the ground-water reservoirs of the area.

The report not only describes, names, and discusses the four principal ground-water reservoirs of the area, but also illustrates by maps, geologic cross sections, block diagrams, hydrographs, and other diagrams, many results of the study. Records of more than 2,070 wells in the Lower Rio Grande Valley area were collected, compiled, and studied (Baker and Dale, 1960, v. 2). The location of these wells is shown on plate 1 and figure 4.

LOCATION AND EXTENT OF THE AREA

The Lower Rio Grande Valley area is in the southernmost part of Texas between the long 97°08′ and 99°11′ W. and lat 25°50′ and 26°48′ N. The area includes Cameron, Hidalgo, Starr, and Willacy Counties. The general location of the area is shown in figure 1.

The area is bounded on the south and southwest by the Rio Grande, which marks the international boundary between the United States and the Republic of Mexico; on the northwest and north by Zapata, Jim Hogg, Brooks, and Kenedy Counties, Tex.; and on the east by the Gulf of Mexico.

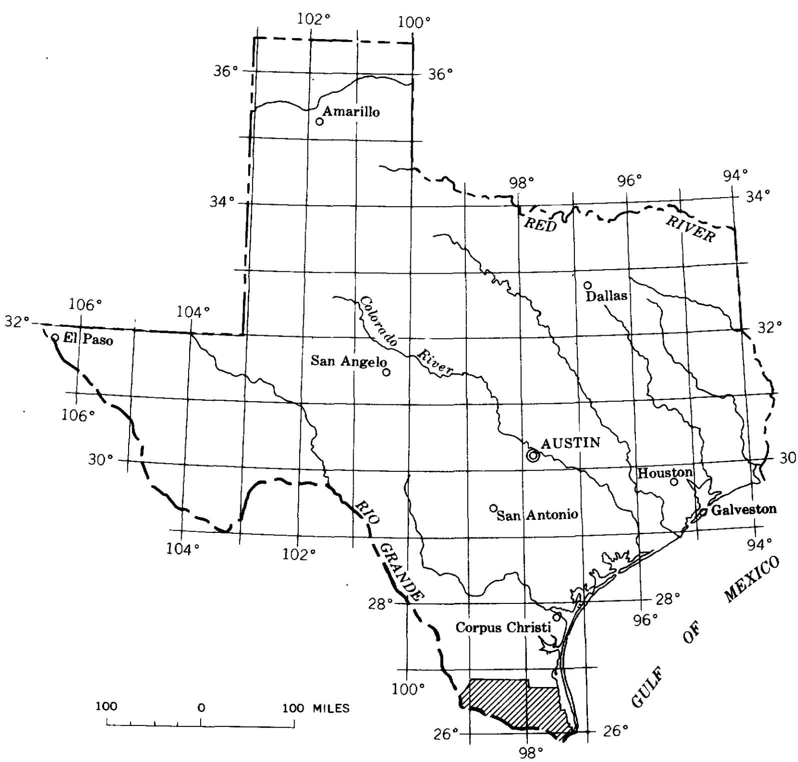

FIGURE 1.—Map of Texas showing the location of the Lower Rio Grande Valley area.

The area covers 4,226 square miles; 883 in Cameron County, 1,541 in Hidalgo County, 1,207 in Starr County, and 595 in Willacy County.

PREVIOUS INVESTIGATIONS

Reports of the U.S. Geological Survey in cooperation with the Texas Board of Water Engineers describing previous investigations of ground-water conditions have been released for the following areas: Hidalgo County (Lonsdale and Nye, 1938; 1941); the Linn district in Hidalgo County (Cromack, 1945); the Linn-Faysville area in Hidalgo County (George, 1947; Follett, White, and Irelan, 1949); Starr County (Dale, 1952); Cameron County (Dale and George, 1954); and the Brownsville–San Benito–La Feria district (Broadhurst, 1941).

An investigation of ground-water conditions in Hidalgo and Cameron Counties was made by G. H. Cromack and W. L. Broadhurst in 1945. The basic data are in the files of the U.S. Geological Survey.

Much of the previous reports consist largely of records of wells, drillers' logs, and chemical analyses of water; most of this basic information has been incorporated in this report.

An investigation of ground-water conditions in Hidalgo, Cameron, and Willacy Counties was made by N. A. Rose (1954). The following is a brief statement of the conclusions given in his report: The principal development of ground water, which was done largely because of drought, has occurred since 1948 when the amount of water available from the Rio Grande was not sufficient to meet the demand for irrigation. Ground water in the Lower Valley is characterized by wide variations in chemical composition. The water of best quality occurs in the alluvial gravel and is suitable for municipal, industrial, and irrigational uses. The remainder of the ground water in the area does not meet accepted standards for drinking water or irrigation. There is no indication of overdevelopment of ground water in the area. In the Lower Valley the failure of wells, loss in production, or change in mineral content of the water can often be eliminated or minimized. A more complete investigation and a continuing evaluation of conditions in the Lower Valley are needed.

Unpublished data from studies of water levels, drainage, and soil conditions in the area made by the Bureau of Reclamation have been reviewed in connection with the preparation of this report.

ACKNOWLEDGMENTS

The writers wish to express their appreciation to the numerous users of ground water in the area who gave information.

The following drillers and drilling companies gave well logs and information about wells: E. J. Rupp, Harlingen; A. D. Killinger, Mission; Gene Liberty, McAllen; A. & T. Drilling Co., Harlingen; Killinger Drilling Co., Mission; and Pursley Drilling Co., Edinburg.

The Harlingen Water Department and the Sun Oil Co. permitted the use of wells for pumping tests. Martin Russo and H. L. Schaeffer of the Sun Oil Co. gave information about the geology of the area.

The cooperation of the following organizations also is appreciated: Humble Oil and Refining Co., Schlumberger Well Surveying Corp., Halliburton Oil Well Cementing Co., Willacy County Agricultural Stabilization and Conservation Committee, McAllen Pipe and Supply Co., Stewart and Stevenson Co., Rural Electrification Association, Central Power and Light Co., and the U.S. Soil Conservation Service.

WELL-NUMBERING SYSTEM

In this report the wells are numbered according to their location within the respective counties. Each county is divided into approximately 10-minute quadrangles although there are some variations in size to allow for irregularities in the shape of the county (pl. 1; fig. 4). Within each county the quadrangles are given successive letter designations starting with A in the upper left quadrangle and moving from left to right. Letters I, O, and Q are excluded. Wells are identified by the letter designation of the quadrangle and are numbered serially within each quadrangle.

GEOGRAPHY

SURFACE FEATURES

Most of the Lower Rio Grande Valley area consists of a broad flat upland plain extending westward from the Gulf of Mexico, which forms the eastern boundary of the area, to about central Starr County. The Bardas escarpment, near the western edge of the outcrop area of the Goliad sand, marks the western boundary of the plain. (See inset map, section *A–A′;* pl. 2.) The plain rises from sea level at Laguna Madre to an altitude of more than 500 feet at some places near the Bordas escarpment. Near its southern edge, the plain slopes generally southeastward.

The Rio Grande forms the southern border of the area and empties into the Gulf of Mexico at its southeastern corner. The river has a gradient less than the slope of the upland plain to the north, and in Starr County its flood plain is more than 100 feet lower than the adjacent upland. Eastward, the river lowland and the upland plain merge into the delta of the Rio Grande.

The surface of the upland plain is fairly flat, but is characterized by numerous minor topographic features. The eastern part of the plain is crossed by channels, most of which are distributaries of the Rio Grande. Also in the eastern part of the area are low clay ridges and mounds generally less than 25 feet high, which have been attributed to wind deposition. Broad shallow depressions associated with the mounds form a "blowout and dune" topography at some places. Common features of the central and western part of the plain are broad, shallow, undrained depressions. In northern Hidalgo and Willacy Counties, wind-deposited sand forms a fairly typical dune topography. In western Hidalgo and eastern Starr Counties the southern edge of the plain has been incised by several small intermittent streams that are tributary to the Rio Grande. In southeastern Hidalgo County a low ridge known as Mission Ridge extends eastward from the vicinity of Mission to Donna on the east. West of Mission the ridge merges with the general level of the upland plain; east of Donna the ridge declines to the general level of the Rio Grande Valley and becomes imperceptible. The ridge is bordered on the south by the valley of the Rio Grande and on the north by a broad valley which separates it from the upland plain.

In western Starr County, west of the Bordas escarpment, the land surface consists of a gently rolling plain having rounded hills and broad valleys. Some of the hills have altitudes of more than 500 feet. The valleys contain intermittent streams tributary to the Rio Grande.

The valley of the Rio Grande on the United States side reaches a maximum width of about 9 miles in the area west of Weslaco. Generally, the valley consists of an alluvial bottomland and one or more terraces. The surface of the alluvial bottomland is crossed by abandoned channels of the Rio Grande. The widths of the bottomland and the terraces differ considerably from one place to another and at some places in Starr County the river flows along the bluffs of the upland plain.

Padre Island, an offshore barrier in the Gulf of Mexico, is about 8 miles east of the mainland and extends from near Port Isabel northward beyond the Willacy County line. South of Padre Island, and separated from it by Brazos Santiago Pass, are Brazos Island and Boca Chica Island, which are continuations of the offshore barrier. They are no longer islands but form a peninsula connected with the mainland at the south end near the mouth of the Rio Grande. Laguna Madre is the body of water lying between the mainland and the offshore barrier. The barrier islands, which average less than a mile in width, consist of sand and are largely dune covered.

DRAINAGE

The area is drained in part by the Rio Grande, which flows along the south side of the area, although much of the drainage goes into Laguna Madre through small coastal streams. The Rio Grande has no large tributaries in the area; however, several small intermittent streams are tributary to the Rio Grande in Starr County and western Hidalgo County. The easternmost tributary to the Rio Grande from the upland plain joins the river about 10 miles west of Mission. Further east, Mission Ridge prevents drainage from the upland plain to the Rio Grande.

Arroyo Colorado is a conspicuous drainage feature in the southern part of the area. It heads in southern Hidalgo County about 2 miles southwest of Mission and about 2 miles north of the Rio Grande. From a point south of Donna, it flows in a general northeasterly direction across most of Cameron County, forms the eastern part of the boundary between Willacy and Cameron Counties, and empties into the Laguna Madre. Much of the drainage in Cameron County empties into the Laguna Madre through former distributary channels of the Rio Grande called "resacas."

The delta of the Rio Grande includes a large area east and northeast of Weslaco, much of which is subject to flooding. The probability of flooding by the river has been reduced greatly by the construction of Falcon Dam in western Starr County at the western edge of the Lower Rio Grande Valley area and by the levees in the floodway system which starts just south of Mission.

In parts of the lower valley, particularly in irrigated areas, the water table has risen close to land surface, and it has been necessary to construct systems of drains to prevent damage from waterlogging.

Most of the upland plain in eastern Starr County and in Hidalgo, Willacy, and Cameron Counties is not drained by through-flowing streams. Much of the rainfall flows into shallow depressions where it evaporates or seeps into the ground. Among the larger of these closed depressions are La Sal Vieja in western Willacy County and Sal Del Ray in northeastern Hidalgo County. These are natural salt-water lakes that are reported to have been important sources of salt in the past.

CLIMATE

The climate of the Lower Rio Grande Valley area has been described as semitropical and semiarid. Very high or low temperatures are uncommon. The mean annual precipitation is low, ranging generally from about 18 inches at Rio Grande City to about 28 inches at Brownsville. Irrigation generally is necessary for raising most crops. The prevailing winds are from the southeast. Hurricanes move inland from the Gulf of Mexico in the summer and early fall in some years, but hurricanes are said to be more welcomed than feared by many people because of the accompanying heavy rains.

The following table gives the maximum, minimum, and long-term mean [1] monthly temperatures at Brownsville and the long-term mean temperature at Raymondville and Rio Grande City. The maximum recorded temperature at Raymondville is 109°F and the minimum is 16°F. At Rio Grande City the maximum recorded temperature is 115°F and the minimum is 7°F. The average length of the growing season at Brownsville is 336 days, at Raymondville 315 days, and at Rio Grande City 297 days.

Monthly temperature data for Brownsville, Raymondville, and Rio Grande City

[Temperature in °F. Data from records of U.S. Weather Bureau]

	Brownsville			Raymondville	Rio Grande City
	Maximum	Minimum	Long-term mean	Long-term mean	Long-term mean
January	87	23	60.5	59.1	58.1
February	94	22	63.9	62.8	61.9
March	99	32	68.0	67.4	69.7
April	100	45	73.7	73.9	76.1
May	100	53	78.9	79.1	81.2
June	101	49	82.6	81.6	84.8
July	103	68	83.8	84.1	86.2
August	100	66	84.1	84.7	86.2
September	104	55	81.4	80.9	81.7
October	95	43	76.0	74.8	75.2
November	94	35	67.8	64.4	66.0
December	88	29	62.4	60.4	59.6
Average			73.6	72.9	73.9

The maximum, minimum, and long-term mean monthly precipitation at Brownsville and the long-term mean precipitation at Raymondville and Rio Grande City are given on the following table:

[1] The long-term mean as used by the U.S. Weather Bureau is a mean based on the 30-year period 1921 to 1950. It is revised every decade by dropping the first 10 years of data and using instead the 10 most recent years.

Monthly precipitation in inches, for Brownsville, Raymondville, and Rio Grande City

[Data from records of the U.S. Weather Bureau]

	Brownsville			Raymondville	Rio Grande City
	Maximum	Minimum	Long-term mean	Long-term mean	Long-term mean
January	5.11	Tr.	1.43	1.78	0.94
February	10.25	Tr.	1.18	.88	.78
March	4.27	.03	1.11	1.52	.88
April	5.85	.02	1.59	1.21	1.06
May	5.46	.01	3.09	3.96	2.37
June	13.06	.01	3.05	3.02	2.11
July	5.59	.03	1.97	2.42	1.50
August	7.08	.24	2.45	1.92	1.67
September	8.90	.50	5.13	4.73	3.07
October	17.12	.56	2.91	2.75	1.55
November	6.26	.01	1.55	1.51	.93
December	9.45	.02	2.16	1.69	.83
Annual	------------	------------	27.62	27.39	17.69

Table 1 shows that the precipitation was slightly below normal each year in the late 1940's in most of the Lower Rio Grande Valley area. In the early and middle 1950's the precipitation was much below normal. Precipitation was above normal at all stations in the area in 1958 for the first year since 1941.

TABLE 1.—*Annual precipitation and departure from normal, 1940–58, at Brownsville, Harlingen, Mission, Raymondville, and Rio Grande City, Tex.*

[Long-term mean used, 1955–1958. Data from records of U.S. Weather Bureau]

Year	Brownsville		Harlingen		Mission		Raymondville		Rio Grande City	
	Precipitation	Departure	Precipitation	Departure	Precipitation	Departure	Precipitation	Departure	Precipitation	Departure
1940	26.81	−0.62	30.62	7.09	22.51	4.44	31.71	7.51	13.62	−2.91
1941	34.49	7.09	45.99	22.46	33.07	15.00	44.15	19.95	30.51	13.98
1942	24.61	−2.79	17.07	−6.46	13.94	−4.13	24.46	.26	13.47	−3.06
1943	25.31	−5.74	22.20	−1.33	21.55	3.48	27.70	3.50	14.92	−1.61
1944	32.87	1.78	33.60	6.13	22.73	1.45	--------	--------	16.76	−.97
1945	29.73	−1.32	23.80	−3.67	16.79	−4.49	19.71	−7.79	--------	--------
1946	28.55	−2.50	27.53	.16	17.67	−3.52	27.57	.18	14.32	−3.37
1947	23.98	−7.07	20.13	−7.06	15.94	−5.25	24.16	−3.23	16.72	−.97
1948	22.93	−8.12	26.75	−.62	19.95	−1.24	24.02	−3.37	26.03	8.34
1949	28.75	−2.30	--------	--------	16.01	−5.18	--------	--------	--------	--------
1950	18.45	−12.60	19.87	−7.50	10.21	−10.98	11.70	−15.69	--------	--------
1951	24.21	−6.84	--------	--------	--------	--------	24.93	−2.46	19.03	1.34
1952	18.83	−12.26	18.22	−9.15	12.61	−8.58	22.94	−4.45	8.55	−9.14
1953	11.59	−17.96	19.61	−7.76	14.58	−6.61	20.04	−7.35	17.42	−.27
1954	22.06	−7.49	20.82	−6.55	27.09	5.90	21.18	−6.21	21.08	3.39
1955	18.86	−10.69	27.20	−.17	12.25	8.94	32.21	4.82	11.72	−5.97
1956	16.74	−12.85	11.39	−15.98	8.53	−12.66	14.35	−13.04	10.00	−7.69
1957	32.40	4.78	22.96	−4.41	15.08	−6.11	22.45	−4.94	19.35	1.66
1958	47.51	19.89	41.56	14.19	29.33	8.14	37.82	10.43	29.98	12.29
Average	27.62	--------	27.37	--------	26.19	--------	27.39	--------	17.69	--------

The average evaporation from a free water surface at Weslaco for the period 1955–57 was 66.8 inches per year. At Falcon Dam in Starr County, the average evaporation for the period April 1950 to April

1956 was 102.3 inches per year (D. W. Bloodgood, oral communication).

POPULATION

According to the 1950 census, the population of the Lower Rio Grande Valley area was 320, 484, distributed as follows:

County	Urban	Rural	Total
Cameron	75, 518	38, 312	125, 170
Hidalgo	91, 973	68, 473	160, 446
Starr	3, 992	9, 956	13, 948
Willacy	9, 136	11, 784	20, 920

The population of the area was estimated by the Lower Rio Grande Valley Chamber of Commerce to be about 413,400 in 1958.

ECONOMY

The economy of the Lower Rio Grande Valley is based largely on agriculture, but manufacturing, processing, and mineral production are also of major importance.

In 1954 about 576,223 acres were irrigated mostly in the southern and southeastern parts of the area. The important crops are cotton, winter vegetables, and citrus fruits. In the northern part of the area, agriculture consists largely of dryland farming, and the large ranches are used for cattle, sheep, and goat raising.

The principal manufactured and processed products are food; petroleum; paper; metal; garments and textiles; stone, clay, and glass products; furniture and fixtures; and transportation equipment. Printing and publishing is also an important industry.

The principal mineral products are oil, natural gas, and natural-gas liquids. Other mineral products are gravel, brick clay, commercial clay, salt, caliche, and sulfur.

The Lower Rio Grande Valley Chamber of Commerce gives the following subdivision of the annual income in the area in 1956: Agriculture, $134.5 million; manufacturing and processing, $100 million; oil and gas production, $60 million; shrimp and commercial fishing, $25 million; tourist business, $40 million; and national defense, $40 million.

TRANSPORTATION

The Lower Rio Grande Valley area is served by many hard-surfaced roads and highways, particularly in the southeastern part of the area. U.S. Highways 77 and 281 enter the area from the north and U.S. Highway 83 enters the area from the west. Highway crossings into

Mexico are at Falcon Dam and over privately owned toll bridges near Roma-Los Saenz, Hidalgo, Progreso, and Brownsville.

Both the Southern Pacific Lines and the Missouri Pacific Lines serve the Lower Rio Grande Valley area and connect with the Mexican National Railways at Brownsville. International airports for air travel to countries to the south are located at Brownsville and McAllen. Port Isabel and Brownsville have deep-water ports. Port Isabel, Brownsville, Harlingen, and Port Mansfield are served by the Intercoastal Waterway, located in Laguna Madre.

HISTORY OF GROUND-WATER DEVELOPMENT

The number of wells drilled and the rate of withdrawal of ground water have differed greatly from year to year, for they depend on the amount of water available from the Rio Grande, on precipitation, temperature extremes, and other factors. Most of the large-capacity wells are used for irrigation and public supply and were drilled when the supply of water from the Rio Grande was inadequate. Many of the wells are not pumped when adequate supplies of water are available from the river. Information is available as to when most of the wells were drilled, but the amount of water withdrawn from wells in past years cannot be determined with any degree of accuracy.

The use of ground water for domestic supplies and stock watering in the area probably extends back for more than a century. As of about 1950 the average daily rate of use for domestic supplies and livestock in the area was estimated to be about 7 million gallons. During the period 1939–59, the average rate of use of ground water for domestic supply and livestock in the area probably has decreased because of urbanization and the conversion of stock ranches to irrigated farms.

The principal industrial use of ground water is in connection with oil and gas production and the processing of petroleum products. Other industrial uses are in food processing, at cotton gins, and by railroads. Most of the industrial wells were constructed in the 1940–50 period.

Most of the public-supply wells are for municipal supply, but several schools also obtain water from wells. Most of the municipal wells are used as supplementary sources of water when the desired amount of water is not available from the river. Many of the municipal wells were drilled in 1953–54 when the Rio Grande was very low.

The development and use of ground water for irrigation has been controlled by the availability of ground water of suitable quality for irrigation, by the demand for produce from irrigated farms, and particularly by the availability of water from the Rio Grande.

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Prior to 1950, irrigation wells were drilled at scattered locations in much of Cameron County and central and southern Hidalgo County; however, most of the irrigation wells were concentrated in areas not served by water districts using river water. These areas are (1) south of Mission and McAllen and (2) south of Weslaco and Mercedes in southern Hidalgo County, (3) the Linn-Faysville area in central Hidalgo County, (4) and an area in Cameron County about 10 miles northwest of Brownsville.

After about 1948, the number of irrigation wells increased greatly because of drought and a resulting shortage of river water. The peak years for the drilling of irrigation wells were 1952 and 1953. Few irrigation wells were drilled in 1954 and 1955, but the drilling activity increased again in 1956 and 1957. Most of the irrigation wells drilled to supplement the water supply from the river are in western Cameron County, southern Hidalgo County, and southeastern Starr County. Available data suggest that the drilling of irrigation wells from 1950 to 1957 to supplement the supply from the river began in the eastern part of the area and spread westward or upriver.

GEOLOGY

GENERAL STRATIGRAPHY

The Lower Rio Grande Valley area is underlain by deposits of silt, sand, gravel, and clay ranging in age from early Tertiary in western Starr County to Recent near the river and the Gulf Coast. The formations dip toward the coast and crop out in belts parallel to it. The oldest formation crops out in the western part of the area, and the younger formations crop out successively nearer the coast. The Quaternary deposits also extend up the Rio Grande Valley.

Table 2 gives a generalized geologic section of the formations exposed or penetrated by wells in the area. The subsurface materials, particularly in the eastern part of the Lower Rio Grande Valley area, are largely flood plain and deltaic deposits of the Rio Grande, which consist of complexly interbedded layers and lenses of clay, silt, sand, and gravel. The character of the material may change in short distances both vertically and laterally, and the deposits cannot be positively correlated with the stratigraphic units. Consequently, all formations containing ground-water reservoirs could not be identified with certainty. Because of these uncertainties, no geologic map is included with this report. Maps showing the geology of the Lower Rio Grande Valley area have been published by Bailey (1926), Darton and others (1937), Trowbridge (1932), and Weeks (1937 and 1945). However, the locations of the geologic units do not agree on any two of the maps.

The Lower Rio Grande Valley has four major sources of ground water. These can be differentiated on the basis of stratigraphic position, geographic location, depth below the land surface, lateral continuity, yields of wells, and quality of the water. Some of the ground-water sources are composed of parts of two or more stratigraphic units. For convenience in discussing the ground-water conditions, three of the major sources of ground water are given appropriate names. The four major ground-water sources are: (1) The Oakville sandstone, which is an important source of water for industrial use in northeastern Starr County; (2) the Linn-Faysville ground-water reservoir, which supplies irrigation water in the Linn-Faysville area in central Hidalgo County; (3) the lower Rio Grande ground-water reservoir; and (4) the Mercedes-Sebastian shallow ground-water reservoir; which supplies considerable irrigation water in southeastern Starr, southern Hidalgo, western Cameron, and southwestern Willacy Counties. The relation of the named reservoirs to the named stratigraphic units is given in the last column of table 2. The Linn-Faysville ground-water reservoir, the lower Rio Grande ground-water reservoir, and the Mercedes-Sebastian shallow ground-water reservoir are parts of a large unnamed aquifer system occurring in deposits of upper Tertiary and Quaternary age in the Gulf Coastal Plain.

Sections constructed from electric logs of oil wells and test holes are shown in plate 2. The correlation lines shown are based on the electrical properties of the materials as indicated by the electric logs and are not necessarily formation boundaries.

Electric logs indicate some of the electrical properties of the material and fluids penetrated by a well. These properties are useful in correlating geologic formations from one well to another and are an aid in interpreting the quality of the water in the water-bearing beds. The electric log generally consists of three or more curves, a spontaneous-potential (self-potential) curve and two or more resistivity curves. In the cross sections (pl. 2), the self- potential curve is on the left side of the electric log and the resistivity curves are on the right.

Deflection of the spontaneous-potential curve to the left indicates sandy layers except in the fresh-water zone where the self-potential curve may not deflect or may deflect either to the left or right depending on the dissolved-solids content of the formation water as compared to that of the drilling fluid. The magnitude of the deflection depends in part on the quality of the water; generally the more dissolved solids in the formation water, the larger is the deflection to the left.

TABLE 2.—*Generalized geologic section of the Lower Rio Grande Valley area*

System	Series	Group	Formation	Character of material	Water-bearing properties
Quaternary	Recent and Pleistocene		Unnamed windblown deposits	Sand and silt.	Not an important source of ground water.
			-Unconformity-		
			Unnamed alluvial deposits	Clay, silt, sand, and gravel. Gravel restricted to mostly lower part.	Yields large supplies of fresh to moderately saline water in the lower Rio Grande ground-water reservoir.
			-Unconformity-		
	Pleistocene		Beaumont clay	Clay and some sand and sandy clay, few calcareous nodules.	Yields small to moderate supplies of fresh to moderately saline water in the lower Rio Grande ground-water reservoir and the Mercedes-Sebastian shallow ground-water reservoir.
			-Unconformity-		
			Lissie formation	Clay, silt, and some sand and gravel; some caliche.	Yields moderate to large supplies of fresh to slightly saline water in the lower Rio Grande ground-water reservoir and the Linn-Faysville ground-water reservoir.
			-Unconformity-		
Tertiary	Pliocene		Goliad sand	Largely clay and sand, and some gravel; much caliche near the land surface.	Yields moderate to large supplies of fresh to slightly saline water in the lower Rio Grande ground-water reservoir and the Linn-Faysville ground-water reservoir. Also yields small to moderate amounts of fresh to moderately saline water in northern Hidalgo County and Willacy County.
			-Unconformity-		
	Miocene(?)		Lagarto clay	Largely clay and sandy clay. Not exposed.	Not an important source of ground water in the Lower Rio Grande Valley area.
			-Unconformity-		
	Miocene		Oakville sandstone	Largely sand, but contains lenses of silt and clay.	Yields moderate supplies of slightly to moderately saline water in northeastern Starr County.
			-Unconformity-		
	Miocene(?)		Catahoula tuff	Tuffaceous sandstone, ash beds; some bentonite.	Yields small supplies of slightly to moderately saline water.
			-Unconformity-		
	Oligocene(?)		Frio clay	Clay, interbedded with some sandstone and tuff.	
	Eocene	Jackson	Undifferentiated sedimentary rocks	Sandstone and clay, containing some coarse gravel and volcanic ash.	Yields small supplies of slightly to moderately saline water.
		Claiborne	Yegua formation	Shale and sandy shale; some concretionary sandstone.	
			-Unconformity-		
			Cook Mountain formation and Sparta sand, undifferentiated	Medium- to fine-grained sandstone interbedded with shale and sandy shale; some lignite.	

The resistivity curves are influenced by the resistivity of the beds in the vicinity of the bore hole, and the resistivity of the formation and bore-hole fluids. The short normal curve (solid line on the sections) is influenced greatly by the resistivity of the drilling fluid and the materials within a short distance from the wall of the hole. The long normal curve (broken line on the sections) gives the apparent resistivity of the materials at a greater distance from the wall of the hole. Layers of sand or other permeable material containing fresh water generally cause a deflection of the resistivity curves to the right. The amount of the deflection is larger if the sand contains fresh water than it is if the sand contains saline or briny water. When the deflection of the long normal curve is less than that of the short normal curve, it usually is an indication that the resistivity of the formation water is lower than the resistivity of the drilling fluid. In most logs, highly saline waters are indicated in sand zones where the long-normal curve is markedly lower than the short normal curve.

STRUCTURE

The correlation lines on the geologic cross sections (pl. 2) show in a general way the structure of the deposits of the Lower Rio Grande Valley area. The formations have a regional dip to the east towards the Gulf of Mexico. Except for the Recent deposits, the angle of dip of the top of each formation is greater than the slope of the land surface; consequently, the formations crop out in northward-trending belts in which the youngest unit is on the east and the oldest on the west. Because the deposits tend to thicken downdip, the older formations have greater dips than the younger deposits.

In addition to the structural movement resulting in the eastward regional dip of the formations, some faulting and folding has taken place in the area. The resulting structural features have an important control over the occurrence of oil and gas and have been identified largely in the depth zones in which oil and gas occur. The faults and folds are less apparent at shallow depths, in part because of the difficulty of distinguishing and correlating the younger stratigraphic units.

Aside from the regional dip, the only structural features that could be identified in this investigation are the Sam Fordyce-Vanderbilt fault and the associated anticlinal fold in eastern Starr County (pl. 2). The Sam Fordyce-Vanderbilt fault is not known to affect the quality or movement of ground water in the Lower Rio Grande Valley area.

GENERAL PRINCIPLES OF GROUND-WATER OCCURENCE AND DEFINITION OF TERMS

Meinzer (1923a) has given an authoritative and comprehensive discussion of the principles of the occurrence and movement of ground water. The following is a brief review of some of the principles as they apply to the Lower Rio Grande Valley.

When water falls on the earth's surface, a part is returned into the air by evaporation and by transpiration by plants, a part runs off in streams as surface water, and a part percolates into the ground and moves downward to the zone of saturation. The water in the saturated zone is termed "ground water."

Ground water moves under the influence of gravity, from places of recharge to places of discharge. Owing to frictional resistance, the rate of movement of ground water is very slow as compared to the flow of water in streams.

Permeability is the capacity of the earth materials to transmit water under pressure. In unconsolidated deposits the fine-grained materials such as silt and clay have very low permeability. These materials do not yield water easily to wells. Deposits of silt and clay may act as barriers to the movement of water into or from more permeable deposits. Coarse-grained materials such as sand and gravel generally have high permeability. Beds of sand and gravel act as conduits through which ground water moves, and they yield water to wells.

A deposit that yields water to wells is known as an aquifer. An aquifer may consist of parts of several formations that have hydraulic connection and act as a single hydrologic unit. Aquifers can be considered as conduits through which the water moves and also as reservoirs in which the water is stored. In this report a ground-water reservoir is a part of an aquifer in which ground water is available for public supply, industrial use, or for irrigation. A ground-water reservoir has hydraulic connection with other parts of the aquifer but the reservoir is bounded either by less permeable material in which water is not available in quantities needed for the uses mentioned or by water of poorer quality which generally is not suitable for these uses.

The coefficient of transmissibility, a measure of the capacity of water-bearing material of an aquifer or ground-water reservoir to transmit water, is defined as the number of gallons of water that will move in 1 day through a vertical section of the water-bearing material 1 foot wide and having a height of the thickness of the water-bearing material under a hydraulic gradient of 1 foot per foot at the prevailing water temperature.

The coefficient of permeability is the rate of flow of water in gallons per day through a cross-sectional area of 1 square foot under a hydraulic gradient of 1 foot per foot at a temperature of 60° F. The field coefficient of permeability is stated at the prevailing temperature of the water. Thus, the field coefficient of permeability is equal to the coefficient of transmissibility divided by the thickness of the water-bearing material.

The coefficient of storage is the volume of water in cubic feet released from storage in each vertical column of the aquifer having a base of 1 foot square when the water table or the piezometric surface declines 1 foot.

Water reportedly occurs under water-table conditions if the water level in a well penetrating the material does not rise above the point where the water was first found. Water under artesian pressure will rise in wells tapping the aquifer to a level above the top of the aquifer and, if under sufficient pressure, the water will flow. The piezometric surface is an imaginary line representing the level to which water rises in wells at any given point. Thus, under water-table or unconfined, conditions, the piezometric surface coincides with the water table; under artesian conditions the piezometric surface is above the top of the aquifer, and at flowing artesian wells it is above land surface.

The water level in a well that is not pumped fluctuates in response to conditions of recharge to and discharge from the aquifer, including the effect of pumping from other wells. This water level is the static level for that well. When water is withdrawn from a well, the water levels in and around the well are lowered and the piezometric surface takes the form of an inverted cone centered at the well. The decline in water level in a pumped well depends upon the physical character of the aquifer, entrance losses at the well, and the rate and duration of pumping. If the rate of discharge from the well is constant, the decline in water level is rapid at first but gradually decreases. The cone of depression spreads and the water level is lowered at distances farther and farther from the well. The difference between the static level and the pumping level in the well is called the drawdown.

The rate of pumping divided by the drawdown in a well is the specific capacity of the well. The drawdown generally is measured in feet and the pumping rate in gallons per minute, and the specific capacity is expressed as gallons per minute per foot.

When pumping from a well is stopped, the water level rises rapidly at first and then at a decreasing rate as it approaches the true static level in the well. The lowering of water level in a well in response to pumping is serious only if it causes water of undesirable quality to move into the water-bearing material or if it results in excessive pumping lift.

Ground water moves slowly from places of recharge to places of discharge. The water is, in effect, in transient storage. The amount of water in transient storage in the ground commonly is very large. However, the deposits of water-bearing material have physical limits in thickness and extent; consequently, the total amount of water in storage has limits.

Under natural conditions, over a fairly long period of time, the amount of water discharged from an aquifer equals approximately the amount of water recharged to the aquifer. Under natural conditions the amount of water in storage remains nearly the same, and upward or downward trends in the water levels are not pronounced.

When water is pumped from an aquifer, the discharge is increased and some of the water comes from storage. When water is taken from storage, the water level is lowered, and it will continue to be lowered until a new recharge-discharge equilibrium is established. Ultimately the lowering of water level in the water-bearing material will result in an increase of recharge to the aquifer, a decrease of natural discharge, a decrease in pumping, or a combination of these factors.

In investigating the ground-water resources of an area, it is important to determine the amount of ground water in storage in the water-bearing material because this is a measure of the amount of water available for use regardless of recharge to the material. Evaluation of the recharge to the water-bearing material is also needed in order to estimate the upper limit of the rate of pumping that can be maintained over long periods. Recharge conditions are controlled mainly by climate and geology and generally are difficult to evaluate quantitatively.

GENERAL QUALITY-OF-WATER TOLERANCES FOR DIFFERENT USES

All ground water contains dissolved minerals. The amount and kind of minerals in solution in ground water depends to a large extent on the physical and chemical character of the materials through which the water has moved and the length of time the water has been in contact with these materials. The suitability of water for most uses depends upon its chemical quality.

The suitability of water for public supply and domestic use can be judged by the standards established by the U.S. Public Health Service (1946) for drinking water used by interstate carriers, which are as follows:

Dissolved constituents	*Maximum permissible concentration (parts per million)*
Iron and manganese	0.3
Magnesium	125
Chloride	250
Sulfate	250
Fluoride	1.5
Dissolved solids	[1] 500

[1] A dissolved-solids content of 1,000 ppm may be permitted if water of better quality is not available.

Water containing sulfate much in excess of 250 ppm (parts per million) or magnesium much in excess of 125 ppm may have a laxative effect. Water high in fluoride content causes mottling of the teeth of children if used during the calcification of the teeth (Dean and others, 1942, p. 1155–1179). Water containing other minerals in excess of the suggested standards may be used without apparent ill effects; however, it may be objectionable because of taste.

Nitrate in water may cause methemoglobinemia ("blue-baby" disease). Maxcy (1950, p. 271) concludes that water containing nitrate in excess of 44 ppm (parts per million) should be regarded as unsafe for infant feeding.

The tolerances in chemical quality of water suitable for industrial use differ widely for different industries and different processes (Moore, 1940, p. 263, 271). In general, water that meets U.S. Public Health Service standards for drinking water is suitable for most industrial uses.

Hardness of water is an important consideration in domestic, public, and industrial supplies. Water containing 60 ppm or less of hardness is usually rated as soft. Water ranging in hardness from 61 to 120 ppm is considered moderately hard; from 121 to 200 ppm, hard; and more than 201 ppm, very hard.

The U.S. Department of Agriculture has collected a large amount of data on the classification of water for irrigation use in arid and semiarid areas. The following information is adapted largely from publications of the U.S. Department of Agriculture, particularly from Handbook 60 (U.S. Salinity Laboratory Staff, 1954).

The classifications given for irrigation waters should be used as a broad guide only because the suitability of water for irrigation use depends on several factors other than the chemical quality of the water. These other factors, some of which are quite local in effect and all of which are beyond the scope of this investigation, are: soil texture, infiltration rate, farm management practices, drainage conditions, climatic factors, and the salt tolerances of different crops.

According to the U.S. Salinity Laboratory Staff (1954, p. 69), The characteristics of an irrigation water that appear to be most important in determining its quality are: (1) total concentration of soluble salts; (2) relative proportion of sodium to the cations; (3) concentration of baron or other elements that may be toxic; and (4) under some conditions, the bicarbonate concentration as related to the concentration of calcium plus magnesium.

Figure 2 shows the classification of irrigation waters with respect to the total concentration of soluble salts and the proportion of the sodium to the cations. The specific conductance of the water is used to show the total concentration of soluble salts or salinity hazard. The sodium-adsorption-ratio (SAR), used to show the sodium (alkali) hazard, is defined as:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{+2} + Mg^{+2}}{2}}}$$

Na^{+}, Ca^{+2}, and Mg^{+2} represent the concentrations in milliequivalents per liter (or equivalents per million for most irrigation waters) of the respective ions.

The following explanation is given by the U.S. Salinity Laboratory Staff (1954, p. 79, 81) for the different classes of water as shown in figure 2:

Low salinity water (C1) can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability.

Medium-salinity water (C2) can be used if a moderate amount of leaching occurs. Plants having moderate salt tolerance can usually be grown without special practices for salinity control.

High-salinity water (C3) cannot be used on soils having restricted drainage. Even with adequate drainage, special management for salinity control may be required, and plants having good salt tolerance should be selected.

Very high salinity water (C4) is not suitable for irrigation under ordinary conditions, but it may be used occasionally under very special circumstances. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and very salt-tolerant crops should be selected.

The classification of irrigation waters with respect to SAR is based primarily on the effect of exchangeable sodium on the physical condition of the soil. Sodium-sensitive plants may, however, suffer injury as a result of sodium accumulation in plant tissues when exchangeable sodium values are lower than those effective in causing deterioration of the physical condition of the soil.

Low-sodium water (S1) can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops such as stone fruit trees and avocados may accumulate injurious concentrations of sodium.

Medium-sodium water (S2) will present an appreciable sodium hazard in fine-textured soils having high cation-exchange-capacity, especially under low-leaching conditions, unless gypsum is present in the soil. This water may be used on coarse-textured or organic soils having good permeability.

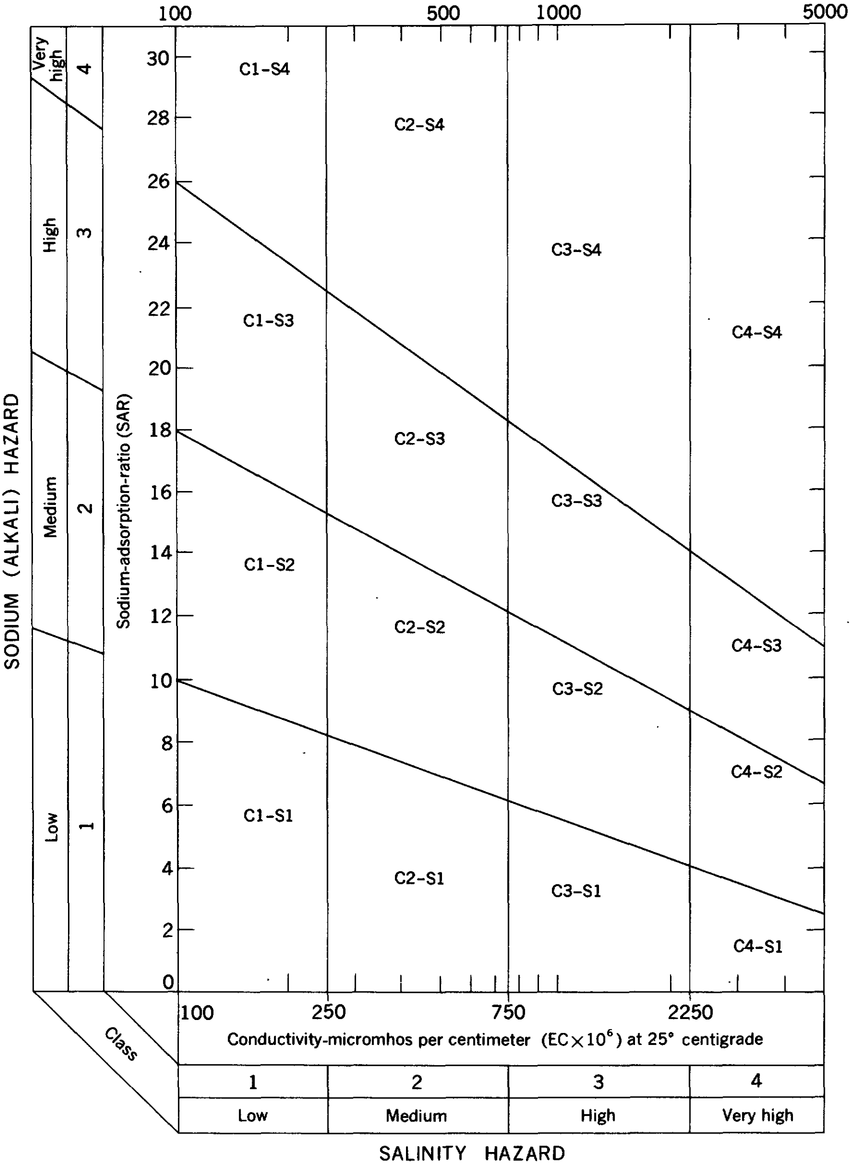

FIGURE 2.—Diagram for the classification of irrigation waters (after United States Salinity Laboratory Staff, 1954, p. 80).

High-sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management—good drainage, high leaching, and organic matter additions. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters. Chemical amendments may be required for replacement of exchangeable sodium, except that amendments may not be feasible with waters of very high salinity.

Very high sodium water (S4) is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity where the solution of calcium from the soil or use of gypsum or other amendments may make the use of the water feasible.

Sometimes the irrigation water may dissolve sufficient calcium from calcareous soils to decrease the sodium hazard appreciably, and this should be considered in the use of C1–S3 and C1–S4 waters. For calcareous soils having high pH values or for noncalcareous soils, the sodium status of waters in classes C1–S3, C1–S4, and C2–S4 may be improved by the addition of gypsum to the water. Similarly, it may be beneficial to add gypsum to the soil periodically when C2–S3 and C3–S2 waters are used.

Scofield (1936, p. 286) proposed the following limits of boron for irrigation water:

TABLE 3.—*Permissible limits of boron for irrigation waters*

Classes of water		Sensitive crops (ppm)	Semitolerant crops (ppm)	Tolerant crops (ppm)
Rating	Grade			
1	Excellent	<0.33	<0.67	<1.00
2	Good	.33 to .67	.67 to 1.33	1.00 to 2.00
3	Permissible	.67 to 1.00	1.33 to 2.00	2.00 to 3.00
4	Doubtful	1.00 to 1.25	2.00 to 2.50	3.00 to 3.75
5	Unsuitable	>1.25	>2.50	>3.75

The residual sodium carbonate (RSC) indicates the excess of bicarbonate (HCO_3) and carbonate (CO_3) concentration over the concentration of calcium (Ca) plus magnesium (Mg).

$RSC=(CO_3^{-2}+HCO_3^{-})-(Ca^{+2}+Mg^{+2})$, all concentrations being in milliequivalents per liter of the respective ions.

The following explanation is given by the U.S. Salinity Laboratory Staff (1954, p. 81) for the effect of RSC (residual sodium carbonate) on the quality of water for irrigation:

> * * * it is concluded that waters with more than 2.5 meq./1. (milliequivalents per liter) "residual sodium carbonate" are not suitable for irrigation purposes. Water containing 1.25 to 2.5 meq./1. are marginal and those containing less than 1.25 meq./1. "residual sodium carbonate" are probably safe. It is believed that the good management practices and proper use of amendments might make it possible to use successfully some of the marginal waters for irrigation. These conclusions are based on limited data and are, therefore, tentative.

Percent sodium is calculated as follows:

$$\frac{Na^{+}\times 100}{Na^{+}+K^{+}+Ca^{+2}+Mg^{+2}}$$

where all constituents are reported in equivalents per million (or milliequivalents per liter). Although percent sodium has been used in various systems of classification in the past, it is reported that the sodium-adsorption-ratio (SAR) is more significant for interpreting water quality than percent sodium because it is more directly related to the adsorption of sodium by the soil.

In appraising the quality of irrigation water, the U.S. Salinity Laboratory Staff (1954, p. 82) recommends that first consideration be given to salinity and alkali hazards (fig. 2). Second consideration should be given to the independent characteristics, boron or other toxic elements and bicarbonate, any one of which may change the quality rating. Recommendations as to the use of a water of a given quality must take into account such factors as drainage and management practices.

Chemical analyses of water from wells in the Lower Rio Grande Valley area are available in the files of the U.S. Geological Survey, Austin, Texas.

SOURCES OF GROUND WATER

GENERAL STATEMENT

Ground water for domestic use and stock watering is available in the Lower Rio Grande Valley area, except in part of western Starr County, eastern Cameron County, and part of eastern Willacy County, where the ground water is generally unsuitable for livestock or human consumption. Ground water suitable for irrigation, public supply, or most industrial uses is available only in parts of the area.

Four sources of ground water suitable for irrigation, public supply, or industrial uses have been recognized in the Lower Rio Grande Valley area. These are the Oakville sandstone, the Linn-Faysville ground-water reservoir, the lower Rio Grande ground-water reservoir, and the Mercedes-Sebastian shallow ground-water reservoir. The extent of the productive areas of these sources of ground water is shown on figure 3.

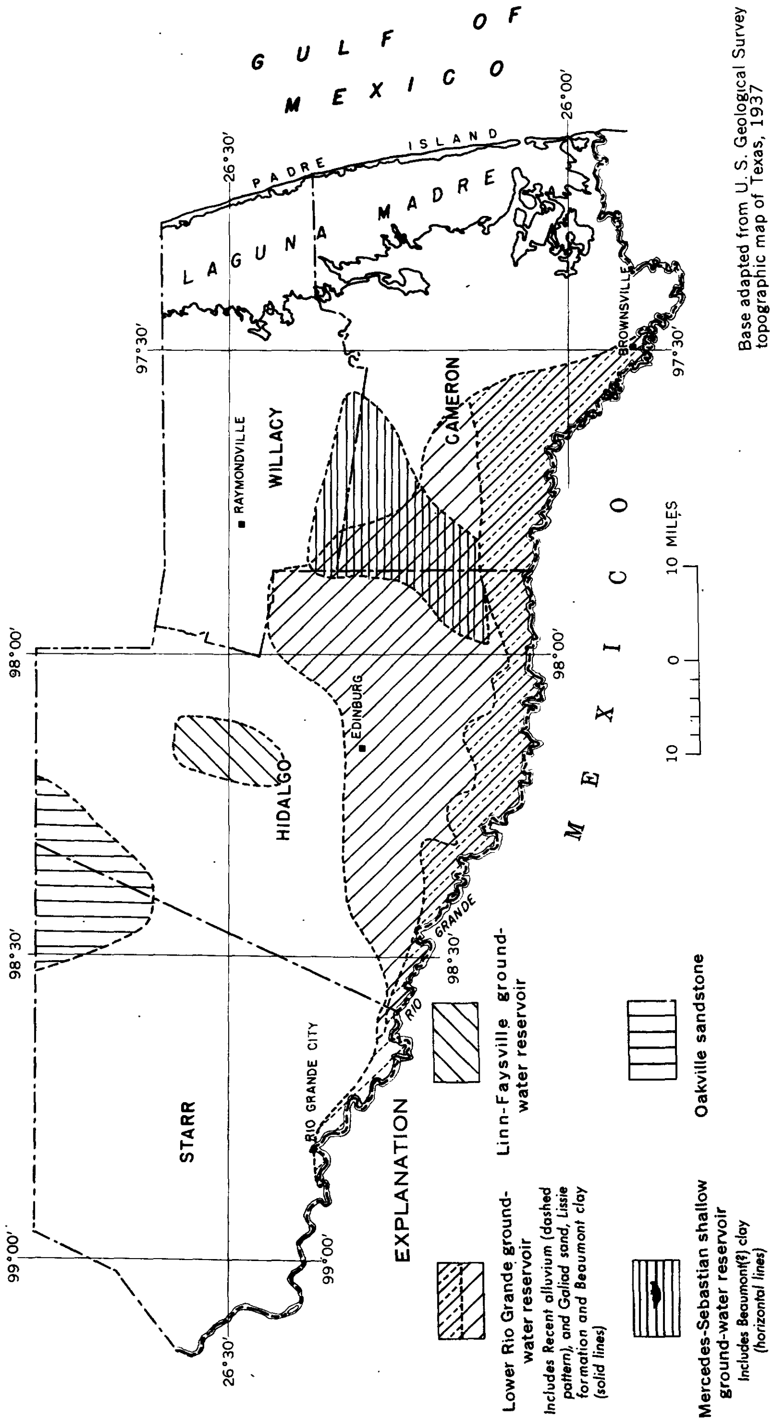

FIGURE 3.—Map showing the approximate productive areas of the major sources of ground water in the Lower Rio Grande Valley area.

OAKVILLE SANDSTONE

GENERAL DESCRIPTION

The Oakville sandstone of Miocene age is an important source of water in northeastern Starr County. The area in which it yields suitable water extends northward into Jim Hogg and Brooks Counties and probably into part of northwestern Hidalgo County.

The Oakville sandstone occurs in the eastern half of Starr County and Hidalgo, Cameron, and Willacy Counties. The Oakville lies unconformably on the Catahoula tuff and is unconformably overlain by the Lagarto clay and the Goliad sand. The Oakville probably does not crop out in the Lower Rio Grande Valley area because the beveled edge of the Oakville is overlapped by the Goliad sand. The base of the Oakville can be determined with reasonable certainty on the electric logs of wells in northeastern Starr County (pl. 2), but its upper contact cannot be determined.

In northeastern Starr County the Oakville sandstone dips in a northeasterly direction. Section *A–A′* (pl. *2*) shows a dip to the east along the line of the section at about 50 feet per mile; the dip along section *D–D′* (pl. *2*) is to the north at about 40 feet per mile. In southeastern Hidalgo County the Oakville sandstone dips about 91 feet per mile to the southeast along the section described by the Corpus Christi Geological Society (1954).

According to the society, the Oakville is about 1,650 feet thick in southern Hidalgo County. The thickness elsewhere in the area is not known.

DEVELOPMENT

Information was obtained for about 26 wells in northeastern Starr County tapping the Oakville sandstone. Other wells in Starr and Hidalgo Counties may tap the Oakville sandstone, but they could not be assigned to it with certainty.

Water from 10 wells is used in plants that process petroleum products; water from eight wells is used or will be used for irrigation; water from the other wells is used by oil well-drilling rigs, for road construction, and by schools and residences. The wells range from 665 to 1,050 feet in depth. The maximum reported yield is about 600 gpm (gallons per minute), and the average yield is probably about 125 gpm. The static water level in some pumped wells tapping the Oakville sandstone is reported to have declined about 125 to 150 feet from 1948 to 1956.

CHEMICAL QUALITY

The chemical analyses of water from nine wells tapping the Oakville sandstone are available in the files of the Geological Survey.

The maximum magnesium content of the water is 47 ppm and the maximum sulfate is 261 ppm. The chloride ranges from 250 to 740 ppm and the dissolved solids range from 870 to 1,780 ppm. In general, the water can be used for domestic and public supply purposes; however, the content of chloride and dissolved solids of the water equals or exceeds the maximum amounts recommended for public supply (p. 19). Most of the water is soft to moderately hard.

The suitability of the water for different industrial uses depends on the quality-of-water tolerances of the different industries. The mineral content is probably too high for most industrial processing; however, the water is used in plants processing petroleum products.

The sodium-adsorption-ratio (SAR) ranges from 8.9 to 31 and the specific conductance ranges from 1,480 to 3,110. By the classification shown on figure 2, the water from all wells except one had very high sodium (alkali) hazard, water from four of the wells had high-salinity hazard, and water from five had very high salinity hazard. The water appears to be unsuitable for irrigation. The success of irrigation would depend on the factors other than the quality of water mentioned on pages 19 to 23.

The water from the Oakville sandstone in east-central Starr County is reported to be more mineralized than the water in the northeastern part of the county and is unsuitable for processing of petroleum products.

HYDRAULIC CHARACTERISTICS

In February 1957, pumping tests were made on Starr County wells J–4 and J–25. Data from a recovery test on J–4 indicated a coefficient of transmissibility of about 5,000 gpd (gallons per day) per foot. A recovery test on well J–25 indicated a coefficient of transmissibility of about 7,700 gpd per ft. The specific capacity of well J–25 after one hour of pumping is about 6 gpm per ft of drawdown.

HYDROLOGY

Information on the quality of water from wells, test holes, and from interpretations of electric logs of oil wells suggests that the Oakville is recharged north of Starr County. However, much more information, both from the Lower Rio Grande Valley area and from the counties lying to the north, is needed before the movement of water in the Oakville can be described adequately.

LINN-FAYSVILLE GROUND-WATER RESERVOIR

GENERAL DESCRIPTION

In the Linn-Faysville area in central Hidalgo County, sand layers, probably consisting of the lower part of the Lissie formation and the upper part of the Goliad sand, are an important source of ground water for irrigation.

The material consists of interbedded layers of sand and clay and some caliche near the land surface. Most wells penetrate a few feet to more than 100 feet of caliche before reaching the more permeable water-bearing beds. The total thickness of the water-bearing beds ranges from about 30 to about 60 feet. The water-bearing beds are laterally discontinuous; at some places they are too thin to yield much water, and dry holes may be drilled within a few hundred feet of productive wells.

Most of the water is taken from wells less than 100 feet deep. The material below a depth of about 150 feet consists of layers of clay or shale and subordinate amounts of sand and generally is less productive than the material above a depth of about 150 feet. Similarities in the chemical analyses of water from wells indicate that the ground-water reservoir extends to a depth of about 260 feet below land surface. Follett and others (1949, p. 6) report that some beds of sand and clay can be correlated between wells several miles apart and that the beds dip eastward about 30 to 50 feet per mile.

The ground-water reservoir underlies an area of about 50 square miles. North and south of the Linn-Faysville area the comparable material is less permeable. Wells tapping comparable deposits yield water of progressively poorer quality eastward. The ground-water reservoir has not been identified west of the Linn-Faysville area. These water-bearing deposits are herein named the Linn-Faysville ground-water reservoir. The approximate productive limit of the reservoir and the location of wells tapping it are shown on figure 4.

Water-bearing materials underlying the Linn-Faysville ground-water reservoir have been penetrated by several wells in the Linn-Faysville area and also in other parts of Hidalgo County. Information about these wells is given in the section describing the Goliad sand.

DEVELOPMENT

An inventory of wells in the area made in 1948 (Follett and others, 1949, p. 11–22) shows that from 1931 to 1944, 11 irrigation wells were drilled, and from 1944 through part of 1948, 64 irrigation wells were drilled.

The records of wells in the area, which are based largely upon the 1948 inventory, show that of the 144 wells in the area, 70 were used for irrigation, 38 for domestic and stock supplies, 3 for industrial supply, and 20 (including some that have been destroyed) were not used. The use of 13 wells was not known.

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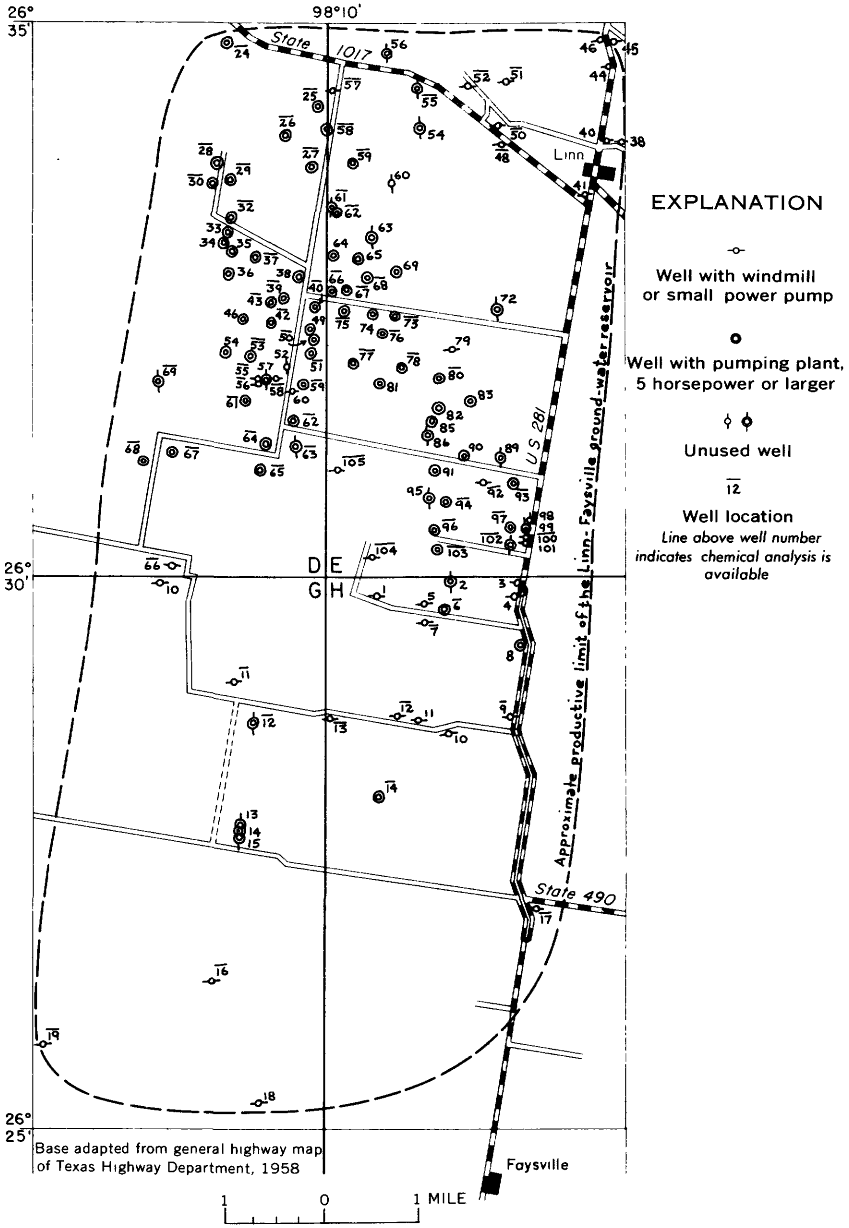

FIGURE 4.—Map showing location of wells tapping the Linn-Faysville ground-water reservoir.

Neither the rate nor the amount of pumping from the Linn-Faysville ground-water reservoir has been determined for any period.

FLUCTUATION OF WATER LEVELS

Measurements of water levels were made in 1939, 1945, and 1947 in some of the shallow wells tapping the Linn-Faysville ground-water reservoir. In 1948 a program of yearly measurements of water levels in the shallow wells was started. Some of the wells were measured two or three times in some years, but generally the measurements were made in May or June of each year. When possible, the water levels were measured a few days after a heavy rain because fewer wells were being pumped.

Figure 5 shows the decline in water levels in some of the shallow wells in the area from March or April 1948 to June 1957. The water level declined 10 feet or more in most of the irrigated part of the area and more than 20 feet in two wells. The decline in water levels can be attributed principally to withdrawals, for the areas showing the largest declines of water levels have the largest concentration of wells. However, it is not possible to make a direct comparison because the rate and amount of the withdrawals are not known.

QUALITY OF WATER

The water from wells tapping the Linn-Faysville ground-water reservoir is used for public supplies and by some industries because it is the best water available locally. However, it does not meet the standards of chemical quality that are generally accepted for these uses. Because of the importance of ground water for irrigation in the Linn-Faysville area, the quality of the water is discussed principally in relation to its suitability for irrigation. Figure 6 is a map showing the salinity hazard and the sodium hazard of water from the wells that tap the Linn-Faysville ground-water reservoir. Throughout most of the area the water ranges from high-salinity hazard to very high salinity hazard and from medium-sodium hazard to very high sodium hazard.

Figure 7 shows the content of boron in water from wells tapping the Linn-Faysville ground-water reservoir. The boron content ranges from 0.78 to 3.6 ppm and averages about 1.6 ppm—a fact that indicates that in most of the area the water is permissible for use on semitolerant and tolerant crops.

Figures 6 and 7 show that the water from the Linn-Faysville ground-water reservoir tends to be more mineralized and less desirable for irrigation in the eastern part of the Linn-Faysville area than in the western part. Reportedly the eastward limit of irrigation in the Linn-Faysville area is governed by the quality of the water.

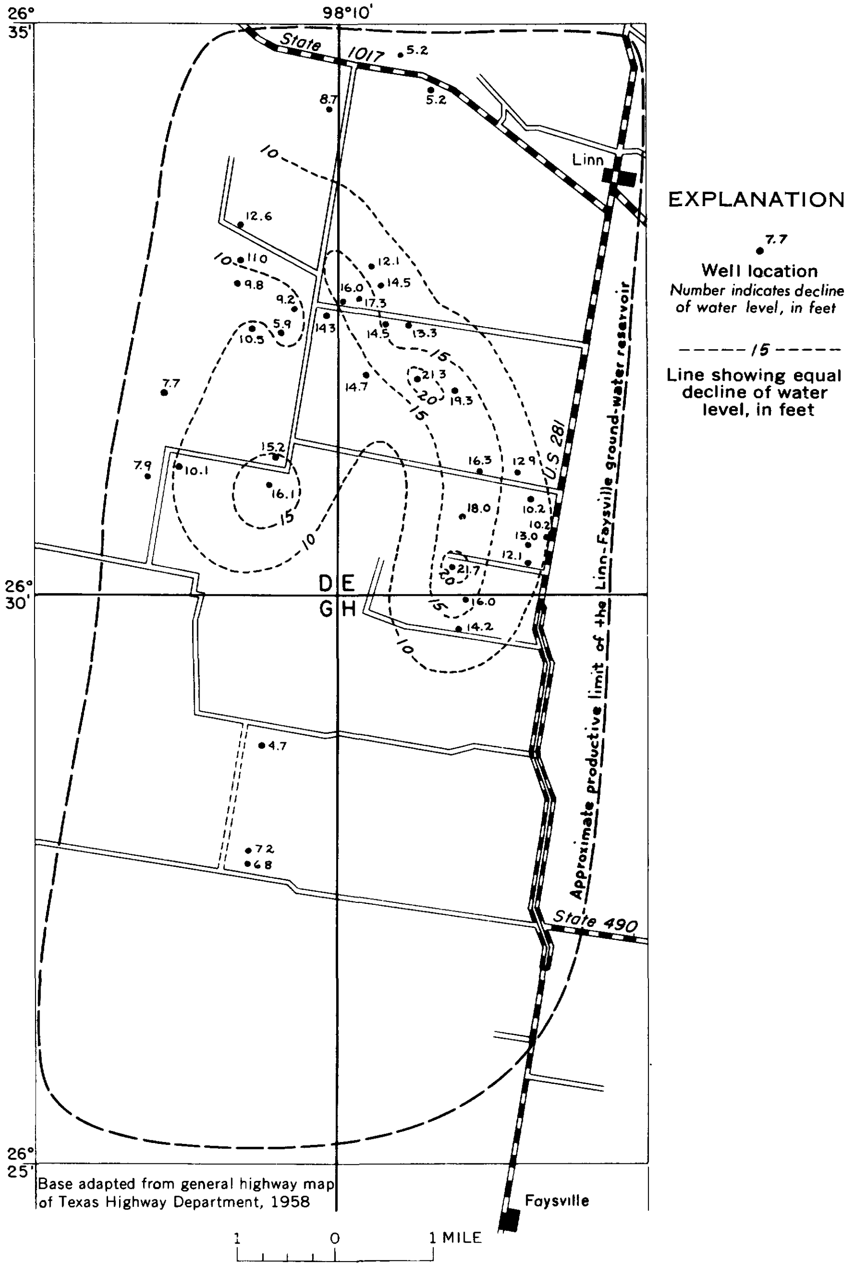

FIGURE 5.—Map showing decline of water levels March or April 1948 to June 1957 in wells tapping the Linn-Faysville ground-water reservoir.

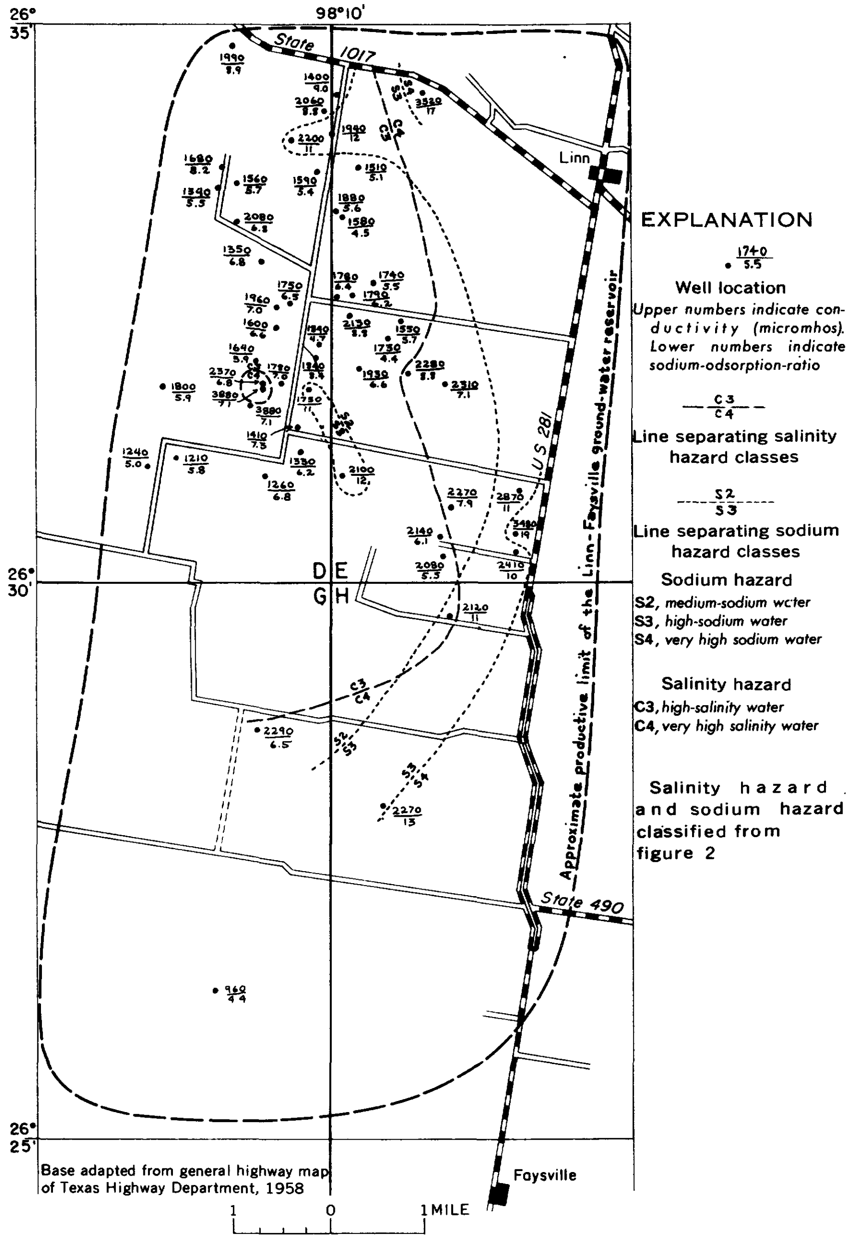

FIGURE 6.—Map showing the salinity hazard and sodium hazard of water from wells tapping the Linn-Faysville ground-water reservoir.

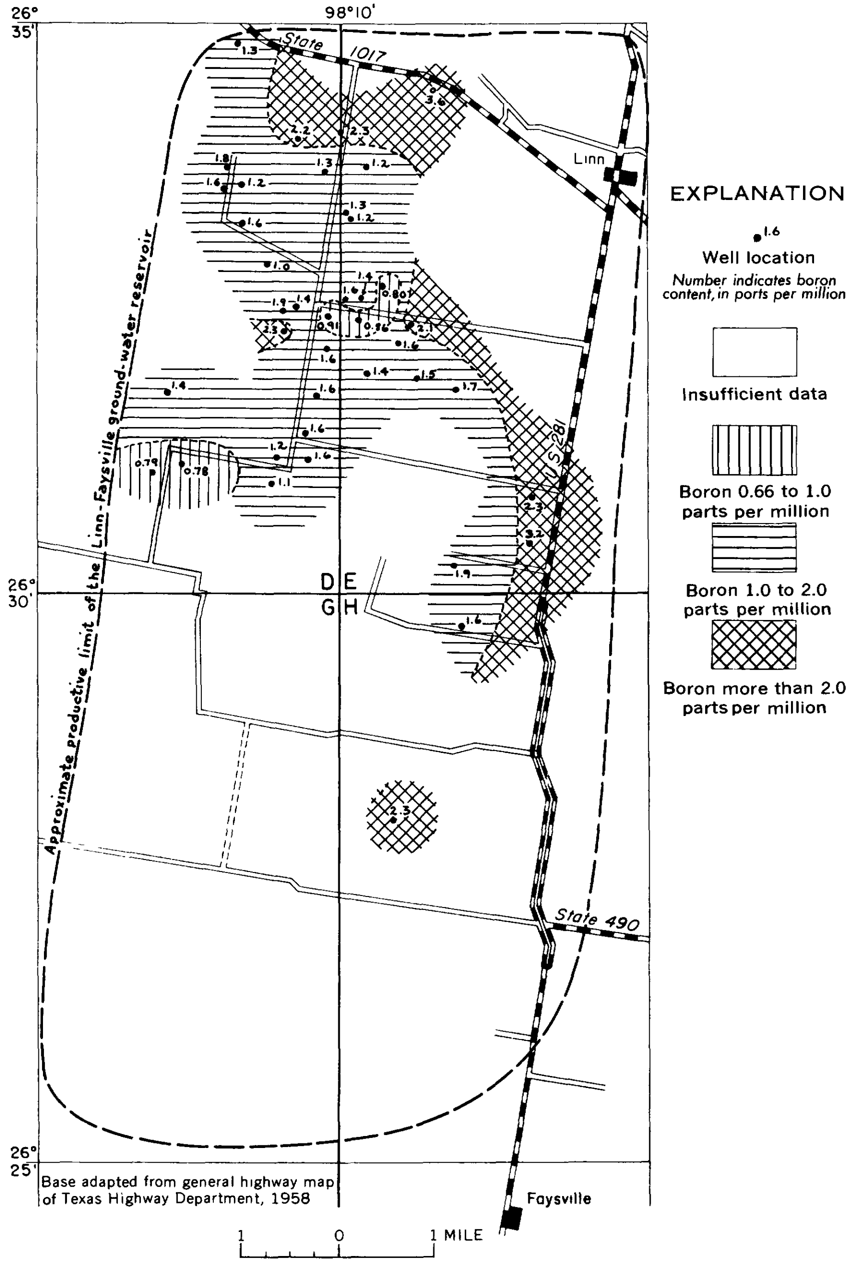

FIGURE 7.—Map showing the boron content of water from wells tapping the Linn-Faysville ground-water reservoir.

Because of the quality, the water from wells in much of the Linn–Faysville ground-water reservoir may not be suitable for irrigation if used exclusively and regularly over a long period of time. However, several other factors given on pages 19 to 23, which are beyond the scope of this investigation, must be considered.

Samples of water have been taken at different times from each of several wells tapping the Linn-Faysville ground-water reservoir. The later samples from many of the wells are slightly more mineralized than the earlier ones; however, the reverse is true of a few of the wells. Insufficient data are available to determine whether a significant change has taken place in the quality of the water.

HYDROLOGY

Water in the Linn-Faysville ground-water reservoir is under water-table conditions. Recharge to the reservoir is largely from precipitation on the area. The distribution of caliche in the upper part of the reservoir is important in controlling the location and amount of recharge. Much additional information about precipitation, fluctuation of water levels, and the location and amount of pumpage is necessary before the magnitude of recharge to the shallow beds can be evaluated.

LOWER RIO GRANDE GROUND-WATER RESERVOIR

GENERAL DESCRIPTION

An important ground-water reservoir lies astride the Lower Rio Grande in Texas and Mexico, although only the part north of the Rio Grande is discussed in this report (fig. 3). The Texas part of the reservoir is in southeastern Starr, southern Hidalgo, and western Cameron Counties, and possibly a small part of southwestern Willacy County.

The ground-water reservoir consists of beds of water-bearing material in the Goliad sand, Lissie formation, Beaumont clay, and the alluvium (fig. 8). Because the permeable beds are hydraulically connected, they behave as a unit; however, locally they are separated by layers of less permeable material. This reservoir is herein named the lower Rio Grande ground-water reservoir.

The alluvium consists largely of flood plain and deltaic deposits of the Rio Grande; most is of Recent age, though in southern Starr County the alluvial terraces may be of Pleistocene age. Much of the area in which the alluvium is exposed formerly was subject to flooding by the Rio Grande; however, some protection now is given by Falcon Dam, levees, and floodways.

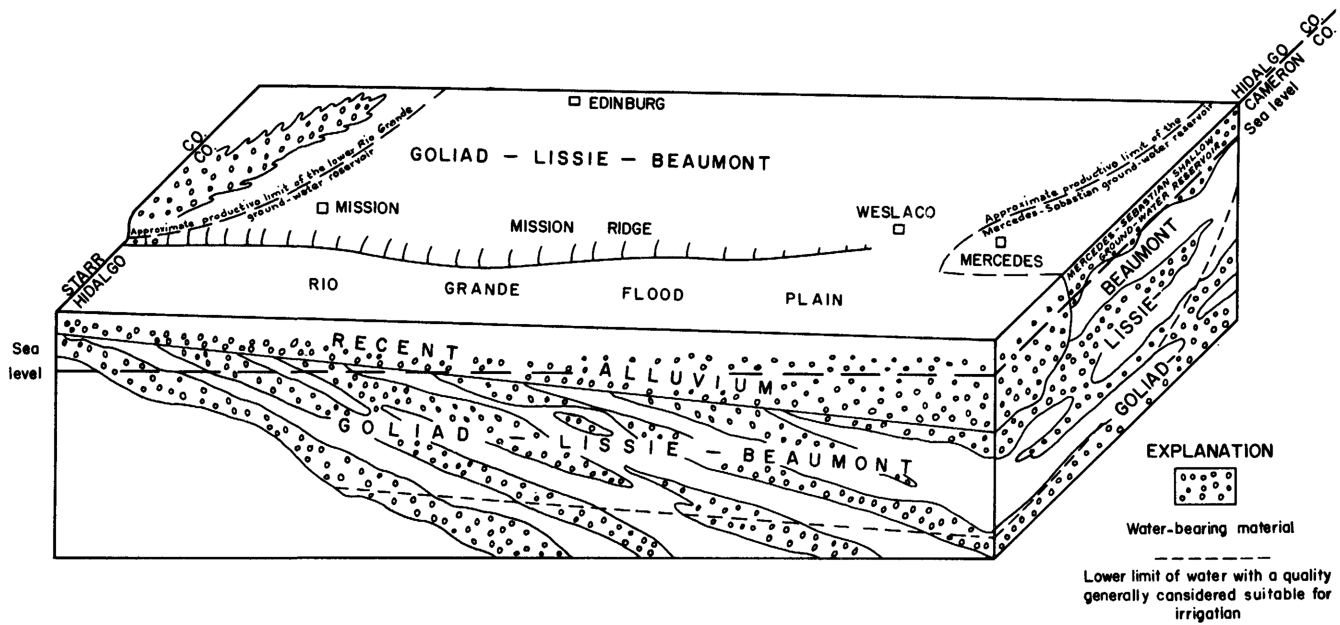

FIGURE 8.—Block diagram showing the relationship between the water-bearing materials in the Goliad sand, Lissie formation, and Beaumont clay, undifferentiated, and the Recent alluvium in the lower Rio Grande ground-water reservoir and the Mercedes-Sebastian shallow ground-water reservoir in southern Hidalgo County, Tex. (Not to scale.)

The alluvium is composed largely of silt and clay but contains many beds of sand and gravel, especially in its lower part. Of particular importance is a bed of water-bearing material in the lower part of the alluvium under and near the Rio Grande that extends from the vicinity of Rio Grande City in Starr County to the vicinity of Brownsville in south-central Cameron County. The approximate area underlain by this zone is shown as Recent alluvium in the lower Rio Grande ground-water reservoir on figure 3. This permeable deposit is fairly well defined by the location of irrigation wells tapping it except in Starr County and near its eastern end in south-central Cameron County. At some places in southern Hidalgo County the zone of water-bearing material in the alluvium apparently does not underlie all the Recent flood plain of the Rio Grande.

In southern Starr County the zone of permeable material in the alluvium does not extend more than 2 miles north of the Rio Grande at most places. In Hidalgo County, the width of the area underlain by the permeable zone ranges from 0 to about 5 miles. In Cameron County the area underlain by the permeable zone is wider, and in south-central Cameron County the northern limit of the zone is as much as 10 miles from the river.

Near Rio Grande City in south-central Starr County, the approximate bottom of the permeable zone in the alluvium is about 50 feet below land surface. At the Starr-Hidalgo County line, it is about 75 feet below land surface and at the Hidalgo-Cameron County line, about 185 feet. In the vicinity of Brownsville in south-central Cameron County, the bottom of the permeable zone is probably deeper than 250 feet, but most of the wells in this area obtain water from the upper part of the zone at depths of about 200 feet. The bottom of the zone dips in the same direction as the river at about 4 feet per mile.

The permeable zone in the alluvium is in hydraulic connection with adjacent and underlying beds of permeable material in the Goliad sand, Lissie formation, and the Beaumont clay; therefore, these deposits have been grouped together as the lower Rio Grande ground-water reservoir.

The Goliad sand crops out in eastern Starr County and western Hidalgo County. The Lissie formation crops out in a north trending band presumably located in eastern Hidalgo County. The Beaumont clay crops out in a band in western Cameron and Willacy Counties between the Lissie and the Recent coastal-plain deposits. The contacts between the Goliad sand and the Lissie formation and the Lissie formation and the Beaumont clay are uncertain; therefore, the formations have not been differentiated in this report.

The Goliad sand, the Lissie formation, and the Beaumont clay consist largely of silt, clay, sand, and some gravel and contain much caliche near the land surface in the Goliad and Lissie. The percentage of sand and gravel in the formations is greatest near the Rio Grande.

In southeastern Starr County and southwestern Hidalgo County, beds of sand and gravel in the Goliad sand and Lissie formation are exposed in the bluffs bordering the Rio Grande flood plain and in the valleys of the smaller streams cutting the upland plain. A gravel pit in the northern part of the town of Mission is in the Goliad sand or Lissie formation. In south-central and southeastern Hidalgo County, beds of sand and gravel are tapped by wells but do not crop out.

Well data indicate three poorly defined zones at shallow depths in the Goliad and Lissie in which beds of sand and gravel are common, and extend from near McAllen to near Donna in southern Hidalgo County. At McAllen the bottom of the upper zone of sand and gravel is about 120 feet below the land surface, the middle zone extends from about 170 feet to about 250 feet, and the lower zone from 300 to 410 feet. At Donna the bottom of the upper zone is at a depth of about 300 feet, and the middle zone extends from about 410 to 500 feet. Water wells do not penetrate to the lower zone in the vicinity of Donna; however, the projected top of the zone is at a depth of about 650 feet. The component of dip of these zones in the Goliad and Lissie is about 20 feet per mile between McAllen and Donna, but the zones could not be traced in the subsurface in other directions and apparently do not crop out at the land surface. The gravel pit in the northern part of the town of Mission probably is in the middle zone. The general location and depths of wells tapping the Goliad and Lissie in southern Hidalgo County suggest that the strike of these zones may be to the northeast.

The extent of the lower Rio Grande ground-water reservoir is defined largely on the basis of the location of the irrigation, industrial, and municipal wells tapping it. The limits of the reservoir may be defined either by a decrease in the permeability of the water-bearing beds or by an increase in the dissolved-solids content of the water.

In Starr County the northern limit of the lower Rio Grande groundwater reservoir is marked by the pinch out of the permeable zone in the Recent alluvium. In Hidalgo County the northern limit of the aquifer probably marks a facies change in the zone of the Goliad, Lissie and Beaumont; this change causes a decrease in permeability to the north. The quality of the contained water tends to deteriorate away from the river. The general limits of the lower Rio Grande ground-water reservoir in a northeasterly and easterly direction are marked by the limits of water of suitable chemical quality for irrigation and industrial use.

In southeastern Hidalgo County and western Cameron County, the shallow deposits (less than 100 feet deep) are treated as a separate reservoir on the basis of the chemical quality of the ground water. (See p. 47 and 48.)

The maximum thickness of the lower Rio Grande ground-water reservoir is about 700 feet; however, the thickness is indefinite and irregular and generally is less than 500 feet. Inasmuch as the dissolved-solids content of the water tends to increase with depth, for most uses an effective lower limit to the reservoir can be defined on the basis of the chemical quality of the water.

The lower Rio Grande ground-water reservoir extends in an east-southeasterly direction along the Rio Grande an airline distance of about 90 miles. The maximum width of the aquifer in Texas is about 28 miles in eastern Hidalgo County. The lateral limits of the reservoir in Texas encompass an area of about 1,150 square miles, of which about 950 square miles is productive. The remaining 200 square miles consists of small, poorly defined unexplored areas or areas where the drillers report insufficient water or water of poor quality.

DEVELOPMENT

About 1,500 irrigation wells, numerous domestic wells, and some industrial and public-supply wells tap the lower Rio Grande ground-water reservoir. In Hidalgo County most of the wells are south and southeast of a line starting about where U.S. Highway 83 enters the county from the west and extending to Edinburg then northeastward to the Willacy County line about 8 miles north of Edcouch (pl. 1).

The maximum reported yield of a well tapping the lower Rio Grande ground-water reservoir is 2,900 gpm, and yields of more than 2,000 gpm were measured at several wells. However, the average yield of the wells tapping the reservoir is estimated to be about 300 gpm.

The total capacity of wells tapping the lower Rio Grande ground-water reservoir is estimated to be about 500,000 gpm. This is about 720,000,000 gpd or 2,200 acre-feet per day. Because of the different kinds and the number of crops grown each year, variations in rainfall, and the variability of the supply of water available from the Rio Grande before the completion of Falcon Dam in 1954, the amount and distribution of pumping in the reservoir has been very irregular, and no quantitative estimates of pumpage can be made.

The rate of pumping from the lower Rio Grande ground-water reservoir fluctuates considerably. During droughts, when the supply of water available from either the Rio Grande or local precipitation is insufficient to meet demand, the rate of pumping may approach the total capacity of the wells tapping the reservoir. During periods of normal or above-normal precipitation, the rate of pumping is generally much smaller that it is during droughts.

FLUCTUATION OF WATER LEVELS

In 1933 and 1939, water levels were measured in numerous wells throughout the area and, in May and June of 1945, water levels were measured in some of the irrigation wells in southern Hidalgo County and in Cameron County. In 1952, water levels were measured in several wells and were reported in other wells in Cameron County (Dale and George, 1954). Rose (1954, p. 70–89) listed water levels for about 100 wells for 1954. In 1957, water-level measurements were made in a large number of irrigation and public-supply wells in Cameron County and southern Starr and Hidalgo Counties. In 1959, water-level measurements were made in 35 wells in Cameron County.

A continuous water-level recording gage was maintained on Hidalgo County well S–60 from 1946 to 1949. A hydrograph of the water level in well S–60 and in the Rio Grande for the periods during 1946–49 when simultaneous record is available is given in figure 11 and is discussed in the section on hydrology.

Plate 3 shows the altitude of the water levels in 1954 and 1957 in wells tapping the lower Rio Grande ground-water reservoir in western Cameron County. It also shows the altitude of the water levels in the same area in 1959 and the rise in water level from 1957 to 1959.

As of 1954 the 20-foot contour (pl. 3) was west and south of San Benito and had a southerly trend. The 30-foot contour was indefinite but is probably south and southwest of Harlingen. The 40-foot contour was near the Hidalgo County line, had a southeasterly trend, and was about 8 miles west of the 20-foot contour indicating an easterly slope of the water level in 1954 of about 2.5 feet per mile.

As of 1957 the 20-foot contour (pl. 3) was still west and south of San Benito and had about the same trend as in 1954. The 30-foot contour was in western Cameron County at about the same location as the 40-foot contour had been as of 1954 and had a general southerly trend. The slope of the water surface in 1957 was to the east at about 1.7 feet per mile.

The contours show that in the southwestern corner of Cameron County the water level was lowered about 10 feet from 1954 to 1957, but that in the area south and southeast of San Benito no appreciable change in water levels took place between 1954 and 1957.

In 1959 the 20-foot water-level contour (pl. 3) was east of San Benito, about 5 miles east of its location in 1954 and 1957. The 40-

foot contour was in southwestern Cameron County and was farther east in 1959 than it was in 1954. The slope of the water surface in 1959 was easterly about 1.7 feet per mile.

Water levels in the lower Rio Grande ground-water reservoir in Cameron County rose markedly from 1957 to 1959 as shown on plate 3. The measured rise ranged from 4 to 21 feet. The rise exceeded 20 feet in a small area near the southwest corner of Cameron County and exceeded 10 feet in most of the southwestern part of the county. Everywhere in the Rio Grande aquifer the water levels stood higher in 1959 than in 1957 or 1954.

QUALITY OF WATER

Even though several zones of permeable material at different depths are present in the Rio Grande aquifer, except for shallow wells most of which are less than 50 feet deep, the quality of the water from wells tapping these deposits seem to fit into a general pattern. The pattern can be shown on maps and several generalizations can be made.

Plate 3 shows the salinity hazard classes and the sodium hazard classes of water from selected wells tapping the lower Rio Grande ground-water reservoir in western Cameron County, and it shows the boron content of water from selected wells tapping the reservoir in western Cameron County. The wells, for which information is given on plate 3, range from 100 to 303 feet in depth. Figure 9 is a section showing the salinity hazard classes and the sodium hazard classes of water from selected wells in Cameron County. Plate 4 shows the salinity hazard classes, the sodium hazard classes, and the boron content of water from selected wells tapping the lower Rio Grande ground-water reservoir in southern Hidalgo County. Figure 10 shows the salinity hazard classes, the sodium hazard classes, and the boron content of water from wells tapping the reservoir in southern Starr County.

In general, plates 3 and 4 and figure 9 show that for the depths indicated water of the best quality in the lower Rio Grande ground-water reservoir is near the Rio Grande and the water tends to be of increasingly poorer quality northward from the river.

The water in the lower Rio Grande ground-water reservoir below a depth of about 250 feet in southern Hidalgo County and about 300 feet in southwest Cameron County generally contains more dissolved solids than does the water from shallower depths. This difference is indicated on figure 9. Water from the basal part of the reservoir at depths greater than 250 feet in Hidalgo County and 300 feet in Cameron County probably would be of poorer quality than indicated on plates 3 and 4.

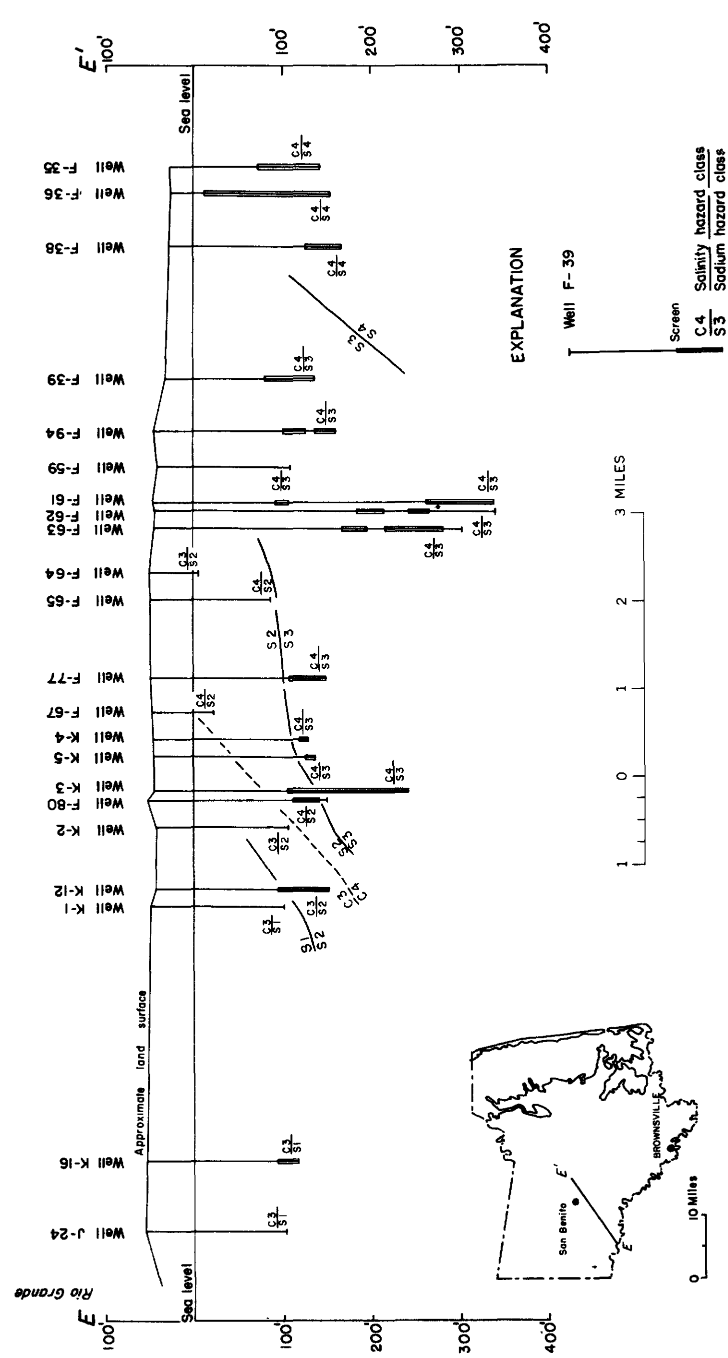

FIGURE 9.—Section showing the salinity hazard classes and the sodium hazard classes of water from selected wells in Cameron County, Tex.

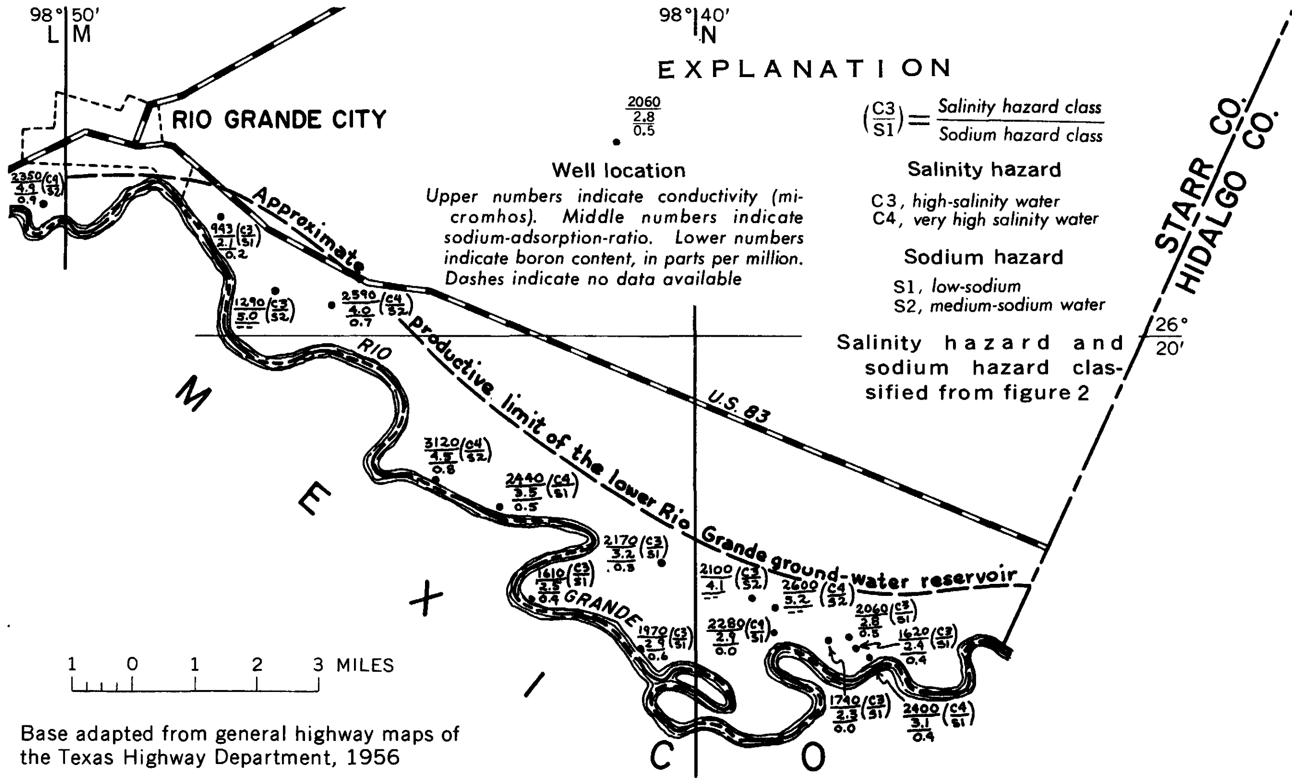

FIGURE 10.—Map showing the salinity hazard, sodium hazard, and boron content of water from wells tapping the lower Rio Grande ground-water reservoir in southern Starr County, Tex.

A few of the wells tapping the lower Rio Grande ground-water reservoir have been sampled more than once. Generally, no significant changes with time of the quality of the ground water are apparent. The water of wells L–102, L–105, and L–110 in Hidalgo County was more mineralized in 1945 than in 1939. However, this change may not indicate a change in the quality of the water over a large area, but instead may be the result of upward or downward movement of more mineralized water in the immediate vicinity of each of the wells.

HYDRAULIC CHARACTERISTICS

In July 1947 a series of pumping tests were made on wells owned by the City of Harlingen in Cameron County. The city well field is about 8 miles southwest of Harlingen and includes Cameron County wells E–51, E–68, E–69, E–70, E–71, E–72, and E–73. All the wells tap the lower Rio Grande ground-water reservoir. The average coefficient of transmissibility was estimated on the basis of the tests to be 54,000 gpd per ft and the average coefficient of storage to be 0.00044. The average coefficient of permeability was computed to be 900 gpd per sq ft.

Other conclusions were drawn from the test. Although the lower Rio Grande ground-water reservoir in the well field consists of beds of sand and gravel extending from 140 and 230 feet in depth and are separated by lenses of clay, the entire thickness of the aquifer acts as a hydraulic unit. The aquifer is overlain by clay and silt, and the water in the reservoir occurs under artesian conditions at the well field. In the vicinity of the well field the silt and clay overlying the water-bearing beds are nearly impermeable, and probably only a very small amount of recharge moves downward from the land surface to the aquifer. Wells will perform best if screened opposite all beds of sand and gravel in the aquifer.

Rose (1954, p. 8) gives the results of seven short pumping tests of wells tapping the alluvium, the results of three pumping tests in wells tapping the Lissie formation, and one test of a well tapping the Reynosa of former usage (Goliad sand of this report). The alluvium and the part of the Lissie formation tapped by the three wells is included in the lower Rio Grande ground-water reservoir in this report. Rose (1954, p. 9) states the following:

Coefficients of transmissibility obtained from tests of seven wells in the alluvium averaged slightly over 30,000. All of these wells did not have the entire section of the alluvium screened, and the overall transmissibility of the alluvium may be somewhat higher.

Tests of the four Lissie-Reynosa wells indicated coeficients of transmissibility generally lower than those obtained in the alluvium. However, these wells have only a small portion of the Lissie-Reynosa screened. The overall transmissibility of the Lissie-Reynosa sands and gravels may be much greater than that indicated by the tests.

Rose (1954, p. 9) reported further that the specific capacities of six wells in the alluvium ranged from 17 to 33 gpm per foot of drawdown.

HYDROLOGY

Water in the upper part of the lower Rio Grande ground-water reservoir generally is under water-table conditions. However, as the water moves downward and laterally it may pass under beds of relatively less permeable material so that locally it is under artesian conditions. Local artesian conditions are indicated by the pumping test at the city of Harlingen well field. Considering that the permeable beds of the reservoir are hydraulically connected so that they behave as a unit and that the water in the upper part of the reservoir is not confined, the reservoir as a whole probably can be considered to be a water-table reservoir.

Recharge to the lower Rio Grande ground-water reservoir occurs in one or more of the following ways: lateral or upward movement of water from adjacent parts of the Goliad sand and the Lissie formation or other formations; downward percolation of water from precipitation, applied irrigation water, or surface water from streams and drains on the outcrop area; and lateral and downward movement of water into the reservoir from the Rio Grande.

Discharge of water from the lower Rio Grande ground-water reservoir occurs in one or more of the following ways: by the lateral or downward percolation of water into other deposits; by the upward movement and subsequent removal of water by evaporation, transpiration, or runoff through surface waterways; by discharge of water from the reservoir into the Rio Grande; or by pumping from wells.

The hydraulic connection between the Rio Grande and the lower Rio Grande ground-water reservoir is indicated by a study of the relation of the fluctuations of water levels in the aquifer to the stage of the river. Water-level measurements were made in Hidalgo County well S–60 with a continuous recorder during parts of 1946, 1947, 1948, and 1949. Well S–60 is about 0.4 mile from the river and 0.6 mile from the Progreso District pump.

Figure 11 is a hydrograph showing the highest daily water level in well S–60 and the daily 6:00 a.m. water level in the Rio Grande at the Progreso District pump for the period of record. The water level in well S–60 (fig. 11) does not fluctuate as rapidly or as much as the water level in the river. It is apparent, however, that the water level in the well follows the trend of the water level in the Rio Grande and is always below it except for short periods when the river level has

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fallen rapidly. One may conclude that water normally moves from the Rio Grande into the aquifer in the vicinity of the Progreso District pump.

The pattern of the quality of water as shown in plates 3 and 4 and figure 9, shows that the least mineralized water occurs near the Rio Grande and that the water is more mineralized at greater distances from the river. This pattern suggests that water is moving from the river into the lower Rio Grande ground-water reservoir.

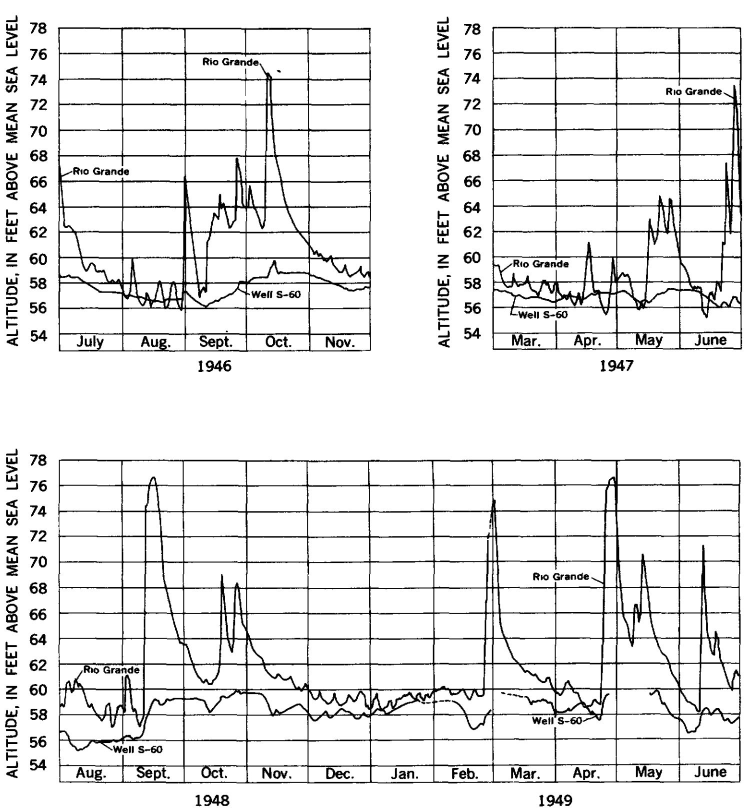

Figure 11.—Hydrograph showing the highest daily water level in Hidalgo County well S-60 and water level at 6:00 a.m. in the Rio Grande at Progreso District pump station in parts of 1946, 1947, 1948, and 1949.

PERENNIAL YIELD OF THE LOWER RIO GRANDE GROUND-WATER RESERVOIR

The perennial yield of the lower Rio Grande ground-water reservoir is controlled largely by the amount of water it contains in storage and the amount and nature of recharge to it.

Water in storage.—The total area of the Rio Grande aquifer is about 1,150 square miles. The water of best quality is near the Rio Grande above a depth of about 300 feet in Cameron County, about 250 feet in southeastern Hidalgo County, about 150 feet in southwestern Hidalgo County, and about 75 feet in Starr County.

The present developed capacity of the wells tapping the Rio Grande aquifer is estimated to be about 2,200 acre-feet per day. Most of the wells tapping the aquifer are used for irrigation, and because water is not needed continuously, the average rate of pumping probably is less than 500 acre-feet per day. The pumping rate during years of below-normal precipitation may be larger, particularly if the quantity of water available from the river is inadequate for irrigation. During periods of above normal precipitation, the pumping rate probably is much less than 500 acre-feet per day.

Assuming water-table conditions and an effective coefficient of storage of 0.1 for the lower Rio Grande ground-water reservoir, the entire reservoir would yield about 75,000 acre-feet of water for each foot the water level was lowered. Under these conditions, with no recharge, a pumping rate of 500 acre-feet per day would lower the water level an average of nearly 2.5 feet per year. All the wells pumping at full capacity would lower the water level an average of nearly 11 feet per year. The depth to which the water level in the reservoir could be lowered ranges from less than 75 feet in Starr County to as much as 300 meet in Cameron County, which is about the depth to the bottom of the zone in which the water of best quality occurs.

Recharge to the aquifer.—Possible sources of recharge to the lower Rio Grande ground-water reservoir are from adjacent or underlying water-bearing beds, from the Rio Grande, or by the percolation of water from the land surface. As ground water moves from areas of higher head to areas of lower head at a rate proportional to the hydraulic gradient, lowering of water levels in the reservoir will increase the rate of inflow from adjacent and underlying beds and from the river. The rate of percolation from the land surface is independent of the water level as long as the water table is below the land surface.

The amount of water that can be recharged from the normal flow of the Rio Grande is relatively small compared to the capacity of the wells tapping the lower Rio Grande ground-water reservoir because of the low transmissibility of the aquifer and the limited contact of the river with the reservoir.

Some of the water from precipitation, canals and drains, and from irrigation percolates downward into the lower Rio Grande ground-water reservoir. The water-level changes in the reservoir from 1954 to 1957 and from 1957 to 1959 shown on plate 3 give some indication of the importance of downward percolation of water from the surface.

Between 1954 and 1957, a period of deficient rainfall, the water level in the lower Rio Grande ground-water reservoir declined about 10 feet (pl. 3). Considering the large quantity of water withdrawn by wells, the amount of decline indicates that there was a fairly large amount of recharge to the reservoir during the period. Precipitation in the lower Rio Grande Valley area was much above normal during 1958, particularly in October when flooding was prevalent. The water levels in the reservoir in Cameron County rose from 4 to 21 feet from 1957 to 1959 (pl. 3). This rise indicates that perhaps as much as several hundred thousand acre-feet of water was recharged into the reservoir during the period. A further contributing factor to the rise in water levels in 1957–59 was the increased availability of water from the Rio Grande and from local precipitation in 1958 which reduced the amount of water pumped from the aquifer. In view of the fact that the amount of water that can be recharged into the resrvoir from the Rio Grande is relatively small when compared to the capacity of the wells, the changes in water level from 1954 to 1957 and from 1957 to 1959 indicate that the downward percolation of water from the land surface is the principal method of replenishing the reservoir.

Discharge from the lower Rio Grande ground-water reservoir.—Ground water is discharged from the lower Rio Grande ground-water reservoir by evapotranspiration, by seepage into streams and drains, including possibly the Rio Grande when it is at low stage, by movement laterally from the reservoir, and by pumping from wells.

Before the land was cleared for farming, most of the discharge from the lower Rio Grande ground-water reservoir was probably by evapotranspiration. The Lower Rio Grande Valley area was covered with a heavy growth of mesquite trees and brush that are capable of using as much as 3 acre-feet per acre of water per year. Mesquite will send roots down to the water table as much as 60 feet below land surface, if necessary. Ground-water discharge also took place into streams during periods when the ground-water levels were above the stream stage and by underflow into adjacent water-bearing beds.

Clearing a large part of the Lower Rio Grande Valley reduced the amount of water discharged by transpiration, and the ground-water level rose until it was near the surface in some localities. Evaporation of water at or near the surface of the land caused local concentrations of salts which were detrimental to crops to form in the soil.

The shallow water levels made the construction of drains necessary. An investigation of the waterlogging conditions was started in 1945 by the U.S. Bureau of Reclamation.

During the prolonged period of low to moderate rainfall that began in 1941, the amount of recharge to the reservoir was reduced. As the drought intensified in the period 1953–56 and the discharge by wells increased, the ground-water levels declined. The high rainfall in 1957 and 1958 caused the water levels to rise to near the land surface again in some places and evaporation from the water surface probably has occurred.

Water is discharged from the lower Rio Grande ground-water reservoir by lateral movement to the north, northeast, and east. Plate 3 shows that in Cameron County the hydraulic gradient is to the northeast and east and is about 1.0 to 2.5 feet per mile. Because of this gradient, the amount of water discharged from the reservoir is very small in comparison to the amount discharged by wells.

Summary of perennial yield.—Apparently most of the recharge into the lower Rio Grande ground-water reservoir is by the downward percolation of water from the land surface. The amount of recharge fluctuates with differences in precipitation, being largest during periods of above-normal rainfall. Prior to development by man, most discharge from the reservoir was by evapotranspiration. The rate of discharge by evapotranspiration was reduced as the land was cleared for cultivation. During periods of normal or above normal precipitation, the reservoir may be filled to near capacity so that waterlogging of the soil occurs. The amount of water available in storage is not large compared to the total potential capacity of the wells. During protracted periods of below normal rainfall, when the rate of pumping is at a maximum and the rate of recharge is at a minimum, the water available in storage could be depleted in a relatively short time.

Data are insufficient to permit a quantitative evaluation of the perennial yield of the lower Rio Grande ground-water reservoir.

MERCEDES-SEBASTIAN SHALLOW GROUND-WATER RESERVOIR

The Mercedes-Sebastian shallow ground-water reservoir consists of permeable deposits of the Beaumont(?) clay that are less than 100 feet below the land surface in southeastern Hidalgo County, western Cameron County, and southwestern Willacy County (fig. 3). The permeable deposits appear to be in a northeastward-trending channel which may have been a former course of the Rio Grande during the Pleistocene. The lateral extent of the reservoir is not well defined; the limits are best defined on the basis of the quality of the water from wells tapping it as shown on plate 4. The quality of the water also is the basis for separating the Mercedes-Sebastian shallow ground-water reservoir from the lower Rio Grande ground-water reservoir which underlies it at most places.

Many wells for public supply, irrigation and domestic, and stock use tap the Mercedes-Sebastian shallow ground-water reservoir. Plate 4 shows the salinity hazard, sodium hazard, and boron content of water from wells tapping the reservoir. The salinity hazard of the water ranges from high to very high and the sodium hazard ranges from low to very high. The low-sodium water is in a small area in the vicinity of Mercedes and in a small area northwest of Harlingen. In general, water of the best quality in the reservoir is in a belt ranging from about 3 to 7 miles wide and extending northeast from Mercedes into Willacy County.

In Willacy County the nitrate in wells E–4, E–6, E–9, and E–12, ranges from 51 to 137 ppm. The depths of these wells range from 22 to 30 feet. High nitrate content commonly is an indication that the water is subject to bacterial contamination, although a high nitrate content may be of natural origin. Water containing more than 44 ppm nitrate is considered unsafe for drinking by infants because it may cause methemoglobinemia ("blue-baby" disease).

The yield of individual wells tapping the Mercedes-Sebastian shallow ground-water reservoir is small. However, a method of constructing irrigation wells in this area is to drive several sandpoints into the reservoir, connect them to a common suction pipe, and pump them with a single centrifugal pump. For example, Cameron County well B–9 consists of 39 sand points ranging from 40 to 60 feet in depth. The reported capacity of well B–9 in 1952 was 1,000 gpm and it was used to irrigate 1,000 to 1,200 acres.

MINOR SOURCES

COOK MOUNTAIN FORMATION AND SPARTA SAND, UNDIFFERENTIATED, YEGUA FORMATION, JACKSON GROUP, FRIO CLAY, AND CATAHOULA TUFF

The Cook Mountain formation and Sparta sand, undifferentiated, Yegua formation, Jackson group, Frio clay, and Catahoula tuff crop out in western Starr County. In most of the outcrop areas of these formations, water has been obtained for domestic use and stock watering from wells generally less than 300 feet deep. The quality of the water differs considerably from place to place, and there does not appear to be much uniformity or pattern to the distribution. In a large area in central, northwest, and west-central Starr County, the water from many wells tapping these deposits is so mineralized that it cannot be used for domestic supplies and in some places cannot be used for stock watering.

GOLIAD SAND

Several hundred wells scattered through eastern Starr County, Hidalgo and Willacy Counties, and western Cameron County are believed to obtain water from the lower part of the Goliad sand. However, the Goliad is considered to be a minor source of ground water outside the areas of the Linn-Faysville and lower Rio Grande ground-water reservoir because of its low permeability and the generally poor quality of the contained water.

The Goliad sand crops out in a broad northward-trending band in eastern Starr and western Hidalgo Counties. It consists of sand, clay, and some gravel. In most of its outcrop area it consists of sand or sand and gravel cemented with caliche, a secondary accumulation of calcium carbonate associated with soil formation in regions of limited rainfall. The Goliad sand lies unconformably on the Oakville sandstone and the Lagarto clay, and it is overlain unconformably by the Lissie formation. With the present available information, the Goliad sand could not be differentiated from the underlying Oakville sandstone and Lagareto clay on well logs. Likewise, the contact between the Goliad sand and the overlying Lissie formation could not be located. In a small part of northeastern Starr County and in a small part of northwestern Hidalgo County, the Goliad sand is covered by sand dunes; in the southern part of the area near the Rio Grande, the Goliad sand is covered by alluvium.

All water wells in the western third of northern Hidalgo County, and all water wells more than 500 feet deep in the eastern two-thirds of northern Hidalgo County and in Willacy County probably tap the Goliad sand. This division is arbitrary, and some of the wells, particularly the deeper wells in western Hidalgo County, probably also tap formations older than the Goliad sand. However, the division gives a basis for studying and showing the quality of the water from the deeper wells in northern Hidalgo County and in Willacy County.

Most of the wells tapping the Goliad sand are for stock watering or domestic use, but some wells are used for irrigation or public supply and a few wells produce water for industrial use such as cotton gins. In some areas the only usable ground water available is from the Goliad sand.

The quality of the water in the outcrop area of the Goliad sand at depths of less than 200 feet differs considerably from place to place. At some places in the outcrop area the water from shallow wells is of good quality and at other places the water is saline. The analyses of water from these shallow wells were not used in making plate 5.

Plate 5 shows the approximate salinity hazard, sodium hazard, and boron content of the water from wells believed to tap the Goliad sand in northern Hidalgo County and Willacy County. The approximate specific conductance of most of the samples in Hidalgo County was computed by multiplying the total solids in parts per million by 1.6. The salinity hazard ranges from high to very high. The sodium hazard ranges from medium to very high, but is medium or high only in two relatively small areas in western Hidalgo County. The boron content of water from the Goliad sand in Hidalgo County ranges from 1.7 to 9.9 ppm and averages 4.0 ppm. In Willacy County the boron content ranges from 2.2 to 11 ppm. In general, the farther downdip to the east the less suitable is the water for irrigation in the Goliad sand.

Because water from the Goliad sand is used extensively for stock and domestic supplies, plate 5 is presented showing the chloride and dissolved-solids content of the water from wells tapping the Goliad sand in northern Hidalgo County, Willacy County, and southern Kenedy County. In nearly all of the water from the Goliad sand the concentrations of chloride and dissolved-solids exceed the maximum amounts recommended by the U.S. Public Health Service for drinking water (p. 19). The sulfate content of the water from many wells tapping the Goliad sand, particularly in eastern Hidalgo County and in Willacy County, exceeds the limit of 250 ppm recommended by the U.S. Public Health Service for drinking water.

The water in the Goliad sand occurs under artesian pressure. Many of the wells that tap the Goliad in central and eastern Hidalgo County are reported to have flowed when they were drilled, or were flowing at the time they were inventoried in 1933 or 1939. The maximum reported flow was 500 gpm. The maximum reported yield of a pumped well tapping the Goliad sand was 1,500 gpm.

Some of the wells tapping the Goliad in Willacy County were reported to flow a few gallons per minute in 1957; one well flowed until 1955 and another flowed until 1956.

GOLIAD SAND AND LISSIE FORMATION, UNDIFFERENTIATED

A few wells less than 500 feet deep are found on exposures of the Lissie formation in northeastern Hidalgo County outside of the limits of the Linn-Faysville or the lower Rio Grande ground-water reservoirs. The few shallow stock wells in this area tap the Goliad sand and Lissie formation, undifferentiated. The water from the wells is of poor quality and is usually reported as salty.

BEAUMONT CLAY

The Beaumont clay crops out in a large area in eastern Hidalgo County and western Willacy and Cameron Counties. It is the source of water for a few domestic and stock wells, but in general it is not an important source of ground water except possibly in the areas of the lower Rio Grande ground-water reservoir and the Mercedes-Sebastian shallow ground-water reservoir.

ALLUVIUM

A few wells in eastern Cameron County yield water from the alluvium outside the limits of the lower Rio Grande ground-water reservoir; however, the yields are small and the water generally is unsuitable for most uses.

SUMMARY OF GROUND-WATER QUALITY

CAMERON COUNTY

In western Cameron County, water from the lower Rio Grande ground-water reservoir is used extensively for irrigation. The water of best quality is obtained in the southwestern part of the county in a band averaging about 1.5 miles wide adjacent to the Rio Grande and in the zone between 100 and 300 feet depth. This water has a high-salinity hazard, a low-sodium hazard, and the boron content is less than 0.66 ppm. Southeastward along the river and to the north and east away from this area, the water in the lower Rio Grande ground-water reservoir at depths between 100 and 300 feet generally is of poorer quality. In the northern, central, and south-central parts of the county the water has a very high salinity hazard and a very high sodium hazard and contains more than 2.0 ppm boron. At most places the water below 300 feet is more mineralized than the water above that depth.

The Mercedes-Sebastian shallow ground-water reservoir, which is less than 100 feet deep and trends toward the northeast from the west-central part of the county, is also used for irrigation. Most of that water is of high-salinity hazard and medium-sodium hazard, and the boron content is less than 1.0 ppm.

Over most of the rest of the county the water is of poor quality, and at most places in the eastern part of the county water suitable for stock and domestic use generally is not available.

HIDALGO COUNTY

In southern Hidalgo County many irrigation wells withdraw water from the lower Rio Grande ground-water reservoir. The water of best quality is obtained at depths ranging from 50 to 250 feet below the land surface in a band of variable width but averaging about 2 miles wide along the Rio Grande. This water has a high-salinity hazard and a low-sodium hazard, and the boron content generally is less than 1.0 ppm.

Northward away from the river the water in the lower Rio Grande ground-water reservoir at depths between 50 and 250 feet deteriorates in quality and, in most of the area in southern Hidalgo County where water from the alluvium and the Lissie formation is used for irrigation, the water has a very high salinity hazard and a very high sodium hazard. At most places, the water below 250 feet probably is of poorer quality than the water above 250 feet.

In southeastern Hidalgo County the Mercedes-Sebastian shallow ground-water reservoir is tapped by several irrigation wells, most of which are less than 50 feet deep. Much of the water produced has a high-salinity hazard, a low-sodium hazard, and a boron content of less than 1.0 ppm.

In central Hidalgo County, water from wells tapping the Linn-Faysville ground-water reservoir (generally less than 150 feet deep) is used for irrigation. The water ranges from high-salinity and medium-sodium hazard in the western part of the area to very high salinity hazard and very high sodium hazard in the eastern part of the area. The boron content ranges from 0.8 to 3.6 ppm, generally tending to be lower in the southwestern part of the area and higher in the northeastern part.

The Goliad sand is tapped by wells scattered over most of the county and is a source of domestic, stock, and irrigation supplies. In the northwestern part of the county the water has a high-salinity hazard and in the rest of the county a very high salinity hazard. Most of the water has a very high sodium hazard. The water from the Goliad is used for drinking, but generally the sulfate, chloride, and dissolved solids contents are somewhat in excess of those recommended in the U.S. Public Health Service standards for drinking water.

STARR COUNTY

In southern and southeastern Starr County numerous irrigation wells tap the lower Rio Grande ground-water reservoir. These wells generally are less than 75 feet deep, and they are in a belt averaging less than 2 miles wide along the Rio Grande. The water has a high to very high salinity hazard and a low- to medium-sodium hazard.

In northeastern Starr County several wells ranging in depth from 665 to 962 feet tap the Oakville sandstone. The principal use of water from the Oakville is for industries processing petroleum products. In general, the chloride and dissolved solids contents of the water exceed the maximum amounts recommended in the U.S. Public Health standards for drinking water. The water has a high to very high salinity hazard and a high to very high sodium hazard.

In most of the county, water for stock and domestic use generally is available at depths less than 300 feet. Generally, big differences are found in the quality of the water from place to place. In some areas, particularly in the central and west-central parts of county, it is difficult to find water suitable for stock watering and domestic use.

WILLACY COUNTY

In southwestern Willacy County a few wells, generally less than 50 feet deep, tap the Mercedes-Sebastian shallow ground-water reservoir. The quality of the water from these shallow wells differs considerably. The water from some wells tapping the reservoir is unsuitable for drinking by infants because of the high nitrate content.

Most of the wells in Willacy County tap the Goliad sand at depths ranging from about 730 to 1,430 feet. The water from the Goliad sand has a very high salinity hazard and a very high sodium hazard, and generally is unsuitable for irrigation. The water from the Goliad sand exceeds the U.S. Public Health Service standards for drinking water in sulfate, chloride, and dissolved solids content. In general, the water from the Goliad sand in the eastern part of the county is more mineralized than that in the western part.

RECOMMENDATIONS FOR FURTHER STUDIES

All the available information on ground water in the Lower Rio Grande Valley area was assembled and reviewed in this investigation. Certain types of information, some of which are necessary to understanding the hydrology and evaluating the perennial yields of the ground-water reservoirs, were not available. Further studies in the following fields are needed to fill important gaps in the available information:

Drilling information.—Logs of wells, samples of material, and samples of water taken as wells are drilled are needed for a better understanding of the subsurface geology. At many places where there are no wells, information is needed as to whether wells were ever attempted and, if so, why they were abandoned.

Water levels.—A program of periodic measurements of water levels in selected wells tapping the lower Rio Grande ground-water reservoir is needed. In addition, the altitudes of the observation wells in Starr and Hidalgo Counties should be obtained by instrumental leveling so that the slope of the water surface can be determined. The water-level information is necessary before the perennial yield of the reservoir can be evaluated.

Pumpage.—A program for obtaining information about the amount and distribution of pumpage from the Linn-Faysville and lower Rio Grande ground-water reservoirs is needed. The perennial yields of the reservoirs cannot be evaluated until pumpage information is available.

Quality of water.—Better coverage of quality-of-water information, particularly in the lower Rio Grande ground-water reservoir in southern Hidalgo County, is needed. At present there are large areas in which no quality-of-water information is available. Periodic resampling from selected wells in all the ground-water reservoirs should be done to show possible changes in the quality of water.

Pumping tests.—Pumping tests are needed to provide a quantitative evaluation of the hydraulic characteristics of the ground-water reservoirs. Of particular importance are pumping tests in wells near the Rio Grande to determine the nature of the hydraulic connection between the lower Rio Grande ground-water reservoir and the river.

A continuing program of ground-water investigation in the Lower Rio Grande Valley area is necessary for collecting adequate basic data. This is particularly true for drilling information, water levels, and pumpage. For example, if a test hole is drilled for an irrigation well and the water obtained is not of suitable quality and the hole is abandoned, a sample of the water for chemical analysis can be obtained only at the time the test hole is drilled. Water levels can be obtained for a given time only by measuring the water levels in wells at that time. Because of the seasonal and annual variations in pumpage in the Lower Rio Grande Valley area, pumpage data should be collected frequently so that the amount and distribution of pumping may be determined.

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