GROUND-WATER RESOURCES OF REFUGIO COUNTY, TEXAS

TEXAS WATER COMMISSION
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TEXAS WATER COMMISSION

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GROUND-WATER RESOURCES OF REFUGIO COUNTY, TEXAS

By

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Prepared by the U. S. Geological Survey
in cooperation with the
Texas Water Commission
and the
Refugio County Water Control and
Improvement District No. 2

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TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd.)

TABLES

TABLE OF CONTENTS (Cont'd.)

Page

ILLUSTRATIONS

Figures

TABLE OF CONTENTS (Cont'd.)

Plates

GROUND-WATER RESOURCES OF REFUGIO COUNTY, TEXAS

ABSTRACT

Refugio County occupies an area of 771 square miles and is in the West Gulf Coastal Plain in south Texas. The principal city is Refugio, with a population of 4,944 in 1960. It is 120 miles southeast of San Antonio and 45 miles north of Corpus Christi. The county has a mild climate with an average rainfall of 33.76 inches per year. The economy is dependent upon livestock raising, petroleum production, and diversified crop growing.

The principal water-bearing formations in Refugio County are the Goliad Sand, Lissie Formation, and Beaumont Clay. These formations crop out in belts roughly parallel with the coast and dip to the southeast at a rate greater than the dip of the land surface. They consist chiefly of sand, silt, and clay. The contacts between the formations are difficult to determine in the subsurface in drillers' or electric logs. As a consequence, the water-bearing sands in the Goliad Sand and Lissie Formation, in wells that are more than about 600 feet deep, are considered as a single aquifer. Similarly, the Lissie Formation and Beaumont Clay in wells that are less than about 600 feet deep are considered as a single aquifer.

In 1961, approximately 2,800 acre-feet, or 2,500,000 gpd (gallons per day), of ground water was pumped, of which 746 acre-feet, or 665,000 gpd, was for public supply and nearly an equal amount, 655,000 gpd, was pumped for industrial use. About 1,000 acre-feet was used for domestic and livestock purposes and about 365 acre-feet was used for irrigation.

Aquifer tests showed that the coefficient of transmissibility ranged from 13,000 to 77,000 gpd per foot in the Goliad Sand and Lissie Formation, undifferentiated, and from 2,500 to 8,500 gpd per foot in the Lissie Formation and Beaumont Clay, undifferentiated.

Formerly all wells producing water from the Goliad and Lissie were flowing wells, but by 1961 most of the wells in the northern part of the county had ceased to flow.

Water in the Goliad Sand and Lissie Formation, undifferentiated, in the northwestern part of the county generally contains less than 300 ppm (parts per million) chloride and less than 1,000 ppm dissolved solids. The water becomes

more highly mineralized toward the southeast. The quality of the water in the Lissie Formation and Beaumont Clay, undifferentiated, ranges from fresh (less than 1,000 ppm dissolved solids) to moderately saline (3,000 to 10,000 ppm dissolved solids).

From available data, on the order of 10 to 20 million acre-feet of ground water is estimated to be in storage in Refugio County. The maximum rate of withdrawal of ground water containing less than 300 ppm chloride from the Goliad Sand and Lissie Formation, undifferentiated, is on the order of 42,000 acre-feet a year for an indefinite period. It seems probable, therefore, that the predicted future needs of more than 11,000 acre-feet a year for industry and public supply can be obtained safely from the Goliad Sand and Lissie Formation, undifferentiated.

GROUND-WATER RESOURCES OF REFUGIO COUNTY, TEXAS

INTRODUCTION

Purpose and Scope

Since the creation of the Refugio County Water Control and Improvement District No. 2, the officials of the district have been aware of the importance of information concerning the availability of a water supply of good chemical quality for industrial and municipal use in Refugio County. In 1960, the district estimated the future water needs for Refugio County and adjacent areas and investigated methods of supplying the needs from surface-water sources (Lockwood, Andrews, and Newnam, 1960). In 1961, the district entered into a cooperative agreement with the Texas Board of Water Engineers (changed to Texas Water Commission, January 1962) and the U. S. Geological Survey to make a study of the ground-water resources of Refugio County and adjoining areas.

The ground-water study of Refugio County was designed to fulfill the following specific objectives:

1. To describe the thickness and extent of the water-bearing units.

2. To delineate areas within the county which are most favorable for the development of ground-water supplies suitable for municipal and industrial use.

3. To estimate the quantity of ground water available.

4. To determine the vertical and lateral variations in the quantity and quality of the ground-water supplies.

5. To determine the hydraulic characteristics of the water-bearing units.

6. To estimate the yields and other characteristics of wells which might be drilled in the county.

7. To evaluate any evident problems related to ground-water development.

In order to meet these objectives, records from 452 selected wells (Table 4), 88 electric logs of wells, and 68 drillers' logs (Table 5) were collected and studied. Aquifer tests were made on 5 wells to determine the hydraulic characteristics of the water-bearing units. Water samples from 88 wells were collected and analyzed chemically in the laboratory of the U. S. Geological

Survey in Austin, Texas, and in addition, the results from 80 analyses made in 1936-37 by the Works Progress Administration were studied. The results of the analyses are given in Table 6. Fieldwork on the project was started in September 1961 and continued through March 1962.

For purposes of this report, small quantities are defined as 0 to 100 gpm (gallons per minute), moderate quantities as 100 to 1,000 gpm, and large quantities as more than 1,000 gpm. Also, fresh water contains less than 1,000 ppm (parts per million) dissolved solids, slightly saline water contains from 1,000 to 3,000 ppm dissolved solids, and moderately saline water contains 3,000 to 10,000 ppm dissolved solids.

The investigation was made under the immediate supervision of A. G. Winslow, district geologist of the U. S. Geological Survey in charge of ground-water investigations in Texas.

Location and Physical Features

Refugio County, which has an area of 771 square miles, is in the West Gulf Coastal Plain in south Texas. It is bounded on the south and southeast by San Patricio and Aransas Counties, on the west and northwest by Bee and Goliad Counties, on the north by Victoria County, and on the east by Calhoun County (Figure 1).

The topography of Refugio County is nearly flat; the land surface slopes toward the southeast at the rate of about 4 feet per mile. The altitude ranges from sea level along the shoreline of the bays to 96 feet along the Refugio-Goliad county line in the northern part of the county.

Refugio County is drained by low-gradient, sluggish streams. The San Antonio and Guadalupe Rivers and their tributaries drain the northern part of the county; the Mission River and its tributaries drain the central part; and the Aransas River and its tributaries drain the southern part. Much of the county is typical of the brush country of south Texas, being covered by mesquite, huisache, cenizo, live oak, prickly pear, and other similar vegetation.

Refugio, the county seat of Refugio County, is the largest city in the county, having a population of 4,944 in 1960. Refugio is about 45 miles north of Corpus Christi and 120 miles southeast of San Antonio. Other communities in the county are Woodsboro, Tivoli, Austwell, and Bayside.

Climate

The climate in Refugio County is subhumid and mild. The mean annual precipitation at Woodsboro during the period 1931-60 was 33.76 inches. Figure 2 shows that the precipitation was less than 20 inches in only 3 years since 1931 and more than 40 inches in 7 years. Figure 3 shows that, on the average, the wettest months are May and September and the driest are March and November.

Long-term records of evaporation and temperature are not available in Refugio County; the nearest station having such records is at Beeville, about 30 miles west of Refugio. The mean annual temperature at Beeville is 70.9°F; the

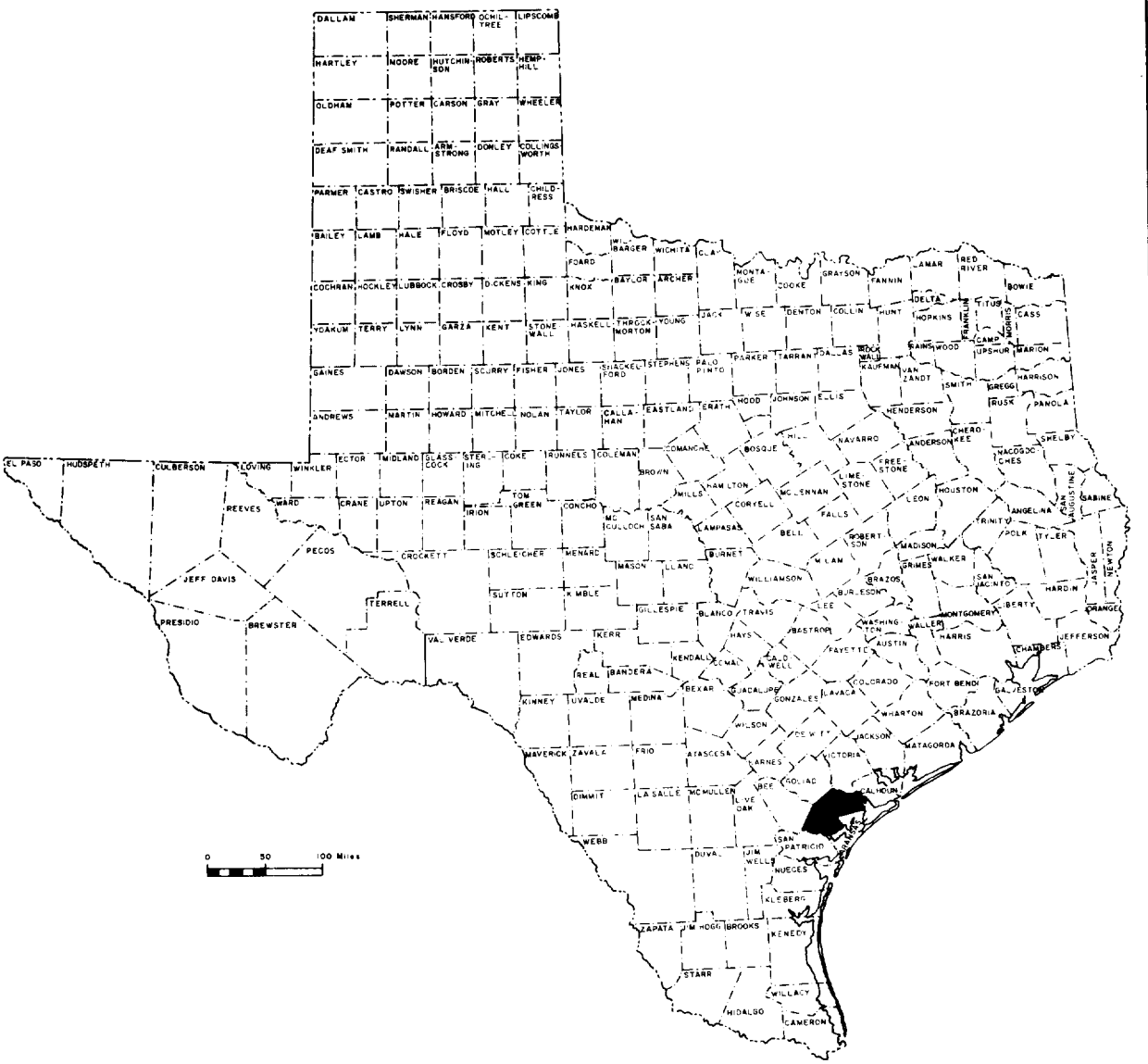

Figure 1

Index Map of Texas Showing Location of Refugio County

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127

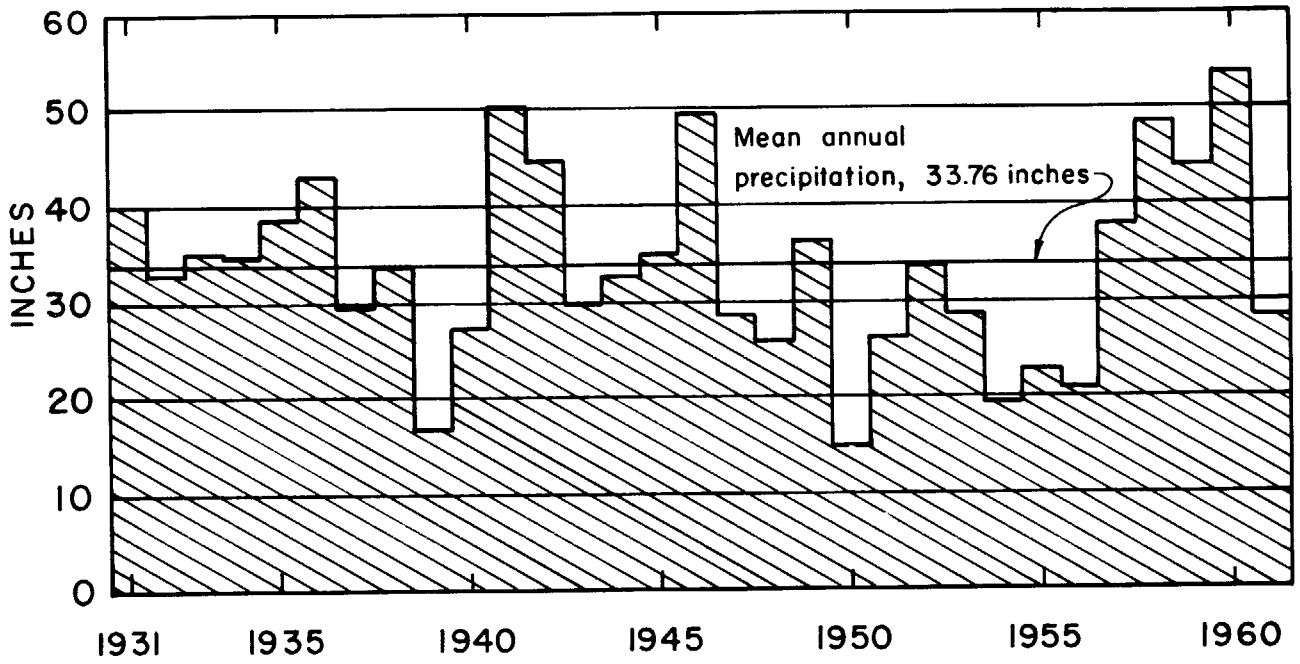
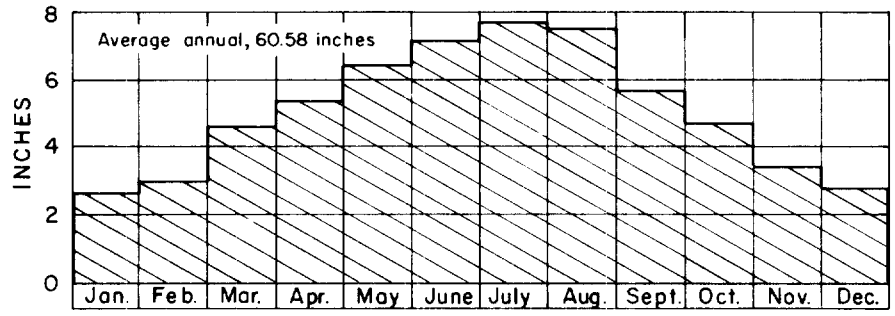


Figure 2

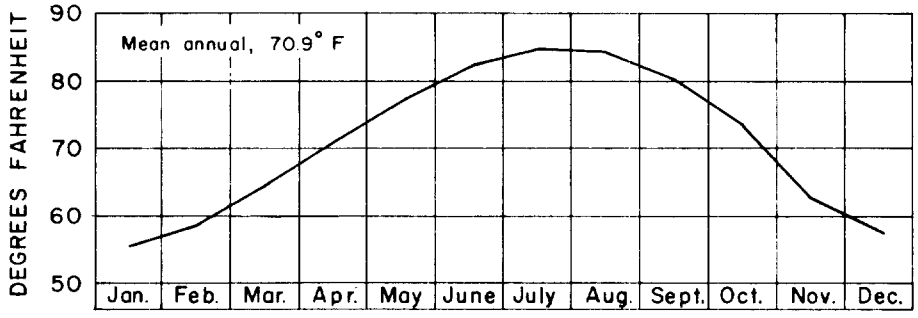
Annual Precipitation at Woodsboro, Texas

(From records of U.S. Weather Bureau)

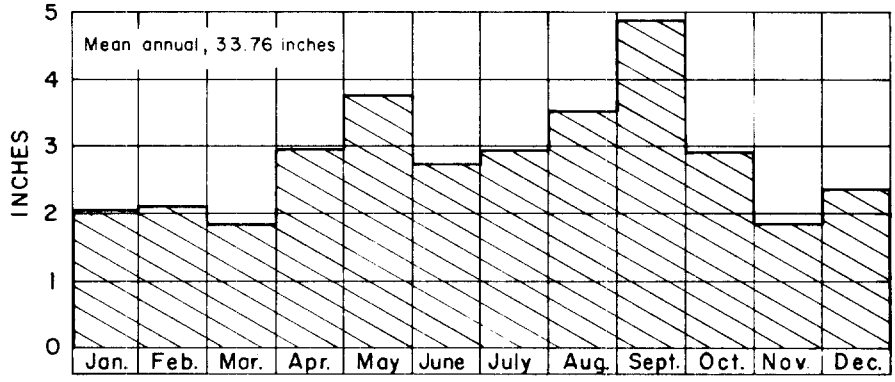
U.S. Geological Survey in cooperation with the Texas Water Commission and the Refugio County Water Control and Improvement District No. 2



Average monthly evaporation at Beeville, 1915–61



Average monthly temperature at Beeville, 1931–60



Mean monthly precipitation at Woodsboro, 1931–60

Figure 3

Monthly Evaporation and Temperature at Beeville and Monthly Precipitation at Woodsboro, Texas

(From records of U.S. Weather Bureau and Bloodgood, Patterson, and Smith, 1954)

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127

mean monthly temperature in January is 56°F and in July 84°F (Figure 3). The average monthly evaporation at Beeville ranges from 7.7 inches in July to 2.6 inches in January. The annual evaporation rate is 60.6 inches (Figure 3), or nearly twice the mean annual precipitation.

Economic Development

The economy of Refugio County is dependent chiefly upon diversified crop growing, livestock raising, and oil production; cotton, grain sorghum, and flax are the principal crops. During 1958, more than 14 million barrels of oil was produced in the county, and the total value of gas and oil production in 1958 was $65,299,548.

The county is served by several hard-surfaced roads and Federal and State highways and one railroad. U. S. Highway 77, the principal traffic artery, passes through the county in a northeasterly direction. U. S. Highway 183 enters the county from the northwest and terminates at Refugio.

Previous Investigations

Little detailed information concerning ground water in Refugio County had been obtained prior to the present study. A report by Muenster and Michal (1938) contains records of wells in Refugio County and a part of Goliad County, together with tables of well logs and water analyses. A report on the public-water supplies of south Texas (Broadhurst, Sundstrom, and Rowley, 1950) contains records of the public water-supply wells in Refugio, Woodsboro, and Austwell. In 1960-61, a reconnaissance study of the ground-water resources of the Gulf Coast region, which includes Refugio County, was made by Wood, Gabrysch, and Marvin (1963).

Detailed reports have been published on the ground-water resources of several counties adjacent to Refugio County. Dale, Moulder, and Arnow (1957) reported on the ground-water resources of Goliad County, and Marvin, Shafer, and Dale (1962) reported on the ground-water resources of Victoria and Calhoun Counties.

Detailed reports on the geology of Refugio County have not been published; however, the general geology of the area was described by Sellards, Adkins, and Plummer (1932), and many others. The geology of the area is shown in a generalized manner on the Geologic Map of Texas (Darton and others, 1937). Doering (1956), in his paper on the Quaternary deposits of the Gulf Coast, has suggested changes to the Geologic Map of Texas, particularly in the mapping of the Pleistocene units. Much of this work is pertinent to Refugio County.

Well-Numbering System

The well-numbering system used in this report is one adopted by the Texas Water Commission for use throughout the State and is based on longitude and latitude. Under this system, each 1-degree quadrangle in the State is given a number consisting of 2 digits. These are the first 2 digits appearing in the well number. Each 1-degree quadrangle is divided into 7-1/2 minute quadrangles

which are also given 2-digit numbers from 01 to 64. These are the third and fourth digits of the well number. Each 7-1/2 minute quadrangle is subdivided into 2-1/2 minute quadrangles and given a single-digit number from 1 to 9. This is the fifth digit of the well number. Finally, each well within a 2-1/2 minute quadrangle is given a 2-digit number in the order in which it is inventoried starting with 01. These are the last 2 digits of the well number. In addition to the 7-digit well number, a 2-letter prefix is used to identify the county. The prefixes for Refugio and adjacent counties are as follows:

County	Prefix
Aransas	AH
Bee	AW
Calhoun	BW
Goliad	KP
Refugio	WH
San Patricio	WW
Victoria	YT

Thus, well WH-79-46-604 is in Refugio County, in the 1-degree quadrangle number 79, in the 7-1/2 minute quadrangle 46, the 2-1/2 minute quadrangle 6, and was the fourth well (04) inventoried in that 2-1/2 minute quadrangle.

On the well-location map of this report (Plate 1), the 7-1/2 minute quadrangles are shown and numbered in the northwest corner of each quadrangle. The 3-digit number shown with the well symbol contains the number of the 2-1/2 minute quadrangle in which the well is located and the number of the well within that quadrangle. Table 1 shows the well numbers used in this report and corresponding numbers previously published.

Acknowledgments

The author is grateful to Mr. J. G. Heard, president of the Refugio County Water Control and Improvement District No. 2, for his cooperation in making the city of Refugio wells available for various tests. The farmers and ranchers of the area cooperated by supplying information on their wells and allowing access to their land. Mr. Kelly of Kelly Water Wells in Refugio and his employees and Mr. Hobbs of H. & S. Well Service in Victoria were helpful in supplying drillers' logs and completion records of many wells in the county.

Table 1.--Well numbers used in this report and corresponding numbers previously used in Refugio County by Muenster and Michal (1938)

New Number	Old Number	New Number	Old Number	New Number	Old Number	New Number	Old Number
WH-79-38-801	256	WH-79-46-503	83	WH-79-48-503	605	WH-80-25-701	517
902	251	504	70	601	601	80-33-202	528
79-39-102	225	602	286	602	603	204	523
201	219	608	21	702	611	401	552
402	229	702	102	79-53-101	413	403	551
403	230	703	94	102	414	501	546
404	248	804	90	404	415	603	535
502	236	806	91	505	416	604	544
601	242	79-47-203	269	603	419	701	550
79-40-101	210	204	270	904	125	703	548
201	208	207	272	79-54-104	103	801	547
401	560	504	282	105	114	802	545
501	558	601	280	107	106	803	577
503	559	602	278	204	109	80-34-101	532
701	561	603	277	205	110	80-41-101	576
702	562	801	303	207	101	102	573
901	567	802	306	403	115	103	594
902	566	803	308	701	126	201	575
79-45-804	410	903	281	79-55-201	307	202	578
79-46-101	40	79-48-101	274	301	309	402	600
102	46	102	606	79-56-102	310	501	593
103	65	104	563	401	311	801	598
201	55	201	565	502	312	80-42-101	586
402	68	502	610	79-63-101	161		

GEOLOGY

General Geology

The principal fresh water-bearing formations underlying Refugio County are the Goliad Sand of Pliocene age and the Lissie Formation and Beaumont Clay of Pleistocene age (Table 2). Alluvial deposits of Pleistocene and Recent age are not an important source of ground water, although they supply water for a few livestock wells. The Lissie Formation, Beaumont Clay, and the alluvium are exposed in Refugio County; the Goliad Sand underlies the younger formations and is exposed in Goliad County to the northwest (Figure 4). The formations, except for the alluvium, dip to the southeast toward the Gulf of Mexico at a greater rate than the slope of the land surface; thus, the formations generally are found at greater depths toward the coast. The formations thicken in the downdip direction also, consequently, the older beds dip more steeply than the younger ones. The dip of the formations probably ranges from about 10 to 40 feet per mile.

The sediments are nonmarine in origin and consist chiefly of sand, clay, and gravel. In general, they become finer and the sand content decreases downdip. The heterogeneous character of the sediments makes correlation of individual sand or clay beds difficult even over short distances. The deposits generally are lenticular, the lenses of clay, sand, or gravel pinching out, coalescing, or grading into each other within short distances. The variations in lithology are shown in the geologic sections (Plates 2, 3, 4, and 5). The contacts between the Goliad Sand, Lissie Formation, and Beaumont Clay are difficult to determine in the subsurface in drillers' or electric logs owing to the similarity of the sediments, and the formations have not been differentiated on the cross sections.

The major structural feature in Refugio County affecting the occurrence of ground water is the homoclinal dip of the formations to the southeast. Faults are of major importance to the occurrence of oil; however, the displacement along the faults is small at shallow depths (Honea, 1956, p. 54), and they apparently have little or no effect on the occurrence of ground water in Refugio County.

Tertiary System

Pliocene Series

Goliad Sand

The Goliad Sand, the oldest formation of importance as a source of ground water in Refugio County, lies unconformably on older rocks of Tertiary age, and is, in turn, overlain unconformably by the Lissie Formation. The Goliad crops out in Bee and Goliad Counties (Figure 4) in a northeastward-trending belt of irregular width and dips southeastward toward the Gulf of Mexico at an estimated maximum rate of about 40 feet per mile.

Table 2.--Geologic formations and their water-bearing properties, Refugio County

System	Series	Formation of unit	Approximate thickness (feet)	Lithology	Water-bearing properties
Quaternary	Recent and Pleistocene	Alluvium	0 - 50	Fine sand, silt, and clay.	Yields small quantities of slightly saline water to livestock wells.
		Unconformity			
	Pleistocene	Beaumont Clay	0 - 600	Predominantly clay interbedded with layers of medium to fine-grained sand.	Yields small to moderate quantities of fresh to slightly saline water to wells in Refugio County.
		Unconformity			
		Lissie Formation	400 - 600	Chiefly sand with lentils of gravel, interbedded with clay and silt.	Yields small to large quantities of fresh to moderately saline water to wells in Refugio County.
		Unconformity			
Tertiary	Pliocene	Goliad Sand	300 - 600	Sand or sandstone interbedded with layers of gravel and clay. Contains caliche in outcrop.	Yields moderate to large quantities of fresh to slightly saline water to wells in Refugio County.

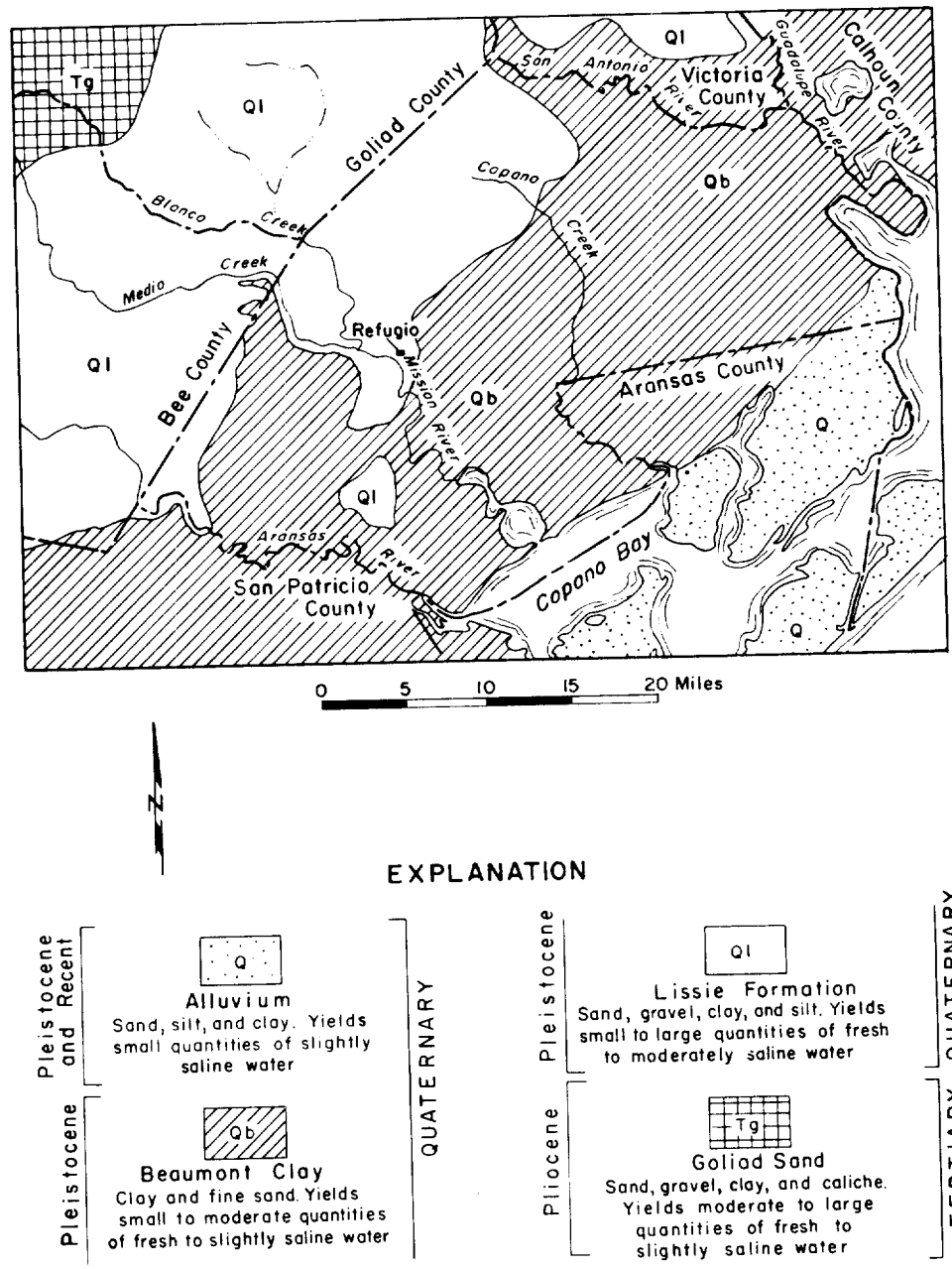

Figure 4

Geologic Map of Refugio County and Adjacent Areas

(After Darton and others, 1937)

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127

The Goliad Sand consists chiefly of sand or sandstone, which is interbedded with layers of gravel and clay. On the outcrop, the sand is fine to coarse, gray or pinkish-gray, and much of it has a salt-and-pepper appearance due to the presence of grains of black chert. In many places, especially on the outcrop, the formation is characteristically white owing to the abundance of caliche, a calcareous deposit usually formed near the surface. The thickness of the Goliad ranges from 300 to 600 feet; the top of the formation in Refugio County is more than 600 feet deep at all places.

The Goliad Sand yields moderate to large quantities of fresh to slightly saline water to wells in Refugio County.

Quaternary System

Pleistocene Series

Lissie Formation

The Lissie Formation crops out in a belt about 20 miles wide in the western and northwestern parts of Refugio County and in southeastern Goliad and Bee Counties (Figure 4). The Lissie unconformably overlies the Goliad Sand and is overlain unconformably by the Beaumont Clay. In the subsurface, it is difficult to determine accurately the contacts between these formations because of the lithologic similarities. The Lissie consists of thin- to thick-bedded sand, which contains lentils of gravel and interbedded clay and silt. The formation has a thickness ranging from about 400 to 600 feet.

The Lissie Formation in Refugio County yields small to large quantities of fresh to moderately saline water.

Beaumont Clay

The outcrop area of the Beaumont Clay occupies about the southeastern two-thirds of Refugio County (Figure 4). The Beaumont lies unconformably on the Lissie Formation and is, in turn, overlain unconformably by Pleistocene and Recent alluvial deposits and windblown sand in the eastern part of the county and in Aransas County. The Beaumont is predominantly clay interbedded with layers of medium to fine sand, the formation ranging in thickness from 0 to about 600 feet.

The Beaumont Clay yields small to moderate quantities of fresh to slightly saline water to wells in Refugio County.

Pleistocene and Recent Alluvium and Windblown Deposits

Alluvium, consisting of fine sand, silt, and clay, mantles a small area in the eastern tip of Refugio County (Figure 4). Minor occurrences of the deposits are found also in some of the stream valleys; however, these are not shown on

the geologic map. Some windblown deposits overlie the alluvium but are not differentiated from the alluvium in this report. The deposits range from 0 to about 50 feet in thickness and yield small quantities of slightly saline water to livestock wells. The alluvium is not an important source of water for public supply, industry, or irrigation in Refugio County.

GROUND WATER

Occurrence

The following is a brief description of the principles of occurrence of ground water as they apply to Refugio County. For a comprehensive treatment of the general principles, the reader is referred to Meinzer and others (1942) and Tolman (1937).

The source of all ground water in Refugio County is precipitation on the surface of Refugio and adjoining counties. Most of the precipitation is evaporated, transpired by plants, or runs off to the Gulf of Mexico. A small part, which falls on or flows across the outcrops of the water-bearing formations, percolates downward to the water table, filling the pore spaces to become ground water. The water in the outcrop is unconfined and is said to be under water-table conditions. As the water moves down the dip of the formations and passes beneath layers of less permeable material, the water becomes confined and is said to be under artesian conditions.

The water in the aquifers underlying Refugio County is in transient storage, moving slowly, generally less than 100 feet a year, from the outcrop southeastward toward the Gulf. Ground water in the county is discharged naturally through springs and seeps in the outcrop (rejected recharge), by evapotranspiration where the water table is near the surface, by vertical seepage through semiconfining beds, and by subsurface movement out of the county toward the southeast. The quantity of water discharged by wells is relatively small compared to the quantity discharged by natural means.

Although ground water in Refugio County occurs in the Goliad Sand, Lissie Formation, and Beaumont Clay, the geologic formations do not comprise individual aquifers. For the purposes of this report, wells that are screened below about 600 feet are considered as tapping the Goliad Sand and Lissie Formation, undifferentiated. Similarly, wells that obtain water from sands above about 600 feet are considered as tapping the Lissie Formation and Beaumont Clay, undifferentiated. Thus, for practical purposes, there are two principal aquifers in Refugio County, the boundary between the two being an ill-defined horizon in the Lissie Formation. The 600-foot depth to the boundary is only approximate; the actual depth may range between about 500 and 700 feet, depending on the location in the county.

The Goliad Sand and Lissie Formation, undifferentiated, underlies all of Refugio County and contains fresh to slightly saline water throughout the county. The approximate altitude of the base of the fresh to slightly saline water in the unit ranges from about 1,700 feet below sea level in the northeastern part of the county to less than 500 feet in the extreme southern part (Figure 5). The base of fresh to slightly saline water is at least 1,800 feet below sea level in the

southeastern part of Victoria County. The control used in the preparation of Figure 5 was based principally on the interpretation of electric logs of oil tests. Chemical analyses of water from wells near oil tests for which electric logs were available showed that, in general, sands having an apparent resistance of 10 ohms were saturated with water containing from 1,000 to 3,000 ppm of dissolved solids. Thus, sands having an electrical resistance of 10 or more ohms on the lateral or long normal curve were considered as containing fresh to slightly saline water.

The slope of the base of fresh to slightly saline water is very irregular as is shown in the geologic sections (Plates 2 to 5) and in Figure 5. The irregularity is due, in part, to a decrease in sand content in the downdip direction, which results in a decrease in the rate of movement of the water and an accompanying increase in mineralization. The marked rise in the base of the fresh to slightly saline water west of Refugio, as shown in Figure 5, is attributed to a decrease in the sand content. Near the eastern edge of the county, the base rises sharply (Plates 4 and 5 and Figure 5), indicating the approximate downdip extent of fresh to slightly saline water in the Goliad Sand and Lissie Formation, undifferentiated.

The approximate thickness of fresh to slightly saline water-bearing sands in the Goliad Sand and Lissie Formation, undifferentiated, in Refugio and adjacent counties is shown in Figure 6. The thickness ranges from about 600 feet in a small area in the southwest corner of the county near the intersection of Goliad, San Patricio, and Refugio Counties to less than 100 feet in the southern corner. At Refugio, the thickness is about 300 feet.

Aquifer Tests

Aquifer tests were made in five wells in Refugio County to determine the ability of the aquifers to transmit and store water. The results of the tests are given in Table 3. The data from the tests were analyzed using the Theis nonequilibrium method as modified by Cooper and Jacob (1946, p. 526-534) and the Theis recovery method (Wenzel, 1942, p. 94-97).

The ability of an aquifer to transmit water is expressed as its coefficient of transmissibility, which is defined as the amount of water in gallons per day that will pass through a vertical strip of the aquifer having a width of 1 foot and a height equal to the saturated thickness of the aquifer under a hydraulic gradient of 1 foot per foot at the prevailing aquifer temperature. The coefficient of storage of an aquifer is defined as the volume of water it releases or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface.

Aquifer tests were made in three wells (WH-79-31-901, WH-79-46-604, and WH-79-46-608, Table 3) that tap the Goliad Sand and Lissie Formation, undifferentiated. The coefficients of transmissibility ranged from 13,000 gpd (gallons per day) per foot in wells WH-79-46-604 and WH-79-46-608 to 77,000 gpd per foot in well WH-79-31-901. The coefficients of storage obtained from tests in well WH-79-46-608 averaged 0.00021, which is in the range generally attributed to artesian aquifers. The specific capacities ranged from 4.7 gpm (gallons per minute) per foot of drawdown in well WH-79-46-604, which yielded 595 gpm, to 28 gpm per foot of drawdown in well WH-79-31-901, which yielded 2,770 gpm.

Table 3.--Results of aquifer tests in Refugio County

Aquifer	Well number	Screened interval (feet)	Average discharge during test (gpm)	Coefficient of transmissibility (gpd/ft.)	Specific capacity (gpm/ft.)	Coefficient of storage	Remarks
Goliad Sand and Lissie Formation, undifferentiated	WH-79-31-901	160-946	2,770	77,000	28	--	Recovery of pumped well.
Do.	WH-79-46-604	578-875	595	13,000	4.7	--	Do.
Do.	WH-79-46-604	578-875	600	16,000	--	--	Do.
Do.	WH-79-46-608	800-875	600	13,000	--	0.00022	Drawdown in observation well.
Do.	WH-79-46-608	800-875	600	13,000	--	0.00020	Recovery in observation well.
Lissie Formation and Beaumont Clay, undifferentiated.	WH-79-54-203	180-270	290	2,500	--	--	Recovery of pumped well.
Do.	WH-79-54-803	? -331	540	8,500	12.0	--	Do.

A comparison of the specific capacities with the coefficients of transmissibility indicate that the wells probably have been developed to their full potential.

Results of aquifer tests in two wells that tap the Lissie Formation and Beaumont Clay, undifferentiated, show that the coefficients of transmissibility were low, ranging from 2,500 gpd per foot in well WH-79-54-203 to 8,500 gpd per foot in well WH-79-54-803. The specific capacity of well WH-79-54-803, which yielded 540 gpm, was 12.0 gpm per foot of drawdown; the specific capacity was not determined for well WH-79-54-203 (Table 3).

The coefficients of transmissibility and storage may be used to predict the drawdown of water levels caused by pumping. Figures 7 and 8 show the theoretical effects that a pumping well will have on the water levels at various distances from the well. The values used in plotting the curves in the illustrations were computed for three different coefficients of transmissibility values: 77,000, 25,000, and 13,000 gpd per foot and assuming the following conditions. The outcrop is a straight line of infinite length 15 miles from the pumped well, recharge is sufficient so that there is no drawdown in the outcrop, and the well has been pumped long enough for maximum drawdown to have occurred. In Figure 8 it is assumed that the aquifer is of infinite areal extent and that the well has pumped continuously for periods of 1 year or 10 years. In both figures it is assumed that the aquifer is homogeneous, has a coefficient of storage of 0.0021, and that the well has been pumped at a continuous rate of 1,000 gpm. The conditions of the assumptions are not entirely met in Refugio County; however, they are close enough so that the use of the curves as approximations probably is valid.

Ground-Water Development

Ground water in Refugio County is used principally for domestic and livestock purposes, and to a lesser extent for public supply, industry, and irrigation. During 1961, approximately 2,800 acre-feet, or 2,500,000 gpd of water was withdrawn from the ground-water reservoir.

Public Supply

The average daily pumpage for public supply in 1961 was about 665,000 gpd (746 acre-feet per year), Refugio and Woodsboro being the largest users of water in the county. Refugio, which obtains its water supply from three wells tapping the Goliad Sand and Lissie Formation, undifferentiated, used 460,000 gpd in 1961. Woodsboro pumped an average of 100,000 gpd in 1961 from three wells tapping the Lissie Formation and Beaumont Clay, undifferentiated. Other public supplies in the county include Tivoli, which used 72,000 gpd from the Goliad Sand and Lissie Formation, undifferentiated, and Austwell, which pumped an estimated 33,000 gpd from the Lissie Formation and Beaumont Clay, undifferentiated.

Early records of pumpage from the cities of Refugio and Woodsboro are not available. Broadhurst, Sundstrom, and Rowley (1950, p. 92, 93) estimated that in 1945 Refugio and Woodsboro pumped 300,000 and 60,000 gpd, respectively. Figure 9 shows the average daily pumpage of ground water by the city of Refugio for the years for which records are available. The figure shows that the

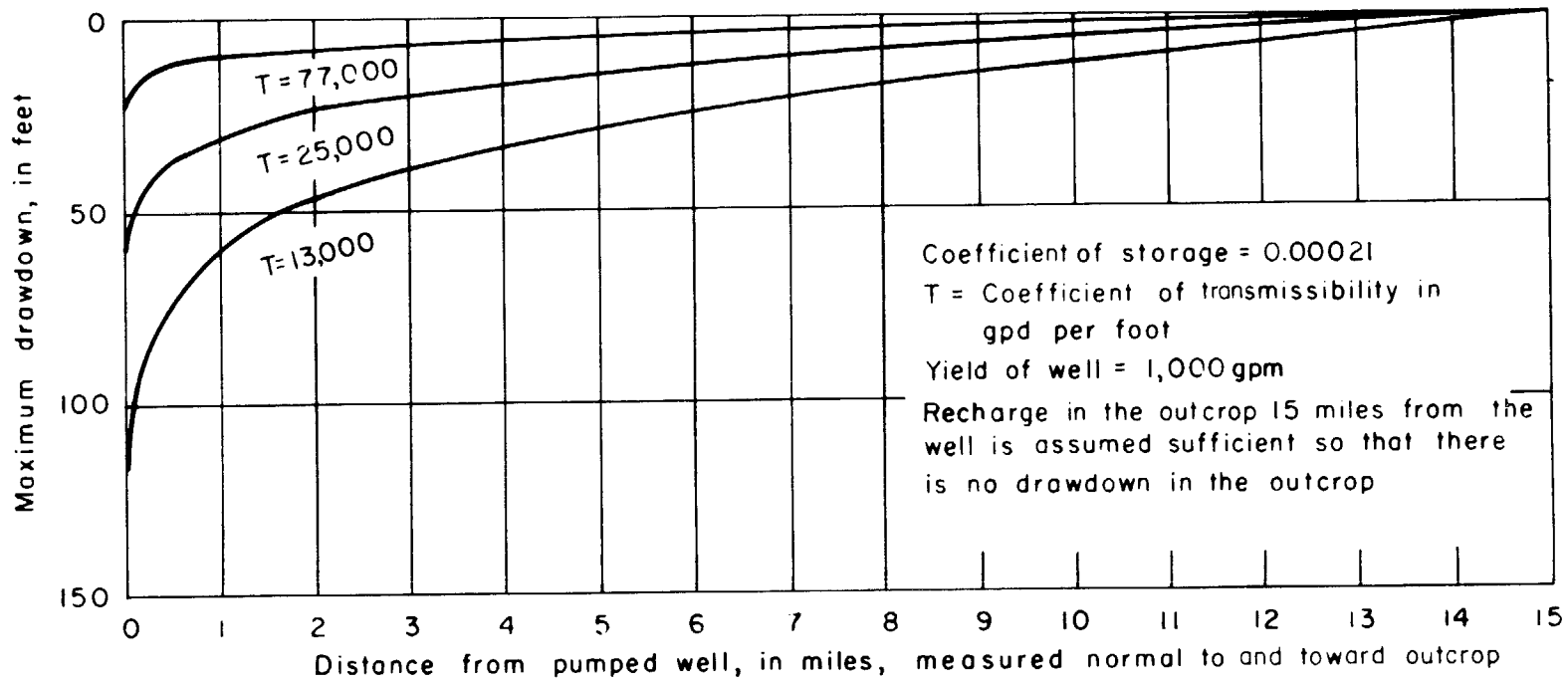

Figure 7

Theoretical Maximum Drawdown Due to Pumping

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127

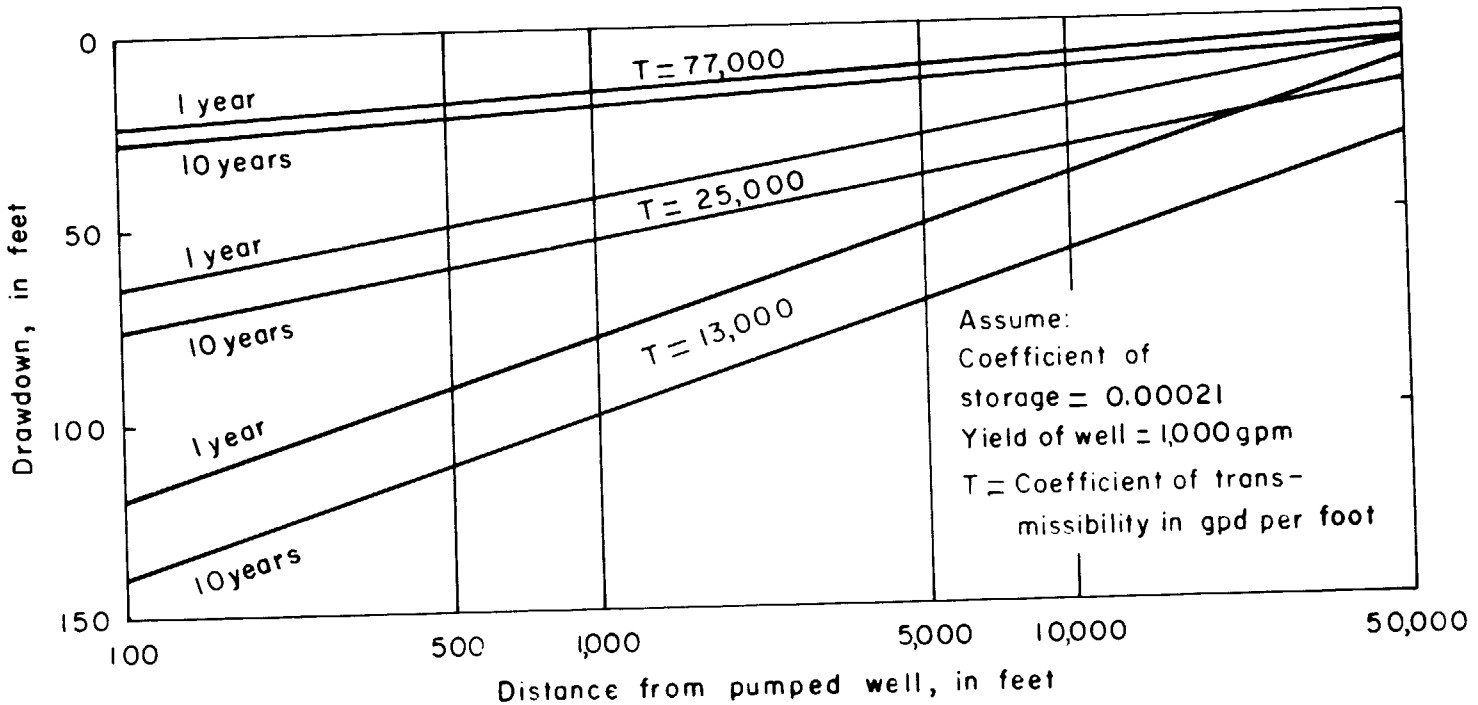

Figure 8

Theoretical Drawdown Due to Pumping in an Infinite Aquifer

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127

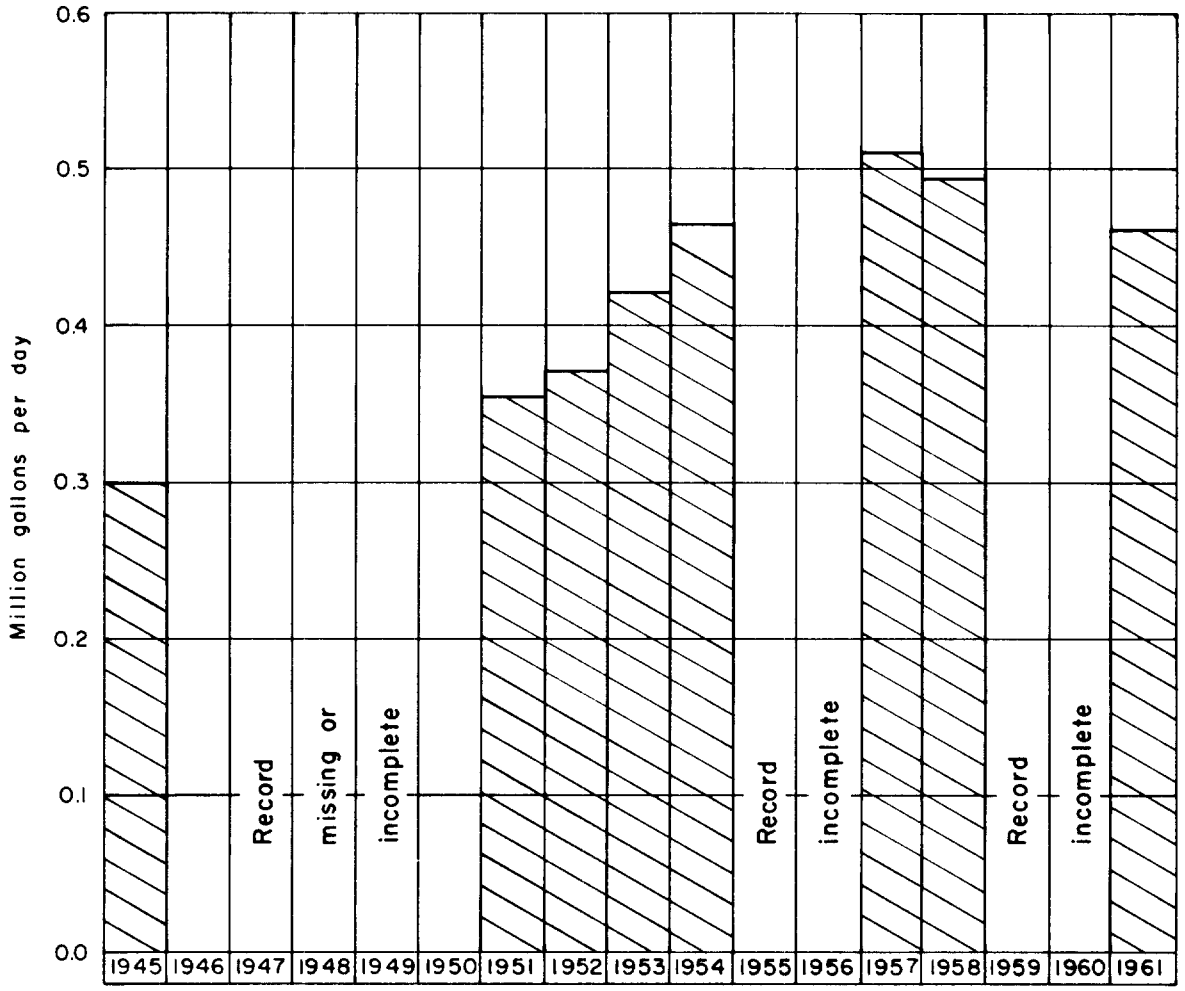

Figure 9

Average Daily Pumpage of Ground Water by City of Refugio

(From records of Texas State Department of Health and Broadhurst, Sundstrom, and Rowley, 1950, p. 92)

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127

pumpage has been somewhat greater than in 1961. In 1957, the last year of a long period of drought, the pumpage was slightly more than 500,000 gpd.

Industrial

The use of ground water for industry in Refugio County is only slightly smaller than that for public supply. In 1961, withdrawal of ground water by 12 industrial wells averaged about 655,000 gpd, or about 734 acre-feet. Most of the industrial pumpage was for cooling purposes at compressor stations and natural gas processing plants.

Irrigation

Irrigation in Refugio County has been on a small scale and for supplemental purposes only. In 1961, approximately 365 acre-feet of water (326,000 gpd) was withdrawn by four wells. Of these, well WH-79-31-901 obtained water from the Goliad Sand and Lissie Formation, undifferentiated, and wells WH-79-54-803, WH-80-41-301, and WH-80-42-104 obtained water from the Lissie Formation and Beaumont Clay, undifferentiated. The wells ranged in yield from 540 gpm to about 1,200 gpm. Four other wells, formerly used for irrigation in the county, were abandoned prior to 1961. Three of these wells, which were in the vicinity of Austwell, yielded water which was of unsatisfactory quality for irrigation. The fourth well, about 5 miles southeast of Woodsboro, was abandoned because the well became partly filled with sand. All of these abandoned wells tapped the Lissie Formation and Beaumont Clay, undifferentiated.

Domestic and Livestock

The largest single use of water in Refugio County is for domestic and livestock purposes. In 1961, approximately 1,000 acre-feet of water was withdrawn from the ground-water reservoir for domestic and livestock purposes. About half of this water was produced from uncontrolled flowing wells. The use of uncontrolled flowing wells has been a major factor in causing the overall decline of water levels in Refugio County.

Changes in Water Levels

Water levels in wells in Refugio County and adjacent areas fluctuate almost continuously, mainly in response to changes in withdrawal rates and changes in ground-water storage. However, a change in the physical condition of a well such as damage to the casing, deepening, or partial plugging also may cause a change in the water level in the well. This type of change in water level occurs because the well bore has gained or lost hydraulic connection with one or more sand zones containing water under a different head. A change in chemical quality of water also may occur in such wells because the quality of water commonly is somewhat different in each sand bed or sand zone.

Relatively rapid changes in water level in a few hours or several days are commonly due to local changes in the withdrawal rates of nearby wells and generally affect a rather small area. Substantially long-term changes in water

levels over a period of weeks, months, or years may be caused by changes in the withdrawal rates of wells or by changes in ground-water recharge. Long-term changes in water levels generally affect a large area.

Prior to extensive ground-water development in Refugio County, practically all of the wells tapping the Goliad Sand and Lissie Formation, undifferentiated, flowed above the land surface. In most of the county, the water levels have declined in recent years due to increased pumping, and as a result, many wells have stopped flowing or their flows have decreased. Except for a few wells in the river valleys, wells north and west of the line shown in Figure 10 were no longer flowing as of 1961. In this part of Refugio County, the water levels in several wells, which flowed in 1938, have declined to depths of 20 to 30 feet below the land surface. In the area between Bayside and Woodsboro, the decrease in the artesian pressure in several flowing wells ranged from 2.7 to 11.6 pounds per square inch, or the equivalent decline in water level of 6.3 to 26.8 feet during the period 1946-62. Although the declines in water levels or artesian pressures have resulted in the installation of pumping units on some wells, the declines have not been serious and the quantity of ground water in storage has not changed appreciably.

Figure 10 shows the approximate altitude of the water levels in wells tapping the Goliad Sand and Lissie Formation, undifferentiated, in 1961-62. The slope of the piezometric surface in Refugio County is fairly gentle, being steepest in the vicinity of Refugio because of the relatively heavy pumping in that area and nearly flat in the northeastern part of the county. The piezometric surface slopes generally southeastward at about 2 feet per mile.

The changes in water levels in wells tapping the Lissie Formation and Beaumont Clay, undifferentiated, have been small. During the period 1936-38 to 1959-62, the changes ranged from a decline of 3 feet to a rise of 12 feet. The water-level declines were not restricted to any particular area, but were irregularly distributed through the county.

Problems of Well Construction

The major problems of well construction in Refugio County are related to the fine grain size of much of the sand and the occurrence of saline water overlying the fresh water-bearing sands in some parts of the county. Because of the unconsolidated nature of the materials penetrated, most wells are completed with wire-wrapped screen or slotted pipe, ranging in diameter from 2 to 12 inches. However, where large yields and sand-free water are required, screens or slotted casing may be ineffective in controlling the passage of sand into the well. For example, well WH-79-55-701, which taps the Lissie Formation and Beaumont Clay, undifferentiated, was completed with 12-inch diameter slotted pipe. The well, which reportedly pumped 1,200 gpm, subsequently was abandoned probably because the slots were too wide to hold out the sand effectively. In addition to the use of a screen of proper size, the sand production may be controlled by enlarging the well bore opposite the water-bearing zones by underreaming and packing the space with gravel. Underreaming increases the area of the face of the well bore and reduces the entrance velocity of the water, thereby increasing the volume of sand-free water pumped. The gravel pack stabilizes and supports the walls of the well, preventing caving and the consequent decrease in yield. In some wells, however, the gravel may be of improper size to control the sand

production. For example, well WH-80-41-301, an irrigation well tapping the Lissie Formation and Beaumont Clay, undifferentiated, is gravel packed but still yields a large amount of sand.

Domestic and livestock wells generally are completed with about 20 feet of small-diameter slotted casing or stainless steel screen. Because the casing above the screen generally is not cemented, the Goliad Sand and Lissie Formation, undifferentiated, may be in hydraulic connection with the overlying Lissie Formation and Beaumont Clay, undifferentiated.

In some parts of the county, the water may move from the deeper aquifer into the shallower aquifer through leaks in the casing. This may be the cause for the cessation of flow in some wells and subsequent resumption of flow after repair of the casing. Large-scale development of ground water from the Goliad Sand and Lissie Formation, undifferentiated, however, may result in a reduction in head below that in the Lissie Formation and Beaumont Clay, undifferentiated. Such a condition would result in a potential reversal in the direction of flow. Therefore, in areas where saline water overlies the chief aquifer, such as between Woodsboro and Bayside, the casings should be cemented to prevent contamination by water moving either through leaks in the casing or along the casing from one aquifer to the other.

Chemical Quality of Ground Water

The mineral constituents of ground water are dissolved principally from the soil and rocks through which the water has passed; consequently, the differences in chemical character of ground water reflect in a general way the nature of the geologic formations that have been in contact with the water. Most deep ground water is free from contamination by organic matter, but the chemical content of ground water usually increases with depth. The temperature of ground water near the land surface generally approximates the mean annual air temperature of the region and increases with depth.

The major factors that determine the suitability of a water supply are the limitations associated with the contemplated use of the water. Various criteria for water-quality requirements have been developed covering most categories of water quality, including bacterial content, physical characteristics, and chemical constituents. Usually, water-quality problems of the first two categories can be alleviated economically, but the removal or neutralization of undesirable chemical constituents can be difficult and expensive. For many purposes the dissolved-solids content constitutes a major limitation on the use of the water. A general classification of water based on dissolved-solids content is as follows (Winslow and Kister, 1956, p. 5):

Description	Dissolved-solids content, in parts per million
Fresh	Less than 1,000
Slightly saline	1,000 to 3,000
Moderately saline	3,000 to 10,000
Very saline	10,000 to 35,000
Brine	More than 35,000

The United States Public Health Service has established standards of drinking water to be used on common carriers engaged in interstate commerce. The standards are designed to protect the traveling public and may be used to evaluate public-water supplies. According to the standards, chemical constituents should not be present in a water supply in excess of the listed concentrations shown in the following table, except where other more suitable supplies are not available. Some of the standards adopted by the U. S. Public Health Service (1962, p. 2152-2155) are as follows:

Substance	Concentration (ppm)
Chloride (Cl)	250
Fluoride (F)	(*)
Iron (Fe)	.3
Manganese (Mn)	.05
Nitrate (NO_3)	45
Sulfate (SO_4)	250
Total dissolved solids	500

*When fluoride is present naturally in drinking water, the concentration should not average more than the appropriate upper limit shown in the following table:

Annual average of maximum daily air temperatures (°F)	Recommended control limits of fluoride concentrations (ppm)		
	Lower	Optimum	Upper
50.0 - 53.7	0.9	1.2	1.7
53.8 - 58.3	.8	1.1	1.5
58.4 - 63.8	.8	1.0	1.3
63.9 - 70.6	.7	.9	1.2
70.7 - 79.2	.7	.8	1.0
79.3 - 90.5	.6	.7	.8

Water having concentrations of chemical constituents in excess of the recommended limits may be objectionable for various reasons. In areas where the nitrate content of water is in excess of 45 ppm, a potential danger exists. Concentrations of nitrate in excess of 45 ppm in water used for infant feeding have been related to the incidence of infant cyanosis (methemoglobinemia or "blue baby" disease), a reduction of the oxygen content in the blood constituting a

form of asphyxia (Maxcy, 1950, p. 271). High concentrations of nitrate may be an indication of pollution from organic matter, commonly sewage. Excessive concentrations of iron and manganese in water cause reddish-brown or dark-gray precipitates that stain clothes and plumbing fixtures. Water having a chloride content exceeding 250 ppm may have a salty taste, and sulfate in water in excess of 250 ppm may produce a laxative effect. Excessive concentrations of fluoride in water may cause teeth to become mottled; however, fluoride in concentrations of about 1 ppm may reduce the incidence of tooth decay (Dean, Arnold, and Elvove, 1942, p. 1155-1179).

Calcium and magnesium are the principal constituents in water that cause hardness. Excessive hardness causes increased consumption of soap and induces the formation of scale in hot water heaters and water pipes. The commonly accepted standards and classifications of water hardness are shown in the following table:

Hardness range (ppm)	Classification
60 or less	Soft
61 - 120	Moderately hard
121 - 180	Hard
More than 180	Very hard

The quality of water for industry is not necessarily referred to potability. A water suitable for industrial use may or may not be acceptable for human consumption. Ground water used for industry may be classified into three principal categories--cooling water, process water, and boiler water.

Cooling water usually is selected on the basis of its temperature and source of supply, although its chemical quality is significant also. Any characteristic which may affect adversely the heat exchange surfaces is undesirable. Substances such as calcium, magnesium, aluminum, iron, and silica may cause the formation of scale. Corrosiveness, another objectionable feature, is that property which makes the water aggressive to metal surfaces. Calcium and magnesium chloride, sodium chloride in the presence of magnesium, acids, and the gases oxygen and carbon dioxide are among the substances that make water corrosive.

The quality of water for the production of steam must meet rigid requirements. Here the problems of corrosion and encrustation are intensified. Some treatment of boiler water may be needed and it may be better to appraise the water source from the viewpoint of suitability for treatment rather than for direct use of raw water. The presence of silica in boiler water is undesirable because it forms a hard scale or encrustation, the scale-forming tendency increasing with pressure in the boiler.

Process water, water incorporated into or coming in contact with manufactured products, is subject to a wide range of quality requirements. Usually rigidly controlled, these requirements commonly involve physical, chemical, and biological factors. In general, water used in the manufacture of textiles must

be low in dissolved-solids content and free of staining effects of iron and manganese. The paper industry, especially where high-grade paper is made, requires water in which all heavy metals are either absent or in small concentrations. Water free of iron, manganese, and organic substances normally is required by many beverage industries. Unlike cooling and boiler water, much of the process water is consumed or undergoes a change in quality in the manufacturing process and generally is not available for reuse.

In appraising the quality of water for irrigation, both the concentration and the composition of dissolved constituents should be considered. The chemical characteristics that appear to be most important in evaluating the quality of water for irrigation in most areas, including Refugio County, are (1) relative proportion of sodium to other cations (an index of the sodium hazard), (2) total concentration of soluble salts (an index of the salinity hazard), (3) amount of residual sodium carbonate (RSC), and (4) concentration of boron.

A system of classification commonly used for judging the quality of a water for irrigation was proposed in 1954 by the U. S. Salinity Laboratory Staff (1954, p. 69-82). The classification is based primarily on the salinity hazard as measured by the electrical conductivity of the water and the sodium hazard as measured by the sodium-adsorption ratio (SAR). Figure 11 is a diagram which can be used for evaluating water to be used for irrigation by plotting the SAR and specific conductance.

The relative importance of the dissolved constituents of water to be used for irrigation is dependent upon the degree to which the constituents accumulate in the soil. Kelley (1951, p. 95-99) cited areas having an average annual precipitation of about 18 inches in which salts did not accumulate in the irrigated soil. Wilcox (1955, p. 15) stated that the system of classification of irrigation water proposed by the Salinity Laboratory Staff "...is not directly applicable to the supplemental waters used in areas of relatively high rainfall." Thus, in Refugio County, where the average annual precipitation is 33.8 inches, the system of classification probably is not fully applicable. Wilcox (1955, p. 16) indicated that water generally may be used safely for supplemental irrigation if its conductivity is less than 2,250 micromhos per centimeter at 25°C and its SAR is less than 14. Each individual situation should be appraised when consideration is being given to irrigating with water of which the specific conductance and SAR exceed these limits, or where soil or drainage conditions are unfavorable, or when the crop to be grown is especially sensitive to the hazards of sodium and salinity.

When the content of carbonate and bicarbonate, in epm (equivalents per million), exceeds that of calcium plus magnesium, residual sodium carbonate (RSC) will be present if the calcium and magnesium in the irrigation water are precipitated as carbonates. Thus, the formation of RSC will accompany the increase in percent sodium. The RSC will cause the water to be alkaline and the organic material of the soil to tend to dissolve. The soil may become a grayish black and the land areas affected are referred to as "black alkali." Wilcox, Blair, and Bower (1954, p. 265) report from results of determinations made on irrigated noncalcareous soil, "...it has been concluded that waters containing more than 2.5 me/l (milliequivalents per litre) of 'residual Na_2CO_3' are not suitable for irrigation, that those containing between 1.25 and 2.5 me/l are marginal, and that those containing less than 1.25 me/l are probably safe. These conclusions

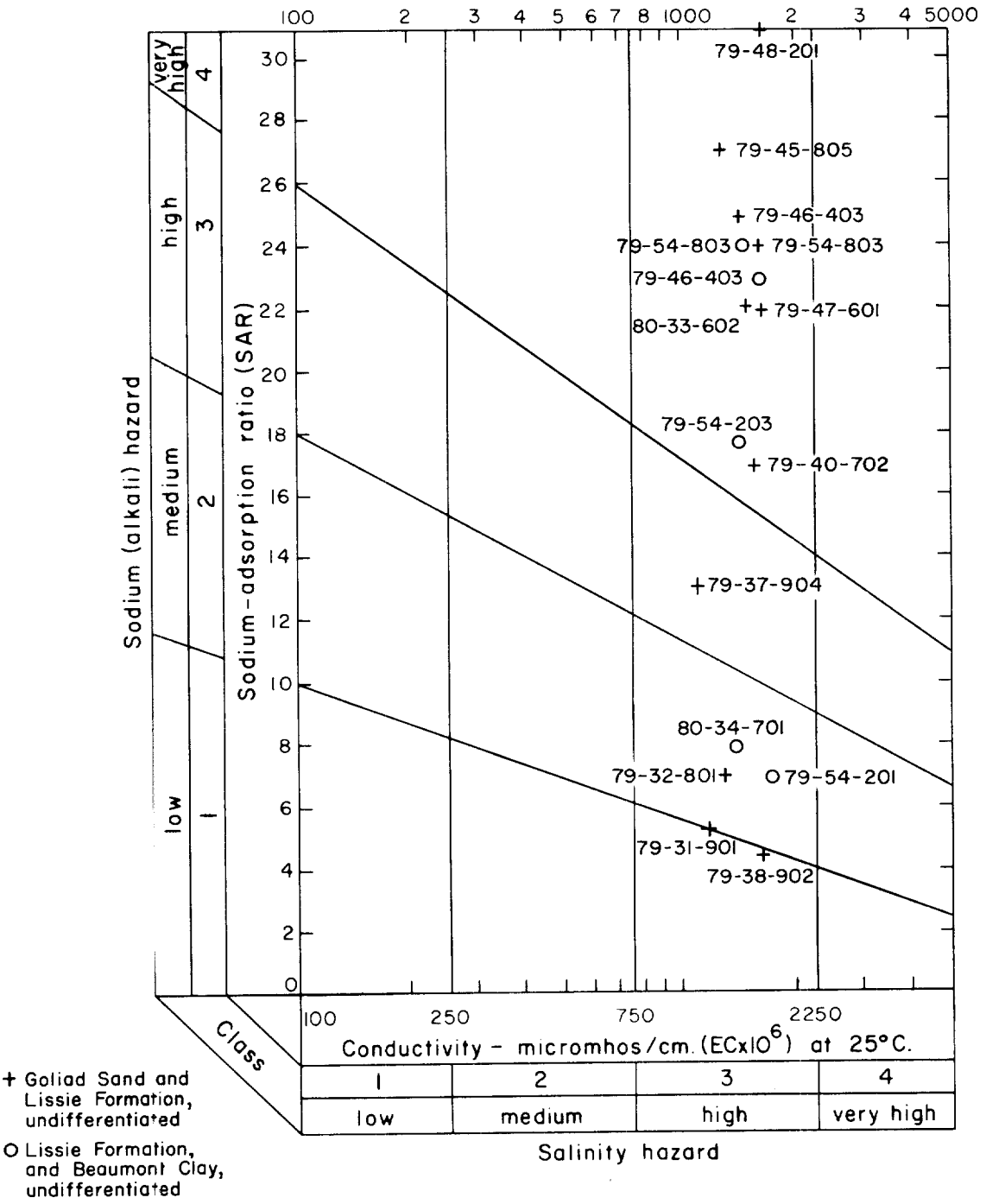

Figure 11

Diagram for the Classification of Irrigation Waters

(After United States Salinity Laboratory Staff, 1954, p. 80)

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127

are, of course, tentative, and subject to change as more data are obtained. Furthermore, degree of leaching will modify permissible limit to some extent."

An excessive concentration of boron also will make water unsuitable for irrigation. Wilcox (1955, p. 11) has indicated that a boron concentration of as much as 1.0 ppm is permissible for irrigating sensitive crops; a concentration of as much as 3.0 ppm is permissible for tolerant crops.

Chemical analyses of water from 155 wells in Refugio County and adjacent areas are given in Table 6. Also, the chloride and dissolved-solids content of water from wells tapping the Goliad Sand and Lissie Formation, undifferentiated, and the Lissie Formation and Beaumont Clay, undifferentiated, are shown in Figures 12 and 13.

Goliad Sand and Lissie Formation, Undifferentiated

The water in the Goliad Sand and Lissie Formation, undifferentiated, in Refugio County generally ranges from fresh to slightly saline, although in a small area about 7 miles south of Woodsboro the water is moderately saline (Figure 12). In nearly all the samples analyzed (Table 6), the dissolved-solids content exceeded the limits recommended by the U. S. Public Health Service. Furthermore, the chloride content of most samples exceeded 250 ppm except in a northeastward-trending belt less than 4 miles wide in the western part of the county. In general, the water is soft to moderately hard and low in sulfate and fluoride.

Figure 12 shows that, in general, the water increases in mineralization southeastward. It shows also that in the part of the county northwest of a line that trends northeastward through Refugio, the water contains less than 1,000 ppm dissolved solids and less than 300 ppm of chloride. Southeast of this line, the chloride content increases rapidly and the water may be unsatisfactory for public supply.

According to the diagram for the classification of water for irrigation (Figure 11), the water in the Goliad Sand and Lissie Formation, undifferentiated, is high in salinity hazard and ranges from low to very high in sodium hazard, indicating that the water may not be suitable for continuous irrigation, although under certain circumstances it probably can be used as a supplemental supply. The residual sodium carbonate (RSC) in 33 samples (Table 6) ranged from 0.9 to 9.6 and averaged 5.6 me/l. The boron content of 3 samples ranged from 2.3 ppm in well WH-80-33-602 to 3.5 ppm in well WH-79-46-604, indicating that boron may be a problem for the irrigation of most crops in Refugio County and adjacent areas.

Lissie Formation and Beaumont Clay, Undifferentiated

The quality of the water in the Lissie Formation and Beaumont Clay, undifferentiated, ranges from fresh to slightly saline except in a small area about 8 miles southwest of Woodsboro, where the water is moderately saline, and in an area between Woodsboro and Bayside, where the water from wells less than 150 feet deep may be moderately or very saline (Muenster and Michal, 1938, p. 33-41). In general, the dissolved-solids and chloride content exceeds the U. S. Public

Health standards, and the water is hard to very hard, although several widely scattered wells yield soft water. Hydrogen sulfide has been reported in some wells in a narrow northwestward-trending belt about 3 miles southwest of Refugio. Although hydrogen sulfide is objectionable, it may be removed by aeration.

Figure 13 shows that water containing less than 250 ppm chloride and less than 1,000 ppm dissolved solids may be obtained from a large area northeast of Refugio. However, no clear pattern of distribution of either chloride or dissolved-solids content is evident. The unpredictable quality of the water may be explained by the high degree of lenticularity of the sands in the Lissie Formation and Beaumont Clay, undifferentiated, as compared with the sands in the Goliad Sand and Lissie Formation, undifferentiated.

Analyses of water from 5 wells in the Lissie Formation and Beaumont Clay, undifferentiated, show that the water is high in salinity hazard and medium to very high in sodium hazard (Figure 11) and has a residual sodium carbonate ranging from 3.0 to 5.6. The boron content of 4 samples ranged from 0.9 ppm in well WH-79-54-203 to 1.8 ppm in well WH-79-46-403.

FUTURE DEVELOPMENT

The future development of ground water in Refugio County is dependent upon many hydrologic factors, the most important of which are the rates of recharge to the aquifers, the amount of water in storage, and the ability of the aquifers to transmit water. The rate of recharge to the aquifers in Refugio County is important only in a determination of the maximum rate of withdrawal beyond which water will be appreciably removed from storage. An accurate determination of the recharge rate generally requires a rather long period of hydrologic observations and was beyond the scope of the present investigation. However, based on estimates of future water requirements in the Refugio County area, it is probable that the rate of recharge is sufficient to supply these needs.

Another important factor in determining the amount of water available for development from an aquifer is the quantity of water in storage. It is estimated that on the order of 10 to 20 million acre-feet of water is in storage in the aquifers in Refugio County. However, these figures are not significant in themselves because much of the water is not available to wells because of the economics of pumping lifts and because much of the water will not drain freely from the sands.

The primary factor in a determination of the availability of ground water in Refugio County is the ability of the aquifer to transmit water to wells. In computing the maximum rate of withdrawal for various areas in the county, the following assumptions were made in addition to the assumptions inherent in the formulas used to determine the hydraulic properties of the aquifers: (1) Water is being discharged by a line of wells parallel with the strike of the aquifers; (2) the distance from the line of wells to the outcrop is 15 miles; (3) the maximum permissible drawdown at the line of discharge is 400 feet; (4) the coefficients of transmissibility used are the average for each area; (5) there is no drawdown in the outcrop; (6) there is no effect of withdrawals from adjoining areas; (7) each well in the line of discharge pumps continuously at a rate of 1,000 gpm; and (8) the hydraulic gradient from the outcrop to the line of discharge is uniform.

The delineation of areas favorable for the development of ground water in Refugio County is based principally on two factors--the saturated sand thickness and the quality of the water. The areas most favorable for future development are those that contain water having less than 300 ppm chloride content (Figure 12) and a total saturated sand thickness of 400 feet or more (Figure 6).

On the basis of these factors, a map (Figure 14) was prepared showing the areas which are most favorable for ground-water development from the Goliad Sand and Lissie Formation, undifferentiated. Such a map was not prepared for the Lissie Formation and Beaumont Clay, undifferentiated, because of the lenticularity of the sands and the extreme variability of the quality of water in that aquifer.

Figure 14 shows two areas northeast of Refugio as the most favorable for large-scale development. On the basis of the above-mentioned assumptions of discharge and a coefficient of transmissibility of 77,000 gpd per foot, approximately 18,000 acre-feet of water per year could be pumped in this area continuously for an indefinite period of time.

Figure 14 also shows an area along the Bee-Refugio county line west of Refugio as probably being favorable for large-scale development. The coefficient of transmissibility of the aquifer in this area was not determined; however, it has been estimated to be about 25,000 gpd per foot on the basis of a proportionately greater sand thickness than that at Refugio, where the coefficient of transmissibility averaged 13,000 gpd per foot. On this basis, the area probably is capable of yielding about 13,000 acre-feet of water per year indefinitely. Adjoining this area on the south is a narrow belt which probably could produce similar quantities of water; however, the water has a chloride content ranging from 300 to 400 ppm.

Figure 14 shows an area including the northern part of the city of Refugio that probably is favorable for moderate future development. Assuming an average transmissibility of 13,000 gpd per foot for this area, about 11,000 acre-feet of water per year could be pumped on an indefinite basis.

Figure 14 also shows other areas where moderate to large quantities of water could be developed, but the chloride content of the water ranges between 300 and 400 ppm and in localized areas it may even exceed 400 ppm.

The area shown as being unfavorable for ground-water development occupies a belt of irregular width along the southern and southeastern edges of the county. The water in this area has a chloride content in excess of 400 ppm and the sand thickness is considerably less than that in the areas that are considered to be favorable for development.

In summary, about 42,000 acre-feet of water containing less than 300 ppm of chloride probably could be pumped each year indefinitely from the Goliad Sand and Lissie Formation, undifferentiated, in the areas indicated. These estimates probably are conservative for several reasons. The computations are based strictly on the ability of the aquifer to transmit water into the areas and no allowance is made for the water which would be removed from storage during the period of pumping. The estimates also may be conservative because allowance was not made for water moving into the areas from adjacent areas or from the overlying Lissie Formation and Beaumont Clay, undifferentiated. In addition,

considerable quantities of water might be obtained from the Lissie Formation and Beaumont Clay, undifferentiated. Because of the extreme variability of the quality of water and the transmissibility of this aquifer, no attempt was made to estimate the potential development; however, throughout much of Refugio County, especially in the eastern part of the county, small yields are possible from the aquifer, and locally the water is of very good chemical quality. The areas where the aquifer is 300 or more feet thick, as between Woodsboro and Bayside and near Austwell, yields of 500 gpm and possibly more may be obtained from the Lissie Formation and Beaumont Clay, undifferentiated. However, in some of these areas the water may be too highly mineralized for most purposes.

Predictions of the future water needs for public supply and industrial purposes in an area including Refugio County were made in an engineering report prepared for the Refugio County Water Control and Improvement District No. 2 (Lockwood, Andrews, and Newnam, 1960, p. 38). The predictions covering the 50-year period, 1960-2010, show that the water requirements are expected to increase from approximately 1,800 acre-feet in 1960 to more than 11,000 acre-feet per year in 2010 (Figure 15) in an area which approximately covers Refugio County. Thus, it is probable that the Goliad Sand and Lissie Formation, undifferentiated, is capable of supplying considerably more than the predicted 2010 requirements for public supply and industrial use in the Refugio County area. It should be pointed out that the estimates of future water requirements do not include irrigation requirements. A large irrigation development using ground water in Refugio County or in southeastern Bee and Goliad Counties could have a serious effect on the availability of water for public supply and industrial use in Refugio County.

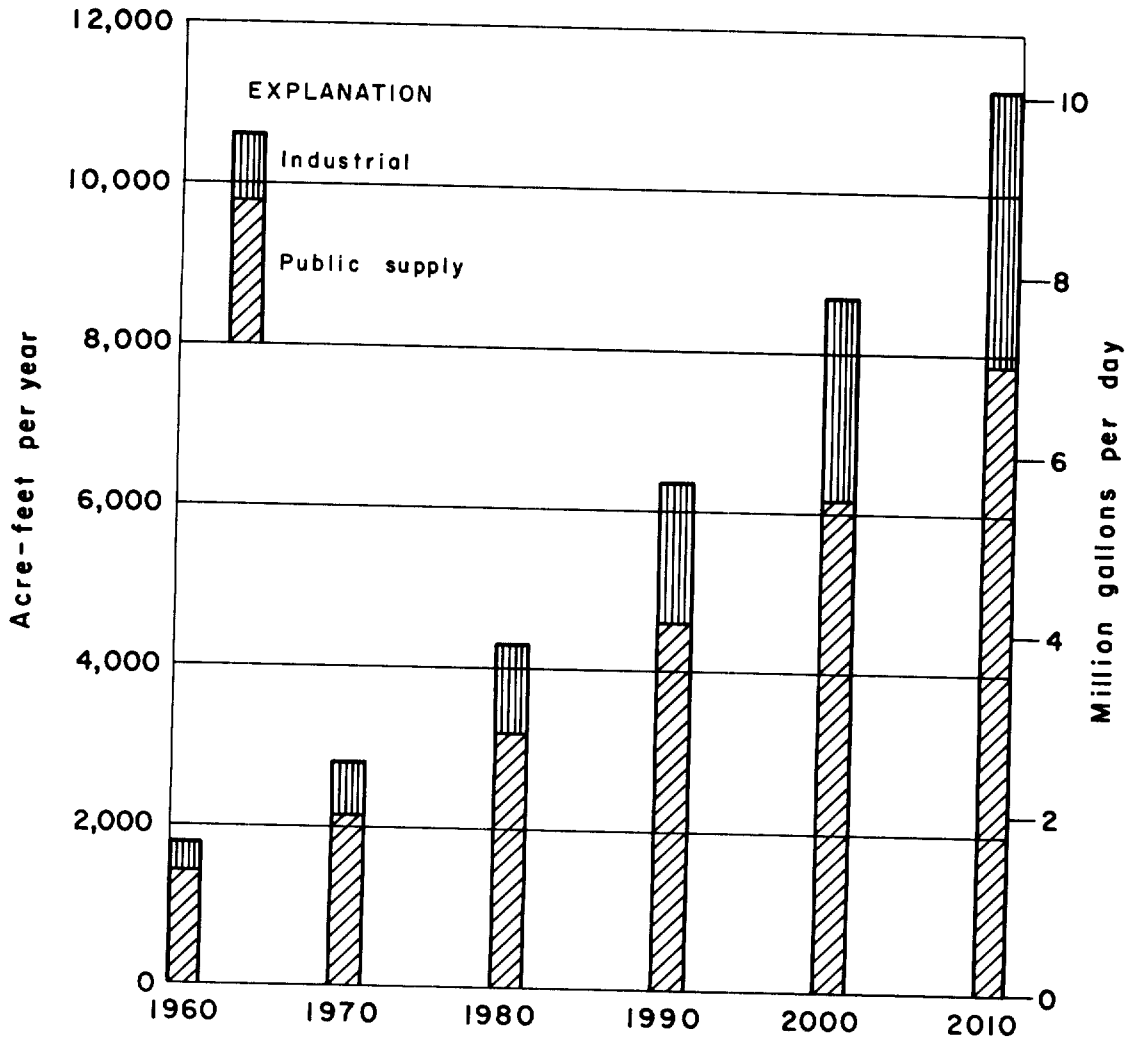

Figure 15

Estimated Future Water Requirements for Approximate Refugio County Area

(Data from Lockwood, Andrews, and Newnam, 1960, p. 38 and fig. 1)

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127

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* Name of Agency changed to Texas Water Commission January 30, 1962.

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-31-901					
Owner: J. F. Welder Estate. Driller: Leonard W. Mickelson.					
Soil and clay----------	23	23	Shale, hard----------	27	516
Clay and sand layers---	29	52	Sand----------	12	528
Clay----------	24	76	Shale, hard----------	21	549
Sand----------	30	106	Shale, sticky----------	31	580
Clay, hard----------	23	129	Sand----------	15	595
Sand and shale layers---	58	187	Shale----------	17	612
Lime----------	20	207	Sand----------	60	672
Sand and shale---------	61	268	Lime and shale----------	49	721
Lime----------	24	292	Sand----------	24	745
Sand and shale---------	33	325	Shale, sandy----------	20	765
Lime and shale---------	5	330	Shale, sticky----------	41	806
Sand and shale---------	14	344	Sand----------	21	827
Lime----------	21	365	Shale----------	5	832
Sand, rocky----------	15	380	Sand----------	112	944
Lime, gumbo and shale--	97	477	Shale, hard sticky------	40	984
Sand and shale---------	12	489	Sand and shale----------	28	1,012
Well WH-79-32-801					
Owner: O'Connor Bros. Driller: Kelley Well Service.					
Sand----------	6	6	Sand and caliche streaks----------	11	56
Clay----------	8	14	Clay----------	29	85
Sand----------	16	30	Sand----------	5	90
Clay----------	15	45	Caliche and clay--------	30	120

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-32-801--Continued					
Sand	6	126	Sand, hard streaks	23	300
Clay and caliche	5	131	Caliche and sand	27	327
Sand	17	148	Sand, soft	9	336
Sand, hard streaks	10	158	Shale	52	388
Caliche, sand streaks	7	165	Sand	20	408
Shale	32	197	Shale	20	428
Sand, hard streaks	15	212	Shale and hard lime	12	440
Shale	36	248	Red bed	25	465
Sand, hard	12	260	Shale	55	520
Shale	17	277	Sand	40	560
Well WH-79-32-804					
Owner: O'Connor Bros. Driller: Kelley Well Service.					
Surface	10	10	Sand	10	290
Sand	45	55	Shale	25	315
Shale	5	60	Sand	25	340
Sand	20	80	Shale	12	352
Shale	20	100	Sand	10	362
Sand	15	115	Shale	23	385
Shale	25	140	Sand	17	402
Sand	28	168	Shale	51	453
Shale	112	280	Sand	8	461

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-32-804--Continued					
Shale	101	562	Sand	12	632
Sand	12	574	Shale	43	675
Shale	46	620	Sand	29	704
			Shale	12	716

Well WH-79-37-903 Partial Log

Owner: Jimmie Jacks. Driller: Kelley Well Service.

Surface	63	63	Shale, broken	105	193
Sand	25	88	Sand	15	208

Well WH-79-37-904

Owner: Jimmie Jacks. Driller: Kelley Well Service.

Surface	12	12	Sand	12	372
Sand	10	22	Shale	63	435
Sand and caliche	13	35	Shale, red	22	457
Shale	188	223	Shale, sandy	56	513
Sand	10	233	Shale	31	544
Caliche	37	270	Sand	10	554
Sand	44	314	Shale	8	562
Shale	8	322	Sand	52	614
Sand	22	344	Shale	7	621
Shale	16	360	Sand	35	656

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Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-37-904--Continued					
Shale----------	2	658	Shale, sandy----------	7	700
Sand----------	35	693	Sand----------	30	730

Well WH-79-38-503

Owner: Mrs. Cyrus Fox. Driller: Kelley Well Service.

Surface----------	20	20	Caliche and sand--------	60	110
Caliche----------	20	40	Sand----------	10	120
Sand----------	10	50	Shale----------	128	248
			Sand----------	24	272

Well WH-79-39-801

Owner: Humble Oil and Refining Co. Driller: Layne-Texas Company.

Surface----------	4	4	Clay----------	13	159
Clay----------	14	18	Sand, broken and clay---	23	182
Sand----------	17	35	Sand----------	11	193
Clay----------	5	40	Clay----------	35	228
Sand----------	16	56	Sand and clay streaks---	17	245
Sand, broken and clay--	21	77	Clay----------	51	296
Clay----------	20	97	Clay, sandy and sand streaks----------	12	308
Sand----------	5	102	Sand----------	6	314
Clay----------	39	141	Clay----------	20	334
Sand----------	5	146	Sand----------	7	341

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)
Well WH-79-39-801--Continued		
Clay	34	375
Sand	8	383
Clay	47	430
Clay, sandy and sand streaks	10	440
Sand	14	454
Clay	8	462
Sand	2	464
Clay	12	476
Sand, clay, and sand streaks	10	486
Clay	35	521
Sand, broken and clay	8	529
Sand (cut clean)	20	549
Sand, broken and clay	41	590
Sand, clay, and layers of clay	15	605
Sand	8	613
Clay	4	617
Sand, broken and clay	5	622
Clay	23	645
Sand, clay, and sand streaks	26	671
Clay with a few boulders	44	715
Sand	14	729
Clay	5	734
Sand, clay breaks	7	741
Clay, sand breaks	8	749
Sand (cut clean)	26	775
Clay, sand streaks	3	778
Sand, few clay breaks	51	829
Clay	17	846
Sand and layers of clay	62	908
Sand and clay	12	920
Sand and fine sand	18	938
Clay	16	954
Clay, sandy and sand streaks	37	991
Clay	3	994
Sand, clay streaks and fine sand	23	1,017
Clay	12	1,029
Clay, sandy	9	1,038
Sand, few clay streaks and fine sand	42	1,080
Clay	6	1,086

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)

Well WH-79-39-802

Owner: Humble Oil and Refining Company. Driller: Layne-Texas Company.

Surface soil----------	4	4	Clay with a few sand streaks----------	44	690
Clay----------	14	18	Clay----------	29	719
Sand, broken and clay--	65	83	Sand----------	12	731
Sand----------	19	102	Clay----------	5	736
Sand, broken and clay--	78	180	Sand and clay streaks---	6	742
Sand----------	18	198	Clay, sandy----------	6	748
Sand, broken and clay--	31	229	Sand (cut clean)--------	29	777
Sand----------	16	245	Clay and sand streaks---	2	779
Clay----------	52	297	Sand with few clay streaks----------	51	830
Sand, broken and clay--	22	319	Clay----------	18	848
Clay----------	13	332	Sand and clay layers----	57	905
Sand----------	10	342	Clay, sandy----------	17	922
Clay----------	30	372	Sand----------	18	940
Sand----------	8	380	Clay----------	15	955
Clay----------	51	431	Clay, sandy with sand streaks----------	39	994
Clay, sandy----------	9	440	Sand, clay streaks------	25	1,019
Sand----------	15	455	Clay----------	13	1,032
Clay----------	68	523	Sand, few clay layers----------	49	1,081
Sand----------	22	545	Clay----------	11	1,092
Sand, broken and clay--	70	615			
Clay----------	31	646			

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)

Well WH-79-39-901 Partial Log

Owner: C. L. Heard. Driller: Carl Vickers.

Gravel, clay, and caliche	211	211	Shale, sand streaks	32	786
Clay, yellow	93	304	Sand, firm	17	803
Shale	128	432	Shale	3	806
Sand	9	441	Sand	40	846
Shale	48	489	Shale	46	892
Sand	6	495	Sand	40	932
Shale	95	590	Shale	21	953
Sand	43	633	Sand	42	995
Shale	5	638	Shale	16	1,011
Sand	21	659	Sand	55	1,066
No record	95	754	Shale	1	1,067

Well WH-79-45-902

Owner: F. B. Rooke and Sons. Driller: Harsdorf Well Drillers.

Sand, shale	80	80	Sand, black with streaks	38	230
Sand	10	90	Sand	20	250
Shale, yellow	15	105	Sand, layers not more than 6 feet thick	185	435
Sand	23	128	Sand	33	468
Shale, with sand streaks	52	180	Shale	7	475
Sand	12	192	Sand	38	513

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-45-902--Continued					
Shale, white----------	47	560	Sand----------	7	725
Sand----------	24	584	Shale----------	40	765
Shale----------	57	641	Sand----------	7	772
Sand----------	26	667	Shale----------	40	812
Shale, sticky----------	35	702	Sand with hard streaks--	8	820
Shale----------	16	718	Sand----------	26	846

Well WH-79-45-904

Owner: F. B. Rooke and Sons. Driller: W. E. Eads.

Surface----------	2	2	Sand----------	20	527
Sand----------	74	76	Shale----------	67	594
Clay----------	6	82	Sand, good----------	16	610
Sand with caliche------	43	125	Shale----------	40	650
Clay, white----------	57	182	Sand, good----------	18	668
Sand (good water sand)-	36	218	Shale----------	30	698
Clay, white----------	48	266	Sand----------	18	716
Sand----------	6	272	Shale----------	38	754
Clay, white----------	58	330	Sand----------	16	770
Sand----------	82	412	Shale----------	10	780
Shale----------	6	418	Sand----------	12	792
Sand----------	42	460	Shale----------	42	834
Shale----------	47	507	Sand----------	29	863

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-45-904--Continued					
Shale	13	876	Shale	28	938
Sand	6	882	Sand	14	952
Shale	14	896	Shale	8	960
Sand	14	910	Sand	28	988

Well WH-79-46-104

Owner: Clay Birmingham. Driller: Kelley Well Service.

Surface	10	10	Shale	15	60
Sand	15	25	Sand	5	65
Caliche	10	35	Shale	93	158
Sand	10	45	Sand	22	180

Well WH-79-46-401

Owner: B. Kelley and F B. Rooke and Sons. Driller: Kelley Well Service.

Surface	15	15	Shale	8	213
Sand	5	20	Sand	20	233
Caliche and shale	35	55	Shale	12	245
Sand	10	65	Sand	17	262
Shale	75	140	Shale	26	288
Sand	20	160	Sand	17	305
Shale	22	182	Shale	17	322
Sand	23	205	Sand	23	345
			Shale	5	350

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-46-403					
Owner: J. B. Kelley. Driller: Kelley Well Service.					
Sand, streaks of caliche	22	22	Sand	12	107
Caliche	8	30	Shale	178	285
Shale	10	40	Sand, fine	20	305
Sand (good)	13	53	Rock	4	309
Shale	7	60	Shale, sandy with streaks of sand	78	387
Sand, streaks of shale and caliche	25	85	Sand, streaks of shale	17	404
Shale	10	95	Sand	32	436
Well WH-79-46-408					
Owner: Jimmie Jacks. Driller: Kelley Well Service.					
Clay, sandy	20	20	Shale, sandy	30	280
Sand with streaks of caliche	50	70	Sand	15	295
Shale with streaks of sand	25	95	Shale, sandy	50	345
Sand	15	110	Shale	23	368
Shale with streaks of sand	45	155	Sand	10	378
Sand with streaks of sh shale	30	185	Shale	42	420
Shale	35	220	Sand	15	435
Sand with streaks of shale	30	250	Shale	25	460
			Sand with streaks of shale	35	495
			Sand	28	523

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Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-46-408--Continued					
Shale	25	548	Sand	15	930
Sand	74	622	Shale	6	936
Shale, sandy	33	655	Sand	12	948
Sand	18	673	Shale	26	974
Shale	57	730	Sand with streaks of shale	16	990
Sand	17	747	Sand	30	1,020
Shale	133	880	Shale	6	1,026
Sand	15	895	Shale with streaks of hard sand	92	1,118
Shale	20	915	Sand	39	1,157
Well WH-79-46-409					
Owner: Jimmie Jacks. Driller: Kelley Well Service.					
Clay	10	10	Shale with streaks of sand	40	362
Sand	30	40	Shale	68	430
Shale	52	92	Sand	15	445
Sand	33	125	Shale	11	456
Shale	57	182	Sand	22	478
Sand	26	208	Shale	19	497
Shale	114	322	Sand	15	512
			Shale	23	535
			Sand	38	573

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)

Well WH-79-46-501

Owner: United Gas Pipe Line Company. Driller: Layne-Texas Company.

Topsoil----------	2	2	Rock----------	1	321
Clay and caliche, sandy----------	40	42	Sand and shale layers---	25	346
Sand----------	43	85	Shale----------	41	387
Sand, caliche and hard streaks----------	17	102	Rock----------	2	389
Caliche (hard)---------	72	174	Shale and rock layers---	23	412
Rock, hard----------	4	178	Shale, sandy and sand---	12	424
Shale, hard and rock layers----------	9	187	Shale----------	41	465
Shale, sandy----------	33	220	Sand and shale, sandy---	17	482
Shale, hard green------	23	243	Shale and rock layers---	23	505
Shale and sandy shale--	41	284	Sand and sandy shale----	30	535
Shale, sandy and sand streaks----------	25	309	Sand and shale breaks---	37	572
Shale and hard layers--	3	312	Shale, sandy----------	10	582
Rock (hard)----------	2	314	Sand----------	17	599
Sand and shale---------	6	320	Shale----------	6	605
			Rock----------	1	606
			Shale----------	5	611

Well WH-79-46-502

Owner: United Gas Pipe Line Company. Driller: Layne-Texas Company.

Topsoil and clay-------	19	19	Sand with rock streaks--	21	66
Sand----------	26	45	Sand and clay streaks---	23	89

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-46-502--Continued					
Clay, sandy----------	23	112	Shale, hard streaks-----	9	290
Sand with clay and sand streaks----------	51	163	Rock----------	2	292
Shale, sandy and shale-	33	196	Shale and rock streaks--	3	295
Shale and rock layers--	4	200	Rock----------	5	300
Sand and shale streaks-	13	213	Sand and rock streaks---	20	320
Shale, sandy----------	6	219	Sand----------	21	341
Rock, hard----------	18	237	Shale----------	23	364
Shale, hard green and rock layers----------	6	243	Shale, sandy----------	38	402
Shale----------	4	247	Sand----------	18	420
Rock----------	1	248	Shale----------	35	455
Shale----------	15	263	Sand and hard streaks---	22	477
Rock----------	3	266	Shale, hard sandy-------	41	518
Shale, sandy and sand streaks----------	15	281	Sand streaks and shale--	25	543
			Sand----------	23	566
			Shale----------	20	586
Well WH-79-46-601					
Owner: City of Refugio. Driller: Layne-Texas Company.					
Surface soil----------	3	3	Sand, white----------	10	60
Clay, white----------	5	8	Clay----------	20	80
Sand----------	7	15	Sand, white----------	35	115
Clay----------	35	50	Shale----------	45	160

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

Well WH-79-406-601--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Shale, hard sandy------	40	200	Rock-------------------	1	386
Shale------------------	60	260	Sand and rock layers----	19	405
Sand-------------------	5	265	Shale-------------------	13	418
Rock, sand------------	15	280	Sand (cut good and clean)----------	27	445
Shale, sandy and rock--	35	315	Shale-------------------	5	450
Sand-------------------	12	327	Sand (cut good and clean)----------	20	470
Rock-------------------	1	328	Sand and boulders-------	15	485
Sand-------------------	17	345	Sand and shale, streaks-	15	500
Shale and rock---------	35	380	Sand (cut good)---------	15	515
Sand-------------------	5	385	Sand, coarse and shale--	10	525

Well WH-79-46-604

Owner: City of Refugio. Driller: Layne-Texas Company.

Surface soil----------	2	2	Shale-------------------	20	485
Clay-------------------	58	60	Sand--------------------	25	510
Shale and sand streaks-	328	388	Shale-------------------	32	542
Sand-------------------	17	405	Sand--------------------	36	578
Shale------------------	11	416	Shale-------------------	9	587
Sand-------------------	25	441	Sand--------------------	28	615
Shale------------------	13	454	Shale-------------------	12	627
Sand-------------------	11	465	Shale and boulders------	84	711

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Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-46-604--Continued					
Sand (good)----------	19	730	Sand and shale streaks--	28	840
Gumbo and boulders-----	66	796	Gumbo----------	12	852
Sand----------	16	812	Sand----------	23	875
			Gumbo----------	10	885
Well WH-79-46-607					
Owner: City of Refugio. Driller: Layne-Texas Company.					
Surface soil----------	2	2	Shale----------	13	370
Clay----------	22	24	Rock----------	1	371
Sand----------	32	56	Sand----------	16	387
Clay----------	23	79	Shale----------	12	399
Sand----------	29	108	Sand, broken----------	39	438
Clay and sand breaks---	65	173	Shale----------	68	506
Sand----------	18	191	Sand and shale----------	10	516
Clay, tough----------	23	214	Sand----------	43	559
Rock----------	1	215	Shale----------	16	575
Sand----------	23	238	Sand----------	16	591
Shale----------	7	245	Shale, sandy----------	117	708
Sand----------	12	257	Sand, broken----------	23	731
Shale----------	46	303	Shale----------	50	781
Sand----------	17	320	Sand----------	49	830
Shale, sandy----------	37	357	Rock----------	3	833

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-46-607--Continued					
Shale----------	36	869	Sand----------	30	1,089
Shale and hard layers--	30	899	Rock----------	2	1,091
Shale, sandy----------	22	921	Sand----------	27	1,118
Shale and hard layers--	54	975	Rock----------	3	1,121
Sand----------	41	1,016	Shale, sandy and hard layers----------	22	1,143
Shale----------	12	1,028	Shale----------	40	1,183
Shale, sandy----------	12	1,040	Sand, broken----------	47	1,230
Sand, broken----------	18	1,058	Shale, hard----------	21	1,251
Rock----------	1	1,059			
Well WH-79-46-608					
Owner: City of Refugio. Driller: Layne-Texas Company.					
Clay----------	58	58	Shale----------	33	320
Sand----------	8	66	Sand----------	12	332
Shale----------	129	195	Shale----------	57	389
Sand----------	12	207	Sand----------	16	405
Shale----------	38	245	Shale----------	11	416
Sand----------	8	253	Sand----------	25	441
Rock----------	1	254	Shale----------	19	460
Sand----------	18	272	Sand----------	8	468
Shale----------	8	280	Shale----------	20	488
Sand----------	7	287	Sand----------	22	510

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Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-46-608--Continued					
Shale	34	544	Rock	2	734
Sand, hard	35	579	Shale, sticky	61	795
Shale	9	588	Sand, good	24	819
Sand	83	671	Shale	10	829
Shale and boulders	28	699	Sand, good	10	839
Sand	10	709	Rock	2	841
Rock	1	710	Shale	16	857
Sand	7	717	Sand, good	20	877
Rock	3	720	Shale	16	893
Sand	12	732	Rock and sand	5	898
			Shale	22	920
Well WH-79-46-703					
Owner: F. B. Rooke and Sons. Driller: E. T. Ellwood.					
Clay	20	20	Clay, white	22	185
Sand	10	30	Sand, coarse	5	190
Gravel	10	40	Shale, brown	50	240
Sand and boulders	45	85	Sand	23	263
Clay, white	35	120	Clay, white	19	282
Sand	6	126	Limerock	3	285
Clay, white	24	150	Clay	2	287
Sand	13	163	Gravel	6	293

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-46-703--Continued					
Clay, mud	9	302	Clay, mixed	33	475
Sand	8	310	Shale, red	30	505
Clay	12	322	Clay, mixed	60	565
Sand and boulder	15	337	Sand	11	576
Clay, mud	17	354	Clay, white	9	585
Sand, coarse	2	356	Sand	6	591
Clay	16	372	Clay	6	597
Sand	5	377	Sand	25	622
Clay	1	378	Clay	6	628
Sand	30	408	Sand	5	633
Clay, red	26	434	Clay	10	643
Sand	8	442	Sand	39	682
Well WH-79-47-101					
Owner: Lawrence Wood. Driller: Kelley Well Service.					
Caliche	30	30	Shale and sand streaks	51	160
Shale	33	63	Shale	178	338
Sand	12	75	Sand	5	343
Shale	27	102	Shale	25	368
Sand	6	108	Shale and sand streaks	10	378
Rock	1	109	Shale	142	520
			Sand	31	551

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-47-201					
Owner: Lawrence Wood. Driller: Kelley Well Service.					
Clay	78	78	Sand	13	553
Sand with streaks of caliche	22	100	Shale	5	558
Shale	40	140	Sand	4	562
Sand	15	155	Shale	33	595
Shale	145	300	Sand	48	643
Shale and sand streaks	15	315	Shale	147	790
Shale	37	352	Sand and shale streaks	25	815
Sand	10	362	Shale	65	880
Shale	103	465	Sand and thin shale streaks	44	924
Sand	12	477	Sand	78	1,002
Shale	43	520	Shale	28	1,030
Sand and shale streaks	15	535	Sand	20	1,050
Shale	5	540	Shale	44	1,094
			Sand	56	1,150
Well WH-79-47-202					
Owner: Lawrence Wood. Driller: Kelley Well Service.					
Clay and caliche	40	40	Shale, sticky	10	90
Sand	20	60	Sand	5	95
Shale, sandy	20	80	Shale, sticky	30	125

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-47-202--Continued					
Sand	20	145	Sand and shale	35	650
Sand and shale	45	190	Sand	15	665
Shale, sandy	30	220	Shale, hard	50	715
Gumbo, sticky	20	240	Sand	10	725
Shale, sticky	85	325	Red bed	50	775
Sand	10	335	Shale, sticky	15	790
Shale	20	355	Sand	20	810
Sand	25	380	Shale, hard	50	860
Shale, sandy	20	400	Sand, hard	30	890
Shale, hard	35	435	Shale	35	925
Sand	10	445	Shale, sticky	40	965
Shale, sticky	45	490	Sand, broken	50	1,015
Sand	5	495	Sand, hard and shale	20	1,035
Shale, sandy	55	550	Sand	20	1,055
Sand, good	65	615	Shale, sandy	25	1,080
			Sand	58	1,138

Well WH-79-47-210 Partial Log

Owner: Lawrence Wood. Driller: Kelley Well Service.

Oldhole	1,150	1,150	Sand	28	1,255
Sand and shale streaks	55	1,205	Shale	10	1,265
Shale	22	1,227	Sand	25	1,290
			Shale	45	1,335

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

Well WH-79-47-301

Owner: United Gas Pipe Line Company. Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil, black	3	3	Shale, gray	12	585
Clay, white and yellow-	15	18	Shale, sandy gray	12	597
Sand, red	6	24	Shale, brown and gray	22	619
Clay, yellow	25	49	Sand, coarse gray	12	631
Sand, red	4	53	Shale, tough blue	105	736
Clay, yellow	10	63	Shale, pink and gray	11	747
Sand, fine, yellow	9	72	Shale, pink and white	23	770
Clay, yellow and gray--	22	94	Sand, coarse gray and shale breaks	65	835
Sand, coarse, white	14	108	Shale, pink and white	11	846
Clay, crumbly gray and yellow	167	275	Sand, gray and shale	13	859
Clay, yellow and white-	37	312	Shale, pink and white	22	881
Sand, coarse gray and shale breaks	9	321	Shale, blue and sand layers	29	910
Shale, yellow and white	45	366	Shale, pink and white	25	935
Shale, sandy	24	390	Sand, gray and shale breaks	15	950
Shale, white and gray--	80	470	Shale, blue and pink	17	967
Shale, gray and brown--	28	498	Sand, gray and few shale breaks	39	1,006
Shale, gray	64	562	Shale, white and blue	15	1,021
Shale, sandy gray	11	573			

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)

Well WH-79-47-701

Owner: Humble Oil and Refining Company. Driller: Carl Vickers.

Surface soil----------	4	4	Shale----------	35	100
Shale----------	11	15	Sand----------	40	140
Sand----------	7	22	Shale----------	293	433
Shale----------	20	42	Sand----------	16	449
Sand----------	23	65	Shale----------	148	597
			Sand----------	48	645

Well WH-79-47-702

Owner: L. W. O'Connor Estate. Driller: Kelley Well Service.

Surface----------	15	15	Caliche----------	5	90
Caliche----------	60	75	Sand----------	8	98
Sand----------	10	85	Shale----------	86	184
			Sand----------	16	200

Well WH-79-47-801

Owner: Tom O'Connor Estate. Driller: Kelley Well Service.

Clay----------	25	25	Sand----------	35	155
Sand----------	15	40	Shale----------	5	160
Shale----------	40	80	Sand----------	30	190
Sand----------	30	110	Shale----------	15	205
Caliche streaks--------	10	120	Sand----------	15	220

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-47-801--Continued					
Shale	50	270	Shale	18	940
Shale, sandy	20	290	Sand	13	953
Sand	35	325	Shale	19	972
Shale	117	442	Sand	58	1,030
Sand	54	496	Shale	10	1,040
Shale	73	569	Sand	12	1,052
Sand	7	576	Shale	4	1,056
Shale	32	608	Sand	5	1,061
Shale, sandy	42	650	Shale	16	1,077
Sand	35	685	Sand	24	1,101
Shale	50	735	Shale	9	1,110
Sand	25	760	Sand	24	1,134
Shale	77	837	Shale	3	1,137
Sand	28	865	Sand	14	1,151
Shale	40	905	Shale	2	1,153
Sand	17	922	Sand	19	1,172

Well WH-79-48-103

Owner: Tom O'Connor Estate. Driller: Kelley Well Service.

Surface	20	20	Sand	15	180
Sand	30	50	Shale	20	200
Shale	115	165	Sand	40	240

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-48-103--Continued					
Shale	20	260	Shale	35	824
Sand	15	275	Sand	11	835
Shale	335	610	Shale	13	848
Sand	80	690	Sand	17	865
Shale	15	705	Shale	52	917
Sand	26	731	Sand	44	961
Shale	22	753	Shale	3	964
Sand	36	789	Sand	48	1,012
Well WH-79-53-301					
Owner: F. B. Rooke and Sons. Driller: Kelley Well Service.					
Clay and caliche	54	54	Sand with lime streaks	15	315
Sand	16	70	Sand	15	330
Clay	10	80	Shale	78	408
Sand	15	95	Sand	22	430
Sand, shale and caliche	42	137	Shale	10	440
			Sand	42	482
Sand, with streaks of caliche	48	185	Shale	170	652
Shale	22	207	Sand	25	677
Sand	13	220	Shale	17	694
Shale	80	300	Sand with streaks of shale	91	785

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-53-301--Continued					
Shale	65	850	Shale	15	1,090
Sand	10	860	Sand, hard streaks	20	1,110
Shale	30	890	Shale	45	1,155
Sand with streaks of shale	35	925	Sand	12	1,167
Shale	60	985	Shale	45	1,212
Sand (test 6 gpm)	25	1,010	Sand	28	1,240
Shale	50	1,060	Shale	25	1,265
Sand, hard streaks	15	1,075	Sand	30	1,295
			Shale	20	1,315
			Sand, salt water	39	1,354

Well WH-79-53-601

Owner: Hewit and Dougherty. Driller: Kelley Well Service.

Clay	20	20	Shale and sand streaks	68	293
Sand and caliche	16	36	Sand	52	345
Shale	28	64	Shale	15	360
Sand and clay	26	90	Sand and shale streaks	24	384
Sand	36	126	Shale	54	438
Shale	69	195	Sand	17	455
Sand	30	225	Sand and shale	5	460
			Sand	20	480

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-53-602					
Owner: F. B. Rooke and Sons. Driller: W. E. Eads.					
Surface	2	2	Sand	25	178
Clay, brown	56	58	Shale, blue	68	246
Sand	92	150	Sand	12	258
Shale, blue	3	153	Shale	6	264
			Sand	6	270
Well WH-79-53-904					
Owner: F. B. Rooke and Sons. Driller: E. T. Ellwood.					
Soil	2	2	Clay and sand mixed	20	330
Clay	33	35	Gumbo, blue	25	355
Sand, brown	13	48	Sand	30	385
Clay, joint	27	75	Gumbo	25	410
Sand	16	91	Gravel	5	415
Sand and clay	69	160	Gumbo	25	440
Clay, brown	10	170	Sand	20	460
Rock	1	171	Shale, red and brown	80	540
Sand and rock strips	26	197	Clay and boulders	25	565
Mud, blue	55	252	Rock, with sand strips	51	616
Sand, coarse	10	262	Shale, brown and blue	17	633
Clay, blue	36	298	Broken formation	17	650
Sand, blue	12	310	Shale, blue and brown	44	694

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-53-904--Continued					
Sand	58	752	Clay, soft	16	856
Clay	88	840	Sand and clay strips	19	875
			Sand	14	889

Well WH-79-54-105

Owner: F. B. Rooke and Sons. Driller: E. T. Ellwood.

Soil	6	6	Shale, soft	18	204
Clay, joint	9	15	Gumbo	32	236
Sand	7	22	Mud	8	244
Clay, joint	5	27	Shale, mixed	6	250
Clay, tough	12	39	Sand	10	260
Sand	8	47	Shale, tough	18	278
Shale, mixed	25	72	Sand, broken	57	335
Sand and rock	44	116	Gumbo	13	348
Shale	1	117	Sand	7	355
Sand	9	126	Gumbo	23	378
Shale	4	130	Shale, soft	4	382
Rock and sand	9	139	Sand	5	387
Gumbo	16	155	Gumbo	3	390
Shale, soft and boulders	12	167	Sand, broken	30	420
Gumbo	19	186	Clay, tough	30	450
			Sand	5	455

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-54-105--Continued					
Gumbo, brown----------	40	495	Rock----------	2	632
Shale, soft----------	5	500	Sand----------	1	633
Sand and strips of clay----------	45	545	Mud and sand----------	7	640
Sand, broken- ---------	61	606	Gumbo----------	18	658
Gumbo----------	24	630	Mud and strips of sand--	8	666
			Gumbo----------	24	690
			Sand, good----------	13	703

Well WH-79-54-106

Owner: F. B. Rooke and Sons. Driller: Harsdorff Well Drillers.

Shale----------	70	70	Sand----------	25	575
Sand----------	125	195	Shale----------	63	638
Shale----------	45	240	Sand----------	17	655
Sand----------	20	260	Shale----------	68	723
No record----------	170	430	Sand, broken----------	17	740
Sand----------	40	470	Sand----------	25	765
Shale----------	8	478	Shale----------	45	810
Sand----------	32	510	Sand, hard and shale-----	10	820
Shale----------	40	550	Sand----------	26	846

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

Well WH-79-54-107

Owner: F. B. Rooke and Sons. Driller: E. T. Ellwood.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil	2	2	Sand and rocks	10	413
Clay, yellow	13	15	Clay	12	425
Sand	7	22	Sand	9	434
Clay, brown	38	60	Clay	11	445
Sand, fine	12	72	Sand and boulders	10	455
Clay	3	75	Clay, red and white	40	495
Limerock	5	80	Rock	9	504
Sand and limerock	35	115	Clay	6	510
Clay, red and white	15	130	Sand	10	520
Sand, strips of clay	38	168	Clay	2	522
Rock	1	169	Rock	5	527
Sand	3	172	Clay, red and blue	11	538
Clay, white	20	192	Sand	12	550
Sand, fine and rocks	5	197	Clay	2	552
Clay, red	42	239	Sand	10	562
Rock	1	240	Rock	2	564
Sand, good	27	267	Sand	17	581
Clay and strips of sand	58	325	Clay	7	588
Sand, coarse	17	342	Rock	2	590
Clay, red	61	403	Rock and sand	10	600

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

Well WH-79-54-107--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay	5	605	Sand and boulders	19	762
Sand	21	626	Shale, hard	8	770
Clay, red and blue	80	706	Sand	4	774
Rock and sand	3	709	Clay	4	778
Clay	3	712	Sand	5	783
Rock	1	713	Rock, soft	7	790
Sand and rocks	11	724	Clay, hard red	32	822
Clay	19	743	Sand, good	15	837

Well WH-79-54-201

Owner: City of Woodsboro. Driller: Texas Water Wells.

Surface, subsoil	2	2	Clay	10	105
Clay	28	30	Sand	35	140
Sand and clay	30	60	Clay	12	152
Sand and boulders	35	95	Sand and shale	35	187
			Sand, fine	16	203

Well WH-79-54-202

Owner: City of Woodsboro. Driller: Texas Water Wells.

Surface soil	2	2	Sand	2	33
Clay, yellow	18	20	Clay, sandy and sand streaks	19	52
Clay and sandy clay streaks	11	31	Clay, sandy	7	59

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-54-202--Continued					
Sand with hard streaks, (boulders)--	19	78	Sand with boulders------	13	93
Gravel----------	2	80	Clay----------	9	102
			Sand----------	33	135
			Clay, heavy----------	10	145

Well WH-79-54-203

Owner: City of Woodsboro. Driller: Layne-Texas Company.

Surface soil----------	2	2	Clay, sandy and sand----	14	227
Clay----------	44	46	Sand and clay streaks---	28	255
Sand, coarse, white----	15	61	Sand----------	11	266
Sand and clay streaks--	13	74	Clay----------	33	299
Rock----------	1	75	Clay, sandy----------	36	335
Sand, coarse gray------	11	86	Sand, coarse gray-------	25	360
Clay----------	20	106	Clay and clay sandy-----	34	394
Sand, coarse gray------	26	132	Sand coarse----------	16	410
Clay----------	6	138	Clay----------	7	417
Sand, coarse gray------	10	148	Sand, fine gray---------	25	442
Clay----------	31	179	Clay, sandy----------	9	451
Sand, coarse----------	34	213	Sand, coarse gray-------	29	480
			Clay----------	21	501

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)

Well WH-79-54-206 Partial Log

Owner: F B. Rooke and Sons. Driller: W. E. Eads.

No record----------	212	212	Shale----------	22	512
Sand----------	20	232	Sand----------	53	565
Shale, blue----------	38	270	Shale----------	30	595
Sand----------	48	318	Sand----------	32	627
Shale, blue----------	128	446	Shale----------	44	671
Sand----------	44	490	Sand----------	43	714

Well WH-79-54-403

Owner: F. B. Rooke & Sons. Driller: E. T. Ellwood.

Soil----------	2	2	Sand----------	8	173
Clay----------	18	20	Shale, brown----------	22	195
Sand----------	6	26	Sand, hard----------	10	205
Clay, brown----------	40	66	Clay, mixed----------	35	240
Sand and limerock------	19	85	Sand, good----------	16	256
Clay----------	9	94	Clay----------	1	257
Sand----------	8	102	Sand, coarse----------	7	264
Shale, brown----------	6	108	Clay, brown and blue----	26	290
Sand, coarse----------	11	119	Sand----------	22	312
Clay----------	11	130	Gumbo, red and blue-----	66	378
Sand, good----------	32	162	Sand, fine----------	7	385
Clay----------	3	165	Clay, mixed----------	25	410

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-54-403--Continued					
Clay, soft	7	417	Clay	4	508
Sand, good	10	427	Sand and gravel	12	520
Clay	1	428	Clay, red	15	535
Sand, fine	2	430	Sand, good	15	550
Gumbo, blue	28	458	Clay, soft and mud	20	570
Sand, coarse	15	473	Sand and gravel	13	583
Gumbo	7	480	Gumbo, blue	14	597
Sand, good	14	494	Sand, coarse	6	603
Clay	2	496	Clay and soft rock	27	630
Sand	8	504	Clay, mixed and shale	110	740
			Sand and gravel	35	775
Well WH-79-54-504					
Owner: H. Schirmer. Driller: Kelley Well Service.					
Surface	20	20	Shale	25	295
Sand	50	70	Sand	25	320
Shale	10	80	Shale	60	380
Sand	100	180	Sand	30	410
Shale	40	220	Shale	55	465
Sand	22	242	Sand	45	510
Shale	8	250	Shale	135	645
Sand	20	270	Sand	25	670

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-54-504--Continued					
Shale----------	25	670	Shale----------	5	846
Sand----------	51	746	Sand----------	29	875
Shale----------	49	795	Shale----------	85	960
Sand----------	10	805	Sand----------	35	995
Shale----------	5	810	Rock----------	5	1,000
Sand----------	31	841	Sand----------	10	1,010

Well WH-79-54-701

Owner: F. B. Rooke and Sons. Driller: E. T. Ellwood.

Soil----------	2	2	Lime and sand----------	5	255
Clay----------	12	14	Shale, brown and blue---	12	267
Sand----------	6	20	Sand, good----------	35	302
Clay, brown----------	55	75	Rock----------	3	305
Sand and boulders------	30	105	Sand, fine----------	23	328
Clay----------	5	110	Clay, soft----------	10	338
Sand, coarse----------	40	150	Sand, coarse----------	10	348
Shale, blue and brown--	27	177	Shale, hard blue----------	12	360
Sand and boulders, strips clay----------	19	196	Sand, fine and rock-----	10	370
Gumbo, blue----------	29	225	Sand, coarse----------	23	393
Sand, good----------	13	238	Gumbo, mixed----------	69	462
Gumbo, blue----------	12	250	Sand and limerock-------	14	476
			Clay, red and blue------	20	496

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Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-54-701--Continued					
Sand, coarse	8	504	Sand, fine, and rock	5	608
Clay, soft	13	517	Gumbo, blue	14	622
Sand	9	526	Sand, coarse	10	632
Gumbo, blue	12	538	Clay, mixed	23	655
Sand, coarse	7	545	Sand, good	105	760
Clay	8	553	Shale	1	761
Sand, good	21	574	Sand	4	765
Rock	2	576	Gumbo	7	772
Gumbo	4	580	Sand	8	780
Sand, good	16	596	Clay, mixed	52	832
Shale, red	7	603	Sand, good	32	864
Well WH-79-54-802					
Owner: Otto Salch. Driller: W. E. Eads.					
No record	142	142	Shale, blue	12	270
Sand with shale streaks	44	186	Sand	8	278
Shale, blue	8	194	Shale	22	300
Sand	64	258	Sand	31	331
Well WH-79-55-503					
Owner: Tom O'Connor Estate. Driller: Kelley Well Service.					
Clay	62	62	Shale, sandy	59	132
Sand, coarse	11	73	Sand, hard	44	176

(Continued on next page)

Table 5 --Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-55-503--Continued					
Shale	18	194	Sand	17	577
Sand	16	210	Shale and sand streaks	208	785
Shale	100	310	Sand	30	815
Sand, hard	15	325	Shale	45	860
Shale	32	357	Sand	18	878
Sand	18	375	Shale	29	907
Shale and sand streaks	185	560	Sand	29	936
Well WH-79-55-602					
Owner: Tom O'Connor Estate. Driller: Kelley Well Service.					
Clay and caliche	30	30	Shale, sticky	60	460
Sand	10	40	Sand	20	480
Shale, shell and sand	80	120	Shale, sandy	20	500
Sand	20	140	Shale, sticky	40	540
Shale, sandy	25	165	Shale, sandy	10	550
Sand	10	175	Sand	40	590
Shale, sandy	45	220	Shale, sandy	45	635
Shale	60	280	Sand	20	655
Sand	15	295	Shale, sandy	45	700
Shale, sandy	40	335	Shale	30	730
Shale, sticky	35	370	Sand	25	755
Shale, sandy	30	400	Shale	15	770

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

Well WH-79-55-602--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Shale, sandy----------	40	810	Red beds----------	20	860
Sand----------	15	825	Shale----------	55	915
Shale----------	15	840	Sand----------	35	950

Well WH-79-55-701 Partial Log

Owner: Mrs. Alfred Vogas. Driller: O. B. Martin.

Shale----------	130	130	Shale----------	3	289
Sand, broken----------	85	215	Sand----------	25	314
Shale----------	31	246	Shale----------	32	346
Sand----------	11	257	Sand----------	22	368
Shale----------	17	274	Shale----------	44	412
Sand----------	12	286	Sand----------	16	428

Well WH-79-56-601

Owner: Tom O'Connor Estate. Driller: Kelley Well Service.

Clay----------	80	80	Sand and shale streaks--	45	440
Sand----------	18	98	Shale----------	30	470
Shale----------	147	245	Sand and shale streaks--	40	510
Sand----------	10	255	Shale----------	60	570
Shale----------	20	275	Sand----------	110	680
Sand----------	65	340	Shale----------	137	817
Shale----------	55	395	Sand----------	16	833

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-56-601--Continued					
Shale	47	880	Sand	22	1,100
Sand	29	909	Shale	40	1,140
Shale, sticky	56	965	Sand	23	1,163
Shale	97	1,062	Shale	65	1,228
Sand and shale streaks	16	1,078	Sand	22	1,250
Well WH-79-63-102					
Owner: O. W. Gilbert. Driller: Youngblood Well Service.					
Clay	60	60	Shale	70	710
Clay with sand streaks	13	73	Shale, sandy	20	730
Sand	32	105	Sand	20	750
Sand with shale streaks	135	240	Shale, sandy	25	775
Sand	45	285	Sand	53	828
Shale, sandy	90	375	Shale	147	975
Sand	35	410	Sand	12	987
Shale, sandy	145	555	Shale, sandy	10	997
Sand	15	570	Sand	13	1,010
Shale	30	600	Shale	23	1,033
Sand	40	640	Sand	22	1,055
Well WH-79-63-202					
Owner: J. E. Bauer. Driller: Kelley Well Service.					
Clay	125	125	Shell	3	148
Sand	20	145	Sand	12	160

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-79-63-202--Continued					
Shale	47	207	Sand	8	388
Sand, fine	63	270	Shale	6	394
Hard streaks	2	272	Sand	26	420
Shale, hard streaks	8	280	Shale	205	625
Sand, coarse	26	306	Sand	10	635
Shale	74	380	Shale	90	725
			Sand	30	755

Well WH-80-33-602

Owner: City of Tivoli. Driller: H & S Well Service.

Clay	20	20	Shale	35	265
Sand and clay streaks	35	55	Sand (tested)	35	300
Shale	63	118	Shale and sand streaks	115	415
Sand	27	145	Sand and shale streaks	25	400
Shale	33	178	Sand, shale and sand streaks	355	795
Sand	12	190			
Clay	20	210	Sand	50	845
Sand	20	230	Shale	8	853

Well WH-80-34-502

Owner: Mrs. Mary Duncan. Driller: Kelley Well Service.

Surface	15	15	Sand	45	120
Shell	60	75	Shale	55	175

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-80-34-502--Continued					
Sand	30	205	Shale	50	405
Shale	60	265	Sand	10	415
Sand	28	293	Shale	69	484
Shale	12	305	Sand	21	505
Sand	50	355	Shale	2	507

Well WH-80-34-503

Owner: Mrs. Mary Duncan. Driller: Kelley Well Service.

Shale	95	95	Sand	15	238
Sand	25	120	Shale	7	245
Shale	43	163	Sand	25	270
Sand	17	180	Shale	40	310
Shale	10	190	Sand	45	355
Sand	20	210	Shale	25	380
Shale	13	223	Sand	49	429

Well WH-80-34-707

Owner: City of Austwell. Driller: H & S Well Service.

Clay	42	42	Sand and gravel	18	123
Sand	2	44	Shale	16	139
Clay	19	63	Sand	6	145
Shale and sand streaks	42	105	Shale	9	154

(Continued on next page)

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WH-80-34-707--Continued					
Sand and gravel--------	19	173	Sand--------------------	7	286
Shale------------------	33	206	Shale-------------------	13	299
Sand and gravel--------	50	256	Sand--------------------	11	310
Shale------------------	10	266	Shale and sand streaks--	15	325
Sand--------------------	9	275	Sand--------------------	25	350
Shale------------------	4	279	Sand streaks------------	12	362
			Shale-------------------	1	363
Well WH-80-41-403					
Owner: Lydia Hunt Herbert Trust. Driller: H & S Well Service.					
Clay--------------------	10	10	Shale-------------------	116	320
Sand--------------------	10	20	Shale, sandy------------	35	355
Shale------------------	25	45	Shale-------------------	35	390
Sand--------------------	23	68	Sand and shale streaks--	110	500
Shale------------------	30	98	Shale, sandy------------	40	540
Sand--------------------	30	128	Shale-------------------	160	700
Shale------------------	17	145	Sand, fine--------------	15	715
Sand and shale streaks-	29	174	Shale-------------------	245	960
Sand--------------------	30	204	Sand, fine--------------	55	1,015
			Shale-------------------	15	1,030

Table 5.--Drillers' logs of wells in Refugio County and adjacent areas--Continued

Refugio County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)

Well WH-80-41-404

Owner: Lydia Hunt Herbert Trust. Driller: H & S Well Service.

Clay----------	10	10	Sand----------	22	120
Sand----------	10	20	Shale----------	13	133
Shale----------	25	45	Sand----------	12	145
Sand----------	23	68	Shale----------	25	170
Shale----------	30	98	Sand and gravel----------	34	204
			Shale----------	4	208

Well WH-80-42-207

Owner: J. E. Bauer. Driller: Kelley Well Service.

Clay and shell----------	95	95	Shale----------	54	170
Sand----------	21	116	Sand----------	21	191

Well WH-80-42-208

Owner: J. E. Bauer. Driller: Kelley Well Service.

Clay, surface----------	10	10	Shell and sand streaks--	64	88
Sand----------	14	24	Shale----------	97	185
			Sand----------	25	210

Table 5.--Drillers' logs of wells in Goliad County and adjacent areas--Continued

Goliad County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well KP-79-37-601					
Owner: Jimmie Bauer. Driller: Kelley Well Service.					
Surface	10	10	Shale	64	148
Caliche and sand streaks	74	84	Shale and sand	6	154
			Shale	99	253
			Sand	20	273
Well KP-79-38-401					
Owner: Wallace Shay. Driller: Kelley Well Service.					
Surface	20	20	Sand	11	95
Sand	20	40	Shale	17	112
Shale	44	84	Sand	58	170
Well KP-79-38-402					
Owner: Wallace Shay. Driller: Kelley Well Service.					
Surface	20	20	Sand	16	56
Caliche	10	30	Shale	101	157
Sand	8	38	Sand	18	175
Caliche	2	40	Shale	5	180
Well KP-79-38-403					
Owner: Wallace Shay. Driller: Kelley Well Service.					
Surface	10	10	Shale	20	75
Sand	45	55	Sand	20	95

(Continued on next page)

Table 5.--Drillers' logs of wells in Goliad County and adjacent areas--Continued

Goliad County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well KP-79-38-403--Continued					
Shale, hard----------	48	143	Shale----------	12	155
			Sand----------	15	170

Well KP-79-38-404

Owner: Wallace Shay. Driller: Kelley Well Service.

Surface----------	15	15	Sand----------	3	83
Sand----------	45	60	Shale----------	153	236
Shale----------	20	80	Sand----------	22	258

Well KP-79-38-702

Owner: Wallace Shay. Driller: Kelley Well Service.

Surface----------	20	20	Shale----------	22	100
Sand----------	20	40	Sand----------	10	110
Shale----------	30	70	Shale----------	13	123
Sand----------	8	78	Sand----------	25	148