TEXAS
WATER
DEVELOPMENT
BOARD

REPORT 37

GROUND-WATER RESOURCES OF SABINE AND SAN AUGUSTINE COUNTIES, TEXAS

JANUARY 1967

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GROUND-WATER RESOURCES OF SABINE AND SAN AUGUSTINE COUNTIES, TEXAS

By

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United States Geological Survey

Prepared by the U.S. Geological Survey
in cooperation with the
Texas Water Development Board
Sabine River Authority of Texas
and
Sabine and San Augustine Counties

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TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd.)

Page

TABLES

ILLUSTRATIONS

Figures

TABLE OF CONTENTS (Cont'd.)

GROUND-WATER RESOURCES OF
SABINE AND SAN AUGUSTINE
COUNTIES, TEXAS

ABSTRACT

Sabine and San Augustine Counties, areas of 554 and 551 square miles, respectively, had populations of 7,302 and 7,722 in 1960. At that time San Augustine, which is the oldest Anglo-American town in Texas and the county seat of San Augustine County, had a population of 2,584. Simultaneously the population of Hemphill, the county seat of Sabine County, was 913. The climate is humid; the average precipitation is about 50 inches a year. The economy of these counties is largely dependent upon lumbering and agriculture. Manufactured items include furniture and bathroom fixtures.

Rocks underlying the area are composed of sand, silt, and clay, and contain lesser amounts of glauconite and lignite. The important aquifers are in the Carrizo Sand and Wilcox Group, the Sparta Sand, and the Yegua Formation.

Precipitation on the outcrops of the aquifers is the primary source of recharge. The aquifers are full and about 46 mgd (million gallons per day) is presently moving downdip through the important aquifers.

Throughout the area about 1.3 mgd was discharged in 1964 from municipal, livestock, rural domestic, industrial, and uncontrolled flowing wells. About 40 percent of the ground water is discharged by municipal wells. The towns of Bronson and Pineland derive their water supplies from ground water, but Hemphill and San Augustine obtain their supplies from surface-water reservoirs.

The quality of water from the important aquifers is generally acceptable for municipal and irrigation use, and many industrial purposes. Water from a few of the drilled wells is relatively high in dissolved solids, and bacteria are probably present in most of the dug wells. Of the 6 dug wells for which analyses were made, 3 contained dangerous numbers of the coliform type of bacteria.

The aquifers in Sabine and San Augustine Counties are practically untapped. Estimates indicate that the Carrizo Sand and Wilcox Group, Sparta Sand, and Yegua Formation are capable of supporting a total perennial ground-water development of at least 44 mgd, and possibly as much as 165 mgd, from pumping levels not exceeding 200 to 400 feet along assumed lines of discharge.

GROUND-WATER RESOURCES OF
SABINE AND SAN AUGUSTINE
COUNTIES, TEXAS

INTRODUCTION

Purpose and Scope of Investigation

The purpose of the investigation was to obtain information as a guide for securing increased benefits from the ground-water supplies of Sabine and San Augustine Counties. Therefore, data relating to the occurrence, quality, availability, quantity, use, and dependability of the ground-water resources were obtained and studied. The report contains information on the surface and subsurface geology and on streams, data from 79 oil tests and 281 water wells and springs (Table 6), and 56 drillers' logs of wells (Table 7). Data on 120 water wells and springs included in the report, were taken from a report by Follett (1943). An effort was made to recheck most of these wells and springs and to obtain additional data about them. The report also contains 284 chemical analyses of water from 263 wells and springs (Table 8). Of the analyses, 173 were unpublished heretofore; of the 173 analyses, 162 were the work of the U.S. Geological Survey laboratory, 4 were processed by a commercial laboratory, and 7 were made by the author with a water-analysis field kit.

Technical terms used in discussing the ground-water resources of the area are defined and listed alphabetically in the section entitled "Definition of Terms."

The investigation, begun in September 1963, is a cooperative project of the U.S. Geological Survey, the Texas Water Development Board, the Sabine River Authority of Texas, and Sabine and San Augustine Counties.

Location and Extent of Area

Sabine and San Augustine Counties, with respective populations of 7,302 and 7,722 in 1960, are 554- and 551-square-mile areas, respectively. This two-county area is in East Texas between latitudes 31°05' and 31°40'N, and longitudes 93°35' and 94°25'W. It adjoins Jasper and Newton Counties on the south, Angelina and Nacogdoches Counties on the west, Shelby County on the north, and the State of Louisiana on the east (Figure 1). San Augustine, the oldest Anglo-American town in Texas, is the largest in the report area. According to 1960 statistics, the population was 2,584 in San Augustine, the county seat of San Augustine County; 913 in Hemphill, the county seat of Sabine County; and 1,236 in Pineland, the site of a sawmill and wood-products manufacturing plant.

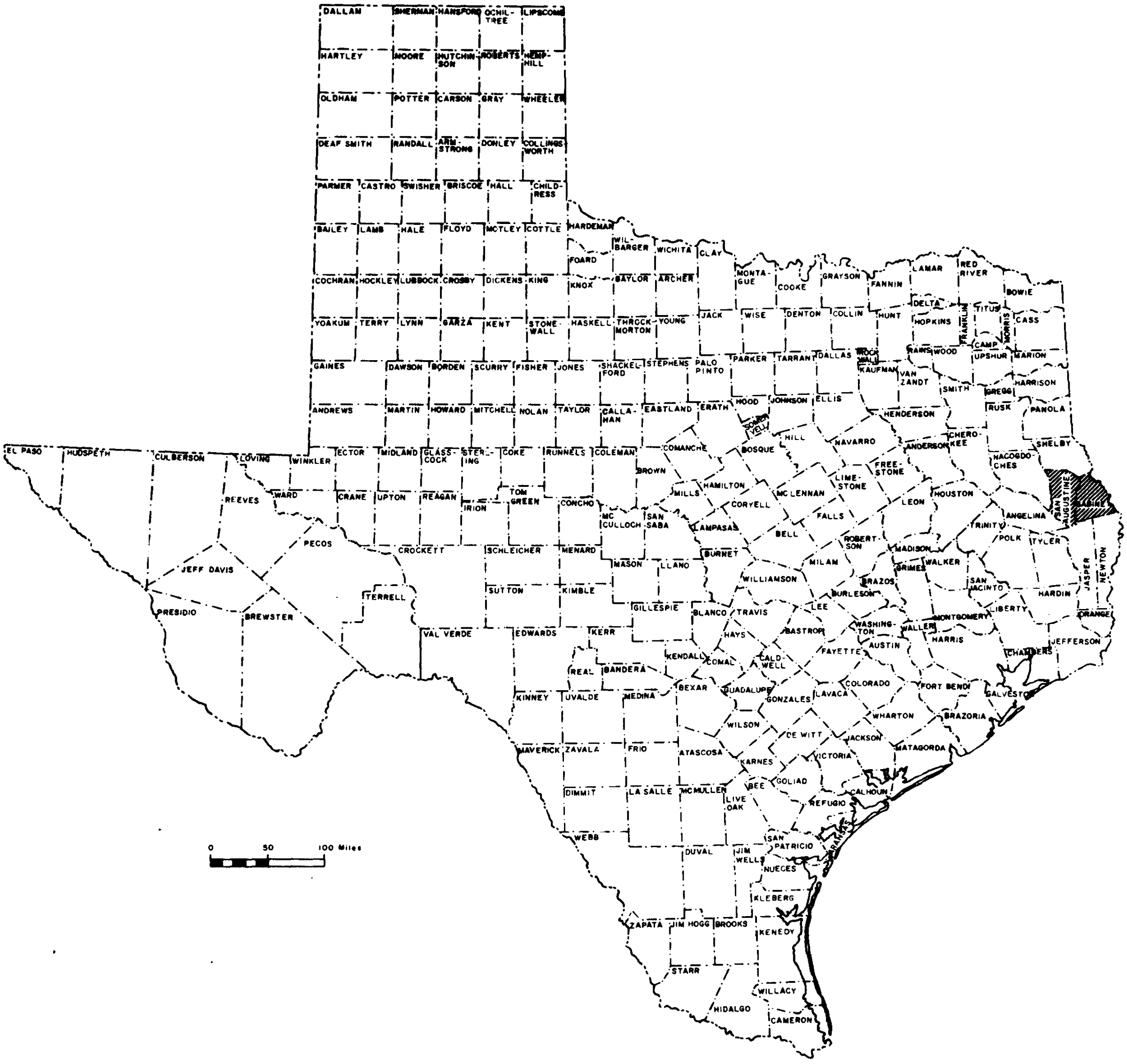


Figure 1

Index Map of Texas Showing Location of Sabine and San Augustine Counties

U. S. Geological Survey in cooperation with the Texas Water Development Board,
Sabine River Authority of Texas, and Sabine and San Augustine Counties

Physiography and Drainage

Sabine and San Augustine Counties are in the West Gulf Coastal Plain physiographic province. The topography ranges from almost flat near the larger streams and in some of the interstream areas in the southern part of the two-county area to hilly in much of the northern part. Two hills, one 3 miles northeast of San Augustine and the other 5 miles northwest of Geneva (11 miles north-northeast of Hemphill), have altitudes about 590 feet above mean sea level and are the highest points in the area. The lowest altitudes, about 100 feet above mean sea level, are where the southward-flowing Ayish Bayou and the Sabine and Angelina Rivers leave the area. These streams and Attoyac Bayou, with the aid of their tributaries, drain the two-county area.

The two-county area is within the Neches and Sabine River drainage basins. About 10 percent of San Augustine County and 80 percent of Sabine County are drained by the Sabine River and its principal tributaries--Patroon, Palo Gaucho, and Housen Bayous, and Big Sandy and Sixmile Creeks. Tributaries to the Neches River, which drain most of San Augustine County and the southwestern part of Sabine County, include the Angelina River and its tributaries--Attoyac and Ayish Bayous.

Economic Development

The major sources of income in Sabine and San Augustine Counties are poultry production, cattle raising, and lumbering. Poultry production is the principal enterprise on farms. Manufactured items include furniture and bathroom fixtures.

About 80 percent of the area is covered by a dense growth of pine and hardwood trees, and grassland is rare except where man has removed the trees. Both counties have been systematically logged for timber for many years. Conservation measures have been effectively practiced and the forested areas have not been substantially reduced. In many places the forest and the undergrowth are so dense that walking through them is difficult.

Truck- and field-crop production is limited by the large forested areas, and neither Sabine nor San Augustine County has had commercial oil or gas production since the San Augustine oil field stopped producing in 1949.

The income of the area is expected to be augmented appreciably by the recreational areas that will develop as a result of completion of Sam Rayburn Dam in 1966 and by Toledo Bend Dam now under construction.

Previous Investigations

Early investigations of the geology and ground-water resources of Sabine and San Augustine Counties were generalized because large areas were investigated, drilled wells were few, and transportation was slow and difficult. Among the first investigations was one by Taylor (1907, p. 63-64), who studied the whole Coastal Plain of Texas. The geology and occurrence of ground water in the two-county area were briefly discussed in his report. A report by

Deussen (1914, p. 37-72, 332-339) described in some detail the geology along the Sabine River, incorporated drillers' logs of 4 wells, and gave additional data on 10 wells and 3 springs.

Understanding of the geology was advanced considerably by a report on the geology of Texas by Sellards, Adkins, and Plummer (1932, p. 571-726) which described in considerable detail the stratigraphy of Sabine and San Augustine Counties and surrounding areas.

Prior to the present report, the only one devoted exclusively to the ground-water resources of Sabine and San Augustine Counties was prepared by C. R. Follett in 1943. His report contained information on 159 wells and springs, chemical analyses of water from 98 of these, and 27 drillers' logs.

Sundstrom, Hastings, and Broadhurst (1948, p. 252-254) reported on the public-water supplies in eastern Texas including those of Hemphill, Pineland, and San Augustine. Their report contained drillers' logs, chemical analyses, pumpage figures, and well-construction data.

Two reconnaissance reports by Baker and others (1963a, 1963b) discussed the order of magnitude of the ground-water supplies available from the principal aquifers of the Sabine and Neches River basins, which include Sabine and San Augustine Counties.

Acknowledgments

Grateful acknowledgment is made to city, county, and industrial officials and personnel, and to the many landowners for their gracious assistance in supplying well data and other information as well as for allowing access to their wells. Mr. Pete Newton of the Newton Well Service Company, San Augustine, and Mrs. C. H. Chambers of the Chambers Drilling Company, Center, have been especially helpful.

Well-Numbering System

The well-numbering system used in this report is one adopted by the Texas Water Development Board for use throughout the State and is based on latitude and longitude. Under this system, each 1-degree quadrangle in the State is given a number consisting of two digits. These are the first two digits appearing in the well number and may range from 01 to 89. Each 1-degree quadrangle is divided into $7\frac{1}{2}$-minute quadrangles which also are given 2-digit numbers from 01 to 64. These are the third and fourth digits of the well number. Each $7\frac{1}{2}$-minute quadrangle is subdivided into $2\frac{1}{2}$-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 $2\frac{1}{2}$-minute quadrangle is given a 2-digit number in the order in which it is inventoried, starting with 01. These are the last two digits of the well number. The $7\frac{1}{2}$-minute quadrangles are shown on the well location map of this report (Figure 13) and numbered in the northwest corner of each quadrangle. Also shown are the 1-degree quadrangles, indicated by the large double-lined Figures 36 and 37. The 3 digits shown with the well symbol include the number of the $2\frac{1}{2}$-minute quadrangle in which the well is located and the last two digits of the well number. In addition to the complete 7-digit number, a

2-letter prefix is used to identify the county. The prefixes for Sabine and San Augustine Counties are WS and WT, respectively. In order to facilitate the use of data from Follett's report, wells and springs inventoried by him in 1942 and used in the present report have been given new numbers. The old and new numbers are cross-referenced in Table 1.

GEOLOGY AS RELATED TO THE OCCURRENCE OF GROUND WATER

General Stratigraphy and Structure

The stratigraphic units that crop out in Sabine and San Augustine Counties are of Eocene, Oligocene, Miocene(?), Pleistocene, and Recent ages. These units are of sedimentary origin and are composed primarily of a series of alternating sand, silt, and clay strata. Locally, beds of glauconite are relatively thick. The units are, from oldest to youngest, the Wilcox Group, Carrizo Sand, Cane River Formation, Sparta Sand, Cook Mountain Formation, Yegua Formation, and Jackson Group (all of Eocene age); the Vicksburg Group of Oligocene age; the Catahoula Sandstone of Miocene(?) age; and alluvium of Pleistocene and Recent age (Table 2).

Repeated submergence beneath the sea and emergence of the area during the deposition of the Eocene, Oligocene, and Miocene(?) rocks resulted in a series of alternating marine and brackish-water deposits and fresh-water beds. Beds of sand in the stratigraphic units that were deposited primarily in marine and littoral environments (such as the Cane River and Cook Mountain Formations, and the Jackson and Vicksburg Groups) generally are thin and, in some places, of small areal extent. Although some of these beds carry fresh to slightly saline water to depths of several hundred feet, they are relatively unimportant as aquifers because the beds yield only small quantities of water and are not widespread. Those stratigraphic units that had a large amount of their sediments deposited under nonmarine environments have thicker and much more numerous beds of sand that are the important aquifers in the area. On the basis of potential well yield and areal extent, the important aquifers, in order of decreasing significance, are in the following formations or groups: Carrizo Sand and Wilcox Group, Sparta Sand, and Yegua Formation. The Catahoula Sandstone, although capable of yielding large quantities of water to wells, is relatively unimportant because of its small areal extent in the two-county area.

In general, the stratigraphic units strike parallel to the coast (Figure 2) and dip southward toward the Gulf of Mexico. Rocks of the Wilcox Group crop out along the north boundary of the two-county area. Southward toward the coast, the rocks become progressively younger, the Catahoula being the youngest formation except for the alluvium. Alluvium (not shown on the geologic map) occurs along many of the streams as flood-plain and higher-level terrace deposits but is not an important aquifer, although small quantities of water can be obtained from it in some areas.

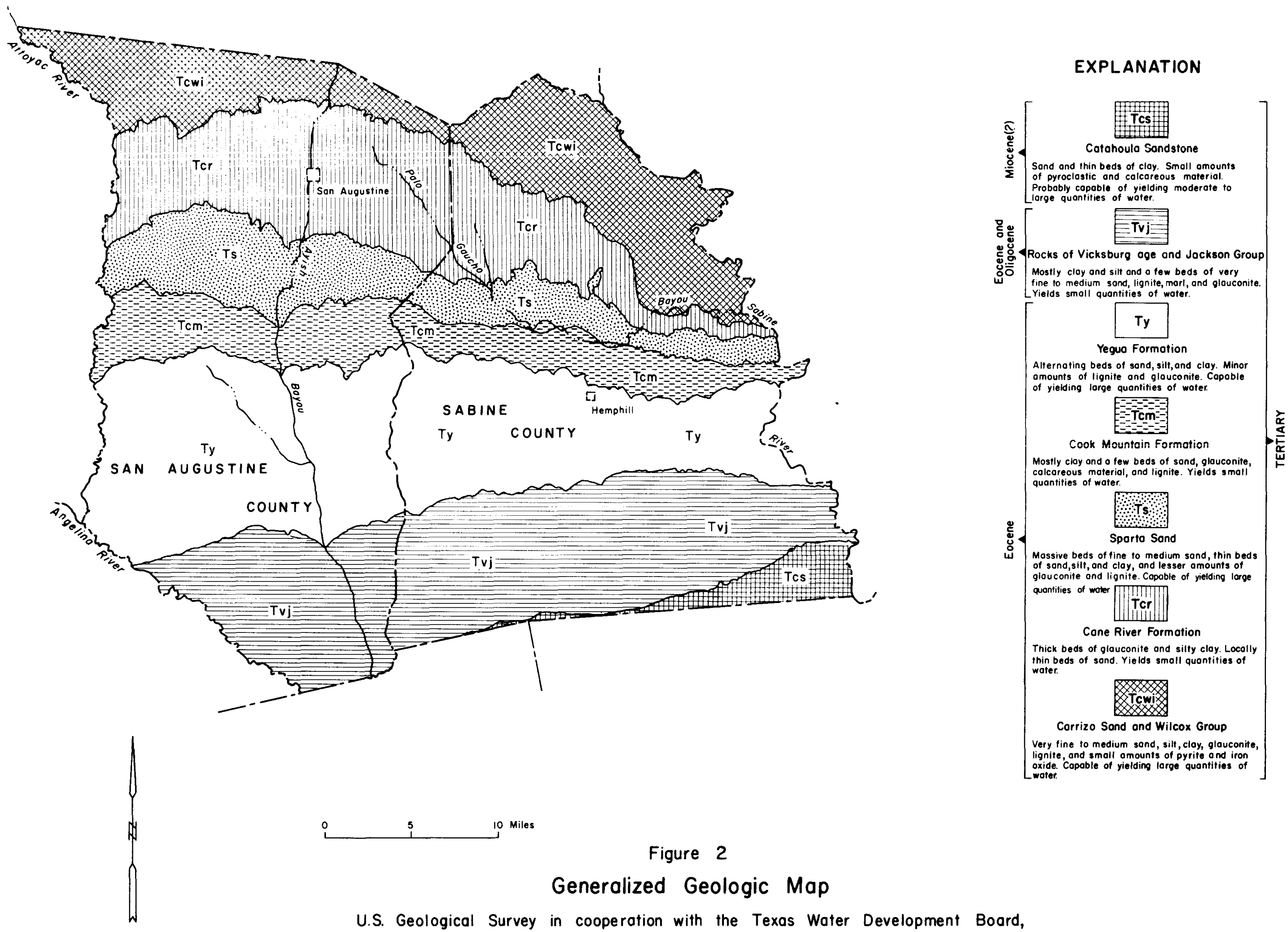
The stratigraphic units commonly change in lithology, dip, and thickness in the direction of the dip and some change slightly in lithology and thickness along the strike (Figures 14, 15, and 16). The thickness of some of the rocks increases with depth of burial whereas others maintain a more or less constant

Table 1.--Well and spring numbers used by Follett (1943) and the corresponding numbers used in this report.

Old number	New number	Old number	New number	Old number	New number	Old number	New number
Sabine County							
1	WS-36-25-506	22	WS-36-33-207	39	WS-36-49-108	57	WS-36-35-804
3	WS-36-26-802	23	WS-36-33-205	40	WS-36-49-111	58	WS-36-43-101
7	WS-36-26-803	24	WS-37-40-601	41	WS-37-56-901	59	WS-36-42-503
10	WS-36-35-101	25	WS-36-33-404	42	WS-37-56-902	60	WS-36-42-811
11	WS-36-35-403	26	WS-36-33-702	43	WS-36-49-704	61	WS-36-50-202
12	WS-36-35-404	27	WS-36-41-101	44	WS-36-33-802	62	WS-36-51-407
13	WS-36-35-402	28	WS-37-48-303	45	WS-36-33-901	63	WS-36-51-408
14	WS-36-34-606	29	WS-37-48-302	46	WS-36-41-206	64	WS-36-43-702
15	WS-36-34-904	30	WS-37-48-304	48	WS-36-42-102	65	WS-36-43-803
16	WS-36-34-501	31	WS-37-48-606	51	WS-36-42-101	66	WS-36-43-901
17	WS-36-34-502	32	WS-36-41-705	52	WS-36-34-702	67	WS-36-51-302
18	WS-36-34-405	34	WS-36-41-706	53	WS-36-34-703	68	WS-36-51-303
19	WS-36-25-802	35	WS-36-49-102	54	WS-36-34-902	69	WS-36-52-403
20	WS-36-25-901	36	WS-36-49-103	55	WS-36-35-701	70	WS-36-52-402
21	WS-36-33-208	37	WS-36-49-104	56	WS-36-35-803		
San Augustine County							
1	WT-37-22-801	21	WT-37-32-110	40	WT-37-31-805	62	WT-37-48-201
2	WT-37-22-901	22	WT-37-32-108	41	WT-37-31-704	63	WT-37-48-401
3	WT-37-30-301	23	WT-37-32-202	42	WT-37-30-903	64	WT-37-47-602
5	WT-37-31-101	24	WT-37-32-203	46	WT-37-38-602	65	WT-37-47-903
6	WT-37-31-202	25	WT-37-32-204	47	WT-37-38-603	66	WT-37-55-102
7	WT-37-31-201	26	WT-37-32-504	48	WT-37-38-906	67	WT-37-55-205
8	WT-37-31-203	27	WT-27-32-602	49	WT-37-46-201	68	WT-37-47-801
9	WT-37-31-506	28	WT-27-32-902	50	WT-37-46-602	70	WT-37-46-604
10	WT-37-31-505	29	WT-37-32-901	51	WT-37-46-603	71	WT-37-46-902
11	WT-37-32-702	30	WT-37-40-306	52	WT-37-46-301	72	WT-37-54-201
12	WT-37-32-701	31	WT-37-40-502	55	WT-37-47-101	73	WT-37-54-301
13	WT-37-32-706	33	WT-37-33-708	56	WT-37-39-704	75	WT-37-55-401
16	WT-37-32-707	35	WT-37-39-605	57	WT-37-47-303	76	WT-37-56-701
17	WT-37-32-404	36	WT-37-39-604	58	WT-37-40-701		
19	WT-37-31-302	38	WT-37-39-502	60	WT-37-40-803		
20	WT-37-32-109	39	WT-37-39-101	61	WT-37-48-202		

Table 2.--Stratigraphic units and their water-bearing properties

System	Series	Group	Stratigraphic unit	Approximate thickness (feet)	Character of rocks	Water-bearing properties
Quaternary	Recent and Pleistocene		Alluvium	0- 50?	Terrace and flood-plain deposits in stream valleys, composed of clay, silt, sand, and gravel.	Locally yields small quantities of fresh water to shallow dug wells.
	Miocene(?)		Catahoula Sandstone	0- 450	Sand and beds of clay. Small amounts of pyroclastic and calcareous material.	Probably capable of yielding moderate to large quantities of fresh to slightly saline water.
	Oligocene	Vicksburg Jackson		0- 780	Mostly clay and silt and a few beds of very fine to medium sand, lignite, marl, and glauconite.	Yields small quantities of fresh to moderately saline water.
			Yegua Formation	0-1,000	Sand, silt, clay, and small amounts of lignite and glauconite.	Yields small to moderate quantities of fresh to moderately saline water. Capable of yielding large quantities.
			Cook Mountain Formation	0- 400	Mostly clay with a few thin beds of sand, glauconite, calcareous material, and lignite.	Yields small quantities of fresh to slightly saline water.
Tertiary	Eocene	Claiborne	Sparta Sand	0- 340	Massive beds of fine to medium sand, thin beds of sand, silt, and clay, and lesser amounts of glauconite and lignite.	Yields small quantities of fresh to slightly saline water. Capable of yielding large quantities.
			Cane River Formation	0- 220	Thick beds of glauconite and silty clay. Locally thin beds of sand.	Yields small quantities of fresh water to shallow dug wells.
			Carrizo Sand	0- 130?	Massive beds of fine to medium sand. Difficult to distinguish from Wilcox Group.	Capable of yielding small to moderate quantities of fresh to slightly saline water.
		Wilcox		1,400-3,000	Very fine to medium sand, silt, clay, glauconite, lignite, and small amounts of pyrite and iron oxide.	Capable of yielding large quantities of fresh to slightly saline water.
	Paleocene	Midway		Not determined	Mostly clay and silt.	Not an aquifer.



Catahoula Sandstone

Sand and thin beds of clay. Small amounts of pyroclastic and calcareous material. Probably capable of yielding moderate to large quantities of water.

Rocks of Vicksburg age and Jackson Group

Mostly clay and silt and a few beds of very fine to medium sand, lignite, marl, and glauconite. Yields small quantities of water.

Yegua Formation

Alternating beds of sand, silt, and clay. Minor amounts of lignite and glauconite. Capable of yielding large quantities of water.

Cook Mountain Formation

Mostly clay and a few beds of sand, glauconite, calcareous material, and lignite. Yields small quantities of water.

Sparta Sand

Massive beds of fine to medium sand, thin beds of sand, silt, and clay, and lesser amounts of glauconite and lignite. Capable of yielding large quantities of water

Cane River Formation

Thick beds of glauconite and silty clay. Locally thin beds of sand. Yields small quantities of water.

Carrizo Sand and Wilcox Group

Very fine to medium sand, silt, clay, glauconite, lignite, and small amounts of pyrite and iron oxide. Capable of yielding large quantities of water.

Figure 2

Generalized Geologic Map

U.S. Geological Survey in cooperation with the Texas Water Development Board,
Sabine River Authority of Texas, and Sabine and San Augustine Counties

Geology modified from Darton and other (1937) thickness. A gradation of sand into clay with increasing depth of burial is typical of many of the formations. The most noteworthy example of this change is the Sparta Sand.

The structure of the rocks is, in general, monoclinal. The amount of dip depends to some extent on the rock unit and its distance from the center of the Sabine uplift which is north of the two-county area; the steepest dips occur in the eastern part of the area along the Sabine River. In Sabine County the monocline seems to be broken by a number of faults, at least one of which may have considerable displacement. These faults could not be accurately located and are not shown in the geologic sections or on the geologic map.

Some caution should be observed in using the geologic map, as the locations of the contacts are only approximate. The contacts were determined by reconnaissance surface mapping, and by projecting subsurface contacts--as determined from electric and drillers' logs--to the surface. Some of the difficulties encountered in mapping the surface geology of the area were the inaccessibility of some parts of the two counties, the gradational nature of some of the contacts, the lithologic similarity of adjacent units, and the lack of exposures.

Physical Characteristics and Water-Bearing Properties of the Geologic Units

The following descriptions of the geologic units in Sabine and San Augustine Counties, for the most part, are restricted to the outcrop and downdip portions of the section that contains fresh and slightly saline water (Table 2).

Tertiary System

Paleocene Series

Midway Group

The Midway Group does not crop out in the two-county area but underlies the Wilcox Group throughout the area. The top of the Midway Group, as used in this report, is where the electric-log characteristics indicate that the lithology changes from the predominant sand and silt of the Wilcox Group to an underlying predominance of clay and silt of the Midway. Electric logs indicate that the Midway is several hundred feet thick, but definite limits were not established. The abundance of clay makes the Midway relatively impermeable and it does not contain aquifers.

Eocene Series

Wilcox Group

The oldest rocks that crop out in the area belong to the Wilcox Group. They are exposed in the northern part of both counties and overlie the relatively impermeable clays of the Midway Group. They are composed of sand, silt, clay, and glauconite, lesser amounts of lignite, and small amounts of pyrite and calcareous material. Because both the glauconite (a silicate of iron and potassium) and the pyrite (a sulfide of iron) weather to yellow, red, and brownish-red oxides and hydrated oxides of iron, most of the outcropping areas of the Wilcox Group reflect these colors.

The Wilcox Group ranges in thickness from about 1,400 feet in the northern part of Sabine County where only part of the group is present to about 3,000 feet downdip where the water in the upper part becomes moderately saline. The rocks contain about 40 percent sand that ranges in size from very fine to medium. Locally the sand is nearly free of iron. Some parts of the Wilcox crop out as light-colored belts of either slightly indurated or loose sand which strongly resembles the Carrizo Sand. In general, however, the Wilcox is somewhat indurated and contains appreciable amounts of silt, clay, and iron oxides.

In general, sand strata in the upper part of the Wilcox contain fresh or slightly saline water farther downdip than do sand strata in the lower part of the unit. According to the log of well WT-37-39-502 (Figure 14) the uppermost 120 feet of the Wilcox below the Carrizo contains fresh water. Below this sand the group contains slightly saline water to a depth of about 1,250 feet, as indicated by the line showing the approximate base of the fresh to slightly saline water. Below 1,250 feet, the Wilcox Group contains more highly mineralized water. A water well drilled at the location of this oil test hole would produce small to possibly moderate quantities of fresh water from the fresh-water sand, at least moderate quantities of slightly saline water from sands between about 650 and 1,250 feet, and large quantities of more highly mineralized water from sands below 1,250 feet.

In the outcrop area most of the wells tapping the Wilcox are shallow and therefore yield only small quantities of fresh water. However, in most of the outcrop area and for some distance downdip the unit is capable of yielding large quantities of fresh to slightly saline water to properly constructed wells that screen a sufficiently thick section. For this reason and because that part of the Wilcox Group containing fresh to slightly saline water underlies a large part of the area, the Wilcox (together with the Carrizo Sand as a hydrologic unit) is potentially the most important aquifer in the two counties.

Claiborne Group

Carrizo Sand.--In Sabine and San Augustine Counties the similarities between the Carrizo Sand and sands in the Wilcox Group make the separation of the Carrizo Sand and the Wilcox Group difficult. The Carrizo, containing massive beds of fine to medium sand, attains a maximum thickness of probably 130 feet where the water in the sand is fresh to slightly saline in the southern one-third of San Augustine County. The formation thins eastward and may not be present in all areas. In most places the Carrizo and Wilcox appear to be one hydrologic unit and will generally be considered as such in this report. The Carrizo-Wilcox contact is not shown on the geologic map, but an inferred contact is indicated in the cross sections (Figures 14, 15, and 16). The altitude of the top of the Carrizo Sand and Wilcox Group and its downdip limit of fresh to slightly saline water are shown in Figure 3. In this figure the top of the unit is shown to dip southward at an average rate of about 140 feet per mile.

Although the Carrizo contains fresh to slightly saline water for many miles downdip, it is a relatively unimportant aquifer when treated separately from the Wilcox. The main reasons for the comparative unimportance of the Carrizo are that the sand tends to be too fine and loose to be effectively screened out of a well, and that the net thickness of sand is relatively small. Hence, the Carrizo is, in some wells, cased off. The Carrizo, however, is capable of yielding small to moderate quantities of fresh to slightly saline water.

Cane River Formation.--The rocks herein called the Cane River Formation overlie the Carrizo Sand and underlie the Sparta Sand. This formation is in the same stratigraphic position as, and is equivalent to, the Reklaw Formation, Queen City Sand, and the Weches Greensand in central and south Texas.

The Cane River Formation is primarily composed of thick beds of glauconite and silty clay. Locally the formation contains thin beds of sand. The full thickness of the formation ranges from about 220 feet near the outcrop in San Augustine County to about 60 feet along the Sabine River. The formation yields only small quantities of water to shallow wells and has no important aquifers.

Sparta Sand.--The Sparta Sand is possibly the second most important aquifer in the report area. This formation consists of rather massive beds of fine to medium sand, thin beds of sand, silt, and clay, and lesser amounts of glauconite and lignite. The full thickness of the Sparta ranges from about 250 feet in the southern one-third of Sabine County to about 340 feet in the southern one-third of San Augustine County. Contours in Figure 4, by which are shown the altitude of the top of the Sparta and its downdip limit of fresh to slightly saline water, reveal that the Sparta dips southward at an average rate of about 130 feet per mile. The Sparta Sand yields small quantities of fresh to slightly saline water to many wells in Sabine and San Augustine Counties. The formation is capable of yielding large quantities of water to properly constructed wells that screen most of its sands.

Cook Mountain Formation.--The Cook Mountain Formation contains no important aquifers in Sabine and San Augustine Counties. It consists primarily of clay but smaller amounts of sand, glauconite, calcareous material, and lignite are well distributed through the formation. Electric logs indicate that the Cook Mountain Formation contains several rather persistent beds of undetermined composition. One of these, which occurs about 140 feet above the base of the formation, is indeed remarkably persistent, as this bed underlies most of the southern half of the two-county area (Figures 14, 15, and 16). The bed is believed to be composed of calcareous material but it may be a thin bed of sand. The Cook Mountain attains a thickness of 400 feet in western San Augustine County.

Most wells in the area of outcrop of the Cook Mountain Formation pass through it and obtain water from the underlying Sparta Sand. However, the Cook Mountain does yield small quantities of fresh to slightly saline water to a few dug wells, possibly to one drilled well, and to a few small springs.

Yegua Formation.--The Yegua Formation, in the south-central part of the area, has, on the average, the widest outcrop of those formations in the report area. The width ranges between 4 and 11 miles, with the maximum being in the western part of San Augustine County.

The formation is primarily composed of an alternating series of beds of sand, silt, and clay; most beds of one material contain appreciable amounts of the other two. Minor amounts of lignite and glauconite are also present. In general, the beds are thin and can be traced only for short distances, although some sand zones may be traceable for many miles. A sand zone at the base of the formation (Figures 14, 15, and 16) occurs throughout most of the area underlain by the Yegua, and in many places electric logs indicate that this zone has the thickest accumulation of sand within the Yegua. This sand zone probably is the most prolific water-yielding zone in the formation. The Yegua attains a thickness of 1,000 feet in southern San Augustine County.

Where the sand is sufficiently thick in the outcrop area it will yield large quantities of fresh to slightly saline water to properly constructed wells. The formation yields water to a relatively large number of dug and drilled wells and a few springs; the city of Pineland derives its water supply from sands in this formation. Although not tapped heavily by wells, the Yegua is considered to be an important aquifer, potentially, in the two-county area.

Jackson Group

The Jackson Group, composed mainly of clay, crops out as a belt about 9 miles wide in southwestern San Augustine County. The belt thins eastward toward the Sabine River where the outcrop is slightly more than 2 miles wide. The Jackson also contains thin beds, sparsely distributed, of very fine to fine sand, considerable amounts of bentonitic clay, and smaller amounts of lignite, marl, and glauconite. Because the contact with the overlying strata equivalent to the Vicksburg Group of Louisiana is obscure in places, the Jackson is not separated from the Vicksburg equivalent on the geologic map or on the geologic sections. Their total maximum thickness is about 780 feet in southeastern Sabine County.

The Jackson yields small quantities of fresh to moderately saline water to wells throughout most of its outcrop. Near its contact with the overlying Vicksburg equivalent in eastern Sabine County the Jackson is reported to yield fresh to slightly saline water only to shallow wells. The Jackson probably has other areas in which only shallow fresh to slightly saline water is available; but because only a few wells tap the Jackson and because too few electric logs are available, these other areas cannot be accurately delineated.

Oligocene Series

Rocks of the Oligocene Series (although not delineated on the geologic map or on the cross sections) crop out as a narrow belt that rarely exceeds 1 mile in width in Sabine County and possibly in San Augustine County also, although the width in the latter county was not definitely determined. The Oligocene rocks, equivalent to the Vicksburg Group of Louisiana, are composed of a lower sand, silt, and clay, the Sandel Formation of Delaney (1958, p. 13; Delaney, 1963, p. 355; and Anderson, 1960), and an upper silty clay which Anderson (1960, p. 106) named the Nash Creek Formation. They and the Jackson Group have a total maximum thickness of 780 feet in southeastern Sabine County.

The Sandel Formation crops out in southern Sabine County as a narrow ribbon of sand, silt, and clay which in some areas forms a narrow range of hills

0.5 to 0.75 mile north of a ridge named the Catahoula Cuesta. Electric logs in Sabine County and in Newton County to the south, as well as surface mapping in the former, show that in some areas the sand beds in the Sandel Formation aggregate a thickness of nearly 30 feet although generally their thickness is much less. The sand ranges in size from very fine to medium. In areas where the sand beds are poorly developed, the contact between the Jackson and Vicksburg equivalent is obscure. Where the sand beds are free of silt and clay they probably carry fresh water for a short distance downdip.

The Nash Creek Formation of Anderson (1960), which separates the Sandel from the overlying Catahoula Sandstone, is composed of silt, clay, and sand. The Nash Creek Formation does not yield water to wells in the two-county area.

Miocene(?) Series

Catahoula Sandstone

The Catahoula Sandstone, the youngest hydrologically significant formation, crops out in a narrow strip that more or less parallels the southern boundary of the two-county area. Much of the outcrop, though, is in Jasper and Newton Counties to the south. The Catahoula is primarily composed of beds of sand and clay. A clay bed more than 100 feet thick occurs at the top of the formation. Small amounts of pyroclastic and calcareous material are widely distributed. The Catahoula yields only small quantities of water to a few shallow dug wells in its sparsely populated outcrop area. However, in the southeastern corner of Sabine County, where the formation reaches a maximum thickness of about 450 feet, the Catahoula probably is capable of yielding moderate to large quantities of fresh to slightly saline water. Towards the west where both the width of the outcrop and thickness diminish, the formation will yield only moderate to small quantities of water. Downdip in the northern parts of Newton and Jasper Counties where the Catahoula is thicker it is generally capable of yielding large quantities of fresh to slightly saline water to properly constructed wells.

Quaternary System

Pleistocene and Recent Series

Alluvium

Terrace and flood-plain deposits occur along some of the larger streams and may thinly cap a few hills. The deposits are composed of gravel, sand, silt, and clay, and are not believed to exceed 50 feet in thickness. The alluvium is not an important aquifer in either of the two counties.

GROUND-WATER HYDROLOGY

General hydrologic principles have been described in considerable detail by Meinzer (1923a, 1923b, and 1932), Meinzer and others (1942), Tolman (1937), and by a number of other authors in the United States and elsewhere. The following discussion applies these principles to the ground-water hydrology of Sabine and San Augustine Counties.

Source and Occurrence of Ground Water

The source of ground water in Sabine and San Augustine Counties is precipitation on the outcrops of the aquifers, primarily in the two counties and in Shelby County to the north. Most of the precipitation, however, is evaporated either at the land surface or from the soil or is transpired by vegetation. Some of the precipitation runs off within a short time to gulfward-flowing streams. A relatively small remainder of the precipitation infiltrates the land surface and reaches the zone of saturation, thereby becoming ground water.

Ground water occurs under water-table and artesian conditions. Under water-table conditions the water is unconfined and does not rise in wells above the level at which it was first encountered. Under artesian conditions the water is confined under hydrostatic pressure in the sands between relatively impermeable beds, and where the elevation of the land surface at a well is considerably lower than the level of the outcrop of the aquifer, the pressure may be sufficient to cause water to rise in the well--possibly even high enough for the well to flow. Although the terms "water table" and "piezometric surface" are synonymous in the outcrops of the aquifers, the term piezometric surface as used in this report is applicable only in the artesian part of the aquifers.

The monoclinal coastward-dipping beds in the two-county area are ideally suited for the occurrence of both artesian and unconfined water. With the exception of the alluvium where ground water is unconfined, artesian conditions prevail downdip from the outcrops in all aquifers throughout the counties. Water-table conditions, however, are restricted to the outcrop of the aquifers.

Recharge of Ground Water

The natural and principal means of recharging the aquifers in the two-county area is precipitation. In general, the greater the precipitation on the outcrop of the aquifers, the greater the recharge. A larger proportion of the precipitation during the dormant or nongrowing season (from early November to late March) will reach the zone of saturation than during the season of active plant growth. The loamy sand and sandy soils that cover much of the area are highly receptive to infiltration of rainfall. Figure 5 indicates that severe droughts are rare, but every year or so part or all of the area experiences dry periods. These dry periods may occur even during years of above-average precipitation. On the average, however, precipitation is fairly well distributed throughout the year but is greatest in January, May, and December (Figure 6). Because rainfall is greatest in several of the winter months, which are largely times of vegetation dormancy, the winter season is most conducive to recharge.

The exact amount of recharge to the aquifers in the area is difficult to determine. Two main factors relating to the amount of recharge are the quantity of ground water being discharged to the streams as base flow and the quantity of water moving downdip through the aquifers. Base flow in the area was not

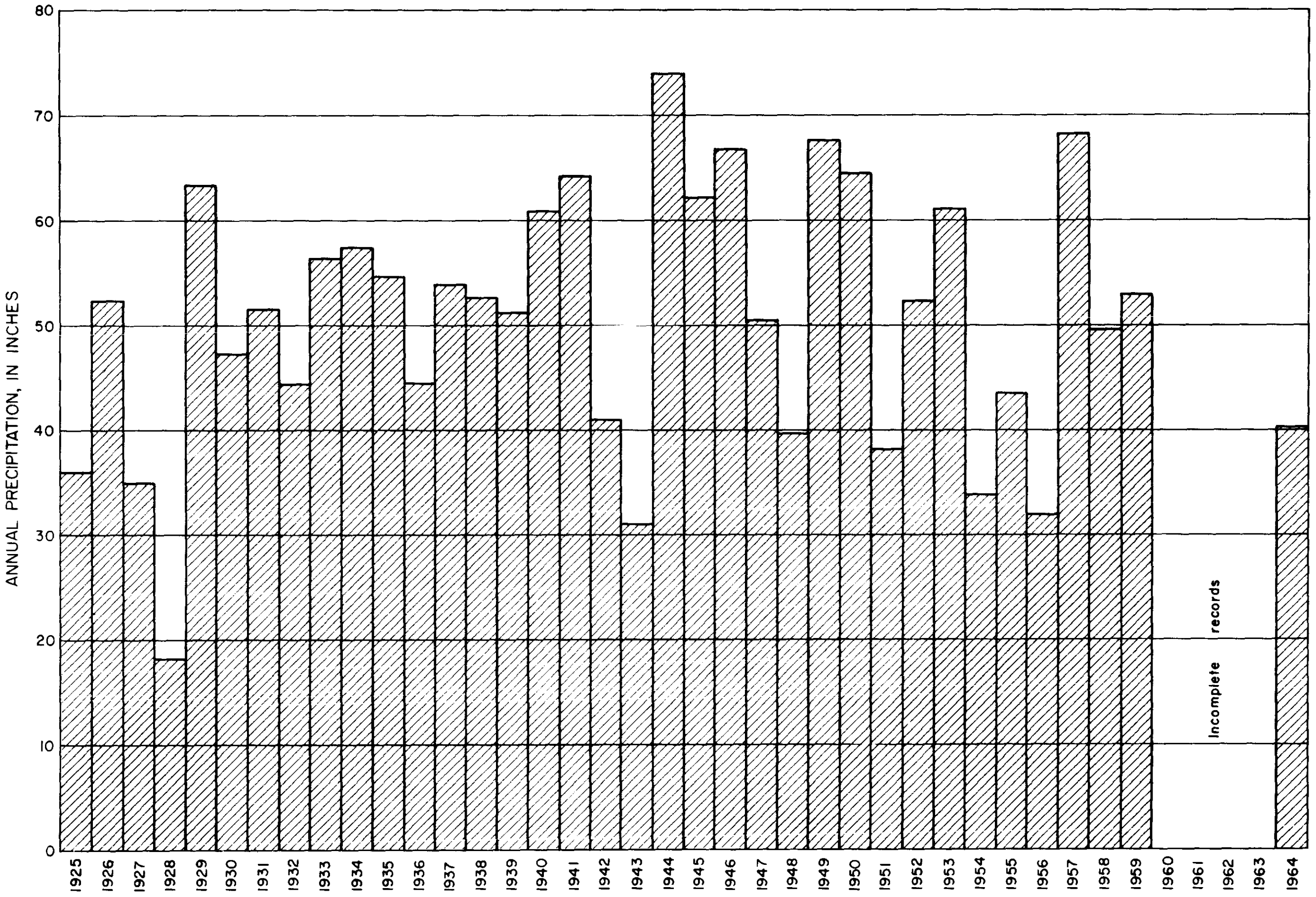


Figure 5

Annual Precipitation at Bronson, 1925-64

(From records of U.S. Weather Bureau)

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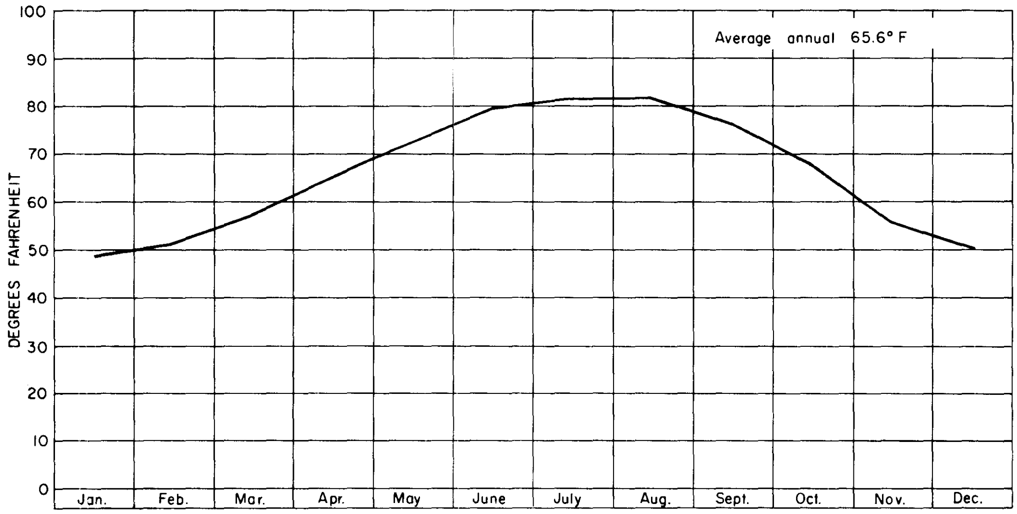
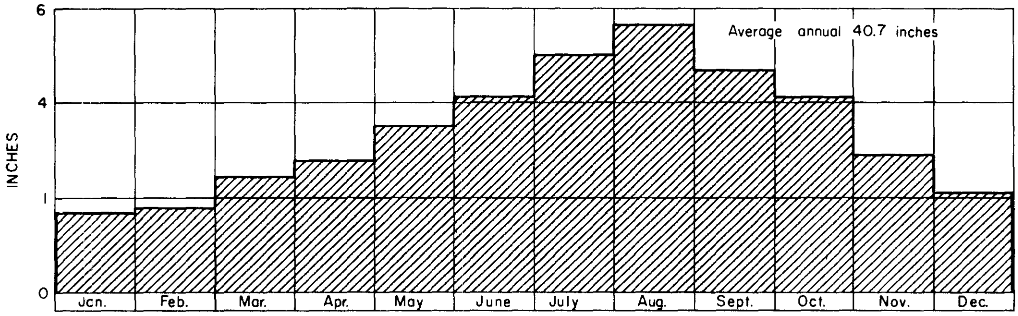
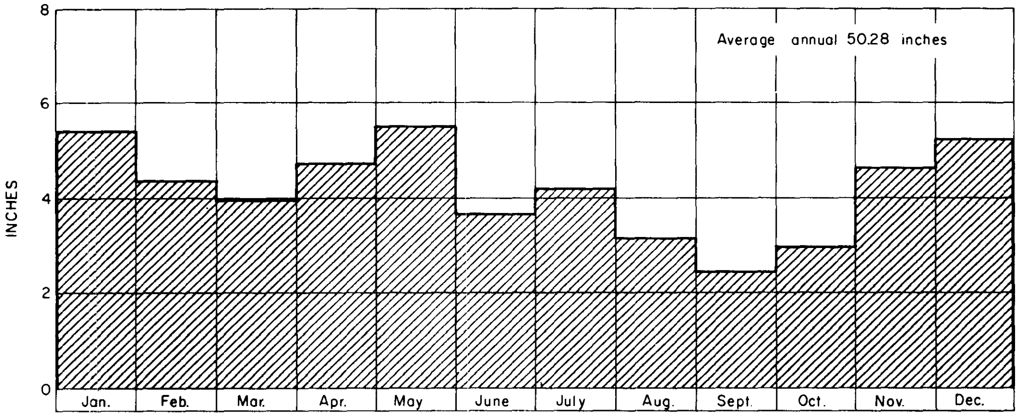


Average monthly temperature at Bronson, Texas, 1935-60



Average monthly gross lake surface evaporation in Sabine and San Augustine Counties 1940-57



Average monthly precipitation at Bronson, Texas, 1924-60

Figure 6

Average Monthly Precipitation and Temperature at Bronson and Average Monthly Gross Lake-Surface Evaporation in Sabine and San Augustine Counties

(From records of U. S. Weather Bureau and Lowry, 1960)

U.S. Geological Survey in cooperation with the Texas Water Development Board,
Sabine River Authority of Texas, and Sabine and San Augustine Counties

determined but is probably equal to one inch or more of annual precipitation on the outcrops of the aquifers. (See subsection entitled "Discharge of Ground Water" in this report.) The quantity of water moving downdip through the important aquifers in Sabine and San Augustine Counties into adjoining counties amounted to about 51,000 acre-feet per year, or 46 mgd (million gallons per day). (See section entitled "Availability of Ground Water" in this report.) This amount represents about 2 inches of annual precipitation that enters the outcrops and becomes ground water.

Movement of Ground Water

The ground water moves from areas of recharge to areas of discharge, gravity being the motivating force in the movement of the water. After initial infiltration the dominant direction of movement through the zone of aeration is vertical. After reaching the zone of saturation, the movement of the water generally has a large horizontal component in the direction of lower altitudes--that is, the water follows the same laws that govern streamflow.

The relatively small residue of water (derived from precipitation) that is not lost by one means or another moves downdip through the water-table part of the aquifer into the artesian part. In the two-county area, water that has entered the aquifer at a higher altitude and moved a considerable number of miles downdip--the exact distance depending upon the dip of the rocks, topography, transmissibility, and other factors--generally has a higher pressure head than water in the overlying sands. Hence, the deeper water moves upward into overlying sands even though the sands may be separated by thick beds of clay. Where beds of this type are present, such as in the Cane River Formation, the movement of water is extremely slow. Where the sands are separated by thinner clays or are locally connected, as in parts of the Wilcox Group, this movement is more rapid.

In the two-county area the velocity of the ground water, based on the natural undisturbed gradient, might be about 10 feet per year. Velocities vary, however, depending on the hydraulic gradient, permeability, porosity, and the temperature of the water at any locality. The ground water generally moves in the direction normal to the strike of the outcrops of the aquifers--that is, southward toward the Gulf of Mexico.

All fresh to slightly saline water underlying the two-county area is in transient storage, a constant state of movement; and the volume of water moving into the aquifers by replenishment is essentially offset by water moving out of the area through the aquifers or being discharged within the area.

Discharge of Ground Water

Ground water is discharged both naturally and artificially in Sabine and San Augustine Counties. The principal methods of natural discharge are transpiration by vegetation, seepage and spring flow to streams, and evaporation. Pumping and flowing wells represent artificial discharge.

Transpiration, chiefly by the forests of the area, probably represents a major means of natural discharge of ground water. The consumptive use of water by forests depends on various factors, such as the amount and distribution of rainfall, climate, topography, and type of trees. Determination of the quantity of ground water transpired by trees was beyond the scope of the report, but on the basis of studies in other areas this form of ground-water discharge in Sabine and San Augustine Counties could be a significant one.

Discharge of ground water to streams by seepage and spring flow in the outcrops of the aquifers reduces the quantity of ground water in storage. This discharge is water that enters the outcrops but, because the aquifers are so full, cannot move down the dip under present hydraulic gradients. Thus the water moves toward topographic lows in the outcrops and runs off. In Sabine and San Augustine Counties, the seepage and spring flow which are common along many of the creeks and streams sustain their flow even during periods of below-normal rainfall. In the Gulf Coast region, within the rainfall belt of 40 to 50 inches per year (annual precipitation in the two-county area is about 50 inches), probably 1 inch or more of the water that enters the outcrops of the aquifers is discharged to the streams in the outcrops as base flow (Wood, 1956, p. 30).

Evaporation in the study area consumes a significant amount of ground water. The average annual gross lake-surface evaporation is about 40.7 inches in Sabine and San Augustine Counties. Evaporation is greatest during the hot summer months when the soil-moisture demand to sustain plant life also is large (Figure 6). The 40.7 inches of annual evaporation is considerably greater than the actual evaporation from the soil. Nevertheless, the moisture evaporated from the soil decreased potential replenishment of ground water to the aquifers.

The withdrawal of ground water by pumping and flowing wells is only a small part of the total quantity of water discharged from the aquifers. In 1964 about 1,457 acre-feet, or 1.3 mgd, was withdrawn by wells in Sabine and San Augustine Counties.

Hydraulic Characteristics of the Aquifers

The value of an aquifer as a source of ground water relates principally to the ability of that aquifer to transmit and store water. Coefficients of transmissibility, permeability, and storage determined by aquifer tests are the measurements of that ability.

Data from three aquifer tests in the report area were utilized in appraising some of the hydraulic characteristics of the aquifers. Additional tests could not be made because well construction precluded measurements of water levels or because pumping conditions were not suitable for obtaining reliable results of tests. Two tests were made by personnel of the U.S. Geological Survey on two of the city of San Augustine wells producing from the Carrizo Sand and Wilcox Group; and another test, a recovery test on a well completed in 1951 in the Yegua Formation, utilized data obtained by the contractor who drilled the well. For the sections tested, the results showed transmissibilities of about 13,000 and 18,000 gpd (gallons per day) per foot for the Carrizo-Wilcox and Yegua, respectively. According to calculations, however, the Carrizo-Wilcox had a higher permeability than the Yegua, as the permeabilities were 280 and 220 gpd per square foot, respectively. On the basis of data obtained from tests of the city of San Augustine wells, the coefficient of storage of the Carrizo-Wilcox was 0.00006.

Extensive testing of the Carrizo Sand and Wilcox Group at the Southland Paper Mill in Nacogdoches County revealed permeabilities of 158, 281, and 213 gpd per square foot. The average of these permeabilities and that determined at San Augustine is about 230 gpd per square foot. On the basis of this permeability and an average sand thickness of 300 feet (Figure 11), the average transmissibility of the fresh to slightly saline water-bearing sands in the Carrizo Sand and Wilcox Group in the two-county area is about 70,000 gpd per foot. In the absence of extensive aquifer testing and if the wells tested screen only a small part of the aquifer, then transmissibilities determined by the above method are necessarily subject to error. This is because the average values of permeability may not apply to the average sand thicknesses.

The average permeability of the Sparta Sand in the two-county area was estimated from the results of testing in Brazos County, Texas, at the city of Bryan well field and at Bryan Air Force Base; in Smith County, at the city of Tyler; in Houston County; and in northern Louisiana. The locations of the test sites and permeabilities (in gpd per square foot) are: city of Bryan, 158, 210, 171, 129, 119, 81, and 138; Bryan Air Force Base, 146 and 200; city of Tyler, 250; Houston County (irrigation well), 120; and northern Louisiana, a range between 245 and 320 (Page and others, 1963, p. 81). On the basis of an average permeability of 200 gpd per square foot and an average sand thickness of 120 feet (Figure 12), the average transmissibility of the fresh to slightly saline water-bearing sands in the Sparta Sand is 24,000 gpd per foot.

The permeability of the Yegua Formation in the two-county area (determined at Pineland to be 220 gpd per square foot) roughly agrees with an assumption of 200 gpd per square foot in Vernon Parish, Louisiana, by Rogers and Calandro (1965, p. 18). On the basis of an average permeability of 200 gpd per square foot and an average sand thickness of 200 feet, the average transmissibility of the fresh to slightly saline water-bearing sands in the Yegua Formation is 40,000 gpd per foot.

The coefficients of transmissibility and storage may be used to predict future drawdowns of water levels in wells caused by pumping. Figure 7 shows the theoretical relation between drawdown and the distance from the center of pumping for the range of coefficients of transmissibility and storage most likely to apply to large-capacity wells in the report area; a theoretical line source of recharge to the aquifer was assumed to be 7 miles from the center of pumping. For example, if the coefficients of transmissibility and storage are 50,000 gpd per foot and 0.001, respectively, the drawdown or decline of the water level would be about 3 feet at a distance of 8,000 feet from a well or group of wells pumping 0.5 mgd (about 350 gpm) for 1 year. If the coefficients of transmissibility and storage are 5,000 gpd per foot and 0.0001, respectively, the same pumping rate for the same time would cause about 30 feet of drawdown at the same distance. Coefficients of transmissibility and storage smaller than 5,000 gpd per foot and 0.0001, respectively, are undoubtedly common; but only the larger capacity wells are likely to be tested and they probably will have values within the range of the curves.

Figure 8 shows the relation of drawdown to distance for various periods of time as a result of discharging 0.5 mgd from an aquifer having coefficients of transmissibility and storage of 15,000 gpd per foot and 0.0001, respectively. A theoretical line source of recharge 7 miles from the point of discharge was assumed. The graph shows that the rate of drawdown or decline of water levels decreases with time. For example, the drawdown or decline 1,000 feet from a

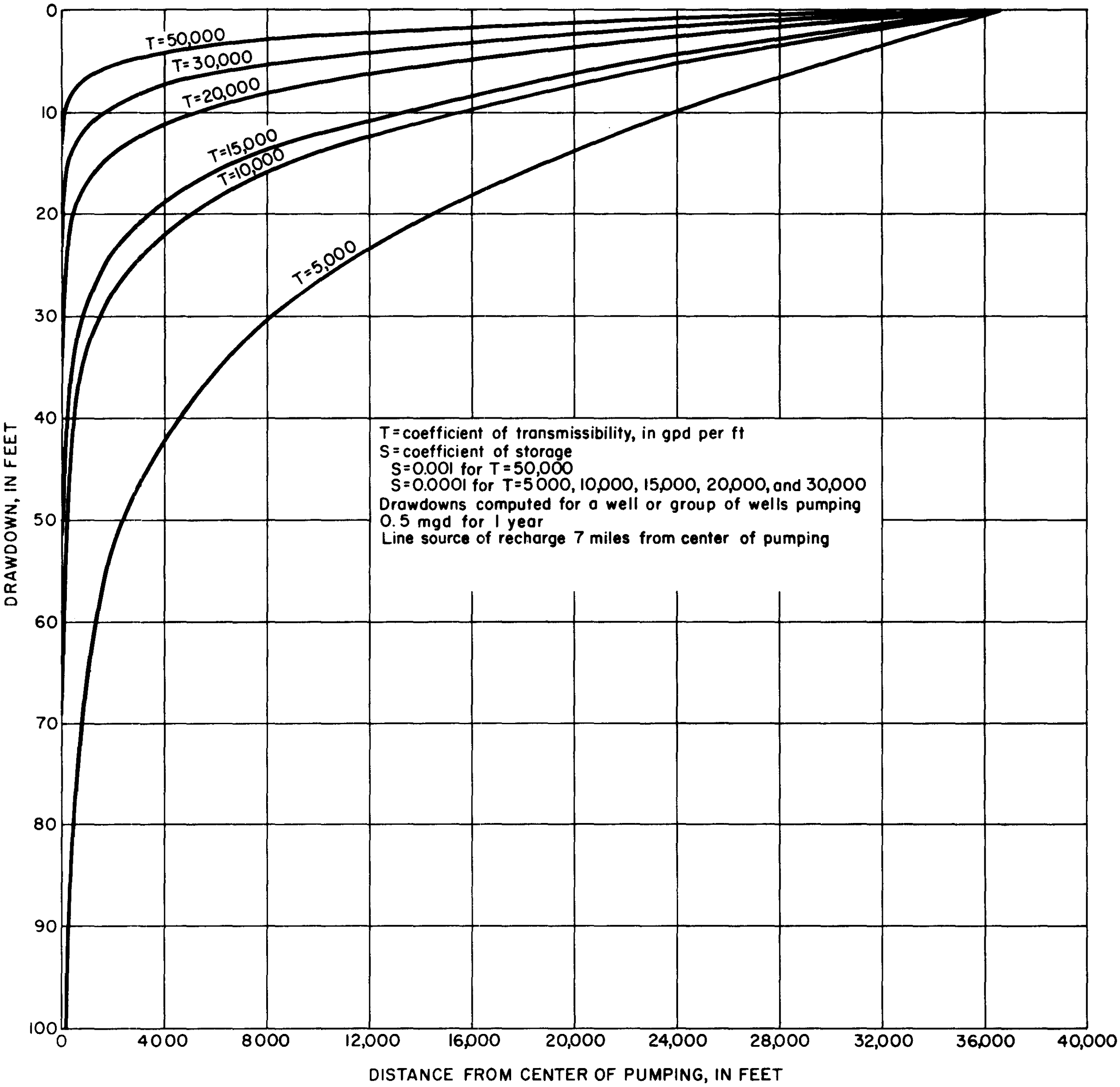


Figure 7

Relation of Drawdown to Distance for Various Coefficients of Transmissibility and Storage

U.S. Geological Survey in cooperation with the Texas Water Development Board, Sabine River Authority of Texas, and Sabine and San Augustine Counties

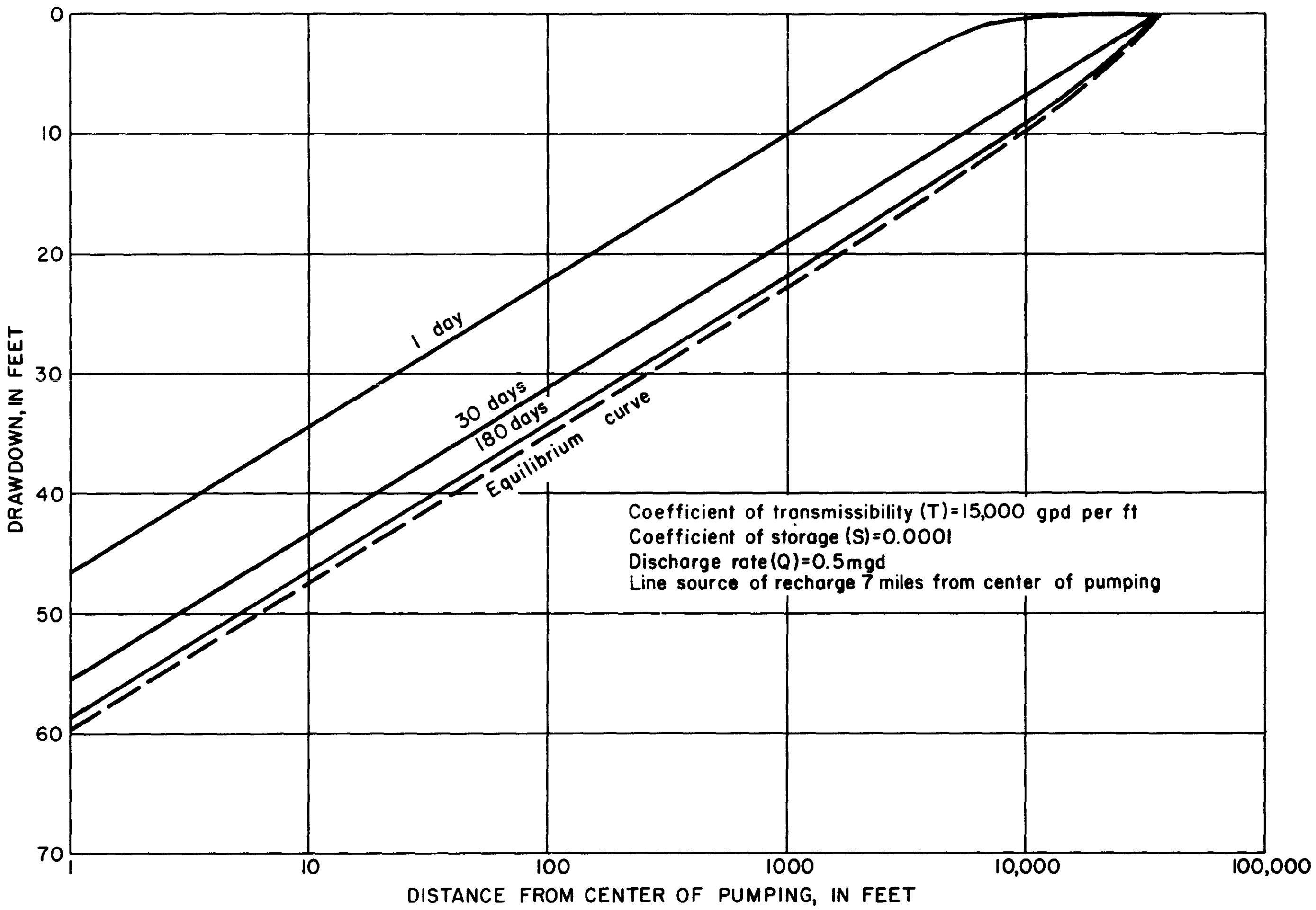


Figure 8

Relation of Drawdown to Distance for Various Periods of Time

U. S. Geological Survey in cooperation with the Texas Water Development Board,
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well would be 10 feet after 0.5 mgd had been pumped for 1 day; after 0.5 mgd had been pumped for 180 days, the drawdown would be about 22 feet. The drawdown after pumping for an unlimited extent of time would not exceed the values indicated by the equilibrium curve.

Wells drilled close together may create cones of depression that intersect. The total drawdown at any one place within the cone of depression or influence of several wells is the sum of their influence. The overlapping of cones of depression, or interference between wells, may cause a decrease in the yield of the wells and an increase in pumping costs.

One of the most meaningful ways in which the yield of wells is expressed is by the specific capacity: the number of gallons per minute a well will yield per foot of drawdown. Until the water level in the discharging well stops declining--that is, reaches an equilibrium--time is a factor; so the length of time the well has been discharging is generally given when reporting the specific capacity. Thus, a well discharging 100 gpm for 2 hours and having a drawdown of 25 feet has a 2-hour specific capacity of 4 gpm per foot.

Development of Ground Water

Records of 267 water wells, 14 springs, and 79 oil tests in the two-county area were used during the ground-water investigation (Table 6). The well inventory made included only a part of the total number of wells in the counties. Locations of the wells inventoried are shown in Figure 13.

The quantity of ground water used by municipalities for public supply and the quantity used for rural, domestic, and livestock purposes was about 0.80 mgd, or about 897 acre-feet in 1964. This quantity does not include an estimated 0.5 mgd or 560 acre-feet per year from flowing wells. About 0.45 mgd (508 acre-feet per year) was estimated to be used for rural domestic and livestock needs in 1964. A very small and insignificant amount of ground water is reported to be used for irrigation and industrial purposes.

Between 1955 and 1964, the withdrawals of ground water for municipal supply ranged from a maximum of about 0.46 mgd in 1958 to a minimum of about 0.23 mgd in 1961, 1962, and 1963 (Table 3). The cities of San Augustine and Hemphill obtain their municipal water supplies from surface-water reservoirs, San Augustine converting to surface water in 1961. San Augustine, however, maintains two standby wells. Pineland has used ground water for its municipal supply for a number of years, and Bronson began using ground water in 1964. About 27 percent of the ground water used in the two-county area in 1964 was for municipal supply.

Changes in Water Levels

Water levels in wells continuously respond to natural and artificial influences which act on the aquifers. In general, the major influences that control water levels are the rates of recharge to and discharge from the aquifer. Relatively minor changes are due to variations in atmospheric pressure and in load on aquifers. Fluctuations usually are gradual, but in some wells levels occasionally rise or fall several inches or even a few feet in a few minutes.

Table 3.--Municipal pumpage of ground water, 1955-64

Year	San Augustine		Pineland		Bronson		Totals	
	Mgd	Acre-ft/yr	Mgd	Acre-ft/yr	Mgd	Acre-ft/yr	Mgd	Acre-ft/yr
1955	0.27	298	0.01	6	0	0	0.27	304
1956	.35	393	.04	49	0	0	.40	442
1957	.36	402	.06	68	0	0	.42	470
1958	.36	399	.10	117	0	0	.46	516
1959	.22	252	.11	123	0	0	.33	375
1960	.26	288	.15	167	0	0	.41	455
1961	0	0	.23	258	0	0	.23	258
1962	0	0	.23	261	0	0	.23	261
1963	0	0	.23	261	0	0	.23	261
1964	0	0	.29	322	.06	67	.35	389

Figures are approximate because some of the pumpage is estimated. Figures are shown to nearest 0.01 mgd and to nearest acre-foot. Totals are rounded to two significant figures.

Water-level declines in water-table or artesian wells usually result from large withdrawals of water from wells or from a decrease in the amount of recharge to the aquifer. In shallow wells under water-table conditions and in some shallow artesian wells near the recharge area, water-level declines may be caused by drought or overpumping in the aquifer. Where artesian conditions prevail, water levels respond to increasing or decreasing hydrostatic pressures in the aquifer; but the change in the quantity of water in storage may be small.

The report area has a few deep wells in which water levels may be measured without causing considerable inconvenience to the well owners, such as the loss of their water supply for one or more hours. Because of the scarcity of water-level data in the drilled wells and because of the relatively steep dip of the beds, most of the water-level data available are from wells that do not tap the same sand bed. Hence, because water-level data for wells tapping the same sand beds were scarce throughout the area, maps showing either the elevations of water levels in wells tapping the major aquifers or the change in water levels could not be prepared.

Long-term records of consecutive annual measurements of water levels in Sabine and San Augustine Counties are not available, but on the basis of measurements made in 1942 and 1964, information on changes of water levels is afforded by several dug wells (under water-table conditions) in the area. The net change from 1942-64 in water levels measured in 10 wells (ranging in depth from 15 to 38 feet) ranged from a decline of 2.0 feet in well WT-37-32-109 tapping the Carrizo Sand and Wilcox Group to a decline of 11.2 feet in well WS-36-41-206 tapping the Yegua Formation. The average decline of water levels in the 10 wells was 6.3 feet. The causes of the declines in the water levels are not known because of an inadequate number of water-level measurements for each well. However, because these wells are very shallow and draw water from the water table, the declines of water levels are probably related to declines in the amount of recharge in the outcrop of the aquifers. Although precipitation in 1942 was essentially the same as in 1964, precipitation in 1940 and 1941 was about 20 inches greater than precipitation in 1962 and 1963 (determined at Spurger, about 50 miles south of Bronson). The deficiency in rainfall in the 2 years prior to 1964 may have contributed to the net declines of water levels in the outcrops.

Well Construction

Large-capacity wells completed in the aquifers underlying the two-county area have been drilled to furnish mostly municipal needs, whereas smaller-capacity wells are used to supply water for rural domestic and livestock needs.

Recently drilled municipal wells are underreamed, screened, and gravel packed. Underreaming enlarges the bore hole opposite the screened section to accommodate the gravel pack. The gravel packing increases the effective diameter of the well, aids in preventing the entrance of sand into the well, and protects the casing from caving of the surrounding formation. A few of the earlier drilled municipal and some industrial wells were completed without gravel packing.

Rural domestic and livestock wells are drilled, bored, or dug; and their capacity is generally small. Most of the wells are equipped with small jet pumps. The shallow dug well penetrates no more than a few feet into the zone of saturation and requires little or no casing. Bored wells, and some drilled wells, are cased nearly to the bottom of the hole and have neither screen nor slotted casing in their construction. Accordingly such wells are termed "open-end" wells. In a well of this type, the ground-water intake is restricted because the bottom opening of the casing is small in area. Therefore, in wells from which larger yields are needed, torch-slotted casing, perforated casing, or screen is installed or else the well is equipped with larger jet pumps or submersible pumps.

The problem of sand being pumped by a well may be avoided by proper well construction. The sand is pumped by some wells because a loose, very fine- to fine-grained sandy texture characterizes some of the aquifers. Sand-pumping reduces the effective life of most pumps, especially submersible pumps. A properly gravel-packed screen will greatly reduce the sand intake and thus lengthen pump life.

QUALITY OF GROUND WATER

Source and Significance of Chemical Constituents and Properties of Water

The chemical constituents in the fresh and slightly saline ground water underlying Sabine and San Augustine Counties are derived principally from the solution of material in the soil and rocks and in some degree from the atmosphere and plants. The differences in the chemical character of the water reflect, at least to some extent, the types of soil and rock that have been in contact with the water. Usually, as the water moves deeper, the chemical content increases by dissolving the rocks through which it moves, by removal of salts held by molecular forces, or by mixing with more concentrated waters. The source and significance of mineral constituents and properties commonly found in water are summarized in Table 4, which is modified from Doll, Meyer, and Archer (1963, p. 39-43).

Suitability of Water for Various Uses

The major factors affecting the use of a water supply for a given purpose are the amount and kind of minerals the water contains. A number of water-quality requirements have been set up to serve as guides in determining the suitability of water for various uses. These guides cover chemical constituents, bacterial content, and physical characteristics (such as temperature, odor, color, and turbidity). The bacterial content and physical characteristics can usually be controlled relatively economically, but the removal of most undesirable chemical constituents can be difficult and expensive.

Table 5 summarizes 284 chemical analyses from 263 wells and springs in Sabine and San Augustine Counties (Table 8) from various ground-water units and compares them with standards recommended by the U.S. Public Health Service and other authorities.

Table 4.--Source and significance of dissolved-mineral constituents and properties of water (Modified from Doll, Meyer, and Archer, 1963, p. 39-43)

Constituent or property	Source or cause	Significance
Silica (SiO_2)	Dissolved from practically all rocks and soils, commonly less than 30 ppm. High concentrations, as much as 100 ppm, generally occur in highly alkaline waters.	Forms hard scale in pipes and boilers. Carried over in steam of high-pressure boilers to form deposits on blades of turbines. Inhibits deterioration of zeolite-type water softeners.
Iron (Fe)	Dissolved from practically all rocks and soils. May also be derived from iron pipes, pumps, and other equipment.	On exposure to air, iron in ground water oxidizes to reddish-brown precipitate. More than about 0.3 ppm stains laundry and utensils reddish brown. Objectionable for food processing, textile processing, beverages, ice manufacture, brewing, and other processes. Large quantities cause unpleasant taste and favor growth of iron bacteria.
Calcium (Ca) and Magnesium (Mg)	Dissolved from practically all soils and rocks, but especially from limestone, dolomite, and gypsum. Calcium and magnesium are found in large quantities in some brines. Magnesium is present in large quantities in sea water.	Cause most of the hardness and scale-forming properties of water; soap consuming (see hardness). Waters low in calcium and magnesium desired in electroplating, tanning, dyeing, and in textile manufacturing.
Sodium (Na) and Potassium (K)	Dissolved from practically all rocks and soils. Found also in oil-field brines, sea water, industrial brines, and sewage.	Large amounts, in combination with chloride, give a salty taste. Moderate quantities have little effect on the usefulness of water for most purposes. Sodium salts may cause foaming in steam boilers and a high sodium content may limit the use of water for irrigation.
Bicarbonate (HCO_3) and Carbonate (CO_3)	Action of carbon dioxide in water on carbonate rocks such as limestone and dolomite.	Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium decompose in steam boilers and hot-water facilities to form scale and release corrosive carbon dioxide gas. In combination with calcium and magnesium, cause carbonate hardness.
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Commonly present in some industrial wastes.	Sulfate in water containing calcium forms hard scale in steam boilers. In large amounts, sulfate in combination with other ions gives a bitter taste to water and a laxative effect.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage, and found in large amounts in oil-field brines, sea water, and industrial brines.	In large amounts in combination with sodium, gives salty taste to drinking water. In large quantities, increases the corrosiveness of water.
Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils. Added to many waters by fluoridation of municipal supplies.	Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of enamel calcification. However, it may cause mottling of the teeth, depending on the concentration of fluoride, the age of the child, amount of drinking water consumed, and susceptibility of the individual (Maier, 1950).
Nitrate (NO_3)	Decaying organic matter, sewage, fertilizers, and nitrates in soil.	Concentration much greater than the local average may suggest pollution. Nitrate has been shown to be helpful in reducing intercrystalline cracking of boiler steel. It encourages growth of algae and other organisms which produce undesirable tastes and odors.
Boron (B)	A minor constituent of rocks and of natural waters.	An excessive boron content will make water unsuitable for irrigation.
Dissolved solids	Chiefly mineral constituents dissolved from rocks and soils.	For many purposes the dissolved-solids content is a major limitation on the use of water.
Hardness as $CaCO_3$	In most waters nearly all the hardness is due to calcium and magnesium. All of the metallic cations other than the alkali metals also cause hardness.	Consumes soap before a lather will form. Deposits soap curd on bathtubs. Hard water forms scale in boilers, water heaters, and pipes. Hardness equivalent to the bicarbonate and carbonate is called carbonate hardness. Any hardness in excess of this is called non-carbonate hardness.
Sodium-adsorption ratio (SAR)	Sodium in water.	A ratio for soil extracts and irrigation waters used to express the relative activity of sodium ions in exchange reactions with soil (U.S. Salinity Laboratory Staff, 1954, p. 72, 156). Water with high SAR values may cause soil damage.
Residual sodium carbonate (RSC)	Sodium and carbonate or bicarbonate in water.	As calcium and magnesium precipitate as carbonates in the soil, the relative proportion of sodium in the water is increased. Water with RSC values in excess of 2.5 may cause soil damage.
Specific conductance (micromhos at 25°C)	Mineral content of the water.	Indicates degree of mineralization. Specific conductance is a measure of the capacity of the water to conduct an electric current. Varies with concentration and degree of ionization of the constituents.
Hydrogen ion concentration (pH)	Acids, acid-generating salts, and free carbon dioxide lower the pH. Carbonates, bicarbonates, hydroxides, phosphates, silicates, and borates raise the pH.	A pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote increasing alkalinity; values lower than 7.0 indicate increasing acidity. The pH is a measure of the activity of the hydrogen ions. Corrosiveness of water generally increases with decreasing pH. However, excessively alkaline waters may also attack metals.

Table 5.--Comparison of quality of ground water in Sabine and San Augustine Counties with standards recommended by the U.S. Public Health Service (1962, p. 7-8) and other authorities

[Chemical constituents in parts per million (ppm)--except specific conductance, sodium-adsorption ratio (SAR), and residual sodium carbonate (RSC)]

	Criteria for public and domestic supply								Criteria for irrigation			
	Silica (SiO_2)	Iron[a/] [b/] (Fe)	Sulfate (SO_4)	Chloride[b/] (Cl)	Fluoride (F)	Nitrate[b/] (NO_3)	Dissolved solids	Hardness as $CaCO_3$	Specific conductance[b] (micromhos at 25°C)	SAR	RSC	Boron
Upper limits[c/]	20	0.3	250	250	1.0	45	500	60	2,250	14	2.5	1.0

Number of determinations

	Total	Over 20 ppm	Total	Over 0.3 ppm	Total	Over 250 ppm	Total	Over 250 ppm	Total	Over 1.0 ppm	Total	Over 45 ppm	Total	Over 500 ppm	Over 1,000 ppm	Total	Over 60 ppm	Total	Over 2,250	Total	Over 14	Total	Over 2.5	Total	Over 1.0
All wells	33	13	83	31	153	12	285	12	56	5	160	23	118	39	11	282	75	184	9	19	12	125	64	5	1
Carrizo Sand and Wilcox Group	11	1	36	22	52	1	95	3	20	2	46	6	35	11	4	95	23	65	1	6	3	52	19	1	0
Sparta Sand	8	4	10	2	25	1	44	2	7	2	18	1	19	7	2	44	13	30	1	4	3	22	13	1	0
Yegua Formation	11	7	17	4	43	6	77	4	17	1	37	5	34	17	4	77	22	49	2	6	4	39	26	2	1
Other formations	3	1	24	3	33	4	69	3	12	0	59	11	30	4	1	66	17	40	5	3	2	12	6	1	0

[a/] Iron in solution at time of analysis or at time of sampling.
[b/] Includes field determinations.
[c/] See section entitled "Quality of Ground Water" in this report.

Public Supply

The U.S. Public Health Service has established standards of drinking water for use on common carriers engaged in interstate commerce. These standards are periodically revised as more information becomes available. The limitations set by the standards are designed to protect the public from exposure to digestively disturbing, unpalatable, unsightly, or poisonous water. The standards suggest that constituents should not be present in a water supply in excess of listed concentrations if more suitable supplies are, or can be made, available at reasonable cost. Many of the constituents for which standards have been set are not normally determined in routine water analyses, either because previous work has indicated that undesirable amounts of these constituents are normally not present in drinking water or because of the combination of this with the high cost of analysis. Below is a partial list of chemical standards adopted by the U.S. Public Health Service (1962, p. 7-8) including those constituents that are in the analyses in the two-county area:

Substance	Concentration (parts per million)
Iron	0.3
Sulfate	250
Chloride	250
Fluoride	1.0*
Nitrate	45
Dissolved solids	500

* Based on the annual average of maximum daily air temperatures (78.3°F) for the town of Bronson, the recommended control limits of fluoride concentration in ppm are: lower, 0.7; optimum, 0.8; and upper, 1.0.

Excessive iron in water is one of the chief water-quality problems in the counties. The minimum concentration of iron found was 0.02 ppm (parts per million) in well WS-36-49-102 (depth 597 feet) tapping the Yegua Formation, and the maximum was 35 ppm in well WT-37-31-602 (depth 271 feet) tapping the Carrizo Sand and Wilcox Group. Iron concentrations exceeded 0.3 ppm in slightly more than one-third of all samples. Of the 36 iron determinations in Sabine County and the 47 determinations in San Augustine County, the iron concentrations found in 6 of the former and 25 of the latter exceeded the limit set by the U.S. Public Health Service. The Carrizo Sand and Wilcox Group had the highest percentage (about 60 percent) of water samples containing more than 0.3 ppm iron; the Yegua Formation had about 25 percent containing more than 0.3 ppm; and the Sparta Sand had only about 20 percent.

Figure 9 shows the concentration of iron in ground water in various aquifers in the two-county area and its relation to depth of occurrence. Most of the water containing less than 0.3 ppm of iron came either from relatively shallow wells or relatively deep wells. The relatively shallow wells produce water containing sufficient oxygen to precipitate iron, and the relatively deep wells produce from a zone of reduction where iron has a low solubility. Wells intermediate in depth produce water from a chemically unstable zone having a high content of soluble iron in the water. Fortunately iron may be partially or completely removed from water by filter systems which are commercially available.

Sulfate is not a significant problem in the two-county area. The minimum concentration of sulfate in the analyzed samples was 0.0 ppm in several wells, and the maximum was 970 ppm in well WS-36-49-702 (depth 278 feet) tapping the Jackson Group. Of 153 samples analyzed for sulfate, only 12 contained more than 250 ppm. Of the major water-bearing formations, the Yegua Formation had the highest percentage of samples (14 percent) containing sulfate in excess of 250 ppm.

Of the 285 chloride determinations, in only 12 did the concentration exceed 250 ppm. The minimum concentration of chloride in the analyzed samples was 0.0 in several wells, and the maximum was 15,050 ppm in well WS-36-35-403 (depth 3,012 feet) tapping the Carrizo Sand and Wilcox Group. However, this well produces from below the base of fresh to slightly saline water.

The upper limit of fluoride for an area varies with the annual average maximum daily air temperatures. On the basis of the annual average of maximum daily air temperatures at Bronson (78.3°F), fluoride in the water should not average more than 1.0 ppm. Fluoride in average concentrations greater than 1.6 ppm constitutes grounds for rejection of the water supply by the U.S. Public Health Service. Fluoride in optimum concentration (0.8 ppm) in drinking water may reduce the incidence of tooth decay if the consumer uses the water during the early period of enamel calcification (Dean, Arnold, and Elvove, 1942, p. 1155-1179; Dean and others, 1941, p. 761-792). Excessive concentrations may cause teeth to become mottled. Of the 56 samples analyzed for fluoride, 37 had concentrations of 0.7 ppm or less, and only 5 had concentrations exceeding 1.0 ppm. The minimum concentration of fluoride in the analyzed samples was 0 from well WT-37-48-201 (depth 26 feet) tapping the Yegua Formation, and the maximum concentration was 1.7 ppm in well WS-36-41-301 (depth 388 feet) tapping the Sparta Formation.

Water containing more than about 45 ppm nitrate may be dangerous for infant feeding. Maxcy (1950, p. 271) has related water containing more than 45 ppm nitrate to the incidence of infant cyanosis (methemoglobinemia or "blue baby" disease). Of 160 nitrate concentrations determined, 23 exceeded 45 ppm. Nitrate ranged from a low of 0.0 in many wells to a high of 300 ppm in well WT-37-48-202 (depth 15 feet) tapping the Yegua Formation.

Nitrate is considered the oxidation product of nitrogenous matter. The presence in water of nitrate in concentrations of more than a few parts per million may indicate past or present contamination by sewage or other organic matter (Lohr and Love, 1954, p. 10). Other organic matter in Sabine and San Augustine Counties includes lignite, which is present in significant quantities in most of the rocks underlying the area, nitrogenous plants, or nitrogen-forming bacteria. Although no chemical analyses of the lignite are available, analyses of lignite from Eocene rocks in other areas show that they contain nitrogen compounds, some of which may be the source material for nitrates in water (Hanway and others, 1963, p. 10).

Figure 9 shows the concentration of nitrate in ground water from many shallow dug wells and from a few deeper drilled or bored wells tapping the aquifers. The shallow dug wells, in general, yielded water containing higher nitrate concentrations than did the deeper drilled wells, but there were some exceptions. The source of the nitrate concentrations in some of the deeper drilled wells is not definitely known although casing deterioration or improper well construction may permit the entry of contaminated shallow water.

A major influence or limitation in the general use of ground water is the dissolved-solids content. It is a measure of the total mineral constituents dissolved in the water and is important because water with a high mineral content generally has an undesirable taste, may act as a laxative, and is generally undesirable for use in industry and agriculture. In this report the classification of water is based on the dissolved-solids content as outlined by Winslow and Kister (1956, p. 5; see quality descriptions in section entitled "Definition of Terms").

Electric logs were used to estimate the base of fresh to slightly saline water by careful interpretation of the resistivity and self-potential curves. Although the interpretations are based primarily on specific principles, considerable experience and judgment are also necessary. The interpretations are more accurate if the results are checked with chemical analyses of water from some of the logged sands. A few checks were available in the report area, although more would be desirable in key areas to substantiate the interpretations used to construct some of the maps and part of all cross sections.

In general, thick or very permeable sands will contain fresh to slightly saline water farther downdip, and hence to greater depths, than will thinner or less permeable sands. The altitude and general configuration of the base of the fresh to slightly saline water (Figures 10, 14, 15, and 16) reveal that the deepest fresh to slightly saline water is in the Wilcox Group in northwestern San Augustine County, and in the Sparta Sand in southern Sabine and San Augustine Counties near Pineland.

Water containing more than 500 ppm dissolved solids is undesirable for drinking and many industrial uses. Of the 118 dissolved-solids concentrations determined, 39 exceeded 500 ppm and 11 exceeded 1,000 ppm. The minimum concentration was 15 ppm in well WS-36-35-101 (depth 20 feet) tapping the Carrizo Sand and Wilcox Group, and also 15 ppm in spring WT-37-31-101 likewise in the Carrizo Sand and Wilcox Group. The maximum concentration was about 25,000 ppm in well WS-36-35-403 (depth 3,012 feet) also tapping the Carrizo Sand and Wilcox Group. The largest percentage of samples exceeding 500 ppm were from the Yegua Formation.

Calcium and magnesium are the principal causes of hardness in water. Hardness is responsible not only for increased soap consumption and the attendant precipitate (the common bathtub ring), but also for inducing the formation of scale in boilers and other objects in which water is heated as well as in the pipes through which the hot water may pass.

Commonly accepted standards and classifications of water hardness are:

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

Ground water that contains moderate quantities of dissolved material may change from hard to soft by ion-exchange reactions in passage through sediments. In the report area, water that contains calcium and magnesium in the outcrop moves downdip and may contain little or no calcium or magnesium at depth. Sodium and bicarbonate are the principal constituents of the deeper fresh water, whereas calcium or magnesium and bicarbonate generally characterize the relatively shallow water.

Of the 282 values for hardness reported in Table 8, approximately 27 percent exceeded 60 ppm. Hardness exceeded 60 ppm in about 25 percent of the water samples from the principal aquifers. The minimum hardness was 0 ppm in well WT-37-39-901 (depth 210 feet) tapping the Sparta Sand, and the maximum was 1,194 ppm in well WT-37-48-201 (depth 26 feet) tapping the Yegua Formation.

Hardness in water may be reduced by water-softening systems commercially available. As large volumes of excessively hard water are relatively expensive to soften, a common practice is to have separate water-distributing systems for treated and untreated water. Thus, water used for lawn or garden irrigation and for sanitary purposes where hardness is not significant may bypass the water-softening system.

Industrial Use

The quality requirements for industrial water range widely, and almost every industrial application has different standards. Because of the wide variations of chemical-quality standards for industrial water, only facts and interpretations of a general nature that can be further studied by those who have special requirements are discussed.

In general, temperature and chemical quality of water are the most significant factors in judging the suitability of a water for most industrial uses. In Sabine and San Augustine Counties, the temperature of ground water increases about 1°F for every 85 feet of depth; the temperature of near-surface ground water is about 66°F.

Table 5 lists 20 ppm as the upper limit for silica in boiler feed water if boiler pressures are as much as 250 pounds per square inch. In the samples analyzed, the minimum concentration of silica was 12 ppm in well WS-36-34-202 (depth 392 feet) tapping the Carrizo Sand and Wilcox Group and in well WS-36-41-301 (depth 388 feet) tapping the Sparta Sand, and the maximum was 56 ppm in well WS-36-49-102 (depth 597 feet) tapping the Yegua Formation. In slightly more than one-third of all samples the silica concentration exceeded 20 ppm. Of the major water-bearing units, the Carrizo Sand and Wilcox Group had the lowest percentage of samples containing more than 20 ppm, and the Yegua Formation had the highest percentage.

Other factors significant for many industrial uses, such as concentrations of iron, dissolved solids, and hardness in ground water, have been discussed in the subsection on suitability of water for public supply.

Irrigation

The suitability of water for irrigation is determined by a number of factors, among the more important of which are: the chemical characteristics of the water; the permeability of the soil and subsoil; the slope of the land surface; the amount, frequency, and duration of rainfall; the quantity of water used; and the type of crop grown. In general, water of poor quality may be satisfactory for irrigation where the soil is well drained, permeable, and adequately leached by sufficient water from rainfall or irrigation.

The chemical characteristics of water that relate specifically to irrigation are specific conductance, SAR (sodium-adsorption ratio), RSC (residual sodium carbonate), and boron. Water becomes less suitable for irrigation as the salinity (dissolved-solids content) or specific conductance, SAR, RSC, and boron increase. The following discussion offers criteria for a general evaluation of the suitability of ground water for irrigation.

The U.S. Salinity Laboratory Staff (1954, p. 69-82) proposes a classification that commonly is used for judging the quality of a water for irrigation. Briefly the classification bases the suitability of irrigation water on the salinity hazard as measured by the specific conductance of the water and on the sodium hazard as measured by the SAR. Generally, water is safe for supplemental irrigation, according to Wilcox (1955, p. 16), if its conductivity is less than 2,250 micromhos per centimeter at 25°C and its SAR is less than 14; because the annual rainfall in the two-county area averages about 50 inches, most irrigation would be supplemental.

The specific conductance exceeded 2,250 micromhos in only 9 of 184 samples. The minimum value was 42 micromhos in well WT-37-32-402 (depth 170 feet) tapping the Carrizo Sand and Wilcox Group, and the maximum was 5,120 micromhos in well WS-36-49-701 (depth 460 feet) tapping the Jackson Group. In only one sample each from the Carrizo Sand and Wilcox Group and the Sparta Sand and in only two samples from the Yegua Formation did the specific conductance exceed 2,250 micromhos. The specific conductance in micromhos per centimeter at 25°C is about 1½ times the dissolved-solids content in parts per million, although this ratio varies to some extent depending upon the amount and type of dissolved constituents.

The upper limit of the SAR for supplemental irrigation is 14. Of the 19 values calculated for SAR, 12 exceeded 14. The minimum SAR was 1.1 in well WS-36-49-704 (depth 23 feet) tapping the Jackson Group, and the maximum was

139 in well WS-36-43-701 (depth 405 feet) tapping the Yegua Formation. In the major water-bearing units, from 50 to 75 percent of the SAR values exceeded the upper limit. Excessive SAR may be expected in relatively deep ground water in the area.

The suitability of water for irrigation is also determined by the RSC. Wilcox (1955, p. 11) reports that water containing more than 2.5 epm (equivalents per million) RSC is undesirable for irrigation, 1.25 to 2.5 epm RSC is marginal, and less than 1.25 epm RSC probably is safe. Water from many of the wells in the two-county area has no RSC. The maximum was 24.9 epm in well WS-36-34-203 (depth 410 feet) tapping the Carrizo Sand and Wilcox Group. RSC exceeded 2.5 epm in about half of the samples tested. Of the major aquifers, the Carrizo Sand and Wilcox Group had the lowest percentage (37 percent) of samples exceeding 2.5 epm.

Boron is also significant in evaluating irrigation water. Although boron is essential to normal plant growth, the required amount is very small and excesses are injurious to some plants. Wilcox (1955, p. 11) suggests that a permissible boron concentration for irrigating boron-sensitive crops can be as much as 1.0 ppm and for boron-tolerant crops as much as 3.0 ppm. In the five samples tested, only one contained more than 1.0 ppm boron. The minimum concentration of boron was 0.04 ppm in well WS-36-49-704 (depth 23 feet) tapping the Jackson Group, and the maximum was 1.7 ppm in well WT-37-55-204 (depth 295 feet) tapping the Yegua Formation.

Deductions Concerning Chemical Quality of Ground Water

As shown by the chemical analyses (Table 8), the quality of water from wells in Sabine and San Augustine Counties varies widely in total solids and in the proportion of the constituents to each other. The analyses further indicate that, with two exceptions, the quality of ground water in the study area cannot be reliably given in general statements. The first exception is that water from most of the shallow dug wells is relatively low in dissolved solids, including iron. The second is that water obtained from relatively deep wells is higher in dissolved solids, RSC, and SAR, and probably relatively low in iron and hardness. The quality of water from wells of intermediate depth ranges widely and is unpredictable.

In summary, ground water of good chemical quality suitable for public supply, irrigation, and many industrial needs is generally obtainable from the major aquifers in Sabine and San Augustine Counties.

Bacteriological Contamination

The high nitrate content of water from several shallow dug wells suggested that they might be contaminated, possibly with bacteria, some of which could make the water dangerous to drink unless it was first boiled or otherwise treated. Water samples whose nitrate content ranged from 0 to 201 ppm were obtained from six dug wells to determine: if the samples contained bacteria; if a relationship existed between nitrate and bacteria; and if a change occurred in the bacteria and nitrate content after the well was pumped long enough to replace an appreciable quantity of the water in the well with additional formation water. Analyses of the samples by the city of Houston Health Department's Bacteriological Laboratory showed that water from all six wells was contaminated with coliform bacteria, three wells dangerously so. The results of the bacteria and nitrate analyses were nevertheless inconclusive in establishing a statistical relationship between nitrate and bacteria; in fact, the sample having the third highest bacteria count was free of nitrate. The results of these analyses are significant, however, in indicating that probably most of the dug wells in the report area are contaminated by bacteria and many are a potential health menace.

Bacterial contamination can be minimized: (1) by sealing the well to prevent surface water and contaminated shallow ground water from seeping into the well; (2) by sealing the part of the well above ground to prevent small animals and other forms of life from falling into the well; and (3) by making certain that wells are uphill from any possible source of contamination from human or animal waste in septic tanks or barnyards.

Bacteria already in the well can be reduced in number or eliminated by periodically treating the well with household (chlorine) bleach. A gallon of bleach is poured into the well and allowed to remain for about 1 hour after which 10 or 20 gallons of water are added to force the bleach behind the casing. The well is then allowed to stand idle for 4 or 5 hours or preferably overnight before it is pumped to remove the bleach. A good practice is to discharge the well containing bleach through the various faucets in the house to clear the pipes of bacteria. All dug wells should be checked periodically for bacteria.

AVAILABILITY OF GROUND WATER

The ground-water resources of Sabine and San Augustine Counties are practically untapped. Of the water available in the aquifers, only a small quantity is currently being used. The principal aquifers are in the Carrizo Sand and Wilcox Group, the Sparta Sand, and the Yegua Formation. Other aquifers or water-bearing units in the county are relatively unimportant because they are small either in areal extent or in sand thickness. The isopachous maps (Figures 11 and 12) which show the thickness of sand containing fresh to slightly saline water in the Carrizo Sand and Wilcox Group and in the Sparta Sand are useful in indicating areas most favorable for developing large ground-water supplies, as areas of relatively thick sands generally yield relatively large quantities of ground water.

The exact quantity of water available from the principal aquifers is difficult to determine. It depends upon the potential rate of recharge to the aquifers, the ability of the aquifers to transmit water, and the quantity of ground water in transient storage. In this report two values are given for the quantity of ground water that is suitable for municipal use as well as for use by most industries and that is perennially available from each of the principal aquifers in the counties. The first value (a minimum value) is the quantity of water currently moving through the aquifer under the present hydraulic gradient. Not included, therefore, in this value, is water which may be salvaged from present evapotranspiration and rejected recharge on the outcrop. The second value is based on: (1) a theoretical line of pumping wells extending the width of the counties parallel to the outcrop of the aquifer, and spaced midway between the outcrop and the downdip limit of fresh to slightly saline water; and (2) pumping lifts not exceeding 400 feet but otherwise in proportion to the potential quantity of water which may be transmitted to the line of pumping wells without exceeding an assumed potential rate of recharge to the aquifer.

The quantity of water perennially available from the Carrizo Sand and Wilcox Group ranges from about 27 mgd (million gallons a day) to possibly as much as 78 mgd. The estimate of the minimum value of 27 mgd, or 31,000 acre-feet per year, was based on the present hydraulic gradient of about 10 feet per mile. The maximum value was based on a theoretical northwesterly-trending line of pumping wells about 2 miles north of San Augustine. At a gradient established by pumping lifts of 400 feet along the line of discharge the Carrizo Sand and Wilcox Group would transmit 78 mgd, or about 87,000 acre-feet per year. The amount of recharge necessary to replace this water was difficult to determine because the effective area of recharge to the two-county area is not known. However, if the Wilcox in about the eastern three-fourths of Shelby County effectively recharges the aquifer in the two-county area, 78 mgd would be equivalent to about 3 inches of water per year on the outcrop.

The thickness of sand containing fresh to slightly saline water in the Carrizo Sand and Wilcox Group (Figure 11) ranges from 0 feet at the downdip limit of fresh to slightly saline water to at least 650 feet immediately south of the outcrop in northern San Augustine County. In areas of relatively thick sand, properly constructed wells screening all available sand in the Carrizo Sand and Wilcox Group may yield in excess of 1,500 gpm (gallons per minute).

The quantity of water available from the Sparta Sand ranges from about 6.4 mgd to possibly as much as 29 mgd. The minimum value of 6.4 mgd or about 7,200 acre-feet per year was based on the present hydraulic gradient of about 7 feet per mile. The maximum value of 29 mgd was based on a theoretical westerly-trending line of pumping wells extending through Hemphill. At a gradient established by pumping lifts of 200 feet along the line of discharge the Sparta Sand would transmit about 29 mgd or about 33,000 acre-feet per year. The amount of recharge necessary to replace water moving downdip (29 mgd) is equivalent to about 5.1 inches of rainfall per year on the area of outcrop. This quantity of water is about 10 percent of the average annual precipitation at Bronson.

The thickness of sand containing fresh to slightly saline water in the Sparta Sand (Figure 12) ranges from 0 feet near its northern margin of outcrop and at the downdip limit of fresh to slightly saline water to at least 150 feet immediately south of the outcrop in west-central San Augustine County. In areas of relatively thick sand, yields of perhaps as much as 1,000 gpm might be obtained from properly constructed wells screening all available sand in the aquifer.

The quantity of water available from the Yegua Formation ranges from about 11 mgd to possibly as much as 58 mgd. The minimum value of 11 mgd or about 12,000 acre-feet per year was based on the present hydraulic gradient of about 8 feet per mile. The maximum value of 58 mgd was based on a theoretical east-northeasterly-trending line of pumping wells extending through Pineland. At a gradient established by pumping lifts of 200 feet at the line of discharge, the Yegua Formation would transmit about 58 mgd or about 65,000 acre-feet per year. The amount of recharge necessary to replace the water moving downdip (58 mgd) is equivalent to about 3.7 inches of rainfall per year on the outcrop area. This quantity of water is about 7 percent of the average annual precipitation at Bronson.

Sufficient electric logs were not available in the area underlain by the Yegua Formation to construct a sand-thickness map. But on the basis of a few scattered electric logs, the thickness of sand containing fresh to slightly saline water in the Yegua ranges from 0 feet near its northern margin of outcrop and at the downdip limit of fresh to slightly saline water in southern Sabine County to about 350 feet near Pineland. In areas of relatively thick sand, yields of 1,000 gpm might be obtained from properly constructed wells screening all available sand in the aquifer.

In summary, the Carrizo Sand and Wilcox Group, Sparta Sand, and Yegua Formation are capable of supporting a ground-water development of at least 44 mgd and possibly as much as 165 mgd indefinitely and without impairing the quality of the water. These quantities are from 34 to 127 times the total discharge in the two-county area in 1964.

The estimates of availability, of course, are based on a limited amount of basic data, theoretical lines of discharge, and assumptions of potential rates of recharge; moreover, no consideration was given to the effect of future large-scale withdrawals from the aquifers in adjoining counties, a possibility which could have a significant influence on the total quantity of water perennially available.

The most beneficial ground-water development in Sabine and San Augustine Counties requires that a wealth of basic data be available. Such data, which include records of pumpage, water levels, and chemical analyses of water, would permit the calculation of more reliable estimates of availability and allow for revision of the estimates as development takes place. A continuing observation-well program for monitoring changes in water levels and water quality is desirable.

DEFINITION OF TERMS

Acre-foot.--The volume of water required to cover 1 acre to a depth of 1 foot. It is equal to 325,851 gallons.

Aquifer.--A formation, group of formations, or part of a formation that is capable of yielding water to wells.

Aquifer test.--A test in which at least one well is pumped and the discharge and water level measured during pumping or after pumping stops. Used to determine the hydraulic properties of aquifers.

Artesian aquifer.--An aquifer overlain by impermeable rocks which confine the water under pressure greater than atmospheric.

Artesian well.--A well in an artesian aquifer.

Base flow of a stream.--The flow of a stream supplied by ground-water discharge.

Coefficient of permeability.--The coefficient of transmissibility divided by the thickness in feet of the aquifer.

Coefficient of storage.--The volume of water released from or taken into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. Stated in a different way, it is the volume of water released by a column of the aquifer having a cross-sectional area of 1 square foot when the head is lowered 1 foot.

Coefficient of transmissibility.--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 thickness of the aquifer under a gradient of 1 foot per foot at the prevailing aquifer temperature.

Cone of depression.--The depression in the water table or piezometric surface surrounding a discharging well.

Equivalents per million (epm).--A way of expressing concentration in which the unit concentration of one ion is equal to the unit concentration of any other ion. It may be computed by dividing concentration of a given ion, expressed as parts per million, by the equivalent weight of that ion.

Interference test.--A type of aquifer test in which one well is pumped and the water decline in one or more nearby wells in the same section is measured. The pump is then stopped, and the water-level rise in all wells is measured.

Main water table.--The upper surface of the lowest zone of saturation in which the water remains unconfined.

Parts per million (ppm).--A measure of the weight ratio of the solute to the solution.

Permeability.--A measure of the ability of a rock to transmit water.

Piezometric surface.--An imaginary surface that everywhere coincides with the static level of the water in an aquifer.

Quality description.--

Description	Dissolved solids (ppm)
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

Specific capacity.--The rate that a well will yield water per unit drawdown. Usually expressed as gallons per minute per foot.

Transpiration.--The process by which water is lost by plants. Generally, the plants lose water to the atmosphere from their leaves.

Water table.--The upper surface of a zone of saturation in which the water is under atmospheric pressure.

Yield.--

Description	Yield (gpm)
Small	Less than 50
Moderate	50 to 500
Large	More than 500

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Table 7.--Drillers' logs of wells in Sabine and San Augustine Counties

Sabine County

Well WS-36-26-901

Owner: Ernest L. Brown. Driller: Newton Well Service.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface	6	6	Shale, hard, and lime	22	66
Clay and shale	16	22	Shale and rock	22	88
Shale, hard	22	44	Shale and sandy shale	27	115

Well WS-36-33-205

Owner: Robert Dennis, well 1. Driller: Sebastian & Cunningham.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Sand	15	15	Rock	2	259
Clay	10	25	Sand, gumbo streaks	141	400
Sand, water	45	70	Sand	25	425
Rock, hard	8	78	Rock	1	426
Gumbo	5	83	Sand, gumbo streaks	75	501
Rock, hard	1	84	Rock	1	502
Gumbo	6	90	Sand and gumbo	33	535
Rock	1	91	Rock	1	536
Gumbo, tough	5	96	Sand	33	569
Packsand, hard	52	148	Rock	2	571
Rock	6	154	Sand	9	580
Sand, water	31	185	Limestone, hard, sandy	1	581
Rock, hard	5	190	Limestone and rock, hard	2	583
Sand	15	205	Sand and boulders	267	850
Gravel	25	230	Gumbo, sandy	150	1,000
Gumbo	27	257	Rock	1	1,001

(Continued on next page)

Table 7.--Drillers' logs of wells in Sabine and San Augustine Counties--Continued

Sabine County

Well WS-36-33-205--Continued

	Thickness (feet)	Depth (feet)
Sand and boulders	139	1,140
Sand, gumbo, and boulders	84	1,224
Limestome, hard, and Rock	6	1,230
Sand	90	1,320
Gumbo, sandy	15	1,335
Packsand, hard	18	1,353
Limestone, hard and rock	3	1,356
Sand	79	1,435
Rock	1	1,436
Sand	29	1,465
Rock	2	1,467
Sand and boulders	63	1,530
Rock	2	1,532
Sand	23	1,555
Sandrock	7	1,562
Gumbo, sandy	33	1,595
Rock	1	1,596
Sand and boulders	38	1,634
Rock	1	1,635
Sand, gummy	55	1,690
Sand	13	1,703
Sand with hard streaks	89	1,792
Sand, hard	88	1,880
Sandrock, hard	5	1,885
Sand, hard	10	1,895
Shale, hard	18	1,913
Sand, hard	20	1,933
Sandrock, hard	9	1,933
Sand, hard	133	2,075
Gumbo, tough	5	2,080
Shale	20	2,100
Shale and sand	42	2,142
Limestone and rock, hard, sandy	4	2,146
Sand, broken, and limestone	4	2,150
Sand	9	2,159
Sand, hard	75	2,234
Limestone and rock, hard	3	2,237
Sand, hard	59	2,296
Gumbo	3	2,299
Limestone and rock, hard	3	2,302
Gumbo	8	2,310
Total Depth		3,531

Table 7.--Drillers' logs of wells in Sabine and
San Augustine Counties--Continued

Sabine County

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

Well WS-36-33-403

Owner: E. D. Henry. Driller: Newton Well Service.

Sand and gravel	22	22	Rock and shell	22	110
Shale and shell	44	66	Shale and sand	29	139
Shale and rock	22	88			

Well WS-36-33-701

Owner: E. R. Fuller. Driller: Newton Well Service.

Topsoil and clay	22	22	Shale, sand and shale	22	110
Shale, black, and sand	22	44	Shale and sandy shale	22	132
Sand and shale, solid	22	66	Shale, sandy	22	154
Shale and shell	22	88	Shale, sandy, and sand	21	175

Well WS-36-34-202

Owner: U.S. Forest Service. Driller: -- Frye.

Topsoil and clay, red	22	22	Rock, soft to medium	21	187
Clay, rock, and clay	21	43	Shale, sandy, and hard shale	20	207
Clay, gray	21	64	Rock and shale	21	228
Shale, blue and lignite	20	84	Shale, sandy and shale	20	248
Shale and some lignite	21	105	Shale and rock	21	269
Shale and thin rock	20	125	Sand and shale, Stratified	20	289
Shale, blue, and hard rock layers	21	146	Sand and shale	21	310
Shale, blue	20	166			

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Table 7.--Drillers' logs of wells in Sabine and San Augustine Counties--Continued

Sabine County

Well WS-36-34-202--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Sand, medium -----------	20	330	Shale and medium sand and shale ------------	21	392
Shale, hard ------------	21	351			
Sand and shale ---------	20	371			

Well WS-36-34-401

Owner: Mrs. Howard Sparks. Driller: Newton Well Service.

Clay, red --------------	10	10	Shale ------------------	22	154
Rock, blue -------------	12	22	Shale and sandy shale --	22	176
Rock, blue and shell ---	22	44	Shale, sandy -----------	44	220
Rock, blue and shale ---	22	66	Shale, hard ------------	44	264
Shale, sandy blue rock--	22	88	Shale, sandy -----------	22	286
Shale, sandy, and rock and shale ------------	22	110	Shale, sandy and rock --	44	330
Shale, sandy, and blue rock -----------------	22	132			

Well WS-36-34-402

Owner: Maxie McCary. Driller: Newton Well Service.

Clay and blue marl------	44	44	Shale ------------------	22	198
Marl, blue -------------	66	110	Shale and sand lenses --	22	220
Shale, sandy -----------	22	132	Shale ------------------	44	264
Shale, sandy and shell -	22	154	Sand and shale ---------	44	308
Shale and shell --------	22	176			

Table 7.--Drillers' logs of wells in Sabine and San Augustine Counties--Continued

Sabine County

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

Well WS-36-34-404

Owner: Halbert Bros. Driller: Newton Well Service.

Clay, sandy, and gravel	22	22	Rock and sand	22	88
Rock, blue and shell	44	66	Sand	9	97

Well WS-36-34-501

Owner: U.S. Forest Service. Driller: --

Clay, red	60	60	Shale, sticky	75	450
Shale	55	115	Shale, sandy and shell	15	465
Shale, sandy, and limy shale	13	128	Shale, hard sandy	19	484
Shale	117	245	Shale	85	569
Shale, sandy and shell	71	316	Sand and sandy limestone	7	576
Sand, gas	59	375	Shale, sandy and sand	105	681

Well WS-36-35-701

Owner: Sabine Oil & Mineral Co. Driller: Will Spurm.

Clay, red and blue	30	30	Sandrock, soft, green, with 1 ft of hard pyrite at bottom	146	241
Sand, white	10	40	Shale(?), soft, with flow of water	59	300
Rock, red, soft	10	50	Shale, blue, and sand	79	379
Shells and rock	2	52	Sand, blue, caving, capped by 1½ ft hard pyrites	149	528
Sandrock with 1 ft of hard pyrite at bottom	7	59			
Marl, blue, and shells	21	80			
Lignite	15	95			

(Continued on next page)

Table 7.--Drillers' logs of wells in Sabine and San Augustine Counties--Continued

Sabine County

Well WS-36-35-701--Continued

	Thickness (feet)	Depth (feet)
Sand, blue, capped by hard rock	6.5	534.5
Sand, 13½ ft underlain by ½ ft shells and rock	13.5	548
Sand	52	600
Shells and rock	4	604
Sandrock, 1 ft of very hard rock at bottom	41	645
Shale and sandrock	29	674
Rock, very hard	6	680
Gumbo	10	690
Sandrock, soft	38	728
Sandrock, soft, gray	72	800
Gravel and pyrites	4	804
Sandrock, soft	56	860
Shale and sand, mixed	15	876
Sandrock, soft, 1 ft very hard rock at bottom	32	907
Sandrock, soft, 2 ft hard rock at bottom	89	996
Sandrock, medium hard, underlain by 2 ft hard pyrites	39	1,035

Well WS-36-41-202

Owner: F. P. Armstrong. Driller: Newton Well Service.

	Thickness (feet)	Depth (feet)
Clay, sandy	22	22
Shale and sand	44	66
Rock and sand	22	88
Sand	11	99

Well WS-36-41-205

Owner: R. B. White. Driller: Newton Well Service.

	Thickness (feet)	Depth (feet)
Sand and shale	22	22
Shale	22	44
Shale, sandy	22	66
Shale and sand	15	81

Table 7.--Drillers' logs of wells in Sabine and San Augustine Counties--Continued

Sabine County

Well WS-36-41-701

Owner: United Gas Pipeline Co. Driller: F. R. Balcar.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay, red, sandy	45	45	Shale	33	372
Shale	59	104	Sand	8	380
Shale, sandy	22	126	Shale, sandy	12	392
Rock	1	127	Shale	25	417
Shale and lignite	67	194	Rock	2	419
Sand	13	207	Shale, sticky	51	470
Shale	53	260	Shale	12	482
Sand and boulders	8	268	Shale, sandy, lignite	107	589
Shale	14	282	Rock	2	591
Sand	18	300	Sand	18	609
Shale	31	331	Shale, hard	11	620
Sand	8	339	Sand	15	635

Well WS-36-41-702

Owner: United Gas Pipeline Co. Driller: Layne-Texas Co., Inc.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Topsoil	6	6	Sand	13	363
Clay, streaks of sand	31	37	Sand and sand streaks	71	434
Clay, sandy clay, layers of rock	229	266	Sand and sandy clay	14	448
Sand, clay layers	19	285	Clay	7	455
Sand and sandy clay	39	324	Sand and sandy clay	13	468
Clay	26	350	Clay, sandy and clay	10	478

(Continued on next page)

Table 7.--Drillers logs of wells in Sabine and San Augustine Counties--Continued

Sabine County

Well WS-36-41-702--Continued

	Thickness (feet)	Depth (feet)
Sand and sandy clay ---	21	499
Clay, and sandy clay --	30	529
Shale, hard and rock layers -------------	53	582
Sand, shale breaks ----	14	596
Clay, sandy, sand streaks ------------	35	631
Clay, sand streaks ----	9	640
Sand -----------------	5	645
Clay -----------------	6	651
Clay and sand layers --	25	676
Sand -----------------	11	687
Shale, sandy, with sandy streaks -------	27	714
Shale, sandy streaks --	40	754
Shale, hard ----------	43	797
Shale and sandy shale -	3	800

Well WS-36-41-703

Owner: Temple Lumber Co. Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)
Topsoil --------------	2	2
Clay -----------------	20	22
Shale ----------------	23	45
Sand -----------------	15	60
Shale, sandy and lignite	30	90
Sand, fine-grained, and shale streaks -------	29	119
Shale, sandy and sand -	51	170
Shale ----------------	31	201
Shale, sandy ----------	10	211
Shale ----------------	32	243
Shale, sandy and shale	36	279
Sand -----------------	12	291
Shale ----------------	18	309
Sand, fine-grained ----	31	340
Shale ----------------	18	358
Shale, sandy and shale-	141	499
Sand, coarse, white, and black specks ----	87	586
Shale ----------------	8	594

Table 7.--Drillers logs of wells in Sabine and San Augustine Counties--Continued

Sabine County

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

Well WS-36-41-704

Owner: Temple Lumber Co. Driller: Layne-Texas Co.

Soil	3	3	Mud, clean, gray	34	334
Clay	12	15	Shale	18	352
Shale, sandy	68	83	Shale, sandy and shale	80	432
Sand, gray and shale layers	47	130	Sand, gray	7	439
Shale, sandy	80	210	Shale, sandy	46	485
Shale, sticky	20	230	Sand, coarse	80	565
Shale, sandy	70	300	Shale	5	570

Well WS-36-42-503

Owner: Warner Stave Co., well 1. Driller: Sebastian & Smith.

Soil	2	2	Gumbo and shale	24	320
Clay	8	10	Rock	1	321
Sand and gravel	23	33	Gumbo, shale, streaks of sand	59	380
Sand and gumbo	25	58	Packsand	10	390
Rock	2	60	Shale and gumbo	50	440
Sand and gravel	80	140	Gumbo, sandy	40	480
Sand and gumbo	50	190	Shale, hard	30	510
Rock	1	191	Sand and boulders	80	590
Sand, shale, and gumbo	59	250	Gumbo, sandy	15	605
Rock	1	251	Shale, hard, streaks of gumbo	45	650
Shale and gumbo	45	296			

(Continued on next page)

Table 7.--Drillers logs of wells in Sabine and San Augustine Counties--Continued

Sabine County

Well WS-36-42-503--Continued

	Thickness (feet)	Depth (feet)
Gumbo and shale --------	65	715
Sand ------------------	60	775
Gumbo, tough -----------	15	790
Gumbo -----------------	20	810
Chalk, green, boulders, and hard gray sand ---	80	890
Shale and boulders -----	150	1,040
Shale -----------------	10	1,050
Gumbo, soft -----------	20	1,070
Gumbo, sandy ----------	8	1,078
Rock, hard ------------	1	1,079
Sand, green -----------	5	1,084
Gumbo -----------------	10	1,094
Shale, sandy ----------	46	1,140
Sand ------------------	50	1,190
Gumbo -----------------	20	1,210
Sand, soft ------------	5	1,215
Sand, and sandy shale --	35	1,250
Gumbo -----------------	3	1,253
Lignite, coal, and sand, 50,000 bbl fresh water	56	1,309
Gumbo -----------------	49	1,358
Sand and shale ---------	38	1,396
Sand and lignite ------	18	1,414
Rock, sand, and lignite	2	1,416
Sand and gumbo --------	90	1,506
Sand -----------------	19	1,525
Gumbo ----------------	9	1,534
Rock, sand, and shale -	1	1,535
Gumbo, tough ----------	69	1,604
Sand -----------------	4	1,608
Sand, streaks of gumbo-	76	1,684
Sandrock, hard --------	4	1,688
Sand, hard -----------	5	1,693
Sandrock, hard --------	1	1,694
Sand -----------------	26	1,720
Gumbo, sandy ----------	10	1,730
Sand -----------------	30	1,760
Shale and sand --------	13	1,773
Rock -----------------	2	1,775
Sand, soft -----------	8	1,783
Packsand, hard --------	15	1,798
Sand, soft, salt water-	44	1,843
Sand -----------------	30	1,872
Total depth ---------		3,785

Table 7.--Drillers logs of wells in Sabine and San Augustine Counties--Continued

Sabine County

Well WS-36-42-807

Owner: Billy D. Sparks. Driller: Newton Well Service.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface clay and rock --	22	22	Rock and shale --------	22	236
Rock and shale ---------	22	44	Shale, hard -----------	22	258
Shale ------------------	44	88	Shale, sandy ----------	22	280
Shale and rock ---------	44	110	Lime and hard shale ---	22	302
Shale, sandy -----------	22	132	Shale, hard -----------	22	324
Shale, sandy, and hard shale ----------------	22	154	Shale and fine sand ---	22	346
			Sand and sandy shale --	22	368
Shale, hard, and sandy shale ----------------	16	170	Shale and sand --------	22	390
Shale ------------------	22	192	Shale -----------------	18	408
Shale and rock ---------	22	214			

Well WS-36-42-810

Owner: L. T. Impson. Driller: Newton Well Service.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface clay -----------	22	22	Shale and sand --------	22	88
Clay and shale ---------	22	44	Sand ------------------	2	90
Shale ------------------	22	66			

Well WS-36-43-102

Owner: R. L. Gooch. Driller: Newton Well Service.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay and gravel --------	22	22	Shale -----------------	22	132
Clay and shale ---------	22	44	Shale and rock --------	22	154
Shale ------------------	44	88	Shale and shell -------	22	176
Shale and rock ---------	22	110	Sand ------------------	21	197

Table 7.--Drillers logs of wells in Sabine and San Augustine Counties--Continued

Sabine County

Well WS-36-43-901

Owner: East Texas Timber & Oil Co. Driller: W. A. Turner.

	Thickness (feet)	Depth (feet)
Soil	2	2
Sand, yellow	33	35
Clay, blue	20	55
Clay, hard, blue	40	95
Rock with fossil shells	3	98
Shale, blue	22	120
Clay, hard, blue	60	180
Rock with fossil shells	5	185
Clay, stiff blue (gumbo)	45	230
Sand	8	238
Gumbo (stiff blue clay)	48	286
Sand, soft	4	290
Gumbo	31	321
Sand	6	327
Rock	4	331
Lignite	44	335
Sand	25	360
Clay, dark-brown	15	375
Coal (lignite)	5	380
Gumbo, blue	62	442
Sandstone	18	460
Limestone	8	468
Gumbo, blue	30	498
Sandstone	18	516
Gumbo, very dark	34	550
Clay, soft	30	580
Clay, hard	60	640
Marl, fossiliferous	9	649
Clay, hard	1	650
Sandstone, fossiliferous	115	665
Rock	1	666
Clay, hard	18	684
Rock, flint, very hard	1	685
Shale, dark-colored	41	726
Sandstone, soft	15	741
Gumbo	26	767
Sandstone, soft	12	779
Shale	5	784
Sandstone, soft with shells	16	800
No record	210	1,010
Sand, good artesian water	20	1,030

(Continued on next page)

Table 7.--Drillers logs of wells in Sabine and San Augustine Counties--Continued

Sabine County

Well WS-36-43-901--Continued

	Thickness (feet)	Depth (feet)
Clays, mostly dark-colored, containing fossil shells	320	1,350
Rock, hard	75	1,425
Artesian salt water	375	1,800
Total depth		1,975

Well WS-36-49-103

Owner: Temple Lumber Co., well 2. Driller: J.D. Adams.

	Thickness (feet)	Depth (feet)
Surface material and clay	40	40
Sand, hard	10	50
Shale and clay	30	80
Gumbo	40	120
Gumbo, hard	10	130
Sand, hard	30	160
Gumbo	52	212
Sand, dry, fine	8	220
Gumbo	60	280
Shale, hard	20	300
Shale	10	310
Lignite	25	335
Gumbo	75	410
Gumbo, hard	11	421
Gumbo	18	439
Sand, water	40	479

Well WS-36-49-105

Owner: Temple Lumber Co., well 4. Driller: F. Balcar.

	Thickness (feet)	Depth (feet)
Sand and red clay	21	21
Shale	28	49
Rock	2	51
Sand, fine, blue	7	58
Gumbo, gray	44	102
Sand, blue	50	152
Shale and gumbo	131	283
Rock	2	285
Shale	50	335
Gumbo	55	390
Shale and rock	4	394
Shale and gumbo	37	431

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Table 7.--Drillers logs of wells in Sabine and San Augustine Counties--Continued

Sabine County

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

Well WS-36-49-105--Continued

Boulders ---------------	6	437	Shale, hard -----------	21	533
Shale, sandy -----------	21	458	Sand ------------------	74	607
Sand -------------------	10	468	Gravel ----------------	12	619
Shale and gumbo --------	39	507	Shale, sticky ---------	14	633
Boulders ---------------	5	512			

Well WS-36-49-109

Owner: J. T. Short. Driller: Newton Well Service.

Surface clay, gray, and shale ----------------	22	22	Shale, sandy ----------	22	318
Shale ------------------	132	154	Shale -----------------	22	340
Rock and shale ---------	32	186	Shale, sandy ----------	22	362
Shale, sandy -----------	22	208	Shale -----------------	22	384
Shale and sandy shale --	22	230	Shale and sandy shale -	44	428
Shale, limey, and dark shale ----------------	22	252	Shale -----------------	22	450
Shale and sand ---------	22	274	Shale and sandy shale -	22	472
Sand and shale ---------	22	296	Shale, sandy, and sand-	27	499

Well WS-36-50-306

Owner: Carl V. Smith. Driller: Newton Well Service.

Clay and sand ----------	22	22	Shale -----------------	22	66
Clay, sand, and shale---	22	44	Sand ------------------	31	97

Table 7.--Drillers logs of wells in Sabine and San Augustine Counties--Continued

Sabine County

Well WS-36-52-402

Owner: Stark & Brown, well 1. Driller: K. E. Menen.

	Thickness (feet)	Depth (feet)
Surface clay	30	30
Clay and hard sand	8	38
Shale	12	50
Sand	10	60
Shale, sand, rock, and gravel	153	213
Sand and shale	64	277
Shale	651	928
Shale and boulders	127	1,055
Shale	114	1,169
Sand	10	1,179
Shale, sandy and boulders	243	1,422
Rock	3	1,425
Shale, sandy, and shale	193	1,618
Rock	1	1,619
Shale with streaks of rock	240	1,859
Sand	18	1,877
Shale, sandy, and boulders	41	1,918
Rock	3	1,921
Shale and boulders	39	1,960
Shale, sandy	153	2,113
Sand	10	2,125
Shale, gummy, lime streaks	72	2,195
Total depth		4,532

Well WS-36-52-403

Owner: Wier Longleaf Lumber Co., well 1. Driller: Crater Oil Co. of Texas.

	Thickness (feet)	Depth (feet)
Sand and clay	16	16
Sandrock	27	43
Quicksand, soft	27	70
Sand, water	51	121
Sand, hard	29	150
Sand, soft	20	170
Sand, hard	10	180
Lignite, soft	2	182
Gumbo, sandy	6	188
Sand	12	200
Sandrock	42	242
Sand	24	266

(Continued on next page)

Table 7.--Drillers logs of wells in Sabine and San Augustine Counties--Continued

Sabine County

Well WS-36-52-403--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Sand, hard	2	268	Gumbo, shale, and boulders	198	1,028
Sand and shale	22	290	Sand, hard, and shale	8	1,036
Sand	20	310	Shale, gummy	65	1,101
Sand and shale	57	367	Sand, brown, and lignite	8	1,109
Shale, green, sandy	219	587	Shale, gummy, lignite, and boulders	174	1,283
Gumbo	54	640	Shale, soft, sandy	32	1,315
Shale, soft	6	646	Shale, gummy	140	1,455
Gumbo	54	700	Rock and sand	15	1,470
Shale, soft	10	710	Shale, sandy	60	1,530
Gumbo and shale	46	756	Shale, brown, sandy	10	1,540
Gumbo	64	820	Total depth		2,963
Shale, soft, sandy, and fossils	10	830			

Well WS-37-48-302

Owner: Gulf, Colorado, and Santa Fe RR. Co. Driller: --

Clay, yellow	30	30	Limestone and rock	1	164
Clay, blue	30	60	Clay, blue	94	258
Shale, brown	43	103	Sand	14	272
Sand	12	115	Clay, blue	50	322
Shale, brown	30	145	Shale, brown	30	352
Sand	10	155	Clay, blue	22	374
Clay, blue	8	163	Clay, blue, and shell	6	380

(Continued on next page)

Table 7.--Drillers logs of wells in Sabine and San Augustine Counties--Continued

Sabine County

Well WS-37-48-302--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay, blue	106	486	Sand, dark	8	818
Sandrock	3	489	Clay, blue	74	892
Clay, blue	89	578	Shale, blue, and shell	36	928
Clay, blue, and boulders	8	586	Shale, dark	90	1,018
Clay, blue	88	674	Sand, water	50	1,068
Sand, water	55	729	Clay, dark	2	1,070
Clay, blue	81	810			

Well WS-37-48-602

Owner: W. W. McBride. Driller: Newton Well Service.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface clay, and sand	22	22	Sand, shale, and hard sand	22	88
Clay, sand, and shale	22	44	Sand	40	128
Shale, sand, and hard shale	22	66			

Well WS-37-48-604

Owner: E. B. Diehl. Driller: Newton Well Service.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface clay, and shale	22	22	Shale, sandy, and shale	24	134
Shale and limerock, shale	22	44	Coal, hard, and shale and coal	20	154
Shale, sandy shale and rock	22	66	Shale and limy sandy shale	22	176
Shale and sandy shale	22	88	Shale and sandy shale	22	198
Shale, sandy, and rock	22	110	Shale and sandy shale	22	220

(Continued on next page)

Table 7.--Drillers logs of wells in Sabine and San Augustine Counties--Continued

Sabine County

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well WS-37-48-604--Continued					
Sand and shale ---------	22	242	Shale and sandy shale -	92	378
Shale -----------------	44	286			

Table 7.--Drillers logs of wells in Sabine and San Augustine Counties--Continued

San Augustine County

Well WT-37-30-302

Owner: J. W. Butler. Driller: L. L. Higgins.

	Thickness (feet)	Depth (feet)
Shale, red	20	20
Marl, blue	145	165
Sand, gray	65	230
Sand	55	285

Well WT-37-30-901

Owner: M. R. Goss. Driller: Newton Well Service.

	Thickness (feet)	Depth (feet)
Surface sand and clay	22	22
Shale and shell	44	66
Shale	22	88
Shale and shell	22	110
Shale and sticky shale	22	132
Shale, sticky, and rock	22	154
Shale and shell	44	198
Shale, shell, and sandy shale	44	242
Sand, hard, and shale	22	264
Sand and shale lenses	22	286
Sand with shale	22	308
Sand	10	318

Well WT-37-31-505

Owner: A. P. Davis, well 1. Driller: T. W. Tennant.

	Thickness (feet)	Depth (feet)
Clay	15	15
Clay, sandy, and gravel	10	25
Clay, gummy	25	50
Sand and gravel	19	69
Sand	20	89
Rock	1	90
Shale, sandy	18	108
Sandrock	41	149
Packsand	57	206
Sand, streaks of lignite	22	228
Sand	218	446
Sand, streaks of lignite	15	461
Rock	1	462
Lignite and sand	4	466

(Continued on next page)

Table 7.--Drillers logs of wells in Sabine and San Augustine Counties--Continued

San Augustine County

Well WT-37-31-505--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Sand	100	566	Rock	1	1,275
Sand, gravel streaks, and shale	40	606	Limerock, sandy	1	1,276
Shale streaks	112	718	Limerock	3	1,279
Sand	20	738	Sand	21	1,300
Shale, sandy	190	928	Shale, sandy	65	1,365
Limerock	3	931	Limerock	2	1,367
Shale, sandy	24	955	Shale	11	1,378
Rock	1	956	Rock	3	1,381
Shale and boulders	127	1,083	Shale, sandy, and	264	1,645
Limerock	3	1,086	Total depth		3,026
Shale, sandy, and boulders	188	1,274			

Well WT-37-31-506

Owner: Santa Fe Railway Co. Driller: --

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay, red	15	15	Clay, blue	12	69
Clay, yellow, and marl	5	20	Shale, brown	3	72
Marl, blue	14	34	Shale, brown, soapy with boulders	10	82
Marl, blue, black as coal when wet	10	44	Shale, brown, soapy	7	89
Marl, blue, streaks of harder marl	8	52	Soapstone, brown, and thin layers of limestone	7	96
Marl, blue	5	57			

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Table 7.--Drillers logs of wells in Sabine and San Augustine Counties--Continued

San Augustine County

Well WT-37-31-506--Continued

	Thickness (feet)	Depth (feet)
Marl, blue	18	114
Clay, blue	1	115
Shale, blue and brown, with hard streaks	17	132
Limestone, blue, and marl with pyrite, very hard	7	139
Sand, hard, gray	2	141
Sand, hard, gray, and pyrite	26	167
Sand, blue and gray	6	173
Clay, brown, and sand	14	187
Sand, brown, and clay streaks	11	198
Sand, brown	10	208
Clay, white	1	209
Gumbo, brown, and clay	29	238
Pyrite	2	240
Sand, water	10	250
Clay, water	10	260
Rock, black, and pyrite	1	261
Clay, brown	6	267
Lime boulders with little oil	1	268
Clay, brown	2	270
Clay, brown, with layers of sand	4	274
Sand, fine	1	275
Clay, brown	2	277
Sand, fine	1	278
Clay, brown	5	283
Lime boulders	2	285
Clay, brown	5	290
Sand, brown	4	294
Clay, brown, with layers of sand	10	304
No record	24	328
Clay, brown, little oil	14	342
Sand, fine	18	360
Sand or clay, fine	8	368
No record	36	404
Clay and shells	19	423
Clay or sand, fine	11	434
Shale with layers of lignite	26	460
Clay or sand, fine	23	483
Sand, fine	2	485
Clay and little lignite	3	488

(Continued on next page)

Table 7.--Drillers logs of wells in Sabine and San Augustine Counties--Continued

San Augustine County

Well WT-37-31-506--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay	15	503	Shale, thin lignite layers	57	588
Shale	5	508	Lignite	2	590
Shale with little lignite	6	514	Shale	1	591
Shale and few shells	4	518	Lignite	4	595
Shale	12	530			
Lignite	1	531			

Well WT-37-31-705

Owner: C. Preajene. Driller: Newton Well Service.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Sand and shale	22	22	Shale and shell	44	242
Shale and rock, blue	22	44	Shale and sandy shale	22	264
Shale and shell	132	176	Shale, sandy, and sand	25	289
Rock, blue	22	198			

Well WT-37-32-201

Owner: James D. Dezelle. Driller: Newton Well Service.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface sand and clay	22	22	Shale, gray, and sand	22	88
Sand	44	66	Sand	29	117

Well WT-37-32-401

Owner: Liberty Hill Baptist Church. Driller: Newton Well Service.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface sand and gravel	22	22	Shale and shell	44	88
Sand, gravel, and blue rock	22	44	Shale, shell, and sandy shale	22	110

(Continued on next page)

Table 7.--Drillers logs of wells in Sabine and San Augustine Counties--Continued

San Augustine County

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

Well WT-37-32-401--Continued

Shale, sandy	22	132	Sand	22	198
Shale	22	154	Shale and sand	22	220
Rock and shale	22	176	Sand	12	232

Well WT-37-32-502

Owner: Mrs. Lois Wilburn. Driller: Newton Well Service.

Surface clay	22	22	Sand	57	101
Sand and pyrite	22	44			

Well WT-37-32-503

Owner: Roy Hardy. Driller: Newton Well Service.

Surface sand and lime	22	22	Sand, hard	34	100
Shale, sandy	22	44			

Well WT-37-32-702

Owner: City of San Augustine. Driller: W. K. Banker.

Surface clay	18	18	Limerock, hard	4	81
Limerock, soft	13	31	Sand, artesian	8	89
Shale, green	4	35	Shale, brown	22	111
Limerock	8	43	Limerock, hard	2	113
Shale	4	47	Shale, brown	57	170
Sand, green, and shale, stratified	30	77	Gumbo	12	182

(Continued on next page)

Table 7.--Drillers logs of wells in Sabine and San Augustine Counties--Continued

San Augustine County

Well WT-37-32-702--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Muck, brown, soft formation	108	290	Sand and gravel, water	45	522
Soapstone	9	299	Gumbo, blue, very hard	24	546
Gypsum, blue	8	307	Limerock, soft	3	549
Shale	7	314	Gumbo, tough	11	560
Gumbo with boulders	34	348	Rock, very hard	2	562
Lignite	5	353	Gumbo, tough	4	566
Gumbo, brown	57	410	Shale, showing of oil	9	575
Soapstone, brown	7	417	Gumbo	50	625
Gumbo, brown	60	477			

Well WT-37-32-703

Owner: City of San Augustine. Driller: Layne-Texas Co., Inc.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay, red	14	14	Shale	206	488
Shale, gray	31	45	Sand	65	553
Shale, green	27	72	Shale	3	556
Sand, blue	32	104	Sand, layers of shale	49	605
Rock, hard	3	107	Layers, hard	1	606
Shale, sandy	30	137	Sand and sandy lime	10	616
Sand	70	207	Layers, hard	1	617
Sand and shale layers	75	282	Sand and layers of shale	84	701

Table 7.--Drillers logs of wells in Sabine and San Augustine Counties--Continued

San Augustine County

Well WT-37-38-301

Owner: Ray Horton. Driller: -- English.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Sand ------------------	25	25	Shale -----------------	25	210
Shale -----------------	50	75	Sand ------------------	5	215
Sand ------------------	35	110	Shale -----------------	205	420
Shale -----------------	30	140	Sand and shale --------	45	465
Rock and shale --------	45	185	Sand ------------------	45	510

Well WT-37-39-603

Owner: Carl Cox. Driller: Newton Well Service.

Sand and hard lenses --	22	22	Sand and sandy shale --	22	88
Shale and sand --------	44	66	Sand ------------------	12	100

Well WT-37-39-701

Owner: Martin H. Stringer. Driller: Chambers Drilling Co.

Topsoil and clay ------	21	21	Shale, blue -----------	34	97
Shale, blue -----------	21	42	Limerock --------------	1	98
Sandrock --------------	½	42½	Shale, blue -----------	4	102
Shale, blue -----------	19½	62	Sand ------------------	23	125
Limerock --------------	1	63			

Well WT-37-39-804

Owner: E. J. Bailey. Driller: Newton Well Service.

Clay, sandy -----------	22	22	Shale and rock --------	22	66
Shale, sandy ----------	22	44	Shale -----------------	22	88

(Continued on next page)

Table 7.--Drillers logs of wells in Sabine and San Augustine Counties--Continued

San Augustine County

Well WT-37-39-804--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Shale and rock	44	132	Shale	22	242
Shale, sandy	22	154	Shale and sandy shale	42	284
Shale, sandy, and rock	22	176	Shale	22	306
Shale, sandy, and sand	22	198	Sand	27	333
Sand and sandy shale	22	220			

Well WT-37-39-805

Owner: A. P. Ross. Driller: Newton Well Service.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface clay	22	22	Shale with hard lenses	22	110
Clay, yellow, and shale	22	44	Shale, and rock, sandy	20	130
Shale, rock, sand, and shale	22	66	Shale, sandy, with hard lenses	24	154
Shale	22	88	Shale, sandy, and sand	29	183

Well WT-37-39-905

Owner: D. L. Spears. Driller: Newton Well Service.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface clay and sand	22	22	Shale and sand	22	154
Clay and sand	22	44	Shale, sandy	22	176
Shale and rock	22	66	Shale, sticky	20	196
Shale	22	88	Shale and shell	22	218
Rock and shale	22	110	Sand	30	248
Shale, sandy	22	132			

Table 7.--Drillers logs of wells in Sabine and San Augustine Counties--Continued

San Augustine County

Well WT-37-40-303

Owner: Weldon Cousins. Driller: Newton Well Service.

	Thickness (feet)	Depth (feet)
Sand, red, and rock	6	6
Clay, yellow, and gravel	11	17
Rock, blue with shell	26	43
Shale and shell	15	58
Shell, very hard, and shell	6	64
Shale and shell	41	105
Pyrites, iron	3	108
Shale	8	116
Sand and shale	27	143
Shale	4	147
Sand and shale	6	153
Sand with shale lenses	15	168
Sand and shale	22	190
Coal and shale	9	199
Dolomite	1	200
Shale	10	210
Dolomite	4	214
Shale, sandy	20	234
Shale	5	239
Shale, sticky	5	244
Shale, sandy	13	257

Well WT-37-40-304

Owner: B. T. Pickard. Driller: Newton Well Service.

	Thickness (feet)	Depth (feet)
Sand and gravel	22	22
Clay and shale	22	44
Shale	44	88
Shale and rock	22	110
Sand and shale	22	132
Sand	10	142

Table 7.--Drillers logs of wells in Sabine and
San Augustine Counties--Continued

San Augustine County

Well WT-37-40-305

Owner: Elbert Ford. Driller: Newton Well Service.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Sand and clay----------	22	22	Sand and shell --------	44	262
Shale and rock, blue --	22	44	Sand ------------------	22	284
Shale and shell -------	152	196	Shale, sandy ----------	44	328
Shale and sand lenses -	22	218	Total depth ---------		431

Well WT-37-40-501

Owner: R. L. Whitesides. Driller: Newton Well Service.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay, red and white ---	22	22	Sand with shale -------	22	176
Sand, clay and gravel -	22	44	Shale -----------------	22	198
Shale, sandy ----------	22	66	Shale and limerock ----	22	220
Sand and shale --------	44	110	Shale and shell--------	176	396
Shale -----------------	22	132	Shale and shelly sand -	46	442
Shale and sand --------	22	154			

Well WT-37-46-601

Owner: Robert Wall. Driller: Newton Well Service.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
No record -------------	15	15	Sand ------------------	6	81
Sand ------------------	10	25	Coal ------------------	3	84
No record -------------	13	38	Sand ------------------	6	90
Coal ------------------	17	55	No record -------------	40	130
No record -------------	18	73	Sand ------------------	5	135
Limerock --------------	2	75	Lime, hard ------------	27	162

(Continued on next page)

Table 7.--Drillers logs of wells in Sabine and San Augustine Counties--Continued

San Augustine County

Well WT-37-46-601--Continued

	Thickness (feet)	Depth (feet)
Shale, sandy, with coal streaks	7	169
No record	119	288
Sand with shale breaks	22	310

Well WT-37-47-101

Owner: U. S. Forest Service. Driller: --

	Thickness (feet)	Depth (feet)
Surface	70	70
Shale, sandy	43	113
Shale and shell	12	125
Shale, sticky	53	178
Shale, sandy, and hard	46	224
Shale and shells	40	264
Shale, sticky	30	294
Shale, sticky, and limy shells	35	329
Shale, sticky	54	383
Shale, sandy, and shells	90	473
Sand	15	488
Shale, hard, and sandy	4	492
Shale, hard	25	517
Shale, sticky	23	540
Shale, sandy and shells	20	560
Sand	65	625

Well WT-37-55-101

Owner: S. T. Bryan. Driller: Newton Well Service

	Thickness (feet)	Depth (feet)
Gravel, sandy, and jointed clay	22	22
Clay, jointed, shale and sand	22	44
Shale, hard	44	88
Shale, hard and soft	22	110
Sand and shale	22	132
Shale and sand	22	154
Shale, sandy	22	176
Shale and sandy shale	44	220
Shale and sand	22	242
Shale and sandy shale	22	264
Shale, sandy, and shale	22	286

(Continued on next page)

Table 7.--Drillers logs of wells in Sabine and San Augustine Counties--Continued

San Augustine County

Well WT-37-55-101--Continued

	Thickness (feet)	Depth (feet)
Shale, sandy, shale and rock ------------	22	308
Shale, hard -----------	22	330
Shale, hard, sandy ----	22	352
Shale, sandy ----------	66	418
Shale -----------------	20	438

Well WT-37-55-102

Owner: Hunter-Longbell, well 2. Driller: --

	Thickness (feet)	Depth (feet)
Clay, sandy -----------	17	17
Sand and gravel -------	34	51
Gravel ----------------	5	56
Rock ------------------	1	57
Sand, gravel, and gumbo	43	100
Shale, sticky, and sand	211	311
Rock ------------------	1	312
Shale, sticky ---------	31	343
Shale, sticky, streaks of sand -------------	316	659
Shale, sticky, and boulders ------------	261	920
Shale, sticky, and boulders ------------	33	953
Marl, hard ------------	4	957
Marl ------------------	86	1,043
Shale, sticky, streaks of rock and marl -------	277	1,320
Shale, sticky, hard sand and marl ------------	30	1,350
Shale, sandy, hard sand and lignite ---------	18	1,368
Shale, sandy, and boulders ------------	119	1,487
Shale, sticky, boulders and hard sand -------	41	1,528
Marl, hard ------------	1	1,529
Marl, green -----------	71	1,600
Marl, hard streaks ----	16	1,616
Marl, green, streaks of shale and sandy streaks	18	1,634
Marl and sandy shale --	18	1,652
Marl, green, and shale-	17	1,669
Shale, hard streaks, sand and boulders ---	36	1,705
Marl ------------------	30	1,735
Shale, gray and brown, sandy ---------------	36	1,771
Shale, very soft, sandy	36	1,807
Sand, soft, and streaks of shale ------------	18	1,825

(Continued on next page)

Table 7.--Drillers logs of wells in Sabine and San Augustine Counties--Continued

San Augustine County

Well WT-37-55-102--Continued

	Thickness (feet)	Depth (feet)
Shale, streaks of soft sand	8	1,833
Sand, water	23	1,856
Shale, boulders, and san sand streaks	155	2,011
Sand, hard, green, and shells	31	2,042
Rock	2	2,044
Sand, hard, green, and shells	12	2,056
Sand, sticky, gray	25	2,081
Sand and sticky shale	21	2,102
Shale, sticky	98	2,200
Shale and boulders	83	2,283
Rock	2	2,285
Shale and boulders	86	2,371
Rock, hard	2	2,373
Shale and boulders	147	2,520
Sand, hard, and shells	8	2,528
Sand and shells, hard streaks	22	2,550

Well WT-37-55-204

Owner: Harris F. West. Driller: Newton Well Service.

	Thickness (feet)	Depth (feet)
Conglomerate	21	21
Sand, yellow, sand and gravel	21	42
Shale and shell	22	64
Shale	18	82
Rock	4	86
Shale	8	94
Shale, light	3	97
Rock	4	101
Shale	10	111
Shale, sandy	14	125
Rock	5	130
Shale, hard, sticky	44	174
Shale, sandy	22	196
Shale, sticky, and rock	22	218
Shale, sand lenses	22	240
Shale and rock	22	262
Sand	31	293