UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary

GEOLOGICAL SURVEY
W. C. Mendenhall, Director

Water-Supply Paper 849

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

1940

PAPERS BY
W. N. WHITE, R. C. CADY, PENN LIVINGSTON
AND OTHERS

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[The letters in parentheses preceding the titles are those used to designate the papers for separate publication]

ILLUSTRATIONS

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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGY AND GROUND-WATER RESOURCES

OF THE

LUFKIN AREA, TEXAS

Prepared in cooperation with the

TEXAS BOARD OF WATER ENGINEERS

AND THE CITY OF LUFKIN

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 849-A

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W. N. WHITE, A. N. SAYRE, AND J. F. HEUSER

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Contributions to the Hydrology of the United States, 1940

(Pages 1-58)

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GEOLOGY AND GROUND-WATER RESOURCES OF THE LUFKIN AREA, TEXAS

By W. N. White, A. N. Sayre, and J. F. Heuser

ABSTRACT

This report covers Angelina County, Texas, of which Lufkin is the county seat, and parts of Nacogdoches and other adjacent counties. The area is underlain by a series of sands, clays, and shales of Eocene age that dip, in general, southward at an angle a little greater than that of the land surface, which also slopes southward, thus creating favorable artesian conditions. The formations cropping out in the area from north to south are the Wilcox group undifferentiated, the Carrizo sand, the Mont Selman formation, consisting of the Reklaw member, the Queen City sand member, and the Weches greensand member, the Sparta sand, the Cook Mountain and Yegua formations, and the Jackson group undifferentiated.

Small supplies of potable water may be obtained from shallow wells in the outcrop areas of most of these formations. Only three of the formations appear to be likely to yield large supplies of water to wells, and in these the water is under sufficient artesian pressure in most places to cause wells to flow. The Yegua formation yields large amounts of water to some wells in the vicinity of Lufkin. However, the water is moderately mineralized and is not acceptable for municipal use except after dilution with surface water and treatment to reduce mineralization. Moreover, most of the wells in this formation yield only small quantities of water, which is highly mineralized. The Sparta sand appears to be likely to yield large supplies of water to wells throughout the northern part of Angelina County. The water, however, is moderately to highly mineralized and cannot be used for purposes that require water of good quality. The Carrizo sand promises to yield large quantities of water low in mineralization in northern Angelina County and southern Nacogdoches County. Computations indicate that the present southward flow through the formation is about 2,750,000 gallons a day, but pumping from wells and thus increasing the hydraulic gradient would greatly increase the flow. Considerable amounts of water will also be released from storage in the formation after pumping begins.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

An investigation of the geology and ground-water resources of the Lufkin area was begun in January 1937 by the Geological Survey, United States Department of the Interior, in cooperation with the Texas Board of Water Engineers and the City of Lufkin, under the general supervision of O. E. Meinzer, geologist in charge of the division of ground water of the Geological Survey.

The purpose of this investigation was to determine the ground-water resources of the area, with special reference to the possibilities of obtaining large quantities of water from wells for municipal and industrial purposes in Angelina County.

J. F. Heuser, under the supervision of A. N. Sayre, collected and arranged most of the data presented in this report. W. N. White, who is in charge of the ground-water work of the Geological Survey in Texas, spent several days in the field and kept in close touch with the work. The hydrologic parts of this report were written chiefly by Messrs. White and Sayre, with the collaboration of Mr. Meinzer.

In the course of the field work 188 wells and 6 springs were located and mapped, of which 158 wells and 5 springs are in Angelina County, 27 wells and 1 spring in Nacogdoches County, 1 well in Trinity County, and 2 wells in San Augustine County. (See pl. 2.) In all 120 water samples were collected and sent to the Geological Survey in Washington, where they were analyzed by Margaret D. Foster. Cuttings and drill cores from wells in Angelina County and samples of Carrizo sand from the outcrop in Nacogdoches County were collected, and selected samples were sent to the Geological Survey in Washington, where they were tested for permeability and mechanical composition by V. C. Fishel. The geology of Angelina and Nacogdoches Counties was studied in the field, but the map presented in plate 1 was taken from the Geological Survey's latest geologic map of the State without revision.

LOCATION AND TOPOGRAPHY

The area studied, which includes Angelina County and parts of Nacogdoches and other adjacent counties, is in eastern Texas, about 100 miles north of Beaumont.

The surface of the area is gently rolling. The maximum altitude above sea level is probably less than 400 feet and the maximum relief is about 150 feet.

CLIMATE

The summers in the area studied are long and warm. The winters are short and mild, though at times "northers" send the temperature below freezing. Unsettled, cloudy weather tends to prevail over long periods in the winter. United States Weather Bureau records show that the mean temperature at Lufkin, the county seat of Angelina County, in January is 50.6° F. and in July 83.5° F., and the mean annual temperature is 67.5° F. The mean annual snowfall is less than ⅛ inch. The average dates of the first and last killing frost are November 13 and March 15, respectively.

According to United States Weather Bureau records the average annual rainfall at Lufkin over a 25-year period was 45.43 inches and the average at Nacogdoches, 20 miles north of Lufkin, over a 29-year period was 45.62 inches. The precipitation is not evenly distributed throughout the year, being lowest in the fall and highest in the winter and spring.

The tables below give the Weather Bureau records of precipitation at Lufkin and Nacogdoches.

Precipitation, in inches, 1907–21, 1925–34, at Lufkin, Angelina County[1]

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1907	1.12	3.78	2.03	3.60	12.48	0.20	1.12	2.18	2.22	5.36	11.21	6.37	51.67
1908	2.94	7.48	3.67	5.39	6.40	.64	3.43	4.01	3.85	.27	4.01	1.67	43.76
1909	.77	4.65	2.62	4.41	5.39	3.04	3.68	1.32	2.51	2.82	1.87	6.87	39.95
1910	1.58	10.60	1.06	4.33	8.48	5.00	1.43	.42	1.93	1.26	1.98	5.19	43.26
1911	.30	1.77	6.10	11.95	2.67	2.32	11.40	2.25	.99	3.10	4.87	9.29	57.31
1912	2.55	2.53	4.73	5.02	2.62	4.70	2.41	3.09	.24	.88	.43	7.89	37.09
1913	3.47	5.02	5.41	2.75	1.03	2.90	1.83	10.5	12.00	1.42	1.86	6.70	45.44
1914	.93	2.60	5.52	4.83	9.81	1.30	Trace	5.27	2.00	1.95	6.04	7.79	49.04
1915	4.46	3.06	1.39	6.82	2.56	2.23	7.18	11.29	.31	.93	1.59	4.15	45.97
1916	5.64	.51	.64	5.49	13.15	4.39	4.27	2.90	1.87	1.84	4.19	3.21	48.10
1917	2.50	4.83	1.96	3.25	3.85	.25	4.56	1.61	2.08	1.05	1.08	.81	27.83
1918	1.15	2.04	1.66	4.06	1.44	2.15	2.78	2.12	2.28	2.71	9.62	2.27	34.28
1919	4.18	4.36	4.88	1.55	5.51	7.48	4.21	2.90	2.85	9.32	1.67	2.80	51.71
1920	8.87	1.32	2.30	5.20	2.23	4.82	2.86	5.64	1.48	3.24	4.13	3.30	45.39
1921	2.80	4.26	6.73	5.53	2.40	6.15	6.02	2.20	1.34	3.14	3.98	4.98	49.53
1925	8.12	1.51	1.45	1.81	1.72	.39	3.08	4.00	1.25	8.45	5.35	1.22	38.35
1926	4.91	.50	5.47	6.31	2.02	5.06	6.97	1.83	1.48	2.74	4.60	8.16	50.05
1927	.38	3.27	6.71	6.18	4.62	8.72	6.03	.15	1.03	2.45	1.68	4.35	45.57
1928	.85	3.88	4.67	2.43	2.11	6.55	4.98	2.18	1.02	1.10	4.73	3.91	38.41
1929	9.36	2.80	3.41	4.24	13.08	1.95	4.37	.57	1.31	1.02	7.40	4.35	53.86
1930	8.76	3.75	2.77	.14	6.48	1.75	.87	1.85	6.59	4.83	5.80	3.92	47.51
1931	2.85	3.97	4.79	3.61	4.31	.91	2.15	6.43	.02	1.92	5.07	7.43	43.46
1932	7.49	7.65	2.14	3.11	4.05	1.60	4.02	2.59	2.18	.90	2.69	11.64	50.06
1933	3.39	3.58	6.85	3.91	1.27	.91	9.70	5.94	3.78	.65	.40	6.76	47.14
1934	6.99	1.81	6.31	4.55	3.79	.19	1.42	.92	5.29	.23	12.38	7.14	51.02
Average	3.85	3.70	3.81	4.42	4.93	3.62	4.03	3.00	2.48	2.54	4.35	5.29	45.43

[1] From U. S. Weather Bureau records.

Precipitation, in inches, 1907–35, at Nacogdoches, Nacogdoches County [1]

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1907	2.96	2.84	2.15	4.65	9.07	0.21	2.33	0.15	0.63	6.44	10.39	4.55	46.37
1908	2.31	6.37	3.40	4.12	6.87	.92	2.46	3.92	5.59	.12	2.98	1.56	40.62
1909	.44	3.24	2.01	3.93	4.79	3.90	4.33	1.15	1.23	2.89	.85	8.40	37.16
1910	1.56	9.76	.89	4.22	8.52	4.92	2.14	1.84	.94	2.27	3.41	5.24	45.71
1911	Trace	2.93	3.89	9.62	.61	.52	11.17	2.09	.53	1.84	5.00	10.51	48.71
1912	1.96	3.57	7.18	7.46	9.44	4.66	.64	2.30	Trace	.91	.80	6.49	45.41
1913	4.04	3.98	4.63	4.42	5.01	1.61	.81	.68	11.87	3.81	2.75	6.44	50.05
1914	1.00	3.87	4.32	4.64	7.32	1.03	Trace	5.22	1.83	.67	4.11	8.90	42.91
1915	4.61	3.19	2.30	2.82	2.87	.75	4.61	7.85	1.53	1.21	3.03	2.44	37.21
1916	7.66	.58	.81	5.28	10.74	2.43	3.57	.76	.67	1.27	3.75	3.18	40.70
1917	3.79	4.26	1.91	3.27	3.25	.77	5.83	.06	3.74	1.38	.69	.11	29.06
1918	1.45	.92	1.81	6.99	1.67	2.63	2.28	3.31	3.87	4.50	6.55	3.02	39.00
1919	4.16	4.49	2.48	1.29	6.96	8.72	1.82	5.49	2.42	9.65	4.06	1.50	53.04
1920	6.93	1.17	5.33	4.94	4.57	3.06	4.74	6.83	1.47	3.51	4.66	5.69	52.90
1921	3.12	2.16	7.28	6.30	1.71	5.90	7.10	3.21	3.22	1.05	.61	4.20	45.86
1922	6.36	6.10	8.35	11.66	5.05	2.74	3.11	3.41	1.03	.70	5.26	3.88	57.65
1923	3.75	6.20	6.22	9.90	4.92	4.20	1.42	1.84	8.80	2.71	5.07	9.38	64.41
1924	5.01	5.16	4.35	5.71	9.46	3.07	.06	Trace	1.97	.05	2.14	2.75	39.73
1925	5.77	1.44	1.00	1.10	1.85	.28	3.02	.63	2.63	11.14	8.79	.93	38.58
1926	3.65	.60	8.39	4.95	2.40	6.62	7.35	1.76	.50	.68	3.50	7.61	48.01
1927	1.27	2.25	7.10	6.13	3.54	7.47	.89	.56	2.49	3.65	1.22	4.42	40.99
1928	.82	3.38	5.66	2.46	2.92	4.38	5.15	.94	1.08	2.31	5.53	3.03	37.66
1929	3.76	2.63	3.00	4.67	12.73	3.28	3.98	.89	1.47	1.55	7.69	7.39	53.04
1930	6.45	4.46	2.35	.48	6.66	2.36	1.74	2.45	4.57	5.48	5.53	3.17	45.70
1931	3.63	5.73	3.52	3.85	2.96	.78	1.99	6.41	.22	2.10	4.17	9.77	45.13
1932	11.61	9.50	3.42	2.42	2.37	.95	1.43	2.36	.92	1.32	2.98	6.85	46.13
1933	1.90	4.32	5.50	4.09	5.50	.60	12.72	.60	1.77	.73	.35	7.40	45.48
1934	8.01	4.86	6.68	6.38	4.39	.93	1.28	.96	3.64	1.88	9.45	4.55	53.01
1935	3.03	2.25	2.37	7.23	15.60	2.73	1.61	.50	3.44	2.83	5.65	5.53	52.77
Average	3.83	2.87	4.08	5.00	5.65	2.84	3.43	2.35	2.55	2.71	4.17	5.13	45.62

[1] From U. S. Weather Bureau records.

DRAINAGE

Angelina County is bounded on the north and northeast by the Angelina River and on the south and southwest by the Neches River (see pl. 2). Discharge measurements for the Neches near Diboll for the period 1923 to 1925 and for the Angelina near Lufkin for the period 1923 to 1934 have been published by the Geological Survey.[1]

The Lufkin gaging station on the Angelina River is on the highway bridge 1 mile above the Texas & New Orleans Railroad bridge and 8 miles north of Lufkin, Angelina County. The drainage area above the station is 1,580 square miles.

The average discharge of the Angelina River at Lufkin for the 11-year period October 1923 to September 1934 was 1,230 second-feet. The maximum daily discharge was 36,800 second-feet, February 24, 1932. The minimum daily discharge recorded was 4.5 second-feet, September 2, 1934. The discharge of the Angelina River is lowest during the period June to November.

During the 11-year period the discharge was less than 30 second-feet 13 percent of the time. During the year ended September 30, 1925, the year of smallest run-off, the maximum discharge was only 650

[1] U. S. Geol. Survey Water-Supply Papers 588, 608, 628, 648, 688, 703, 718, 733, 748, and 763.

second-feet and the discharge was 30 second-feet or less for 116 days, which occurred in three periods of 4, 51, and 61 successive days. The discharge was also less than 30 second-feet for a period of 89 days, July 5 to September 30, 1934. This period may have continued beyond September 30, 1934, but the records were discontinued on that date.

ECONOMIC DEVELOPMENT

Lumbering is the most important industry in Angelina County. Two of the largest sawmills in east Texas and numerous small sawmills are located in the county. Practically all of the county was originally well forested, with mostly short-leaf yellow pine and hardwood. All the virgin pine has been cut, and second-growth timber is now being utilized. The southeastern part of the county has been deforested to a great extent by excessive cutting and forest fires, but under the regimen of the Forest Services of the State and Federal Governments steps toward the prevention of forest fires and educational campaigns emphasizing forest conservation and reforestation have aided materially in preserving the timber.

Farming is also extensively practiced in the county. According to the Texas Almanac for 1936 there are 2,802 farms comprising 215,077 acres in Angelina County, and more than half of the farms are operated by the owners or part owners.

The chief crops are corn, cotton, sorghum, sugar cane, tomatoes, and hay, and the usual variety of truck garden fruits and vegetables. Pecans and walnuts grow wild in the woods.

Although many wells have been drilled in Angelina County in search for oil and gas, the only yield thus far has been from a small shallow oil field near Huntington, which produces a high-grade lubricating oil.

ACKNOWLEDGMENTS

The writers are indebted to many persons who have contributed information and assistance in the field and in the preparation of this report. Geologists of the Humble Oil & Refining Co., the Gulf Oil Corporation, and the Sun Oil Co. have supplied valuable information about the geology of the area. Mr. Sam L. Olson, of the Layne-Texas Co., has furnished valuable well data and water analyses. Mr. K. L. McHenry, geologist of the Angelina Lumber Co., has given freely of his store of geologic information about the area and has furnished many well logs from his files. Mr. Ernest Kurth, general manager of the Angelina Lumber Co., has given useful information on the quantity and quality of water needed for paper milling. Mr.

Ed. C. Burris, secretary of the Lufkin Chamber of Commerce, has supplied information relating to Angelina County and the probable future demand for water in the county. Mr. S. F. Turner, of the Geological Survey, made preliminary studies of the geology and hydrology of the area. Dr. John Campbell, director of research of the International Paper Co., has supplied information on the maximum permissible mineralization and chemical character of water suitable for use in paper milling. Miss Margaret D. Foster, of the Geological Survey, analyzed the water samples and aided in the interpretation of the chemical analyses.

HISTORY OF WELL EXPLORATION IN THE LUFKIN AREA

Prior to 1935 the City of Lufkin had drilled several wells to different depths in an effort to obtain a suitable and adequate groundwater supply. None of these wells furnished potable water. In 1935 three test wells, Nos. 39, 46, and 54, were drilled 5½ miles north, 2½ miles north, and 3 miles northwest, respectively, of Lufkin post office. (See pl. 2.) The water obtained from the Sparta and Carrizo sands was sampled and analyzed. The analyses showed that only the water from the Carrizo sand in well 39 was acceptable; the other waters were too highly mineralized for municipal or industrial purposes.

In July 1937 the Lufkin Chamber of Commerce, following the recommendation contained in a memorandum by A. N. Sayre and J. F. Heuser, presented in April 1937 to the Mayor and City Council of Lufkin, drilled another test well (No. 20) 2¼ miles north of well 39 to test the water from all the water-bearing formations encountered in that locality down to and including the Wilcox, except the Queen City sand member of the Mount Selman formation. The water from the Queen City sand was not tested because in well 17, the Gulf Pipe Line Co. well 1 mile west of well 20, this sand yields highly mineralized water so would likely also yield highly mineralized water in well 20.

This drilling test was carried to a depth of 1,198 feet, and drill stem samples of water were obtained from sands at the following depths: 226 to 236 feet; 291 to 301 feet; 757 to 767 feet; 822 to 832 feet; 1,064 to 1,074 feet; 1,102 to 1,112 feet. Washed samples of the drill cuttings were obtained at 10-foot intervals and at every other horizon that showed a change in the character of the formation between depths of 178 and 1,032 feet. The water samples were analyzed and the sand samples were tested for permeability in the laboratories of the Geological Survey at Washington. Mechanical analyses of 10 of the sand samples were also made there. The results of the analyses of the water are given on page 35, the log of the well on page 41, the results of the permeability tests on page 34, and the results of the mechanical analyses on page 35.

GENERAL GEOLOGY

Except for the alluvium of the river valleys all the rocks that crop out in Angelina and Nacogdoches Counties are of Eocene age. They comprise a thick series of shallow marine, littoral, deltaic, and continental deposits which, because of poor exposures and lack of economic value, have been but little studied within the area. Such published information as is available concerning them is furnished chiefly by reports of the Geological Survey and the Texas Bureau of Economic Geology.[2] Most of the formations contain irregularly bedded water-bearing sands that vary in character, thickness, and lateral extent. Only two of the formations, the Sparta and the Carrizo sands, contain water-bearing sands that have sufficient permeability, extent, and thickness to constitute aquifers of great economic importance. Both of these are overlain and underlain by impermeable beds. From northern Nacogdoches County southward successively younger rocks crop out as follows: Wilcox group, undifferentiated, Carrizo sand, Mount Selman formation (Reklaw member, Queen City sand member, and Weches greensand member), Sparta sand, Cook Mountain formation, Yegua formation, and the Jackson group undifferentiated. (See pl. 1.) Recent stream deposits of shallow depth occur along the Angelina and Neches Rivers. The following table gives a generalized description of these formations and their water-bearing properties.

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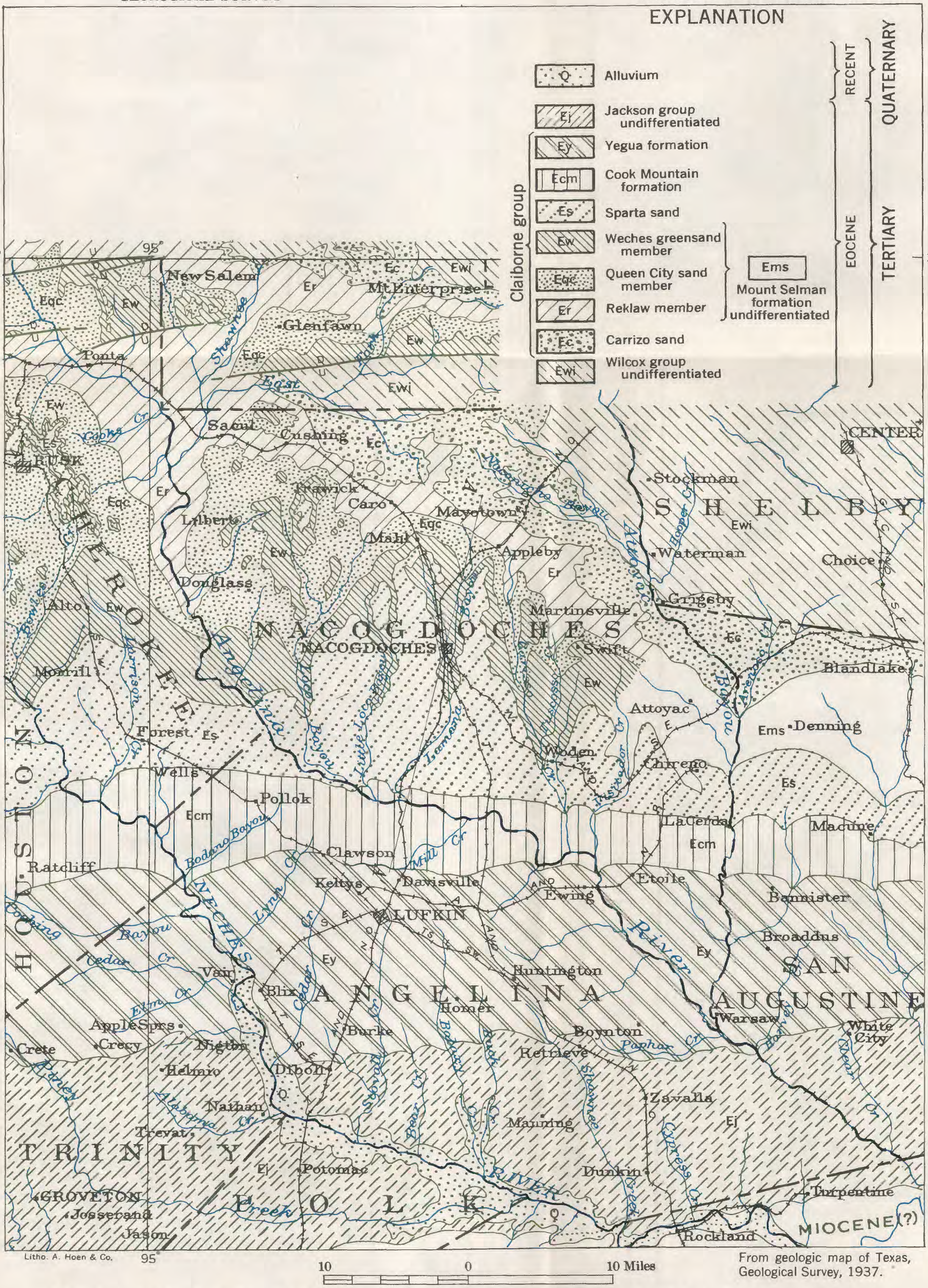
[2] Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, pp. 29-68, 114-115, 309, 1914. Geologic map of Texas: 1:500,000. U. S. Geol. Survey, 1937. Sellards, F. H., Adkins, W. S., and Plummer, F. B., The geology of Texas, vol. 1, Stratigraphy: Texas Univ. Bull. 3232, pp. 571-699, 1932.

Outline of stratigraphy of Angelina and Nacogdoches Counties, Tex.

System	Series	Group	Formation		Approximate thickness (feet)	Character of rocks	Water-bearing properties
Quaternary.	Recent.				0–25	Silt, sand, clay, and gravel, confined to stream valleys.	Not known to yield water to wells in material quantities.
Tertiary.	Eocene.	Jackson group.	Jackson group (undifferentiated).		100–500	Red and gray clays, sandstone, limestone, boulders, and petrified wood.	Yields potable water to springs and shallow wells and rather highly mineralized water to deep wells.
		Claiborne group.	Yegua formation.		500–800	Light-colored gypsiferous sand, sandy clays, light-brown shales, numerous ferruginous concretions, and an abundance of petrified wood.	Furnishes water of varying quality, usually moderately to highly mineralized, to many of the farms and towns of Angelina County, including Lufkin, where wells in this formation yield as much as 1,200,000 gallons a day.
			Cook Mountain formation.		350–450	Dark-red clays and shales partly gypsiferous, thin beds of sand, in places containing deposits of limonite.	Yields to wells water that is usually scant and highly mineralized.
			Sparta sand.		150–250	Gray to buff-colored sand interbedded with clays and sandy clays.	Test wells indicate that this formation is capable of yielding large supplies of moderately to highly mineralized water.
			Mount Selman formation.	Weches greensand member.	125–230	Massive fossiliferous greensand interbedded with gray to chocolate-colored clays and shales.	Not known to yield water to wells except in small quantities.
				Queen City sand member.	10–130	Light-gray fine-textured micaceous sands alternating with chocolate-colored sandy shale. In places lignitic.	Supplies water of varying quality to farms on the outcrop in Nacogdoches County. Yields a flow of 4 gallons a minute of highly mineralized water to well 17 in northern Angelina County.
				Reklaw member.	130–350	Chocolate-colored glauconitic shales with carbonaceous, micaceous sandy shales. Lignitic brown sands at the base (Cane River of some geologists).	Not known to yield water in material quantities from upper part. Test well 20, 6¾ miles north of Lufkin, had a flow of 8 gallons a minute of moderately mineralized water from the basal sand.
			Carrizo sand.		40–200	Clean white medium-grained quartz sand interbedded with thin beds of shale and sandy shale.	Yields abundant supplies of water of good quality in southern Nacogdoches and northern Angelina Counties.
		Wilcox group.	Wilcox group (undifferentiated).		800–2,300	Gray, green, and reddish-brown clays and shales in places containing minable lignite. Thin beds of sand and lignitic sandy shales.	Yields supplies of water rather high in bicarbonate to farm, stock, and sawmill wells in Nacogdoches County. Furnished a flow of 8 gallons a minute to well 20 in Angelina County.



GEOLOGIC MAP OF ANGELINA AND NACOGDOCHES COUNTIES AND ADJACENT AREAS, TEXAS

1940

STRUCTURAL GEOLOGY

The geologic structure of the area is simple. The formations dip toward the south at a rate of 50 to 60 feet to the mile, a dip somewhat greater than that of the land surface. Several faults in Angelina County and adjacent areas in Polk and Nacogdoches Counties have been reported by oil geologists. Most of the faults observed have a northeastward trend and a rather small displacement. One such fault may be seen along the old Zavalla-Manning road at the western edge of Zavalla, in the southeastern part of Angelina County. Another fault is inferred from the high dips observed at the underpass of the St. Louis & Southwestern Railroad about three-quarters of a mile northwest of Keltys. A third was observed near Highway 35 about 1 mile south of the Neches River in Polk County. A fault is indicated by well logs near the Cook Mountain-Yegua contact about 2 miles south of Redland. This fault has an eastward trend and extends from the Lufkin-Nacogdoches highway to the Angelina River. However, no surface indications of the fault were observed in the locality or in cuts along the Texas & New Orleans Railroad right-of-way from Lufkin north to the Angelina River. Another fault that appears to have an eastward trend in Nacogdoches County on Highway 35 about half a mile north of the Angelina River is reported. A dome-shaped structure on the Sam Peavy timber lease about 7 miles west of Lufkin and about 1 mile north of Hudson School appears to indicate local doming of the formations. However, it is reported that test wells show that the doming is confined to the Cook Mountain formation. The beds below the Cook Mountain have normal dips in this area.

A series of 18 boreholes (Angelina County wells 18, 22, 23, 24, 26, 27, 29, 30, 32, 33, 34, and 35 and Nacogdoches County wells 291–A, 292–A, 296–A, 297–A, 300–A, and 305–A) were drilled by the Angelina Lumber Co. north and northeast of Lufkin to the top of the Weches greensand member of the Mount Selman formation for the purpose of determining whether structural irregularities exist in that area. Mr. K. L. McHenry, who was in charge of this work, reports that he found no evidence of faulting.

GENERAL PRINCIPLES OF THE OCCURRENCE AND MOVEMENT OF GROUND WATER

For detailed discussions of the general principles of the occurrence and movement of ground water and for exhaustive bibliographies of the work of earlier students of these subjects the reader is referred to papers by Meinzer [3] and Wenzel.[4]

[3] Meinzer, O. E., The occurrence of ground water in the United States: U. S. Geol. Survey Water-Supply Paper 489, 321 pp., 1923; Outline of ground-water hydrology: U. S. Geol. Survey Water-Supply Paper 494, 71 pp., 1923; Movements of ground water: Am. Assoc. Petroleum Geologists Bull., vol. 20, pp. 704–725, June, 1936.

[4] Wenzel, L. K., The Thiem method for determining permeability of water-bearing materials and its application to the determination of specific yield: U. S. Geol. Survey Water-Supply Paper 679, pp. 1–57, 1936.

The discussion of these broad subjects is limited in the present report to those phases that are essential to an understanding of the problems under consideration.

The two general physical characteristics of rocks commonly considered in connection with the occurrence of ground water are porosity, that is, capacity to contain water, and permeability, capacity to transmit water.

Fine-grained sediments such as clay and silt are likely to have a relatively high porosity, but because of the small size of the pores they do not transmit water readily under the pressure commonly found in nature and are therefore said to be impermeable. Coarse-grained sediments, such as sand, commonly have less porosity than clay, but the pore spaces are larger and water moves through them more easily. They are said to be permeable. The present report is chiefly concerned with rocks that have the capacity to transmit water, that is, with sand and sandstone.

Water from surface precipitation or from the surface streams moves downward through the sand until it reaches the top of the zone of saturation, in which all of the interstitial openings are filled with water. The top of this zone is known as the water table. The water table is not a level surface, but has irregularities which, although smaller, are similar to and related to the topography of the land surface. In places the land surface is lower than the water table, and some of the ground water emerges as springs, or, where drainage is poor, swamps or lakes.

In areas such as the one under discussion, where the water-bearing beds dip beneath impermeable beds, the water in the outcrop area occurs under water-table conditions, but down the dip beneath the impermeable material the water is confined under hydrostatic pressure and in a well would rise above the top of the sand. As the altitude to which the water rises is greater than the altitude of the land surface in most places down the dip, flowing artesian wells are common.

The reservoirs of ground water are being continually replenished by rains that fall on the outcrop areas of the sand. The water moves slowly down the dip of the formation until it is either intercepted by wells or is discharged through some natural outlet, or it may escape by slow movement into overlying beds. Most of the formations in this area must have contained salty water at one time, either because they were deposited in the sea or in brackish-water zones near the sea or because the sea flooded the area shortly after their deposition and sea water was absorbed by the permeable formations. The persistent permeable beds of sand in these formations are now filled with relatively fresh water far down the dip from the outcrop areas, indicating that fresh water absorbed by the sand at the outcrop has flushed out the salty water. In some of the formations the beds of sand are lenticular or pinch out a short distance down the dip. The water encountered in these beds is usually highly mineralized.

Faulting may hinder the normal movement of ground water, and if the displacement is great enough may completely stop it, and the water thus pocketed is likely to be highly mineralized. In this area the displacement along the faults described above is hardly sufficient to materially affect the movement or quality of the water in the water-bearing formations over wide area, although it may cause local stoppage of flow and accumulation of highly mineralized water.

The coefficient of permeability, as used by the Geological Survey, is the rate of flow, in gallons a day, through a cross section of 1 square foot, under the hydraulic gradient of 100 percent and at 60° F.; or, expressed in terms applicable to field conditions, it is the rate of flow, in gallons a day, through a cross section 1 foot high and 1 mile wide under a hydraulic gradient of 1 foot to the mile at 60° F.

Darcy's law, the accuracy of which has been demonstrated by a large number of tests, states that the rate of flow is proportional to the hydraulic gradient. Hence the rate at which water will move through a water-bearing formation at a given temperature is proportional to the permeability, the cross-sectional area, and the hydraulic gradient and may be expressed by the formula

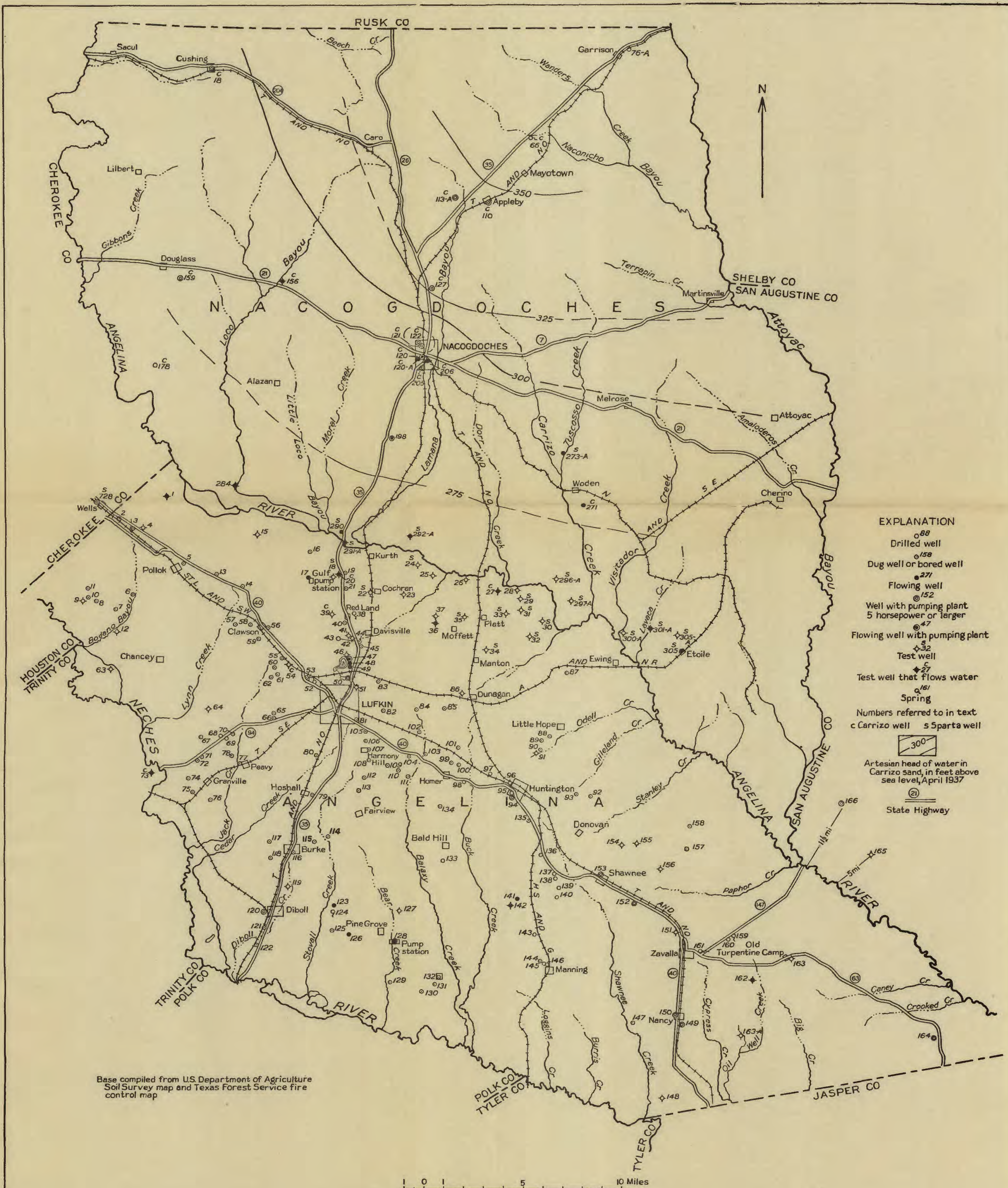
$$Q=PIA$$

in which Q is the quantity of water discharged in a unit of time, P is the coefficient of permeability, I is the hydraulic gradient, and A is the cross-sectional area through which the water percolates.

Under water-table conditions, when a well is pumped water is taken from the water-bearing formation near the well and a hydraulic gradient is established that causes water to move toward the well from all directions. The water table around the well thus assumes a shape that has been compared to an inverted cone, although it is not a true cone, which is called the cone of depression. Within a few hours or at most a few days after pumping starts, the cone of depression assumes near the well an essentially constant shape, which may be expressed by Thiem's formula, modified by Wenzel,[5] as follows:

$$s=\frac{527.7\ q \log_{10} \frac{a_1}{a}}{mP}+s_1$$

[5] Wenzel, L. K., op. cit., p. 23.



MAP OF ANGELINA AND NACOGDOCHES COUNTIES SHOWING LOCATION OF WELLS.

in which s and s_1 = draw-down at two observation wells on the cone of depression, in feet;
a and a_1 = distance of two observation wells from the pumped well, in feet;
q = quantity of water pumped, in gallons a minute;
m (for water-table conditions) = the average vertical thickness (at a and a_1) of the saturated part of the water-bearing bed, in feet;
m (for artesian conditions) = the average vertical thickness of the water-bearing formation, in feet;
P = coefficient of permeability.

Near the edges of the cone, equilibrium is reached only after a considerable period of time, when the natural flow of water into the cone of depression is equal to the amount of water pumped. Until that time the cone continues to expand at its periphery and the water level within the cone gradually declines, but about the same hydraulic gradients are maintained on each part of the cone, except near the periphery, that is, the whole cone declines parallel to itself.

Up to the time that the cone of depression ceases to expand, the parts of the formation between the original water table and the cone of depression will be unwatered. The water recovered by draining this part of the formation is said to be removed from storage. The amount of water thus removed may be calculated by multiplying the volume of the unwatered formation by the specific yield of the formation. The specific yield of a water-bearing material is defined as the ratio of (1) the volume of water that it will yield by gravity after saturation to (2) its own volume. This ratio is expressed as a percentage. Under artesian conditions a formation will not commonly be unwatered, but it will be slightly compressed when the artesian pressure of the water is decreased by withdrawal of water from the well.[6]

From the above, it is apparent that when pumping from a well or a group of wells first begins, the proportion of water taken from storage to that taken from recharge will be rather large, but as pumping continues the proportion of water taken from storage will gradually decrease as the proportion taken from recharge increases. The amount of water taken from storage under either water-table or artesian conditions may be large when a water-bearing formation is first developed, and for a time the water may be withdrawn from the formation at a rate materially greater than the rate that can be perennially maintained.

[6] Meinzer, O. E., Compressibility and elasticity of artesian aquifers: Econ. Geology Bull., vol. 23, pp. 263-291, 1928.

QUALITY OF WATER

The chemical character of the water from the different formations that crop out in the area is discussed later in this report in the section entitled "Rock formations and their water-bearing properties."

Samples of water from 112 wells throughout the area, representing the character of water in each of the principal water-bearing formations, and samples from three surface sources were collected and analyzed in the water resources laboratory of the Geological Survey. Analyses of water from wells that had been closed before the investigation was begun were obtained from other sources. These analyses are shown in the table on pages 35–39 and are grouped according to formations. The outstanding facts disclosed by the records are as follows: The Carrizo sand yields by far the best water as regards low mineral content. The water is of the sodium-bicarbonate type. The bicarbonate content increases gradually from the outcrop southward but continues relatively low through Nacogdoches County into northern Angelina County as far south as the Lufkin Chamber of Commerce test well (No. 20), about 6¾ miles north of Lufkin. South of that well both the bicarbonate and total dissolved solids in the few Carrizo wells that have been put down and sampled was relatively high.

As shown in the table on pages 36–37 the water from the Carrizo sand in well 20 was of satisfactory quality for most purposes. The water from the sand immediately above the Carrizo tentatively assigned to the basal Reklaw was next in quality to the water in the Carrizo, although much higher in both total dissolved solids and in bicarbonate. The samples analyzed from the beds assigned to the Sparta were comparatively high in chloride, bicarbonate, and total dissolved solids. They contained considerably more than the one part per million of fluoride, which in drinking water is commonly recognized as being sufficient to cause mild mottling of the enamel on the teeth of some of the young children who use it continually.[7] The waters from the horizons below the Carrizo, presumably belonging to the Wilcox, group, although soft and low in chloride, were high in bicarbonate and moderately high in total dissolved solids.

The records show that most of the shallow wells in all parts of the area, regardless of the formations they tap, yield comparatively soft fresh water that is low in total dissolved solids. This is probably due to the fact that the salts normal to most of the formations have been flushed out at shallow depths by water from local rainfall, which in this part of Texas is rather high. In some of the shallow wells that were sampled during or immediately after the heavy rains in the spring of 1937 the water was almost as free from mineral matter as rain water.

[7] Dean, H. T., Chronic endemic fluorosis: Am. Med. Assn. Jour., vol. 107, pp. 1269–1272, 1936.

The analyses relate only to the chemical quality of the water and not to its sanitary character. Very shallow wells, especially those that are dug, are more subject to bacterial contamination than deeper drilled wells, and the water in them may be unsafe to drink.

As a general rule the deep wells of the area that derive water from any formation except the Carrizo yield water that is high in mineral content. Exceptions to this rule were noted in two moderately deep wells that are believed to yield water from the Sparta sand, one at Wells, in Cherokee County (No. 728), and the other in southern Nacogdoches County (No. 290). Both are on or near the outcrop of the Sparta.

ROCK FORMATIONS AND THEIR WATER-BEARING PROPERTIES

In the discussion below, beginning with the Wilcox, the formations that underlie the area are listed in the order in which they were laid down and in which they are successively crossed in traveling southward from northeastern Nacogdoches County to the southern boundary of Angelina County. (See fig. 1.) The wells mentioned in this section are described in the table of well records, pages 50–53, and their location is shown on plate 2. Each well is given a number, which is assigned to it on the map. Analyses of waters from most of the wells mentioned are given on pages 35–39.

TERTIARY SYSTEM

EOCENE SERIES

WILCOX GROUP UNDIFFERENTIATED

The Wilcox group crops out in southeastern Rusk County and in a large area embracing northeastern Nacogdoches County and most of Shelby County.

The Wilcox contains both marine and nonmarine sediments. According to the University of Texas, Bureau of Economic Geology,[8] the group comprises three formations—the Seguin formation, which is dominantly littoral marine in origin; the Rockdale, which is continental; and the Sabinetown, which is dominantly near-shore marine. Clay, laminated carbonaceous shale, lenticular sand, massive sandstone, sandy shale, and thick seams of lignite are characteristic of the group. Very few wells have passed entirely through the Wilcox group in Angelina and Nacogdoches Counties, and therefore comparatively little is known regarding its true thickness. According to Wendlandt and Knebel,[9] the Wilcox group in east Texas ranges in thickness from 800 to 2,300 feet.

[8] Sellards, E. H., Adkins, W. S., and Plummer, F. B., The geology of Texas, vol. 1, Stratigraphy: Texas Univ. Bull. 3232, pp. 571–601, 1932.

[9] Wendlandt, E. A., and Knebel, M. G., Lower Claiborne of east Texas, with special reference to Mount Sylvan dome and salt movement: Am. Assoc. Petroleum Geologists Bull. vol. 13, p. 1350, 1929.

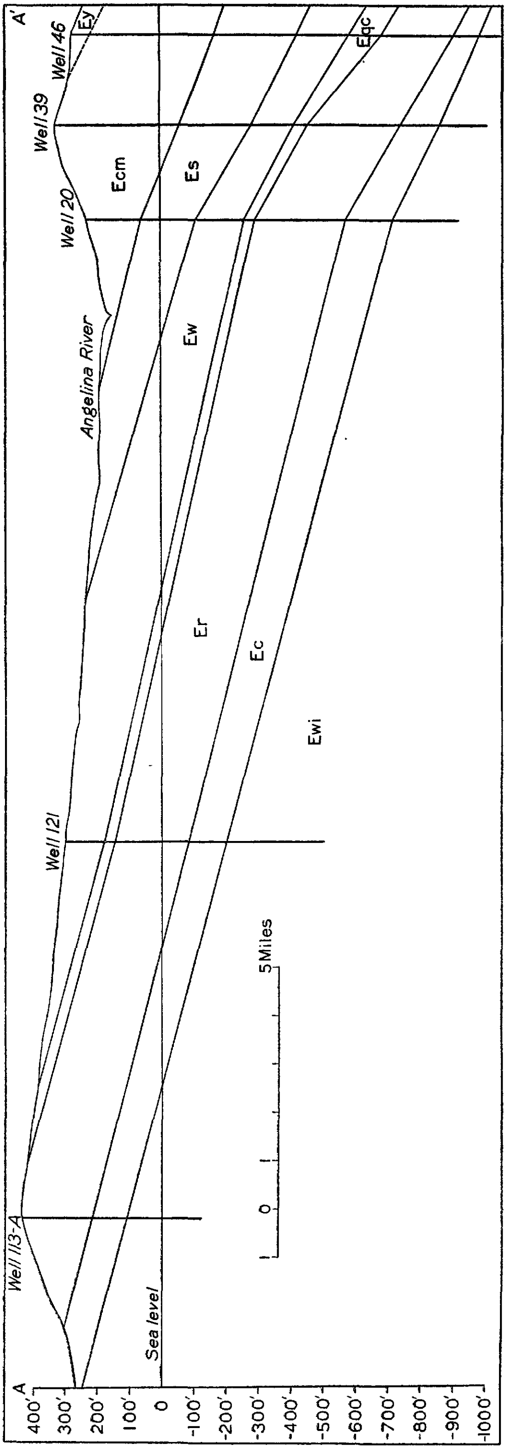


FIGURE 1.—*Generalized geologic section along line A-A′, plate 1.* Ewi, Wilcox group, undifferentiated; Ec, Carrizo sand; Er, Reklaw member, Eqc, Queen City sand member, Ew, Weches greensand member, Mount Selman formation; Es, Sparta sand; Ecm, Cook Mountain formation; Ey, Yegua formation.

The Pollok-Sessions No. 1 oil test (well 4) 13¾ miles northwest of Lufkin, Angelina County, penetrates the Wilcox Group. According to the paleontologic determination made by the Humble Oil & Refining Co., which is shown below, the Wilcox has a thickness of 2,497 feet.

Pollock-Sessions No. 1 oil test (well 4)

	Feet
Cook Mountain formation	0 to 185
Sparta sand	185 to 377
Undetermined	377 to 406
Mount Selman formation:	
Weches greensand member	406 to 539
Queen City sand member	539 to 627
Reklaw member	627 to 975
Carrizo sand	975 to 1,174
Wilcox group (undifferentiated)	1,174 to 3,671
Midway formation	3,671 to 4,009

The information available on the quantity and quality of the water available from the Wilcox in Angelina County is scant because few wells penetrate it and because information on water-bearing properties of the sand beds in the group was generally not obtained in the course of drilling. Numerous wells on the outcrop of the Wilcox in Nacogdoches County yield water for domestic use. Well 76–A, which is 280 feet deep, is half a mile northeast of Garrison, in the northeastern part of Nacogdoches County on the outcrop of the Wilcox group. It yields water that is very soft but rather high in bicarbonate from a 98-foot stratum of sand. (See table p. 36).

Test well 20 of the Lufkin Chamber of Commerce yielded 8 gallons of water a minute from a sand in the upper part of the Wilcox 50 feet thick between 1,100 and 1,150 feet beneath the surface. The artesian pressure in this sand was sufficient to raise the water about 40 feet above the ground or about 270 feet above sea level. Only 10 feet of screen, set from 1,102 to 1,112 feet, was used to tap the sand. The water was comparatively soft but was relatively high in bicarbonate (826 parts per million, see table p. 35).

Although the data presented above are meager, they support the general conclusion regarding the quality of the water from the Wilcox group that would be reached from a study of the geology of the group. The beds of sand are lenticular, and there is no free intercommunication between the various beds. Therefore the water probably varies considerably in chemical character from place to place but probably tends, in general, to be highly mineralized.

No pumping tests were made on Wilcox wells, but due to the fact that the sand beds are not persistent or everywhere continuous, it appears probable that no large quantities of water are to be expected from this group. The available data support this conclusion. Well 20 in Angelina County had a flow of only 8 gallons a minute from the Wilcox, although the altitude of the well site is relatively low.

CLAIBORNE GROUP

CARRIZO SAND

Geology.—The Carrizo sand is a poorly cemented moderately coarse grained permeable sand with shale lenses. As it comes from wells it is white. At the surface it is usually red and cross-bedded, the color being due to iron oxide, but where the iron oxide is leached out the sand is white to light brown. The formation is believed to be chiefly continental.

The Carrizo sand, which lies unconformably above the Wilcox group, appears at the surface in a belt 2 to 8 miles wide across southern Rusk, northeastern Nacogdoches, southwestern Shelby, northern San Augustine, and northern Sabine Counties.

Starting in southern Rusk County, where it ends against a fault, the outcrop widens toward the east, attaining its maximum width in the vicinity of Attayac Bayou.

The cross section shown in figure 1, drawn along the line A–A′, plate 1, shows the dip of the formation. The following table gives the altitude of the top of the Carrizo in wells along that line.

Table showing altitude of the top of the Carrizo sand along line A–A′, plate 1

	Distance south of outcrop (miles)	Altitude above or below (—) sea level (feet)		Distance south of outcrop (miles)	Altitude above or below (—) sea level (feet)
Outcrop		±350	Well 20	18½	−575
Well 113-A	3	210	Well 39	21	−741
Well 121	8	−75	Well 46	23	−950

Thus it is seen that the Carrizo dips toward the south at an average rate of about 50 feet to the mile. According to the records of some 17 wells (see p. 18) the thickness of the formation ranges from 42 feet in well 27 to 199 feet in well 4. A part of this range undoubtedly represents an actual range in the thickness of the formation, as the contact between the Carrizo sand and the Wilcox group is unconformable and therefore uneven. It is doubtful, however, if the range in thickness is as great as is indicated by the logs. Some wells may have passed through faults, which would tend to make the thickness of the formation appear greater or less than the actual thickness, depending upon the direction of the displacement. Also the accuracy of parts of the drillers' logs is open to question, and the thickness of the Carrizo as determined in such logs is questioned in the table. At least along the section shown in figure 1 it seems probable that the average thickness of the formation is about 125 feet. The logs seem to indicate that the Carrizo thickens toward the west.

Quality of water from Carrizo sand in Nacogdoches and Angelina Counties, Tex.

Nacogdoches County

Well number	Distance from outcrop (miles)	Depth of well (feet)	Depth to top of Carrizo (feet)	Thickness of Carrizo sand (feet)	Quality of water (parts per million)			
					Total dissolved solids	Bicarbonate (HCO_3)	Chloride (Cl)	Hardness as $CaCO_3$
66	0	Spring				4	1	32
18	2½	320	165	142		18	12	87
110	2½	560±				24	5	50
113-A	2½	400				108	12	92
127	6	540				168	7	1.5
156 [1]	9	700				40	15	111
121	9	484	374	115+	131	108	7	6
120	10	500	340	160		122	9	10
120-A	10	500±				48	6	1.5
205	10	536	427	109				
206	10	530				120	9	1.5
159	11	525	502	23+		142	12	63
271	12	400			222	222	4	21
198	14	550			170	162	5	1.5
178	15				193	154	9	41
Angelina County								
28 [1]	17	3,482	751?	189?				
27	18	810	745?	42?		346	11	19
37 [1]	21	2,010	954	100				
20	22	1,198	802	142	288	210	7	9.4
4 [1]	23	4,009	975	199?				
39 [2]	24	1,188	1,066	128	483	318	17	12.7
42	24	1,500	1,077	139?				
46 [2]	25	1,243	1,178	70	668	430	26	7.3
54 [2]	26	1,449	1,269	126	846	720	65	8.3
63 [1]	30	3,321	1,199?	.129?				
64 [1]	30	1,305	1,223	82?				

[1] Oil test.
[2] Analysis by Curtis Laboratories, Houston, Tex.

Quality of water.—In the table above the wells are arranged in the order of their distance from the outcrop of the Carrizo sand beginning with the spring (No. 66, Nacogdoches County), which is on the outcrop, and ending with well 64 (Angelina County), 30 miles south of the outcrop. The total dissolved solids, bicarbonate, chloride, and hardness are shown for the water of each of the wells from which it was possible to obtain a sample. In Nacogdoches County and the northern part of Angelina County the water from wells that draw only from the Carrizo is relatively soft and low in dissolved solids. The water is, in general, of the sodium-bicarbonate type. Both the total dissolved solids and the bicarbonate tend to increase in the wells toward the south; that is, down the dip, and in the vicinity of Lufkin the water is rather highly mineralized. The table shows that the increase is not uniform and that some wells yield water of higher mineral content than others that are at a greater distance from the outcrop. This irregularity may be due to the fact that some of the wells are admitting water from basal Reklaw sands (see pp. 25–26), immediately above the Carrizo. In the Lufkin Chamber of Commerce test well (No. 20) the water from the lower part of the Reklaw was much higher in bicarbonate than that from the underlying Carrizo. The bicarbonate and total dissolved solids in the water from Carrizo test wells 39, 46, and 54, a few miles south of well 20, apparently were relatively high. Therefore, it seems likely that the farther north from Lufkin that wells are drilled into the Carrizo sand the better will be the quality of the water.

Permeability.—The Carrizo sand is rather permeable. The weighted average of the permeabilities of well cuttings and cores from well 20 determined by laboratory tests (see table p. 34), was 171. This would be equivalent to a field coefficient of permeability of 190. In pumping tests on wells 121 and 122 of the City of Nacogdoches the draw-down in well 121 after 3 hours of pumping at the rate of 700 gallons a minute was 56.45 feet. This pumping caused a decline of 17.52 feet in well 122, which is 200 feet north of well 121. The coefficient of permeability below was calculated from Thiem's formula [10]

$$P=\frac{527.7q\log_{10}\frac{a_1}{a}}{m\ (s-s_1)}$$

in which P=coefficient of permeability;

q=rate of pumping in gallons a minute;

a and a_1=the distances of two observation wells from the pumped well, in feet;

m=the vertical thickness of the water-bearing bed, in feet;

s and s_1=the draw-down at the two observation wells, in feet.

Substituting in the formula

$$P=\frac{527.7\times700\times\log_{10}\left(\frac{200}{10/12}\right)}{115\times(56.45-17.52)}=195$$

Thus the coefficient of permeability is found to be 195. However, as only two wells were available for determination of the draw-down, and one of these was the pumped well, it was necessary to use for the quantity a the radius of the pumped well and for the quantity s the draw-down in the pumped well and to assume that there was no loss in head due to entrance losses in the well. Entrance losses may be small in a properly constructed well, but they cannot be entirely eliminated. Hence the substitution of the draw-down in the pumped well for the quantity s in the formula results in a calculated permeability somewhat less than the actual permeability. On the other hand, the

[10] Wenzel, L. K., op. cit., p. 10.

effective diameter of the well is somewhat greater than the actual diameter as a result of the development operations, and this difference results in a calculated permeability somewhat greater than the actual permeability. On the basis of these results, 190 is assumed as the average coefficient of permeability for the Carrizo sand. Actually, however, the sands are the most permeable near the outcrop and decrease in permeability down the dip.

Hydraulic gradient.—In April 1937 the altitude to which the water would rise was determined in several wells in Carrizo sand in Nacogdoches County by measuring the depth to water in the nonflowing wells and the shut-in pressure in the flowing wells and then referring these measurements to sea level by means of a surveyor's aneroid. In well 113–A, near the outcrop area, the water rose to an altitude of 342 feet above sea level; in well 18 at Cushing, Nacogdoches County to an altitude of 295 feet; in well 127, 2¾ miles north of Nacogdoches, the water rose to an altitude of 329 feet. The water in wells 121 and 122 of the City of Nacogdoches rose to an altitude of 276 feet. In wells 156 and 205 water rose to an altitude of about 290 feet. In well 198, Piney Woods Country Club, the water rose to an altitude of 277 feet. It was impossible to measure the true shut-in pressure in well 271 as pressure leaks developed when the flow of water was cut off. It was possible to measure the static head in only two wells in Angelina County (Nos. 20 and 27). Water from the Carrizo sand in both of these wells rose to an altitude of 270 feet above sea level. The pressure measurements in both wells were taken after the wells had been closed down only about half an hour. It is believed that if the pressure had been allowed to build up for 24 hours it would have risen somewhat higher.

From the above data it is apparent that the water in the Carrizo sand is confined under artesian pressure and that the hydraulic gradient is toward the south. The gradient between well 113–A, in Nacogdoches County, and well 20, in Angelina County, a distance of about 21 miles, amounts to 73 feet, or an average gradient of about 3½ feet to the mile.

In most parts of the area an artesian flow may be obtained from wells drilled into the Carrizo sand except where the discharge from the wells has caused a decline in the static level of the water, as at Nacogdoches. There the water level in 1907 in a well of the Nacogdoches Ice & Cold Storage Co. was 40 feet above the ground surface according to Deussen.[11] Deussen states that the well produced from the Wilcox. The upper part of Deussen's Wilcox is now called the Carrizo sand.

[11] Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, pp. 309–316, 1914.

This well is presumably well 120–A, now belonging to the Southern Ice Co., and the present static level of the water in this well is 1 foot above the top of the casing. Thus there has been a decline in static level of about 39 feet during the past 30 years, due chiefly to the withdrawal of water from the Carrizo in Nacogdoches. In the city wells the altitude of the static water level is about 5 feet lower than in well 120–A, and although there are not enough wells to permit the drawing of a detailed map of the pressure-indicating surface of the water in the Carrizo, it is evident that there is a cone of depression centering in the Nacogdoches city wells. It seems likely that there are also cones of depression centering in well 198 (Piney Woods Country Club) and well 271 (L. C. Jacobs).

On plate 2 lines are drawn representing the best estimate that can be made from the data obtained on the altitudes above sea level to which water would rise in the wells in Nacogdoches County that obtain their supplies from the Carrizo sand. Such lines are comparable with contour lines on a topographic map, but instead of indicating the form of the land surface they indicate the form of a water surface represented by the static water levels in wells, which is known as the piezometric surface. Ground water moves in the direction of the hydraulic gradient, which is at right angles to the contour lines on the piezometric surface. According to the map the water in the Carrizo sand in Nacogdoches County is moving a little west of south.

The fact that water from the Carrizo sand north of Redland is only moderately to slightly mineralized, whereas near Lufkin it is highly mineralized, also indicates that water from the outcrop area is moving down the dip.

Present yield of wells.—In Nacogdoches County, wells in the Carrizo sand yield moderate amounts of water, but none of them have been tested to determine how much water they would yield by pumping, except the two wells of the City of Nacogdoches (Nos. 121 and 122), which are pumped alternately and are reported to furnish an average supply of about 800,000 gallons a day. The L. C. Jacobs well (No. 271) has a flow of about 40 gallons a minute. This well formerly supplied the Woden CCC Camp, but the water is now wasted into a nearby creek. The Piney Woods Country Club well (No. 198) has a flow of 15 gallons a minute and is sometimes pumped to supply water to the club house, golf greens, and swimming pools. The Yuba Oil Refining Co. well (No. 206) has a flow of 13 gallons a minute, which is wasted, as the refinery is not operating.

No wells to determine the capacity of the formation have been developed in the Carrizo sand in Angelina County, and no pumping tests have been made on the exploratory wells. Therefore no direct information is available as to the quantity of water that the Carrizo

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sand is capable of yielding to wells in the county. A natural flow of 33 gallons a minute was obtained from the Carrizo sand in the Lufkin Chamber of Commerce test well through a section of screen 10 feet in length, and a flow of 40 gallons a minute was obtained from the sand in well 27.

Maximum perennial yield of wells in Angelina County.—The problem of estimating future yields from water-bearing formations is a difficult one. Two lines of approach appear to be applicable in the present investigation: (1) Computation of probable yield from such data as are available, and (2) comparison with other areas where pumpage has been maintained over a period of years and where investigations have resulted in a reliable figure for the perennial yield.

The rate at which water is moving, in gallons a day, through each mile of the formation measured at right angles to the direction of movement (Q) may be calculated by the use of Darcy's formula as follows:

$$Q=PIA$$

The several factors in this equation have approximately the following values: $P=190$, the coefficient of permeability; $I=3.5$, the natural hydraulic gradient in feet per mile; $A=125$, the average thickness in feet of the formation through which the water moves.

It is thus calculated that under the existing hydraulic gradient, 83,125 gallons a day flows through each mile of the formation. As the width of the two counties is about 35 miles, measured at right angles to the direction in which the ground water is moving, the entire calculated flow through the formation in these counties amounts to about 2,900,000 gallons a day.

The rate of flow of the ground water can be greatly increased by heavy pumping, because the pumping will lower the static level in the vicinity of the pumped wells and will thereby increase the average hydraulic gradient from the outcrop area to the wells. If it were possible to lower the static level 150 feet along a nearly east-west line at right angles to the direction of flow and passing through the Lufkin Chamber of Commerce test well (No. 20), then the difference in head between well 113–A, which is near the southern margin of the intake area, and the line passing through well 20 would be increased about threefold, and the rate of flow would eventually become about three times the present rate.

If the water were pumped from a series of wells situated at intervals along the line passing through well 20, the ultimate draw-down in the wells would have to be considerably greater than 150 feet to produce the postulated results because of the local cone of depression that would be developed around each well.

If the water level along this line were lowered too much by heavy pumping some of the ground water from the south, which is of poor quality, would be drawn into the wells. However, the northward movement would necessarily be slow.

The outcrop area of the Carrizo sand that can be regarded as intake area of the formation in these two counties covers about 190 square miles. The intake facilities are fairly good, and the average annual precipitation in the area is about 45 inches. It can be safely concluded that the rate of recharge in the outcrop area of the Carrizo sand is several times the present flow through the artesian part of the formation and greater than the induced flow that is represented by the foregoing postulated development.

Water available from storage.—The foregoing discussion relates to the ultimate rate of yield of water after equilibrium has been established. However, prior to the time that equilibrium is established, a part of the water pumped is taken from storage.

It is known that the yield of water from artesian water-bearing beds, particularly in the early stages of their development, greatly exceeds the yield that may be perennially obtained from the artesian beds after equilibrium has been established. Meinzer [12] has summarized the evidence bearing on this problem and has concluded that the artesian pressure exerts force that acts against the weight of the overlying rocks. When wells are drilled and water is withdrawn the hydrostatic pressure is reduced and the formation is compressed. There is not sufficient information available on this subject to permit an accurate determination of the amount of compression of the Carrizo sand that would occur under the conditions of pumping postulated above, and it is therefore not possible to determine the amount of water that would be released from storage by the compression or how long it would take to establish equilibrium. Experience indicates, however, that if the Carrizo sand is heavily pumped the total amount of water that will be released from storage by compression of the sand will be of the order of magnitude of a few hundred millions of gallons for each mile of width of the formation.

Comparison with Winter Garden area.—An investigation has been made by the Geological Survey, in cooperation with the Texas Board of Water Engineers,[13] of the safe yield of the Carrizo sand in the Winter Garden area, of southwest Texas, where there has been heavy pumping for irrigation during many years. In that investigation virtually all the methods were used that have been used in the Lufkin area. In addition, inventories were made of the pumpage and of the

[12] Meinzer, O. E., Compressibility and elasticity of artesian aquifers: Econ. Geology, vol. 23, pp. 263–291, 1928.

[13] White, W. N., Turner, S. F., and Lynch, A. W., Ground water in Dimmit and Zavala Counties, Texas: U. S. Dept. Interior memorandum for the press, No. 83105, April 11, 1934.

resulting fluctuations in the static water levels over a period of years, and the pumpage and water levels were correlated. The results obtained from the inventory method corroborated those obtained from computations of the transmission capacity.

In Dimmit and Zavala Counties, in the Winter Garden area, about 25,000 acres is irrigated from several hundred pumped wells in the Carrizo sand. These wells are irregularly spaced in a belt about 45 miles long and 4 to 12 miles wide and roughly parallel to the outcrop of the Carrizo sand. It has been estimated that the safe yield of the Carrizo sand in Dimmit and Zavala Counties, provided the pumping is well distributed throughout the area, amounts to about 20,000 acre-feet a year, or the equivalent of a continuous discharge of about 17,700,000 gallons a day.

In the following table the chief characteristics of the Carrizo sand in Dimmit and Zavala Counties are compared with those of the formation in Angelina and Nacogdoches Counties.

Comparison of the Carrizo sand in the Winter Garden area with that in the Lufkin area

	Winter Garden area (Dimmit and Zavala Counties)	Lufkin area (Angelina and Nacogdoches Counties)
Area of outcrop acres	175,000	120,000
Average thickness feet	200	125
Average permeability	200	190
Width of section miles	45	35
Average hydraulic gradient feet per mile	10	[1] 3.5

[1] Gradient under natural conditions; could be increased by pumping as postulated above.

Evidence indicates that the average annual rainfall of about 26 inches on the outcrop area of the Carrizo sand in the Winter Garden area is sufficient to supply all the water that the sand can transmit, and the computations of the safe yield were made on that basis. In Nacogdoches County, as indicated above, the average annual rainfall of about 45 inches is more than sufficient, and therefore the safe yield can be postulated on the transmission capacity of the formation. In comparing the transmission capacity of the sand in the two areas it should be considered that in Angelina and Nacogdoches Counties the width of the section is about 77 percent, the thickness of the Carrizo sand about 62 percent, and the permeability of the sand as computed about 95 percent of those features in Dimmit and Zavala Counties. Moreover, it may be considered that, although the present hydraulic gradient in the Lufkin area is only about one-third that of the Winter Garden area, it would be about the same under full development. It should also be considered that the pumpage in the Winter Garden area is widely distributed, which is necessary for maximum development.

MOUNT SELMAN FORMATION

Reklaw member.—The Mount Selman formation overlies the Carrizo sand. Throughout most of the area it has been subdivided into three members, which from bottom to top are the Reklaw member, Queen City sand member, and Weches greensand member. In the eastern part of the area it has not been subdivided.

The term "Mount Selman formation" has been dropped by the Texas Bureau of Economic Geology,[14] and the Reklaw is given full formational rank. The Reklaw member, the basal bed of which is classified by some of the local geologists as Cane River, but generally has not been differentiated from the Carrizo by the water-well drillers of the area, overlies the Carrizo sand and crops out in a rather regular belt 2 to 5 miles wide across eastern Cherokee County and northern and eastern Nacogdoches County (pl. 1). According to well logs it has a thickness of 130 to 350 feet where it is under cover in Nacogdoches and Angelina Counties. It consists of glauconitic, pyritic shales, brown carbonaceous sandy shales and clays, and limonitic concretionary ledges. At the base is a bed of lignitic, micaceous brown sand ranging in thickness from 20 to 80 feet. It is this basal sand that has been termed the "Cane River" by some geologists.[15]

The only known water-bearing bed in the Reklaw member is the basal sand. Relatively little is known regarding the quantity or quality of water in this sand, as heretofore it has generally been considered a part of the Carrizo sand. In the Lufkin Chamber of Commerce test well (Angelina County well 20), a flow of 8 gallons a minute was obtained from it. The water contained 592 parts per million of bicarbonate and 651 parts per million of total dissolved solids. Three samples of sand from this bed in well 20 were tested in the laboratory for permeability and were found to have co fficients of permeability of only 65, 7, and 40 (see p. 34).

Well 36, owned by A. P. Kimmey, 2½ miles west of Platt, in Angelina County, probably derives most of its water from the basal sands of the Reklaw. This is an abandoned oil test drilled to about 3,000 feet, then plugged back to 1,303 feet. Deussen [16] states regarding it:

> The 10-inch casing extends to 305 feet; water from it flows, probably from first horizon, 430 to 456 feet. The 6-inch casing extends to 950 feet, and from this water from the horizon 1,024 to 1,070 feet rises at least 32 feet above the ground.

Deussen [17] also reports that on September 19, 1907, the sand from 430 to 456 feet [Sparta?] furnished water which had 1,874 parts per

[14] Sellards, E. H., Adkins, W. S., and Plummer, F. B., op. cit., pp. 608–628.

[15] Ellisor, A. C., Correlation of the Claiborne of east Texas with the Claiborne of Louisiana: Am. Assoc. Petroleum Geologists Bull., vol. 13, p. 1343, 1929.

[16] Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, p. 118, 1914.

[17] Deussen, Alexander, idem, table of analyses, opposite p. 110 and p. 117.

million of total dissolved solids, sands at 688 to 750 and at 860 to 901 furnished artesian flows, and the sand from 1,024 to 1,070 feet [Carrizo?] furnished water which contained 758 parts per million. When the well was visited on February 11, 1937, it was found that the flow from the 10-inch casing had stopped, but a flow of 15 gallons of water a minute was coming from the 6-inch casing. This water contained 2,322 parts per million of dissolved solids. The tenant on the place reported that the water became more highly mineralized after the removal of a section of the 6-inch casing in 1936. The increase in mineralization is probably due to an inflow of water from the Reklaw (depth, 860 to 901 feet) or possibly from the Queen City sand (depth, 688 to 750 feet), which resulted from the removal of the section of casing.

Queen City sand member.—The Queen City sand, like the Reklaw, is given full formational rank by the Texas Bureau of Economic Geology.[18]

The Queen City sand member overlies the Reklaw member and crops out in an irregular belt 4 to 10 miles wide across northern and central Nacogdoches County (pl. 1). According to well logs it ranges in thickness from 10 to 128 feet in Angelina County.

The member consists primarily of strata of a rather impermeable micaceous sand alternated with strata of micaceous, carbonaceous sandy shale containing thin beds of lignite.

Well 17, at the Gulf Pipe Line Co. station, in Angelina County, derives its water solely from the Queen City sand. The water from this well is high in bicarbonate (HCO_3) and very high in chloride (Cl). It is not an acceptable water for either municipal or industrial purposes. In general the water from the Queen City sand would be expected to be rather highly mineralized because of the character of the bed.

Well 17 has a flow of approximately 4 gallons a minute, and a larger yield is sometimes obtained from the well by pumping with air. No other wells are known to derive water solely from the Queen City. Hence, there is little information available regarding its yield. However, the permeability is relatively high. Laboratory tests of three samples of sands from the Lufkin Chamber of Commerce well, which were correlated as Queen City, gave coefficients of permeability of 150, 160, and 185 (see p. 34).

Weches greensand member.—The Weches greensand member, like the Reklaw and Queen City sand members, has been raised to full formational rank by the Texas Bureau of Economic Geology.[19] It is immediately above the Queen City sand and appears at the surface

[18] Sellards, E. H., Adkins, W. S., and Plummer, F. B., op. cit., pp. 628–635.

[19] Sellards, E. H., Adkins, W. S., and Plummer, F. B., op. cit., pp. 635–651.

in a belt 4 to 8 miles wide across central Nacogdoches County. It also caps a few hills in north-central Nacogdoches County. (See pl. 1.) It consists of very fossiliferous glauconitic sand, sandy shale, and shale. According to well logs it ranges in thickness in this area from 125 to 230 feet.

A few shallow dug wells in the outcrop area of the Weches greensand furnish small supplies of water to farmhouses for domestic use and stock. Down the dip from the outcrop area this member is not known to be water bearing.

SPARTA SAND

The definition and regional geology of the Sparta sand is discussed by the Texas Bureau of Economic Geology.[20] It overlies the Weches greensand and crops out in an irregular zone 3 to 12 miles wide across southern Cherokee, northwestern Angelina, and south-central Nacogdoches Counties. The outcrop area widens both from the east and from the west toward State Highway 35 in Nacogdoches County (pl. 1). The formation consists of a loose usually gray to buff-colored sand interbedded with clay, sandy clay, and shales. Lignitic material throughout the formation gives the sand a salt-and-pepper appearance.

The following table gives the thickness and position of the Sparta sand recorded in 23 wells in Nacogdoches and northern Angelina Counties. The average thickness of the formation is about 185 feet.

Sparta sand in wells in Angelina and Nacogdoches Counties

Nacogdoches County

Well No.	Thickness (feet)	Depth of sand below surface (feet)	Well No.	Thickness (feet)	Depth of sand below surface (feet)
291-A	162	10 to 172	300-A	191	199 to 390
292-A	145	0 to 145	301-A	178	167 to 345
296-A	180	6 to 186	305-A	150	265 to 415
297-A	193	93 to 286			

Angelina County

Well No.	Thickness (feet)	Depth of sand below surface (feet)	Well No.	Thickness (feet)	Depth of sand below surface (feet)
4	192	185 to 377	33	204	156 to 360
20	161	174 to 335	35	235	230 to 465
22	180	225 to 405	37	176	329 to 505
23	196	198 to 394	39	215	381 to 596
24	175	40 to 215	46	256	439 to 695
27	154	203 to 357	54	181	565 to 746
30	193	127 to 320	63	175	485 to 660
32	214	157 to 371	64	224	575 to 799

According to data obtained in the course of a water-well inventory made by the Works Progress Administration and sponsored by the

[20] Sellards, E. H., Adkins, W. S., and Plummer, F. B., op. cit., pp. 651-655.

Texas Board of Water Engineers most of the wells in the outcrop area of the Sparta sand in Nacogdoches County yield water of relatively low mineral content, but the wells are shallow and probably give little clue as to the character of the waters from deeper wells in the Sparta. Well 728, in Cherokee County, a Sparta well, near the outcrop area of the sand, furnishes the public water supply for the village of Wells. This water has 236 parts per million of total dissolved solids, is rather soft, contains a moderate amount of bicarbonate, and is acceptable for most purposes. Well 292–A, in southern Nacogdoches County, 200 feet in depth, yields good water from this formation. The water from well 301–A, in the southeastern part of Nacogdoches County, contains 542 parts per million of bicarbonate but is low in other constituents except sodium. Well 290, in Nacogdoches County, formerly a Carrizo well, may now derive some of its water from the Sparta sand. This well is reported to have furnished clean, clear water prior to 1930, but during the 7 years 1930 to 1937 sand and a black precipitate of iron sulphide have accompanied the flow. The sand now being discharged from the well is thought to be Sparta sand. The water contains 466 parts per million of bicarbonate and 646 parts per million of total dissolved solids.

The water from the Sparta in wells 39, 46, and 54, in northern Angelina County, was rather highly mineralized and had respectively, 1,512, 2,086, and 1,598 parts per million of total dissolved solids according to analyses by the Curtis Laboratories of Houston. These waters were all soft but were high in bicarbonates, sodium, and potassium. The Sparta water from test well 20 was also rather highly mineralized, having 1,038 to 1,101 parts per million of total dissolved solids and 4.0 to 4.8 parts per million of fluoride.

No pumping tests were made on the test wells in Angelina County to determine the quantity of water available from the Sparta. However, laboratory tests on six samples of Sparta sand from well 20 gave an average coefficient of permeability of 238, which is fairly high. Wells in Nacogdoches County having a natural flow from the Sparta sand are as follows: Well 290 has a flow of about 35 gallons a minute; well 292–A has a flow of 8 gallons a minute; well 301–A has a flow of 30 gallons a minute; and well 291–A has a flow of 2 gallons a minute.

The question of whether or not the quality of the water in the Sparta sand in northern Angelina County will be improved by heavy pumping is a difficult one to answer. As has been pointed out, wells in the formation yield less highly mineralized water in the outcrop area and in certain localities near the outcrop than wells farther down the dip. Heavy pumping down the dip will tend to make the water move toward the wells from the direction of the outcrop at a faster rate than now obtains. Even with such acceleration, however, the movement will be comparatively slow. Moreover, the depression will cause water to move toward the wells along the strike and up the dip of the sand as well as down the dip. Therefore it appears probable that heavy pumping will produce no very great change in the quality of the Sparta water in Angelina County, and any change that does take place will be relatively slow. The Sparta yields good water to well 292–A, in Nacogdoches County, and to well 728, in Cherokee County, both of which are on the outcrop of this sand or very close to the outcrop. Therefore the possibility of developing supplies on the outcrop of the Sparta in Nacogdoches County 2 to 4 miles north of Angelina County is believed to merit consideration.

It seems probable that an abundant supply of water may be obtained from wells in the Sparta sand, but the water is more highly mineralized than the water from the Carrizo sand and is not acceptable for municipal or most industrial uses. It is, however, 8 to 10 degrees cooler than the Carrizo water and for that reason would be more economical than the Carrizo water for cooling.

COOK MOUNTAIN FORMATION

The name Crockett has been applied by Wendlandt and Knebel,[21] to the marine beds overlying the Sparta sand and this usage is followed by many of the geologists of Texas and by the Texas Bureau of Economic Geology.[22] The term Cook Mountain formation, however, is retained on the geologic map of Texas, published in 1937 by the Geological Survey, and this usage is followed in this report. The Cook Mountain formation consists of dark-red gypsiferous clays, reddish-brown sandstone, and sandy clays and in places contains thin beds of limestone and lignite.

The Cook Mountain formation overlies the Sparta sand and is overlain by the Yegua formation. It crops out in a rather regular belt 6 to 8 miles wide across central Houston, northern Angelina, and southern Nacogdoches Counties and according to well logs ranges in thickness from 350 to 450 feet in this area.

Shallow dug wells in the outcrop area furnish small supplies of potable water to farmhouses, but down dip, where the formation is under cover, it is not known to yield material quantities of water to wells.

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[21] Wendlandt, E. A., and Knebel, M. G., Lower Claiborne of east Texas: Am. Assoc. Petroleum Geologists Bull. 13, p. 1360. 1929.

[22] Sellards, E. H., Adkins, W. S., and Plummer, F. B., The geology of Texas, vol. 1, Stratigraphy: Texas Univ. Bull. 3232, pp. 655–666, 1932.

YEGUA FORMATION

The Yegua formation has been named Cockfield by some geologists,[23] but the term Yegua is now generally accepted. The Yegua consists of a series of alternating beds of light-colored sands and thin-bedded, laminated, chocolate-colored clays and shales. Crystals and grains of selenite are found throughout the formation. Limonitic concretions and silicified wood are abundant, and lignite is present in layers that range from thin seams to beds of commercial thickness. The formation appears at the surface in a zone 14 to 16 miles wide across central Angelina and the southeastern tip of Nacogdoches Counties. (See pl. 1.) The thickness of the formation is variable and ranges from about 500 to 800 feet in Angelina County.

The following drilled wells in Angelina County derive their water from the Yegua formation: Nos. 47, 48, 49, 50, 52, 94, 97, 120, 126, 128, 133, 136, 139, 140, 141, 152, and 153. (See well tables, pp. 50–53.) Wells 47, 48, and 49, belonging to the City of Lufkin, yield water that is only moderately mineralized, but they have been abandoned as a source of public supply because the water has such a high content of iron that it is unsatisfactory for municipal use. Well 50, also a City of Lufkin well, is not used except during dry seasons, when there is not sufficient lake water to supply the city. The water from this well is pumped into the city lake in order to permit the iron, which it contains in considerable quantities, to precipitate and settle before the water enters the city water system.

Well 52, at Keltys, supplies water having only 121 parts per million of total dissolved solids. This well is about 1,000 feet from the millpond and may be getting its water in part by seepage from the pond.

The water from wells in the Yegua formation varies considerably in mineral character. (See table of analyses, pp. 38–39.) For example, wells 94, 97, 140, and 153 yield waters which, although rather highly mineralized, would perhaps be acceptable for municipal purposes; whereas wells 120, 133, 136, 139, 141, and 153 yield waters that are too highly mineralized for municipal or industrial use. In general, the water from shallow wells in the Yegua, although low in mineralization, is unsatisfactory for municipal and industrial uses because it tends to be corrosive. Water from the deep wells in the formation as a rule are too highly mineralized to be used for municipal or industrial purposes.

Well 50, belonging to the City of Lufkin, has a reported pumpage from the Yegua of 1,200,000 gallons a day from a sand 98 feet thick. Well 52, of the Angelina Lumber Co., has a reported yield of 150

[23] Sellards, E. H., Adkins, W. S., and Plummer, F. B., op. cit., pp. 666–677.

gallons a minute, or 216,000 gallons a day from a sand 56 feet thick. Well 47, also a City of Lufkin well, has a flow of 5 gallons a minute and a reported yield of 210,000 gallons a day under pump from a 47-foot sand. Well 94 is reported to yield 1,000 gallons an hour. Well 120 is reported to yield 150 gallons a minute or 170,000 gallons a day. It has a draw-down of 53 feet after being pumped at that rate for 4 minutes.

Although in a few places wells in the Yegua yield large quantities of water acceptable for municipal and industrial purposes, in most places the wells in the formation yield little water and that of poor quality; so the Yegua cannot generally be considered as a promising source of water for municipal and industrial uses.

JACKSON GROUP UNDIFFERENTIATED

As used here the Jackson group includes all of the Eocene strata above the Claiborne group. The Texas Bureau of Economic Geology[24] has discussed the definition and regional geology of the group and has termed a part of the group the Fayette formation.

The Jackson group, which overlies the Yegua formation conformably, ranges in thickness from 100 to 500 feet. It crops out at the surface in a belt 12 to 14 miles wide across southern Angelina and southern San Augustine Counties (pl. 2). The Jackson in Angelina County consists of lignitic chocolate-colored clays, sandstones, sands, sandy shales, and limestone. In places some of the sandstones are indurated to form hard blue quartzitic beds. The group contains a few concretions and an abundance of opalized and silicified wood.

There are many springs in the Jackson group which yield water of good quality, though the quantity is small. The water from wells in the Jackson group varies greatly in mineral content from well to well. In some wells the mineral content is low and in others it is moderate to high. The Jackson group furnishes water to the following wells, all more than 50 feet deep.

Well 123, depth 74 feet, furnishes water that has 1,459 parts per million of total dissolved solids (see tables of analyses, p. 39). This water is hard and high in chloride (Cl), sulphate (SO_4), and bicarbonate (HCO_3). Well 124 is a quicksand pit more than 100 feet deep that yields a flow of highly mineralized water. Well 125, depth 156 feet, furnishes water that is potable but moderately mineralized. Well 138, depth 232 feet, furnishes potable but rather hard water containing 544 parts per million of total dissolved solids. Well 162, an abandoned uncased oil test on Oil Well Creek having a reported depth of about 1,800 feet, has a flow of water with only 99 parts per million of total dissolved solids. Because this well is

[24] Sellards, E. H., Adkins, W. S., and Plummer, F. B., op. cit., pp. 677–699.

uncased it has undoubtedly caved, shutting off all but the shallow aquifers, from which it derives its water.

Comparatively little is known regarding the quantity of water that can be withdrawn from the Jackson group in this area; however, the following artesian flows have been measured. Well 126 had a reported flow of 60 gallons a minute when it was drilled; it is now filled with debris, and the flow is only 1 gallon a minute. Well 123 has a flow of 40 gallons a minute. Well 128 has a flow of 12 gallons a minute and yields 125 gallons a minute under pump. Well 162 has a flow of 40 gallons a minute. Springs 159 and 161 have flows of 3 and 5 gallons a minute respectively. Well 160 has a draw-down of 90 feet after pumping 12 gallons a minute for 20 minutes.

In view of the variation in the quality of water from place to place, it is believed that the water-bearing beds are lenticular and that no large quantities of potable water are likely to be developed from wells in this group.

QUATERNARY SYSTEM

RECENT SERIES

The stream valleys in Angelina and Nacogdoches Counties contain Recent alluvial deposits of sand, clay, silt, and gravel that are restricted to very narrow areas and are not known to yield water in material quantities to wells.

CONCLUSIONS

In their areas of outcrop, most of the formations encountered in Angelina and Nacogdoches Counties yield potable water to wells of shallow to moderate depth. However, down the dip from their outcrop areas, where they are overlain by younger formations, most of them yield water that is increasingly mineralized as the distance from the outcrop increases. The water from most of the formations is not potable beyond a few miles down the dip from the outcrop areas. The water from the Carrizo sand, however, is potable for a distance of about 25 miles from the outcrop.

The Wilcox group, because its sands are lenticular, comparatively thin, and fine in texture, is not likely to yield large quantities of water to wells; moreover, where the formation is under cover the water is likely to be moderately to highly mineralized.

The basal sand of the Reklaw member of the Mount Selman formation is fine-grained and yields small quantities of mineralized water.

The Queen City sand consists primarily of rather fine grained sand. Its water-bearing characteristics are known only in one well, and there the water was rather highly mineralized. It is not believed that this formation will yield large quantities of water.

The Weches greensand member of the Mount Selman formation is not known to yield water to wells except in its outcrop area.

The Sparta sand promises to yield, next to the Carrizo sand, the largest quantities of water yielded by any of the formations in the area. The water, except in the outcrop area, may be highly mineralized and therefore not acceptable for municipal or most industrial uses. However, its temperature is 8 to 10 degrees lower than that of the Carrizo water; so the Sparta may be valuable as a source of water for refrigeration and for supplementing the Carrizo supply.

The Cook Mountain formation, which crops out in a belt 6 to 8 miles wide in the northern part of Angelina County, is not known to yield potable water to wells except in its outcrop area, where shallow wells of small yield supply water for domestic use.

Many wells in Angelina County yield water from the Yegua formation. One well, belonging to the City of Lufkin, has been pumped at a rate of 1,200,000 gallons a day, and there are other wells of rather large yield. Most of the wells in this formation yield only small quantities of water, and in general it is too highly mineralized or contains too much iron for industrial and municipal uses without treatment.

The Jackson group of formations supplies water of good quality to several small springs in the southern part of Angelina County. Numerous wells yield small to moderate amounts of water from the formation. The water is, for the most part, moderately to highly mineralized.

The Carrizo sand, which lies between the Wilcox group and the Reklaw member of the Mount Selman formation, is the most promising water-bearing formation in the area. It yields fairly large quantities of water to wells in Nacogdoches County and may be expected to provide similar yields to wells in the northern part of Angelina County. In Nacogdoches County the water is of acceptable quality as regards mineral content for most industrial uses, but it may be somewhat corrosive. In Angelina County the water becomes progressively more mineralized toward the south.

At the Lufkin Chamber of Commerce test well (No. 20) the water is acceptable in quality. At Redland, 4½ miles north of Lufkin, it contains considerable amounts of bicarbonate but is acceptable for most uses. Near Lufkin it is soft but fairly highly mineralized and not suitable for most industrial uses.

The amount of water of satisfactory quality that the Carrizo sand will yield perennially south of its outcrop area is limited by the transmission capacity of the sand, that is, its capacity to transmit water from the outcrop area, where the water enters the formation, to the wells. Its transmission capacity, which depends on the hydraulic gradient between the outcrop area and the wells, can be increased by creating a regional draw-down in the pumped areas. However, if the regional draw-down is too great, water of poor quality will be drawn into the wells from the south. In addition to the perennial yield of the Carrizo, a large amount of water can be recovered from storage for a considerable period of time.

At the time this investigation was made the principal interest in ground water related to projected large developments in the northern part of Angelina County. After consideration of all available data, the authors conclude that if the wells are drilled at regular intervals along the east-west line through well 20 in Angelina County or are widely and rather evenly distributed throughout the area in Angelina County north of this line, it will be practicable to pump as much as 10,000,000 gallons a day for a period of several years; but long-continued pumping at this rate will eventually lower the water level below the limit of economical pumping and may cause highly mineralized water to enter the wells.

If large supplies are obtained from wells in the Carrizo sand in this area, chemical analyses should be made of water samples from each well for each year, and also a permanent record should be kept of the pumpage and of the fluctuations in the water levels as determined at regular intervals by measurements of the depth to water in the principal pumped wells and in several selected observation wells. These data, collected over a period of several years, will serve to indicate the accuracy of the above predictions and to give advance warning of serious declines in water level or changes in the chemical character of the water that would necessitate changes in the pumping or in the location of wells.

CHARACTER OF WATER-BEARING MATERIALS

Permeability of water-bearing materials from well 20 (Lufkin Chamber of Commerce test well), Angelina County

[Determinations by V. C. Fishel]

Depth (feet)	Coefficient of permeability	Depth (feet)	Coefficient of permeability
178–182	100	730–740	Less than 1.0
182–190	25	765–774	65
190–195	8	785–792	7
225–235	40	792–802	40
236–246	435	812–822	225
245–255	250	822–832	340
255–265	170	842–852	220
265–270	135	852–862	340
270–275	400	862–872	220
276–281	12	872–880	260
281–291	12	890–900	190
295–305	160	900–910	165
305–315	150	910–920	400
315–325	90	920–930	180
445–450	80	930–944	145
486–490	160	1,005–1,015	6
500–510	150	1,025–1,032	8
520–521	185		

Mechanical analyses of water-bearing materials, in percent by weight, from well 20 (Lufkin Chamber of Commerce test well), Angelina County

[Determinations by V. C. Fishel]

Depth (feet)	Size of grain (percent)					
	Larger than 1.00 mm.	1.00–0.50 mm.	0.50–0.25 mm.	0.25–0.125 mm.	0.125–0.062 mm.	Less than 0.062 mm.
182–190	2.0	3.1	5.9	49.3	26.9	12.0
245–255	1.1	.4	31.3	55.6	8.9	1.3
271–281	.9	1.1	10.9	54.5	19.1	13.8
295–305	.6	.3	13.8	32.2	49.1	3.4
486–490	.4	.3	1.6	66.0	27.9	3.5
765–774	.6	.3	3.0	40.2	33.3	21.7
792–802	1.3	1.0	5.6	40.4	40.6	11.0
842–852	.3	.3	27.6	64.6	4.0	1.6
910–920	.2	.4	21.0	71.0	5.6	.7
1,025–1,033	1.0	1.7	8.3	30.5	30.7	27.6

WATER ANALYSES

Chemical analyses of water, in parts per million, from well 20 (Lufkin Chamber of Commerce test well), Angelina County

[Margaret D. Foster, Analyst]

	1	2	3	4	5	6	7
Silica (SiO_2)	16	15	14	14	16	12	16
Iron (Fe)	.08	.19	.09	.07	.09	.30	.08
Calcium (Ca)	2.9	3.5	4.8	3.3	2.1	4.6	1.1
Magnesium (Mg)	1.4	1.3	1.6	.9	1.0	1.7	.7
Sodium (Na)	416	415	439	263	102	344	372
Potassium (K)	6.1	5.8	7.7	4.3	1.6	5.8	5.8
Carbonate (CO_3)	30	29	41	53	16	79	47
Bicarbonate (HCO_3)	830	830	829	592	178	752	862
Sulphate (SO_4)	1.4	1.2	1.2	4.5	44	13	1.0
Chloride (Cl)	134	136	162	10	7.0	16	31
Fluoride (F)	4.0	4.8	4.2	.6	.7	1.5	1.3
Nitrate (NO_3)	.15	.05	.25	0	0	0	0
Total dissolved solids	1,044	1,038	1,101	651	288	826	910
Total hardness as $CaCO_3$	13	14	19	12	9.4	18	5.6
Color	110	110	110	90	20	55	30

1. Sample taken with screen set at 226–236 feet (upper Sparta) after well was pumped 6 hours, June 30 1937.
2. Sample taken with screen set at 226–236 feet (upper Sparta) after pumping 3 hours and then bailing, July 1, 1937.
3. Sample taken with screen set from 291 to 301 feet (lower Sparta), July 2, 1937.
4. Sample taken with screen set from 757 to 767 feet (lower Reklaw), July 7, 1937.
5. Sample taken with screen set at 822 to 832 feet (Carrizo), July 8, 1937.
6. Sample taken with screen set at 1,064 to 1,074 feet (upper Wilcox), July 11, 1937.
7. Sample taken with screen set at 1,102 to 1,112 feet (upper middle Wilcox), July 13, 1937.

Chemical analyses of water, in parts per million, from Angelina, Nacogdoches, and adjoining counties

[Analyses by Margaret D. Foster, U. S. Geological Survey, except 39, 46, and 54, which are by W. W. Curtis, Houston, Tex.]

Wilcox group

Well No.	Location	Owner	Depth (feet)	Calcium (Ca)	Magnesium (Mg)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total hardness as $CaCO_3$	Date of collection
	NACOGDOCHES COUNTY										*1937*
76-A	Garrison, 0.5 mile NE	A. G. Jones	280			519	46	18	0	7.5	June 21

Carrizo sand

Well No.	Location	Owner	Depth (feet)	Calcium (Ca)	Magnesium (Mg)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total hardness as $CaCO_3$	Date of collection
	NACOGDOCHES COUNTY										
18	Cushing	Cariker & Lacey	320			18	36	12	0	87	May 25
66	Nacogdoches, 10 miles NE	State Highway Department	Spring			4.0	1	1.0	6.0	32	May 31
110	Nacogdoches, 6½ miles NE	J. W. Boyd, formerly Mrs. J. S. Troutman	560			24	7	5.0	0	50	Do.
113-A	Nacogdoches, 6½ miles N	Wm. McCuistian	400			108	51	12	2.5	92	Aug. 17
120	Nacogdoches	Southern Ice Co	500			122	23	9.0	0	10	May 31
120-A	do	do	500			48	34	6.0	1.5	1.5	May 12
121	do	City of Nacogdoches	494			108	22	7.0		6.0	Feb. 8
127	Nacogdoches, 2¾ miles N	Thomas Hall	540			168	46	7.0	0	1.5	May 31
156	Nacogdoches, 7 miles NW	Sam Hayter	700			40	64	15	0	111	Do.
159	Nacogdoches, 11 miles W	Texas Pipe Line Co. station	525			142	64	12	0	63	Do.
178	Nacogdoches, 12 miles W	Shell Pipe Line Co. station		9.0	4.6	154	37	9.0		41	Feb. 8
198	Nacogdoches, 4 miles SW	Piney Woods Country Club	550			162	19	5.0	0	1.5	Jan. 12
206	Nacogdoches	Yuba Oil & Refining Co	530			120	20	9.0	0	1.5	May 31
271	Woden, 1 mile SE	L. C. Jacobs	400±			222	22	4.0		21	Feb. 9
284	Nacogdoches, 10½ miles SW	A. T. Mast	870			809	52	25	0	1.5	June 18
290	Nacogdoches, 9½ miles SSW	Guy Blount	570			442	30	113		Less than 5	Mar. 18
290	do	do	570			466	32	133	0	10	Jan. 12
	ANGELINA COUNTY										
1	Lufkin, 14¼ miles NW	McKnight	1,200±			1,029	35	189	.25	1.5	June 17
27	Lufkin, 10¼ miles NE	Angelina Lumber Co	810	5.4	1.3	346	24	11	0	19	May 10
39	Lufkin, 4¾ miles N	City of Lufkin	1,060-1,188	2.4	1.6	310	76	17		13	
46	Lufkin, 2½ miles N	do	1,178-1,243			430	101	26		7.3	
54	Lufkin, 3 miles NW	do	1,269-1,342			720	22	65		8.3	
36	Platt, 2½ miles W	A. P. Kimmey	3,000	14	7.4	1,092	4	858		65	Feb. 11
43	Lufkin, 3¾ miles N	W. A. Collmorgan	700			625	37	34	0	7.5	Jan. 14
142	Huntington, 5½ miles S	G. L. DuPuy	2,186	11	4.8	432	360	140		47	Feb. —

	TRINITY COUNTY										
73	Lufkin, 11 miles WSW	J. L. Bonner	1,500			668	1	310	0	12	May 12
	CHEROKEE COUNTY										
658	Alto	Village of Alto	600			590	6	61	0	1.5	Jan. 11
	Queen City sand										
	ANGELINA COUNTY										
17	Lufkin, 6¾ miles NNW	Gulf Pipe Line Co. station	523			780	1	1,400		33	Jan. 19
	Sparta sand										
	NACOGDOCHES COUNTY										
273-A	Nacogdoches, 8½ miles SE	Ed Parish	281			232	30	10	0	52	May 7
292-A	Nacogdoches, 9 miles S	Angelina Lumber Co				68	18	9.0	0	57	June 18
301-A	Etoile, 2.2 miles NW	do		3.8	2.0	542	1.6	21	0	18	May 6
	CHEROKEE COUNTY										
728	Wells	Village of Wells				124	65	26	0	80	Jan. 11
	ANGELINA COUNTY										
39	Lufkin, 4¾ miles N	City of Lufkin	567	5.0	2.2	877	18	141		22	
46	Lufkin, 2½ miles N	do	580-655			1,165	5.2	276		18	
54	Lufkin, 3 miles NW	do	668-696			1,008	13	81		15	
164	Lufkin, 35.5 miles SE	CCC Camp F-23-T	1,510	10	2.3	226	91	920	19	34	Apr. 1
	Cook Mountain formation										
	ANGELINA COUNTY										
5	Lufkin, 11¼ miles NW	Works Progress Administration (Pollok, Tex.).	50			5.0	11	10		14	Mar. 25
13	Lufkin, 10 miles NW	N. Carson	24			114	6	22		99	Mar. 26
14	Lufkin, 8½ miles NW	Central School	40			6.0	1	6.0		12	Jan. 25
38	Lufkin, 5 miles N	H. A. Maberry	Spring			6.0	1	7.0		14	Feb. 10
56	Lufkin, 6 miles NW	Irvin Hopper	22			12	46	144		52	Mar. 26
57	Lufkin, 6¾ miles NW	R. G. Brown	25			7.0	5	10		10	Apr. 16

Chemical analyses of water, in parts per million, from Angelina, Nacogdoches, and adjoining counties—Continued

Yegua formation

Well No.	Location	Owner	Depth (feet)	Calcium (Ca)	Magnesium (Mg)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_4)	Total hardness as $CaCO_3$	Date of collection
	ANGELINA COUNTY										1937
47	Lufkin, 2½ miles N	City of Lufkin	63			36	5	15		26	Jan. 18
49	Lufkin, 2½ miles N	do	400			314	1	30		33	Do.
50	Lufkin, 1½ miles N	do	110			6.0	120	50		75	Jan. 22
52	Lufkin, 1½ miles NW	Angelina Lumber Co	68			34	17	31	14	68	Jan. 11
53	Lufkin, 2¼ miles NW	J. W. Shearrard	18			18	19	13	22	32	Do.
55	Lufkin, 4 miles NW	W. H. Stubblefield	65			440	30	207	10	87	June 11
58	Lufkin, 6¼ miles NW	T. Finley	20			10	35	46	1.3	26	Do.
59	Lufkin, 5½ miles NW	B. Fagen	50			32	4	9.0	0	81	Do.
60	Lufkin, 3¾ miles NW	W. H. Stubblefield	31			52	10	3.0	1.2	30	Do.
61	Lufkin, 3½ miles NW	E. Huffman	28			68	5	6.0	.50	66	Do.
68	Lufkin, 6¼ miles W	Sam Peavy	195			324	200	55		183	Jan. 18
69	Lufkin, 6 miles W	Hudson School	105			200	45	60		198	Do.
70	Lufkin, 6 miles W	Texas Agricultural Experiment Station	80			204	170	84		285	Do.
74	Lufkin, 8¾ miles WSW	A. G. Johnson	18			122	40	134	68	123	May 31
75	Lufkin, 9 miles WSW	do	62			78	15	48	.25	93	Do.
76	Lufkin, 8½ miles WSW	Granville Church	17			182	50	6.0	.50	128	Do.
77	Lufkin, 6 miles WSW	C. A. Juergans	41			88	28	157	6.2	150	Do.
78	Lufkin, 6 miles WSW	T. R. Horton	23			200	180	465	400	465	Do.
80	Lufkin, 3¼ miles S	John Bennett	20			82	40	68		76	Mar. 30
81	Lufkin, 1¼ miles SE	E. T. Haygood	40			34	25	22	.25	40	June 5
82	Lufkin, 2½ miles E	D. W. Massingill	50			124	130	382		438	Mar. 22
83	Lufkin, 2½ miles NE	S. W. Beckham	57			64	70	75		162	Feb. 10
85	Lufkin, 5¼ miles E	George Korn	32			70	20	50		90	Mar. 22
92	Lufkin, 14 miles ESE	Lee Johnson	32			72	360	65	90	214	June 3
93	Lufkin, 13¼ miles ESE	J. L. Forrest	18			12	44	70	12	22	Do.
94	Lufkin, 10 miles ESE	V. C. Davis	300	30	9.2	298	275	105		113	Feb. 12
97	Lufkin, 8¼ miles ESE	Dr. H. M. Wilson	440			235	96	52		7.5	Feb. 18
100	Lufkin, 6¾ miles ESE	J. C. Nerren	42			76	100	1,080		1,080	Apr. 1
103	Lufkin, 4¾ miles SE	E. C. Greene	23			385	250	253		213	Mar. 31
105	Lufkin, 2 miles SE	C. Goodson	41			86	230	126	16	190	June 2
106	Lufkin, 2½ miles SE	Lee Graham	28			74	5	44	35	110	Do.
107	Lufkin, 2¾ miles SE	G. B. Cornell	31			102	8	70	.25	96	Do.
108	Lufkin, 3¼ miles SE	do	55			120	3	201	0	246	Do.
110	Lufkin, 4¾ miles SE	W. R. Hagood	30			8.0	2	80	50	90	Do.
111	Lufkin, 5¼ miles SE	W. T. Harbuck	23			462	25	142	47	159	Do.
112	Lufkin, 4 miles SSE	Claude Registar	65			116	18	87	.5	136	Do.
113	Lufkin, 4½ miles SSE	J. E. Burrows	55			111	24	178	0	348	Do.
114	Lufkin, 7 miles S	L. G. Capps	24			120	50	22	0	54	Do.
115	Lufkin, 7½ miles SSW	Mrs. Allsberry	35			582	200	268	100	366	Do.

116	Lufkin, 8 miles SSW	Jim Speers	30			249	270	241		204	Mar. 30
117	Lufkin, 8¼ miles SSW	J. M. Copeland	38			240	500	305	6.2	357	June 1
118	Lufkin, 8¾ miles SSW	G. F. Weeks	29			280	130	285	10	180	Do.
120	Lufkin, 11½ miles SSW	Southern Pine & Lumber Co.	420			402	350	138		210	Jan. 20
120	Lufkin, 11½ miles SSW	do	420			920	3	221	0	3.0	May 25
133	Lufkin, 9½ miles SE	R. P. Stinson	440			562	120	118	1.2	3.0	June 2
136	Lufkin, 13¼ miles ESE	Lala Hill School	250			298	800	202		504	Jan. 20
139	Lufkin, 14¾ miles SE	W. A. Beaty	435	72	20	416	609	375		262	Feb. 18
140	Lufkin, 15 miles SE	J. F. Blake	600	8.5	5.5	352	249	95		44	Feb. 11
141	Lufkin, 13¾ miles SE	C. L. DuPuy	286			517	600	195		128	Do.
153	Lufkin, 16¼ miles SE	Shawnee School	478			802	4	141		12	Feb. 19
157	Lufkin, 19½ miles ESE	Boynton Lumber Co.	33			180	5	105	0	130	June 3
158	Lufkin, 19¼ miles ESE	Roy Fletcher	20			94	60	450	486	518	Do.
	Jackson group										
	ANGELINA COUNTY										
121	Lufkin, 12¼ miles S	E. J. Kohn	50			15	20	78		27	Feb. 22
122	Lufkin, 13 miles S	Floyd Wheeler	31			6.0	200	275		252	Do.
123	Lufkin, 10¾ miles S	George Ginter	74	49	15	444	460	211		184	Feb. 17
124	Lufkin, 10¾ miles S	J. L. Russell	Spring			686	400	118		114	Do.
125	Lufkin, 11¾ miles S	do	156			102	200	84		105	Do.
126	Lufkin, 12¼ miles SSE	Dr. Weeks	900			571	139	220		12	Do.
128	Lufkin, 13¼ miles SSE	Sun Oil Co.	800			589	18	92		1.5	Do.
129	Lufkin, 14¾ miles SSE	Southern Pine & Lumber Co.	21			12	5	12	0.75	22	June 1
130	Lufkin, 15½ miles SSE	Elbert Havard	44			2.0	18	67	190	120	Do.
131	Lufkin, 15¼ miles SSE	do	28			4.0	10	95	100	84	Do.
132	Lufkin, 15 miles SSE	Olive School	14			6.0	18	9.0	.75	38	Do.
138	Lufkin, 14½ miles SE	W. O. Gainer	232	32	12	274	146	66		129	Feb. 12
143	Lufkin, 16 miles SE	E. J. Gibbs	368	24	6.6	481	352	573		76	Feb. 12
144	Lufkin, 17¼ miles SE	Carter-Kelly Lumber Co.	30	21	15	10	4	133		114	Feb. 22
145	Lufkin, 17½ miles SE	do	541			574	210	250		18	Do.
147	Lufkin, 22¾ miles SE	Jackson Barge	14			6.0	5	104	38	90	June 15
150	Lufkin, 23¾ miles SE	CCC Camp 827	300			45	70	36		57	Apr. 15
152	Lufkin, 18¼ miles SE	Atlantic Pipe Line Co. station	452			516	1,200	360		123	Jan. 20
159	Lufkin, 23½ miles SE	Camp Perry	Spring			8.0	1	4.0	0	30	June 5
160	Lufkin, 23½ miles SE	do	225			142	23	8.0	0	63	June 4
161	Lufkin, 22½ miles SE	Texas & New Orleans Railroad (Zavalla station).	Spring			2.0	2	20		6.0	Jan. 22
162	Lufkin, 25¼ miles SE	do	1,800			54	19	17		4.5	Feb. 16
	Surface waters										
	Neches River, at Angelina and Polk county line on Highway 35					20	35	38		57	Feb. 22
	Angelina River, Angelina and Nacogdoches county line					20	17	55	0	46	May 28
	Angelina River, Angelina and Nacogdoches county line					8.0	28	35	0	32	Jan. 14
	Lake at Lufkin. Taken directly from tap			11	3.9	16	46	17	0	43	Apr. 2

WELL LOGS AND WELL RECORDS

Drillers' logs of wells in Angelina County

[Measurement of depth is from land surface]

Well 15 (Seven Wells Corporation oil test), about 9 miles north-northwest of Lufkin post office

	Thickness (feet)	Depth (feet)
Sparta sand; Weches greensand and Queen City sand members of Mount Selman formation:		
Surface	125	125
Shale	203	328
Sand and gravel	14	342
Shale	23	365
Reklaw member of Mount Selman formation:		
Sand and boulders	65	430
Shale	80	510
Shale and boulders	68	578
Shale	22	600
Shale and boulders	60	660
Carrizo sand:		
Sand, water	89	749
Sand	10	759
Wilcox group:		
Shale	85	844
Lime rock	1	845
Sand and shale	4	849
Shale	46	895
Hard sand	7	902
Hard shale	28	930
Sandy shale	15	945
Sticky shale	41	986
Sand, water	11	997
Shale	63	1,060

Total depth, about 3,000 feet.

Well 17 (Gulf Pipe Line Co.), 6¾ miles north of Lufkin post office

	Thickness (feet)	Depth (feet)
Cook Mountain formation:		
Clay	12	12
Sand, surface water	10	22
Blue gumbo	25	47
Rock	2	49
Blue gumbo	13	62
Rock	1	63
Blue gumbo	27	90
Fine blue gumbo	25	115
Blue gumbo	29	144
Sparta sand:		
Rock	1	145
Blue gumbo	21	166
Fine blue sand	16	182
Blue gumbo	28	210
Loose gray sand	66	276
Weches greensand member of Mount Selman formation:		
Blue gumbo	40	316
Rock	4	320
Blue gumbo	27	347
Rock	2	349
Gumbo	12	361
Rock	3	364
Gumbo	3	367
Rock	4	371
Gumbo	25	396
Rock	2	398
Gumbo	41	439
Rock	2	441
Gumbo	36	477
Rock	1	478
Gumbo	5	483
Queen City sand member of Mount Selman formation:		
Sand, water	40	523

Drillers' logs of wells in Angelina County—Continued

Well 20 (Lufkin Chamber of Commerce No. 1 Cameron), 6¾ miles north of Lufkin post office

[Altitude, 230 feet]

	Thickness (feet)	Depth (feet)
Cook Mountain formation:		
Soil and red sandy clay	12	12
White clay	10	22
Brown shale	23	45
Green shale, shells, and boulders	33	78
Sandy shale, shells, pyrite, and glauconite	49	127
Light-gray shale	47	174
Sparta sand:		
Light-gray sand	18	192
Gray shale	5	197
Sand, shale streaks	26	223
Sand	60	283
Shale	5	288
Sand and shale layers	9	297
Fine hard brown sandy shale	38	335
Weches greensand member of Mount Selman formation:		
Green shale, shells	32	367
Hard rock	1	368
Green shale, shells	2	370
Hard rock	1	371
Green shale, shells	112	483
Queen City sand member of Mount Selman formation:		
Sand	35	518
Reklaw member of Mount Selman formation:		
Sandy shale and shale streaks	57	575
Sticky brown shale	63	638
Hard rock	1	639
Sticky brown shale	6	645
Hard rock	1	646
Sticky brown shale	19	665
Hard lime rock	1	666
Sticky brown shale	42	708
Brown shale	13	721
Green sandy shale	16	737
Sand	34	771
Sand, streaks of shale	18	789
Fine white sand	10	799
Carrizo sand:		
Sand, shale streaks (1 foot)	13	812
Coarse white sand	20	832
Coarse white sand (3-inch streak of shale at 880 feet)	89	921
Shale	3	924
Coarse white sand	20	944
Wilcox group:		
Sandy shale	3	947
Shale, sand streaks	65	1,012
Very fine hard packed greensand	20	1,032
Hard shale	32	1,064
Hard shale, sandy streaks	33	1,097
Sandy shale, sand streaks	28	1,125
Shale, sandy shale, sand streaks	29	1,154
Sandy shale	44	1,198

Well 37 (Howze Oil Co. No. 1, Finley), 7 miles northeast of Lufkin post office

[Altitude 281 feet]

Cook Mountain formation:		
Surface	132	132
Hard shale	31	163
Rock	1	164
Shale	29	193
Rock	2	195
Shale	134	329
Sparta sand:		
Rock	6	335
Shale	106	441
Sand and sandy shale	64	505
Weches greensand member of Mount Selman formation:		
Shale	88	593
Dark shale, greensand	48	641
Queen City sand member of Mount Selman formation:		
Shale and sand	42	683
Shale	11	694

Drillers' logs of wells in Angelina County—Continued

Well 37 (Howze Oil Co. No. 1, Finley), 7 miles northeast of Lufkin post office—Continued

	Thickness (feet)	Depth (feet)
Reklaw member of Mount Selman formation:		
Brown shale	67	761
Shale	32	793
Hard lime	4	797
Shale and lime, with shells	28	825
Shale and lime	10	835
Shale	48	883
Sandy shale	25	908
Sand and shale, some oil odor	10	918
Sand and shale	5	923
Sand	10	933
?	10	943
Shale and sand	11	954
Carrizo sand:		
Sand	50	1,004
Sand, water	50	1,054
Sandy shale	59	1,113
Wilcox group:		
Shale	33	1,146
Hard sandy shale	5	1,151
Hard rock	2	1,153
Sand, water at 1,161 feet	16	1,169
Shale	34	1,203
Hard sand	37	1,240
Sand and shale	23	1,263
Shale	35	1,298
Sandy shale	6	1,304
Rock	2	1,306
Sand, cored	5	1,311
Sandy shale	28	1,339
Shale	4	1,343
Lime rock	2	1,345
Shale	60	1,405
Shale and sand	46	1,451
Rock	2	1,453
Shale and sand	10	1,463
Shale	58	1,521
Sand and shale	16	1,537
Sticky shale	4	1,541
Shale and sandy shale	23	1,564
Rock	4	1,568
Shale	4	1,572
Hard rock	2	1,574
Shale	59	1,633
Hard lime	3	1,636
Shale	19	1,655
Sand and shale	10	1,665
Shale and boulders	18	1,683
Shale	26	1,709
Sandy shale	2	1,711
Sticky shale	30	1,741
Hard rock	2	1,743
Sandy shale and boulders	9	1,752
Sticky shale and boulders	23	1,775
Shale	11	1,786
Shale and boulders	4	1,790
Sandy shale	7	1,797
Shale and lime	22	1,819
Sandy shale	21	1,840
Shale and boulders	53	1,893
Shale	117	2,010

Paleontologic determinations by Humble Oil & Refining Co.: Cook Mountain formation, at depth of 0 to 330 feet; Sparta sand, 330 to 510 feet; Weches greensand member, 510 to 651 feet; Queen City sand member, 651 to 746 feet; Reklaw member, 746 to 1,004 feet; Carrizo sand, 1,004 to 1,142 feet; Wilcox group, 1,142 to 2,010 feet.

Well 39 (City of Lufkin test well 2), 0.5 mile west of Redland

[Altitude, 329 feet]

Cook Mountain formation:		
Surface sand	2	2
Red clay	24	26
Shale	10	36
Fine greensand, shale	23	59
Soft blue shale, shells	65	124
Soft rock	1	125
Soft brown shale and shells	80	205

Drillers' logs of wells in Angelina County—Continued

Well 39 (City of Lufkin test well 2), 0.5 mile west of Redland—Continued

	Thickness (feet)	Depth (feet)
Cook Mountain formation—Continued.		
Soft brown shale and shells	20	225
Rock	1	226
Soft shale	10	236
Rock	2	238
Shale, rock at 287 feet and 304 feet	67	305
Sticky shale, rock at 325 feet	33	338
Soft brown shale	23	361
Brown shale, thin sandy layers	20	381
Sparta sand:		
Brown shale, rock at 435 feet	55	436
Sand layers, shale, some lignite	28	464
Brown shale	19	483
Fine sand	9	492
Soft shale	14	506
Fine sand (static head, 144 feet)	57	563
Brown shale, thin layers of rock	12	575
Sand	21	596
Weches greensand member of Mount Selman formation:		
Brown shale, shells, lignite rock at 620 feet	26	622
Hard sticky shale	5	627
Rock	2	629
Soft shale. shells, lignite	4	633
Rock	2	635
Soft green shale and shells	11	646
Green sticky shale, shells	15	661
Soft green shale and shell, rock at 700 feet	51	712
Rock	2	714
Hard sticky shale, rock at 729 feet	11	725
Soft green shale	10	735
Rock	1	736
Queen City sand member of Mount Selman formation:		
Soft shale	19	755
Sand	5	760
Soft brown shale, rock at 775 feet	11	771
Reklaw member of Mount Selman formation:		
Soft shale, thin layers of sand	16	787
Hard rock	1	788
Soft shale, thin layers of rock	16	804
Soft shale	10	814
Hard brown shale	42	856
Hard sticky shale	42	898
Soft shale	5	903
Rock	1	904
Hard sticky shale, rock at 912 feet	8	912
Rock	1	913
Sticky shale	12	925
Hard rock	1	926
Soft blue shells and shale	53	979
Sticky shale and shells	7	986
Soft shale	35	1,021
Sand	5	1,026
Hard shale	3	1,029
Soft rock	1	1,030
Shale, thin layers of sand	26	1,056
Carrizo sand:		
Sand	10	1,066
Water sand	23	1,089
White water sand (static head, 43 feet)	95	1,184
Wilcox group:		
Soft shale	4	1,188

Paleontologic determinations by F. W. Rolshausen, of the Humble Oil & Refining Co.: Cook Mountain, at depth of 40 to 350 feet (with *Operculinella* at 150 feet); Sparta sand, 385 to 541 feet; Weches greensand member, 610 to 716 feet (*Discocyclina* from 625 to 660 feet); Queen City sand member, 745 to 780 feet; Reklaw member, 835 to 1,025 feet; Carrizo sand, 1,065 to 1,180 feet.

Well 42 (H. L. Jennings No. 1, W. A. Collmorgan), 3½ miles north of Lufkin post office

Cook Mountain formation:		
Surface sand and clays	121	121
Shale	57	178
Lime shells	1	179
Shale	4	183
Shells	1	184
Shale	40	224

Drillers' logs of wells in Angelina County—Continued

Well 42 (H. L. Jennings No. 1, W. A. Collmorgan), 3½ miles north of Lufkin post office—Continued

	Thickness (feet)	Depth (feet)
Cook Mountain formation—Continued.		
Lime shells	24	248
Shells	67	315
Shale	21	336
Shells	3	339
Shale	16	355
Shells	1	356
Shale	26	382
Sparta sand:		
Sand, water	18	400
Sandy shale	57	457
Shale and sand	67	524
Weches greensand member of Mount Selman formation:		
Shale	46	570
Broken sand	17	587
Sandy shale	21	608
Lime shells	1	609
Sand	2	611
Lime shells	1	612
Shale	8	620
Shells	1	621
Sticky shale	12	633
Shale and shells	45	678
Gumbo	2	680
Queen City sand member of Mount Selman formation:		
Shells	1	681
Shale	5	686
Sand, show of gas	2	688
Shale and shells	12	700
Hard shale	17	717
Blue lime	3	720
Reklaw member of Mount Selman formation:		
Shale	9	729
Lime	1	730
Sandy shale	63	793
Hard sand	3	796
Lime shells	2	798
Sandy shale	47	845
Lime	1	846
Sticky shale	62	908
Hard lime	2	910
Sticky shale	16	926
Shale, green	24	950
Brown shale	50	1,000
Oil sand	7	1,007
Hard sand	1	1,008
Blue sand	10	1,018
Blue and green shale	2	1,020
Blue sand	34	1,054
Blue dry sand	21	1,075
Sandy shale	2	1,077
Carrizo sand:		
White sand, water	57	1,134
Gray sand	26	1,160
Hard shells	1	1,161
Gray sand	51	1,212
Hard lime	1	1,213
Hard sand	3	1,216
Wilcox group:		
Streaked shale	4	1,220
Hard sand with blue shale streaks	101	1,321
Hard lime	2	1,323
Sandy shale	17	1,340
Gumbo	11	1,351
Sandy shale	6	1,357
Gumbo	19	1,376
Sticky shale	24	1,400
Sandy shale	20	1,420
Shale	60	1,480
Sand rock	5	1,485
Sticky shale	15	1,500

Drillers' logs of wells in Angelina County—Continued

Well 46 (City of Lufkin test well 1), 2½ miles north of Lufkin post office

[Altitude, 266 feet]

	Thickness (feet)	Depth (feet)
Yegua formation:		
Surface soil and sand	10	10
Clay and some lignite	15	25
Sand	32	57
Shale	38	95
Sandy shale	18	113
Sand	8	121
Shale, small rocks	37	158
Sandy shale, few boulders	125	283
Soft rock	2	285
Sandy shale and boulders	76	361
Cook Mountain formation (?):		
Shale	51	412
"Pack sand"	2	414
Shale	18	432
Rock	2	434
Sparta sand:		
Shale, rock at 459 feet	83	517
Shale	7	524
Sand and shale	21	545
Shale	10	555
Sand and shale	12	567
Soft shale	8	575
Sand, water	21	596
Soft shale	5	601
Sand, water	63	664
Hard blue shale	26	690
Weches greensand member of Mount Selman formation:		
Brown shale, lignite, shells, little show of gas	36	726
Rock	1	727
Black shale, shells, thin layers of rock and lignite	38	765
Soft rock, shells, and shale	8	773
Sticky shale	17	790
Shale	15	805
Soft gray shale	8	813
Rock	1	814
Soft green shale, some shell	11	825
Tough hard shale	25	850
Queen City sand member of Mount Selman formation:		
Hard shale, thin layers of sand, thin rock	22	872
Hard shale	12	884
Hard sand, rock at 894 feet	5	889
Hard shale, broken with thin layers of rock, shell	16	905
Reklaw member of Mount Selman formation:		
Hard brown shale and thin layers of sand	16	921
Cored hard brown shale, thin layers of sand	5	926
Hard brown shale, layers of sand	5	931
Hard shale	19	950
Soft brown shale, showing of gas	61	1, 011
Hard shale, layers of rock	10	1, 021
Hard rock	2	1, 023
Hard sticky shale	10	1, 033
Hard rock	1	1, 034
Hard shale	6	1, 040
Hard rock	1	1, 041
Hard shale	5	1, 046
Hard brown shale	22	1, 068
Soft shale	10	1, 078
Hard and sticky light-blue shale	42	1, 120
Fine gray sand, cored	6	1, 126
Fine sand	4	1, 130
Soft shale	15	1, 145
Hard shale with thin layers of sand	18	1, 163
Sticky dark-brown shale	10	1, 173
Carrizo sand:		
"Pack sand" (water)	70	1, 243

Paleontologic determination by Wilma Waddell, LaRue & Co., Athens: Yegua formation, at depth of 0 to 366 (?) feet; Cook Mountain formation. 366 (?) to 439 feet; Sparta sand, 439 to 695 feet; Weches greensand member, 695 to 855 feet; Queen City sand member, 855 to 955 feet; Reklaw member, 955 to 1,083 feet; Cane River formation, 1,083 to 1,178 feet; Carrizo sand, 1,178 to 1,248 feet.

Drillers' logs of wells in Angelina County—Continued

Well 54 (City of Lufkin test well 3), 1 mile west of Keltys

	Thickness (feet)	Depth (feet)
Yegua formation:		
Surface sand	1	1
Red clay	30	31
Gray sandy clay	31	62
Soft clay	3	65
Yellow sand	20	85
Thin layers of rock and sand	7	92
Fine sand, layers of shale	67	159
Fine sand and lignite	14	173
Dark-brown soft shale	73	246
Cook Mountain formation:		
Soft shale and shell	32	278
Soft blue shale and shells, thin rock at 304 feet	21	299
Hard blue shale	10	309
Soft blue shale	34	343
Hard blue shale	15	358
Hard blue shale and shells, thin rock at 380 feet	20	378
Sticky blue shale and shells, rock at 390 feet	7	385
Soft shale, shells	4	389
Rock	2	391
Soft blue shale, shells	24	415
Hard blue shale and shells	37	452
Rock	1	453
Hard shale	8	461
Sand	2	463
Soft flakes and shells	52	515
Soft flakes, shale and shells, rock at 533 feet	29	544
Rock	2	546
Hard brown shale	19	565
Rock	1	566
Sparta sand:		
Hard brown shale, shells, rock at 580 feet and 592 feet	29	595
Fine sand, some lignite	25	620
Soft brown shale, shells	23	643
Sand	7	650
Soft brown shale, shells	13	663
Sand	28	691
Shale	8	699
Soft brown shale	23	722
Fine sand	24	746
Weches greensand member of Mount Selman formation:		
Dark-brown shale, soft shell, rock at 830 feet and 850 feet	107	853
Hard sticky green shale	15	868
Soft rock	2	870
Soft green shale, layers of shell	35	905
Hard green shale	9	914
Rock	1	915
Soft green shale	9	924
Hard rock	1	925
Hard sticky green shale	23	948
Queen City sand member of Mount Selman formation:		
Fine gray sand (cored)	20	968
Reklaw member of Mount Selman formation:		
Hard flaky green shale	30	998
Hard rock	1	999
Soft shale	9	1,008
Rock	1	1,009
Soft shale	11	1,020
Rock	1	1,021
Soft brown shale	18	1,039
Fine gray water sand and hard brown shale, thin layers of sand, cored	8	1,047
Hard brown shale, rock at 1,085 feet	58	1,105
Green and brown sandy clay, cored	3	1,108
Hard brown shale	9	1,117
Rock	1	1,118
Hard shale	2	1,120
Hard rock	2	1,122
Hard shale	6	1,128
Hard rock	2	1,130
Hard shale	9	1,139
Hard rock	1	1,140
Brown shale	8	1,148
Hard rock	1	1,149
Soft brown shale	64	1,213
Hard sticky shale	11	1,224
Soft shale	6	1,230
Green sand, water, cored	8	1,238
Soft brown shale	26	1,264

Drillers' logs of wells in Angelina County—Continued

Well 54 (City of Lufkin test well 3), 1 mile west of Keltys—Continued

	Thickness (feet)	Depth (feet)
Carrizo sand:		
Sand	73	1,337
Soft shale	10	1,347
Sand	24	1,371
Sand, layers of shale	19	1,390
Wilcox group:		
Sand	20	1,410
Soft brown shale	39	1,449

Well 64 (Humble Oil & Refining Co. well 1-A, J. L. Bonner), 6½ miles west of Lufkin post office

[Altitude, 212 feet]

	Thickness (feet)	Depth (feet)
Yegua formation:		
Surface and sand	12	12
Sand	8	20
Sandy shale and gravel	40	60
Sandy shale	36	96
Shale with streaks of sand (sandy shale). Lower part of sand is green-gray	24	120
Cook Mountain formation:		
Hard grayish-brown shale with fossil fragments	33	153
Rock (brown clay ironstone)	1	154
Sandy shale, streaks of gray sand	62	216
Brown clay ironstone	1	217
Sandy shale	16	233
Brown clay ironstone	1	234
Sandy shale with streaks of gray sand	22	256
Hard shale	5	261
Sandy shale, greenish, glauconitic, and fossiliferous	16	277
Hard shale	19	296
Brown shale, few streaks of sand	18	314
Rock	1	315
Hard shale	13	328
Shale, greenish, glauconitic, and fossiliferous	2	330
Hard sandy shale, dark, slightly greenish-gray	11	341
Hard shale	16	357
Gray shale, sticky	37	394
Rock	1	395
Gray shale, sticky	5	400
Gray shale	5	405
Gray shale, boulders	14	419
Hard gray shale, sticky	30	449
Same, fossiliferous	47	496
Gray-brown sticky shale, streaks of glauconite, fossiliferous; 4-inch rock at 496 feet	47	543
Sandy shale, streaks of sand	21	564
Sparta sand:		
Sand, 6-inch rock at 564 feet	11	575
Sandy shale	20	595
Brown sand	31	626
Rock	2	628
Sandy shale	6	634
Shale, sticky	15	649
Sand, gray and brown, streaks of lignite	19	668
Hard shale, shells	2	670
Brown sand, streaks of lignite	53	723
Hard sticky shale	15	738
Sand	41	779
Sticky shale	20	799
Weches greensand member of Mount Selman formation:		
Brown sand	7	806
Sticky shale	16	822
Sand	8	830
Sticky shale	15	845
Glauconitic greensand	2	847
Hard shale	3	850
Greensand marl	8	858
Soft glauconitic shale	10	868
Greensand marl	1	869
Soft glauconitic shale	32	901
Glauconitic greensand	8	909
Brown shale	7	916
Rock	1	917
Greensand	2	919
Brown shale	11	930
Sandy shale, oil-bearing (Nacogdoches producing horizon), shallow pool	4	934
Sandy shale	5	939
Dark gray shale	20	959
Shale and boulders	8	967

Drillers' logs of wells in Angelina County—Continued

Well 64 (Humble Oil & Refining Co. well 1-A, J. L. Bonner), 6½ miles west of Lufkin post office—Con.

	Thickness (feet)	Depth (feet)
Queen City sand member of Mount Selman formation:		
Glauconitic shale and boulders	9	976
Sand	71	1,047
Sandy shale	8	1,055
Gray sticky shale with streaks of sandy shale	9	1,064
Gray sticky shale	31	1,095
Reklaw member of Mount Selman formation:		
Sand	3	1,098
Sticky brown shale, partly glauconitic	9	1,107
Sand	2	1,109
Sticky shale	6	1,115
Rock	1	1,116
Greensand	2	1,118
Sticky shale	7	1,125
Rock	1	1,126
Shale, streaks of greensand and fossils	15	1,141
Rock	1	1,142
Brown shale, streaks of glauconite	62	1,204
Fossiliferous bluish-gray shale with some lime, calcareous	4	1,208
Brown sticky shale with greensand	15	1,223
Carrizo sand:		
Sand	41	1,264
Sandy shale	8	1,272
Sand, water	33	1,305

Total depth, about 2,000 feet.

Paleontologic determination by Humble Oil & Refining Co.: Yegua formation, at a depth of 0 to 120 feet; Cook Mountain formation, 120 to 575 feet; Sparta sand, 575 to 806 feet; Weches green sand member, 806 to 976 feet; Queen City sand member, 976 to 1,098 feet; Reklaw member, 1,098 to 1,223 feet; Carrizo sand, 1,223 to 1,305 feet.

Well 120 (Southern Pine & Lumber Co.), Diboll

Jackson group:		
Soil and blue clay	66	66
Soapstone	22	88
Hard blue clay	77	165
Fine blue sand	30	195
Blue clay	30	225
Soft blue rock	50	275
Hard blue clay	30	305
Fine blue sand	40	345
Hard blue clay	38	383
Fine blue sand	22	405
Clay	15	420

Well 142 (Dudley J. LeBlanc No. 1, Carter Lumber Co. (C. L. Depuy)), 14 miles southeast of Lufkin post office

[Altitude, 211 feet]

Yegua formation:		
Surface clay	20	20
Gummy shale	61	81
Gray sand	29	110
Sandy shale	265	375
Gummy shale and boulders	240	615
Hard rock	1	616
Sandy shale and shells	64	680
Sand and lignite	10	690
Shale and boulders	170	860
Shale	160	1,020
Sandy shale	25	1,045
Shale, streaks of sand	23	1,068
Hard shale	12	1,080
Cook Mountain formation :		
Sandy shale and shells	40	1,120
Shale and shells	70	1,190
Sticky shale	30	1,220
Gummy shale and boulders	136	1,356
Shale and shells	42	1,398
Sticky shale	12	1,410
Sand and boulders	10	1,420

Drillers' logs of wells in Angelina County—Continued

Well 142 (Dudley J. LeBlanc No. 1, Carter Lumber Co. (C. L. Depuy)), 14 miles southeast of Lufkin post office—Continued

	Thickness (feet)	Depth (feet)
Sparta sand:		
Sand, boulders, and shells	155	1,575
Rock	2	1,577
Shale and boulders	62	1,639
Shale and shells	81	1,720
Weches greensand member of Mount Selman formation:		
Sandy shale, shells and boulders	40	1,760
Shale and boulders	15	1,775
Shale	10	1,785
Gummy shale and boulders	65	1,850
Sandy shale and shells	13	1,863
Queen City sand member of Mount Selman formation:		
Shale and shells	17	1,880
Reklaw member of Mount Selman formation:		
Shale	30	1,910
Sandy shale	20	1,930
Shale, streaks of sand and boulders	24	1,954
Shale, streaks of sand	12	1,966
Brown shale, streaks of sand	13	1,979
Shale and volcanic ash	35	2,014
Shale	2	2,016
Sand	1	2,017
Shale, streaks of sand	9	2,026
Hard shale, streaks of sand	14	2,040
Shale	26	2,066
Sand	20	2,086
Carrizo sand:		
Sand and shale	100	2,186

Well 156 (Hunter-Longbell No. 3), 4 miles north of Zavalla

[Altitude, 275]

Jackson group undifferentiated and Yegua formation:		
Surface clay	15	15
Sand and gravel, streaks of shale, inch	82	97
Streaks of shale and sand	403	500
Sand and shale	283	783
Shale	16	799
Rock	4	803
Sandy shale	15	818
Hard shale	32	850
Rock	1	851
Cook Mountain formation:		
Hard shale and shells	176	1,027
Sparta sand:		
Sandy shale and greensand	303	1,330
Shale and boulders	138	1,468
Weches greensand member of Mount Selman formation:		
Sandy shale and greensand, cored 1,578 to 1.594 feet	110	1,578
Green sandy shale with fossils	16	1,594
Gumbo	29	1,623
Sandy shale and hard marl, cored 1,699 to 1,685 feet	46	1,669
Dark-green marl, hard gummy streaks, cored 1,685 to 1,701 feet	16	1,685
Hard green marl and fossils, cored 1,701 to 1,717 feet	16	1,701
Dark geeen marl, cored	5	1,706
Queen City sand member of Mount Selman formation:		
Green and brown sandy marl with pyrites, cored	2	1,708
Gray shale laminated with sand, trace of oil, cored 1,717 to 1,733 feet	9	1,717
Reklaw member of Mount Selman formation:		
Gray shale, streaks of oil sand, cored 1,733 to 1,749 feet	16	1,733
Brown shale, cored 1,749 to 1,765 feet	16	1,749
Dark-brown shale	11	1,760
Dark greenish-brown marl, cored 1,765 to 1,783 feet	5	1,765
Dark-brown marly shale, cored 1,783 to 1,793 feet	18	1,783
Dark-brown shale	5	1,788
Dark-green marl, core 1,793 to 1,805 feet	5	1,793
Green marl with fossils, cored 1,805 to 1,821 feet	12	1,805
Green marl with fossils, cored 1,821 to 1,828 feet	16	1,821
Light-green marl, gummy streaks, cored 1,828 to 1,844 feet	7	1,828
Light-green marl	1	1,829
Limy sand, trace of oil	5	1,834
Light-green marl	5	1,839
Light-green shale, streaks of marl, cored 1,844 to 1,854 feet	5	1,844
Light-green marl and marly shale	10	1,854
Light-green marl, cored 1,864 to 1,873 feet	10	1,864
Light-green marl	7	1,871
Green marly sand, cored 1,873 to 1,889 feet	2	1,873

Drillers' logs of wells in Angelina County—Continued

Well 156 (Hunter-Longbell No. 3), 4 miles north of Zavalla—Continued

	Thickness (feet)	Depth (feet)
Wilcox group [1]:		
Green marly sand with fossils	12	1,885
Brown shale with streaks of lignitic sand	4	1,889
Shale and sand, cored 1,908 to 1,924 feet	19	1,908
Sand	22	1,930
Hard shale and boulders, streaks of soft sand	30	1,960
Green sandy shale	200	2,160
Shale and boulders	249	2,409
Sticky shale	81	2,490
Hard shale	36	2,526

[1] No evidence was found on which to separate the Carrizo from the Wilcox.

Drillers' logs of wells in Nacogdoches County

Well 18 [1] (Cariker & Lacey), 15 miles northwest of Nacogdoches

	Thickness (feet)	Depth (feet)
Reklaw member of Mount Selman formation:		
Clay	50	50
Shale, sandy shale, and rock	115	165
Sand, water	21	186
Gumbo	22	208
Carrizo sand:		
Sand, water	99	307
Gumbo	13	320

Well 120 [1] (Southern Ice Co.), Nacogdoches

	Thickness (feet)	Depth (feet)
Weches greensand, Queen City sand, and Reklaw members of Mount Selman formation:		
Black loam	12	12
Brown stone and gravel	10	22
Fine blue sand and blue soapstone	70	92
Clay or soapstone with sand and boulders	201	293
Hard shale with streaks of sand	7	300
Sand	30	330
Shale	10	340
Carrizo sand:		
White sand, varying in fineness, with some streaks of shale 6 inches thick	160	500

Well 121 [1] (Nacogdoches City well 7), Nacogdoches

	Thickness (feet)	Depth (feet)
Weches greensand, Queen City sand, and Reklaw members of Mount Selman formation:		
Surface sand	7	7
Sandy clay	9	16
Iron ore rock	2	18
Black sand	19	37
Green rock	1	38
Green shale	37	75
Sand rock	1	76
Boulders and black shale	30	106
Shale and boulders	47	153
Sand, rock	1	154
Hard shale	25	179
Sticky shale	28	207
Hard sand	7	214
Hard rock	1	215
Sandy shale	4	219
Sandy rock	1	220
Hard sandy shale	18	238
Sand rock	1	239
Hard shale	18	257
Shale and rock	2	259
Hard shale	53	312
Sandy shale	57	369
Carrizo sand:		
White sand	5	374
Sand	110	484

[1] Number refers to well in Works Project Administration report on Nacogdoches County.

Records of wells in Nacogdoches County

[All drilled wells except No. 66]

No.	Distance from Nacogdoches	Owner	Driller	Date completed	Altitude above sea level (feet)	Depth of well (feet)	Diameter of well (inches)	Geologic horizon	Height of measuring point above ground level (feet)	Water level: Above or below measuring point (feet)	Water level: Date of measurement	Method of lift [2]	Use of water [3]	Remarks
18	15 miles NW	Cariker & Lacey	J. N. Heard	1936	410	320	6	Carrizo	0.0	−115.0	Sept. 4, 1936	CE	PS	280 feet of 6-inch casing, 40 feet of 4½-inch screen; water level reported. Pump capacity 50 gallons a minute. (See log p. 50.)
66	10 miles NE	State Highway Department.			319			do	1.6	+6.0	Apr. 30, 1937	Flows	do	A spring, flows 2 gallons a minute, temperature 72° F.
76-A	16.5 miles NE	A. G. Jones	Wells & Montague.	1937		280	6	Wilcox				Air	Ind	Well draws from 98 feet of sand at 182 to 280 feet.
110	6.5 miles NE	J. W. Boyd; formerly Mrs. J. S. Troutman.		1913	402	560	5$\frac{9}{16}$	Carrizo				CE	PS	Water has very strong hydrogen sulphide odor.
113-A	6.5 miles N	Wm. McCuistian.	Montague	1937	417	400	6	do	1.8	−75.10	Aug. 6, 1937	Air	D, S	
120	In Nacogdoches	Southern Ice Co.		1925	280	500	12½	do	3.4	+1.0	Apr. 30, 1937	CE	Ind	Flows 6 gallons a minute; draw-down 6 feet after pumping 30 gallons a minute for 3 hours. (See log p. 50.)
120-A	do	do		Old	278	±500	8	do	.5	+1.0	Apr. 28, 1937		None	Flows 6 gallons a minute. (See log p. 50.)
121	do	City of Nacogdoches.	Layne-Texas Co.	1933	298	484	20	do	1.5	−22.48	do	CE	PS	Yields 710 gallons a minute, temperature 75° F., draw-down 56.45 feet after pumping 3 hours. City well 7.
122	do	do	do	1929	294	485	20	do	1.5	−18.56	do	do	do	Yields 700 gallons a minute, temperature 75° F., draw-down 17.52 feet when well 121 is pumping. City well 6.

[1] Number refers to well in Works Project Administration report on Nacogdoches County.
[2] CE, Centrifugal electric; Air, air lift.
[3] PS, Public supply; Ind., industrial; D, domestic; S, stock; Irr., irrigation.

Records of wells in Nacogdoches County—Continued

[All drilled wells except No. 66]

No.	Distance from Nacogdoches	Owner	Driller	Date completed	Altitude above sea level (feet)	Depth of well (feet)	Diameter of well (inches)	Geologic horizon	Height of measuring point above ground level (feet)	Water level: Above or below measuring point (feet)	Water level: Date of measurement	Method of lift	Use of water	Remarks
127	2.75 miles N	Thomas Hall	Lesterjett	1914	419	540	4	do	0	−90.0	Sept. 18, 1936	Air	D, S	Drilled to 2,007 feet but plugged back to 540 feet; casing perforated at 540 feet; yields 200 gallons a minute.
156	7 miles NW	Sam Hayter, Pearl Oil Co.	J. C. McNeil	1930	281	700	10	do	0	+9.0	Apr. 29, 1937	Flows	S	Oil test drilled to 4,314 feet but plugged back to 700 feet. Flows 28 gallons a minute. Water has strong hydrogen sulphide odor.
159	11 miles W	Texas Pipe Line Co.	W. M. Brown & Co.	1934		525	6	do	0	−34.0	Oct. 11, 1936	CE	Ind	
178	12 miles W	Shell Pipe Line Co.					5¾6	do				do	do	Yields 4 gallons a minute; temperature 74° F.
198	4 miles SW	Piney Woods Country Club.		1922	272	550	8	do	1.0	+5.0	Apr. 30, 1937	Air / Flows	do	Flows 15 gallons a minute; temperature 76° F.
205	1 mile S	J. B. Fenley	Layne-Texas Co.	1933		536	6	do	0	−18.0	do	CE	do	Supplies swimming pool at Reeds Lake.
206	0.5 mile S	Yuba Oil & Refining Co.			277	±530	12	do	0	+5.0	May 31, 1937	Flows	None	Flows 13½ gallons a minute; temperature 74° F.
271	10.5 miles SE	L. C. Jacobs	Elliott & Fox	1922	210	±400	6	do	8.0	+39.0	Apr. 30, 1937	do	do	Estimated flow 60 gallons a minute; temperature 74° F.; water level by pressure gauge.
273-A	8.5 miles SE	Ed. Parish	Fox & Horton	Before 1920.	214	281	4½	Sparta	0		do	do	Irr., S	Estimated flow 50 gallons a minute; casing collapsed, forming pit.
284	10.5 miles SW	A. T. Mast	Joe Long	1936	200	870	10	Carrizo	3.0	+40.0	May 6, 1937	do	None	Estimated flow 40 gallons a minute.

290	9.5 miles SW	Guy Blount	Frank Tucker	1916	188	570	8	Sparta	0	+8.0	Apr. 30, 1937	do	do	Estimated flow 35 gallons a minute; very much sand in suspension.
291-A	do	Angelina Lumber Co.	K. L. McHenry	1937		265	3	do	0	+1.0	June 16, 1937	do	do	Original flow 2 gallons a minute.
292-A	8.5 miles S	do	do	do	200	200	3	do	0	+1.0	do	do	do	Flows 8 gallons a minute.
296-A	11 miles SE	do	do	do	171	225	3	do	0				do	
297-A	14 miles SE	do	do	do	191	325	3	do	0				do	
300-A	15.5 miles SE	do	do	do	212	435	3	do	0				do	
301-A	16 miles SE	do	do	do	173	395	3	do	0	+16.0	May 6, 1937	Flows	do	Flows 30 gallons a minute; temperature 72° F.
305-A	17 miles SE	do	do	do	188	465	3	do	0				do	
305	17.5 miles SE	Tom Parton	Geo. E. Ginter	1931		252	6	do	3.0	+2.0	May 6, 1937	Flows	D, S	Flows 2½ gallons a minute; temperature 72° F.

ADDENDUM

Since the foregoing report was written ground-water supplies have been developed at three places in Angelina County. Data concerning these developments have been obtained by R. W. Sundstrom, of the Geological Survey, chiefly from Messrs. C. L. Stine, city manager, and Thomas Russell, water superintendent, of the city of Lufkin; from Messrs. E. L. Kurth, president, and K. L. McHenry, geologist, of the Southland Paper Mills, Inc.; from Mr. Sam L. Olson, vice president of the Layne-Texas Co.; and from Mr. W. T. Denard, superintendent of the pipe line station of the Gulf Refining Co.

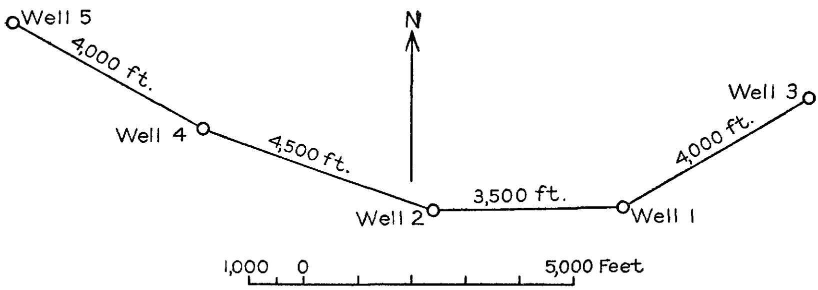

FIGURE 2.—Sketch map showing location ol wells of Southland Paper Mills, Inc.

The largest development consists of five wells drilled by the Layne-Texas Co. for the Southland Paper Mills, Inc. Well 1 was drilled at the site of well 23 in Angelina County (see pl. 2), 6¾ miles north of Lufkin. The relative locations of the other wells are shown on the sketch map (fig. 2). The depth and screen setting of all of the wells and the altitudes of the land surface and static water level are shown in the following table.

Data on wells of the Southland Paper Mills, Inc.

[Measurements in feet]

No.	Depth	Screen setting	Altitude of land surface above sea level	Static water level above sea level	No.	Depth	Screen setting	Altitude of land surface above sea level	Static water level above sea level
1	1,025	878 to 997	245	283	4	998	854 to 976	260	283
2	1,050	897 to 1,018	255	283	5	986	823 to 944	233	283
3	933½	822 to 924	228	283					

The wells, which are drilled, are cased 18 inches in diameter from the land surface to the top of the Carrizo sand and are underreamed to a diameter of 30 inches through the Carrizo. Screens 10 inches in diameter, ranging in length from 100 to 120 feet, are set in the Carrizo sand and are surrounded artificially by filter sand. Mr. McHenry reports that the static water level in the wells is about 283 feet above mean sea level. Therefore the wells flow strongly. According to Mr. Olson each well has a capacity of 2,750,000 gallons a day and is equipped with a 200-horsepower deep-well turbine. The plant is not operating yet, but when operation begins the five wells are to be pumped at not more than 10,000,000 gallons a day. As much of the water as possible is to be recirculated, and it is hoped that when the plant is operating steadily the pumpage will be not more than about 6,000,000 gallons a day.

The well for the city of Lufkin, 1,500 feet west of the schoolhouse at Redland, Angelina County (see pl. 2), was drilled by the Layne-Texas Co. to a depth of 1,169 feet. It is 16 inches in diameter from the surface to a depth of 1,046 feet, below which it was underreamed to 30 inches. A 10-inch screen was set from 1,055 to 1,106 feet and from 1,116 to 1,167 feet. While the well was being developed, fine gravel was introduced into it to surround the screen. The well draws water from the Carrizo sand. The pump has a capacity of about 1,000,000 gallons a day. According to Mr. Russell, the pumpage from the well from August to December was as follows: August 23,000,000 gallons; September, 24,000,000 gallons; October, 23,000,000 gallons; November, 20,000,000 gallons; December, 20,000,000 gallons. Mr. Russell states that on July 29, 1939, the water level when the well was pumped was 152 feet below the pump base and that after the pump had been shut down for 30 minutes the water had risen to a level of 95 feet below the pump base. On August 17 the water level was 157 feet below the pump base when the well was being pumped, and after a 25-minute shut-down it was 101 feet below the pump base. On September 24 the water level was 165 feet below the pump base during pumping, but the water rose to a level 100 feet below the pump base after the well was shut down. On November 14 the level was 162 feet below the pump base during pumping and rose to 100 feet after the well was shut down. The length of time during which the well was shut down before the last two measurements of high levels is not known. Mr. Russell states that when operations began on the present city well the flow from well 43, which is reported to be 700 feet deep and is believed to draw water from the Queen City sand, was strong but that at the present time there is only a small flow. Observations made by members of the Geological Survey show that on May 8 the pressure head of well 43 was 30.2 feet above the measuring point, which is 2.1 feet above the ground. On July 20, 1939, it was 28 feet, and on December 13 it was 10.2 feet with reference to the measuring point.

The well at the pumping station on the pipe line of the Gulf Refining Co. is at the same location as well 17 in this report (see pl. 2). The well is 6 inches in diameter at the surface but is reduced to 4½ inches in diameter between depths of 773 and 959 feet. Four-and-one-half-inch wire-wrapped screen is set between depths of 908 and 928 feet. The well has a flow of 104 gallons a minute. In October 1939 the pressure head in this well was 43 feet with reference to the land surface.

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