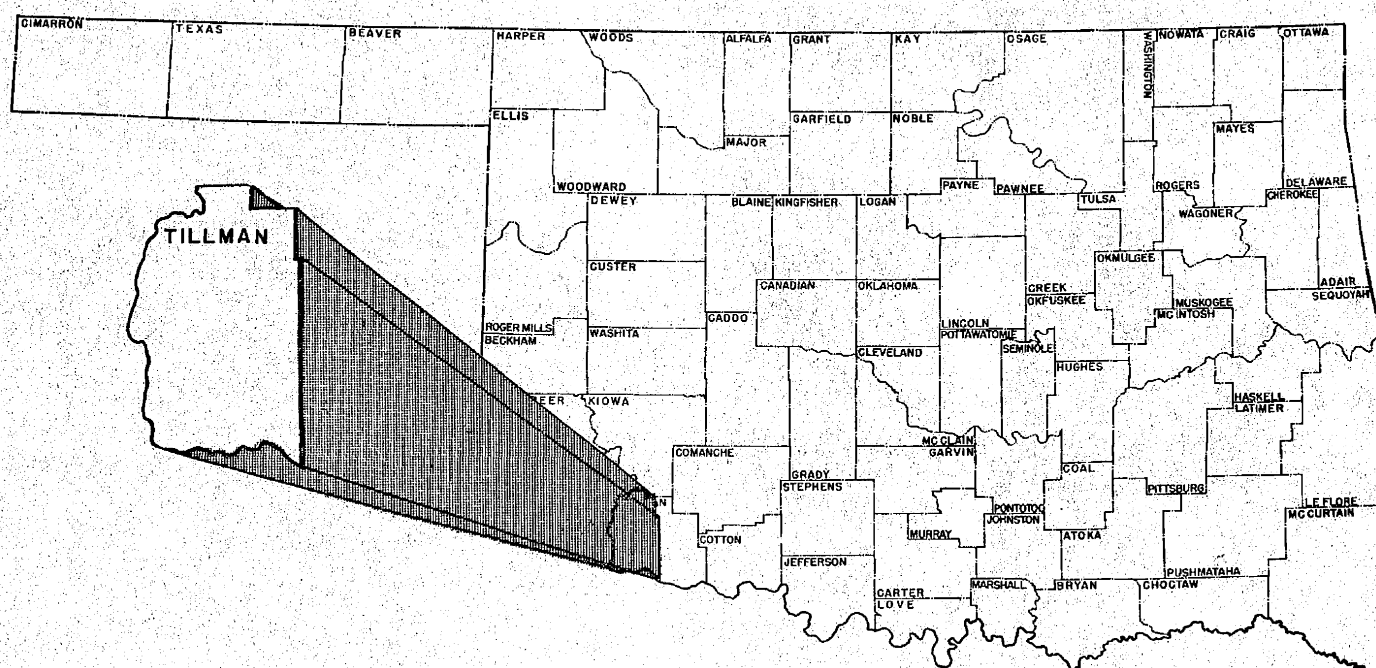
Ground Water Resources Of Western Tillman County, Oklahoma



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GROUND-WATER RESOURCES
OF THE TERRACE DEPOSITS AND ALLUVIUM
OF WESTERN TILLMAN COUNTY, OKLAHOMA

BY

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U. S. GEOLOGICAL SURVEY

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Abstract

The area of investigation discussed in this report is in southwestern Oklahoma, in the western half of Tillman County. It includes an area of about 285 square miles in which the principal aquifers are unconsolidated sediments including alluvium of the present streams and terrace deposits laid down by the ancestral streams at higher levels. The average annual precipitation is about 27.37 inches, and the normal annual temperature about 63°F. Farming is the principal occupation, and cotton, wheat, and alfalfa are the major crops. Cotton ginning is the major industry, and a small quantity of petroleum is produced. Frederick, the largest city in the area, contains most of the other diversified industry that is necessary for the welfare of the community.

The rocks at the surface range in age from pre-Cambrian to Quaternary, terrace deposits and alluvium of Quaternary age covering most of the area. The primary purpose of this investigation was to ascertain the water-bearing properties of the terrace deposits and alluvium.

The terrace deposits and alluvium consist of interfingering lentils of clay, sandy clay, sand, and gravel. Test drilling showed that the average thickness of the terrace deposits is about 42 feet, and the average thickness of the alluvium is about 31 feet. In the zone of saturation about 38 percent of the terrace deposits and about 97 percent of the alluvium is gravel and coarse sand that appears to be highly permeable. Wells tapping these deposits supply most of the water for domestic use and 82 irrigation wells obtain water from them. The municipalities of Frederick, Tipton, Manitou, and Davidson get their water from the terrace deposits. Except for hardness, the water is generally of good quality and is suitable for most uses.

Rocks of Permian age form the bedrock upon which the alluvium and terrace deposits rest (pl. 1). No wells are known to obtain large amounts of water from the Permian strata, but small amounts of water, adequate for stock and domestic wells, might be obtained from lenticular sandstones and from cracks in the shale.

Aquifer tests were made on eight wells tapping the terrace deposits. Coefficients of transmissibility ranged from 8,200 to 67,000 gpd/ft and averaged 37,500 gpd/ft. The coefficients of storage ranged from 0.010 to 0.087 and averaged 0.036, but they are thought to be too low because most of the pumping periods were short, and complete drainage within the cones of depression was not possible. The sediments in the upper part of the terrace deposits are fine grained, and they are the sediments that were drained during the pumping tests--not the gravels and coarse sands that yield most of the water pumped from the wells. It was estimated that 0.10 represents the coefficient of storage in the upper part of the terrace deposits and 0.15 is a reasonable figure for the entire thickness of water-bearing sediment.

The "safe" yield of the terrace deposits is estimated tentatively as about 103 gpm/square mile. This is based on an estimated recharge of 11.5 percent of the normal rainfall in the area. The amount of water stored in the aquifer averages 3.45 acre-feet per acre. If half the water in storage can be recovered by pumping, withdrawals at the estimated rate of the "safe" annual yield may continue for a period of about 6 years, even if no recharge occurs.

Introduction

The terrace deposits in the western half of Tillman County, Oklahoma, have long been recognized as a source of relatively large supplies of ground water. These deposits supply water for domestic and irrigation uses and for the municipalities of Frederick, Tipton, Davidson, and Manitou. Nevertheless, detailed information on the quantity and quality of the ground water in these deposits has been lacking.

In 1949 the Oklahoma State Legislature, because of the value of the ground-water resources of the State, passed the Oklahoma Ground Water Law (Title 82, secs. 1001-1019 incl., Okla. Statutes, 1951). The Oklahoma Planning and Resources Board is responsible for administering the law and is required to make a hydrographic survey to establish the facts necessary for the adjudication of water rights. The Board is authorized to cooperate with Federal agencies in making such surveys and may accept and use the results of the work of agencies of the Federal Government.

Purpose and Scope of this Investigation

In anticipation of increased demands for ground water from the terrace deposits, especially for irrigation, it was believed that an appraisal of this important aquifer was needed. Accordingly, an investigation that is the basis for this report was begun in July 1951 as a cooperative project of the United States Geological Survey and the Division of Water Resources of the Oklahoma Planning and Resources Board. The work was done under the general administration of A. N. Sayre, chief of the Ground Water Branch, U. S. Geological Survey; Morton R. Harrison, Board chairman, and Ira C. Husky, director, Division of Water Resources, Oklahoma Planning and Resources Board. Stuart L. Schoff, district geologist, U. S. Geological Survey, directly supervised the work.

Location and Extent of the Area

The area investigated is in southwestern Oklahoma (fig. 1), in the western half of Tillman County. It is bounded on the south by the Red River; on the west by the Red River and the North Fork of the Red River; and on the north by Kiowa County. Most of the area lies west of an imaginary line extending north and south through the city of Frederick. Its maximum length from north to south is about 29 miles, its maximum width is about 13 miles, and its area is about 285 square miles.

Previous Work in the Area

Clifton (1928) briefly mentioned the terrace deposits of the western part of Tillman County as "an area of Quaternary or Recent exposures, consisting of sands and alluvium." His report contains a geologic map on which these deposits are shown.

In November 1944 a 24-hour aquifer test was conducted on the irrigation well at the Southwestern Cotton Substation, near Tipton. The results are given in this report in the section on aquifer tests.

In May 1945, five test holes were contracted for by the town of Tipton, in search of a supplementary water supply for public use. The logs of these wells are included in appendix B of this report.

Reed and Schoff (1947) discussed the water-level fluctuations recorded from 1940 to 1947 in the irrigation well at the Southwestern Cotton Substation, drawing

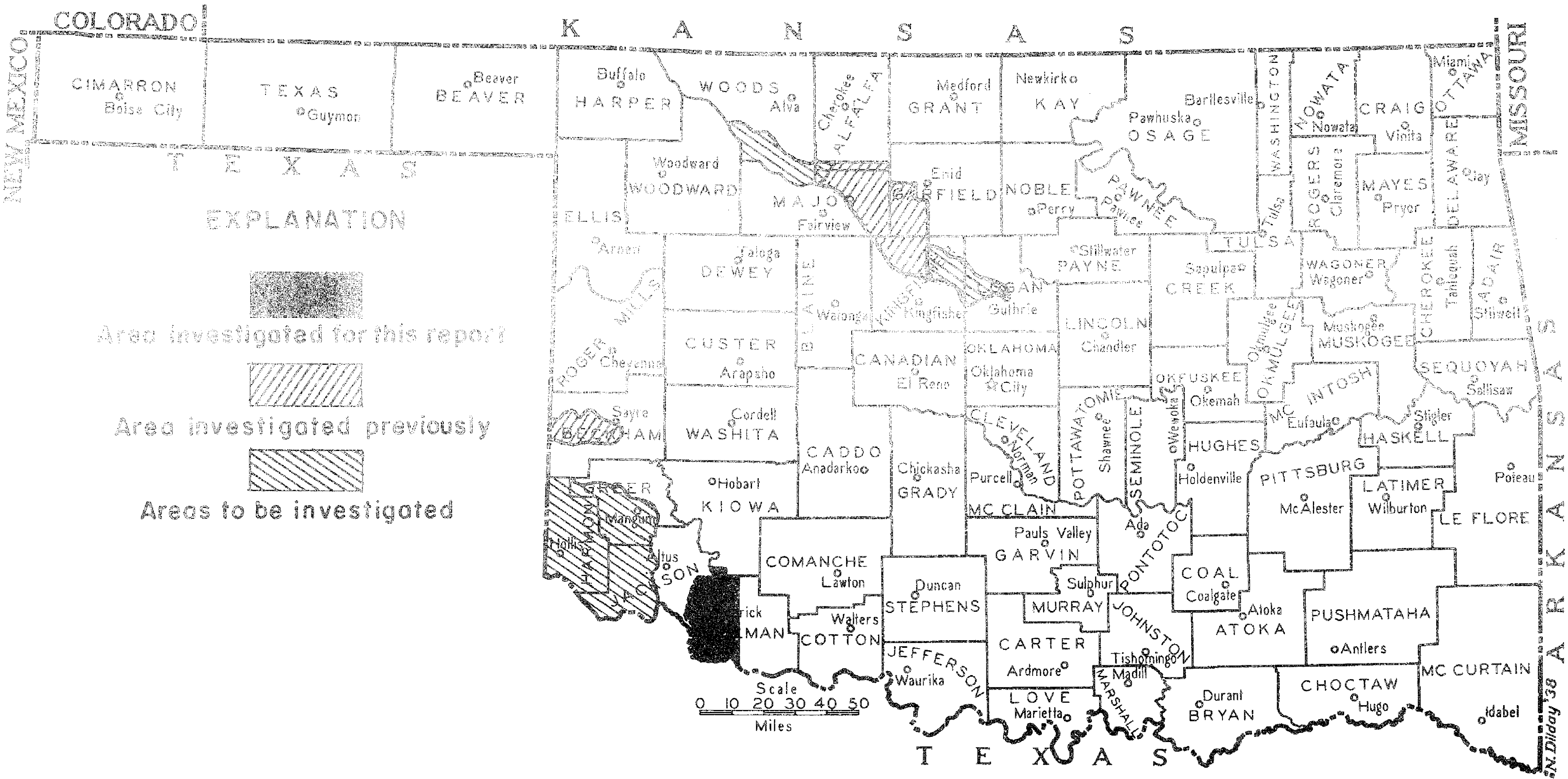

Figure 1. Index map of Oklahoma, showing area investigated for this report and other areas under investigation by the United States Geological Survey and the Oklahoma Planning and Resources Board.

preliminary conclusions on ground-water storage. They also gave a short discussion of the aquifer test made on this well in 1944.

In 1948 the Layne-Western Co. of Wichita, Kans., drilled 40 test holes in the terrace deposits for the city of Frederick. They constructed six wells and made an aquifer test on one of them. Logs of the test holes are included in appendix B, and the results of the test are discussed in the section on aquifer tests of this report.

Measurements of water level in the irrigation well at the Southwestern Cotton Substation have been made since 1940 by personnel of the substation. From March 1940 to June 1940 the measurements were made at irregular intervals; from June 1940 to December 1944 they were made twice a month; and since December 1944 they have been made weekly. Precipitation is recorded at the substation for the U. S. Weather Bureau, and since 1944 has been reported to the Geological Survey along with the water-level data. The record of the pumpage at the substation has been included in these reports since 1946. Semiannual measurements of water level in nine other wells tapping the terrace deposits have been made by Planning and Resources Board and Survey personnel since 1949.

Methods of this Investigation

Field work was started in July 1951, when 55 test holes were drilled, under contract let by the Planning and Resources Board, to determine the thickness and lithology of the terrace deposits. These were supplemented by 17 test holes drilled in April 1953, under contract let by the Planning and Resources Board, of which 10 were in the terrace deposits and 7 were in the alluvium north of Otter Creek. In addition, the logs of the 45 test holes drilled for the city of Frederick and the town of Tipton were collected. All logs of wells and test holes are given in appendix B. Surface altitudes of wells and test holes were determined by trigonometric leveling by a field party of the Oklahoma Planning and Resources Board.

In October and November 1952, aquifer tests were made on six wells that obtain water from the terrace deposits, following procedures in general use in the Geological Survey.

Geologic mapping of the area was done by the junior author in December 1952 and January 1953, on aerial photographs on a scale of about 3.2 inches to the mile. The geologic contacts then were transferred to a base map on a scale of 1 inch to the mile. The base map itself was prepared from a county highway map issued by the Oklahoma Highway Department, to which was added the drainage as it appears on aerial photographs.

Coincident with the start of the geologic mapping, an inventory of wells was begun. Special emphasis was given to finding wells in which the depth to water could be measured, but an attempt was made also to obtain a count of all the wells in the area, and 856 wells were recorded. Of these, about 175 typical ones are listed in appendix A.

Samples of water from 17 wells were analyzed in the U. S. Geological Survey laboratory at Stillwater (now at Oklahoma City). This laboratory is a cooperative project of the Oklahoma Planning and Resources Board, the U. S. Geological Survey, and the Engineering Experiment Station of Oklahoma Agricultural and Mechanical College. The analyses are given in table 4.

Well-Numbering System

The well numbers used in this report are based on the land-survey system of the General Land Office. They locate the well to the nearest square mile and consist of the following elements, in the order indicated: township, range, and section. For example, a well numbered 1S19W-13 is in sec. 13, T. 1 S., R. 19 W. It is the only well recorded for sec. 13. Where several wells have been recorded for the same section, serial numbers have been added to identify the individual wells. Thus, well 1N18W-3-2 is the second well in sec. 3. Test holes and shot holes are numbered in the same way as water wells, and cannot be distinguished from the wells by the type of number used. They can be distinguished, however, by the symbols used on the map (pl. 3) and are appropriately identified in the table of well records (app. A). If the location to the nearest 40 acres is desired, it may be found by reference to that table.

Acknowledgments

The writers wish to express appreciation for the cooperation of the well owners in supplying information and permitting the use of their wells for observation purposes. Mrs. Anna Young and Messrs. J. A. Banker, W. A. Dotson, W. B. Hudson, T. G. Jennings, Jr., and Oran Roberts were especially helpful in allowing the use of their wells for aquifer tests.

Mr. J. J. Zumwalt, superintendent of utilities at Frederick, was very helpful in supplying information regarding the wells of the city of Frederick. The Layne-Western Co., of Wichita, Kans., supplied logs of test holes drilled for the city of Frederick and data from an aquifer test made at one of the city's wells. Mr. J. M. Maddox, manager of the Southwest Rural Electric Assoc., Inc., at Tipton, supplied records of the pumping rates of many irrigation wells.

Special thanks are due Mr. C. L. Fox who has made weekly measurements of water level in the well of the Southwestern Cotton Substation (well 1S19W-25) (the system of numbering wells is given above) since 1944, and has supplied them as well as precipitation and pumpage records.

Topography and Drainage

The maximum regional relief, as determined from the altitude of several stations, is 265 feet. The highest recorded altitude is 1,396 feet at a test hole in sec. 15, T. 7 S., R. 18 W., and the lowest is 1,131 feet at a seismograph hole in sec. 13, T. 4 S., R. 19 W.

A discontinuous strip of sand dunes, ranging in width from less than half a mile to 1½ miles, occurs along the margin of the terrace deposits bordering the Red River and the North Fork of the Red River. The dunes range from 5 to 30 feet in height. Most of them have been stabilized by vegetation and many of the smaller and lower dunes are under cultivation.

The surface of the terrace deposits slopes generally westward to the North Fork of the Red River or southward to the Red River. Exceptions to this general slope occur in the north part of the area, where the slope is toward Otter Creek, and in the east part of the area, north of Frederick, where the east boundary of the terrace deposits lies along a drainage divide. Streams flowing eastward from this divide have cut through the terrace deposits and exposed the Permian bedrock.

The northern quarter of the area is drained by Otter Creek, which heads outside the mapped area and flows southward and westward across the area to join the North Fork of the Red River in sec. 23, T. 1 N., R. 19 W. It is a perennial stream along the lower 2 or 3 miles of its course, where its flow is maintained by seepage from the terrace deposits and alluvium. In the upper half of its course across the area, Otter Creek flows in a broad valley that ranges from 1 to 4 miles in width. In the lower half of its course, where the stream passes through a belt of sand dunes, the valley is less than half a mile wide.

The southern three-quarters of the area is drained by five unnamed, intermittent streams, three that flow directly into the Red River, and two that flow into the North Fork of the Red River (pl. 1). All five streams head within the area of terrace deposits and flow only when precipitation is enough to cause runoff. They have shallow channels except where the dunes have been piled high on both sides; and, for the most part, they have little or no flood plain.

Climate

The area has a dry subhumid climate (Thornthwaite, 1941, pl. 3). The normal annual temperature as reported by the U. S. Weather Bureau for Frederick is 63.3°F, and the average length of the growing season is 227 days. The normal annual precipitation is 27.37 inches; the lowest monthly normal precipitation is in January and the highest is in May.

Records of precipitation and temperature have been kept at Frederick since 1904, and a summary of these data is given in tables 1 and 2.

Population

The area investigated has a population of about 10,800 according to the 1950 census. Frederick, with a population of 5,467, is the largest city in the area. The populations of towns in the area are: Tipton, 1,172; Davidson, 490; and Manitou, 293.

Agriculture

The area covered by this report is devoted primarily to agriculture. The principal crops are cotton, wheat, and alfalfa. Vetch, oats, barley, castor beans, clover, potatoes, grain sorghum, and sudan are grown in small quantities. Some of the land is used exclusively for grazing, and some of the cultivated land is used for grazing during fall, winter, and spring months.

Industries

The Oklahoma Planning and Resources Board, in its publication, Oklahoma Manufacturers' Directory (1952, p. 121), lists by cities or towns the following industrial or commercial enterprises in the area: Tipton, 3 cotton gins; Davidson, 3 cotton gins; and Frederick, 9 cotton gins, 2 alfalfa-processing companies, a soft-drink bottling plant, a fishing tackle company, 3 printing and publishing firms, a dairy-products company, an ice company, a pottery plant, a cabinet shop, a truck body shop, an air-conditioner shop, an oil production-distribution plant, a mattress company, a bakery, and a metal shop for making tanks, ventilators, and skylights. There are several sand and gravel pits in the area, some of which appear not to have been worked for several years.

Table 1. Summary of precipitation at Frederick, in inches.

1904-52							
Month	Max.	Min.	Norm.	Month	Max.	Min.	Norm.
January	4.94	0.00	1.06	August	6.50	0.00	2.07
February	4.13	.00	1.17	September	9.77	.00	2.91
March	5.14	.00	1.76	October	11.91	.00	3.04
April	9.67	.05	2.80	November	6.66	.00	1.62
May	9.95	.75	4.01	December	6.41	.00	1.42
June	11.55	.01	3.36	Annual	43.79	14.40	27.37
July	6.59	.00	2.15				

Table 2. Normal temperatures in degrees Fahrenheit at Frederick.

1904-52					
January	41.3	June	79.5	October	65.1
February	45.7	July	83.9	November	52.6
March	53.8	August	85.6	December	42.4
April	62.4	September	76.5	Annual	63.3
May	70.6				

A small quantity of oil is produced in the area, but the amount is not published separately from the production of the county as a whole. Records of the Oklahoma Corporation Commission show that the production of oil from the county was 198,757 barrels in 1952.

Geologic History

Rocks exposed in the area range in age from pre-Cambrian to Quaternary, and their geologic history is intimately related to events in the history of the Wichita Mountains. The oldest Paleozoic rocks were apparently deposited when the area was relatively stable, but it is believed that crustal deformation occurred during early Pennsylvanian time, resulting in the uplift of the Wichita Mountains. Clifton (1928, p. 7; 1930, p. 193) summarized the later geologic history of the region as follows:

> "Subsequent to the early Pennsylvanian uplift, the upturned beds were subjected to erosion and finally peneplanation to a marked degree and by the close of Pennsylvanian time, this area again became submerged. Detrital material forming the clastic and indirectly the non-clastic beds of the Permian, was deposited on the eroded Pennsylvanian surfaces. *** deltaic Permian deposits were laid down on the truncated and tilted older beds, as a more or less narrow border or periphery around the Wichita uplift. To the south, away from the Wichita uplift, deposition was continuous from early Pennsylvanian to the close of Permian time, since the evidence of a marked unconformity between the late Pennsylvanian and the early Permian beds disappears rapidly to the south. Later, and after the close of Permian time the Wichita Mountain area again was elevated to its present height, thus tilting the beds in the four counties southwestward."

Any sediments that may have been deposited in the area between the middle of Permian time and Quaternary time were removed in a long period of erosion. One effect of the erosion was to create an uneven surface, as shown by contours drawn on the bedrock surface (pl. 2). This surface was lowest in the south, had a maximum relief--in the area covered by this report--of about 300 feet, and a maximum local relief of about 90 feet. Test holes drilled for this investigation penetrated bedrock at many points, yet do not suffice to permit detailed delineation of the old drainage system. There is, however, evidence of a major valley, now buried, that trended southward 2 or 3 miles east of the present North Fork of Red River.

Geologic Formations and their Water-Bearing Properties

A mantle of alluvial and eolian sediments of Quaternary age covers most of the area, but streams along the east border have cut through the Quaternary sediments to expose the underlying Permian strata Granite of pre-Cambrian age. It is exposed in two low hills north of Otter Creek.

Pre-Cambrian Rocks

Pre-Cambrian granite is exposed in low hills in secs. 21-24, T. 2 N., R. 18 W., and is surrounded by sediments of Quaternary age. These hills are part of the Wichita Mountains, which trend northwestward across Greer, Kiowa, Jackson, Tillman, and Comanche Counties. The granite was not studied in detail during the course of this investigation, and was not encountered in any of the test holes. No wells are known to obtain water from it, but it was observed to be intricately jointed, and wells that intersect the joints below the water table might yield moderate quantities of water.

Permian System

The bedrock nearest the surface in most of the area covered by this report is reddish-brown argillaceous siltstone of Permian age, in which are included thin layers of gray and reddish-brown shale. Outcrops shown on the geologic map of Oklahoma indicate that these strata have a gentle regional dip to the southwest. In the southeastern part of the area a gray shale ranging in thickness from less than 1 foot to about 4 feet is present in some exposures of Permian strata. The siltstone weathers to a clay-like mass that looks very much like some of the overlying Quaternary clays, and in some places it is difficult to distinguish one from the other. A few well-cemented layers of siltstone stand out as thin ledges. One of the most characteristic features of the Permian strata is a mottling of light greenish gray, which commonly takes the form of isolated nearly circular spots best seen on freshly broken surfaces. In some exposures this mottling is the only criterion for separating the Permian red beds from fine-grained reddish materials in the overlying terrace deposits.

This report is primarily concerned with water from the terrace deposits and alluvium, and an inventory of the wells that tap the Permian strata was not attempted. No wells are known to obtain large amounts of water from the Permian strata, but small amounts of water, adequate for stock and domestic use, might be obtained from lenticular sandstones and from cracks in the shale.

Quaternary System

Alluvial and eolian sediments of Quaternary age cover most of the area west of an escarpment which trends north and south and passes just west of Frederick. The Quaternary sediments extend for an undetermined distance northward into Kiowa County where their upper surface slopes upward to the granite peaks of the Wichita Mountains. Quaternary sediments are present also in the eastern part of Tillman County, but for the most part they are thin and are believed not to contain much water. They are separated from the area mapped as Quaternary sediments in this report, by the escarpment mentioned above, along which Permian strata crop out.

Terrace Deposits

The terrace deposits consist of interfingering lentils of clay, sandy clay, sand, and gravel. The sand and gravel generally are not well sorted, although some of the fine-grained gravel found in the lower portions of the test holes was very well sorted. Colors of the sediments are gray, brown, and reddish brown. Much of the clay contains scattered pebbles of quartz, is brown to reddish brown, and has either an earthy or starchy fracture. In some exposures, calcareous nodules are present in the clay. Layers of caliche as much as 1 foot thick were penetrated in some of the test holes, but no beds of this kind were found in surface exposures.

Measurements of water level were made in 47 of the test holes drilled during this investigation. The logs of these test holes indicate that about 40 percent of the rock material in the zone of saturation is sand and gravel, and about 32 percent is coarse enough to be highly permeable.

The gravels are composed predominantly of quartz pebbles but contain also minor amounts of feldspar and ferruginous shale. Rounded pebbles of red shale and siltstone are common in the bottom few feet of Quaternary sediments. Crossbedded conglomeratic sandstone beds ranging from 1 foot to 2 feet in thickness are exposed in the NE¼ sec. 7, T. 2 S., R. 17 W. and the SE¼ sec. 3, T. 1 S., R. 17 W. They unconformably overlie the red beds and are overlain by thin beds of sand and gravel.

The thickness of the terrace deposits differs greatly from place to place because of the irregularity of the bedrock surface on which they were deposited and because of erosion subsequent to their deposition (See pls. 4 and 6). Test drilling indicates an average thickness of about 42 feet. The deposits are believed to thin northward from Tillman County, and no wells are known to obtain large amounts of water from them in Kiowa County.

The terrace deposits are assigned to the Quaternary system on the basis of fossil evidence. Cook (1930, p. 6, 8, 17, and 23) described 25 fragments of fossil vertebrates taken from a gravel pit about 1 mile north of Frederick. They are believed to be parts of animals that existed only during the Quaternary period. Vertebrate fossils from this gravel pit are believed to be equivalent in age to vertebrate fossils from rocks of Pleistocene age in Seward County, Kans., identified by Hibbard (1953, p. 125). Meade (1950, p. 57) also reports that fossil vertebrates of early Pleistocene age were found in high terrace deposits near Frederick, Okla.

The terrace deposits are the principal aquifer in the area, being tapped by about 840 wells. The yields of individual wells in the terrace deposits differ considerably partly because of differences in well construction and partly because the sediments are far from uniform in thickness and permeability. Although very hard, the water is generally of good quality. The water from a few wells contained more sulfate, chloride, or iron than is acceptable for water used for drinking purposes according to standards set by the U. S. Public Health Service (1946, pp. 382-83). Some of it is used for drinking, because water of better quality is not available.

Alluvium

Alluvium is sediment deposited by streams, as are terrace deposits, and the two are lithologically similar. The alluvium underlies the bottom lands along the streams, and in much of the area it is separated from the terrace deposits by a poorly defined topographic break. Along the North Fork of the Red River the break is vague for several miles, and in the northern part of the area the flood plains of Otter Creek and of the North Fork are hardly distinguishable from an extensive flat plain that rises imperceptibly to abut on granite hills. In these localities, therefore, the boundary of the alluvium is drawn arbitrarily.

As revealed by seven test holes, the alluvium north of Otter Creek contains less clay and caliche than do the terrace deposits. The alluvium ranges in thickness from 27 to 47 feet, and averages 34 feet; about 70 percent was below the water table. Of this saturated portion about 97 percent is gravel or very coarse sand that should be highly permeable.

Because influent flow--that is, flow from the stream into the alluvium--may occur under natural conditions or be induced by pumping, the water in the alluvium may be similar in quality to the water in the stream, and it may vary somewhat in response to variations in the quality of the stream. In the area covered by this report, one irrigation well is in the alluvium of the Red River and eight are in the alluvium north of Otter Creek.

Dune Sand

A narrow, discontinuous strip of sand dunes lies along the north side of the Red River and the east side of the North Fork of the Red River. This strip ranges in width from less than one-half mile to about 1½ miles. Materials at the surface consist mainly of loose to friable light-brown to reddish-brown fine to course sand. The dunes range from 5 to 30 feet in height and most of them have been stabilized by vegetation.

As shown by eight test holes, the sediments in the dune area range from 15 to 69 feet in thickness and average 46 feet. The dune sand is above the water table and therefore is not a source of ground water, but it plays a significant part in the ground-water hydrology of the area because the sandy soil favors a relatively high rate of infiltration.

Ground water

The pores of permeable rocks that lie below the land surface generally are partly or completely filled with water called "subsurface water." Below a certain level the pores are completely filled with water, called "ground water"; this zone is called the "zone of saturation." The permeable rocks that lie above the zone of saturation are said to be in the "zone of aeration." This zone is subdivided into the capillary fringe at the bottom, the intermediate belt, and the belt of soil water at the top--the last immediately below the land surface.

In one form or another, water occurs almost everywhere. Although most of the total water supply is stored in the oceans, a constant circulation is taking place. Evaporation from the surfaces of the oceans, streams, and lakes is continual. Most of the moisture so evaporated condenses and returns to the ocean or to the earth's surface as rain, snow, or other precipitation. Part of this precipitation is evaporated directly from the earth's surface, part of it returns to the ocean as surface runoff, and part of it infiltrates beneath the surface of the earth. Some of the water that infiltrates into the ground is held by capillarity near the surface and is evaporated; some is used by vegetation and returned to the atmosphere by transpiration; and some joins the ground water and slowly, by ground-water flow, returns to the streams. This sequence of events is the hydrologic cycle and is represented in figure 2.

Water-Table and Artesian Conditions

Ground water occurs under either artesian or water-table conditions. Artesian conditions exist when the aquifer contains water that has an artesian pressure head. This pressure head occurs where the water in the aquifer is confined by a relatively impervious overlying stratum. Because of this pressure head, water will rise above the upper surface of the aquifer in any well that taps the aquifer.

Water-table conditions exist where the upper surface of the water is not confined by an impermeable bed and the water surface is free to fluctuate. This upper surface of the ground water is the water table. In the area of this report, the water in the terrace deposits and alluvium is largely unconfined and its upper surface is the water table, but the water in the Permian bedrock is confined and is therefore artesian.

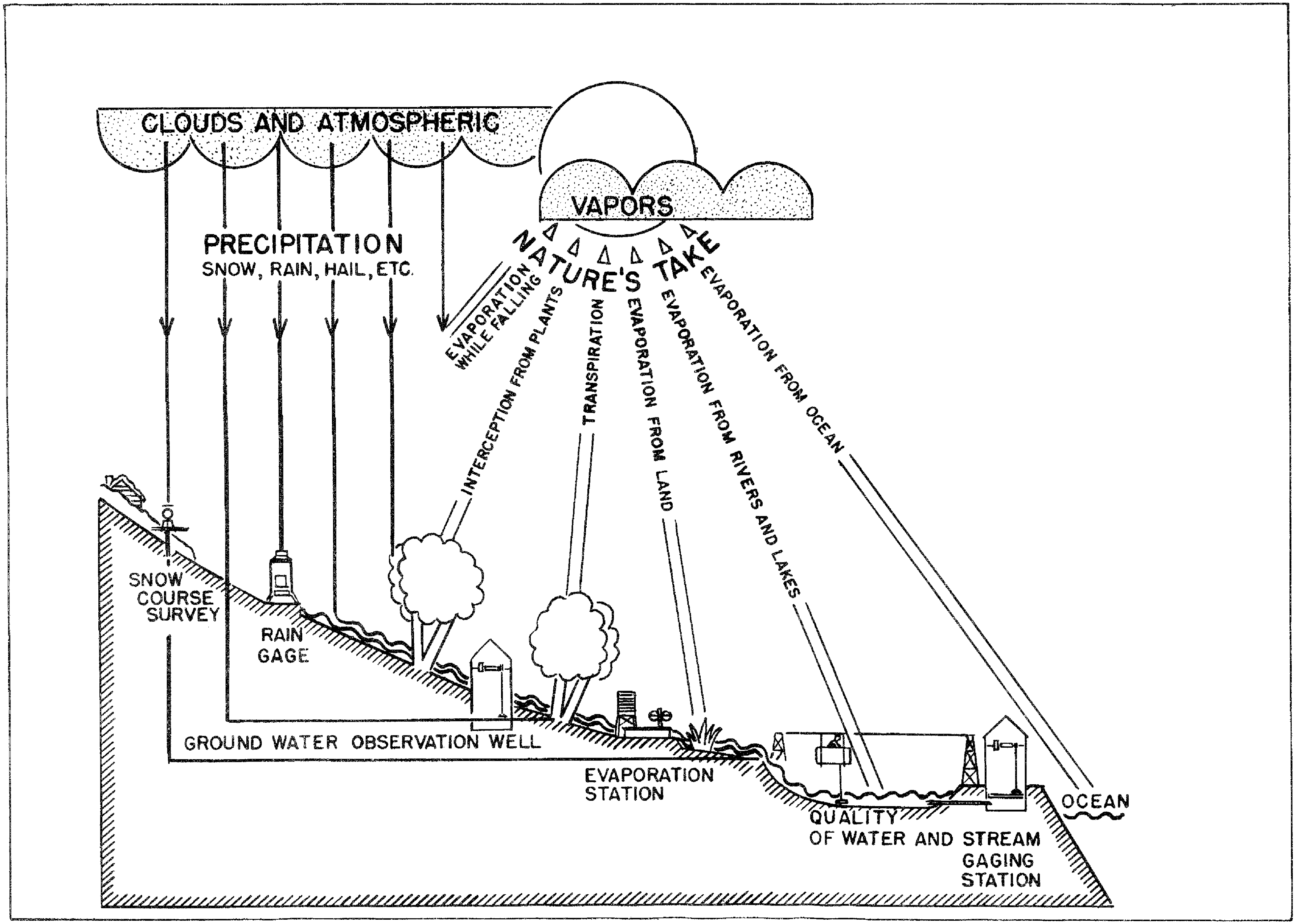

Figure 2.---Hydrologic cycle.

Movement of Ground Water

Ground water, like other liquids, has the tendency to seek equilibrium by moving from a point of higher head to one of lower head. The difference in altitude between any two points on the water table is the difference in head at those two points. The material through which the water moves is the aquifer, and the ease with which water moves depends on the permeability of the aquifer. Permeability depends on the size and arrangement of the particles and on the interconnection of the pore spaces, but it is not directly dependent on the total pore space or porosity of the material. A fine-grained sediment, such as clay, may have a high porosity but a low permeability because the openings are so small that the force of molecular attraction offers resistance to the movement of water.

The water table is not a plane or level surface, but a slightly irregular, sloping surface that corresponds in general with the slope of the land surface. The water table generally has less relief than the land surface and is a subdued replica of the surface topography. The many irregularities in the shape of the water table are caused by differences in permeability and thickness of the water-bearing material and by unequal additions of water to, or removal from, the ground-water reservoir. Where the rate of replenishment, or recharge, is exceptionally high, the water table may form a mound or a ridge from which the water spreads out to surrounding areas. This spreading out takes place slowly because of the resistance to flow through the aquifer. The water table in western Tillman County slopes generally westward to the Red River and the North Fork of the Red River at an average rate of about 18 feet per mile, but in the eastern part of the southern third of the area the water table slopes southward toward the Red River. In the north, the water table slopes toward Otter Creek, and there is a ground-water divide in T. 1S., R. 18 W., trending along a line from sec. 3 to the NE¼ sec. 25. North and west of the divide the ground water drains into Otter Creek and the North Fork of the Red River, whereas east of the divide it drains off to the eastern edge of the terrace deposits where some of it emerges as small springs and some of it is evaporated as fast as it nears the surface.

Along the North Fork of the Red River, from the north boundary of Tillman County to a point 7 or 8 miles south of Tipton, the water table has a relatively slight and irregular slope. (See pl. 3.) The writers believe that, when the water table is high, the terrace deposits and alluvium discharge water into the river; but, when the water table is low and the river has considerable flow, the river contributes water to the zone of saturation. This opinion is based on measurements of streamflow made by the Surface Water Branch of the U. S. Geological Survey at three different times when surface runoff was negligible (table 3.) The measured flow therefore represented base flow, or ground water that had seeped into the channel. The measurements were made at four points along the North Fork of the Red River, at two points along Otter Creek, and at two points along the Red River (See fig. 3.) The quantities of water are small, but they indicate the changing relationship between the river and the aquifer.

The first series of measurements, made November 23-30, 1945, showed an alternation of gain and loss in flow. Between stations 1 and 2 the flow increased by 420,000 gpd, but as this is less than was added to the river by Otter Creek at a point 2 miles upstream from station 2, there actually was a loss in flow of 1,293,000 gpd. This loss can hardly be due to evaporation, because in late November the evaporation losses should have been small. Between stations 2 and 3 there was a loss in flow of 713,000 gpd. Between stations 3 and 4, on the other hand, there was a gain in flow of 27,013,000 gpd, which no doubt was due to the discharge of ground water from the terrace deposits.

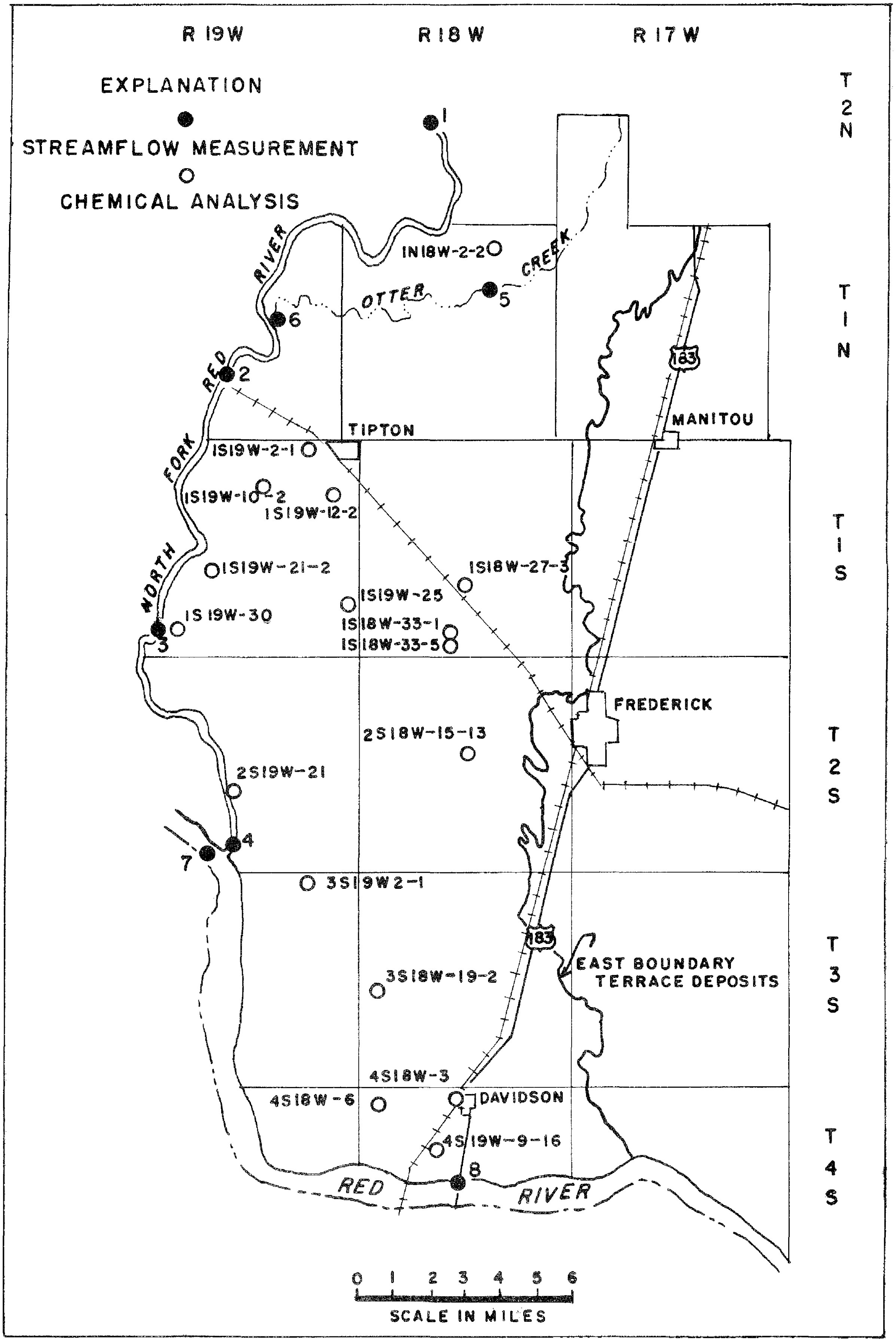

Figure 3. Map showing locations where streams were gaged and where samples of ground water were collected for chemical analysis.

Table 3. Measurements of streamflow in the area of this report

Location of measurement	Date of measurement	Flow (gpd)
North Fork of Red River		
1. C. N½ sec. 21, T. 2 N., R. 18 W.	11-28-45	9,600,000
C. N½ sec. 21, T. 2 N., R. 18 W.	2-13-53	2,760,000
C. N½ sec. 21, T. 2 N., R. 18 W.	4-22-53	5,894,000
2. NE¼NE¼ sec. 28, T. 1 N., R. 19 W.	11-29-45	10,020,000
NE¼NE¼ sec. 28, T. 1 N., R. 19 W.	2-13-53	1,092,000
NE¼NE¼ sec. 28, T. 1 N., R. 19 W.	4-22-53	7,543,000
3. SE¼NE¼ sec. 31, T. 1 S., R. 19 W.	11-29-45	9,307,000
SE¼NE¼ sec. 31, T. 1 S., R. 19 W.	2-13-53	576,000
SE¼NE¼ sec. 31, T. 1 S., R. 19 W.	4-22-53	8,273,000
4. At mouth	11-30-45	36,320,000
At mouth	2-13-53	No flow
At mouth	4-22-53	9,824,000
Otter Creek		
5. SW¼SW¼ sec. 11, T. 1 N., R. 18 W.	11-29-45	297,000
SW¼SW¼ sec. 11, T. 1 N., R. 18 W.	2-13-53	No flow
SW¼SW¼ sec. 11, T. 1 N., R. 18 W.	4-22-53	No flow
6. At mouth	11-29-45	1,713,000
At mouth	2-13-53	487,000
At mouth	4-22-53	554,000
Red River		
7. Above mouth of North Fork	11-30-45	162,000
Above mouth of North Fork	2-13-53	16,090,000
Above mouth of North Fork	4-22-53	23,910,000
8. At bridge in sec. 16, T. 4 S., R. 18 W.	11-30-45	49,250,000
At bridge in sec. 16, T. 4 S., R. 18 W.	2-13-53	16,350,000
At bridge in sec. 16, T. 4 S., R. 18 W.	4-22-53	35,350,000

The second series of measurements, made at the same stations on February 13, 1953, showed a progressive loss in flow downstream. Between stations 1 and 2 the loss was 1,668,000 gpd, despite the 487,000 gpd being added to the river by Otter Creek. Between stations 2 and 3 there was a further loss in flow of 516,000 gpd; and between stations 3 and 4 the remaining 576,000 gpd disappeared, and the river was dry at station 4. As in 1945, the loss due to evaporation should have been small. In other words, the water table sloped away from the river and influent conditions prevailed.

The third series of measurements, made at the same stations on April 22, 1953, showed a progressive increase in flow downstream. Between stations 1 and 2 the gain in flow was 1,649,000 gpd--1,095,000 gpd more than was added to the river by Otter Creek above station 2. Between stations 2 and 3 the flow increased by 730,000 gpd, and between stations 3 and 4 it increased by 1,551,000 gpd. This series of measurements, like the other two, was taken during a relatively dry period when the surface runoff into the streams was negligible. The flow, therefore, was ground-water discharge, and it indicates that the slope of the water table all along the North Fork of Red River was toward the river, not away from it.

When the measurements of flow were made in the North Fork of the Red River, all streams entering the river from the west were checked, and each time their contribution to the river was found to be negligible. The terrace deposits west of the North Fork of Red River are believed to be too thin to contribute much flow to the river.

Fluctuations of Water Level

The water table rises and falls in response to variations in the recharge to and discharge from the underground reservoir. After replenishment during wet seasons, the water table normally is relatively high. After dry seasons, during which the flow of perennial streams has been maintained by discharge of ground water, the water table normally is lower. Discharge of water by evaporation, by transpiration, or by pumping from wells also will lower the water table. The position of the water table at any one time depends on the balance between recharge and discharge. It expresses the net effect of the opposing forces, recharge and discharge. It shows whether there has been a gain or loss in storage. The position of the water table is found by measuring depths to water in wells, and changes in it are detected by measuring the depths periodically.

Some fluctuations of water level in wells are due to causes not related to recharge and discharge, such as earthquakes and variations of atmospheric (barometric) pressure. Of these other causes it is believed that only the barometric pressure affects water levels significantly in the area covered by this report.

Measurements of water level in well 1S19W-25 have been made at weekly intervals since December 1944. Since that time the water level in the well has fluctuated through a range of about 6 feet, and it was about 1.4 feet lower in December 1952 than it was in December 1944 (fig. 4). The well is used for irrigation, and except for periods of pumping, which are indicated in figure 4 by a dashed line, the lowest recorded water level between December 1944 and December 1952 occurred in the summer of 1950.

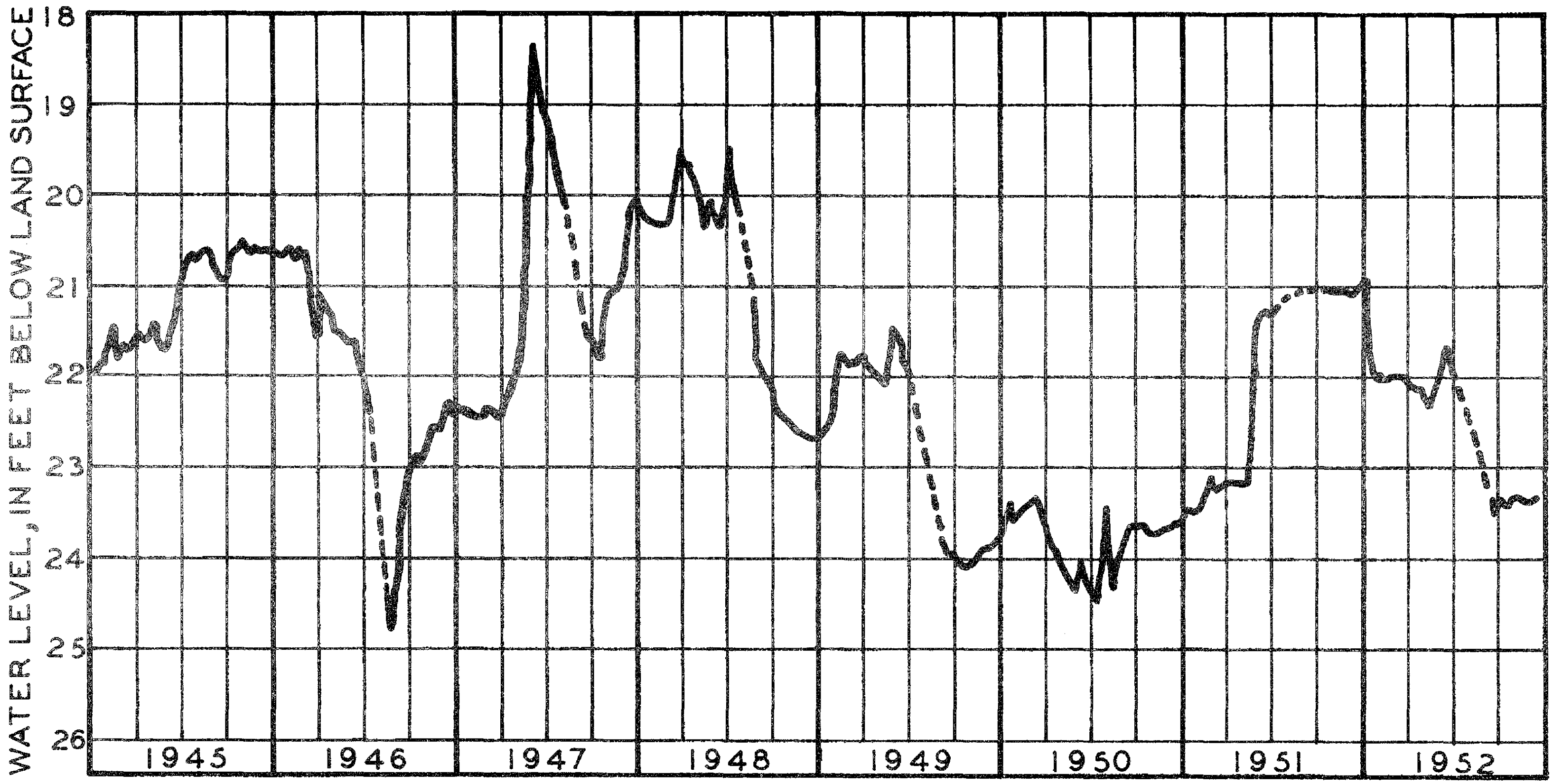

Figure 4.--Water-level fluctuations in well 1S 19W-25.

Discharge of Ground water

Ground water is continuously being discharged from an aquifer by effluent seepage, evaporation, flow or pumping from wells, underflow into another aquifer, or transpiration by plants.

Effluent Seepage

Discharge by effluent seepage, as the word "effluent" suggests, is that water which flows out of the zone of saturation and into a stream whose surface is lower than the water table. A stream or part of a stream is effluent with respect to ground water if it receives water from the zone of saturation.

The streams that pass through or by the area investigated in this report are, for the most part, effluent with respect to the ground water of the area. Measurements of streamflow show that the Red River increases in flow as it passes by, and that Otter Creek gains in flow as it crosses the area. The North Fork of the Red River, which forms most of the western boundary of Tillman County, cannot be so neatly cataloged with respect to the ground water of western Tillman County. As was pointed out in the section on movement of ground water, the North Fork of the Red River was influent along its entire course past the area in one series of flow measurements; it was effluent along the same stretch in another series of measurements, and it was effluent along part of the stretch and influent along another part in still another series of measurements.

To compute the loss of ground water from the area of this investigation by effluent seepage into streams it is necessary to determine the gains in the flows of the North Fork of the Red River and the Red River as they pass along the western and southern boundaries of the area. Part of the flow in the North Fork comes from outside the area covered by this investigation; so, the flow at the upstream stations 1 and 5 (fig. 3) must be subtracted from the flow at station 4. Possibly, also, some effluent seepage from the west augments the flow of the North Fork, but this contribution is believed to be negligible. Part of the gain in flow of the Red River between stations 7 and 8 is due to effluent seepage from terrace deposits in Texas, on the south side of the river, and part is due to the flow contributed by the North Fork near station 4. After subtracting the contribution of North Fork, the gain in the Red River due to effluent seepage from western Tillman County is assumed to be half the remaining gain in flow between stations 7 and 8. The sum of this latter figure plus the gain in flow of the North Fork would therefore approximate the effluent seepage from the area covered by this investigation.

By using the above method the effluent seepage from western Tillman County on November 30, 1945, was estimated to be 32,800,000 gpd; on February 13, 1953, it was 130,000 gpd; and on April 22, 1953, it was 4,740,000 gpd. Additional ground water is discharged at several places along the eastern margin of the area of this investigation where the bedrock is exposed or is near the surface. At some of these places there are small intermittent springs, and at other places the water issues so slowly that it is evaporated as fast as it is discharged.

Evaporation

Where the water table is near the land surface, ground water may be discharged into the air by evaporation. Factors governing the rate of evaporation are temperature, wind velocity, humidity, type of soil, and depth to water. White (1932, p. 8) found by experiment that the depth to the water table is the principal controlling factor. He compared evaporation at different depths with evaporation from a free water surface, and expressed the evaporation at depth as a percentage of the evaporation from the free water surface. For depths ranging from 5 to 85 inches, the evaporation was found to range from 80 to 2 percent, respectively. As the depth to water in the area of this report generally is greater than 85 inches, the amount of water evaporated from the water table is probably small. On the other hand, the loss by evaporation from the belt of soil moisture may be rather large, but most of the water thus discharged does not come from the zone of saturation.

Transpiration

The discharge of water into the atmosphere by plants during the process of growing is called transpiration. The water may be taken into the roots of plants from the belt of soil moisture, from the zone of saturation, or from the capillary fringe--which in turn is supplied from the zone of saturation.

Computation of the total amount of transpiration in an area involves many variables that cannot as yet be accurately measured. Where plants are able to take water from the zone of saturation, transpiration may be a major factor in the discharge of ground water. For example, along Otter Creek, where the water table is close to the surface, many trees and other plants discharge ground water. Some plants, such as alfalfa, have root systems that extend to considerable depth and they are capable of drawing water from the zone of saturation where the depth to water is 25 feet or more.

Underflow

Where one aquifer is adjacent to and in contact with another aquifer, ground water can move from the one having the higher head into the one having the lower head. Such movement from one aquifer into another probably takes place along the line of contact between the terrace deposits, which have the higher water table, and the alluvium. This is a form of discharge from the terrace deposits, and it occurs along Otter Creek, along the North Fork of the Red River (at least along some stretches and at some seasons), and along the Red River. The ground water that thus drains from the terrace deposits doubtless moves toward the stream channels to appear as surface flow, to be transpired or evaporated into the atmosphere, or to move downstream through the alluvium. It is conceivable that in places some water seeps downward from the terrace deposits into the underlying Permian red beds, for few if any rocks are absolutely impermeable, but the relatively impermeable character of the red beds implies that the amount of water entering them from the terrace deposits is negligible.

The rate of underflow depends on the hydraulic gradient and the coefficient of transmissibility of the aquifer; and the amount can be computed by use of Darcy's law (Darcy, Henry, 1856) which may be written

$$Q = TIW$$

Where Q is the flow in gallons per day, T is the coefficient of transmissibility in gallons per day per foot, I is the hydraulic gradient in feet per mile, and W is the width of the aquifer in miles. The average coefficient of transmissibility of the terrace deposits, adopted elsewhere in this report, is 20,000 gpd/ft; the average hydraulic gradient of the water table, as determined from the water-table map (pl. 3), is about 20 feet per mile; and the width of the aquifer is 63 miles. The latter is the length of the contact between the terrace deposits and alluvium (along Otter Creek, the North Fork of Red River, and the Red River) plus 7 miles of the contact between terrace deposits and red beds along the eastern boundary near Manitou where the water is discharged as springs or by evapotranspiration. The rest of the latter boundary, south of Manitou, is not counted because water is not discharged along it; as shown by plate 3, the water table slopes away from it, not toward it. Substituting these values in the equation given above, the quantity of water involved in the underflow is calculated to be 25,200,000 gpd.

Pumpage

The discharge of ground water in 1952 by pumping from wells in the terrace deposits of western Tillman County was small compared with the total quantity of water discharged naturally from the aquifer. It was small, also, in comparison with the total quantity stored in the aquifer, which, in the section on ground-water storage, is estimated as 205 billion gallons. The largest use of ground water was for irrigation. An inventory of the pumpage from 24 of the 79 irrigation wells in the area showed that about 583.8 million gallons was pumped, or about 24.3 million gallons per well. Of the 55 wells for which an estimate of pumpage was not obtained, 25 were completed in October or later, and they probably were pumped little or not at all in 1952. If each of the 30 remaining wells were pumped at the same rate as the average of the 24 for which records were obtained, the total irrigation pumpage would have been about 1,300 million gallons for the year, or 3.6 mgd. The water pumped for public supply is small by comparison--only about 388.6 million gallons for the year, or 1.06 mgd. Thus the total pumpage for irrigation and public supply was 1,680 million gallons, or an average of about 4.6 mgd. For the sake of completeness, something should be added to these figures for the water pumped from domestic and stock wells on farms, but compared with the quantities pumped for irrigation and municipalities the quantity of water is so small as to be practically negligible. The pumpage differs greatly from farm to farm, and records of it are not kept. Hence, the work required to get reasonably acceptable figures on such pumpage is disproportionate to their value.

Recharge of Ground water

The replenishment of ground water in an aquifer is known as recharge, and under natural conditions an aquifer may receive water from one or more of several sources. Recharge may be obtained from streams that introduce water from outside the catchment area of the aquifer, from percolation from another aquifer, and from infiltration of precipitation.

The Red River, Otter Creek, and the North Fork of the Red River bring water from outside the area. Measurements of stream flow in the area, made in November 1945 and in February and April 1953, show that the flow of Otter Creek and the Red River increases as these streams pass through the area (table 3). Therefore, they do not recharge the terrace deposits or the alluvium but instead drain water from them. The flow of the North Fork of the Red River is more difficult to analyze. In the first of three series of flow measurements, this stream showed a loss in flow in the first half of its course through the area, but a large increase in the last half. In the second series of measurements, the stream lost flow along its entire course, and in the third series it gained flow along its entire course. (See section on Movement of ground water.) In order to determine how much water the North Fork of the Red River is adding to or taking from the terrace deposits and alluvium, many series of flow measurements taken over a period of several years will be needed.

The terrace deposits and alluvium are underlain by Permian red beds whose low permeability prevents large-scale movement of water. Thus, movement of water in or out of the Permian red beds probably is negligible.

How much will be added to the zone of saturation by infiltration from precipitation depends on several factors, among which are: the permeability of the soil and of the sediments above the water table, the opportunities for the rain to leave the area by runoff or evapotranspiration before it can reach the water table, and the amount and distribution of rainfall.

The sandy soil of western Tillman County favors a high rate of infiltration, but test holes drilled in the area reveal the presence of considerable clay and caliche between the surface of the terrace deposits and the water table. The clay and caliche are believed to occur in discontinuous layers that will not prevent infiltration of precipitation to the zone of saturation except locally, but they will slow the rate of infiltration in some areas by making the route of infiltration indirect. Slowing the rate may increase opportunities for evaporation of the water that is en route to the zone of saturation, at least locally.

The northern one-fourth of the area is drained by Otter Creek, a perennial stream whose flow is maintained by seepage of ground water. Surface drainage tributary to Otter Creek is not well developed; so, precipitation that falls in the northern part of the area has a good chance to infiltrate to the ground-water zone. The southern three-fourths of the area is drained by five intermittent streams that flow only in response to precipitation. These streams remove precipitation by surface runoff before it has time to soak into the ground, but the amount carried out of the area is probably small except after very heavy rains.

Recharge to the ground-water zone as a result of infiltration of precipitation can be calculated by taking many measurements of water levels in several wells over a period of years and comparing the rises of water level with the precipitation. How much the ground-water level will rise depends on how much water is added to the reservoir. It also depends on how much space per unit of volume is available in the sediments to receive water. If 10 percent of the volume of the sediments can be filled with water, the addition of 1 inch of water should cause a rise of 10 inches in ground-water level. Conversely, a rise of 10 inches in ground-water level is equivalent to a layer of water 1 inch deep. This space factor is approximately the same as the coefficient of storage. Elsewhere in this report it has been shown that the coefficient of storage of the saturated terrace deposits of western Tillman County ranges rather widely, but in the zone of water-table fluctuation it probably averages about 10 percent.

Records of water-level fluctuations are too few and too short to be used for calculations of recharge, but a tentative estimate of the recharge received from precipitation can be made by comparing western Tillman County with an area for which such calculations of recharge have been made. A preliminary estimate of the recharge in an area of terrace deposits west of Enid, Garfield County, Okla., gives the recharge as 14.45 percent of the precipitation. The terrace deposits west of Enid are geologically similar to the deposits in western Tillman County, but there are some significant differences. The soil is not as sandy and probably is not as permeable in western Tillman County as it is west of Enid, because of the predominance of sand dunes in the latter area. Thus surface drainage is more highly developed, and consequently more precipitation is removed by surface flow in western Tillman County than in the area west of Enid. Therefore, the percentage of the precipitation that becomes recharge in western Tillman County is probably less than it is west of Enid. Obviously, the exact difference between the rates of recharge in the two areas is not known, but in order to arrive at a tentative estimate of the recharge for western Tillman County it is assumed that the rate is about a fifth less than it is in the area west of Enid.

On this basis, the recharge in western Tillman County would be about 11.5 percent of the precipitation. At Frederick the normal annual precipitation is 27.37 inches, and 11.5 percent of this would be 3.15 inches, or somewhat more than 0.25 foot. This estimate lacks precision and is strictly a preliminary figure subject to revision as more data become available to permit refinement, but it is enough to show that the recharge received on an average acre is far less than the quantity of water needed to irrigate that acre. Just as clearly, the replenishment is not enough to permit irrigation of the entire area. Full-scale irrigation inevitably would require pumping from reserve storage and would lead to declining water levels and ultimate exhaustion of the reservoir.

Chemical Character of Ground Water

All natural waters contain mineral matter dissolved from the rocks and soils with which they have come in contact. The quantity of dissolved mineral matter in the water depends primarily on the type of rock or soil through which the water has passed, the length of time of contact, and pressure and temperature conditions. In addition to these natural factors are others connected with human activities, such as use of streams and wells for disposal of sewage and industrial waste, and diversion and use of water for many purposes.

The mineral constituents and physical properties of ground water reported in the analyses of table 4 are those having a practical bearing on the value of the waters for most purposes: silica, iron, calcium, magnesium, sodium, potassium (or sodium and potassium reported together as sodium), carbonate, bicarbonate, sulfate, chloride, fluoride, nitrate, dissolved solids, hardness, pH, specific conductance, and temperature.

Chemical analyses of water from 17 wells in western Tillman County are listed in table 4. The wells chosen for sampling are distributed widely (fig. [illegible]) and the analyses therefore represent very nearly the full range in quality that may be expected.

The following discussion of the chemical constituents of ground water has been summarized from several papers prepared by the Quality of Water Branch of the U. S. Geological Survey.

Dissolved Solids

The figures given under "dissolved solids" show approximately the total quantity of dissolved mineral matter as determined by evaporating a measured quantity of clear water and weighing the residue after it has been dried at 180°C. for 1 hour.

Table 4.--Chemical Analysis of Water in Parts Per Million from Wells in Western Tillman County, Oklahoma.

Aquifer: A, Alluvium; T, terrace deposits.

Well No.	Total depth (feet)	Aquifer	Date col-lected	Temper-ature (°F)	Parts Per Million													Hardness as $CaCO_3$		Per-cent sodium	Specific conductance (micromhos at 25°C)
					Silica (SiO_2)	Iron (Fe)	Cal-cium (Ca)	Mag-nesium (Mg)	Sodium (Na)	Potas-sium (K)	Carbo-nate (CO_3)	Bicar-bonate (HCO_3)	Sul-fate (SO_4)	Chlo-ride (Cl)	Fluor-ide (F)	Ni-trate (NO_3)	Dis-solved solids	Total	Non-carbonate		
T. 1N., R. 18W.																					
1N18W- 2-2	40	A	6-4-53	67	15	0.0	62	26	112	1.9	--	355	84	70	0.3	38	584	260	0	48	969
T. 1S., R. 18W.																					
1S18W-27-3	52	T	1-30-52	62	--	--	81	15	51		--	324	35	44	--	13	430	264	0	30	722
33-1	47	T	1-28-52	56	--	--	84	19	104		--	336	78	104	--	12	594	288	12	44	1,000
33-5	50	T	10-31-52	65	13	.0	81	19	116	3.8	--	368	68	88	.9	34	600	280	0	47	1,010
T. 1S., R. 19W.																					
1S19W- 2-1	58	T	4-1-46	65	16	.06	80	33	158	10	--	422	93	173	.6	3	788	335	--	--	1,340
10-2	45	T	1-29-52	--	--	--	39	34	80		--	346	39	36	--	46	454	238	0	42	768
12-2	55	T	10-29-52	64	14	.0	59	27	136	1.1	--	422	78	69	1.1	32	612	258	0	53	1,030
21-2	35	T	1-29-52	65	--	--	53	39	375		--	646	187	270	--	3	1,260	292	0	74	2,120
21-2	35	T	11-14-52	67	10	0.0	52	36	364	4.1	--	659	180	240	1.8	1.7	1,220	278	0	74	2,010
25	54	T	11-17-44	65	16	.02	81	32	160	18	--	367	128	182	.5	16	822	334	--	--	1,480
30	--	A	6-5-53	65	13	.0	162	29	166	5.5	--	277	352	222	.1	1.2	1,100	525	298	40	1,690
T. 2S., R. 18W.																					
2S18W-15-13	60	T	1-29-52	65	28	.0	61	15	111	4.6	--	347	52	69	.5	23	536	214	0	52	873
T. 2S., R. 19W																					
2S19W-21	10	A	6-5-53	69	10	.0	51	69	202	2	--	430	179	202	1.3	40	967	410	58	52	1,630
T. 3S., R. 18W.																					
3S18W-19-2	24	T	1-30-52	65	--	--	182	178	673		--	426	680	1,120	--	17	3,200	1,190	837	55	4,790
T. 3S., R. 19W.																					
3S19W-2-1	60	T	1-25-52	67	--	--	86	36	**101**		--	331	91	128	--	43	689	362	92	38	1,150
2-1	60	T	11-6-52	67	16	0.0	199	80	283	3.5	--	328	93	710	0.7	51	1,860	826	556	43	2,910
T. 4S., R. 18W.																					
4S18W-3	69	T	1-30-52	--	20	.02	68	40	56	1.9	--	350	59	48	.7	50	515	334	47	27	839
6	68	T	11-19-52	66	14	.36	49	32	59	1.3	--	316	38	24	.7	64	423	255	0	33	708
9	23	A	6-5-53	70	24	.0	95	23	14	70	--	387	42	24	.0	66	568	330	13	7	888

Hardness

Hardness is the characteristic of water that receives the most attention with reference to industrial and domestic use. Hardness is the calcium carbonate ($CaCO_3$) equivalent of calcium and magnesium, and of all other individually determined cations having soap-consuming and encrusting properties. Hard water is objectionable because it forms a lather with difficulty, and it causes a scale in boilers, water heaters, radiators, and pipes, thereby decreasing the rate of heat transfer and creating the possibility of boiler failure and loss of flow. Hardness is caused almost entirely by compounds of calcium and magnesium. Other constituents such as iron, manganese, aluminum, barium, strontium, and free acid also cause hardness, but they are not usually found in appreciable quantities in most natural waters.

Water having a hardness of less than about 50 parts per million is generally rated as soft, and does not require softening except for special use. Hardness of 50 to 150 parts per million does not seriously interfere with the use of water for most purposes, but it slightly increases the consumption of soap. Therefore, its removal, by a softening process, is profitable for laundries or other industries using large quantities of soap. Water having a hardness in the upper part of this range will cause considerable scale in steam boilers. Hardness above 150 parts per million is easily detectable, and in areas where it is above 300 parts per million it is common practice to soften water for household use or to install cisterns for storing soft rain water. Where municipal supplies are softened an attempt is generally made to reduce the hardness to less than 100 ppm.

Water from the wells of this area is generally very hard. The hardness ranges from 214 to 1,190 ppm in water from the terrace deposits and 260 to 525 ppm in water from the alluvium.

Iron

Iron is present in most ground water, but generally only in comparatively small amounts in this area. Water containing more than a few tenths of a part per million iron is objectionable because of its reddish appearance after exposure to the air and because the iron stains clothing and fixtures. Such water, therefore, may require treatment. Excessive iron may interfere with the efficient operation of exchange-silicate water softeners. Of the 13 analyses for iron, the only one that indicates an objectionable concentration is the analysis of water from well 4S18W-6, which had an iron content of 0.36 ppm. This is only slightly above the limit of 0.3 ppm recommended by the U. S. Public Health Service (1946, p. 382-83).

Sodium and Potassium

Moderate quantities of sodium and potassium have little effect on the suitability of water for most industrial or domestic uses. More than 50 ppm of the two may cause foaming in steam boilers. Generally, if the equivalents per million of sodium exceed the sum of the equivalents per million of calcium and magnesium in water used for irrigation, there is some danger of damage to the soil. The sodium and potassium content ranges from 51 to 673 ppm in water from the terrace deposits and from 84 to 204 ppm in water from the alluvium.

Carbonate and Bicarbonate

Carbonate and bicarbonate affect the usability of water mainly when present with certain other constituents. Bicarbonate is the principal dissolved constituent in most natural water, especially that from limestone aquifers. A high concentration of sodium bicarbonate will cause foaming in boilers and may be objectionable in water for irrigation.

Sulfate

Sulfate may be dissolved in water passing through gypsum. It also may be formed by the oxidation of the sulfides of lead, zinc, and iron. When combined with calcium and magnesium, sulfate contributes to noncarbonate hardness, and hence to boiler scale and to equipment-maintenance costs as well as to the cost of softening water. Two samples of water from the terrace deposits contained more than 250 ppm of sulfate, the suggested upper limit for sulfate in drinking water (U. S. Public Health Service, 1946).

Chloride

Chloride combined with sodium is common salt, and both generally are present in ground water. Chloride in small amounts has little effect on the usefulness of water, but in concentrations of several hundred parts per million it gives water a salty taste, and therefore is undesirable for domestic use. Heavy concentrations of chloride may impart corrosiveness to water, requiring frequent replacement of water pipe or measures to prevent corrosion, such as the lining of pipe with a noncorroding material. Three analyses of water from the terrace deposits show a chloride content greater than 250 ppm, the suggested upper limit of chloride in water used for drinking.

Fluoride

The principal effect of fluoride in water is on the dental health of children, and it is beneficial or detrimental according to the concentration. In concentrations up to about 1.0 part per million, fluoride is believed by many health authorities to lessen teeth decay, but in higher concentrations it may contribute to a permanent dental defect known as mottled enamel (Dean, 1936), which appears in teeth in the formative stage--that is, in the teeth of children up to about 12 years of age.

Determinations of fluoride were made in 13 analyses given in table 4. Only one sample contained more than the limit of 1.5 ppm recommended by the U. S. Public Health Service (1946, p. 382-83); that sample contained 1.8 ppm.

Nitrate

Nitrate in water is considered a final oxidation product of nitrogenous material and, in some instances, may indicate previous contamination by sewage or other organic matter. It has been reported that as little as 2 ppm of nitrate in boiler water tends to decrease intercrystalline cracking of boiler steel.

Water containing an excessive amount of nitrate has been suspected of causing a form of cyanosis ("blue baby") when used in preparation of formulas for feeding infants (Waring, 1949, p. 147). The Oklahoma State Health Department now considers water containing less than 10 ppm nitrate (asN; approximately 45 ppm when reported as NO_3) as safe for use.

Of the analyses in table 4, four of water from the terrace deposits and one of water from the alluvium show a nitrate content of more than 45 ppm.

Hydrogen-ion Concentration (pH)

The degree of acidity or alkalinity of water is determined by the hydrogen-ion concentration and is expressed as the pH. A pH of 7.0 indicates that the water is neutral, being neither acid or alkaline. Figures below 7.0 indicate acidity whereas those above 7.0 indicate alkalinity. The pH of 15 samples of water from wells tapping the terrace deposits ranged from 7.2 to 8.0, and the pH of 4 samples from wells in the alluvium ranged from 7.6 to 7.9.

Suitability for Drinking

Standards by which to judge the suitability of water for drinking have been established by the U. S. Public Health Service (1946, p. 382-83). They indicate the maximum concentration of certain constituents, in parts per million, that is acceptable for drinking and culinary water used on interstate carriers, and they have been adopted by most of the State health departments. Among the constituents included in table 4, six are considered significant and the maximum limits for them are given below.

Constituent	Parts per million
Magnesium (Mg)	125
Chloride (Cl)	250
Sulfate (SO_4)	250
Fluoride (F)	1.5
Dissolved solids	500 (1,000 acceptable)
Iron and manganese together	0.3

The water from all but five wells is shown to be within limits of the above suggested standards. (See table 4.) Of the five waters not meeting the above standards, four were from wells tapping the terrace deposits and one was from a well tapping the alluvium.

Suitability for Irrigation

Whether a water is satisfactory for irrigation depends on several factors in addition to the mineral content of the water, among them the amount of water applied to the soil, the precipitation, the drainage, and the physical and chemical characteristics of the soil. This subject is discussed by Smith (1942, pp. 16-18). The total amount of dissolved mineral matter and the percentage of sodium are the principal factors in evaluating the analysis of water for irrigation.

The percentage of sodium is explained by Wilcox (1948, p. 4) as follows: "To find the percentage of sodium of a water, the results of the analysis must be reported in equivalents per million. The quantity of sodium is then divided by the sum of the quantities of calcium, magnesium, sodium, and potassium, and the results expressed as a percentage. To know this is important, because waters of high sodium percentage so react with the soil that it becomes difficult to till and is hard when dry, sticky when wet, and 'takes water' very slowly." Figure 5 (adapted from empirical diagram of Wilcox, 1948) affords a graphical method of appraising the water from the terrace deposits and alluvium of western Tillman County. If plotted on this figure all but two analyses fall in the suitable area. One analysis falls in the "unsuitable" area, and one falls in the "doubtful to unsuitable" area. Both analyses represent water from wells in the terrace deposits.

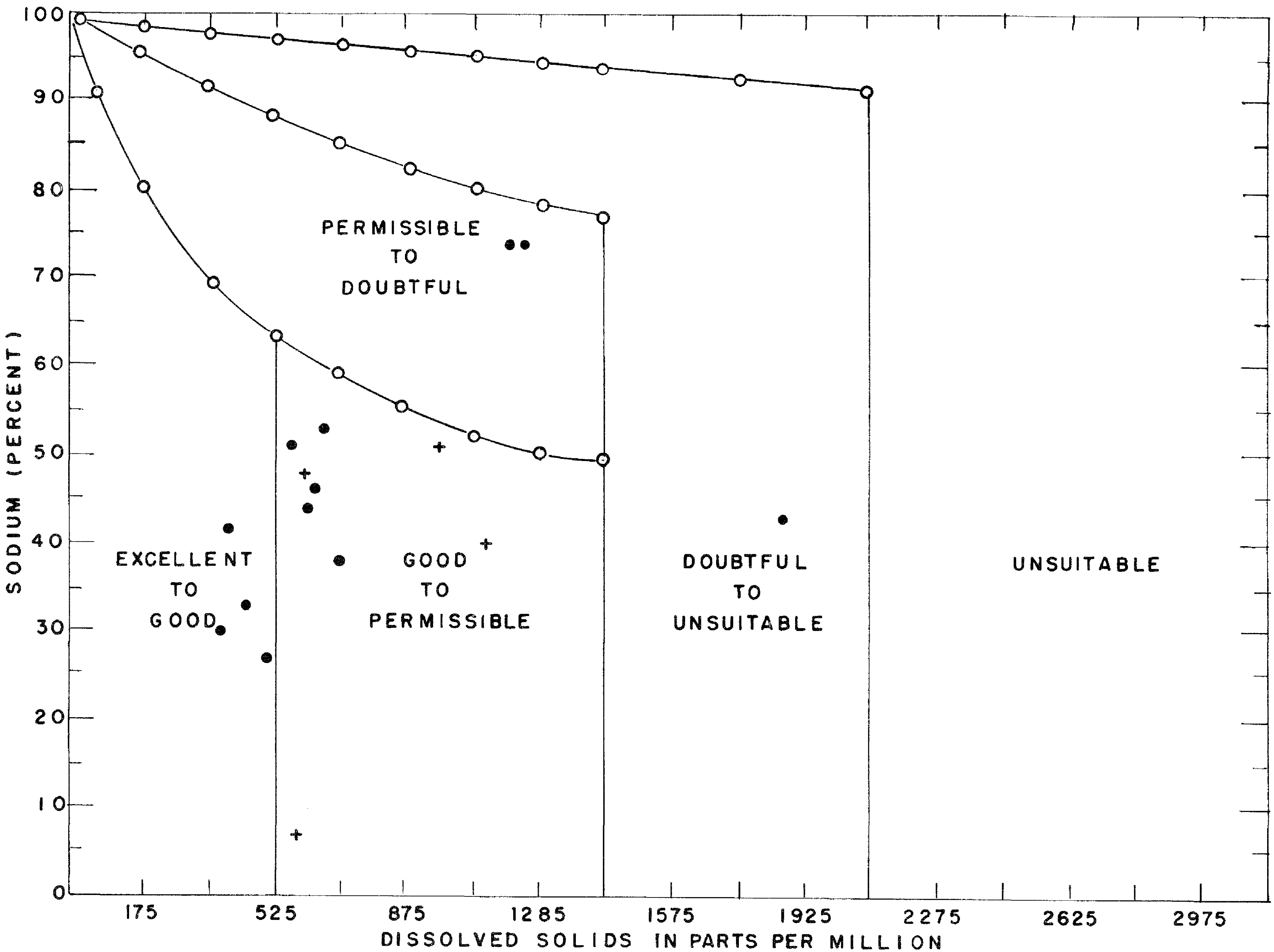

Figure 5.--Diagram for interpreting analyses of irrigation water (after Wilcox, L.V., 1948; modifications by T.B. Dover, United States Geological Survey) Dots represent analyses of ground water from terrace deposits, and crosses represent analyses of ground water from alluvium of western Tillman County, Oklahoma.

The importance of adequate soil drainage was pointed out by Magistad and Christiansen (1944), who stated: "Soil salinity may be handled by the farmer on an account basis. Salt in the irrigation water is sometimes added at rates as high as 2 tons to 1 acre-foot. It is removed primarily by the drainage water. If the additions exceed the losses, salt is accumulating in the soil. The losses are difficult to measure, but in a few small areas with tile drains this has been done. In general, the conception of a salt balance is beneficial because it so clearly demonstrates the need for drainage. The place of some particular salts or ions in such a balance sheet has not been determined. For instance, a considerable proportion of the calcium entering a soil in the irrigation water may precipitate as calcium carbonate, which is almost inert so far as salinity is concerned. Some calcium and sulfate is precipitated as calcium sulfate, which is only partly soluble. Actually, a salt that is precipitated is removed almost as effectively as though it disappeared with the drainage water."

Utilization of Ground Water

Except for the water used by five irrigators who pump from Otter Creek, all the water used in the area for domestic, irrigation, industrial, and municipal supplies is ground water. Most of the water used for livestock is ground water, but some is taken from Otter Creek and from ponds.

In the 285 square miles considered in this report, 856 wells were counted. Of these, 82 are irrigation wells and 28 are public-supply wells. The remainder were drilled as domestic or stock wells, some of which are not being used. Appendix A summarizes the data for selected wells, test holes, and shot holes. The following paragraphs contain brief discussions of the construction and use of the irrigation and public-supply wells in the area.

Public-Supply Wells

The municipalities of Frederick, Tipton, Manitou, and Davidson draw ground water from the terrace deposits within the area of this investigation; also, two rural schools have wells that are listed as public-supply wells in appendix A. The municipal wells are described below.

Frederick

Frederick has four wells in the S½ sec. 3, T. 2 S., R. 18 W. that range in depth from 42 to 54 feet. The wells are gravel walled and have steel casing and Transite screens. The city also has 14 wells in the S½ sec. 15, T. 2 S., R. 18 W. that range in depth from 48 to 61 feet; they are gravel walled and have steel casing and screens. Each pump is so operated as to yield 80 gpm. From this pumping rate and other information furnished by the city water superintendent, it is estimated that 252,600,000 gallons of water was pumped in 1952.

Tipton

Tipton has two wells in the NW¼NE¼ sec. 2, T. 1 S., R. 19 W. The wells are 58 and 52 feet deep, have steel casings 10 inches in diameter, and are gravel walled. They are pumped at the rate of 300 gpm and in 1952 they supplied about 97,800,000 gallons of water.

Manitou

Manitou obtained approximately 37,000,000 gallons of water in 1952 from five wells in the NE¼NW¼ sec. 6, T. 1 S., R. 17 W. Two wells are 18 feet deep, one is 21 feet deep, and the depths of the other two are not known. The wells all have galvanized-iron casing 12 inches in diameter and are gravel walled.

Davidson

Davidson has one well in the NW¼NW¼ sec. 3, T. 4 S., R. 18 W. The well is 67 feet deep, is gravel walled, and has 18-inch steel casing. It is pumped at rates ranging from 350 to 400 gpm, and in 1952 it supplied about 1,240,000 gallons of water.

Irrigation Wells

By 1952 irrigation with water pumped from wells had been under way for several years. An inventory of water wells, begun in December 1952 and finished in March 1953, revealed a total of 82 irrigation wells in the area of this report. All these wells obtain water from the terrace deposits except seven that get water from the alluvium.

Most of the wells have steel, aluminum, or galvanized-iron casing, are gravel packed, and are equipped with turbine pumps powered by gasoline- or butane-burning engines or by tractors. A few pumps are operated by electric motors and many others are being adapted for this type of power. The maximum yield of individual wells ranges from 100 to 900 gpm, but most of them yield from 300 to 500 gpm. Details for each well will be found in appendix A. Estimates of pumpage, obtained from well owners, show that 24 wells pumped a total of about 583,807,000 gallons or 1,790 acre-feet of water during 1952, to irrigate about 1,100 acres.

In this area the uneven distribution of precipitation during the year may mean an excess of moisture early in the growing season followed by a deficiency. Irrigation, therefore, may mean the difference between success and failure, or between a bumper crop and a mediocre one. This was clearly demonstrated in 1952, when the severe drought from June through October caused almost complete failure to the cotton crop in areas of Tillman County where irrigation was not practiced. In the irrigated areas the cotton crop was about average.

Test Drilling

Information on the thickness and lithology of the terrace deposits is afforded by 45 test holes drilled for the towns of Frederick and Tipton, 72 test holes drilled under contract for this investigation, and 1 test hole drilled at the site of each of 6 aquifer tests. Logs of the 123 test holes are given in appendix B.

Test Holes for Frederick

In November 1947 the city of Frederick had 19 test holes drilled by the Layne-Western Co. of Wichita, Kans. In May 1948 the same company drilled 7 test holes, and in July it drilled 14 more. The area tested is 2 to 4 miles northwest of Frederick in secs. 27, 28, 33, and 34 T. 1 S., R. 18 W.; and secs. 3 and 4, T. 2 S., R. 18 W. The test holes penetrated terrace deposits that ranged in thickness from

39 to 60 feet and averaged 51.5 feet. Water-level measurements made in 35 of the test holes showed a maximum of 39 feet of saturated materials and an average of 29 feet. Of the total of 1,019 feet of water-bearing sediments penetrated, 195 feet (19 percent) was described as gravel or coarse sand.

Test Holes for Tipton

In May 1945 E. R. Kelley, of Oklahoma City, Okla., jetted five test holes into the terrace deposits for the town of Tipton. The terrace deposits were 43 and 51 feet thick in the two test holes that penetrated them completely. Gravel and sand in the five test holes ranged in thickness from 3 to 25 feet and averaged 15 feet.

Test Holes for This Investigation

Test drilling for this investigation was done in two parts under contracts let by the Oklahoma Planning and Resources Board. In July 1951, 55 test holes were drilled by C. R. Frazier, of Oklahoma City, and in April 1953, 17 additional test holes were drilled by T. J. Jennings, Jr., of Tipton, Okla. The test sites were those for which logs from other sources were not available. Rotary-hydraulic drilling machines, mounted on trucks and employing 3-inch steel bits, were used to drill all the test holes. The first 55 test holes were spaced about 2 miles apart, and all holes were drilled deep enough to make sure that the underlying bedrock actually was reached and that all the terrace deposits were penetrated. The test holes ranged from 20 to 70 feet in depth and averaged 41 feet. Drill cuttings were collected by hand from the shallow ditch between test hole and slush pit. Logs were written on the spot and then were revised after microscopic examination of the cuttings. The logs of these test holes, given in appendix B, therefore, are composites of field and laboratory observation.

About 57 percent of the terrace deposits and alluvium are in the zone of saturation. This means that, on the average, the saturated part of the sediments is about 23 feet thick. Within the zone of saturation about 40 percent of the materials appear to be highly permeable, 50 percent moderately permeable, and about 10 percent relatively impermeable.

Aquifer Tests

The amount of water a well will yield depends on the hydraulic properties of the aquifer. The coefficient of transmissibility is defined as the rate of flow of water in gallons per day through a vertical strip of the aquifer 1 foot wide and extending the full saturated height, under a hydraulic gradient of 100 percent at the prevailing temperature of the ground water; and the coefficient of storage is the volume of water, expressed as a fraction of a cubic foot, yielded from storage in each vertical column of the aquifer and associated beds having a base 1 foot square as the water level drops 1 foot (Weirzel, 1942, p. 87). These coefficients can be determined directly from aquifer tests.

This report gives results of tests made on the Jennings, Dotson, Banker, Hudson, Roberts, Young, and Southwestern Cotton Substation irrigation wells and on one of the public-supply wells of Frederick. All but the test on the Frederick well were made by personnel of the U. S. Geological Survey and the Oklahoma Planning and Resources Board. The test on the well at the Cotton Substation was made in 1944, the one on the Frederick well was made in 1948, and the rest were made in 1952 as part of the investigation described in this report.

The procedure for all tests was essentially the same: a well was pumped from 12 to $24\frac{1}{2}$ hours at as nearly a constant rate as possible, the drawdown and recovery of water level in it was measured so far as possible, and the quantity of water discharged by the pump was recorded. At the same time, measurements of the drawdown and recovery of water level were made in six nearby observation wells penetrating the same aquifer. All the wells that were pumped penetrate all the terrace deposits and reach the underlying bedrock, and all but the Roberts well are gravel walled. The observation wells were spaced at uneven intervals out to a maximum of 200 feet from the pumped well. All tests were analyzed by methods in general use by the U. S. Geological Survey.

T. J. Jennings Well 1S19W-12-2

On October 28-30, 1952, an aquifer test was made on the T. J. Jennings well (1S19W-12-2), which was 55 feet deep and had 14-inch aluminum casing that was perforated opposite the water-bearing sand and gravel. The well was equipped with a turbine pump powered by a gasoline engine, and the pump discharged water into an irrigation ditch leading east from the well. This ditch carried water 120 feet east, then south for about 150 to 300 feet where the water flowed westward onto a field. The discharge was measured by means of a 90-degree triangular-notch weir installed in the irrigation ditch 50 feet east of the pumped well. For the $24\frac{1}{2}$ hours that the well was pumped the discharge averaged 200 gpm. To detect possible changes in the chemical character of the water, a total of 11 samples of water were collected in 8-ounce bottles at intervals throughout the pumping. These were tested in the laboratory for specific conductance, calcium, magnesium, sodium, chloride, hardness, and percent sodium. Just before the pump was stopped, a 1-gallon sample of water was collected, which later was analyzed for all the items listed in table 4.

For observation of ground-water levels in the vicinity of the pumped well, six wells consisting of $1\frac{1}{4}$-, $1\frac{1}{2}$-, and 2-inch iron pipe with well points 24 inches long were provided. These were in a straight line passing east and west through the pumped well, with three on each side at distances of 50, 100, and 200 feet from the pumped well. The observation wells ranged from 54 to 56 feet in depth and were drilled through the terrace deposits and seated on the underlying bedrock. Drawdown and recovery measurements could not be made in the pumped well.

W. A. Dotson Well 1S18W-33-5

On October 30 and 31, 1952, an aquifer test was made on the W. A. Dotson well (1S18W-33-5), which was 47 feet deep and had 14-inch steel casing that was perforated opposite the water-bearing sand and gravel. The well was equipped with a turbine pump powered by a tractor engine, and the pump discharged water into an irrigation ditch leading east from the well. This ditch was dammed about 30 feet east of the well and it was tapped at about 10 feet east of the well by another ditch that carried the water to the south for about 400 feet, where it overflowed onto a field. The discharge was measured at regular intervals by means of a 90-degree triangular-notch weir installed in the irrigation ditch 60 feet south of the pumped well. For the 23 hours that the well was pumped the discharge averaged 190 gpm. To detect possible changes in the chemical character of the water, a total of 10 samples of water were collected in 8-ounce bottles at intervals throughout the pumping. These were tested in the laboratory for specific conductance, calcium, magnesium, sodium, percent sodium, hardness, and chloride. Just before the pump was stopped, a 1-gallon sample of water was collected, which later was analyzed for all the items listed in table 4.

For observation of ground-water levels in the vicinity of the pumped well, six wells consisting of $1\frac{1}{4}$-, $1\frac{1}{2}$-, and 2-inch iron pipe with well points 24 inches long were provided. These were in a straight line passing a little north of east through the pumped well, with three on each side at distances of 50,100, and 200 feet from the pumped well. The observation wells ranged from $42\frac{1}{2}$ to 48 feet in depth and were drilled through the terrace deposits and seated on the underlying bedrock. The specific capacity of the pumped well was about 12 gpm per foot of drawdown.

J. A. Banker Well 3S19W-2-1

On November 5 and 6, 1952 an aquifer test was made on the J. A. Banker well (3S19W-2-1), which was 60 feet deep and had 14-inch steel casing. The well was equipped with a turbine pump powered by a tractor engine, and the water was pumped through aluminum irrigation pipe to the drainage ditch along the road, about 500 feet north of the well. The discharge was measured during the first part of the test my means of a 90-degree, triangular-notch weir that was installed in the drainage ditch about 10 feet west of the end of the aluminum pipe. The weir could not be kept in position, however, so the discharge during the remainder of the test was estimated from measurements of the freeboard in the discharge pipe. For the $18\frac{1}{2}$ hours that the well was pumped, the discharge averaged 200 gpm. To detect possible changes in the chemical character of the water, a total of 26 samples of water were collected in 8-ounce bottles at intervals throughout the pumping. These were tested in the laboratory for specific conductance, calcium, magnesium, sodium, chloride, hardness, and percent sodium. Just before the pump was stopped, a 1-gallon sample of water was collected, which later was analyzed for all the items listed in table 4.

For observation of ground-water levels in the vicinity of the pumped well, six wells consisting of $1\frac{1}{4}$-, $1\frac{1}{2}$-, and 2-inch iron pipe with well points 24 inches long were provided. These were in a straight line passing east and west through the pumped well, with three on each side at distances of 50,100, and 200 feet from the pumped well. The observation wells ranged from 55 to 59 feet in depth. Drawdown measurements could not be made in the pumped well.

W. B. Hudson Well 4S18W-6-2

On November 11 and 12, 1952, an aquifer test was made on the W. B. Hudson well (4S18W-6-2), which was 68 feet deep and had 16-inch steel casing that was perforated opposite the water-bearing sand and gravel. The well was equipped with a turbine pump powered by a butane-burning engine, and the pump discharged water into an irrigation ditch that carried the water half a mile north and then a quarter of a mile east to the drainage ditch along the road. The discharge was measured in the first part of the test by means of a 90-degree triangular-notch weir that was installed in the irrigation ditch 250 feet north of the pumped well, and a measurement of the freeboard in the discharge pipe was made at the same time. The weir could not be kept in position, however, so the discharge during the remainder of the test was estimated by measuring the freeboard in the discharge pipe. The pumping rate did not vary noticeably during the test. For the 12 hours that the well was pumped, the discharge rate was 215 gpm. To detect possible changes in the chemical character of the water, a total of 7 samples of water were collected in 8-ounce bottles at intervals throughout the pumping. These were tested in the laboratory for specific conductance, calcium, magnesium, sodium, chloride, hardness, and percent sodium. A 1-gallon sample of water was collected a few days after the aquifer test, and it was analyzed for all the items listed in table 4.

For observation of ground-water levels in the vicinity of the pumped well, six wells consisting of $1\frac{1}{4}$-, $1\frac{1}{2}$-, and 2-inch iron pipe with well points 24 inches long were provided. These were in a straight line passing north and south through the pumped well, with three on each side at distances of 50, 100, and 200 feet from the pumped well. The observation wells ranged from 54 to 76 feet in depth. Drawdown measurements could not be made in the pumped well.

Oran Roberts Well 1S19W-21-2

On November 13 and 14, 1952, an aquifer test was made on the Oran Roberts well (1S19W-21-2), which was 35.5 feet deep and had 14-inch steel casing. The well was equipped with a turbine pump powered by a gasoline engine, and the pump discharged water through a canvas tube to an irrigation ditch 250 feet east of the well. This ditch carried the water 80 feet farther east and then diverted the water southward onto a field. The discharge was measured at regular intervals by means of a 90-degree, triangular-notch weir installed in the irrigation ditch about 50 feet from the end of the canvas tube. For the 18 hours that the well was pumped, the discharge averaged 285 gpm. To detect possible changes in the chemical character of the water, a total of 18 samples of water were collected in 8-ounce bottles at intervals throughout the pumping. These were tested in the laboratory for specific conductance, calcium magnesium, sodium, chloride, hardness, and percent sodium. About 6 hours after the pump was stopped, a 1-gallon sample of water was collected, which later was analyzed for all the items listed in table 4.

For observation of ground-water levels in the vicinity of the pumped well, six wells consisting of $1\frac{1}{4}$-, $1\frac{1}{2}$-, and 2-inch iron pipe with well points 24 inches long were provided. These were in a straight line passing east and west through the pumped well, with three on each side at distances of 50, 100, and 200 feet from the pumped well. The observation wells ranged from 54 to 56 feet in depth and were drilled through the terrace deposits and seated on the underlying bedrock. The capacity of the pumped well was about 20 gpm per foot of drawdown.

Anna Young Well 1N19W-25-1

On November 18 and 19, 1952, an aquifer test was made on the Anna Young well (1N19W-25-1), which was 54 feet deep and had 14-inch galvanized iron casing. The well was equipped with a turbine pump powered by a tractor engine, and the pump discharged water through a section of aluminum pipe to an irrigation ditch 30 feet south of the well. This ditch carried the water southward for about 300 feet where it overflowed onto a field. The discharge was measured at regular intervals by means of a 90-degree triangular-notch weir installed in the irrigation ditch 50 feet from the end of the aluminum pipe. For the $21\frac{1}{2}$ hours that the well was pumped, the discharge averaged 130 gpm. To detect possible changes in the chemical character of the water, a total of 14 samples of water were collected in 8-ounce bottles at intervals throughout the pumping. These were tested in the laboratory for specific conductance, calcium, magnesium, sodium, chloride, hardness, and percent sodium.

For observation of ground-water levels in the vicinity of the pumped well, six wells consisting of $1\frac{1}{4}$-, $1\frac{1}{2}$-, and 2-inch iron pipe with well points 24 inches long were provided. These were in a straight line passing east and west through the pumped well, with three on each side at distances of 50, 100, and 200 feet from the pumped well. The observation wells ranged from 52 to 54 feet in depth and were drilled through the terrace deposits and seated on the underlying bedrock. Drawdown measurements could not be made in the pumped well.

Southwestern Cotton Substation Well 1S19W-25

On November 16-18, 1944, an aquifer test was made on the Southwestern Cotton Substation Well (1S19W-25), which was 54 feet deep and had 20-inch casing at the surface and 18-inch casing near the bottom. The casing was perforated opposite the water-bearing sand. The well was equipped with a turbine pump powered by an electric motor and the pump discharged water into a drainage ditch. The discharge was measured by noting the time necessary for a given volume of water to be discharged into a rectangular concrete tank. For the 24 hours the well was pumped, the discharge averaged 188 gpm. To detect possible changes in the character of the water, a total of 30 samples of water were collected in 8-ounce bottles at intervals throughout the pumping. These were tested in the laboratory for chloride. Before the pump was stopped, a 1-gallon sample of water was collected, which later was analyzed for the items listed in table 4.

For observation of ground-water levels in the vicinity of the pumped well, six wells consisting of 1½-inch iron pipe with well points 30 inches long were provided. These were in an almost straight line passing east and west through the pumped well, with three on each side at distances of 10, 20, and 40 feet from the pumped well. All the observation wells, except one, were more than 30 feet deep. The specific capacity of the pumped well was about 15 gpm per foot of drawdown.

City of Frederick Well 2S18W-3-27

On June 11, 12, 13, and 14, 1948, an aquifer test was conducted on the city of Frederick well (2S18W-3-27) by the Layne-Western Co. The well was 57 feet deep and had a gravel envelope 34 inches in outside diameter surrounding an 18-inch steel casing that had 13 feet of Transite screen at the bottom. This well was pumped for about 79 hours at a rate of 210 gpm.

For observation of ground-water levels in the vicinity of the pumped well, three wells were drilled at distances of 100, 200, and 300 feet east of the pumped well. The specific capacity of the pumped well was about 9 gpm per foot of drawdown.

Interpretation of Aquifer Tests

The drawdowns measured in the observation wells were analyzed by the Theis nonequilibrium method (Wenzel, 1942, p. 87-89) and by the generalized graphical method of Cooper and Jacob (1946, p. 527, 528). Coefficients of transmissibility and storage were determined for each test and are summarized in table 5.

Table 5 shows that both coefficients differ considerably from well to well. The coefficients of transmissibility range from 8,200 to 67,000 gpd/ft. and average 37,500 gpd/ft. The coefficients of storage range from 0.010 to 0.087 and average 0.036. Such large differences are to be expected in an aquifer having large differences in thickness and lithology. Clearly the coefficients based on these tests should be used with due regard for their applicability if improper design of wells is to be avoided. In localities where many wells tap the terrace deposits or alluvium, aquifer tests in each well could lead to average values for the coefficients of transmissibility and storage. These in turn would permit selection of the most favorable pumping rates.

Table 5. Summary of results of aquifer tests

Well no.		Coefficient transmissibility (gpd/ft.)	Coefficient of storage
1N19W-25-1	Mrs. Anna Young	14,600	.033
1S18W-33-5	W. A. Dotson	35,000	.040
1S19W-12-2	T. G. Jennings	8,200	.010
1S19W-21-2	Oran Roberts	50,200	.063
1S19W-25	Southwestern Cotton Substation	58,000	.010
2S18W-3-27	City of Frederick	22,000	.087
3S18W-2-1	J. A. Banker	45,000	.033
4S18W-6-2	W. B. Hudson	67,000	.020
	Average	37,500	.036

The wells used in the aquifer tests were in some of the more favorable locations. Some of the sites had been selected by test drilling. Other sites may have been selected without sub-surface information but they also proved favorable. Thus the average value for the coefficient of transmissibility as determined in the aquifer tests may be higher than the true average for the terrace deposits as a whole. If aquifer tests were made at sites uniformly distributed over the area--at intervals of 1 or 2 miles, as are the test holes--they undoubtedly would reveal values both higher and lower than those obtained in this investigation, but the average probably would be lower. For this reason, 20,000 gpd/ft has been adopted as a reasonably conservative average coefficient of transmissibility for use in computations applicable to the area as a whole. Computations based on it, therefore, presumably include a factor of safety.

The coefficients of storage given in table 5 are probably too low because pumping periods were short. Complete drainage of the initially saturated sediments within the cone of depression was not possible before pumping stopped and the recovery of water level began. Wenzel (1942, p. 135) states that the specific yield (i.e., coefficient of storage) as determined from a 24-hour aquifer test on an irrigation well near Gothenburg, Neb., was 16 percent of the specific yield determined in the laboratory tests of the same material, where drainage was complete.

The period of pumping in the test at the city of Frederick well (2S18W-3-27) was approximately 79 hours, and the coefficient of storage derived from this test should be more nearly right than any of the others. It was 0.087. Even this may be too low, for the only materials drained of their water by pumping were fine-grained sand and clay, which the log of the pumped well shows at and just below the water table. The 8.7 percent applies to these fine-grained materials, not to the coarse sands and gravels that yielded most of the water pumped during the test. It is concluded, therefore, that a figure of 10 percent may fairly represent the coefficient of storage in the upper part of the terrace deposits within the range of fluctuations of the water table and within the normal range of drawdowns in the rocks surrounding pumped wells, but that 15 percent may be a more reasonable figure for the entire thickness of water-bearing materials.

Water drains slower from fine-grained sand, silt, and clay than from coarse-grained sand and gravel. This must be considered when evaluating coefficients of storage obtained from aquifer tests. For example, table 5 shows the coefficient of storage for the Roberts well (1S19W-21-2) to be higher than that for the Dotson well (1S18W-33-5), even though the Dotson well was pumped 5 hours longer. Water drained from the sediments faster in the Roberts test because they were coarser than the sediments drained in the Dotson test. Coefficients of storage computed from the several tests are summarized in table 6. Also shown is the approximate lithology of the sediments drained at some of the observation wells, as determined by field identification of drill cuttings. When the coefficients of storage are evaluated in relation to the sediments drained and the length of time each well was pumped they show a reasonable relationship.

Expectable Yields

Because the water-bearing materials of the terrace deposits differ in texture and thickness from place to place, the yields from wells will differ considerably. The highest yield reported for the area is from J. W. Haynie's irrigation well (1S19W-28-4), which, according to a measurement made by the Southwest Rural Electric Assoc., Inc., was pumped at the rate of 910 gpm. This well is drilled into a buried valley, where the thickness of saturated materials is between 30 and 40 feet (pls. 2 and 5). In some localities yields of more than 500 gpm will not be unusual, but in much of the area of terrace deposits yields will be substantially less, perhaps 100 to 300 gpm.

The logs of test holes drilled north of Otter Creek indicate that the alluvium in that locality is favorable for the development of irrigation wells. No aquifer tests were made in that area, but it is reported that a few irrigation wells yield as much as 500 gpm. It is believed that additional wells could be expected to yield up to 500 gpm if favorably situated and appropriately designed and constructed.

Ground-Water Storage

Although ground water moves from areas of recharge to areas of discharge, the movement is very slow. Consequently, the water-bearing rocks may be regarded as a huge underground reservoir. The amount of water stored in them depends on their thickness and lateral extent and on their porosity. The porosity, however, is not an exact measure of how much water is available in the rocks, because molecular attraction holds some of the water tightly to the sand grains. This water may be regarded as permanently stored, because it will not drain out of the rocks when pumping or natural causes make the water table decline. This permanently stored water, therefore, is not included in the figures for coefficient of storage, which is a measure of the quantity of stored ground water that, theoretically, can be recovered by pumping from wells. On another page of this report it was estimated that 15 percent is a reasonable figure for the average coefficient of storage of the saturated part of the terrace deposits, and this figure is used in estimating the quantity of stored water.

Table 6. Relation of coefficient of storage (S) to pumping time and lithology of sediments drained.

Distance from pumped well	Sediments drained: Depth in feet below land surface (approximate)	Sediments drained: Lithology
	Roberts Well: S = .063; pumping time = 18 hours	
50 ft. east	9.3 - 11.5	Sand, medium to coarse; gravel, fine
100 ft. east	9.3 - 11.2	Sand, medium to coarse; gravel, fine
200 ft. east	9.0 - 10.0	Sand, medium, clayey
50 ft. west	9.8 - 12.8	Sand, medium to coarse; gravel, fine
100 ft. west	11.4 - 13.0	Sand, coarse; gravel, fine
200 ft. west	9.7 - 10.6	Sand, medium
	Dotson Well: S = .040; pumping time = 23 hours	
50 ft. east	24.4 - 26.2	Sand, coarse
100 ft. east	25.4 - 27.2	Sand, medium to coarse
50 ft. west	24.8 - 27.3	Clay, sandy
100 ft. west	25.8 - 28.0	Sand, coarse to medium; gravel, fine
200 ft. west	22.9 - 24.1	Clay
	Young Well: S = .033; pumping time = 21.5 hours	
100 ft. east	21.1 - 23.1	Sand, medium
200 ft. east	22.4 - 23.0	Sand, medium
50 ft. west	20.8 - 25.6	Sand, medium to coarse; clay lenses
	Banker Well: S = .033; pumping time = 18.5 hours	
50 ft. east	28.0 - 32.0	Sand, fine to medium, clayey
200 ft. east	27.7 - 29.0	Sand, fine
50 ft. west	22.0 - 30.3	Sand, medium; clay streaks
100 ft. west	26.0 - 28.5	Clay, sandy
	Hudson Well: S = .020; pumping time = 12 hours	
50 ft. north	28.7 - 34.8	Sand, fine to medium
100 ft. north	26.2 - 27.7	Sand, coarse; gravel, fine
200 ft. north	25.4 - 26.2	Sand, coarse
100 ft. south	32.7 - 35.6	Sand, medium to coarse
200 ft. south	33.2 - 34.2	Sand, fine to medium
	Jennings Well: S = .010; pumping time = 24.5 hours	
100 ft. east	23.7 - 33.4	Clay
200 ft. east	23.6 - 31.2	Clay, sandy
50 ft. west	23.5 - 36.3	Clay, sandy
100 ft. west	26.3 - 33.3	Clay, sandy
200 ft. west	22.2 - 27.2	Sand, medium

The average thickness of water-bearing material penetrated in the test holes is 23 feet, and the amount of ground water stored per acre equals 23 x 0.15 or 3.45 acre-feet. The total stored in the 285 square miles (182,400 acres) of terrace deposits and alluvium is about 630,000 acre-feet or about 205 billion gallons. It should be emphasized that these are average figures and that the amount stored per acre differs greatly from one acre to another because of differences in the thickness and coefficient of storage of the water-bearing material.

The quantity of water stored in the terrace deposits is not constant but will vary with fluctuations of the water table. Not all the stored water can be recovered by pumping from wells, but the large amount of water in storage is like a savings account, which may be drawn upon heavily in time of great need, to be replenished later. Thus, the pumpage in several drought years might greatly exceed the replenishment, but low irrigation pumpage plus high recharge in succeeding wet years would replace the reserve supply, so long as the average withdrawal did not exceed the average replenishment over a long period including both wet and dry years.

Effect of Pumping on the Water Table

When a well is pumped, the hydraulic head in the well is lowered, a hydraulic gradient is set up toward the well from all sides, and water flows into the well. The water table around the well assumes a shape somewhat like an inverted cone, and the depressed part is called the cone of depression.

As pumping continues, the cone of depression expands and water from greater and greater distances percolates toward the well. If no recharge occurs, the cone will continue to expand, at a decreasing rate, until the limits of the formation are reached, or until the water level in the well approaches the bottom of the formation. Recharge to the formation may halt the development of the cone of depression. If the rate of discharge is less than the ability of the aquifer to transmit water to the well, and if a well is pumped continuously at a constant rate, the cone of depression around the well will reach a state of "dynamic" equilibrium--that is, the cone then will expand during dry periods and shrink during periods of recharge.

The shape and size of the cone of depression around a well being pumped depend on the rate and duration of pumping, the hydraulic properties of the aquifer, the extent of the aquifer, and the amount of recharge. The lowering of the water table at any point within the cone of depression is directly proportional to the rate of pumping. That is, other conditions being the same, the drawdown at a certain distance from a well being pumped at 200 gpm will be twice the drawdown caused by a well being pumped at 100 gpm. Similarly, the drawdown at any point within the cone of depression will increase with further pumping, but at a decreasing rate, until a condition of approximate equilibrium is reached.

Assuming a constant pumping rate, the coefficient of transmissibility governs the depth of the cone of depression in relation to the diameter of the base of the cone. If the coefficient is high, the cone will be shallow and broad; if the coefficient is low, the cone will be deeper but not so broad.

The coefficient of storage is related to the volume of water withdrawn from the cone of depression. Theoretically, the volume of dewatered aquifer within the cone of depression multiplied by the coefficient of storage should equal the total volume of water pumped. Excluded here is the insignificant amount released from the saturated portion of the aquifer when the head is lowered (the amount, however, that makes up the entire coefficient of storage of artesian aquifers). The volume of the cone of depression during the early stages of its development has to exceed the theoretical volume in order to yield the water pumped, because the water drains slowly from the dewatered part of the aquifer.

To illustrate the expansion of the cone of depression, drawdown curves have been prepared according to the Theis nonequilibrium formula (Wenzel, 1942, pp. 87-89) showing the expected drawdown at various distances from the pumped well after periods of 1, 10, 30, and 300 days (fig. 6). In the computations it is assumed that the aquifer is of infinite extent, that the coefficient of transmissibility is 20,000 gpd per foot, that the pumping well discharges 100 gpm continuously, that the coefficient of storage is 10 percent, and that all the water is taken from storage and is released instantly with the decline in head. The figure of 10 percent is used because it represents the coefficient of storage in the upper part of the terrace deposits--within the normal range of drawdowns in the rocks surrounding pumped wells.

Rock formations are not of infinite extent. They all terminate somewhere; that is, they have boundaries. If the cone of depression around a pumped well expands until it meets a formation boundary, its further development depends on the nature of the boundary and the possibilities for recharge. If the boundary is at a stream or lake from which water may enter the formation, an essentially stable hydraulic gradient will develop between the source of recharge and the pumped well, and most of the water supplied to the well eventually will come from the source of recharge. If the supply for recharge is ample, the cone of depression will then stabilize, and its expansion will stop. If, on the other hand, the boundary is the edge of the formation or is an impermeable fault plane, no water will be available for recharging the aquifer. Expansion of the cone of depression will be stopped at such a boundary because there is no room for further growth, but in other directions the expansion will be accelerated because more water must come from those directions if the discharge rate is to be maintained. At the same time, the drawdown rate will be accelerated in the well being pumped.

So far as is known, the only boundaries that could affect a cone of depression in the terrace deposits or alluvium of western Tillman County, which are believed to be a single aquifer--hydrologically indistinguishable along most of their contact--are the edges of the deposits. These are Otter Creek on the north, the North Fork of Red River on the west, the Red River on the south, and a low escarpment on the east. These boundaries will not appreciably affect the cones of depression around wells in the middle of the terrace deposits in the near future. Only where wells yielding large quantities of water are near the boundaries--perhaps within a mile or two--can boundary effects be expected to appear soon in cones of depression.

Because the coefficients of transmissibility and storage of the terrace deposits differ greatly from place to place in the area considered in this report, an average drawdown curve that would be generally useful in planning development of a well field cannot be prepared. If large quantities of water are sought, adequate preliminary test drilling and test pumping afford the best means of getting the facts on which to base specifications for well locations and spacing, pumps, and power.

Estimate of Safe Annual Yield

According to Oklahoma law, the safe annual yield of a ground-water basin is defined as the average annual recharge of the basin. This law, the Oklahoma Ground

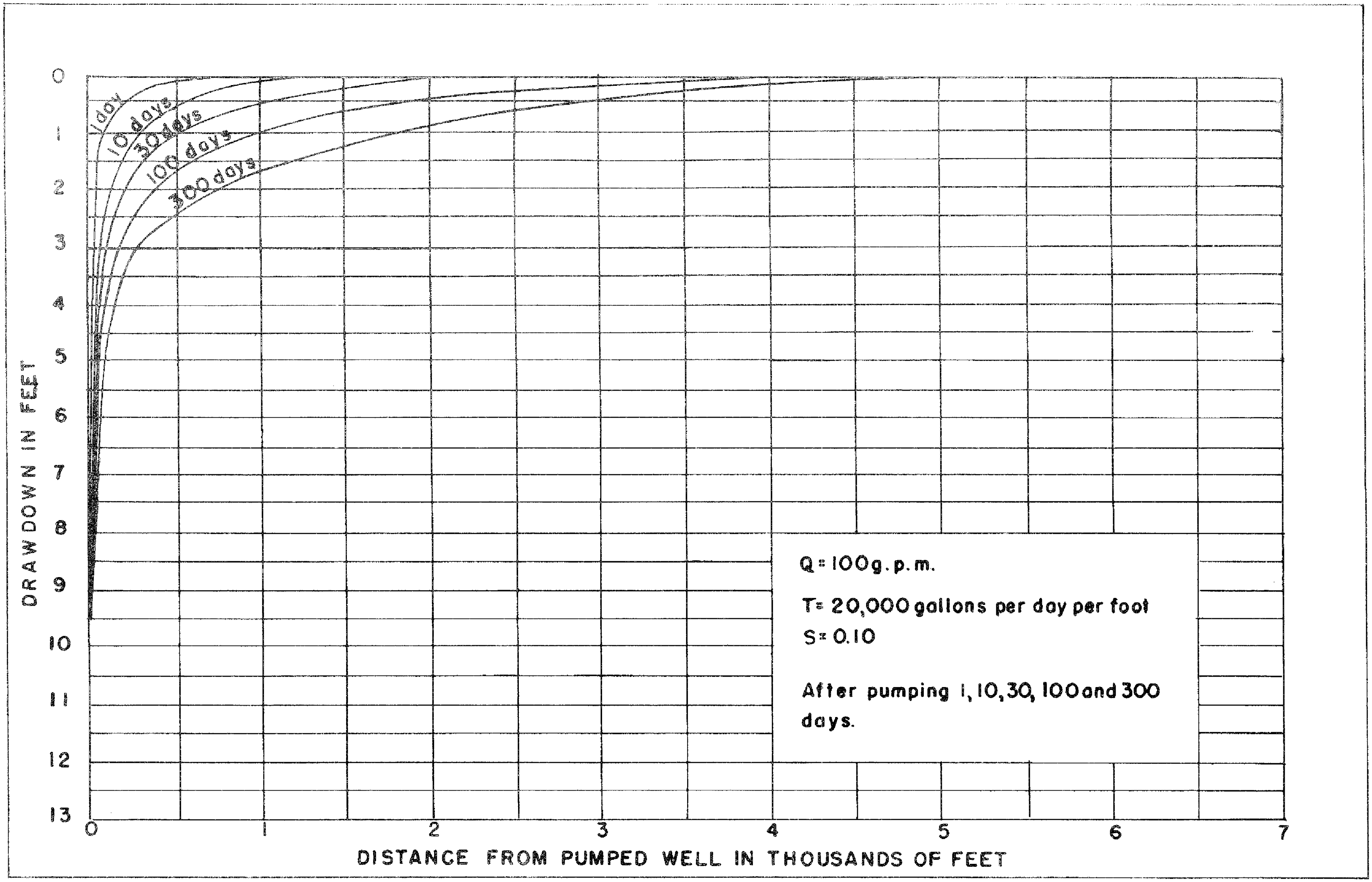

Figure 6.---Theoretical drawdown of the water level in an infinite aquifer, computed from the Theis nonequalibrium formula, after periods of 1, 10, 30, 100 and 300 days.

Water Law (Title 82, secs. 1001-1019 incl., Okla. Statutes, 1951), was passed by the Oklahoma State Legislature in 1949. In a newly developed basin there is usually a large amount of stored water that can be withdrawn. The safe yield can be exceeded for a time without apparent ill effect, but there is a limit to the amount of this stored water that can be withdrawn without adversely affecting water levels in the basin.

A comparison of western Tillman County with a similar area west of Enid, Okla. suggested that in western Tillman County the recharge amounts to about 11.5 percent of the annual precipitation. (See section on Recharge of ground water.) A study is needed of the complex relationships of precipitation, recharge, and discharge as evidenced over several years before this or any other figure can be regarded as well founded.

The average precipitation for the area, based on the records of the Weather Bureau station at Frederick, is 27.37 inches. If 11.5 percent fairly represents the fraction of this annual precipitation that becomes ground water, the average annual recharge is about 166 acre-feet per square mile. This amounts to 103 gpm per square mile, which should also be the amount lost from the ground-water reservoir by natural discharge. Where water is put on the land for irrigation, a part seeps into the ground to become ground water again and is available for re-use.

Losses of ground water are due to transpiration, evaporation, effluent seepage, and underflow. The average amount lost through transpiration is probably small per unit area, because in general the water table is 10 feet or more below the land surface--out of reach of most plants--and the localities where plants such as alfalfa are believed to take water from the zone of saturation represent only a small fraction of the total area investigated. The amount lost through evaporation also is believed to be small (see section on discharge). The losses due to effluent seepage and underflow are not known accurately; they could be recovered in part by strategically located wells that would intercept the water before it could reach the places of natural discharge.

From the above it is clear that the natural discharge cannot yet be accurately estimated, and that the figure of 103 gpm per square mile is only a tentative estimate of the recharge. However, this estimate is conservative and much of the discharge is believed to be salvageable; hence, 103 gpm per square mile appears to be a reasonable estimate for the safe yield of the terrace deposits.

The safe yield of the aquifer is not to be confused with the maximum yield of individual wells. The yield of wells is governed by the ability of the aquifer to transmit to the wells whatever water already is in it. Not until the water stored in the aquifer has been depleted beyond the limits of practical recovery can the safe yield of the aquifer limit the yield of a well, and then only approximately. Individual wells can be pumped at rates many times greater than the average safe yield of the aquifer as expressed above in gallons per minute per unit of area, simply because the aquifer is capable of delivering the water in it faster than it may be receiving water. The extra water comes either by drawing water from storage, or by drawing recharge water from outlying parts of the aquifer. If the draft is on water in storage, and is long continued, practical exhaustion of the underground reservoir will result.

What applies to one well also applies to a well field, provided that the field does not embrace the entire aquifer or its output does not exceed the sum of the total natural recharge and the amount of water returned to the aquifer from irrigation.

In T. 1 S., R. 19 W., there are 41 irrigation wells in an area of about 23 square miles. In parts of this area as many as 8 wells are being pumped in a square mile. Obviously, so many irrigation wells are capable of exceeding the safe annual yield of the aquifer, which elsewhere is estimated as 103 gpm per square mile throughout the year. Local overdevelopment is likely to occur. Therefore, some irrigators in this area may soon find that their ground-water levels are declining and that the yields of their wells are decreasing, especially if all the wells are utilized fully during each irrigation season. It would be appropriate, therefore, to use the water prudently, with a minimum of waste, and to maintain records of water levels and pumpage so that a fair and reasonable operating procedure may be established, if one proves desirable.

Conclusions

The terrace deposits and alluvium of western Tillman County are among the best aquifers in the State. In 1952 the total pumpage of ground water from them was only about 12 percent of their estimated safe yield. Considerable further development is possible but the concentration of wells in some of the localities most favorable for irrigation creates a danger of local overdevelopment. Yields of individual wells differ considerably from place to place because of wide differences in the lithology and thickness of the saturated sediments. On the average, wells can be expected to yield from 200 to 300 gpm, but locally they may yield more than 900 or less than 50 gpm.

An estimate of the probable amount of ground-water recharge in the area suggests that the safe yield may average about 103 gpm per square mile. This figure is strictly preliminary. If all the water available under the designation "safe yield" were to be used for irrigation and applied at a net consumptive rate of 2 acre-feet per acre, about an eighth of the entire area could be irrigated.

The amount of ground water stored in the terrace deposits averages about 3.45 acre-feet per acre. If half the water in storage can be recovered by pumping, withdrawals at the rate of the safe annual yield may continue for a period of 6 years, even if no recharge occurs. The significance of this statement is that the amount of water in storage is enough to outlast most droughts. The amount in storage differs greatly from place to place, of course, and in some localities doubtless is insufficient for a protracted drought; in most places, however, the stored water is believed to be adequate to sustain a rate of pumping equal to the safe yield for considerable periods without excessive lowering of water levels or declines in yield.

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Appendix A. Records of Water Wells, Test Holes and Shot Holes in Western Tillman County, Okla.

Type: B, Bored; Dg, dug; Dr, drilled; Dn, driven; J, jetted.
Type of casing: A, Aluminum; B, brick; C, concrete; GI, galvanized iron; I, iron; N, none. S, steel; T, tile.
Geologic source: A, Alluvium; R, red beds; T, terrace deposits.

Pump: A, Airlift; C, cylinder; J, jet; N, none; T, turbine.
Power: B, Butane; E, electricity; G, gasoline; H, hand; W, wind.
Use of water: D, Domestic; I, irrigation; O, observation; PS, public supply; S, stock.

Well no.	Location in section	Owner or tenant	Type	Depth (feet)	Diameter (inches)	Type of casing	Geologic source	Pump and power	Use of water	Date of measurement	Water level: Altitude above mean sea level (feet)	Water level: Depth below land surface (feet)	Altitude of surface (feet)	Altitude of bedrock (feet)	Remarks
T.1N., R.17W.															
1N17W-18	SW¼SW¼	W. H. Martin	Dr	45	24	C	T	C,H	D,S	--	--	--	--	--	
31	SW¼SE¼	M. H. Swartz	Dr	39	6	GI	T	C,H	D,S	12/9/52	1,336	34	1,370	1,331	
T.1N., R.18W.															
1N18W- 1-1	NW¼SW¼	James Riggs	--	34	16	S	A	T,B	I	3/12/52	--	12	--	--	
1-2	NW cor.	U.S.G.S.	Dr	30	3	N	A	N	O	4/23/53	1,301	11	1,312	1,285	Test hole (log, appendix B)
2-1	SE¼SW¼	M. R. Bailey	Dr	53	14	S	A	T,E	I	3/12/53	1,300	8	1,308	1,255	
2-2	NW¼SW¼	M. R. Bailey	Dr	40	14	S	A	T,E	I	3/12/53	1,299	8	1,307	1,266	Chemical analysis (table 4)
2-3	NW cor.	U.S.G.S.	Dr	40	3	N	A	N	O	--	--	--	1,309	1,274	Test hole (log, appendix B)
3-1	NE¼SE¼	O. J. Tebow	Dr	42	12	S	A	T,B	I	--	--	--	1,306	1,264	
3-2	NE¼SE¼	O. J. Tebow	Dr	40	12	S	A	T,B	I	--	--	--	1,308	1,268	
7-1	SE¼NE¼	E. F. Marteney	Dr	17	6	GI	A	C,W	S	--	--	--	--	--	
9	NW cor.	U.S.G.S.	Dr	50	3	N	A	N	O	4/23/53	1,290	12	1,302	1,255	Test hole (log, appendix B)
10	NE¼SE¼	U.S.G.S.	Dr	30	3	N	A	N	O	4/23/53	1,282	12	1,294	1,265	Test hole (log, appendix B)
11	SW¼SW¼	F. H. Kirk	Dr	100	6	GI	R	J,E	D	--	--	--	--	--	
12	SW¼SE¼	C. O. Stearns	Dr	20	8	S	T	J,E	D	12/10/52	1,322	11	1,333	1,313	
13	NW¼NE¼	C. O. Stearns	Dg	16	48	B,C	R	C,H	S	12/10/52	1,328	8	1,336	1,320	
14-1	SE¼NE¼	H. P. Adams	Dr	48	6	S	T	C,H	D	12/9/52	--	7	--	--	
14-2	SE¼NE¼	T. L. Hatcher	Dr	18	6	GI	T	N	O	12/11/52	--	16	--	--	
14-3	NE¼SE¼	C. C. McClard	Dg	26	30	C	T	J,E	D	12/11/52	--	22	--	--	
15	NE¼NE¼	D. G. Morgan	Dg	31	29	C	T	J,E	D,S	--	--	--	--	--	
16-1	SW¼SE¼	G. A. De Yong	Dr	59	6	GI	T	C,H	D,S	--	--	--	--	--	
16-2	NW cor.	U.S.G.S.	Dr	46	3	N	A	N	O	4/23/50	1,286	11	1,297	1,254	Test hole (log, appendix B)
17-1	SW¼SE¼	J. W. (Bill) Boyd	Dr	--	6	S	T	J,E	D,S	--	--	--	--	--	
18	NE¼SE¼	B. L. Wilson	Dr	78	6	S	T	J,E	D	12/12/52	1,277	44	1,321	1,243	
19-1	SW¼SW¼	A. A. De Yong	Dr	57	14	S	T	T,E	I	12/17/52	1,274	21	1,295	1,240	
19-2	SE¼SE¼	H. H. Goodman	Dg	50	36	C	T	J,E	D	--	--	--	--	--	
20-1	NE¼NE¼	Murl Sturgess	Dr	43	6	GI	T	S,H	D	12/16/52	1,286	26	1,312	1,269	
20-2	NW¼NW¼	C. L. Adams	Dr	70	6	S	T	J,E	D,S	--	--	--	--	--	
21-1	SE cor.	U.S.G.S.	Dr	33	3	N	T	N	O	7/24/51	1,318	8	1,326	1,294	Test hole (log, appendix B)
21-2	SE¼NE¼	G. A. De Yong	Dr	59	7	S	T	J,E	D,S	12/16/52	1,294	22	1,316	1,257	

Appendix A.--Records of Water Wells, Test Holes and Shot Holes in Western Tillman County, Okla.

Type: B, Bored; Dg, dug; Dr, drilled; Dn, driven; J, jetted.
Type of casing: A, Aluminum; B, brick; C, concrete; GI, galvanized iron; I, iron; N, none, S, steel; T, tile.
Geologic source: A, Alluvium; R, red beds; T, terrace deposits.

Pump: A, Airlift; C, cylinder; J, jet; N, none; T, turbine.
Power: B, Butane; E, electricity; G, gasoline; H, hand; W, wind.
Use of water: D, Domestic; I, irrigation; O, observation; PS, public supply; S, stock.

Well no.	Location in section	Owner or tenant	Type	Depth (feet)	Diameter (inches)	Type of casing	Geologic source	Pump and power	Use of water	Date of measurement	Water level: Altitude above mean sea level (feet)	Water level: Depth below land surface (feet)	Altitude of surface (feet)	Altitude of bedrock (feet)	Remarks
1N18W-22	SE¼SE¼	Laing school	Dg	29	46	--	T	J,E	PS	12/10/52	1,331	19	1,350	1,321	
23	NE¼NE¼	Paul Collins	Dr	18	6	GI	T	C,H	S	--	--	--	--	--	
24-1	SE¼SW¼	N. A. Williams	B	24	6	GI	T	J,E	D,S	12/10/52	1,344	13	1,357	1,333	
24-2	SE cor.	U.S.G.S.	Dr	40	3	N	T	N	O	--	--	--	1,363	1,323	Test hole (log, appendix B)
25-1	SE¼NE¼	Mrs. B. C. Hoover	Dr	39	6	GI	T	N	O	12/10/52	--	9	--	--	
25-2	NE¼NW¼	W. M. Kamp	Dr	20	6	GI	T	C,W	D,S	--	--	--	--	--	
25-3	SW¼SW¼	Leon Hutcheson	Dr	51	6	GI	T	C,E	D	12/16/52	--	21	--	--	
25-4	SW¼SW¼	Kate Swartz	Dr	33	6	GI	T	N	O	12/10/52	--	11	--	--	
26-1	NW cor.	U.S.G.S.	Dr	53	3	N	T	N	O	7/24/51	1,332	6	1,338	1,287	Test hole (log, appendix B)
26-2	NE¼NE¼	N. Ammons	Dg	18	48	C	T	C,W	D,S	12/10/52	1,340	11	1,351	1,333	
26-3	NW¼NW¼	S. B. McDonald	B	48	6	S	T	J,E	D,S	12/10/52	1,332	12	1,344	1,296	
26-4	NW¼SW¼	J. R. Young	Dr	45	36	C	T	J,E	D,S	--	--	--	--	--	
26-5	NE¼SE¼	W. M. Pothorst	Dg	44	30	B	T	C,H	D,S	--	--	--	--	--	
27-1	NE¼NE¼	J. B. Kirk	Dr	56	8	S	T	J,E	D	--	--	--	--	--	
27-2	NE¼NE¼	O. Potter	Dr	33	6	GI	T	J,E	D,S	--	--	--	1,357	1,324	
27-3	SW¼NE¼	O. Potter	Dr	23	6	GI	T	C,H	D,S	12/10/52	--	11	--	--	
28-1	NW cor.	U.S.G.S.	Dr	31	3	N	T	N	O	7/24/51	1,301	17	1,318	1,287	Test hole (log, appendix B)
28-2	SE¼NE¼	R. L. Sturgess	Dg	30	36	C	T	J,E	D,S	12/11/52	--	27	--	--	
28-3	NE¼SE¼	--	Dr	31	6	S	T	--	D	12/11/52	1,340	19	1,359	1,328	
29-1	SE¼SE¼	G. W. Trimue	Dr	42	6	S	T	C,H	D	12/16/52	1,316	26	1,342	1,300	
30	NW cor.	U.S.G.S.	Dr	52	3	N	T	N	O	7/24/51	1,277	19	1,296	1,245	Test hole (log, appendix B)
31-1	SW¼SE¼	U.S.G.S.	Dr	38	3	N	T	N	O	7/23/51	1,281	22	1,303	1,267	Test hole (log, appendix B)
31-2	NE¼NE¼	H. G. Gortside	Dr	25	6	S	T	J,E	D,S	--	--	--	--	--	
32-1	SE cor.	U.S.G.S.	Dr	46	3	N	T	N	O	7/23/51	1,336	24	1,360	1,316	Test hole (log, appendix B)
32-2	NW¼NW¼	Mrs. J. H. Ethridge	--	60	6	S	T	J,E	D	--	--	--	--	--	
34	SW¼SW¼	R. K. Huff	Dr	62	6	GI	T	J,E	D,S	--	--	--	--	--	
35-1	SW cor.	U.S.G.S.	Dr.	37	3	N	T	N	O	7/23/51	1,368	9	1,377	1,341	Test hole (log, appendix B)
35-2	SE¼NE¼	H. W. Todd	Dr	54	7	S	T	C,H	D	--	--	--	1,375	1,321	
35-3	SE¼NE¼	H. W. Todd	Dr	54	7	S	T	T,E	D,S	--	--	--	--	--	
35-4	SE¼SW¼	Mrs. Barr	Dr	21	6	S	T	C,H	D,S	12/11/52	1,364	15	1,379	1,358	
35-5	SE¼SE¼	Elmer Campbell	Dr	28	6	S	T	C,H	D,S	12/11/52	--	19	--	--	

Appendix A--Records of Water Wells, Test Holes and Shot Holes in Western Tillman County, Okla.

Type: B, Bored; Dg, dug; Dr, drilled; Dn, driven; J, jetted.
Type of casing: A, Aluminum; B, brick; C, concrete; GI, galvanized iron; I, iron; N, none, S, steel; T, tile.
Geologic source: A, Alluvium; R, red beds; T, terrace deposits.

Pump: A, Airlift; C, cylinder; J, jet; N, none; T, turbine.
Power: B, Butane; E, electricity; G, gasoline; H, hand; W, wind.
Use of water: D, Domestic; I, irrigation; O, observation; PS, public supply; S, stock.

Well no.	Location in section	Owner or tenant	Type	Depth (feet)	Diameter (inches)	Type of casing	Geologic source	Pump and power	Use of water	Date of measurement	Water level: Altitude above mean sea level (feet)	Water level: Depth below land surface (feet)	Altitude of surface (feet)	Altitude of bedrock (feet)	Remarks
1N18W-35-6	NE¼SE¼	Elmer Campbell	Dr	35	6	S	T	J,E	D,S	--	--	--	--	--	
36-1	NE¼NW¼	S. G. Roark	--	17	6	GI	T	C,H	D	12/9/52	1,358	9	1,367	1,349	
36-2	NE¼SE¼	M. J. Roark	Dr	40	6	S	T	C,H	S	--	--	--	--	--	
36-3	NE¼SE¼	G. A. Roark	Dg	28	18	C	T	C,H	D	--	--	--	--	--	
36-4	NW cor.	U.S.G.S.	Dr	42	3	N	T	N	O	--	--	--	1,367	1,326	Test hole (log, appendix B)
36-5	SE cor.	U.S.G.S.	Dr	50	3	N	T	N	O	--	--	--	1,380	1,332	Test hole (log, appendix B)
T.1N., R.19W.															
1N19W- 1	SE¼SW¼	U.S.G.S.	Dr	29	3	N	A	N	O	4/23/53	1,279	7	1,286	1,259	Test hole (log, appendix B)
13	NE¼SE¼	Olen Mitchell	Dr	56	6	S	T	J,E	D,S	--	--	--	--	--	
24	SE¼SE¼	H. L. Hadlock	Dr	50	6	GI	T	J,E	D,S	--	--	--	--	--	
25-1	NW¼NW¼	Anna Young	Dr	54	14	GI	T	T,G	I	12/16/52	1,262	22	1,284	1,229	Aquifer test. Chemical analysis (table 4)
25-2	SW¼NW¼	Mollie Cody	Dr	54	6	GI	T	C,E	D,S	12/17/52	--	22	--	--	
25-3	NW¼NW¼	U.S.G.S.	Dr	53	2-1½	I	T	N	O	11/18/52	1,262	21	1,283	1,231	Test hole (log, appendix B)
26-1	NE cor.	U.S.G.S.	Dr	54	3	N	T	N	O	7/24/51	1,275	19	1,294	1,241	Test hole (log, appendix B)
26-2	SW¼NE¼	Anna Young	Dr	47	14	GI	T	T,B	I	12/16/52	1,259	17	1,276	1,229	
26-3	NW¼SE¼	Edna M. Laing	Dr	56	16	S	T	T,G	I	12/18/52	1,256	20	1,276	1,220	
26-4	SW¼SE¼	Edna M. Laing	Dr	57	14	S	T	T,E	I	12/18/52	1,256	19	1,275	1,218	
27	NE cor.	U.S.G.S.	Dr	20	3	N	T	N	O	7/24/51	1,266	9	1,275	1,260	Test hole (log, appendix B)
T.2N., R.17W															
2N17W-29	SW¼NW¼	B. V. Richardson	Dr	41	12	GI	A	N	I	3/12/53	--	15	--	--	
30-1	NE¼NE¼	B. V. Richardson	Dr	40	16	S	A	T,B	I	--	--	--	--	--	
30-2	NE¼NE¼	B. V. Richardson	Dr	41	14	GI	A	N	I	3/12/53	--	13	--	--	
T.2N., R18W.															
2N18W-25	SE cor.	U.S.G.S.	Dr	35	3	N	A	N	O	4/23/53	1,305	10	1,315	1,282	Test hole (log, appendix B)
T.1S., R.17W															
1S17W- 6-1	NE¼NW¼	City of Manitou	Dr	--	12	GI	T	T,E	PS	--	--	--	--	--	
6-2	NE¼NW¼	City of Manitou	Dr	18	12	GI	T	T,E	PS	--	--	--	--	--	
6-3	NE¼NW¼	City of Manitou	Dr	--	12	GI	T	T,E	PS	--	--	--	--	--	
6-4	NE¼NW¼	City of Manitou	Dr	21	12	GI	T	T,E	PS	12/9/52	1,337	11	1,348	1,330	
6-5	NE¼NW¼	City of Manitou	Dr	18	12	GI	T	T,E	PS	--	--	--	--	--	
6-6	NE¼SW¼	Ralph Wittmezer	Dg	14	30	GI	T	T,B	I	2/12/53	--	5	--	--	

Appendix A.--Records of Water Wells, Test Holes and Shot Holes in Western Tillman County, Okla.

Type: B, Bored; Dg, dug; Dr, drilled; Dn, driven; J, jetted.
Type of casing: A, Aluminum; B, brick; C, concrete; GI, galvanized iron; I, iron; N, none, S, steel; T, tile.
Geologic source: A, Alluvium; R, red beds; T, terrace deposits.

Pump: A, Airlift; C, cylinder; J, jet; N, none; T, turbine.
Power: B, Butane; E, electricity; G, gasoline; H, hand; W, wind.
Use of water: D, Domestic; I, irrigation; O, observation; PS, public supply; S, stock.

Well no.	Location in section	Owner or tenant	Type	Depth (feet)	Diameter (inches)	Type of casing	Geologic source	Pump and power	Use of water	Date of measurement	Water level: Altitude above mean sea level (feet)	Water level: Depth below land surface (feet)	Altitude of surface (feet)	Altitude of bedrock (feet)	Remarks
1S17W- 6-7	SW¼SW¼	Ralph Wittmezer	Dr	56	15	S	T	T,B	I	2/12/53	1,341	36	1,377	1,321	
T.1S., R.18W.															
1S18W- 4	NW¼NE¼	U.S.G.S.	Dr	69	3	N	T	N	O	7/24/51	1,363	29	1,392	1,326	Test hole (log, appendix B)
7-1	NW¼NW¼	--	Dr	35	--	N	T	N	O	--	--	--	1,302	1,267	Shot hole
7-2	SW¼SW¼	--	Dr	26	--	N	T	N	O	--	--	--	1,295	1,269	Shot hole
7-3	SE cor.	U.S.G.S.	Dr	50	3	N	T	N	O	7/23/51	1,321	13	1,334	1,285	Test hole (log, appendix B)
12	SW¼NW¼	U.S.G.S.	Dr	66	3	N	T	N	O	4/23/53	1,352	24	1,376	1,312	Test hole (log, appendix B)
15-1	NE cor.	U.S.G.S.	Dr	67	3	N	T	N	O	7/16/51	1,371	25	1,396	1,331	Test hole (log, appendix B)
15-2	NW cor.	U.S.G.S.	Dr	65	3	N	T	N	O	7/16/51	1,362	23	1,385	1,322	Test hole (log, appendix B)
17	NE cor.	U.S.G.S.	Dr	40	3	N	T	N	O	7/16/51	1,327	12	1,339	1,302	Test hole (log, appendix B)
18-1	SW¼NW¼	--	Dr	40	--	N	T	N	O	--	--	--	1,289	1,249	Shot hole
18-2	SW¼SW¼	--	Dr	35	--	N	T	N	O	--	--	--	1,286	1,251	Shot hole
20-1	W¼ cor.	--	Dr	65	--	N	T	N	O	--	--	--	1,306	1,241	Shot hole
20-2	SW¼SW¼	--	Dr	53	--	N	T	N	O	--	--	--	1,300	1,247	Shot hole
25	SE¼NE¼	C. U. Smith	--	38	6	GI	R	C,H	S	12/8/52	1,357	28	1,385	--	
26-1	NW cor.	U.S.G.S.	Dr	57	3	N	T	N	O	7/16/51	1,340	20	1,360	1,305	Test hole (log, appendix B)
26-2	NE¼NE¼NE¼	Bill Puridy	Dr	55	14	S	T	T,E	I	--	--	--	1,356	1,301	
27-1	NE cor.	U.S.G.S.	Dr	45	3	N	T	N	O	7/16/51	1,337	17	1,354	--	Test hole (log, appendix B)
27-2	NW cor.	U.S.G.S.	Dr	52	3	N	T	N	O	7/16/51	1,333	22	1,355	1,303	Test hole (log, appendix B)
27-3	NW¼NW¼	Doc. Clark	Dr	52	10	S	T	T,G	I	10/19/49	1,332	23	1,355	1,303	Chemical analysis (table 4)
27-4	SW¼SW¼	City of Frederick	Dr	48	--	N	T	N	O	11/12/47	--	14	--	--	Test hole (log, appendix B)
27-5	S¼ cor.	City of Frederick	Dr	51	--	N	T	N	O	11/12/47	--	14	--	--	Test hole (log, appendix B)
27-6	SE¼SE¼	Oliver Meeks	Dr	60	18	GI	T	T,G	I	--	--	--	1,360	1,300	
28-1	NW cor.	U.S.G.S.	Dr	58	3	N	T	N	O	7/16/51	1,279	25	1,304	1,249	Test hole (log, appendix B)
28-2	SE¼SW¼	--	Dg	31	36	B	T	C,H	D	2/11/53	--	26	--	--	
28-3	SW¼SW¼	City of Frederick	Dr	40	--	N	T	N	O	--	--	18	--	--	Test hole (log, appendix B)
28-4	SE cor.	City of Frederick	Dr	45	--	N	T	N	O	--	--	13	--	--	Test hole (log, appendix B)
29-1	NW cor.	U.S.G.S.	Dr	50	3	N	T	N	O	2/16/51	1,276	20	1,296	1,247	Test hole (log, appendix B)
29-2	SW¼NW¼	--	Dr	29	--	N	T	N	O	--	--	--	1,313	1,284	Shot hole
29-3	SW¼SW¼	--	Dr	30	--	N	T	N	O	--	--	--	1,317	1,287	Shot hole
31-1	NW¼NW¼	--	Dr	45	--	N	T	N	O	--	--	--	1,277	1,232	Shot hole

Appendix A--Records of Water Wells, Test Holes and Shot Holes in Western Tillman County, Okla.

Type: B, Bored; Dg, dug; Dr, drilled; Dn, driven; J, jetted.
Type of casing: A, Aluminum; B, brick; C, concrete; GI, galvanized iron; I, iron; N, none, S, steel; T, tile.
Geologic source: A, Alluvium; R, red beds; T, terrace deposits.

Pump: A, Airlift; C, cylinder; J, jet; N, none; T, turbine.
Power: B, Butane; E, electricity; G, gasoline; H, hand; W, wind.
Use of water: D, Domestic; I, irrigation; O, observation; PS, public supply; S, stock.

Well no.	Location in section	Owner or tenant	Type	Depth (feet)	Diameter (inches)	Type of casing	Geologic source	Pump and power	Use of water	Date of measurement	Water level: Altitude above mean sea level (feet)	Water level: Depth below land surface (feet)	Altitude of surface (feet)	Altitude of bedrock (feet)	Remarks
1S18W-31-2	NW¼SW¼	--	Dr	10	--	M	T	N	O	--	--	--	1,286	1,276	Shot hole
31-3	NW¼SE¼	--	Dg	24	6	GI	T	C,H	D	2/11/53	1,296	21	1,317	1,292	
32	SW¼NW¼	--	Dr	35	--	N	T	N	O	--	--	--	1,319	1,284	Shot hole
33-1	SE¼NE¼	Virgil Hale	Dg	47	72	C	T	T,E	I	10/18/49	1,322	25	1,347	1,300	Chemical analysis (table 4)
33-2	NE¼NE¼	City of Frederick	Dr	43	--	N	T	N	O	11/11/47	--	21	--	--	Test hole (log, appendix B)
33-3	N¼ cor.	City of Frederick	Dr	41	--	N	T	N	O	11/11/47	--	20	--	--	Test hole (log, appendix B)
33-4	SW¼SW¼	R. D. Jeffries	Dr	48	14	S	T	T,G	I	1/20/53	1,314	29	1,343	1,295	
33-5	NE¼SE¼	W. A. Dotson	Dr	50	14	S	T	T,B	I	10/30/52	1,320	27	1,347	1,297	Aquifer test. Chemical analysis (table 4)
33-6	NE¼SE¼	W. A. Dotson	Dr	42	14	GI	T	T,G	I	--	--	--	1,343	1,301	
33-7	SE¼SE¼	City of Frederick	Dr	44	--	N	T	N	O	--	--	14	--	--	Test hole (log, appendix B)
33-8	NE¼SE¼	U.S.G.S.	Dr	47	2-1¼	I	T	N	O	10/30/52	1,315	27	1,342	1,295	Test hole (log, appendix B)
34	SW cor. NW¼	City of Frederick	Dr	40	--	N	T	N	O	--	--	16	--	--	Test hole (log, appendix B)
35	NW¼NW¼	--	Dg	29	20	B,C	T	C,H	D	1/23/52	1,321	24	1,345	--	
T.1S., R.19W.															
1S19W- 1	NE¼NE¼	--	Dg	31	32	C	T	A	O	7/24/51	--	21	--	--	
2-1	NW¼NE¼	Town of Tipton	Dg	58	10	S	T	T,E	PS	--	--	--	1,272	1,214	Chemical analysis (table 4)
2-2	NW¼NE¼	Town of Tipton	Dn,J	52	10	S	T	T,E	PS	--	--	--	1,270	1,218	
2-3	NW¼NW¼	Leon Stansell	Dr	41	7	S	T	R,E	D,S	12/17/52	1,249	24	1,273	1,232	
2-4	NW¼NW¼	Leon Stansell	Dr	54	16	S	T	T,E	I	12/17/52	1,252	23	1,275	1,221	
2-5	NE¼SW¼	W. A. Walling	Dr	53	14	S	T	T,B	I	--	--	--	1,271	1,218	
2-6	NE¼SW¼	W. A. Walling	Dr	49	16	GI	T	T,B	I	--	--	--	1,272	1,223	
2-7	SE¼SW¼	W. A. Walling	Dr	49	16	S	T	T,B	I	12/18/52	1,247	20	1,267	1,218	
2-8	SE¼SW¼	W. A. Walling	Dr	49	16	GI	T	T,B	I	12/18/52	1,246	21	1,267	1,218	
2-9	NE¼NW¼	Town of Tipton	J	55	--	--	T	N	O	--	--	--	1,271	--	Test hole (log, appendix B)
2-10	SW¼NE¼	Town of Tipton	J	51	--	--	T	N	O	--	--	--	1,271	1,220	Test hole (log, appendix B)
2-11	NE¼SW¼	Town of Tipton	J	55	--	--	T	N	O	--	--	--	1,263	--	Test hole (log, appendix B)
3-1	NE¼NE¼	Town of Tipton	J	44	--	--	T	N	O	--	--	--	1,277	1,234	Test hole (log, appendix B)
3-2	SW¼SW¼	--	Dr	46	--	N	T	N	O	--	--	--	1,261	1,215	Shot hole
3-3	W¼ cor.	--	Dr	53	--	N	T	N	O	--	--	--	1,273	1,220	Shot hole
4	NE cor.	U.S.G.S.	Dr	39	3	N	T	N	O	7/23/51	1,256	6	1,262	1,226	Test hole (log, appendix B)
10-1	NE¼NW¼	I. W. Kinney	Dr	49	12	GI	T	T,B	I	12/20/52	1,240	24	1,264	1,215	

Appendix A--Records of Water Wells, Test Holes and Shot Holes in Western Tillman County, Okla.

Type: B, Bored; Dg, dug; Dr, drilled; Dn, driven; J, jetted.
Type of casing: A, Aluminum; B, brick; C, concrete; GI, galvanized iron; I, iron; N, none, S, steel; T, tile.
Geologic source: A, Alluvium; R, red beds; T, terrace deposits.

Pump: A, Airlift; C, cylinder; J, jet; N, none; T, turbine.
Power: B, Butane; E, electricity; G, gasoline; H, hand; W, wind.
Use of water: D, Domestic; I, irrigation; O, observation; PS, public supply; S, stock.

Well no.	Location in section	Owner or tenant	Type	Depth (feet)	Diameter (inches)	Type of casing	Geologic source	Pump and power	Use of water	Date of measurement	Water level: Altitude above mean sea level (feet)	Water level: Depth below land surface (feet)	Altitude of surface (feet)	Altitude of bedrock (feet)	Remarks
1S19W-10-2	NE¼NW¼	I. W. Kinney	Dr	45	14	S	T	T,E	I	4/13/49	1,244	21	1,265	1,220	Chemical analysis (table 4)
10-3	NE¼NW¼	I. W. Kinney	Dr	51	12	GI	T	T,B	I	12/22/52	1,244	24	1,268	1,217	
11-1	SE¼NE¼	F. L. Wagnin	Dr	65	14	S	T	T,G	I	4/13/49	1,245	22	1,267	1,202	
11-2	NW¼SE¼	C. A. Parks	Dr	59	14	--	T	T,G	I	--	--	--	1,266	1,207	
11-3	NE cor. NE¼	Mrs. R. V. Seymore	Dr	50	14	GI	T	T,E	I	--	--	--	1,268	1,218	
11-4	NE¼NE¼	F. L. Wagnin	Dr	61	14	S	T	T,G	I	12/20/52	1,248	20	1,268	1,207	
11-5	NW¼SW¼	Irene Parks	Dr	51	16	S	T	T,B	I	12/18/52	1,244	21	1,265	1,214	
11-6	NW¼NE¼	Town of Tipton	J	53	--	--	T	--	O	--	--	--	1,263	--	Test hole (log, appendix B)
12-1	SW cor.	U.S.G.S.	Dr	37	3	N	T	N	O	7/23/51	1,260	12	1,272	1,238	Test hole (log, appendix B)
12-2	SW¼NW¼	T. G. Jennings, Jr.	Dr	55	14	A	T	T,G	I	1/30/52	1,249	21	1,270	1,215	Aquifer test. Chemical analysis (table 4)
12-3	NE¼NW¼	T. G. Jennings	Dr	61	14	A	T	T,G	I	1/30/52	1,247	25	1,272	1,211	
12-4	SW¼NW¼	U.S.G.S.	Dr	54	2-1¼	I	T	N	O	10/28/52	--	24	1,270	1,216	Test hole (log, appendix B)
13	NE¼SW¼	Gist estate	Dr	47	14	S	T	T,E	I	--	--	--	1,275	1,228	
14	NW cor.	U.S.G.S.	Dr.	53	3	N	T	N	O	7/23/51	1,240	20	1,260	1,210	Test hole (log, appendix B)
15-1	SE¼SW¼	Mrs. E. Jones	Dr	60	16	I	T	T,G	I	--	--	--	1,258	1,200	
15-2	NE¼NE¼	R. H. Chambers	Dr	51	14	GI	T	T	I	--	--	--	1,258	1,207	
15-3	SE¼SE¼	Frank Stretsky	Dr	42	8	S	T	T,B	I	12/20/52	1,238	17	1,255	1,213	
15-4	NE¼SE¼	Frank Stretsky	Dr	49	14	GI	T	T,B	I	12/20/52	1,237	19	1,256	1,207	
15-5	NW¼NW¼	--	Dr	42	--	N	T	N	O	--	--	--	1,254	1,212	Shot hole
15-6	W¼ cor.	--	Dr	28	--	N	T	N	O	--	--	--	1,244	1,216	Shot hole
16	NW cor	U.S.G.S.	Dr	31	3	N	T	T,B	O	7/23/51	1,241	4	1,245	1,214	Test hole (log, appendix B)
20	SE¼SW¼	J. W. Haynie	Dr	31	16	S	T	T	I	--	--	--	1,215	1,184	
21-1	NW¼NW¼	A. L. Boyd	Dr	38	18	I	T	T,G	I	4/12/49	1,233	11	1,244	1,206	
21-2	NW¼SW¼	Oran Roberts	Dr	35	14	--	T	T,G	I	4/13/49	1,223	9	1,232	1,199	Aquifer test. Chemical analysis (table 4)
21-3	NW¼SE¼	R. H. Dunlap	Dr	35	18	GI	T	N	O	4/13/49	--	7	--	--	
21-4	NW¼SE¼	R. H. Dunlap	Dr	35	14	GI	T	T,E	I	11/13/50	1,227	8	1,235	1,200	
21-5	NE¼NE¼	A. L. Boyd	Dr	39	14	S	T	N	O	1/30/52	--	20	--	--	
21-6	NW¼SW¼	Oran Roberts	Dr	34	14	S	T	T	I	--	--	--	1,235	1,201	
21-7	NW¼SW¼	U.S.G.S.	Dr	33	2-1¼	I	T	N	O	11/13/52	1,221	9	1,230	1,197	Test hole (log, appendix B)
22-1	NE¼NW¼	J. W. Boyd	Dr	53	18	--	T	T,G	I	4/12/49	1,236	19	1,255	1,202	
22-2	NE¼NE¼	J. W. Haynie	Dr	48	14	GI	T	T,B	I	1/30/52	1,236	17	1,253	1,205	

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Type of casing: A, Aluminum; B, brick; C, concrete; GI, galvanized iron; I, iron; N, none, S, steel; T, tile.
Geologic source: A, Alluvium; R, red beds; T, terrace deposits.

Pump: A, Airlift; C, cylinder; J, jet; N, none; T, turbine.
Power: B, Butane; E, electricity; G, gasoline; H, hand; W, wind.
Use of water: D, Domestic; I, irrigation; O, observation; PS, public supply; S, stock.

Well no.	Location in section	Owner or tenant	Type	Depth (feet)	Diameter (inches)	Type of casing	Geologic source	Pump and power	Use of water	Date of measurement	Water level: Altitude above mean sea level (feet)	Water level: Depth below land surface (feet)	Altitude of surface (feet)	Altitude of bedrock (feet)	Remarks
1S19W-22-3	NE¼NE¼	J. W. Haynie	Dr	47	14	GI	T	T,B	I	--	--	--	1,254	1,207	
22-4	NW¼NE¼	J. W. Haynie	Dr	62	14	S	T	T,E	I	--	--	--	1,255	1,193	
22-5	NW¼NW¼	Edith Van Orstrum	Dr	53	14	GI	T	T,E	I	--	--	--	--	--	
22-6	NW¼SW¼	W. M. Lovejoy	Dr	55	14	S	T	T,E	I	1/8/53	1,236	15	1,251	1,196	
22-7	SE¼SE¼	Sam Dickey	Dr	45	14	GI	T	T,G	I	--	--	--	1,250	1,205	
22-8	NW¼NW¼	--	Dr	40	--	N	T	N	O	--	--	--	1,250	1,210	Shot hole
22-9	W¼ cor.	--	Dr	34	--	N	T	N	O	--	--	--	1,236	1,202	Shot hole
22-10	SW¼SW¼	--	Dr	25	--	N	T	N	O	--	--	--	1,230	1,205	Shot hole
23	SE cor.	U.S.G.S.	Dr	40	3	N	T	N	O	7/16/51	1,230	29	1,259	1,220	Test hole (log, appendix B)
25	NE¼SE¼	S. W. Cotton Substation	Dr	54	20	--	T	T,E	I	12/15/52	--	23	--	--	Aquifer test. Chemical analysis (table 4)
27-1	NE cor.	U.S.G.S.	Dr	30	3	N	T	N	O	7/16/51	1,219	16	1,235	1,207	Test hole (log, appendix B)
27-2	NW¼SW¼	Paul Brunk	Dr	46	14	S	T	T,B	I	--	--	--	1,242	1,196	
28	SE¼SE¼	B. W. Miller	Dr	35	15	S	T	T,E	I	2/20/53	1,225	12	1,237	1,203	
29-1	NE¼NE¼	Bob Abernathy	Dr	37	14	S	T	T	I	--	--	--	1,235	1,198	
29-2	SE¼NE¼	J. R. Abernathy	Dr	39	14	GI	T	T,E	I	--	--	--	--	--	
29-3	NE¼SE¼	J. R. Abernathy	Dr	40	14	GI	T	T,E	I	--	--	--	1,237	1,197	
29-4	SE cor.	U.S.G.S.	Dr	35	3	N	T	N	O	4/22/53	1,219	7	1,226	1,195	Test hole (log, appendix B)
30	NE¼NE¼	J. W. Haynie	Dr	--	1¼	I	A	C,W	S	--	--	--	--	--	Chemical analysis (table 4)
31	NE¼NW¼	B. J. Stansell	Dr	54	3	GI	T	T,E	I	--	--	--	--	--	
32-1	SW¼NW¼	Gulf Oil Co.	Dr	36	--	N	T	N	O	--	--	--	--	--	Shot hole
32-2	SW¼SW¼	Gulf Oil Co.	Dr	35	--	N	T	N	O	--	--	--	--	--	Shot hole
33	NE¼SE¼	John A. Banker	Dr	44	3	S	T	T,G	I	--	--	--	1,239	1,195	
34-1	NE¼NW¼	B. J. Stansell	--	47	16	GI	T	T,B	I	1/7/53	1,225	14	1,239	1,192	
34-2	NE¼SW¼	Sybil Taylor	Dr	57	14	S	T	T,B	I	--	--	--	1,238	1,181	
34-3	NW¼SE¼	Carl Cassidy	Dr	42	14	GI	T	T	I	1/8/53	1,224	15	1,239	1,197	
34-4	SW¼SW¼	--	Dr	38	--	N	T	N	O	--	--	--	1,230	1,192	Shot hole
36	SW cor.	U.S.G.S.	Dr	28	3	N	T	N	O	7/16/51	1,251	16	1,267	1,242	Test hole (log, appendix B)
T.2S., R.18W.															
2S18W- 1-1	NE¼NE¼	--	Dg	35	36	C	T	N	O	2/17/53	1,334	32	1,366	--	
1-2	NW cor.	U.S.G.S.	Dr	52	3	N	T	N	O	--	--	--	1,352	1,297	Test hole (log, appendix B)
2	NW¼SW¼	Sam Dickey	Dr	55	16	S	T	T	I	--	--	--	1,350	1,295	

Appendix A.--Records of Water Wells, Test Holes and Shot Holes in Western Tillman County, Okla.

Type: B, Bored: Dg, dug; Dr, drilled; Dn, driven; J, jetted.
Type of casing: A, Aluminum; B, brick; C, concrete; GI, galvanized iron; I, iron; N, none, S, steel; T, tile.
Geologic source: A, Alluvium; R, red beds; T, terrace deposits.
Pump: A, Airlift; C, cylinder; J, jet; N, none; T, turbine.
Power: B, Butane; E, electricity; G, gasoline; H, hand; W, wind.
Use of water: D, Domestic; I, irrigation; O, observation; PS, public supply; S, stock.

Well no.	Location in section	Owner or tenant	Type	Depth (feet)	Diameter (inches)	Type of casing	Geologic source	Pump and power	Use of water	Date of measurement	Water level: Altitude above mean sea level (feet)	Water level: Depth below land surface (feet)	Altitude of surface (feet)	Altitude of bedrock (feet)	Remarks
2S18W- 3-1	NE cor. NW¼	City of Frederick	Dr	49	--	N	T	N	O	11/7/47	--	19	--	--	Test hole (log, appendix B)
3-2	NW¼NW¼	City of Frederick	Dr	46	--	N	T	N	O	11/10/47	--	21	--	--	Test hole (log, appendix B)
3-3	NW cor.	City of Frederick	Dr	48	--	N	T	N	O	11/6/47	--	21	--	--	Test hole (log, appendix B)
3-4	NE¼SW¼	City of Frederick	Dr	57	12	S	T	T,E	PS	7/31/48	--	25	--	--	Log, appendix B
3-5	NW¼SW¼	City of Frederick	Dr	53	--	N	T	N	O	11/13/47	--	16	--	--	Test hole (log appendix B)
3-6	NW¼SW¼	City of Frederick	Dr	49	--	N	T	N	O	--	--	--	--	--	Test hole (log appendix B)
3-7	NW cor. SW¼	City of Frederick	Dr	50	--	N	T	N	O	11/8/47	--	23	--	--	Test hole (log appendix B)
3-8	NW¼SW¼	City of Frederick	Dr	54	12	S	T	T,E	PS	--	--	--	--	--	Log, appendix B
3-9	NW¼SW¼	City of Frederick	Dr	55	--	S	T	T,E	PS	--	--	--	--	--	Log, appendix B
3-10	NW¼SW¼	City of Frederick	Dr	55	--	N	T	N	O	--	--	--	--	--	Test hole (log, appendix B)
3-11	NE¼SW¼	City of Frederick	Dr	53	--	N	T	N	O	--	--	--	--	--	Test hole (log, appendix B)
3-12	NE¼SW¼	City of Frederick	Dr	54	--	N	T	N	O	--	--	--	--	--	Test hole (log, appendix B)
3-13	NE¼SW¼	City of Frederick	Dr	55	--	N	T	N	O	7/28/48	--	24	--	--	Test hole (log, appendix B)
3-14	NE¼SW¼	City of Frederick	Dr	55	--	N	T	N	O	7/28/48	--	25	--	--	Test hole (log, appendix B)
3-15	SE¼SW¼	City of Frederick	Dr	53	--	N	T	N	O	7/26/48	--	25	--	--	Test hole (log, appendix B)
3-16	SW¼SW¼	City of Frederick	Dr	55	--	N	T	N	O	7/31/48	--	26	--	--	Test hole (log, appendix B)
3-17	SW¼SW¼	City of Frederick	Dr	55	--	N	T	N	O	7/31/48	--	26	--	--	Test hole (log, appendix B)
3-18	SW¼SW¼	Clarence De Yong	Dr	--	4	S	T	N	O	10/19/49	--	33	--	--	
3-19	SW cor. SW¼	City of Frederick	Dr	55	--	N	T	N	O	11/7/47	--	16	--	--	Test hole (log, appendix B)
3-20	SW¼SW¼	City of Frederick	Dr	55	--	N	T	N	O	7/24/48	--	27	--	--	Test hole (log, appendix B)
3-21	SW¼SW¼	City of Frederick	Dr	55	--	N	T	N	O	7/26/48	--	27	--	--	Test hole (log, appendix B)
3-22	SW¼SW¼	City of Frederick	Dr	55	--	N	T	N	O	11/8/47	--	23	--	--	Test hole (log, appendix B)
3-23	SE¼SW¼	City of Frederick	Dr	59	--	N	T	N	O	5/15/48	--	26	--	--	Test hole (log, appendix B)
3-24	SE¼SW¼	City of Frederick	Dr	59	--	N	T	N	O	5/14/48	--	26	--	--	Test hole (log, appendix B)
3-25	SE¼SW¼	City of Frederick	Dr	60	--	N	T	N	O	5/13/48	--	26	--	--	Test hole (log, appendix B)
3-26	SE¼SW¼	City of Frederick	Dr	60	--	N	T	N	O	11/8/47	--	26	--	--	Test hole (log, appendix B)
3-27	SW cor. SE¼	City of Frederick	Dr	57	18	S	T	T,E	PS	5/15/48	--	26	--	--	Aquifer test. Log, appendix B
3-28	SE¼SE¼	City of Frederick	Dr	58	--	N	T	N	O	11/12/47	--	17	--	--	Test hole (log, appendix B)
4-1	NE¼NE¼	City of Frederick	Dr	41	--	N	T	N	O	11/10/47	--	22	--	--	Test hole (log, appendix B)
4-2	NE cor. NW¼	City of Frederick	Dr	40	--	N	T	N	O	11/6/47	--	20	--	--	Test hole (log, appendix B)
6-1	NE cor	U.S.G.S.	Dr	20	3	N	T	N	O	7/16/51	1,313	5	1,318	1,301	Test hole (log, appendix B)

Appendix A.--Records of Water Wells, Test Holes and Shot Holes in Western Tillman County, Okla.

Type: B, Bored; Dg, dug; Dr, drilled; Dn, driven; J, jetted.
Type of casing: A, Aluminum; B, brick; C, concrete; GI, galvanized iron; I, iron; N, none, S, steel; T, tile.
Geologic source: A, Alluvium; R, red beds; T, terrace deposits.

Pump: A, Airlift; C, cylinder; J, jet; N, none; T, turbine.
Power: B, Butane; E, electricity; G, gasoline; H, hand; W, wind.
Use of water: D, Domestic; I, irrigation; O, observation; PS, public supply; S, stock.

Well no.	Location in section	Owner or tenant	Type	Depth (feet)	Diameter (inches)	Type of casing	Geologic source	Pump and power	Use of water	Date of measurement	Water level: Altitude above mean sea level (feet)	Water level: Depth below land surface (feet)	Altitude of surface (feet)	Altitude of bedrock (feet)	Remarks
2S18W- 6-2	SW¼NW¼	Mrs. Dellie Erwin	Dg	20	36	B,T	T	N	O	2/17/53	1,296	19	1,315	--	
6-3	SW¼NW¼	--	Dr	25	--	N	T	N	O	--	--	--	1,314	1,289	Shot hole
6-4	SW¼SW¼	--	Dr	31	--	N	T	N	O	--	--	--	1,322	1,291	Shot hole
7-1	W¼ cor.	--	Dr	25	--	N	T	N	O	--	--	--	1,326	1,301	Shot hole
7-2	SW¼SW¼	--	Dr	18	--	N	T	N	O	--	--	--	1,313	1,295	Shot hole
9-1	SW cor.	U.S.G.S.	Dr	60	3	N	T	N	O	7/16/51	1,310	27	1,337	1,280	Test hole (log, appendix B)
9-2	NE cor.	City of Frederick	Dr	54	--	N	T	N	O	5/18/48	--	26	--	--	Test hole (log, appendix B)
9-3	NE¼NE¼	I.X.L. School	Dg	32	24	C	T	N	O	2/17/53	1,312	31	1,343	--	
10-1	W¼ cor.	City of Frederick	Dr	54	--	N	T	N	O	5/18/48	1,310	28	1,338	1,284	Test hole (log, appendix B)
10-2	SW cor.	City of Frederick	Dr	49	--	N	T	N	O	5/18/48	1,300	35	1,335	1,286	Test hole (log, appendix B)
15-1	SW¼SE¼	City of Frederick	Dg	48	42	S	T	T,E	PS	--	--	--	--	--	
15-2	SW¼SE¼	City of Frederick	Dg	52	42	S	T	T,E	PS	--	--	--	--	--	
15-3	SW¼SE¼	City of Frederick	Dg	61	42	S	T	T,E	PS	--	--	--	--	--	
15-4	SE¼SW¼	City of Frederick	Dg	61	12	S	T	T,E	PS	--	--	--	--	--	
15-5	SE¼SW¼	City of Frederick	Dg	55	14	S	T	T,E	PS	--	--	--	--	--	
15-6	SE¼SW¼	City of Frederick	Dg	55	14	S	T	T,E	PS	--	--	--	--	--	
15-7	SE¼SW¼	City of Frederick	Dg	55	14	S	T	T,E	PS	--	--	--	--	--	
15-8	SE¼SW¼	City of Frederick	Dg	61	14	S	T	T,E	PS	--	--	--	--	--	
15-9	SE¼SW¼	City of Frederick	Dg	61	14	S	T	T,E	PS	--	--	--	--	--	
15-10	SE¼SW¼	City of Frederick	Dg	61	14	S	T	T,E	PS	--	--	--	--	--	
15-11	SE¼SW¼	City of Frederick	Dg	61	14	S	T	T,E	PS	--	--	--	--	--	
15-12	SW¼SW¼	City of Frederick	Dg	60	12	S	T	T,E	PS	--	--	--	--	--	
15-13	SW¼SW¼	City of Frederick	Dr	60	12	S	T	T,E	PS	--	--	--	--	--	Chemical analysis (table 4)
15-14	SW¼SW¼	City of Frederick	Dg	60	12	S	T	T,E	PS	--	--	--	--	--	
18-1	SW¼NW¼	--	Dr	30	--	N	T	N	O	--	--	--	1,297	1,267	Shot hole
18-2	SW¼SW¼	--	Dr	50	--	N	T	N	O	--	--	--	1,293	1,243	Shot hole
18-3	NE cor.	U.S.G.S.	Dr	35	3	N	T	N	O	7/16/51	1,316	18	1,334	1,302	Test hole (log, appendix B)
20	SW¼SW¼	--	Dg	34	24	S	T	N	O	2/17/53	1,276	34	1,307	--	
22	SE¼SE¼	--	--	22	6	GI	T	N	O	2/17/53	--	18	--	--	
23	NW¼NE¼	--	Dg	19	--	--	T	N	O	2/17/53	1,266	16	1,282	--	
27	NE cor.	U.S.G.S.	Dr	22	3	N	T	N	O	7/15/51	1,289	6	1,295	1,274	Test hole (log, appendix B)

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Geologic source: A, Alluvium; R, red beds; T, terrace deposits.

Pump: A, Airlift; C, cylinder; J, jet; N, none; T, turbine.
Power: B, Butane; E, electricity; G, gasoline; H, hand; W, wind.
Use of water: D, Domestic; I, irrigation; O, observation; PS, public supply; S, stock.

Well no.	Location in section	Owner or tenant	Type	Depth (feet)	Diameter (inches)	Type of casing	Geologic source	Pump and power	Use of water	Date of measurement	Water level: Altitude above mean sea level (feet)	Water level: Depth below land surface (feet)	Altitude of surface (feet)	Altitude of bedrock (feet)	Remarks
2S18W-28-1	NE cor.	U.S.G.S.	Dr	39	3	N	T	N	O	7/15/51	1,298	19	1,317	1,281	Test hole (log, appendix B)
28-2	NW cor.	U.S.G.S.	Dr	34	3	N	T	N	O	7/15/51	1,280	29	1,309	1,276	Test hole (log, appendix B)
29	NE¼NW¼	--	Dg	31	36	C	T	N	O	2/17/53	1,279	28	1,307	--	
30-1	NE cor.	U.S.G.S.	Dr	35	3	N	T	N	O	--	--	--	1,299	1,267	Test hole (log, appendix B)
30-2	SW¼SE¼	John Simmons	Dr	36	6	S	T	N	O	2/19/53	1,270	25	1,295	1,259	
30-3	NW¼NW¼	--	Dr	60	--	N	T	N	O	--	--	--	1,274	1,214	Shot hole
30-4	SW¼SW¼	--	Dr	45	--	N	T	N	O	--	--	--	1,269	1,224	Shot hole
31	SW¼NW¼	--	Dr	36	--	N	T	N	O	--	--	--	1,266	1,230	Shot hole
35	SW¼SW¼	Ed Cassidy	Dg	25	36	C	T	J,E	D,S	2/17/53	1,206	21	1,227	1,202	
T.2S., R.19W.															
2S19W- 3-1	SE cor.	U.S.G.S.	Dr	40	3	N	T	N	O	4/22/53	1,239	22	1,261	1,224	Test hole (log, appendix B)
3-2	NW¼SW¼	--	Dr	29	--	N	T	N	O	--	--	--	1,226	1,197	Shot hole
5	NW cor.	U.S.G.S.	Dr	35	3	N	T	N	O	7/16/51	1,213	4	1,217	1,184	Test hole (log, appendix B)
7	N¼ cor.	Gulf Oil Co.	Dr	38	--	N	T	N	O	--	--	--	--	--	Shot hole
8	W¼ cor.	Gulf Oil Co.	Dr	38	--	N	T	N	O	--	--	--	--	--	Shot hole
9-1	NW¼NW¼	Gulf Oil Co.	Dr	30	--	N	T	N	O	--	--	--	--	--	Shot hole
9-2	NW cor.	U.S.G.S.	Dr	33	3	N	T	N	O	4/22/53	1,212	11	1,223	1,192	Test hole (log, appendix B)
10-1	NW¼NW¼	--	Dr	25	--	N	T	N	O	--	--	--	1,227	1,202	Shot hole
10-2	NW¼SW¼	--	Dr	34	--	N	T	N	O	--	--	--	1,224	1,190	Shot hole
10-3	SW¼SW¼	--	Dr	31	--	N	T	N	O	--	--	--	1,224	1,193	Shot hole
13	SW¼NW¼	A. O. Lewis	Dr	70	14	S	T	T,B	I	1/13/53	1,243	36	1,279	1,212	
14	NW¼SE¼	Walter Ray	Dr	60	14	S	T	T,B	I	1/14/53	1,241	33	1,274	1,222	
15-1	NW¼SW¼	--	Dr	16	--	N	T	N	O	--	--	--	1,221	1,205	Shot hole
15-2	SW¼SW¼	--	Dr	20	--	N	T	N	O	--	--	--	1,219	1,199	Shot hole
21	NE¼SW¼	Harry Dotson	Dr	10	1¼	S	A	C,G	S	--	--	--	--	--	Chemical analysis (table 4)
23	SE cor.	U.S.G.S.	Dr	60	3	N	T	N	O	7/15/51	1,236	24	1,260	1,202	Test hole (log, appendix B)
24	NE¼SE¼	W. G. Weaver	Dr	75	8	S	T	J,E	D	--	--	--	1,282	1,212	
26	NE¼SE¼	I. S. Richard, Jr.	Dr	61	14	S	T	--	I	1/14/53	1,238	28	1,266	1,205	
27	NW¼NW¼	--	Dr	18	--	N	T	N	O	--	--	--	1,215	1,197	Shot hole
34-1	NW¼NW¼	--	Dr	26	--	N	T	N	O	--	--	--	1,211	1,185	Shot hole
34-2	NW¼SW¼	--	Dr	30	--	N	T	N	O	--	--	--	1,210	1,180	Shot hole

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Geologic source: A, Alluvium; R, red beds; T, terrace deposits.
Pump: A, Airlift; C, cylinder; J, jet; N, none; T, turbine.
Power: B, Butane; E, electricity; G, gasoline; H, hand; W, wind.
Use of water: D, Domestic; I, irrigation; O, observation; PS, public supply; S, stock.

Well no.	Location in section	Owner or tenant	Type	Depth (feet)	Diameter (inches)	Type of casing	Geologic source	Pump and power	Use of water	Date of measurement	Water level: Altitude above mean sea level (feet)	Water level: Depth below land surface (feet)	Altitude of surface (feet)	Altitude of bedrock (feet)	Remarks
T.3S., R.17W.															
3S17W-30	NW¼NW¼	--	Dr	22	24	--	T	H	O	12/22/52	1,148	16	1,164	--	
T.3S., R.18W.															
3S18W- 2	NW cor.	U.S.G.S.	Dr	30	3	N	T	N	O	4/22/53	1,206	19	1,225	1,199	Test hole (log, appendix B)
3	NW¼SW¼	--	Dg	23	36	C	T	N	O	3/6/53	--	9	--	--	
4-1	NE¼NE¼	--	Dg	25	24	C	T	S,H	D	2/17/53	1,267	18	1,285	--	
4-2	NW cor.	U.S.G.S.	Dr	26	3	N	T	N	O	4/22/53	1,276	12	1,288	1,264	Test hole (log, appendix B)
7	NW¼NW¼	--	Dr	25	--	N	T	N	O	--	--	--	1,273	1,248	Shot hole
13	NW¼NE¼	--	Dr	33	6	S	T	C,W	D,S	3/9/53	--	15	--	--	
14	NW cor.	U.S.G.S.	Dr	20	3	N	T	N	O	7/15/51	1,181	7	1,188	1,169	Test hole (log, appendix B)
15	NW cor.	U.S.G.S.	Dr	29	3	N	T	N	O	7/15/51	1,184	16	1,200	1,174	Test hole (log, appendix B)
16	NW cor.	U.S.G.S.	Dr	20	3	N	T	N	O	7/15/51	1,214	12	1,226	1,210	Test hole (log, appendix B)
17	NW¼NW¼	M. L. Wells	Dg	20	24	C	T	N	O	3/6/53	--	17	--	--	
18-1	NE cor.	U.S.G.S.	Dr	20	3	N	T	N	O	--	--	--	1,260	1,241	Test hole (log, appendix B)
18-2	SW¼NW¼	Wilson school	Dg	38	36	C	T	J,E	PS	--	--	--	--	--	
18-3	SW¼SW¼	--	Dr	25	--	N	T	N	O	--	--	--	1,254	1,229	Shot hole
19-1	SW¼SW¼	Ed Cassidy	Dg	27	36	C	T	N	O	2/12/53	1,207	23	1,230	--	
19-2	NW cor. NE¼	J. G. Norwood	Dg	24	36	B	T	T,E	D	1/30/52	1,197	19	1,216	1,192	Chemical analysis (table 4)
19-3	NW¼SW¼	--	Dr	30	--	N	T	N	O	--	--	--	1,233	1,203	Shot hole
20	NE¼NW¼	--	Dg	11	36	C	T	N	O	3/10/53	--	10	--	--	
21-1	NE¼NW¼	Mrs. Helen Fisher	Dr	46	16	S	T	T,B	I	--	--	--	1,199	1,155	
21-2	SW¼SE¼	--	Dg	23	36	C	T	N	O	3/10/53	--	18	--	--	
22-1	SW cor.	U.S.G.S.	Dr	18	3	N	T	N	O	7/16/51	1,171	5	1,176	1,160	Test hole (log, appendix B)
22-2	SE cor.	U.S.G.S.	Dr	20	3	N	T	N	O	7/16/51	1,167	19	1,176	1,159	Test hole (log, appendix B)
26	NE cor.	U.S.G.S.	Dr	45	3	N	T	N	O	7/15/51	1,154	14	1,168	1,130	Test hole (log, appendix B)
28	NW cor.	U.S.G.S.	Dr	45	3	N	T	N	O	7/16/51	1,168	18	1,186	1,143	Test hole (log, appendix B)
29	NW cor.	U.S.G.S.	Dr	25	3	N	T	N	O	7/16/51	1,186	10	1,196	1,173	Test hole (log, appendix B)
30-1	SE¼SW¼	Joe Dickerson	Dr	--	--	--	T	--	I	--	--	--	1,210	--	
30-2	NW¼NW¼	--	Dr	54	--	N	T	N	O	--	--	--	1,224	1,170	Shot hole
30-3	SW¼SW¼	--	Dr	38	--	N	T	N	O	--	--	--	1,202	1,164	Shot hole
31-1	SW¼SW¼	--	Dr	65	--	N	T	N	O	--	--	--	1,189	1,124	Shot hole

Appendix A.--Records of Water Wells, Test Holes and Shot Holes in Western Tillman County, Okla.

Type: B, Bored; Dg, dug; Dr, drilled; Dn, driven; J, jetted.
Type of casing: A, aluminum; B, brick; C, concrete; GI, galvanized iron; I, iron; N, none, S, steel; T, tile.
Geologic source: A, Alluvium; R, red beds; T, terrace deposits.

Pump: A, Airlift; C, cylinder; J, jet; N, none; T, turbine.
Power: B, Butane; E, electricity; G, gasoline; H, hand; W, wind.
Use of water: D, Domestic; I, irrigation; O, observation; PS, public supply; S, stock.

Well no.	Location in section	Owner or tenant	Type	Depth (feet)	Diameter (inches)	Type of casing	Geologic source	Pump and power	Use of water	Date of measurement	Water level: Altitude above mean sea level (feet)	Water level: Depth below land surface (feet)	Altitude of surface (feet)	Altitude of bedrock (feet)	Remarks
3S18W-31-2	NE¼SW¼	J. C. Dickerson	Dr	72	16	S	T	T,B	I	--	--	--	--	--	
33	SW¼SW¼	Mrs. J. L. Tucker	Dr	63	15	S	T	T,B	I	--	--	--	1,177	1,115	
35	SW cor.	U.S.G.S.	Dr	55	3	N	T	N	O	7/17/51	1,129	18	1,147	1,093	Test hole (log, appendix B)
36	SW cor.	U.S.G.S.	Dr	48	3	N	T	N	O	7/17/51	1,134	16	1,150	1,105	
T.3S., R.19W															
3S19W- 2-1	NW¼NE¼	J. A. Banker	Dr	60	14	GI	T	T,B	I	11/5/52	1,227	28	1,255	1,195	Aquifer test. Chemical analysis (table 4)
2-2	NW¼NE¼	J. A. Banker	Dr	60	5	GI	T	J,E	O	1/25/52	1,225	30	1,255	1,195	
2-3	NW¼NE¼	U.S.G.S.	Dr	58	2-1¼	I	T	N	O	11/5/52	1,225	28	1,253	1,195	Test hole (log, appendix B)
3-1	NE¼NW¼	D. D. Alexander	Dr	--	--	--	T	--	I	--	--	--	1,216	--	
3-2	SE¼NW¼	D. D. Alexander	Dr	--	--	--	T	--	I	--	--	--	1,215	--	
3-3	SW¼SW¼	--	Dr	25	--	N	T	N	O	--	--	--	1,207	1,182	Shot hole
10	SW¼SW¼	--	Dr	45	--	N	T	N	O	--	--	--	1,215	1,170	Shot hole
11-1	SW cor.	U.S.G.S.	Dr	39	3	N	T	N	O	7/15/51	1,214	10	1,224	1,186	Test hole (log, appendix B)
11-2	C SE¼	A. C. Streit	Dr	--	--	--	T	--	I	--	--	--	1,233	--	
12	SW cor.	U.S.G.S.	Dr	40	3	N	T	N	O	7/15/51	1,228	17	1,245	1,206	Test hole (log, appendix B)
22-1	NE¼NE¼	Harold Grant	Dr	43	15	S	T	T,B	I	2/12/53	1,196	27	1,223	1,180	
22-2	NE¼NW¼	Harold Grant	Dr	48	6	S	T	C,W	S	2/12/53	1,187	34	1,221	1,173	
23	SE cor.	U.S.G.S.	Dr	40	3	N	T	N	O	7/16/51	1,180	15	1,195	1,158	Test hole (log, appendix B)
26	NW cor.	U.S.G.S	Dr	43	3	N	T	N	O	7/23/51	1,173	24	1,187	1,146	Test hole (log, appendix B)
28-1	NE cor.	U.S.G.S.	Dr	53	3	N	T	N	O	7/16/51	1,158	12	1,170	1,119	Test hole (log, appendix B)
28-2	NW cor NE¼	Jack Jameson	Dr	40	16	S	A	T,G	I	1/30/52	1,156	8	1,164	1,123	
T.4S., R.18W.															
4S18W- 3	NW¼NW¼	City of Davidson	Dr	69	18	S	T	T,E	PS	--	--	--	--	--	Chemical analysis (table 4)
4-1	NE cor.	U.S.G.S.	Dr	66	3	N	T	N	O	7/17/51	1,155	21	1,176	1,111	Test hole (log, appendix B)
4-2	C SW¼	William Conrad	Dr	--	--	--	T	--	I	--	--	--	1,176	--	
4-3	SW¼SW¼	William Conrad	Dr	80	14	S	T	T,B	I	--	--	--	1,176	1,096	
5-1	NE cor.	U.S.G.S.	Dr	68	3	N	T	N	O	7/17/51	1,160	17	1,177	1,112	Test hole (log, appendix B)
5-2	NW cor.	U.S.G.S.	Dr	70	3	N	T	N	O	7/17/51	1,164	20	1,184	1,115	Test hole (log, appendix B)
6-1	SE¼NE¼	U.S.G.S.	Dr	76	2-1¼	N	T	N	O	11/11/52	1,156	32	1,188	1,112	Test hole (log, appendix B)
6-2	SE¼NE¼	W. R. Hudson	Dr	68	16	S	T	T,B	I	1/30/52	1,158	29	1,187	1,112	Aquifer test. Chemical analysis (table 4)
7	NW¼NW¼	--	Dr	26	--	N	T	N	O	--	--	--	1,159	1,133	Shot hole
9	SW¼SW¼	Ira Roberts	Dr	23	1¼	GI	A	C,W	S	--	--	--	--	--	Chemical analysis (table 4)

Appendix A.--Records of Water Wells, Test Holes and Shot Holes in Western Tillman County, Okla.

Type: B, Bored; Dg, dug; Dr, drilled; Dn, driven; J, jetted.
Type of casing: A, Aluminum; B, brick; C, concrete; GI, galvanized iron; I, iron; N, none, S, steel; T, tile.
Geologic source: A, Alluvium; R, red beds; T, terrace deposits.
Pump: A, Airlift; C, cylinder; J, jet; N, none; T, turbine.
Power: B, Butane; E, electricity; G, gasoline; H, hand; W, wind.
Use of water; D, Domestic; I, irrigation; O, observation; PS, public supply; S, stock.

Well no.	Location in section	Owner or tenant	Type	Depth (feet)	Diameter (inches)	Type of casing	Geologic source	Pump and power	Use of water	Date of measurement	Water level: Altitude above mean sea level (feet)	Water level: Depth below land surface (feet)	Altitude of surface (feet)	Altitude of bedrock (feet)	Remarks
4S18W-18	NW¼NW¼	--	Dr	23	--	N	T	N	O	--	--	--	1,131	1,108	Shot hole
T.4S., R.19W.															
4S19W- 2	NE cor.	U.S.G.S.	Dr	52	3	N	T	N	O	7/15/51	1,170	10	1,180	1,129	Test hole (log, appendix B)

Appendix B: Logs of Test Holes and Wells

The logs on the following pages record the materials penetrated in the drilling of 123 test holes and wells. All the logs are of test holes except those for wells 2S18W-3-4, 2S18W-3-8, 2S18W-3-9, and 2S18W-3-27. They are arranged by townships from 1 to 2 north then from 1 to 4 south, and ranges from east to west. Within a township they are arranged by section number and by serial number within the section. Those logs described as sample logs were made by field and microscopic analyses of the drill cuttings by Lee C. Burton. Those logs described as driller's logs were made by field analyses of the drill cuttings by the well driller. The altitudes refer to ground level at the mouth of the hole and are in feet above mean sea level.

1N18W-1-2. NW cor. Sample log. Altitudes: land surface, 1,312; water table, 1,301; bedrock, 1,285.

	Thickness (feet)	Depth (feet)
Sand, medium to coarse	2	2
Sand and clay, brown	8	10
Sand, very coarse	5	15
Gravel, medium	12	27
Red beds	--	--

1N18W-2-3. NW cor. Sample log. Altitudes: land surface, 1,309; bedrock, 1, 274.

Sand, brown, medium to coarse	5	5
Sand, coarse to very coarse; gravel, fine to medium	10	15
Gravel, fine to medium; clay stringers, brown	5	20
Sand, very coarse; gravel, fine	5	25
Gravel, fine to medium; sand, very coarse	5	30
Gravel, fine to medium; arkosic	5	35
Red beds	--	--

1N18W-9. 18 feet south and 1 foot east of NW cor. Sample log. Altitudes: land surface, 1,302; water table, 1,290; bedrock, 1,255

Sand, medium	5	5
Sand, brown, fine to medium, argillaceous	5	10
Sand, coarse to very coarse	5	15
Gravel, fine to medium, arkosic; sand, very coarse; clay streaks, brown	4	19
Gravel, fine to medium, arkosic	23	42
Red beds	--	--

1N18W-10. 750 feet south of E¼ cor. Sample log. Altitudes: land surface, 1,294; water table, 1,282; bedrock, 1,265.

Sand, brown, medium to coarse, argillaceous; gravel, fine	5	5
Clay and sand, brown	1	6
Sand, brown, medium to very coarse	14	20
Gravel, medium, arkosic; sand, very coarse	10	30
Gravel, medium	4	34
Red beds	--	--

1N18W-16-2. NW cor. Sample log. Altitudes: land surface, 1,297; water table, 1,286; bedrock, 1,254.

Sand, medium to very coarse, argillaceous; gravel, fine	4	4
Clay, dark gray, sandy	8	12
Sand, brown, medium to coarse; gravel, fine	3	15
Sand, coarse to very coarse; gravel, fine to medium	5	20
Gravel, medium; sand, very coarse	8	28
Gravel, medium; clay, reddish brown	2	30
Gravel, coarse; sand, very coarse	5	35
Sand, coarse to very coarse; gravel, fine to medium	8	43
Red beds	--	--

1N18W-21-1. 200 feet west and 20 feet north of SE cor. Sample log. Altitudes: land surface, 1,326; water table, 1,318; bedrock, 1,294.

	Thickness (feet)	Depth (feet)
Sand, dark brown, fine	5	5
Clay, reddish brown, sandy	5	10
Sand, reddish brown, fine, clayey	5	15
Sand, reddish brown, medium; gravel, fine	10	25
Gravel, medium; sand, medium; clay streak, red	6.5	31.5
Red beds	--	--

1N18W-24-2. 42 feet north and 21 feet west of SE cor. Sample log. Altitudes: land surface, 1,363; bedrock, 1,323.

Clay, dark brown; sand, medium, argillaceous	5	5
Clay, dark gray to brown, sandy	2	7
Sand, medium	2	9
Clay, dark gray to brown, sandy	1	10
Clay and sand, reddish brown; caliche	26	36
Gravel, fine; sand, coarse to very coarse	3.5	39.5
Red beds	--	--

1N18W-26-1. 120 feet east and 15 feet south of NW cor. Sample log. Altitudes: land surface, 1,338; water table, 1,332; bedrock, 1,287.

Sand, dark brown, medium, clayey	20	20
Clay, brown, sandy	5	25
Clay, brown to reddish brown, sandy; caliche	5	30
Sand, brown, fine, calcareous; clay streaks, reddish brown, sandy	5	35
Clay, reddish brown, sandy, calcareous	5	40
Sand, reddish brown, medium; clay streaks, reddish brown, sandy, clacareous	5	45
Sand, reddish brown, medium; gravel, fine	6	51
Red beds	--	--

1N18W-28-1. 20 feet south and 10 feet east of NW cor. Sample log. Altitudes: land surface, 1,318; water table, 1,301; bedrock, 1,287.

Sand, dark brown, medium	5	5
Sand, reddish brown, medium, clayey	5	10
Clay, brown, sandy	10	20
Sand, brown, coarse, clayey; gravel, fine; clay streak, red; caliche	10.5	30.5
Red beds	--	--

1N18W-30. 130 feet east and 20 feet south of NW cor. Sample log. Altitudes: land surface, 1,296; water table, 1,277; bedrock, 1,245.

Clay, dark gray, sandy	5	5
Sand, brown to reddish brown, medium	5	10
Sand, reddish brown, medium, clayey	5	15
Sand, reddish brown, medium	10	25
Sand, reddish brown, medium, clayey; caliche	5	30
Sand, brown, coarse	15	45
Sand, brown, medium; gravel, fine	6	51
Red beds	--	--

1N18W-31-1. 550 feet east and 30 feet north of SW cor. of SE¼. Sample log. Altitudes: land surface, 1,303; water table, 1,280; bedrock, 1,266.

	Thickness (feet)	Depth (feet)
Sand, gray, fine, clayey	5	5
Sand, reddish brown, fine, clayey; caliche	5	10
Sand, reddish brown, medium, clayey	5	15
Clay, brown and gray, sandy	12	27
Gravel, fine; sand, reddish brown, medium, clayey	8	35
Gravel, medium	1	36
Red beds	--	--

1N18W-32-1. 528 feet west and 30 feet north of SE cor. Sample log. Altitudes: land surface, 1,360; water table, 1,336; bedrock, 1,316.

Sand, dark brown, medium; gravel, fine	5	5
Sand, reddish brown, medium, clayey	10	15
Clay, reddish brown, sandy	5	20
Clay, reddish brown, sandy; caliche	15	35
Gravel, medium; sand, coarse	9	44
Red beds	--	--

1N18W-35-1. 65 feet east and 25 feet north of SW cor. Sample log. Altitudes; land surface, 1,377; water table, 1,368; bedrock, 1,341.

Clay, dark brown, sandy	4	4
Clay, gray and reddish brown, sandy	11	15
Clay, reddish brown, sandy; caliche	18.5	33.5
Clay, dark gray	1.5	35
Sand, brown, fine, dlayey; caliche	1	36
Red beds	--	--

1N18W-36-4. 27 feet south and 57 feet east of NW cor. Sample log. Altitudes: land surface, 1,367; bedrock, 1,326.

Sand, reddish brown, medium to coarse, argillaceous	5	5
Sand, reddish brown, fine to medium, argillaceous	5	10
Sand, medium to coarse; clay, reddish brown to gray, sandy	10	20
Sand and clay, reddish brown; caliche	5	25
Clay, reddish brown; caliche	1	26
Sand, very coarse; gravel, fine to medium	4	30
Gravel, fine to medium; sand, very coarse, argillaceous	5	35
Gravel, fine to medium, arkosic; sand, very coarse	6	41
Red beds	--	--

1N18W-36-5. 54 feet north and 27 feet west of SE cor. Sample log. Altitudes: land surface, 1,380; bedrock, 1,332.

Clay and sand, reddish brown	5	5
Sand, reddish brown, very fine to medium, argillaceous	5	10
Sand, brown, medium to coarse	10	20
Sand, brown, medium to coarse; gravel, fine to medium	7	27
Clay, reddish brown	.5	27.5
Sand, medium to coarse; caliche	2.5	30

1N18W-36-5.--Continued.

	Thickness (feet)	Depth (feet)
Clay, maroon and green; caliche	2	32
Sand, medium to very coarse; gravel, fine; clay stringers, reddish brown; caliche	8	40
Gravel, medium; sand, very coarse	5	45
Gravel, medium	3.5	48.4
Red beds	--	--

1N19W-1. 15 feet north and 72 feet west of S¼ cor. Sample log. Altitudes: land surface, 1,286; water table, 1,279; bedrock, 1,259.

Clay, brown, sandy	5	5
Sand, brown, very coarse; gravel, fine	5	10
Sand, very coarse; gravel, fine to medium; clay, brown, thin stringers	10	20
Sand, very coarse; gravel, fine to medium	7	27
Red beds	--	--

1N19W-25-3. NW¼NW¼. Sample log.

Sand, brown, medium, argillaceous	10	10
No sample	5	15
Sand, brown, medium	15	30
Sand, brown, medium to coarse	10	40
Sand, coarse	10	50
Sand, coarse; gravel, medium	2	52
Red beds	--	--

1N19W-26-1. 65 feet west and 10 feet south of NE cor. Sample log. Altitudes: land surface, 1,294; water table, 1,275; bedrock, 1,241.

Sand, brown, medium	5	5
Sand, brown to reddish brown, medium, clayey	5	10
Clay, reddish brown, sandy	10	20
Clay, reddish brown and gray, sandy	5	25
Sand, brown, medium; gravel, medium; clay, brown, sandy	5	30
Sand, brown, coarse	10	40
Sand, coarse, calcareous; gravel, medium; clay, reddish brown, streaks	10	50
Gravel, coarse; sand, coarse	3	53
Red beds	--	--

1N19W-27. 120 feet south and 15 feet west of NE cor. Sample log. Altitudes: land surface, 1,275; water table, 1,266; bedrock, 1,260.

Sand, brown, medium	5	5
Sand, reddish brown, medium, clayey; gravel, fine	10	15
Red beds	--	--

2N18W-25. 15 feet north and 42 feet west of SE cor. Sample log. Altitudes: land surface, 1,315; water table, 1,305; bedrock, 1,282.

Clay and sand, brown; gravel, medium; caliche	8	8
Sand, brown, very coarse; gravel, fine to medium, arkosic	11	19
Clay, dark gray	1	20
Sand, very coarse; gravel, medium	13.5	33.5
Red beds	--	--

1S18W-4. 1,946 feet west and 25 feet south of NE cor. Sample log. Altitudes: land surface, 1,392; water table, 1,363; bedrock, 1,326.

	Thickness (feet)	Depth (feet)
Sand, fine, silty; gravel, fine	5	5
Sand, reddish brown, medium	20	25
Sand, reddish brown, medium, clayey	20	45
Sand, brown, medium; clay, reddish brown and gray, sandy; gravel streaks; caliche	5	50
Clay, gray, sandy; caliche	6	56
Sand, brown, coarse; gravel, fine	10	66
Red beds	--	--

1S18W-7-3. 370 feet west and 25 feet north of SE cor. Sample log. Altitudes: land surface, 1,334; water table, 1,321; bedrock, 1,285.

Sand, dark brown, medium, clayey	10	10
Sand, gray, fine, clayey	5	15
Clay, reddish brown, sandy	5	20
Clay, reddish brown, sandy; caliche	10	30
Sand, brown, medium; gravel, fine	10	40
Sand, medium; gravel, fine; clay, brown	5	45
Gravel, medium; sand, coarse	4	49
Red beds	--	--

1S18W-15-1. 75 feet west and 15 feet south of NE cor. Sample log. Altitudes: land surface, 1,396; water table, 1,371; bedrock, 1,331.

Clay, dark reddish brown, sandy	5	5
Sand, reddish brown, medium, clayey; clay, gray	5	10
Sand, reddish brown, medium	5	15
Sand, reddish brown, medium, clayey	20	35
Sand, fine, clayey; gravel, fine; clay, reddish brown	5	40
Gravel streaks, medium; sand, medium; caliche	5	45
Gravel, medium; sand, reddish brown, coarse	5	50
Sand, coarse; clay streak, tan, sandy; caliche	5	55
Clay, tan to reddish brown; sand, coarse; gravel, fine; caliche	5	60
Gravel, medium; sand, coarse; clay, tan to reddish brown, sandy	4	64
Red beds	--	--

1S18W-12. 9 feet north and 19 feet east of W¼ cor. Sample log. Altitudes: land surface, 1,376; water table 1,352; bedrock, 1,312.

Sand and clay, reddish brown	10	10
Clay and sand, reddish brown; caliche	12	22
Sand, coarse to very coarse; gravel, fine to medium	11	33
Clay, reddish brown	2	35
Sand, coarse to very coarse; gravel, medium	8	43
Caliche	2	45
Sand, coarse	1	46
Caliche	.5	46.5
Clay, reddish brown, sandy; caliche	3.5	50
Sand, coarse to very coarse; gravel, fine	5	55
Gravel, fine to medium	9	64
Red beds	--	--

1S18W-15-2. 40 feet south and 20 feet east of NW cor. Sample log. Altitudes: land surface, 1,385; water table, 1,362; bedrock, 1,322.

	Thickness (feet)	Depth (feet)
Sand, dark reddish brown, medium, silty	5	5
Clay, dark reddish brown, sandy	20	25
Clay, brown to gray, sandy	5	30
Sand, gray, medium	5	35
Sand, gray, medium; clay, brown, sandy	5	40
Sand, medium; gravel, fine; clay, reddish brown, sandy	5	45
Sand, coarse; gravel, fine	4	49
Clay, reddish brown, sandy	1	50
Gravel, medium	5	55
Gravel, coarse; sand, coarse; clay streaks, gray, sandy	5	60
Gravel, coarse	3	63
Red beds	--	--

1S18W-17. 125 feet west and 20 feet south of NE cor. Sample log. Altitudes: land surface, 1,339; water table, 1,327; bedrock, 1,302.

Sand, dark brown, coarse; gravel, fine	5	5
Clay, dark gray, sandy; caliche	5	10
Clay, reddish brown, sandy; caliche	24	34
Gravel, medium; sand, coarse	3	37
Red beds	--	--

1S18W-26-1. 120 feet east and 20 feet south of NW cor. of NE¼. Sample log. Altitudes: land surface, 1,360; water table, 1,340; bedrock, 1,350.

Clay, dark brown, sandy	5	5
Clay, dark brown and gray, sandy	5	10
Sand, brown, medium, sandy	5	15
Clay, reddish brown, sandy; caliche	8	23
Sand, reddish brown, medium	2	25
Sand, reddish brown, coarse; gravel, fine	5	30
Sand, brown, medium	5	35
Sand, coarse; gravel, fine	11	46
Gravel, medium; sand, coarse	9	55
Red beds	--	--

1S18W-27-1. 500 feet west and 15 feet south of NE cor. Sample log. Altitudes: land surface, 1,354; water table, 1,337.

Clay, dark gray, sandy; caliche	4	4
Clay, dark brown, sandy	1	5
Clay, gray and brown sandy; caliche	5	10
Clay, reddish brown to tan, sandy; caliche gravel, fine	20	30
Sand, coarse; gravel, fine; clay, reddish brown	5	35
Gravel, medium; sand, coarse	10	45

1S18W-27-2. 140 feet east and 15 feet south of NW cor. Sample log. Altitudes: land surface, 1,355; water table, 1,333; bedrock, 1,303.

Clay, dark brown, sandy	6	6
Sand, brown and gray, fine, clayey	14	20

1S18W-27-2.--Continued.

	Thickness (feet)	Depth (feet)
Sand, brown and gray, fine, silty	10	30
Sand, medium; gravel, fine	8	38
Clay, reddish brown, sandy; caliche	2	40
Gravel, fine; sand, coarse	10	50
Red beds	--	--

1S18W-27-4. 1,320 feet east of SW cor. Driller's log supplied by Layne-Western Co.

Soil, sandy	1	1
Clay, brown, sandy	4	5
Clay, red	5	10
Clay, yellow	12	22
Sand, fine	2	24
Sand, fine; caliche	3	27
Sand, fine	3	30
Clay, red	1	31
Sand, fine; clay streaks	13	44
Boulders	3	47
Sand, fine to medium	1	48
Red beds	--	--

1S18W-27-5. S¼ cor. Driller's log supplied by Layne-Western Co.

Soil, sandy	1	1
Clay, brown, sandy	4	5
Clay, brown	5	10
Clay, blue and yellow	14	24
Clay, blue; sand, fine	6	30
Sand, fine; clay streaks, blue, soft	5	35
Sand, fine; clay streaks	16	51
Red beds	--	--

1S18W-28-1. 80 feet east and 20 feet south of NW cor. Sample log. Altitudes: land surface, 1,304; water table, 1,279; bedrock, 1,249.

Clay, dark gray, sandy	5	5
Clay, reddish brown, sandy; caliche	22	27
Sand, reddish brown, medium	3	30
Sand, reddish brown, fine, clayey	10	40
Clay, reddish brown, sandy; caliche	5	45
Sand, fine, clayey; clay streaks, reddish brown; caliche	5	50
Sand, brown, medium	5	55
Red beds	--	--

1S18W-28-2. SE cor. Driller's log supplied by Layne-Western Co.

Soil, sandy	1	1
Clay, brown, sandy	3	4
Clay, blue, sandy	6	10
Clay, blue	5	15
Clay, red	4	19
Sand, fine; clay streaks	10	29
Clay; sand, fine	5	34
Sand, fine; clay streaks	11	45
Red beds	--	--

1S18W-28-3. 1,320 feet east of SW cor. Driller's log supplied by Layne-Western Co.

	Thickness (feet)	Depth (feet)
Soil	1	1
Clay, brown, sandy	3	4
Clay, red	6	10
Clay, yellow	8	18
Clay, red; sand, fine	22	40
Red beds	--	--

1S18W-29. 60 feet east and 15 feet south of NW cor. Sample log. Altitudes: land surface, 1,296; water table, 1,276; bedrock, 1,247.

Clay, reddish brown, sandy	5	5
Sand, brown, coarse; caliche streaks	5	10
Clay, reddish brown, sandy; caliche	10	20
Sand, brown, coarse, clayey; gravel, fine; caliche streaks	10	30
Sand, brown, coarse; caliche streaks	5	35
Sand, medium, clayey; gravel, fine; caliche	5	40
Sand, coarse; gravel, medium	9	49
Red beds	--	--

1S18W-33-1. 1,320 feet west of NE cor. Driller's log supplied by Layne-Western Co.

Soil, sandy	1	1
Clay, black, sandy	5	6
Clay, red	10	16
Sand, fine	8	24
Caliche	1	25
Sand, fine	4	29
Sand, fine; clay streaks	11	40
Sand, fine	3	43
Red beds	--	--

1S18W-33-2. N¼ cor. Driller's log supplied by Layne-Western Co.

Soil, sandy	1	1
Clay, black, sandy	4	5
Clay, blue	5	10
Clay, yellow; caliche	10	20
Sand, fine	2	22
Caliche	.5	22.5
Clay; sand, fine	3.5	26
Sand, fine; clay streaks	9	37
Caliche	.5	37.5
Boulders	1.5	39
Gravel, coarse	2	41
Red beds	--	--

1S18W-33-3. 1,320 feet north of SE cor. Driller's log supplied by Layne-Western Co.

Soil, sandy	1	1
Clay, black, sandy	3	4
Clay, blue	6	10
Clay, red; caliche streaks	11	21
Sand, fine	1	22
Clay, red; sand, fine	22	44
Red beds	--	--

1S18W-33-8. NE¼SE¼. Sample log.

	Thickness (feet)	Depth (feet)
Soil; sand, brown, medium	6	6
Clay, gray	13	19
Clay, brown, sandy	6	25
Sand, brown, coarse	5	30
Sand, medium; gravel, fine	4	34
Clay, gray and brown	3	37
Sand, coarse	4	41
Gravel, medium; sand, coarse	6	47
Red beds	--	--

1S18W-34-1. SW cor. NW¼. Driller's log supplied by Layne-Western Co.

Soil, sandy	1	1
Clay, black, sandy	3	4
Clay, red; caliche	7	11
Clay, yellow	6	17
Sand, fine	6	23
Clay, yellow	.5	23.5
Sand, fine	16	39.5
Red beds	--	--

1S19W-2-9. 20 feet west and 12 feet south of NE cor. NW¼. Sample log. Altitude: land surface, 1,271.

Clay, sandy	3	3
Clay, gray	5	8
Clay, gray; sand, medium	5	13
Sand, fine to medium	7	20
Clay, gray	1	21
Sand, medium	9	30
Sand, coarse; clay streaks, red	4	34
Gravel	1	35

1S19W-2-10. 30 feet north and 110 feet west of E¼ cor. Altitudes: land surface, 1,271; bedrock, 1,220.

Soil and clay	9	9
Sand and caliche	5	14
Sand, fine; clay streaks	6	20
Clay, sandy	10	30
Sand, fine	5	35
Sand, coarse	5	40
Sand, fine	8	48
Gravel, fine	3	51
Red beds	--	--

1S19W-2-11. 4 feet west and 24 feet south of NE cor. SW¼. Sample log. Altitude: land surface, 1,263.

Sand, fine; clay	10	10
Clay; caliche	4	14
Caliche	1	15
Sand, fine	10	25
Sand, medium	13	38
Gravel	17	55

1S19W-3-1. 60 feet west and 10 feet south of NE cor. Sample log. Altitude: land surface, 1,277.

Sand, fine, clay, gray	10	10
Clay, gray	5	15
Sand, medium to coarse	8	23
Clay, sandy	7	30

1S19W-3-1.--Continued.

	Thickness (feet)	Depth (feet)
Sand, medium	2	32
Sand, coarse; gravel, fine	3	35
Sand and clay; gravel, fine	5	40
Sand, medium to coarse; gravel, fine	3	43
Red beds	--	--

1S19W-4. 1,742 feet west and 10 feet south of NE cor. Sample log. Altitudes: land surface, 1,262; water table, 1,256; bedrock, 1,226.

Sand, brown, medium; gravel, fine	8	8
Sand, red, coarse, clayey; caliche	2	10
Sand, medium; gravel, fine	25	35
Gravel, medium	1	36
Red beds	--	--

1S19W-11-6. 15 feet east and 50 feet south of NW cor. NE¼. Sample log. Altitude: land surface, 1,263.

Sand, fine, argillaceous	5	5
Clay, gray	8	13
Clay, sandy; caliche	2	15
Sand, medium	5	20
Sand, fine	10	30
Sand, medium to coarse; gravel	10	40
Gravel, fine to medium	5	45
Gravel, medium	8	53

1S19W-12-1. 65 feet north and 15 feet east of SW cor. Sample log. Altitudes: land surface, 1,272; water table, 1,260; bedrock, 1,238.

Sand, medium; clay, dark brown	5	5
Sand, brown, medium, clayey; clay, red; caliche	5	10
Clay, reddish brown, sandy; caliche	15	25
Clay, reddish brown, sandy; gravel, fine; caliche	9	34
Red beds	--	--

1S19W-12-4. SW¼NW¼. Sample log.

Soil	3	3
Clay, white	4	7
Sand, argillaceous	3	10
Sand, medium	4	14
Clay, brown	6	20
Clay, reddish brown	13	33
Sand, medium to coarse	5	38
Gravel, fine to medium	12	50
Sand, coarse; gravel, fine to medium	4	54

1S19W-14. 115 feet east and 15 feet south of NW cor. Sample log. Altitudes: land surface, 1,260; water table, 1,240; bedrock, 1,210.

Sand, dark brown, fine	5	5
Clay, dark brown, sandy	5	10
Clay, dark brown to reddish brown, sandy; caliche	5	15
Sand, brown, medium, clayey; caliche	5	20
Sand, brown, medium	5	25
Sand, coarse; gravel, fine; clay, brown, sandy; caliche	5	30
Sand, brown, coarse	7	37
Gravel, medium	13	50
Red beds	--	--

1S19W-16. 45 feet east and 10 feet south of NW cor. Sample log. Altitudes: land surface, 1,245; water table, 1,241; bedrock, 1,214.

	Thickness (feet)	Depth (feet)
Sand, dark brown, medium, clayey	5	5
Sand, coarse; gravel, fine; clay streaks, brown	5	10
Gravel, medium; sand, coarse; clay, brown; caliche	5	15
Gravel, coarse	16.5	31.5
Red beds	--	--

1S19W-21-7. NW¼SW¼. Sample log.

Sand, fine to medium	10	10
Sand, coarse; gravel, fine	10	20
Sand, coarse; gravel, fine to medium	10	30
Gravel, medium	3	33
Red beds	--	--

1S19W-23. 70 feet west and 15 feet north of SE cor. Sample log. Altitudes: land surface, 1,259; water table, 1,230; bedrock, 1,220.

Sand, red, medium; clay, red	5	5
Sand, red, coarse	10	15
Sand, red, coarse, clayey	5	20
Sand, brown, medium, clayey	5	25
Gravel, clayey	1	26
Clay, reddish brown, sandy; caliche	4	30
Sand, reddish brown, medium; clayey; gravel, fine	5	35
Gravel, medium; sand, coarse; caliche	4	39
Red beds	--	--

1S19W-27-1. 65 feet south and 15 feet west of NE cor. Sample log. Altitudes: land surface, 1,235; water table, 1,219; bedrock, 1,207.

Clay, dark gray, sandy, fossiliferous	10	10
Clay, light gray and reddish brown, sandy	10	20
Sand, medium brown; caliche	5	25
Gravel, medium; sand, coarse	3	28
Red beds	--	--

1S19W-29-4. 42 feet north and 18 feet west of SE cor. Sample log. Altitudes: land surface, 1,226; water table, 1,219; bedrock, 1,195.

Silt, brown; sand, medium to very coarse	5	5
Sand and clay, brown	4	9
Sand, very coarse; gravel, fine	6	15
Gravel, fine to medium, arkosic sand, very coarse	10	25
Gravel, fine to medium	6	31
Red beds	--	--

1S19W-36. 75 feet north and 20 feet east of SW cor. Sample log. Altitudes: land surface, 1,267; water table, 1,251; bedrock, 1,242.

Clay, dark reddish brown, sandy	5	5
Clay, reddish brown, sandy; gravel, fine; caliche	10	15
Clay, reddish brown, sandy; caliche	5	20
Clay, reddish brown, sandy; gravel, fine; caliche	5	25
Red beds	--	--

2S18W-1-2. 18 feet south and 50 feet east of NW cor. Sample log. Altitudes: land surface, 1,352; bedrock 1,297.

	Thickness (feet)	Depth (feet)
Clay, brown, sandy	5	5
Sand and clay, brown	6	11
Sand, medium, argillaceous	9	20
Sand, medium to coarse, argillaceous; caliche	9	29
Clay, light gray and brown	1	30
Sand, brown, medium	1	31
Clay, greenish gray to brown, sandy	4	35
Clay, gray	5	40
Clay, gray, sandy, shell fragments, sandy; caliche	9	49
Sand, very coarse; gravel, fine	6	55
Red beds	--	--

2S18W-3-1. NE cor. NW¼. Driller's log supplied by Layne-Western Co.

Soil, sandy	1	1
Clay, black, sandy	2	3
Clay, red	18	21
Sand, fine	4	25
Clay, red	2	27
Sand, fine	7	34
Clay, red	2	36
Sand, fine	2	38
Clay, red	1	39
Sand, fine; clay streaks	7	46
Gravel, coarse	3	49
Red beds	--	--

2S18W-3-2. 1320 feet east of NW cor. Driller's log supplied by Layne-Western Co.

Soil, sandy	1	1
Clay, black, sandy	3	4
Clay, red	7	11
Clay, yellow and red	7	18
Sand, fine; clay streaks	8	26
Sand, fine; limestone streaks	4	30
Sand, fine; clay streaks	16	46
Red beds	--	--

2S18W-3-3. NW cor. Driller's log supplied by Layne-Western Co.

Soil, sandy	1	1
Sand, fine; clay	4	5
Clay, red, hard	5	10
Clay, blue, soft	5	15
Clay, red, soft	8	23
Sand, mucky	2	25
Sand, fine	5	30
Sand, medium to fine	10	40
Clay, blue	1	41
Rock	.5	41.5
Sand, coarse; gravel	6.5	48
Red beds	--	--

2S18W-3-4. 1,410 feet east and 231 feet south of W¼ cor. Driller's log supplied by Layne-Western Co.

Soil	1	1
Clay, red, sandy	2	3
Clay, gray, tough	11	14
Clay, red and gray, sandy	6	20

2S18W-3-4.--Continued.

	Thickness (feet)	Depth (feet)
Sand, fine; clay, streaks	10	30
Sand, fine	4	34
Sand, fine	6	40
Sand, fine to coarse	10	50
Sand, medium to coarse; gravel	6	56
Red beds	--	--

2S18W-3-5. 1,320 feet east of W¼ cor. Driller's log supplied by Layne-Western Co.

Soil, sandy	1	1
Clay, brown, sandy	2	3
Clay, blue	6	9
Sand, fine	1	10
Clay, red; sand, fine	4	14
Clay, red, hard	1	15
Sand, fine; clay, streaks	4	19
Clay; sand, fine	6	25
Caliche	1	26
Sand, fine	5	31
Clay, red, soft; caliche	4	35
Sand, fine	11	46
Rocks	1	47
Sand, medium to fine	3	50
Sand, coarse; boulders	3	53

2S18W-3-6. 610 feet east and 231 feet south of W¼ cor. Driller's log supplied by Layne-Western Co.

Soil	1	1
Clay, sandy	4	5
Clay, orange and yellow; gravel	7	12
Sand, fine; clay	8	20
Sand, fine; clay	5	25
Sand, medium to fine; clay streaks	5	30
Sand, fine	5	35
Sand, medium to coarse; clay	5	40
Sand; gravel	9.5	49.5
Red beds	--	--

2S18W-3-7. NW cor. SW¼. Driller's log supplied by Layne-Western Co.

Soil, brown, sandy	4	4
Clay, red	5	9
Sand, fine; clay, streaks	19	28
Clay, red	1	29
Sand, fine	18	47
Boulders	1	48
Sand, medium to coarse	2	50
Red beds	--	--

2S18W-3-8. 210 feet east and 1,659 feet north of SW cor. Driller's log supplied by Layne-Western Co.

Soil	1	1
Clay, red, sandy	3	4
Clay; gravel	10	14
Sand; clay, streaks	6	20
Sand, fine	10	30
Sand, fine; clay streaks	10	40
Sand, fine to medium; gravel	15	55
Red beds	--	--

2S18W-3-9. 810 feet east and 1,659 feet north of SW cor. Driller's log supplied by Layne-Western Co.

	Thickness (feet)	Depth (feet)
Soil	1	1
Clay, brownish gray	4	5
Clay, red; gravel	12	17
Sand, red, fine	8	25
Sand, red, fine; clay	5	30
Sand, fine to medium; clay, streaks	5	40
Sand, brown, medium to coarse, tight	5	45
Sand, coarse; gravel	4	49
Sand; gravel	5	54
Red beds	--	--

2S18W-3-10. 1,010 feet east and 1,659 feet north of SW cor. Driller's log supplied by Layne-Western Co.

Soil	1	1
Clay, gray	4	5
Clay, red; gravel	8	13
Clay, sandy	7	20
Sand, fine; clay	5	25
Sand, brown, fine	5	30
Sand, fine; clay, streaks	10	40
Sand, medium, tight	5	45
Sand, medium to coarse; gravel	5	50
Sand, gravel	5	55
Red beds	--	--

2S18W-3-11. 1,006 feet west and 1,659 feet north of S¼ cor. Driller's log supplied by Layne-Western Co.

Soil	1	1
Clay, red, hard	9	10
Clay, sandy	5	15
Clay	5	20
Sand; clay	5	25
Clay	5	30
Sand, fine	5	35
Sand, fine to medium, tight; clay	5	40
Sand, medium, tight; clay	5	45
Sand; gravel; clay	5	50
Sand; gravel	3.5	53.5
Red beds	--	--

2S18W-3-12. 806 feet west and 1,659 feet north of S¼ cor. Driller's log supplied by Layne-Western Co.

Soil	1	1
Clay, tough	11	12
Clay, sandy; sand streaks	8	20
Sand, fine; clay	5	25
Clay; sand; rock	6	31
Sand, fine; clay, streaks	9	40
Sand, medium to coarse, tight, clay, streaks	9	49
Sand; coarse, tight; gravel; clay	6	54
Red beds	--	--

2S18W-3-13. 606 feet west and 1,659 feet north of S¼ cor. Driller's log supplied by Layne-Western Co.

Soil	1	1
Clay	13	14
Sand; clay	6	20
Sand, fine; clay, streaks	7	27

2S18W-3-13.--Continued.

	Thickness (feet)	Depth (feet)
Clay	3	30
Sand, fine	3	33
Clay	2	35
Sand, fine	5	40
Sand, coarse; clay streaks	5	45
Sand, coarse, clayey	5	50
Sand; gravel; clay, streaks	5	55
Red beds	--	--

2S18W-3-14. 306 feet west and 1,659 feet north of S¼ cor. Driller's log supplied by Layne-Western Co.

Soil	1	1
Clay, gray	4	5
Clay, red	7	12
Sand, fine; clay, streaks	8	20
Clay, red, hard	20	25
Sand, medium; clay streaks	10	35
Sand, cemented, tight	2	37
Sand, medium, tight; clay	13	50
Sand, coarse; clay	5	55
Red beds	--	--

2S18W-3-15. 895 feet west and 859 feet north of S¼ cor. Driller's log supplied by Layne-Western Co.

Soil	1	1
Clay, hard	7	8
Clay, soft, sandy	2	10
Clay, red, hard	3	13
Clay; sand	7	21
Sand; fine	5	26
Clay	3	29
Sand, fine; clay	6	35
Clay	3	38
Sand, medium to coarse	8	46
Clay	2	48
Clay; sand; gravel	5	53
Red beds	--	--

2S18W-3-16. 1,395 feet west and 859 feet north of S¼ cor. Driller's log supplied by Layne-Western Co.

Soil	1	1
Clay, red, hard	2	3
Clay, gray	3	6
Clay, red, tough	6	12
Clay, sandy; sand streaks	14	26
Clay, soft; sand streaks	11	37
Clay	3	40
Sand, fine	5	45
Sand, medium to coarse	5	50
Sand, medium to coarse; gravel; clay	5	55
Red beds	--	--

2S18W-3-17. 1,695 feet west and 859 feet north of S¼ cor. Driller's log supplied by Layne-Western Co.

Soil	1	1
Clay, red	2	3
Clay, gray	11	14
Clay, red	3	17
Sand, fine; clay streaks	16	33
Clay	6	39
Sand, fine; clay streaks	6	45
Sand, medium to coarse, tight; clay	5	50
Sand; gravel	3	53

2S18W-3-17.--Continued.

	Thickness (feet)	Depth (feet)
Clay	1	54
Gravel	1	55
Red beds	--	--

2S18W-3-19. SW cor. SW¼. Driller's log supplied by Layne-Western Co.

Soil, sandy	1	1
Clay, black, sandy	5	6
Clay, brown, soft	4	10
Clay, red, soft	7	17
Clay, yellow, hard	1	18
Sand, fine	3	21
Clay, red	.5	21.5
Sand, fine	3.5	25
Clay, red	1	26
Sand, fine	7	33
Clay, red	1	34
Sand, fine	3	47
Sand, fine to medium	8	55
Red beds	--	--

2S18W-3-20. 534 feet east of SW cor. Driller's log supplied by Layne-Western Co.

Soil	1	1
Clay, red	20	21
Sand, fine; clay, streaks	10	31
Clay; sand	5	36
Sand, medium; clay	7	43
Sand, fine to medium	5	48
Sand; gravel	7	55
Red beds	--	--

2S18W-3-21. 1,084 feet east of SW cor. Driller's log supplied by Layne-Western Co.

Soil	1	1
Clay, gray	6	7
Clay, red, hard	5	12
Clay, sandy	10	22
Sand, fine; clay streaks	8	30
Clay; sand streaks	13	43
Sand, medium; clay streaks	4	47
Sand; gravel	8	55
Red beds	--	--

2S18W-3-22. 1,320 feet east of SW cor. Driller's log supplied by Layne-Western Co.

Soil, sandy	1	1
Clay, brown, sandy	4	5
Clay, red, hard; caliche	6	11
Sand, fine; clay streaks	6	17
Clay, red, soft	2	19
Sand, fine	8	27
Clay, red	2	29
Caliche	.5	30.5
Sand, fine	2.5	33
Sand, fine; clay streaks	14	47
Boulders	1.5	48.5
Sand, coarse; gravel	5.5	55
Red beds	--	--

2S18W-3-23. 31 feet north and 200 feet west of S¼ cor. Driller's log supplied by Layne-Western Co.

	Thickness (feet)	Depth (feet)
Clay, dark brown, silty	5	5
Clay, reddish, sandy	9	14
Sand, reddish brown, fine; clay lenses, red	24	38
Sand, cemented; clay streaks, dark brown	1	39
Sand, brown, coarse	14	53
Gravel, coarse	6	59
Red beds	--	--

2S18W-3-24. 53 feet north and 100 feet west of S¼ cor. Driller's log supplied by Layne-Western Co.

Clay, dark brown, silty	4	4
Clay, brownish gray, silty	2	6
Clay, brown, gray, red; gravel	8	14
Sand, red, fine; clay lenses, red	8	22
Sand, yellow, fine	5	27
Sand, reddish yellow, fine; clay lenses, red	11	38
Clay, red, sandy	2	40
Sand, coarse	19	59
Red beds	--	--

2S18W-3-25. 75 feet north and 11 feet west of S¼ cor. Driller's log supplied by Layne-Western Co.

Clay, dark brown, silty	5	5
Clay, light gray	3	8
Clay, red, gray, brown, sandy	6	14
Sand, red, fine; clay lenses, red	21	35
Clay, red	2	37
Sand, brown, fine	7	44
Sand, brown, medium	6	50
Sand, brown, coarse; gravel	10	60
Red beds	--	--

2S18W-3-26. 43 feet west of S¼ cor. Driller's log supplied by Layne-Western Co.

Soil, sandy	1	1
Clay, black, sandy	2	3
Clay, brown, hard	9	12
Clay, yellow, soft	4	16
Sand, fine	7	25
Sand, fine; clay streaks	18	38
Clay, red, soft	2	40
Sand, fine	15	55
Rocks	.5	55.5
Sand, coarse; gravel	4.5	60
Red beds	--	--

2S18W-3-27. 9 feet north and 306 feet east of S¼ cor. Driller's log supplied by Layne-Western Co.

Clay loam, dark brown, silty	5	5
Clay, red	10	15
Sand, brown, fine; clay lenses, red	39	54
Gravel, coarse	6	60
Red beds	--	--

2S18W-3-28. 1,320 feet west of SE cor. Driller's log supplied by Layne-Western Co.

	Thickness (feet)	Depth (feet)
Soil, sandy	1	1
Clay, brown, sandy	3	4
Clay, red	8	12
Clay, red; sand, fine, streaks	4	16
Sand, fine; clay streaks, red	8	24
Caliche	.5	24.5
Sand, fine; clay streaks	18.5	43
Sand, fine; caliche streaks	2	45
Sand, fine; clay streaks	5	50
Sand, fine to medium	4	54
Clay, red	1	55
Sand, fine to medium	3	58
Red beds	--	--

2S18W-4-1. 1,320 feet west of NE cor. Driller's log supplied by Layne-Western Co.

Soil	1	1
Clay, black, sandy	4	5
Clay, red, soft	5	10
Clay, blue, soft	4	14
Clay, yellow	3	17
Sand, fine	10	27
Sand, fine; clay streaks	3	30
Sand, fine	5	35
Clay, red	1	36
Boulders	1	37
Sand, fine to medium	4	41
Red beds	--	--

2S18W-4-2. NE cor. NW¼. Driller's log supplied by Layne-Western Co.

Soil, black, sandy	1	1
Sand, fine; clay	5	6
Clay, red	4	10
Clay, yellow	7	17
Sand, fine	11	28
Clay, red	.5	28.5
Sand, fine	11.5	40
Red beds	--	--

2S18W-6-1. 50 feet west and 15 feet south of NE cor. Sample log. Altitudes: land surface, 1,318; water table, 1,313; bedrock, 1,301.

Clay, dark gray, sandy; caliche	5	5
Clay, dark gray and brown, sandy; caliche	11	16
Claiche	1	17
Red beds	--	--

2S18W-9-1. 100 feet north and 15 feet east of SW cor. Sample log. Altitudes: land surface, 1,337; water table, 1,310; bedrock, 1,280.

Clay, reddish brown, sandy	20	20
Clay, reddish brown, sandy; caliche	17	37
Sand, brown, medium; clay, reddish brown, sandy, streaks; caliche	6	43
Sand, coarse; gravel, fine; clay, reddish brown, sandy, calcareous	12	55
Gravel, medium; sand, coarse	2	57
Red beds	--	--

2S18W-9-2. 165 feet south and 27 feet west of NE cor. Driller's log supplied by Layne-Western Co.

	Thickness (feet)	Depth (feet)
Clay loam, brown, silty	3	3
Clay, red, sandy	7	10
Sand, red, clayey	4	14
Sand, red, fine	6	20
Sand, reddish brown, fine; clay lenses	10	30
Sand, light brown, medium; clay lenses, red	15	45
Sand, light brown, coarse	9	54
Red beds	---	---

2S18W-10-1. 20 feet east of W¼ cor. Driller's log supplied by Layne-Western Co.

Clay loam, dark brown, silty	3	3
Clay, blue	5	8
Clay, reddish brown, sandy	6	14
Sand, reddish brown, fine	6	20
Sand, light brown, medium; clay lenses, red	34	54
Red beds	---	---

2S18W-10-2. 92 feet north and 19 feet east of SW cor. Driller's log supplied by Layne-Western Co.

Clay loam, brown, silty	3	3
Clay, blue	7	10
Sand, reddish brown, fine; clay lenses, red	30	40
Sand, light brown, medium; clay lenses, red	7	47
Sand, brown, coarse	2	49
Red beds	---	---

2S18W-18. 100 feet south and 15 feet west of NE cor. Sample log. Altitudes: land surface, 1,333; water table, 1,316; bedrock, 1,302.

Clay, reddish brown, sandy; sand, reddish brown, clayey	10	10
Clay, reddish brown, sandy	15	25
Clay, reddish brown, sandy; caliche	7	32
Red beds	---	---

2S18W-27. 65 feet south and 15 feet west of NE cor. Sample log. Altitudes: land surface, 1,295; water table, 1,289; bedrock, 1,274.

Soil	2	2
Clay, brown and gray, sandy, calcareous	5	7
Sand, medium; gravel, fine	3	10
Sand, medium; gravel, fine; clay, reddish brown; caliche	5	15
Sand, coarse; gravel, medium	6	21
Red beds	---	---

2S18W-28-1. 180 feet south and 12 feet west of NE cor. Sample log. Altitudes: land surface, 1,317; water table, 1,298; bedrock, 1,281.

	Thickness (feet)	Depth (feet)
Clay, dark reddish brown, sandy; soil	8	8
Caliche, streak	1	9
Clay, dark reddish brown, sandy	1	10
Sand, brown, coarse	20	30
Sand, medium; clay, reddish brown; caliche	4	34
Gravel, medium; sand, coarse	2	36
Red beds	---	---

2S18W-28-2. 250 feet east and 25 feet south of NW cor. Sample log. Altitudes: land surface, 1,309; water table, 1,280; bedrock, 1,276.

Clay, reddish brown to dark brown, sandy	5	5
Clay, reddish brown, sandy; caliche	10	15
Caliche; clay, reddish brown, sandy	6	21
Gravel, medium; sand, coarse	12	33
Red beds	---	---

2S18W-30-1. 50 feet west and 25 feet south of NE cor. Sample log. Altitudes: land surface, 1,299; water table, 1,267.

Clay, dark brown, sandy	5	5
Sand, dark brown, fine, clayey	4	9
Sand, brown, fine	1	10
Clay, dark brown and gray, sandy; gravel, fine	5	15
Clay, reddish brown and gray, sandy	5	20
Clay, brown, sandy; caliche	5	25
Clay, brown and gray; sand, medium; gravel, fine; caliche	7	32
Red beds	---	---

2S19W-3. 90 feet north and 21 feet west of SE cor. Sample log. Altitudes: land surface, 1,261; water table, 1,239; bedrock, 1,224.

Clay and sand, brown	5	5
Clay and sand, reddish brown	5	10
Clay and sand, reddish brown; caliche; gravel, medium	5	15
Sand, brown, medium to very coarse, argillaceous; caliche	5	20
Sand, brown, coarse, argillaceous	7	27
Clay and sand, brown; gravel, medium	3	30
Gravel, medium, arkosic; sand, very coarse	7	37
Red beds	---	---

2S19W-5. 240 feet east and 10 feet south of NW cor. Sample log. Altitudes: land surface, 1,217; water table, 1,213; bedrock, 1,184.

Sand, dark brown, coarse, clayey	5	5
Clay, reddish brown and brown, sandy; caliche	10	15
Sand, brown, medium; gravel, fine; clay, brown, sandy	5	20
Sand, coarse; gravel, fine; clay, dark gray, blue gray, light and dark brown	5	25
Gravel, medium; sand, coarse	8	33
Red beds	---	---

2S19W-9. 18 feet south and 48 feet east of NW cor. Sample log. Altitudes: land surface, 1,223; water table, 1,212; bedrock, 1,192.

	Thickness (feet)	Depth (feet)
Sand, brown, coarse	5	5
Sand and clay, reddish brown; caliche	5	10
Sand, brown, medium, argillaceous	4	14
Clay, brown	1	15
Gravel, fine to medium; sand, very coarse	16	31
Red beds	---	---

2S19W-23. 90 feet west and 15 feet north of SE cor. Sample log. Altitudes: land surface, 1,260; water table, 1,236; bedrock, 1,202.

Sand, brown, medium	7	7
Clay, gray, sandy; caliche	3	10
Clay, gray and brown, sandy; caliche	5	15
Clay, reddish brown, sandy; caliche	10	25
Clay, brown and gray, sandy; caliche	8	33
Caliche, streak	1	34
Clay, brown and gray, sandy; caliche	2	36
Gravel, medium; sand, coarse	9	45
Gravel, medium; sand, medium; clay streak, reddish brown	10	55
Gravel, medium	3	58
Red beds	---	---

3S18W-2. 100 feet south and 21 feet east of NW cor. Sample log. Altitudes: land surface, 1,225; water table, 1,206; bedrock, 1,199.

Clay, dark brown to reddish brown, sandy	5	5
Clay, reddish brown, sandy; caliche; sand, medium	5	10
Clay, reddish brown, sandy; caliche	9	19
Gravel, medium to coarse	7	26
Red beds	---	---

3S18W-4-2. 21 feet south and 63 feet east of NW cor. Sample log. Altitudes: land surface, 1,288; water table, 1,276; bedrock, 1,264.

Clay, dark gray; caliche; clay, brown, sandy	5	5
Clay, light gray, sandy	10	15
Clay, light gray and light brown, sandy	4	19
Sand, medium to coarse	5	24
Red beds	---	---

3S18W-14. 100 feet east and 15 feet south of NW cor. Sample log. Altitudes: land surface, 1,188; water table, 1,181; bedrock, 1,169.

Clay, dark gray and reddish brown, sandy; caliche	5	5
Clay, reddish brown, sandy; caliche	12	17
Gravel, medium; sand, coarse	2	19
Red beds	---	---

3S18W-15. 90 feet east and 20 feet south of NW cor. Sample log. Altitudes: land surface, 1,199; water table, 1,183; bedrock, 1,174.

	Thickness (feet)	Depth (feet)
Clay, dark reddish brown, sandy	5	5
Clay, dark brown; sand, medium; gravel, fine; caliche	5	10
Sand, medium; gravel, fine	4	14
Sand, brown, medium, clayey	2	16
Clay, reddish brown, sandy; caliche	10	26
Red beds	---	---

3S18W-16. 100 feet east and 12 feet south of NW cor. Sample log. Altitudes: land surface, 1,226; water table, 1,214; bedrock, 1,210.

Sand, brown, medium; gravel, fine	5	5
Sand, dark brown, medium, clayey; caliche	10	15
Gravel, fine; sand, coarse	1	16
Red beds	---	---

3S18W-18-1. 85 feet west and 15 feet south of NE cor. Sample log. Altitudes: land surface, 1,260; bedrock, 1,241.

Clay, dark brown, sandy	3	3
Sand, brown, coarse	2	5
Clay, brown, silty, sandy; caliche	9	14
Gravel, medium; sand, coarse	5	19
Red beds	---	---

3S18W-22-1. 120 feet east and 10 feet north of SW cor. Sample log. Altitudes: land surface, 1,176; water table, 1,171; bedrock, 1,160.

Clay, dark brown, sandy, silty; soil	5	5
Clay, dark gray to brown; caliche	6	11
Silt, dark brown; clay, reddish brown; caliche	4	15
Red beds	---	---

3S18W-22-2. 65 feet north and 15 feet west of SE cor. Sample log. Altitudes: land surface, 1,176; water table, 1,167; bedrock, 1,159.

Clay, dark gray, sandy; calcareous; soil	5	5
Clay, reddish brown and light gray, sandy; caliche; sand, fine	10	15
Clay, reddish brown, sandy; caliche	2	17
Red beds	---	---

3S18W-26. NE cor. Sample log. Altitudes: land surface, 1,168; water table, 1,154; bedrock, 1,130.

Clay, dark brown, sandy; caliche	12	12
Sand, coarse; gravel, medium	13	25
Clay, reddish brown, sandy; sand, coarse; gravel, fine; calcareous	5	30
Sand, coarse; gravel, medium	8	38
Red beds	---	---

3S18W-28. 90 feet south and 15 feet east of NW cor. Sample log. Altitudes: land surface, 1,186; water table, 1,168; bedrock, 1,143.

	Thickness (feet)	Depth (feet)
Sand, brown, medium	2	2
Clay, dark brown, sandy	3	5
Clay, gray, sandy; caliche	5	10
Silt, light reddish brown and gray, clayey	5	15
Clay, reddish brown, sandy; calcareous	10	25
Clay, reddish brown and gray, sandy; caliche	5	30
Clay, reddish brown, sandy; caliche	13	43
Red beds	--	--

3S18W-29. 100 feet east and 15 feet south of NW cor. Sample log. Altitudes: land surface, 1,196; water table, 1,186; bedrock, 1,173.

Clay, dark brown, sandy; calcareous	5	5
Clay, reddish brown, sandy; caliche	15	20
Clay, reddish brown, sandy; caliche; gravel, fine, few	3	23
Red beds	--	--

3S18W-35. 170 feet north and 20 feet east of SW cor. Sample log. Altitudes: land surface, 1,147; water table, 1,129; bedrock, 1,093.

Clay, dark brown and tan, sandy	10	10
Sand, brown, fine	5	15
Sand, medium; clay, reddish brown	5	20
Clay, reddish brown, sandy; caliche	15	35
Sand, medium, calcareous; clay, reddish brown	3	38
Gravel, fine; sand, coarse; clay streak, reddish brown; caliche	7	45
Sand, medium; gravel, fine; clay streak, reddish brown	9	54
Red beds	--	--

3S18W-36. 200 feet east and 10 feet north of SW cor. Sample log. Altitudes: land surface, 1,150; water table, 1,133; bedrock, 1,105.

Clay, dark brown, sandy	10	10
Clay, reddish brown, sandy; caliche	15	25
Clay, reddish brown; sand, brown, fine; clayey; caliche	10	35
Sand, brown, medium, clayey	5	40
Sand, medium; gravel, fine; clay, reddish brown	5	45
Red beds	--	--

3S19W-2-3. NW¼NE¼. Sample log.

Sand, brown, fine to medium	8	8
Sand, reddish brown, medium, argillaceous; caliche	2	10
Sand, reddish brown, clay streaks	10	20
Sand, brown, fine to medium, argillaceous	18	38
Sand, coarse; gravel, fine; clay streaks	7	45
Sand, very coarse; gravel, fine	5	50
Gravel, fine to coarse	8	58
Red beds	--	--

3S19W-11-1. 90 feet east and 12 feet north of SW cor. Sample log. Altitudes: land surface, 1,224; water table, 1,214; bedrock, 1,186.

	Thickness (feet)	Depth (feet)
Sand, dark brown, fine, clayey, calcareous	5	5
Sand, fine; clay, gray and reddish brown	8	13
Sand, brown, medium	11	24
Clay, red, sandy	1	25
Clay, reddish brown, sandy, calcareous	5	30
Clay, reddish brown, sandy	6	36
Gravel, medium	2	38
Red beds	--	--

3S19W-12. 170 feet east and 10 feet north of SW cor. Sample log. Altitudes: land surface, 1,245; water table, 1,228; bedrock, 1,206.

Clay, dark brown, sandy	5	5
Sand, medium; clay, yellowish brown and gray, calcareous	10	15
Clay, reddish brown and gray, sandy, calcareous	5	20
Sand, fine, clayey; clay, reddish brown	5	25
Sand, reddish brown, medium, clayey; caliche	5	30
Sand, brown, fine	9	39
Red beds	--	--

3S19W-23. 50 feet north and 15 feet west of SE cor. Sample log. Altitudes: land surface, 1,195; water table, 1,180; bedrock, 1,158.

Clay, dark brown and tan, sandy; calcareous	4	4
Sand, brown, medium, clayey	3	7
Sand, brown, medium; caliche streaks	8	15
Clay, reddish brown, sandy; gravel, fine; caliche	12.5	27.5
Sand, brown, coarse; gravel, medium	9.5	37
Red beds	--	--

3S19W-26. 25 feet south and 25 feet east of NW cor. Sample log. Altitudes: land surface, 1,187; water table, 1,173; bedrock, 1,146.

Clay, dark brown, sandy	5	5
Sand, tan, medium	5	10
Sand, yellow stained, medium, clayey; clay, gray and brown, sandy	12	22
Clay, reddish brown, sandy	3	25
Sand, tan, medium; clay streak, reddish brown, sandy	5	30
Sand, tan, coarse	5	35
Sand, coarse; gravel, fine, clayey	5	40
Red beds	--	--

3S19W-28-1. 15 feet west and 10 feet south of NE cor. Sample log. Altitudes: land surface, 1,169; water table, 1,158; bedrock, 1,119.

	Thickness (feet)	Depth (feet)
Sand, brown, medium; gravel, fine; clay streaks, reddish brown	22	22
Sand, brown, medium	3	25
Gravel, medium; sand, coarse	12	37
Gravel, medium; sand, coarse; clay, streaks, reddish brown	8	45
Gravel, medium; sand, coarse	6	51
Red beds	--	--

4S18W-4-1. 250 feet west and 15 feet south of NE cor. Sample log. Altitudes: land surface, 1,176; water table, 1,155; bedrock, 1,111.

Clay, dark brown, sandy	5	5
Clay, dark brown, sandy; sand, gray, clayey; caliche	5	10
Sand, reddish brown, medium, clayey	10	20
Clay, reddish brown, sandy	5	25
Sand, brown, medium	14	39
Gravel, fine	1	40
Sand, medium, clayey; gravel; caliche	5	45
Clay, reddish brown and gray, sandy, fossiliferous	10	55
Gravel, medium; sand, medium	10	65
Red beds	--	--

4S18W-5-1. 120 feet west and 15 feet south of NE cor. Sample log. Altitudes: land surface, 1,177; water table, 1,160; bedrock, 1,112.

Clay, dark brown, sandy	5	5
Sand, reddish brown and gray, medium, clayey	15	20
Sand, fine; clay streaks, reddish brown	15	35
Sand, brown, medium	5	40
Sand, medium, clayey; caliche	5	45
Sand, fine; gravel, fine	5	50
Sand, coarse; gravel; clay, reddish brown; caliche	5	55
Gravel, medium	5	60
Sand, brown, medium, clayey; gravel	5	65
Red beds	--	--

4S18W-5-2. 40 feet east and 15 feet south of NW cor. Sample log. Altitudes: land surface, 1,184; water table, 1,164; bedrock, 1,115.

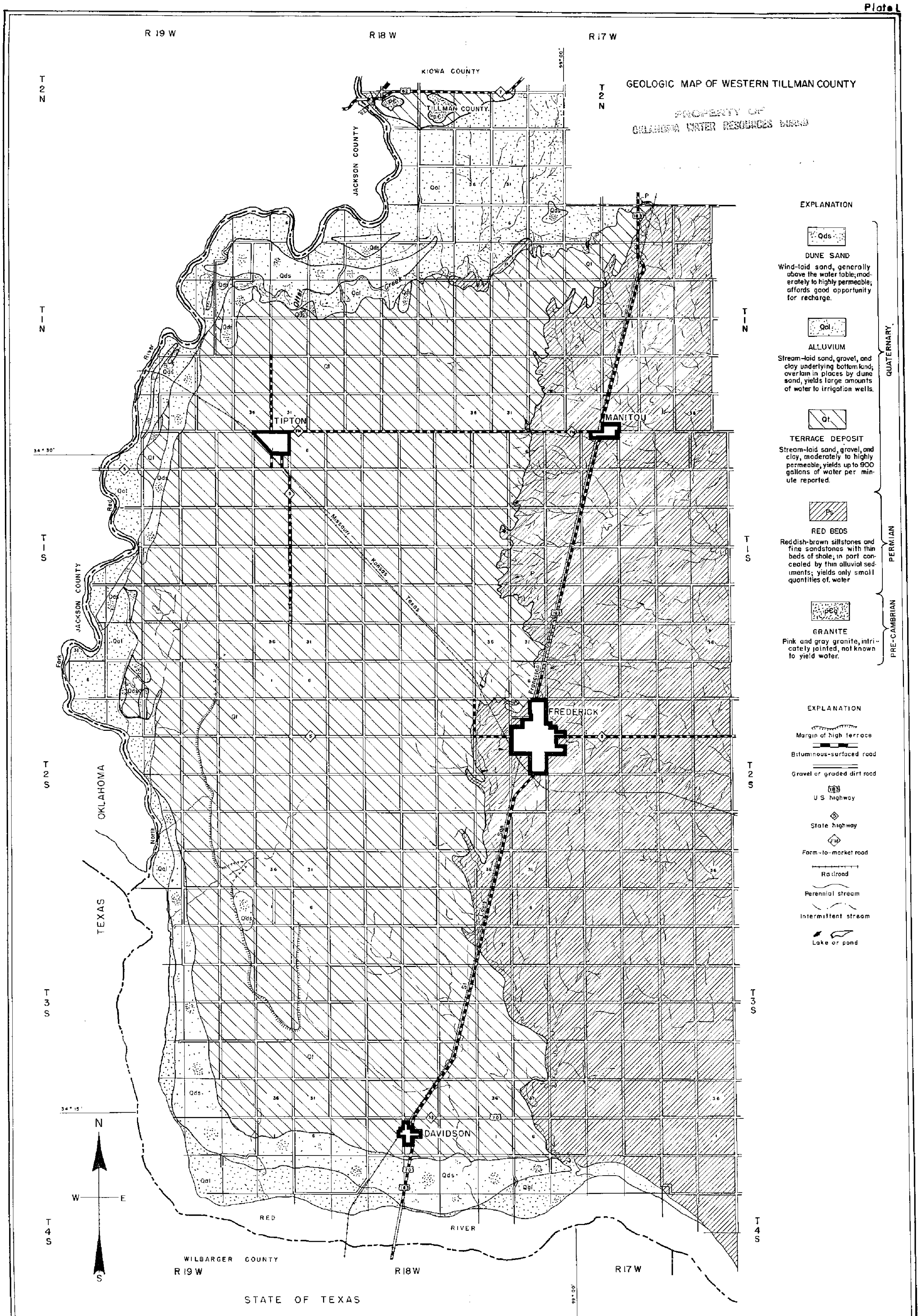
	Thickness (feet)	Depth (feet)
Clay, dark brown, sandy	5	5
Sand, fine; clay, gray and brown, yellow stain, calcareous	5	10
Sand, medium, clayey; caliche	5	15
Sand, brown, medium, clayey	5	20
Sand, brown, medium; gravel, fine; clay, red	5	25
Sand, medium; gravel, fine	5	30
Sand, medium; clay, red, sandy	5	35
Sand, brown, fine	3	38
Sand, brown, medium, clayey	11	49
Gravel, fine; sand, coarse	1	50
Sand, medium; clay, reddish brown and gray; gravel, fine	5	55
Gravel, fine; sand, medium	5	60
Sand, coarse; clay, reddish brown; gravel, medium; caliche	5	65
Gravel, medium	4	69
Red beds	--	--

4S18W-6-1. SE¼NE¼. Sample log.

Sand, brown, fine to medium	12	12
Clay, brown, sandy	1	13
Sand, medium; clay streaks, sandy	5	18
Clay, gray, sandy	2	20
Sand, brown, fine to medium; clay streaks	10	30
Sand, brown, medium	11	41
Clay, brown, sandy	2	43
Sand, brown, fine to medium	7	50
Sand, medium to coarse	8	58
Gravel, fine to medium; sand, coarse	2	60
Gravel, medium to coarse	11	71
Gravel, fine to medium; sand, coarse	5	76
Red beds	--	--

4S19W-2. 40 feet west and 10 feet south of NE cor. Sample log. Altitudes: land surface, 1,179; water table, 1,170; bedrock, 1,128.

Sand, brown and gray, fine	20	20
Sand, brown, medium; caliche	5	25
Sand, brown and gray, fine, clayey; caliche	3	30
Sand, brown, fine, clayey	3	33
Gravel, medium; sand, coarse	18	51
Red beds	--	--



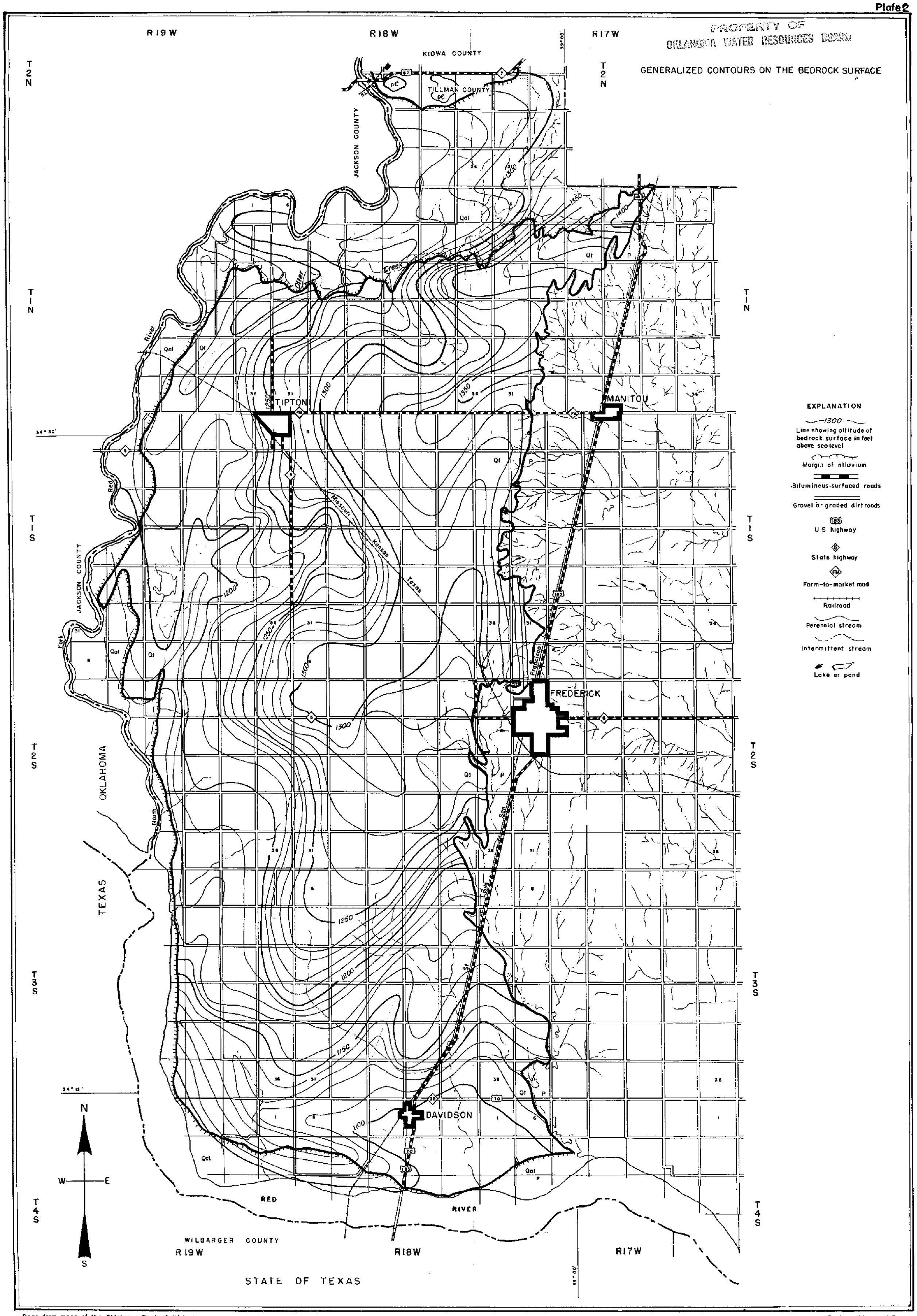
Base from maps of the Oklahoma Dept. of Highways
Drainage from aerial photographs

Geology By Lee C. Burton

GEOLOGIC MAP OF WESTERN TILLMAN COUNTY, OKLAHOMA

0 1 2 3 4 5 Miles

Plate 2



Base from maps of the Oklahoma Dept. of Highways
Drainage from aerial photographs

Contoured by Lee C. Burton

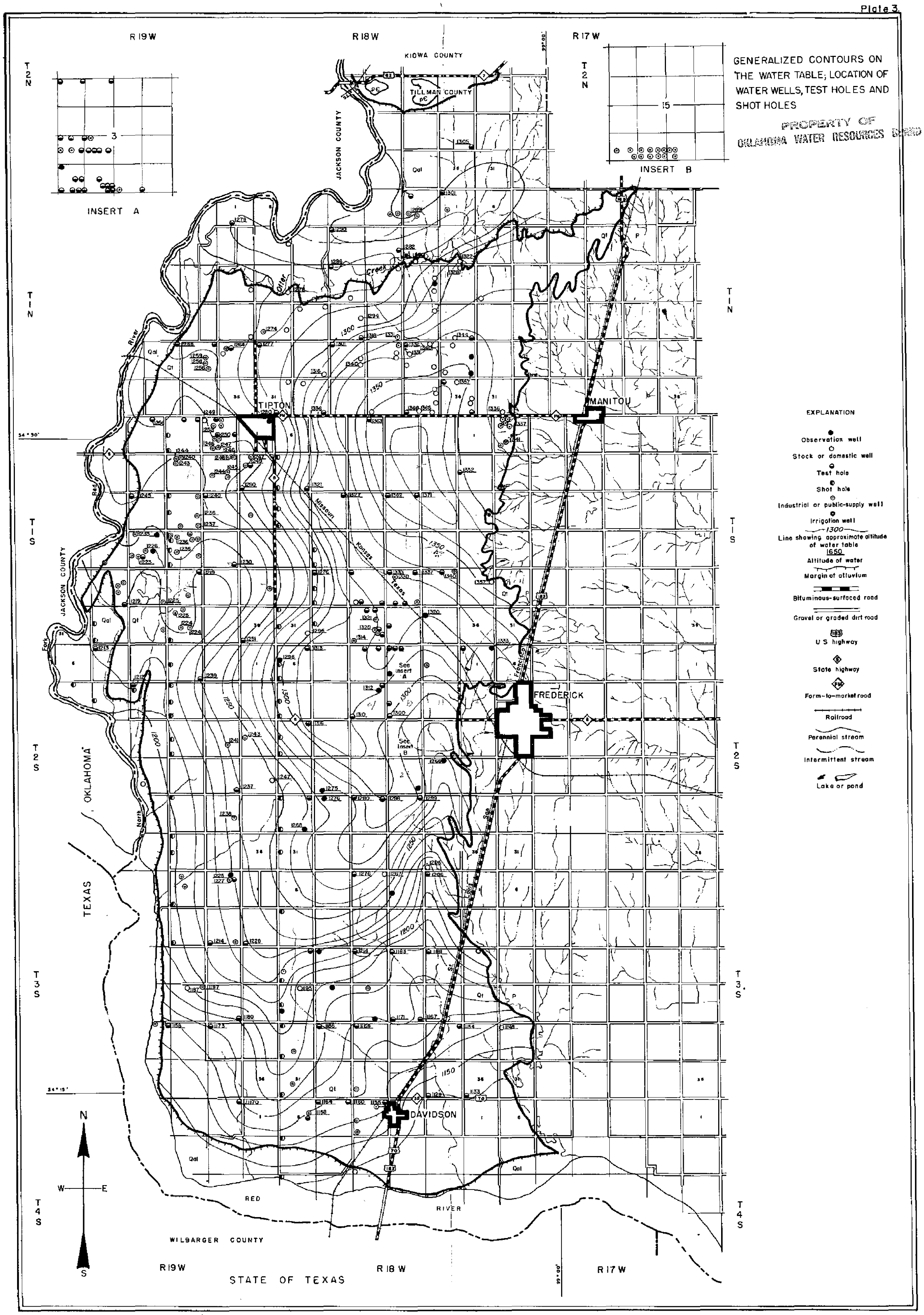
MAP OF WESTERN TILLMAN COUNTY, OKLAHOMA

SHOWING

GENERALIZED CONTOURS ON THE BEDROCK SURFACE

1 0 1 2 3 4 5 Miles

CONTOUR INTERVAL 10 feet
Datum is mean sea level



Base from maps of the Oklahoma Dept. of Highways
Drainage from aerial photographs

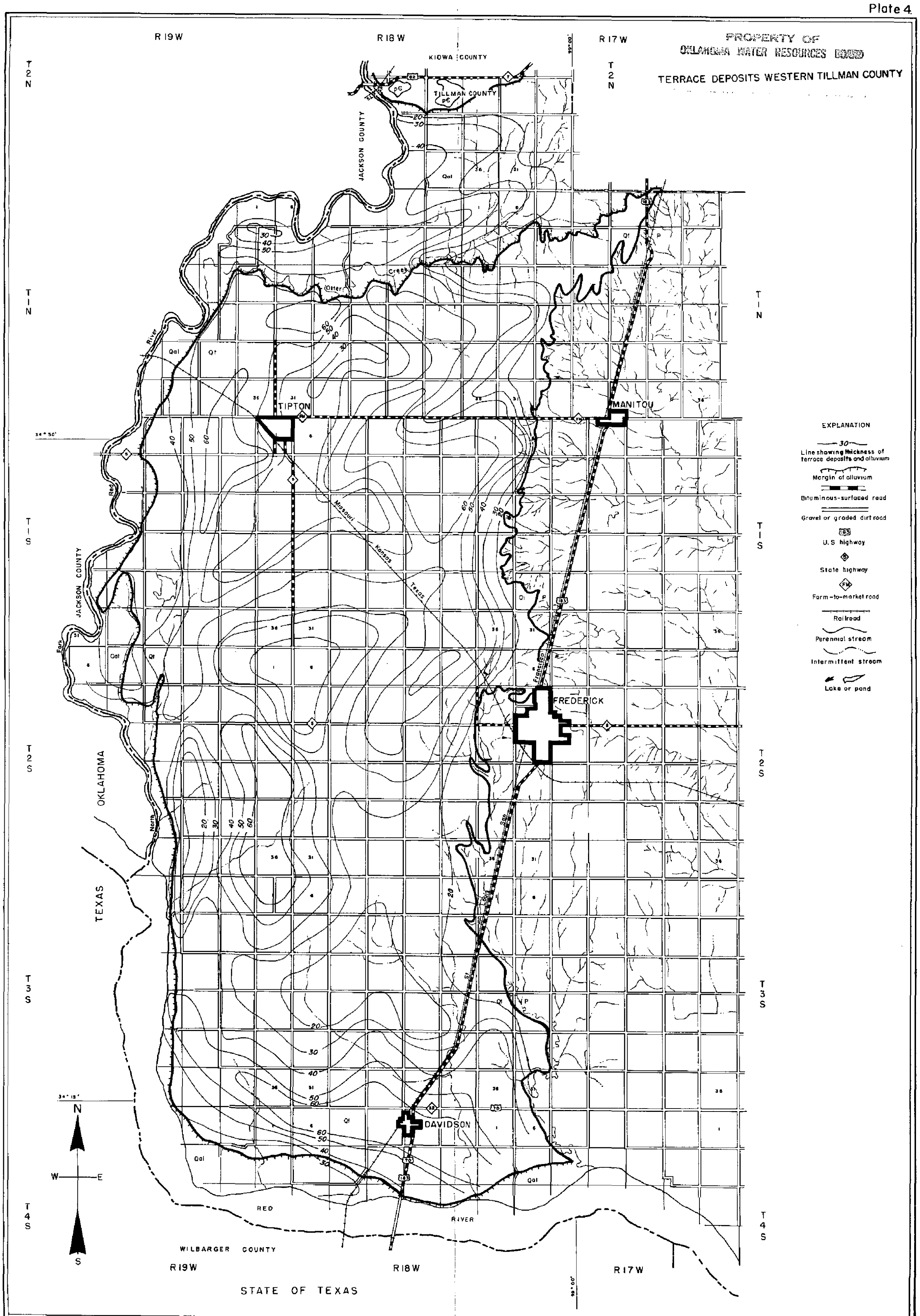
MAP OF WESTERN TILLMAN COUNTY, OKLAHOMA

SHOWING

GENERALIZED CONTOURS ON THE WATER TABLE; LOCATION OF WATER WELLS, TEST HOLES AND SHOT HOLES

1 0 1 2 3 4 5 Miles

CONTOUR INTERVAL 10 feet
Datum is mean sea level



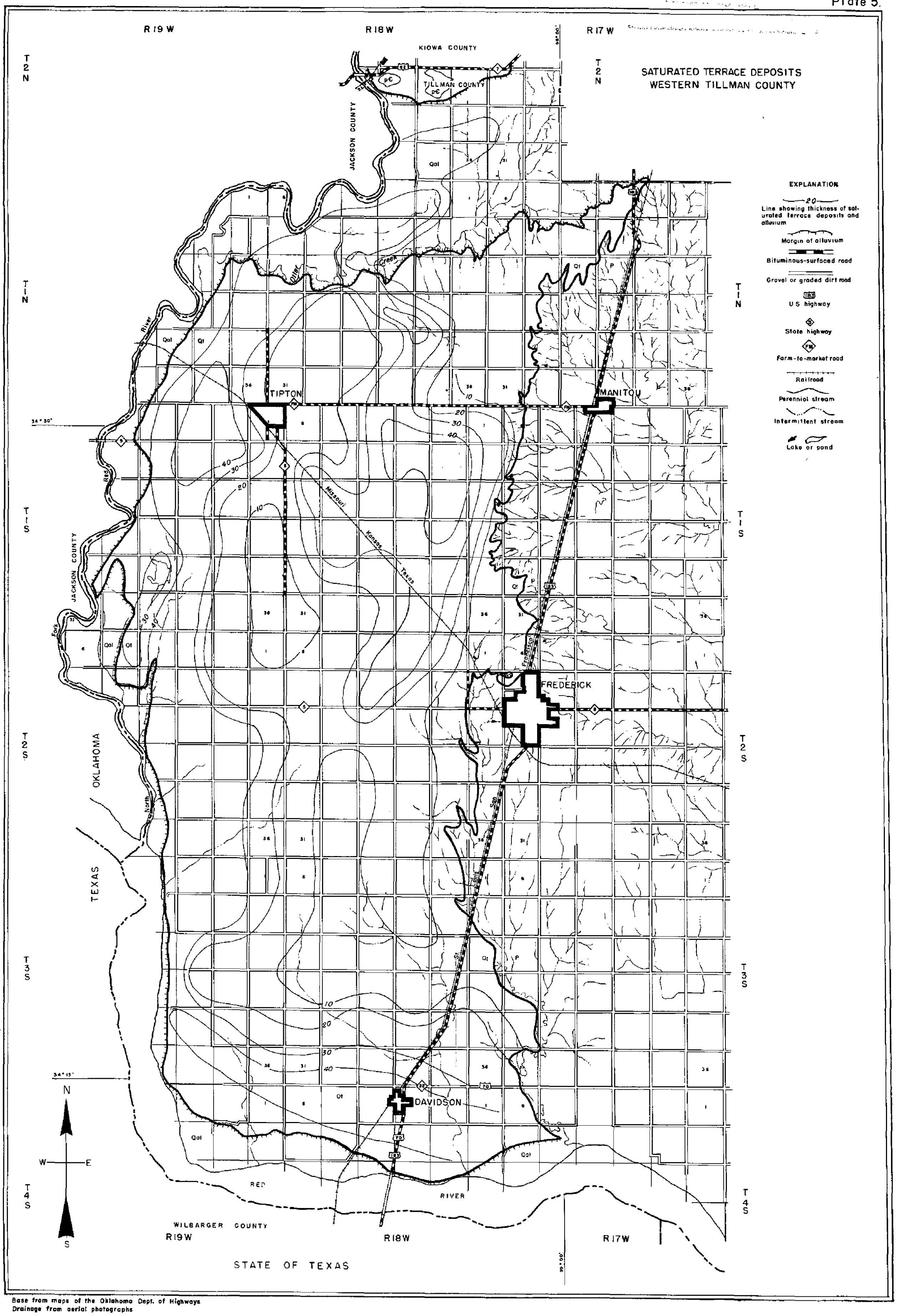
Base from maps of the Oklahoma Dept. of Highways
Drainage from aerial photographs

MAP OF WESTERN TILLMAN COUNTY, OKLAHOMA

SHOWING THICKNESS OF

TERRACE DEPOSITS AND ALLUVIUM

1 0 1 2 3 4 5 Miles



Base from maps of the Oklahoma Dept. of Highways
Drainage from aerial photographs

MAP OF WESTERN TILLMAN COUNTY, OKLAHOMA

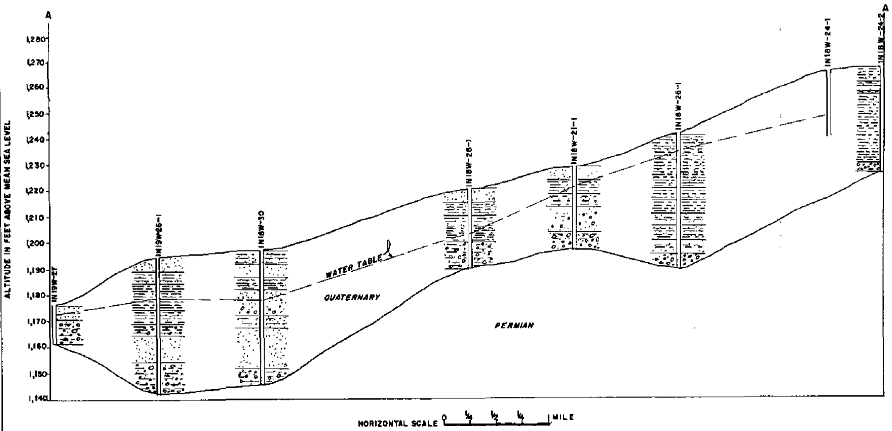
SHOWING THICKNESS OF

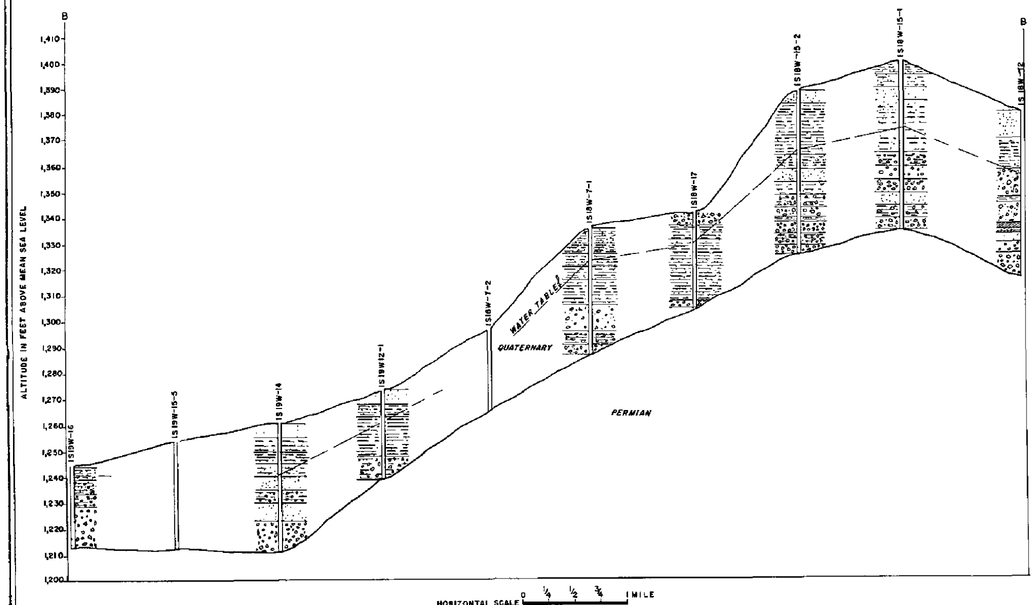
SATURATED TERRACE DEPOSITS AND ALLUVIUM

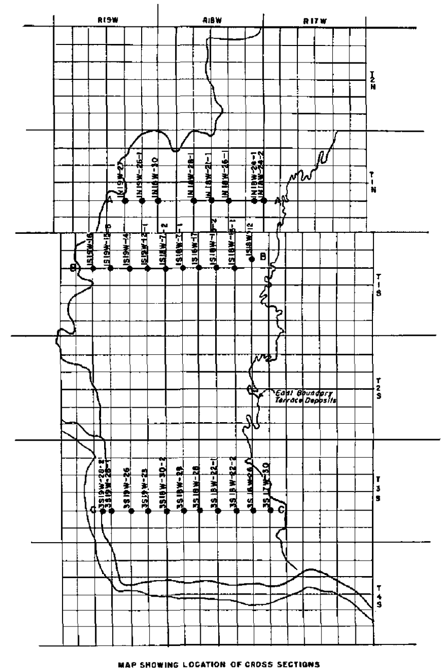
0 1 2 3 4 5 Miles

GEOLOGIC CROSS SECTIONS IN TILLMAN COUNTY OKLAHOMA

EXPLANATION







MAP SHOWING LOCATION OF CROSS SECTIONS