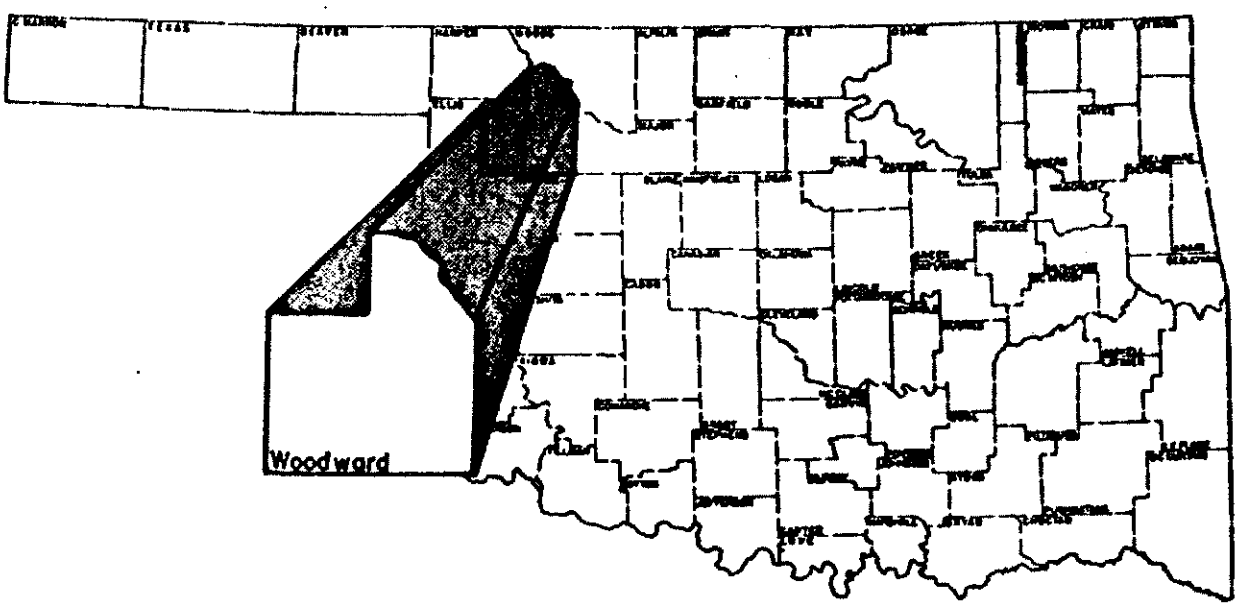
Ground Water Resources Of Woodward County, Oklahoma



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This report describes the geology of Woodward County as it pertains to the occurrence of ground water; it describes and interprets the geologic and hydrologic features that determine the source, movement, quantity, and quality of ground water; and it assembles basic ground-water data that will be useful in planning and developing the ground-water resources of the county.

Oklahoma Water Resources Board

GEOLOGY AND GROUND-WATER RESOURCES OF WOODWARD COUNTY, OKLAHOMA

By

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U.S. Geological Survey

Prepared by

the United States Geological Survey

in cooperation with

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Climate

The climate of Woodward County is controlled by the interaction of tropical and polar airmasses, and is characterized by wide deviations from average precipitation and wide ranges in temperature. Precipitation, resulting from both cyclonic (frontal) and thunderstorm activities, occurs throughout the year but is greatest during the spring and summer. (See tables 1 and 2.)

Records of precipitation from eight stations[2] of the U.S. Weather Bureau in or near the county are summarized in table 1. The monthly precipitation during the period 1956-57 for all stations (fig. 2) is given in table 2. The annual precipitation for the period of record, the cumulative departure from the average annual precipitation, and the average monthly precipitation at the Woodward station are shown graphically on figure 4. The records (tables 1 and 2) and the graphs (fig. 4) show the monthly distribution and intensity of the rainfall in different parts of the county, and the graph of the annual precipitation at Woodward illustrates how the annual precipitation deviates from the long-term average. The precipitation trends during the period 1895-1962 are indicated by the graph showing the cumulative departure from average; upward trends on this graph represent periods of greater than average precipitation. The alternating wet and dry periods at Woodward correlate generally with similar periods at other stations in the Great Plains region (Thomas, 1962, fig. 11, p. 25), and suggest that prevailing dry periods, each lasting about 8 years, alternate with wet periods of 5 to 15 years' duration.

Table 3 shows the monthly temperatures at four stations in the area. Midsummer temperatures often exceed 100°F, and extremes as high as 115°F have been recorded at Woodward and Mutual. In the winter, temperatures often drop below freezing and lows of 10° to 20°F are common. The data given in table 3 show that during July, the hottest month, temperatures average about 82°, and during January, the coldest month, temperatures average about 35°. The mean annual temperature is about 59°. The length of the average growing season, or frost-free period, is about 200 days. Because of the clearness of the air, low humidity, and rapid radiation, differences between day and night temperatures may be great.

The average annual evaporation from free-water surfaces, such as lakes or ponds, in the county area has been shown to be about 64 inches (Kohler and others, 1959). Lake evaporation averages about 7.5 inches

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[2] For information on station locations, altitudes, exposures, instrumentations, records, and observers from date stations established through 1955, the reader is referred to a publication of the U.S. Weather Bureau (1956).

The North Canadian River valley has been referred to the Western Sand-Dune Belt (fig. 3) because it is largely covered by sand that has been blown by the prevailing southerly winds into hummocky dunes or sandhills. In most places the dunes or sandhills are more or less stabilized by vegetation, and randomly oriented sand dunes 10 to 30 feet in height are separated by relatively flat sand-covered basins or depressions of various sizes. These depressions trap and hold the local precipitation until the water can be absorbed by the highly permeable deposits. Hence, surface drainage is absent or poorly developed.

The High Plains geomorphic unit of southwestern Woodward County (fig. 3) is part of an extensive fluvial plain that stretches northward from western Texas and southeastern New Mexico, across northwestern Oklahoma, western Kansas and Nebraska, and into southwestern South Dakota. This vast plain is often described as monotonously flat because, from a distance, minor features resulting from the erosive actions of wind and water are not apparent. When viewed more closely, as in southwestern Woodward County, the plains' surface is seen to be composed of flat uplands; broad, low hills; gentle erosional slopes; wide, shallow valleys; low escarpments outlining resistant caliche-cemented beds; and sand dunes formed by the prevailing southerly winds, all these features have resulted from the removal of mechanically and chemically disintegrated rock materials by runoff during local rains.

The North Canadian River (fig. 2) drains the southern two-thirds of the county and is the principal drainageway for the county, even though the streambed is dry for part of the year. The few tributaries from the north are short and mostly intermittent, whereas some of those from the south, namely Wolf, Indian, Persimmon, and Bent Creeks, are 10 to more than 20 miles long and are commonly perennial in their lower reaches. The sand-filled river channel is bordered in places by a low flood plain that is covered by brush, small trees, and phreatophytes (plants that use large quantities of ground water).

The river's average rate of flow past the gaging station at Woodward during the 24-year period 1938-62 was 257 cfs (cubic feet per second). The mean monthly discharge during the same period ranged from 0 to 2,263 cfs. The river gradient is about 4 feet per mile southeastward, and its altitude drops from about 2,020 to about 1,720 feet within the county.

The Cimarron River (fig. 2) forms the northeastern boundary of the county and its numerous tributaries drain the northern and northeastern parts of the county. The river, though perennial, has a wide sandy channel containing braided watercourses that shift frequently. In the reach where it forms the north boundary of Woodward County, the river has a gradient of about 4 feet per mile southeastward, and its altitude drops from about 1,640 to 1,440 feet. Its average discharge for the 25-year period 1937-62 was 420 cfs. Its mean monthly discharge during the same period ranged from 0.03 to 5,674 cfs.

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GEOLOGY AND GROUND-WATER RESOURCES OF WOODWARD COUNTY, OKLAHOMA

By P. R. Wood and B. L. Stacy

Abstract

Woodward County, in northwestern Oklahoma, has an area of 1,232 square miles, and ranges in altitude from 1,440 to 2,520 feet above sea level. The average annual precipitation is 24 inches. In 1960 the county had a population of 13,900, of which 56 percent lived in the Woodward metropolitan area, 11 percent in small towns, and 33 percent in rural areas. Livestock raising and wheat farming are the principal types of agriculture, and natural gas production is the major industry.

The oldest rocks exposed in the county are red sandstone, siltstone, and shale of Permian age. The Permian formations also contain beds of dolomite and gypsum and, in the subsurface, salt and salt-impregnated shale. Wells in the Permian rocks yield small quantities of water of fair to poor quality. Deep wells encountering solution cavities in beds of gypsum, or in beds of shale below the gypsum, yield large quantities of water containing much gypsum and salt.

The Ogallala Formation of Pliocene age is the principal source of ground water in the southwestern part of the county. Although relatively undeveloped, the formation should be capable of yielding 300 gpm (gallons per minute) or more of water to properly constructed wells in areas where the thickness of saturated materials is great. The water, although hard, is suitable for most uses.

Deposits of Quaternary age in the valleys of the North Canadian River and its principal tributaries are the most important source of ground water in the county. They supply water for Woodward and Mooreland and a large part of the industrial and irrigation needs in the area. The deposits are moderately permeable and in most places their saturated thickness is great enough to meet reasonable water demands provided heavy pumping is not concentrated in small areas. The water from the alluvial deposits is suitable for most uses, but may require softening for some purposes.

Dune sand blankets a large area north of the North Canadian River, along the valley, and on the Ogallala Formation in the southwestern part of the county. Because this unit is generally above the water table, it does not yield water to many wells, but it facilitates recharge to the underlying hydrologic units.

Most ground water in Woodward County originates as precipitation within the county, although some enters as subsurface inflow from Ellis and Harper Counties. Ground water in the Ogallala Formation moves generally northeastward, but it is diverted toward major streams where it discharges into the alluvium or emerges as springs at the base of the formation. Ground water in Quaternary deposits of the North Canadian River valley moves southward and southeastward, discharging into the river and making it a gaining stream.

The largest use of ground water is for irrigation, but water is pumped for municipal, industrial, rural domestic, and stock use also. In 1960 the total pumpage of ground water is estimated to have been 12,000 acre-feet.

After the drought-breaking rains in 1957, ground-water recharge from precipitation and subsurface inflow was estimated to have been 260,000 acre-feet. Water added to ground-water storage in 1957 replaced most of the water lost during the 1951-56 drought. During the 4-year period 1958-61 rainfall remained above average, and the quantity of water added to the ground-water storage reservoir was computed to be about 23,000 acre-feet per year.

INTRODUCTION

The Oklahoma Water Resources Board controls and coordinates the development of the State's water resources and establishes rules for its use and protection. The Board, which was created in 1957 by the twenty-sixth Oklahoma Legislature under Senate Bill 138, succeeds the Water Resources Division of the Oklahoma Planning and Resources Board.

Duties of the Board include: (1) recording and administering all water rights; (2) compiling and indexing all available information concerning the State's ground-water reservoirs in a form that will be accessible to the public; (3) investigating the hydrologic characteristics of each source of water supply in the State; (4) negotiating contracts and other agreements with agencies of the Federal Government for work pertaining to the use and development of water resources; (5) administering the pollution laws of the State so as to protect available ground-water supplies, and cooperating with all other agencies who have responsibilities under the law for pollution control; (6) approving the design and engineering of all waterworks except those constructed by agencies of the Federal Government that are exempt from such approval; and (7) developing local and statewide plans to assure the best and most effective use and control of water to meet current and long-range needs.

In order to fulfill its duties with respect to ground water, the Board needs basic water facts and information concerning the geologic and hydrologic processes that govern the occurrence, movement, quantity, quality, and availability of water in the State's ground-water reservoirs. Much of the required information is obtained through the coordinated efforts of the Ground Water, Surface Water, and Quality of Water Branches of the Water Resources Division of the U.S. Geological Survey. These agencies, working in cooperation with the Water Resources Board, collect, compile, analyze, and synthesize data pertaining to the State's water resources. To date (1965), ground-water studies have been directed toward estimating the quantity of water contained in, and rates of replenishment to, specific water-bearing formations, or aquifers.

Scope, Purpose, and History of This Investigation

In 1955 the Division of Water Resources of the Oklahoma Planning and Resources Board (now the Oklahoma Water Resources Board) requested that the U.S. Geological Survey investigate the ground-water resources of Woodward County. Information on ground water was needed to provide for orderly and scientific development of this resource for municipal, industrial, and irrigation use. Several years of drought had heightened local interest in an appraisal of ground water available for irrigation.

Accordingly, the purpose of this report is to present and to interpret the available information pertaining to the geology, ground-water hydrology, and chemical quality of the ground-water resources of Woodward County.

The objectives of the investigation were (1) to determine the principal sources of ground water, which included preparation of a geologic map of the county and a study of logs obtained from test holes, well drillers, and other sources; (2) to determine the geologic and hydrologic conditions that control the occurrence, movement, availability, and quality of ground water; (3) to estimate the quantity of water available for use in, and rates of replenishment to, deposits of Tertiary and Quaternary age, which are the most important sources of ground water in the county; (4) to tabulate well records, water-level measurements, pumpage estimates, chemical analyses, and selected well logs; and (5) to prepare a report outlining the results of the study.

From the start of the project in October 1955 until he resigned to enter private practice in May 1959 C. E. Steele, Hydraulic Engineer, U.S. Geological Survey, served as project chief. During this period most of the geologic and hydrologic data used in this report were collected, and preliminary analyses and tabulations were prepared.

Mr. B. L. Stacy served as acting project chief from May 1959 to January 1961, when he resigned to enter The University of Oklahoma. Mr. Stacy worked on the project from its beginning, did most of the geologic mapping (pl. 1), supervised the compilation and tabulation of hydrologic data, and prepared a manuscript report covering the geology and some phases of the ground-water resources of the county.

In August 1962 P. R. Wood, the present project chief, was assigned to synthesize information compiled earlier, make an evaluation of the county's ground-water resources, and complete the report.

A preliminary report (Wood and Stacy, 1963) contained records of wells, well logs, chemical analyses of ground and surface water, and maps showing the location of wells and the availability of ground water in the county.

From its beginning in 1955 to its culmination in 1964, this investigation was financed by cooperative agreement between the U.S. Geological Survey and the Oklahoma Water Resources Board. The report was prepared under the immediate supervision of A. R. Leonard, district geologist of the Geological Survey in charge of ground-water investigations in Oklahoma.

Methods of Investigation

Reconnaissance mapping of the principal geologic units began in 1955 and was completed in 1958. The mapping was done on areal photographs and adjusted to township plats at a scale of 1 inch to the mile. The final geologic map (pl. 1) was compiled by adjusting the township plats to a planimetric base map of the county prepared from Oklahoma Highway Department maps.

Most large-capacity wells and representative domestic, stock, and unused wells in the county were inventoried by employees of the Water Resources Board and the Geological Survey, and all pertinent data were compiled. (See table, Appendix A.) The well locations are shown on plate 2.

One hundred thirteen test holes, ranging in depth from 22 to 500 feet and totaling 10,950 feet, were drilled under contract during 1957. Test drilling was the primary source of subsurface geologic data and provided much valuable information on the occurrence of ground water.

During 1956 and 1957, measurements of water level in 50 to 60 wells were made at weekly, biweekly, or monthly intervals, and water-level recorders were operated on six wells in order to record detailed fluctuations of the water table. From 1958 to 1963, measurements of water level in 20 to 30 wells were made at monthly intervals, and recorders were operated on two wells to obtain detailed information on water-level fluctuations.

The altitudes of many of the wells and test holes were determined by personnel of the Oklahoma Water Resources Board and the Geological Survey by use of surveying instruments. Precise altitudes were used to relate the ground-water surface and the concealed surface of the red beds (bedrock) to mean sea-level datum.

The hydrologic properties of the principal water-bearing materials were determined by means of eight "multiple-well" aquifer tests. Six of these tests were made on large-capacity irrigation or public-supply wells tapping terrace deposits and alluvium; and two tests were made on irrigation wells tapping the Ogallala Formation.

The base flow of streams draining the Ogallala Formation in the southwestern part of the county (fig. 2 and pl. 1) was measured by the Surface Water Branch of the Geological Survey to aid in determining the natural ground-water discharge from these rocks. (See table 6.)

To obtain a record of the distribution of precipitation in the county, eight rain gages were installed to supplement the seven permanent gages maintained by the U.S. Weather Bureau. (See fig. 2.) These additional stations were established in 1956 with the cooperation and assistance of the Weather Bureau, and were serviced during 1956 and 1957 by volunteer observers residing in the county.

Fifty-one samples of water were collected for chemical analysis from selected wells, springs, test holes, and streams in all parts of the county. The analytical results were used to rate the suitability of the water for irrigation and other uses, to correlate water quality with the geologic source of the water, and to determine more fully the relation between surface water and ground water. (See tables, Apps. C and D.)

Acknowledgments

Appreciation is expressed to the officials of public agencies, private companies, landowners, well drillers, and other individuals who cooperated and assisted in the collection of field data used in this report. The Oklahoma Water Resources Board furnished information on many irrigation wells, and personnel from that office assisted in data-collection and compilation phases of the investigation. The U.S. Army Corps of Engineers, Tulsa District, made available information on wells and test holes drilled at Woodward Army Air Force Base (now West Woodward Airfield) and logs of test holes drilled during the construction of Fort Supply Dam. Officials of the cities of Woodward and Mooreland supplied logs of wells and test holes and information on yields of wells and quantities of water pumped in their respective well fields. The Woodward County Commissioners gave permission for the drilling of test holes and observation wells along county rights-of-way.

Special thanks are due Omer Clayton, H. E. Merklin, E. R. Adams, M. R. Beuke, George Stricker, Dr. R. L. Tripplett, Martin Ruttman, and L. A. Parsons, for serving as observers at precipitation stations located near their homes; to Clifford Miller, Wayne Cox, Jimmie Phillips, T. Z. Wright, Estel Peoples, Audry Richmond, L. A. Parsons, and the city of Woodward for generously permitting the Geological Survey to drill test wells and use their large-capacity wells and pumping equipment to determine aquifer characteristics; and to the officials of the Ferguson Ranches for their cooperation and assistance in providing hydrologic information on ranch property.

Several oil companies supplied data on land-surface altitudes obtained during geophysical surveys, and logs of geophysical shotholes and oil-test holes.

The Layne-Western Co., Wichita, Kans., made available an unpublished report containing hydrologic information and electric logs of test holes in an area near Mooreland.

R. B. Duffin, Extension Irrigation Specialist, Oklahoma State University, and D. P. Schwab, County Agent at Large, Stillwater, Okla., supplied data on acreage irrigated with ground and surface water.

Valuable information on wells and test holes was furnished by E. O. Grade and E. E. Caldwell, well drillers, and by the Alexander Engineering Co., Oklahoma City.

Well-Numbering System

Wells and test holes are referred to in this report by numbers and letters which indicate their locations within legal rectangular subdivisions of the public land, referenced to the Indian base line and meridian. For example, in the number 23N-20W-19cbb1, which was assigned to a well about a mile north of the city of Woodward, the first two segments of the number designate the township (23N) and range (20W); the third segment gives the section number (19), followed by three letters and a numeral. The first lowercase letter (c) is the quarter section (160-acre tract): a--northeast quarter, b--northwest quarter, c--southwest quarter, d--southeast quarter, as illustrated in figure 1; the second lowercase letter (b) is the quarter-quarter section (40-acre tract); and the third (b) the quarter-quarter-quarter section (10-acre tract). Within each 10-acre tract the wells are numbered serially, as indicated by the final digit of the number. Thus, well 23N-20W-19cbb1 is the first well to be listed in the NW$\frac{1}{4}$NW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 19, T. 23 N., R. 20 W (fig. 1).

Springs, test holes, and precipitation stations also were assigned numbers according to this system.

Previous Investigations

Red beds that crop out in Woodward County and elsewhere in Oklahoma and Kansas have been of interest to geologists for a long time. F. W. Cragin (1896 and 1897), a pioneer Kansas geologist, first described, subdivided, and classified the red beds. C. N. Gould (1902 and 1905), Oklahoma's great pioneer geologist, was the first to describe and classify the rocks that crop out in the area that is now Woodward County. Since that time, several reports have been published on the red beds. Papers of interest to geologists studying the stratigraphy, petrography, and age relationships of these rocks in the Woodward County area include those of Aurin (1917), Sawyer (1924), Gould (1924), Freie (1930), Evans (1931), Norton (1939), Miser (1954), Swineford (1955), and Fay (1962).

Isolated patches of Cretaceous rocks in the county (not shown on pl. 1) were mapped and described by Bullard (1928). The Ogallala Formation, which covers the southwestern part of the county, is part of a great mass of material that forms the High Plains in Oklahoma and adjoining States. The most detailed studies of the stratigraphy, petrography, and age relationships of these rocks have been made by geologists and hydrologists of the State and Federal Geological Surveys working on cooperative ground-water investigations in the region. Recent publications containing detailed information on the geologic and hydrologic aspects of the Ogallala include those of Frye and others (1956), Taylor (1960), and Marine (1963).

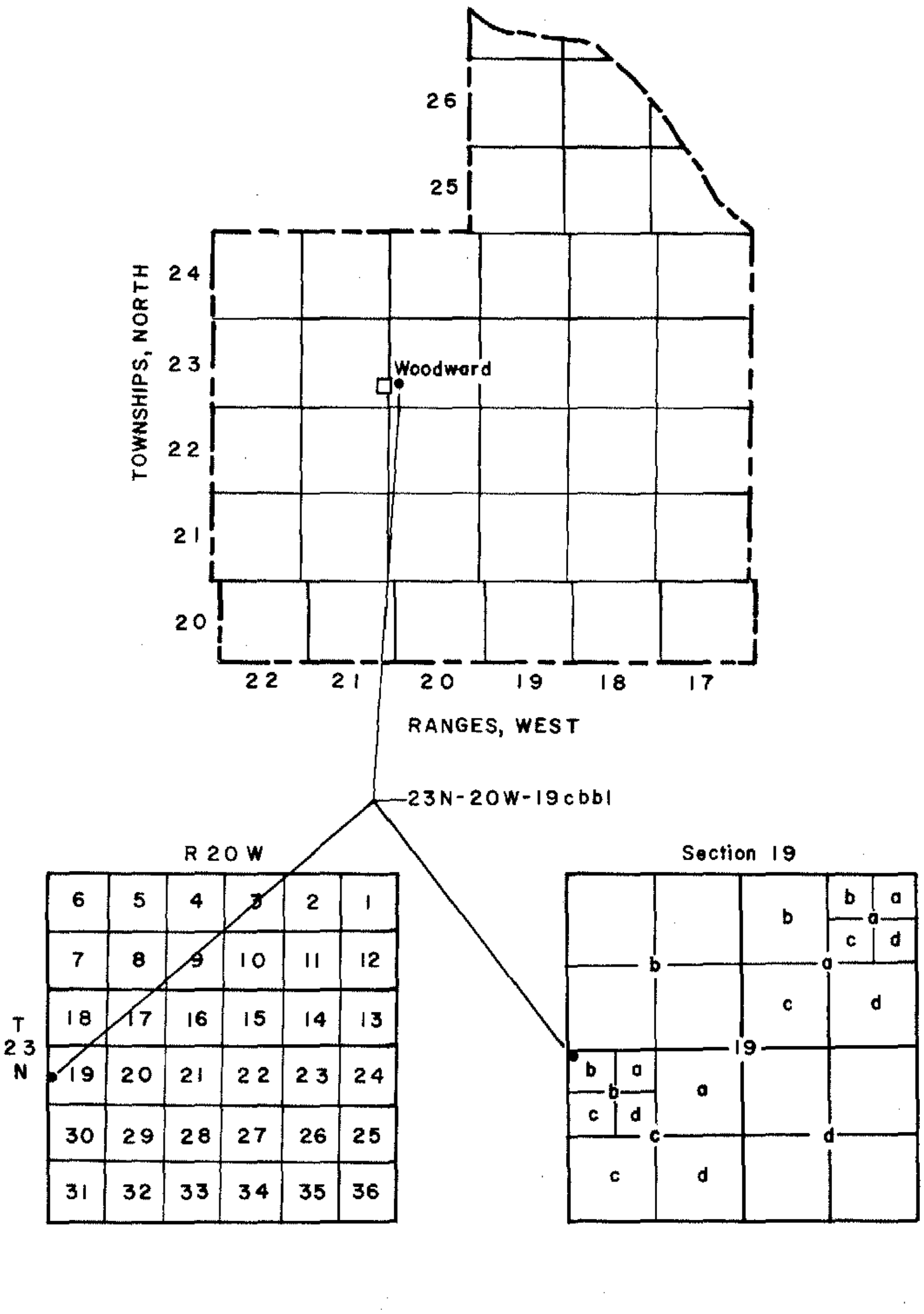

Figure 1. —Sketch showing well-numbering system.

Brief descriptions of the geography and physiography of the area are included in comprehensive reports by Snider (1917) and Fenneman (1922). In 1957, the Oklahoma Geological Survey (Curtis and Ham) issued a physiographic map of the State showing five physiographic units in the Woodward County area.

The soils of the county were mapped and described by Fitzpatrick and Boatright (1938) and Nance, E. C., and others (1963).

Records

The records of 538 wells and test holes are given in Appendix A. It contains information about well locations, use, depth, water levels, principal aquifer or water bearing zone, and other data. The land-surface altitudes shown in the appendix were determined by leveling to relate the ground-water surface and the Permian (bedrock) surface to mean sea-level datum.

Appendix B contains logs of 185 wells and test holes. Logs described as sample logs were made by field and microscopic analysis of the drill cuttings by either B. L. Stacy or M. E. Davis. Logs described as drillers' logs were made by field analysis of the drill cuttings by the well driller. Interpretive information and stratigraphic correlations were supplied by the authors. The locations of wells and test holes are shown on plate 2.

Appendixes C and D contain the results of 51 chemical analyses of water from wells, springs, and streams. The appendixes give information about geologic source, temperature, hardness, content in parts per million (ppm) of major mineral constituents, and other related data.

GEOGRAPHY

Location and General Features of the Area

Woodward County is in the northwestern part of Oklahoma (fig. 2). Woodward, the county seat, is on the south bank of the North Canadian River, about 140 miles northwest of Oklahoma City, the State Capital. The county is readily accessible via U.S. Highways 183 and 270, and State Highways 3, 15, 34, and 50. Several bus and motor-freight lines provide competitive transportation and freight facilities. The Santa Fe Railway Co. maintains an east-west trunk line that passes through Woodward and provides passenger and freight service to all points. The Missouri-Kansas-Texas Railroad Co. maintains a north-south trunk line that crosses the Santa Fe tracks at Woodward and provides freight service to major points in Oklahoma and adjoining States. Central Airlines, Inc., maintains air-freight and passenger service from Woodward to larger cities, where connections are made with major transcontinental airlines.

Of the 77 counties in Oklahoma, Woodward County ranks 11th in area, comprising 1,232 square miles, and 44th in population, with 13,902 inhabitants in 1960. About 56 percent of these inhabitants live in the Woodward metropolitan area, 11 percent live in small towns, and 33 percent live in rural areas. Many of those living in the towns own or operate farms or ranches, and consequently a large majority of the inhabitants earn their living from agriculture. The principal agricultural activities are the production and sale of livestock, small grains, and hay.

Natural gas was discovered about 5 miles southeast of Woodward in December 1956, and by 1960 the county had 8 gas-producing areas and one marginal oil well (Jordan, 1960). Up to 1960, all gas and oil produced within the county was from rocks of Pennsylvanian and Mississippian ages at depths ranging from about 5,000 to more than 8,000 feet below land surface.

Industries other than those related to agriculture and natural gas have not been extensively developed. Bentonitic volcanic ash occurs in small lens-shaped bodies in unconsolidated deposits of Tertiary and Quaternary ages (Ham, 1949). These ash deposits have been prospected at several places in the central and southwestern parts of the county and at least one prospect (T. 23 N., R. 22 W., secs. 13, 14, and 25) was mined briefly.

Beds of gypsum (Blaine Gypsum, pl. 1) crop out in a wide, sinuous belt that extends across the entire northeastern part of the county. Although the amount of gypsum at or near the surface has not been estimated, ample quantities probably are available to supply a very large

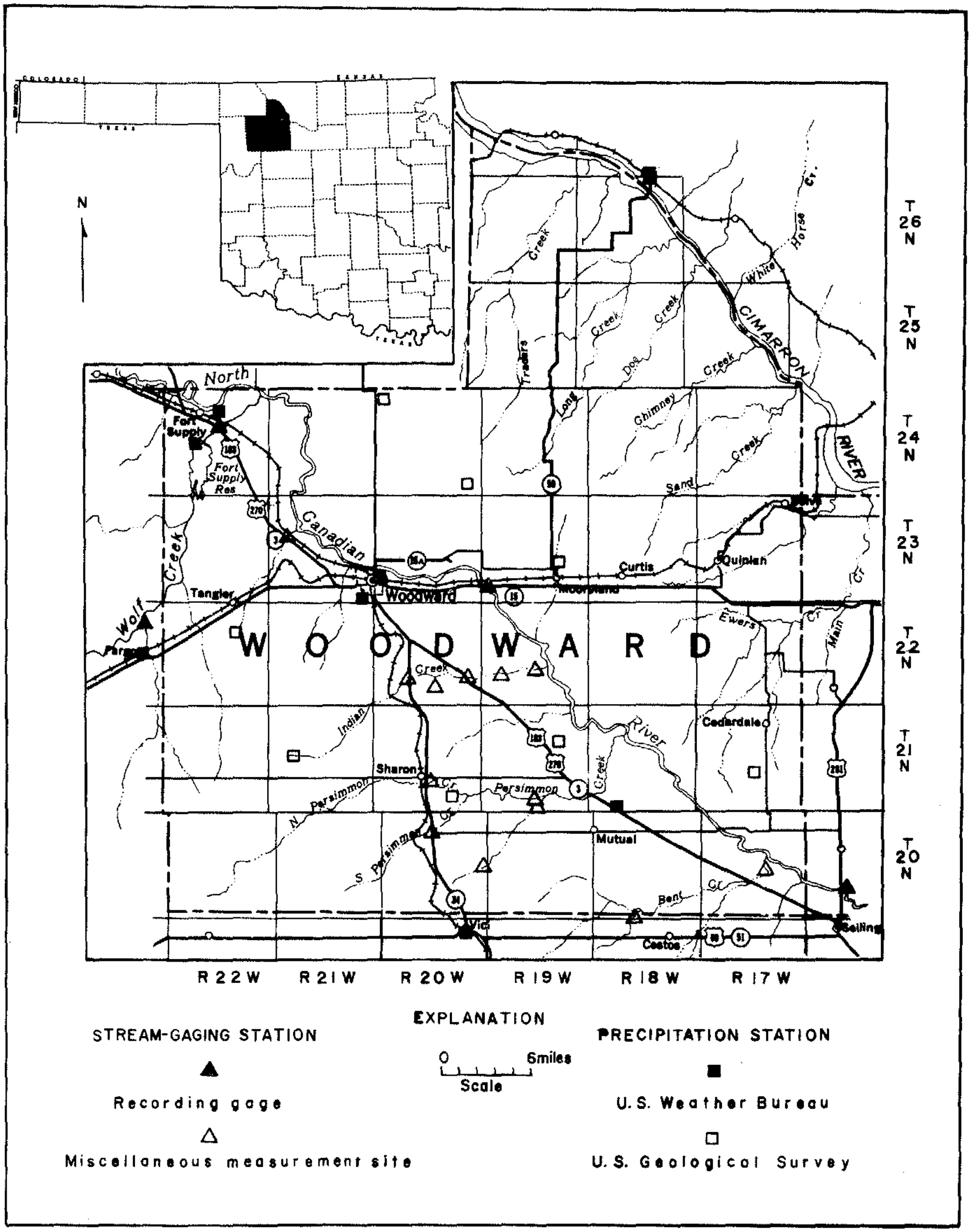

Figure 2.--Map of Woodward County and vicinity showing precipitation and stream-gaging stations

industrial plant for an indefinite period. An area most favorably situated for commercial development is near the railroad that crosses outcropping beds of gypsum between Quinlan and Belva.[1]

In the extreme northern part of Woodward County (T. 27 N., R. 19 W., sec. 33), salt (chiefly NaCl) occurs at the surface as a result of evaporation of brines issuing from salt springs bordering the southwestern part of the Big Salt Plain of Cimarron River. The salt has been produced commercially only on a very small scale for local use. Rock salt, in lenticular beds of varying thickness, has been logged in test holes drilled into the Flowerpot Shale at depths ranging from about 30 feet below land surface in the northern part of the county near Cimarron River to more than 1,000 feet in the southwestern part of the county.

Sand and gravel are produced from temporary quarries in Tertiary and Quaternary deposits, for local building and highway construction.

Recreational facilities include Alabaster Caverns State Park (T. 26 N., R. 18 W., sec. 33), site of one of the largest known gypsum caves; Boiling Springs State Park (T. 23 N., R. 20 W., sec. 23), an 880-acre tract of land with accommodations for camping, hiking, swimming, fishing, boating, and horseback riding; and Fort Supply Reservoir on Wolf Creek about 12 miles northwest of Woodward.

Topography and Drainage

The land surface in Woodward County is characterized by several types of topography, which may be divided into five geomorphic units (Curtis and Ham, 1957) as shown on figure 3. The topography of each of these units reflects the geology of the underlying rocks and the erosional effects of wind and water.

The Central Redbed Plains, which constitute the surface of the red beds in much of central, south-central, and northwestern Oklahoma, is identified in Woodward County as a narrow band ranging in altitude from about 1,450 to 1,600 feet along the south side of the Cimarron River. (See fig. 3.) In this area the unit has been developed on the soft, easily eroded Flowerpot Shale. (See pl. 1.) The surface of the Plains is relatively flat, contains little or no soil, and is characterized by numerous odd-shaped pinacles, buttes, and ridges. These odd-shaped landforms have resulted from differential erosion of resistant and nonresistant beds in the shale sequence.

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[1]For information on the geology, petrology, and industrial possibilities of gypsum the reader is referred to Snider, L. C., 1913; Burwell, A. L., 1955; and Ham, W. E. 1962.

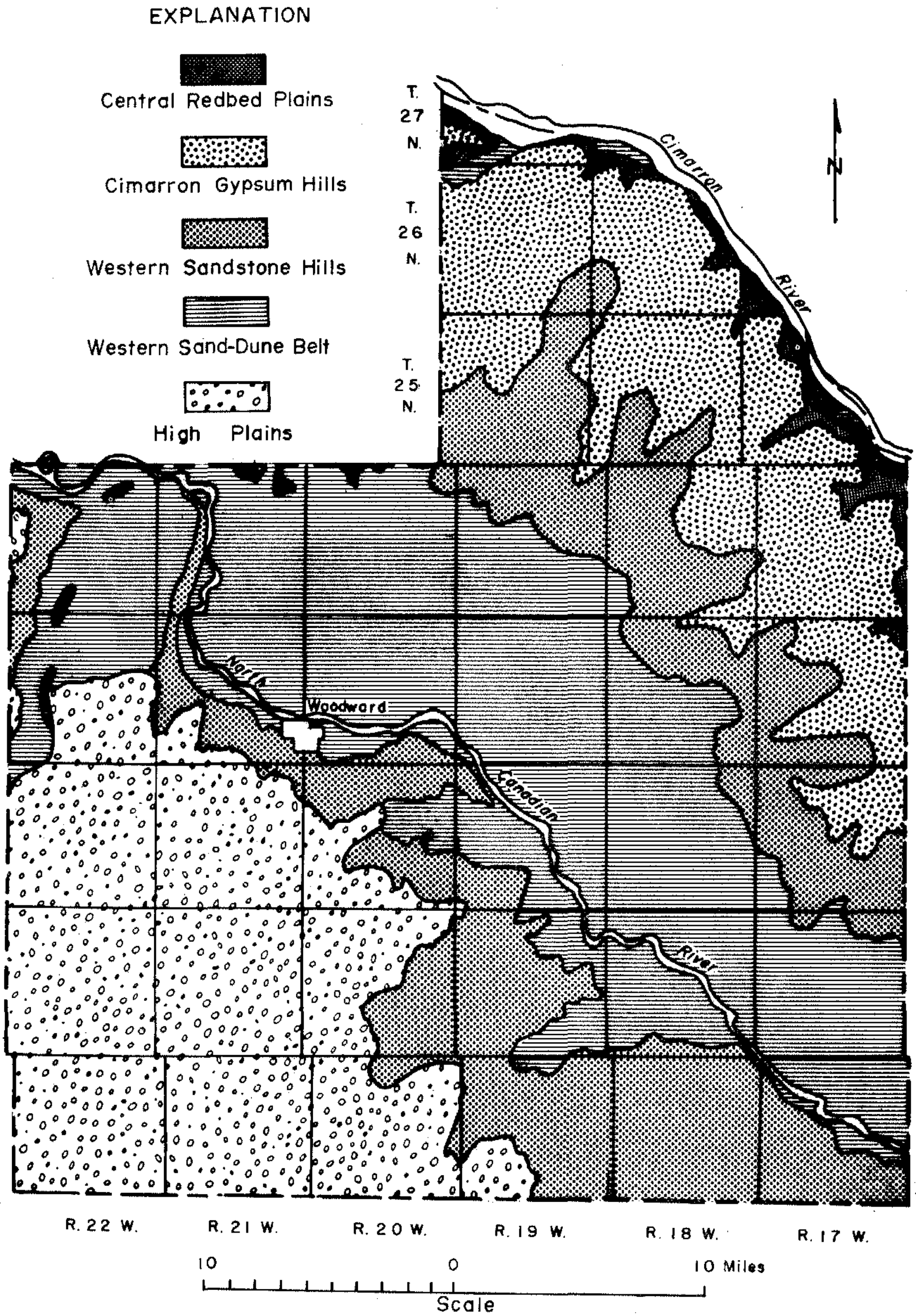

FIG. 3-- MAP OF WOODWARD COUNTY, OKLAHOMA, SHOWING GEOMORPHIC UNITS (Modified after Curtis and Ham, 1957)

The Cimarron Gypsum Hills (fig. 3), also called the Gypsum, or "Gyp" Hills, rise abruptly 100 to 300 feet above the Central Redbed Plains, forming a steep northeastward-facing escarpment. Early settlers, traveling westward across the plains, referred to this group of hills as "the first line of hills" because they form an unbroken ridge, extending in a northwesterly direction. The hills range in altitude from 1,700 to 1,800 feet and consist of a series of rough terracelike surfaces of varying widths. These surfaces, or ledges, are held up by resistant beds of gypsum and dolomite (Blaine Gypsum, pl. 1) ranging from less than a foot to about 30 feet in thickness. When viewed from above, the hills exhibit a rugged relief because of the many steep-walled canyons being cut by headward-eroding tributaries of Cimarron River.

In many places, exposed gypsum ledges exhibit a karstlike topography (Myers, 1960a, 1960b, and 1961; Snider, 1913, p. 149-150). Sinkholes, caves, subterranean streams, natural bridges, and elongated collapse depressions formed in places where underground drainage channels have been unroofed; and other features resulting from solution by surface and ground water are common. In many places, small solution valleys, generally less than a mile in length, contain intermittent streams which drain into sinks. So far as is known, all the subsurface drainage channels empty into intermittent streams which collect runoff from local drainage basins and discharge into Cimarron River. (See fig. 2.)

The Western Sandstone Hills geomorphic unit (fig. 3) is composed chiefly of easily eroded beds of sandstone and shale which geologists have referred to the Whitehorse Group and Cloud Chief Formation. (See pl. 1.)

In Woodward County the North Canadian River has separated this unit into two areas. North of the river, altitudes in the unit range from 1,800 to 2,100 feet, and the hills form a northwest-trending ridge that serves as the drainage divide between the North Canadian and Cimarron Rivers. The ridge has weathered to form a series of rounded sandstone hills. Where one or more of the hills is capped by gypsum or dolomite, it commonly is flat topped and is bounded on one or more sides by steep escarpments. Ledges formed by resistant beds cropping out along the sides of hills also form low escarpments. When viewed from the east, these hills and escarpments are easily seen because they rise 100 to 300 feet above the ledgelike gypsum hills and because their relatively steep northeastern slopes have been deeply dissected by headward-eroding tributaries of Cimarron River. They form the second line of hills mentioned in older reports and in the journals of pioneers traveling westward in wagon trains.

South of the river, the Western Sandstone Hills unit is an undulating erosional plain ranging from 1,800 to 2,000 feet in altitude. In several places rounded hillocks, low rounded ridges, and small mesalike surfaces, each capped by resistant beds of gypsum or dolomite, extend above the general surface.

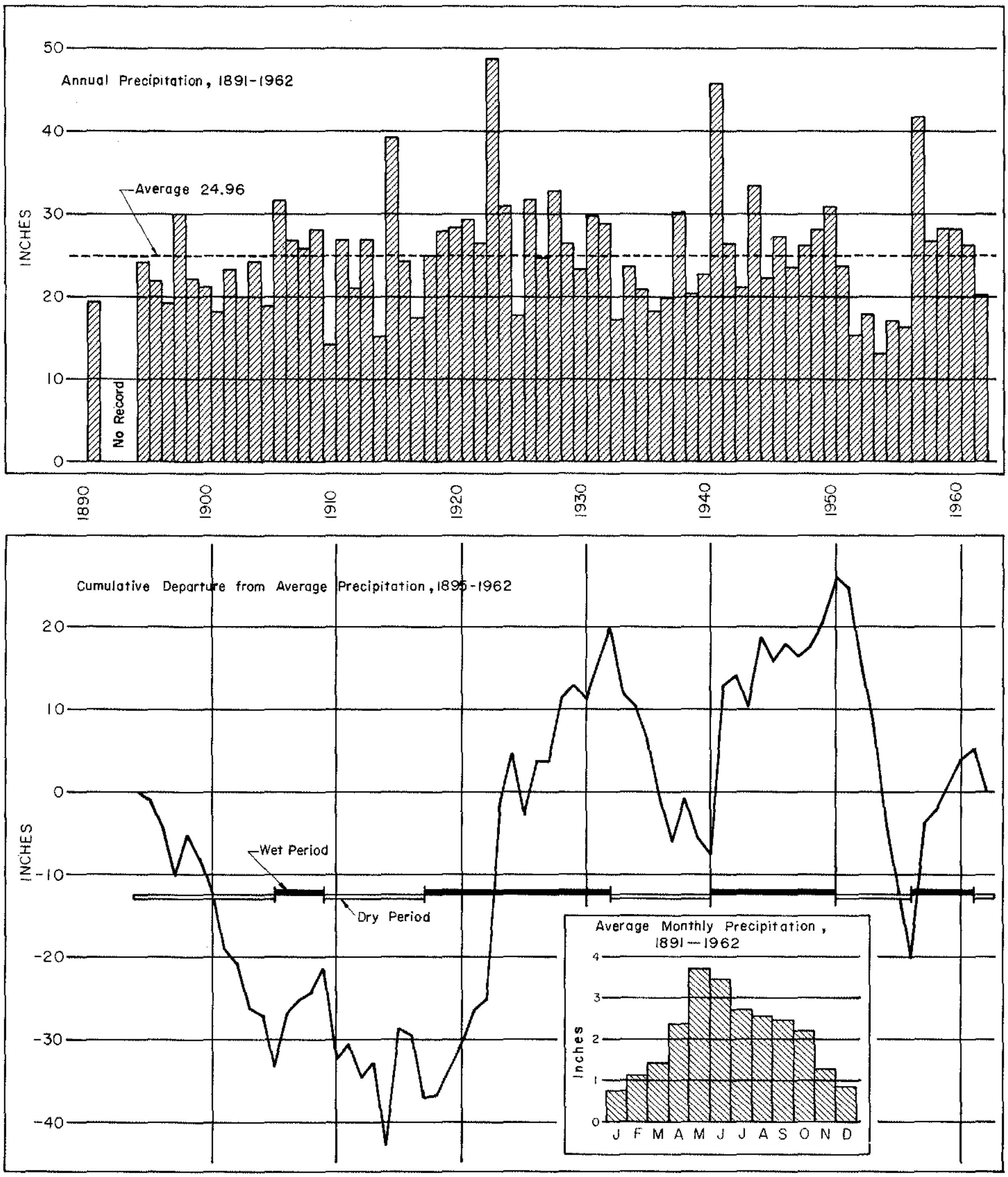

FIG. 4--GRAPHS SHOWING PRECIPITATION AT WOODWARD, OKLAHOMA

Table 1.--Average precipitation (in inches) at eight stations in or near Woodward County

(Data from U.S. Weather Bureau annual summaries)

Month	Supply (1875-1962)	Fort Supply dam (1941-62)	Woodward (1891-1962)	Woodward Field Station (1953-62)	Fargo (1940-62)	Mutual (1908-62)	Vici (1956-62)	Freedom (1949-62)
January	0.65	0.59	0.74	0.54	0.62	0.67	0.50	0.54
February	1.01	1.12	1.11	.99	1.08	.93	1.20	1.18
March	1.38	1.55	1.43	1.64	1.24	1.41	2.15	1.65
April	2.19	1.94	2.38	1.59	1.92	2.61	1.86	2.36
May	3.51	3.85	3.70	1.35	3.80	3.65	4.36	4.73
June	3.04	3.38	3.46	3.86	3.36	3.25	4.31	4.41
July	2.87	2.95	2.70	2.89	2.85	1.87	2.66	3.38
August	2.12	2.22	2.56	2.72	2.33	2.49	2.80	2.95
September	1.93	2.00	2.46	2.09	1.70	2.73	2.45	2.62
October	1.78	2.03	2.20	2.09	2.19	2.24	2.37	1.57
November	1.18	.91	1.28	.65	.92	1.25	.83	.79
December	.75	.76	.88	.66	.76	.83	.99	.47
Average annual	21.78	23.18	24.96	24.08	22.76	24.08	26.35	25.89
	[a]50	[a]21	[a]69	[a]10	[a]19	[a]47	[a]7	[a]12

[a] Number of years' record used to compute average annual precipitation

Table 2.--Monthly precipitation at 16 stations in or near Woodward County, 1956-57

Station and Observer	Altitude (feet)	Year	Precipitation, in inches Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
19N-20W-2d, U.S. Weather Bureau Vici....................	2,265	1956	0.13	0.61	0.70	T	2.77	1.79	3.19	1.50	0.00	1.87	0.48	0.80	13.78
		1957	.71	1.38	5.74	4.32	10.67	5.69	.08	.40	1.99	4.39	1.43	.12	36.99
21N-17W-22d, Omer Clayton	1,760	1956	....	....	1.13	.54	2.86	....	1.48	2.13	.00	1.01	.48	.74	.....
		1957	.94	1.25	5.27	4.56	.16	6.06	.49	.36	4.34	3.87	1.35	.17	28.82
21N-18W-33c, U.S. Weather Bureau Mutual, 2 NE..............	1,820	1956	.13	.37	1.17	.20	3.49	1.39	2.53	2.98	T	1.37	.55	.80	14.98
		1957	1.51	1.36	3.69	3.94	10.03	5.79	.59	.08	3.89	3.81	1.26	.14	36.09
21N-19W-11c, H. E. Merklin	1,810	1956	.07	.42	.88	.13	2.55	1.20	2.30	2.51	.00	.77	.55	.86	12.24
		1957	.82	1.35	3.90	3.31	10.18	5.14	.00	.00	5.23	3.51	1.49	.13	35.06
21N-20W-26c, E. R. Adams	2,040	1956	.09	.26	.42	.05	.....	....	4.05	1.70	....	.73	.38	.60	.....
		1957	.72	1.13	3.91	3.72	10.58	5.96	.04	.30	3.37	3.96	1.16	.14	34.99
21N-21W-17d, M. R. Beuke	2,230	1956	.15	.30	.41	.42	2.88	1.08	2.29	1.46	.00	1.09	.15	....	.....
		1957	.80	1.35	4.32	5.76	10.34	5.46	.28	.77	4.08	4.18	1.43	.14	38.91
22N-22W-11c, George Stricker	2,200	1956	....	....	....	....	....	1.94	3.03	2.81	.00	.76	.15	.44	.....
		1957	.76	1.14	4.23	3.95	9.09	6.57	.00	.85	2.20	4.32	1.33	.11	34.55
22N-23W-24b, U.S. Weather Bureau Fargo.....................	2,100	1956	.27	.51	.46	T	1.79	2.30	4.34	2.28	.00	1.06	.11	.34	13.46
		1957	.79	1.03	5.57	3.39	9.06	6.93	.39	1.11	2.28	4.09	1.51	.02	36.17
23N-19W-26b, Dr. R. L. Tripplett	1,910	1956	.23	.48	.79	.32	3.01	2.47	1.92	1.02	.00	1.20	.40	.54	12.88
		1957	1.03	1.95	5.18	4.98	13.42	6.82	1.11	....	....	....	....	....	.....
23N-20W-30d, U.S. Weather Bureau Woodward..................	1,908	1956	.17	.49	.58	.17	2.84	4.70	3.30	2.81	.00	.73	.17	.44	16.40
		1957	.43	1.17	5.04	3.79	12.02	7.11	1.12	.72	4.23	4.11	1.39	.10	41.73
23N-21W-35b, U.S. Weather Bureau Woodward Field Station	1,976	1956	.15	.56	.43	.16	2.74	3.72	3.31	3.07	.00	.76	.16	.32	15.38
		1957	.80	1.17	5.54	3.83	12.03	7.72	1.09	.70	3.95	4.35	1.56	.11	42.85
24N-20W-6c, L. A. Parsons	2,050	1956	.24	.56	.73	.00	4.18	1.27	1.87	3.33	.00	6.76	.16	.32	19.42
		1957	.46	.96	4.96	2.50	14.63	11.22	2.40	.08	5.45	4.33	.84	.00	47.83
24N-20W-36b, Martin Ruttman	2,080	1956	.84	....	1.55	1.00	.58	3.80	1.17	2.80	.00	.58	.35	.55	.....
		1957	.27	1.40	5.62	5.70	7.73	7.35	1.05	.45	4.72	4.55	....	....	.....
24N-22W-9d, U.S. Weather Bureau Supply, 1E...............	1,970	1956	.18	.80	.51	.12	1.52	1.12	5.19	2.29	.00	.60	.20	.12	12.62
		1957	1.10	1.35	5.06	3.17	11.88	8.38	.59	1.42	2.39	4.97	1.51	.00	38.82
24N-22W-17d, U.S. Weather Bureau Fort Supply dam	2,075	1956	.22	.42	.36	.02	1.88	1.17	3.91	2.53	.00	.61	.11	.26	11.49
		1957	.83	1.31	4.51	2.99	11.60	8.26	.80	1.68	3.05	3.91	1.63	.06	40.63
27N-18W-35d, U.S. Weather Bureau Freedom	1,530	1956	.10	.32	.78	T	2.26	1.45	5.30	3.08	T	.66	.29	.10	14.34
		1957	.69	.68	4.29	3.95	12.34	7.28	.45	2.78	3.74	3.59	2.20	T	41.99

T, Trace of Precipitation

per month in the growing season (April through September) and about 3 inches per month for the rest of the year. During July, the hottest month, evaporation averages 8.6 inches.

Table 3.--Average temperatures (°F) at four stations in or near Woodward County

(Data from U.S. Weather Bureau annual summaries)

Month	Fort Supply dam (1940-62)	Woodward (1895-1962)	Woodward Field Station (1948-62)	Mutual (1905-62)	Freedom (1948-62)
January- - - - - - - -	38.0	36.1	34.1	35.7	35.0
February - - - - - - -	40.7	40.1	38.7	40.3	41.7
March- - - - - - - - -	46.0	48.9	44.5	47.6	47.0
April- - - - - - - - -	58.4	59.1	57.4	57.6	60.6
May- - - - - - - - - -	67.2	67.6	67.6	66.5	69.9
June - - - - - - - - -	76.9	77.3	77.4	76.7	77.7
July - - - - - - - - -	81.1	82.1	81.4	81.9	81.7
August - - - - - - - -	80.9	81.3	80.9	80.6	80.6
September- - - - - - -	72.5	73.2	72.5	73.2	72.5
October- - - - - - - -	61.9	61.0	61.1	61.4	61.8
November - - - - - - -	46.9	47.7	46.1	47.4	46.4
December - - - - - - -	35.8	37.4	37.7	38.0	37.4
Average annual	59.0 [a]20	59.4 [a]51	57.7 [a]15	58.9 [a]10	58.4 [a]7

[a] Number of years' record used to compute average annual temperature

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

The rocks exposed in Woodward County include consolidated sedimentary rocks of Permian age, consolidated and semiconsolidated sedimentary rocks of late Tertiary age, and unconsolidated deposits of Quaternary age. Isolated patches of Cretaceous rocks (not shown on pl. 1 or table 4) occur at widely separated places in the eastern and southeastern parts of the county. The rocks are not in place but appear to have slumped or slid to their present positions from higher slopes. In most places, the Cretaceous rocks are believed to be related to collapse structures (sinkholes) resulting from the solution of gypsum and salt from evaporite sequences in the Permian rocks. In the subsurface, Pennsylvanian and older rocks occur but they are at depths too great to be tapped by water wells.

The regional structure of the county is simple. The Permian rocks dip gently (about 14 feet per mile) to the southwest, and are part of a thick sequence of southwestward-dipping sedimentary rocks that constitute the north limb of a large asymmetrical syncline known as the Anadarko basin.

The upper Tertiary and Quaternary rocks rest unconformably on the unevenly eroded surface of the Permian rocks. Although these groups of rocks have not been structurally deformed, they do have slight eastward and southeastward dips that approximately parallel the Permian erosion surface, except in areas where the beds have been subsequently altered by differential compaction, slumping, or collapse.

In Woodward County, the Permian rocks are not a good source of ground water. Their areal distribution is shown on plate 1; and their thickness, physical character, and water-bearing properties are summarized in table 4.

The upper Tertiary rocks (Ogallala Formation, pl. 1 and table 4) are part of a great mass of fluvial material that forms the High Plains in Oklahoma and adjoining States. These rocks, which were laid down under continental conditions by ancient streams flowing eastward from the Rocky Mountain region, are the principal source of ground water in the southwestern part of the county. (See pls. 1, 5, and 6.) Although relatively undeveloped, the upper Tertiary rocks should be capable of yielding 500 gallons per minute (gpm) or more of water to properly constructed wells in areas where the thickness of saturated materials is great.

Deposits of Quaternary age include (1) windblown sand and silt, which in some areas forms a mantle that obscures older rocks and in other areas forms hummocky dunelike topography; (2) terrace deposits that underlie two or more levels along the North Canadian River valley; and (3) alluvium along the channels and flood plains of the larger streams. (See pl. 1.)

Table 4.--Generalized section of geologic formations in Woodward County, Okla.

System	Series	Subdivision		Thickness (feet)	General character	Water-bearing properties
QUATERNARY	Recent	Dune sand		0-30±	Fine- to coarse-grained windblown sand. Consists chiefly of rounded to subrounded quartz grains. In some areas the sand forms a mantle that obscures older rocks; in other areas it forms hummocky surfaces. Most extensive deposits along the north side of North Canadian River.	Highly permeable but mostly above the water table and not saturated. Where saturated, yields water readily to domestic or stock wells, but supply may not be permanent. Water most likely to occur in this unit where underlain by relatively impermeable red beds. Important chiefly as infiltration areas for recharge from precipitation.
	Pleistocene and Recent	Loess		0-10±	Gray silt, in part sandy or clayey; contains caliche locally. Mantles the bedrock in upland areas in the southeastern part of the county.	Moderately permeable but above the water table. May afford good opportunity for recharge.
		Low-terrace deposits and alluvium		0-90	Unconsolidated and interfingering lenses of sand, silt, clay, and gravel along the flood plains (including deposits of the first low terrace of North Canadian River) and channels of the principal streams.	Moderately permeable. Yields large quantities of water to deep wells in North Canadian River valley. Yields small to moderate quantities of water to shallow wells in valleys of larger streams. Water suitable in quality for most uses but may require softening for some purposes.
		High-terrace deposits		0-130	Unconsolidated and interfingering lenses of sand, silt, gravel, and clay that occur at one or more levels above the first low terrace and flood plain of North Canadian River.	Moderately permeable. Yields large quantities of water to deep wells. Water quality suitable for most uses.
TERTIARY	Pliocene	Ogallala Formation		0-400	Poorly to well-consolidated interfingering beds and discontinuous lenses of sand, silt, gravel, clay, sandstone, conglomerate, caliche, limestone, and volcanic ash.	Moderately permeable, and relatively undeveloped. Capable of yielding large quantities of water to deep wells. Water quality suitable for most uses.
PERMIAN		Cloud Chief Formation		0-20	Beds of red shale and sandstone; contains thin layers of gypsum and Day Creek Dolomite Member at base.	Exposed rocks not a source of ground water in Woodward County. May contribute some water to deep wells that penetrate bedrock beneath the Ogallala Formation.
		Whitehorse Group	Rush Springs Sandstone	130±	Well-consolidated beds of fine-grained reddish-brown and grayish-green crossbedded sandstone, red shale, and red siltstone containing disseminated gypsum and thin beds of dolomite at or near base.	Poorly permeable. Yields small quantities of water to domestic and stock wells but insufficient quantities for irrigation. Water quality suitable for most uses but water may be "gyppy" locally.
			Marlow Formation	120-200	Well-consolidated beds of fine-grained orange-red sandstone, containing beds of shale, siltstone, and dolomite. Locally crossbedded and well cemented with calcium carbonate (Doe Creek Sandstone Member).	Poorly permeable. Yields small quantities of water to domestic and stock wells but insufficient quantities for irrigation. Water quality suitable for most uses.
		El Reno Group	Dog Creek Shale	35-140	Reddish-brown, maroon, and green shale containing thin beds of fine-grained sandstone, dolomitic sandstone, and gypsum.	Very poorly permeable. Yields meager quantities of "gyppy" water to wells.
			Blaine Gypsum	80-125	Four beds of massive white gypsum interbedded with reddish-brown and grayish-green shale and gray dolomite.	Very poorly permeable except where crevices, channels, or larger cavities have been formed in beds of gypsum as a result of the solvent action of descending ground water. In some places yields water under artesian pressure to wells. Water normally high in dissolved solids, particularly sulfate. Generally unsuitable for domestic use but satisfactory for irrigation, where large supplies are tapped.
			Flowerpot Shale	180-200	Reddish-brown shale containing a few beds of gypsiferous and dolomitic sandstone and many intersecting veins of satin spar. Beds of salt and beds of sandstone and shale containing disseminated salt have been cored in test holes in north part of county.	Not tapped by water wells in Woodward County. Probably contains water high in chloride and sulfate.

Collectively, the Quaternary deposits are the most important source of ground water in the county (table 4). The deposits are moderately permeable and, in many places, their saturated thickness is great enough to meet reasonable water demands provided heavy pumping is not concentrated in small areas. (See pls. 5 and 6.)

Permian System

In Woodward County rocks of Permian age, generally called red beds by local residents, compose the bedrock beneath Tertiary and Quaternary deposits. The Permian rocks consist primarily of dark-reddish-brown sandstone, siltstone, shale, and sandy shale. Most of the sandstone is fine to very fine grained, and silt is a common constituent of both the shale and the sandstone. Gypsum occurs in all the lithologic units as a cementing agent, as tiny flakes, as thin irregular veinlets that may intersect the beds at any angle, and as irregular beds ranging from a fraction of an inch to more than 30 feet in thickness. Thin, discontinuous zones of white, gray, or green sandstone occur within the red beds at many places. At several places, especially in the areas where the upper units of the Permian crop out, thin beds of gray or white dolomite cap the low hills, or form resistant ledges.

Salt (NaCl), ranging from disseminated crystals in shale to thick beds of halite, also is a constituent of the Permian rocks in the subsurface (Jordan and Vosburg, 1963). The salt beds are covered by considerable thicknesses of shale, and, except for the most northerly part of the county (T. 27 N., R. 19 W.). and the northwestern part of T. 26 N., R. 19 W.), are too deeply buried to be tapped by wells drilled for water-supply purposes.

In this report and on the geologic map (pl. 1), the Permian rocks have been subdivided into (1) the El Reno Group, which includes the Flowerpot Shale, Blaine Gypsum, and Dog Creek Shale; (2) the Whitehorse Group, which includes the Marlow Formation and the Rush Springs Sandstone; and (3) the Cloud Chief Formation.

El Reno Group

Flowerpot Shale

The Flowerpot Shale, the lowest formation of the El Reno Group, is the oldest of the Permian rocks exposed in Woodward County. It crops out in the northeastern part of the county (pl. 1), and forms steep bluffs and typical badlands topography along the south side of the Cimarron River, and in the steep-walled canyons cut by streams draining eastward and northeastward toward the river. In many places, eroded slopes appear to be covered with fragments of shale and many-hued flakes of selenite and satin spar.

Lithologically, the Flowerpot consists of lenticular reddish-brown shale, reddish-orange siltstone, and very fine-grained reddish-brown and reddish-orange sandstone. At many places thin bands of light-gray and greenish-gray gypsiferous shale or siltstone break the monotony of the red beds.

The Flowerpot is estimated to be about 200 feet thick, but only the upper part of the formation is exposed in Woodward County. The Flowerpot conformably underlies the Blaine Gypsum and, in outcrop areas to the east and southeast of the county, it rests conformably on the Cedar Hills Sandstone Member of the Hennessey Shale (Miser, 1954). Information obtained from core holes and electric logs of oil wells indicates that as the Cedar Hills is traced from its outcrop westward into the subsurface it thins, interfingers with shale, and disappears before reaching Woodward County. Consequently, the base of the Flowerpot cannot be traced with certainty in the subsurface in the county.

The shale beds range from a few inches to about 8 feet in thickness. The individual siltstone beds range from 1 to 3 inches in thickness and thicken and thin along the outcrop. The siltstone and sandstone beds generally are lighter in color than the shale beds. Typically they are moderate reddish-orange, and the more sand a bed contains, the more nearly it approaches moderate reddish-orange. Individual sand beds range from a fraction of an inch to about 12 feet in thickness. Some layers show crossbedding, some show little or no bedding, and some have approximately horizontal beds alternating with thicker zones of irregular or indistinct bedding.

The following section, measured by B. L. Stacy along the steep bluff facing the Cimarron River at the south end of the bridge on State Highway 50, shows the lower part of the Blaine Gypsum and the upper part of the Flowerpot Shale.

Section of the Blaine Gypsum and Flowerpot Shale

in the NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 10, T. 26 N., R. 18 W.

	Thickness (feet)
Permian:	
Blaine Gypsum:	
Gypsum, grayish-white, top eroded (Nescatunga Gypsum of Norton, 1939)	4.0
Shale, dark-reddish-brown, slumped	8.0
Gypsum, grayish-white (Medicine Lodge Gypsum of Cragin, 1896)	25.0
Shale, dark-grayish-green and dark-reddish-brown	1.0
Dolomite, light-brown and grayish-green	.4
Total of Blaine Gypsum	38.4

	Thickness (feet)
Permian--Continued.	
Flowerpot Shale:	
Shale, grayish-green, silty	.5
Shale, dark-reddish-brown, mottled grayish-green; dark-grayish-green layer at base	4.0
Shale, dark-reddish-brown, mottled grayish-green, silty	2.5
Gypsum, large crystals, grayish-green, silty	.4
Shale, dark-reddish brown	2.0
Siltstone, grayish-green	.3
Shale, dark-reddish-brown	2.0
Siltstone, grayish-green; contains gypsum nodules 0.5 inch in diameter and dark-reddish-brown shale	1.5
Sandstone, light-brown, and dark-reddish-brown shale in alternating beds; contains a few beds of grayish-green sandstone	5.0
Sandstone, grayish-green, very fine-grained, and dark-reddish-brown shale in alternating beds 0.3 to 0.5 inch thick; contains a few beds of light-brown sandstone	1.5
Section projected from west side of highway, 1,500 feet south of the south end of bridge to east side of highway near south end of bridge.	
Shale, mostly covered	22.0
Shale, dark-reddish-brown, silty, ledge of grayish-green gypsiferous shale at top	8.0
Shale, silty and sandy, gypsiferous, forms small ledge	1.5
Shale, gypsiferous along bedding planes	6.5
Shale, very gypsiferous along bedding planes	4.0
Shale, gypsiferous	3.0
Shale, dark-reddish-brown, mottled grayish-green in middle and at top, very gypsiferous at top	3.5
Shale, dark-reddish-brown	1.8
Shale, dark-reddish-brown, mottled grayish-green; top is grayish-green, and very silty	3.0
Siltstone, grayish-green, hard; forms small ledge	.3
Shale, dark-reddish-brown; conchoidal fractures; thin-bedded grayish-green silty shale 0.1-0.3 foot thick	20.0
Riverbed	
Total of Flowerpot Shale	93.3

Beds of salt and salty shale were encountered in test holes drilled into shale of the Flowerpot near the Big Salt Plain (T. 27 N., R. 19 W.) on the Cimarron River and near Fort Supply Dam (T. 24 N., R. 22 W.). Near the Big Salt Plain, salt deposits were encountered in several test holes at depths ranging from 30 to more than 175 feet below land surface (Ward, 1961). During exploration studies of Fort Supply Dam, deep test holes drilled along the proposed axis of the dam and spillway in secs. 16 and 17, T. 24 N., R. 22 W., encountered salt, salty shale, and shale containing crystals and seams of gypsum at depths ranging from about 390 to more than 500 feet below land surface. In these test holes the uppermost salt deposits were encountered at 35 to 70 feet below the base of the Blaine Gypsum.

Blaine Gypsum

The Blaine Gypsum, the middle formation of the El Reno Group (pl. 1), is one of the most extensive and easily traced formations of the Permian red beds. It is distinguished from formations above and below by several ledge-forming beds of gypsum. In its outcrop area in northeastern Woodward County (pl. 1), the Blaine is about 80 feet thick. In the subsurface its thickness ranges from about 100 feet in the north to about 125 feet in the southwestern part of the county. (See App. B.) At most places in the outcrop area, the Blaine consists of two thick ledge-forming beds of gypsum and dolomite separated by easily eroded reddish-brown shale. At some places, as in T. 26 N., R. 18 W., it has four beds of gypsum separated by shale layers. Following is a section, measured by B. L. Stacy along State Highway 50 in T. 26 N., R. 18 W., showing the general lithology and the typical alteration of ledge-forming and slope-forming beds of the Blaine.

Section of the Blaine Gypsum along State Highway 50

in T. 26 N., R. 18 W.

	Thickness (feet)
Permian:	
Dog Creek Shale.	
Blaine Gypsum:	
Gypsum (Haskew Gypsum Member of Evans, 1931), ledge-forming	5
Shale, reddish-brown, and very fine-grained reddish-brown sandstone; slope-forming	5
Gypsum (Shimer Gypsum Member of Cragin, 1896); ledge-forming	8
Dolomite, light-gray, dense; weathered surfaces deeply pitted and fluted (Altona Dolomite Member of Gould, 1902)	1
Shale, reddish-brown; thin bed of reddish-brown sandstone at top; slope-forming	8

Permian--Continued	Thickness (feet)
Blaine Gypsum--Continued.	
Gypsum (Nescatunga Gypsum Member of Norton, 1939); ledge-forming[3]	8
Shale, reddish-brown; slope-forming	8
Gypsum (Medicine Lodge Gypsum Member of Cragin, 1896); ledge-forming	30
Dolomite (Cedar Springs Dolomite bed of Fay, 1962), and shale	2
Total thickness of Blaine Gypsum	75
Flowerpot Shale.	

The topography in the outcrop area of the Blaine is rough. Many of the resistant ledges formed by gypsum and dolomite terminate in steep northeastward-facing escarpments. In many places the eroded tops of exposed gypsum ledges exhibit a karstlike topography. Excellent examples of this type of topography can be seen at Alabaster Caverns State Park (T. 26 N., R. 18 W.), site of one of the largest gypsum caves known. The rocks overlying the Blaine have many collapse features formed as a result of the solution and removal of gypsum from one or more gypsum layers in the Blaine or from the solution and removal of salt from the Flowerpot which underlies the Blaine. Evidences of slumping, sinkhole filling, and down-warped beds can be seen in many places. Two easy-to-reach areas include one in the SE$\frac{1}{4}$ sec. 34, T. 23 N., R. 20 W., about 4 miles east of Woodward; and one in the NE$\frac{1}{4}$ sec. 11, T. 24 N., R. 19 W., about 10 miles north of Mooreland. The collapse feature in the SE$\frac{1}{4}$ sec. 34 covers about 40 acres. Its center is a few hundred feet north of the county road that traverses the south line of the section. This feature involves rocks of Tertiary, Cretaceous, and Permian ages. It is outlined by a thin unit, the Day Creek Dolomite Member of the Cloud Chief Formation (Norton, 1939) the base of which serves as the base of the Cloud Chief Formation (pl. 1) in northwestern Oklahoma. The dolomite on the perimeter of the collapse feature dips inward toward the center of the disturbed area. The central part of the collapsed area, which has been breached by an intermittent stream, contains caliche-cemented sand and gravel of the Ogallala Formation; blocks of olive-green shale, shell fragments, and other materials of Cretaceous age; and blocks of red and green sandstone and red shale of Permian age all jumbled together. The collapse feature in the NE$\frac{1}{4}$ sec. 11, T. 24 N., R. 19 W., has been exposed in a road cut on State Highway 50. This feature, about 180 feet in diameter, involves the Marlow Formation and the Rush Springs Sandstone of the Whitehorse Group (pl. 1). Evidently

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[3] In many outcrops to the north and south a thin dolomite bed (Magpie Dolomite Member of Gould, 1902), ranging from 0.5 to about 2 feet in thickness, occurs above the shale beneath the Nescatunga Gypsum Member. In places farther south the dolomite contains abundant molds of the fossil clam <u>Permophorus</u> (Fay, 1962, p. 39-40). In Woodward County, however, the dolomite appears to be barren of fossils.

the jumbled materials in the collapsed areas serve as plugs sealing large cavities formed by the solution of gypsum in the Blaine, or possibly solution of salt beds in the Flowerpot, by circulating ground water. Although sinkholes and other collapse structures have not been formed in Woodward County during modern times, the solution and removal of gypsum and salt by circulating ground water probably is a continuing process. Well drillers have reported encountering cavities at one or more levels in interbedded shale and gypsum at several places in the county. Myers (1960b, and 1961) described caves, sinkholes, and subterranean drainage courses formed in gypsum in Alabaster Caverns State Park, and he presented evidence showing that these features have resulted chiefly from solution and removal of gypsum by circulating water. Fay (1958) concluded that a modern sinkhole found in a field in central Blaine County was formed when the roof of a large solution cavern collapsed. According to him, the cavern had been formed by ground water circulating through a bed of gypsum buried more than 100 feet below land surface.

Dog Creek Shale

The Dog Creek Shale, the uppermost formation of the El Reno Group, includes all the deposits between the uppermost gypsum of the Blaine and the base of the Whitehorse Group (pl. 1). In places where one or more beds of the Blaine Gypsum is missing the Dog Creek probably includes shale that in other areas has been referred to the Blaine. Thus, thicknesses measured along the outcrop of the Dog Creek are variable, ranging from about 35 feet in T. 25 N., R. 18 W., to about 60 feet in areas to the southeast. The formation thickens southward and southwestward in the subsurface; and in the southwestern corner of the county, it is reported to be about 140 feet thick.

The Dog Creek is principally a reddish-brown blocky clay shale. Light-gray and grayish-green bands similar to those in the Flowerpot are common, but the bands are not persistent and grade into the surrounding shale within relatively short distances. Much of the shale is massive, but included in it are thin hard layers and ledges of grayish-green dolomitic siltstone and very fine-grained sandstone.

Water-Bearing Properties of the El Reno Group

In Woodward County the rocks of the El Reno Group are not a good source of ground water. In most places, the rocks are so fine textured and so well indurated that they are incapable of yielding more than a few gallons of water per minute. Wells drilled within the outcrop areas of the Flowerpot Shale and Dog Creek Shale (pl. 1) probably obtain most of their water supplies from a zone of weathered material above the relatively unaltered host rock. Below the weathered zone water is obtained from cavities left by removal of soluble materials and from fractures intersected during drilling. In most places the water is of poor quality; and though suitable for stock use, is generally unsuitable for domestic use because of the gypsum dissolved from flakes, veinlets, and cementing materials in the rocks.

The Blaine Gypsum is poorly permeable, except where crevices, channels, or larger cavities have been formed in gypsum layers as a result of the solvent action of circulating ground water. Wells tapping the Blaine obtain most of their water supplies from these solution openings. If a well encounters one or more water-filled cavities, a large yield may be obtained; if not, the yield may be adequate only for watering stock. Yields of more than 1,000 gpm have been obtained from wells drilled into solution cavities in beds of gypsum in southwestern Oklahoma (Schoff, 1948), although a good many dry holes and wells of small yield have been drilled and abandoned in the midst of more productive ones. The surest way of finding water-filled cavities in the Blaine is by test drilling.

In Woodward County the Blaine has not been prospected as a source of water, except locally for stock supply. Several wells, most of which were drilled in search of oil, have tapped water in the Blaine under sufficient pressure to flow at the land surface, but the water in excess of stock requirements has been allowed to flow to waste.

The water from the Blaine is highly mineralized, containing especially large amounts of calcium sulfate. Although it is unsuitable for domestic, municipal, or most industrial uses, it probably can be used successfully in some places for irrigation. In southwestern Oklahoma, water of similar quality has been pumped from solution cavities in beds of gypsum and gypsiferous shale and used to irrigate large areas with no harmful effects on soil or crops. Changes in water quality with depth should be recorded during test drilling, because the salt (NaCl) content of the water seems to increase rapidly with depth. The source of the salt is not known, but it may be from halite in the basal section of the Blaine, or from salty beds in the Flowerpot Shale underlying the Blaine.

Whitehorse Group

In Woodward County, the Whitehorse Group consists of 250 to 330 feet of fine-grained sandstone, siltstone, shale, gypsum, and dolomite. It includes all the Permian strata between the top of the Dog Creek Shale and the base of the Cloud Chief Formation (pl. 1). The top of the group is at the base of the Day Creek Dolomite, which crops out for about 60 miles in a southeast-trending belt in Harper and Woodward Counties.

Rocks assigned to the group crop out along both sides of the North Canadian River valley, form the drainage divide between the Cimarron and

North Canadian Rivers, and constitute the Permian bedrock surface concealed beneath the Tertiary and Quaternary deposits in the southern two-thirds of the county. The concealed bedrock surface is an erosional unconformity having a topographic relief of several hundred feet (pl. 4). The relief has been caused by Pleistocene and Recent cycles of erosion, by pre-Pliocene and post-Cretaceous cycles of erosion, and by collapse structures resulting from solution of gypsum and salt from deeper Permian rocks.

South of the North Canadian River, rocks composing the group have weathered to form a gently rolling plain, containing rounded hillocks, and low rounded ridges capped by resistant beds of dolomite or dolomitic limestone. Along the drainage divide between the North Canadian and Cimarron Rivers, rocks of the group have weathered to form rounded sandstone hills containing occasional flat-topped ridges capped by resistant beds of dolomite and bounded on one or more sides by low, steep escarpments.

Where feasible, the Whitehorse Group has been subdivided into the Marlow Formation and the Rush Springs Sandstone (pl. 1). The boundary between the two formations has been marked at the top of a thin dolomite, or dolomitic sandstone, Upper Relay Creek Dolomite of Evans (1931). This boundary cannot be easily recognized in many parts of the county. Hence, in areas where the boundary was not identified, the rocks were mapped (pl. 1) as the Whitehorse Group.

The following section, measured by B. L. Stacy along a southwest-trending draw in the NW¼WN¼ sec. 18, T. 24 N., R. 18 W., shows the general lithology of the rocks composing the Whitehorse Group.

Section of the Whitehorse Group in NW¼NW¼ sec. 18, T. 24 N., R. 18 W.

	Thickness (feet)
Permian:	
Dolomite, gray, dense (Day Creek Dolomite)	2.0
Whitehorse Group:	
Rush Springs Sandstone:	
Sand, grayish-green, shaly	1.0
Shale, mottled moderate-reddish-brown and grayish-green, partly covered	9.0
Sandstone, grayish-green	1.0
Shale, moderate-reddish-brown, mottled grayish-green	8.0
Dolomite, moderate-reddish-brown	.3
Sandstone, light-reddish-brown, crossbedded	1.0
Covered, probably sandy shale	16.0
Sandstone, mottled dark-reddish-brown and grayish-green	1.0
Shale, dark-reddish-brown	5.5
Sandstone, moderate-reddish-brown, mottled grayish-green at top, shaly in middle	8.0

Permian--Continued.

Whitehorse Group--Continued

Rush Springs Sandstone--Continued	Thickness (feet)
Sandstone, grayish-green, dolomitic; contains sand balls	.2
Sandstone, moderate-reddish-brown, massive; forms ledge	14.0
Shale, sandy	1.0
Sandstone, silty	3.0
Shale, moderate-reddish-brown, mottled slightly grayish-green, sandy	7.0
Sandstone, light-reddish-brown, mottled grayish-green, very silty	1.8
Shale, dark-reddish-brown, mottled grayish-green	5.5
Sandstone, grayish-green, very fine-grained	1.5
Shale, dark-reddish-brown	2.0
Sandstone, moderate-reddish-brown, mottled grayish-green with top 3.0 feet all grayish-green; bottom 4.0 is shaly	9.0
Sandstone, grayish-green, crossbedded; shale layers at base	.8
Shale, moderate-reddish-brown, mottled grayish-green	2.6
Sandstone, grayish-green, mottled moderate-reddish-brown, friable, silty at bottom	1.8
Shale, dark-reddish-brown	1.5
Sandstone, grayish-green, top 0.5 foot mottled moderate-reddish-brown, very fine-grained, friable	2.5
Shale, moderate-reddish-brown	2.0
Sandstone, mottled grayish-green and moderate-reddish-brown	1.8
Shale, dark-reddish-brown, mottled grayish-green at top	5.0
Total thickness of Rush Springs Sandstone	113.8

Marlow Formation:	
Dolomite, white, contains dark-red and black grains (Upper Relay Creek Dolomite of Evans, 1931)	.5
Sandstone, fine-grained, crossbedded; top bed 1 to 2 feet thick is grayish-green, lower part is pale-reddish-brown; color change cuts sharply across beds; unit thins and thickens, and has a purple hue	4.5
Shale, moderate-reddish-brown	2.8
Sandstone, moderate-reddish-brown, silty at base, grayish-green at top	11.5
Shale, moderate-reddish-brown, conchoidal fracture, grades upward into mottled grayish-green sandstone	6.0

Permian--Continued.
Whitehorse Group--Continued
Marlow--Continued

	Thickness (feet)
Sandstone, moderate-reddish-brown, sand balls in upper part, mottled grayish-green at top; forms ledges	5.0
Shale, mottled moderate-reddish-brown and grayish-green, sandy	3.5
Sandstone, moderate-reddish-brown, shaly and silty	5.0
Dolomite, dushy-red and light-brown, contorted laminations (Lower Relay Creek Dolomite of Evans, 1931)	.2
Sandstone, pale-reddish-brown, thin-bedded, tightly cemented, bottom not exposed (Doe Creek Sandstone Member)	1.8
Total of Marlow Formation measured	40.8
Total measured section of Whitehorse Group	154.6

Marlow Formation

The Marlow Formation overlies the Dog Creek Shale and is the lower of the two formations making up the Whitehorse Group (pl. 1). In Woodward County the Marlow is composed principally of soft, friable, fine-grained sandstone. It includes the Doe Creek Sandstone Member, and has at the top two thin dolomite beds, the Upper and Lower Relay Creek Dolomite of Evans (1931).

The top of the formation is marked at the top of the Upper Relay Creek Dolomite[4] of Evans. This unit is not easily recognized in many parts of the county; and in areas where it was not identified, the Marlow and the overlying Rush Springs Sandstone were mapped as the Whitehorse Group, undifferentiated. (See pl. 1.)

The Marlow is judged to be conformable with the underlying Dog Creek Shale even though in some places, crossbedded sands of the Marlow appear to be as much as 30 feet below the general top of the Dog Creek. The suggested local unconformities probably reflect the variable thickness of the Dog Creek or local structures rather than a period of erosion before deposition of the Dog Creek. Where it has been differentiated,

4 The Oklahoma Geological Survey, in a report prepared by Dr. R. O. Fay (1962), has applied new names to the Upper and Lower Relay Creek Dolomites. Fay states (p. 69): "The Upper Relay is herein named the Emanuel Dolomite Bed, ***. The Lower Relay Creek is herein named the Relay Creek Dolomite Bed. The type locality and type section of the Emanuel and Relay Creek Beds are those of the Upper and Lower Relay Creek Beds, respectively."

the Marlow ranges from 120 to about 200 feet in thickness and consists predominantly of moderate-reddish-orange to moderate-reddish-brown friable, fine grained quartzose sandstone. In most places, basal beds are distinctly crossbedded, and in some places, as in the SW$\frac{1}{4}$ sec. 36, T. 25 N., R. 19 W., the base is marked by a conglomerate of reworked red-bed materials.

The following section, measured by B. L. Stacy along the bed of a north-trending creek in the SE$\frac{1}{4}$ sec. 1, T. 24 N., R. 19 W., shows the lithology of the lower part of the Marlow Formation.

Section of the Marlow Formation in the SE$\frac{1}{4}$ sec. 1, T. 24 N., R. 19 W.

	Thickness (feet)
Permian:	
Marlow Formation:	
Sandstone, moderate-reddish-brown, shaly	4.0
Dolomite, grayish-pink and white laminations	.1
Sandstone, dolomitic, grayish-purple; contains dendrites and grayish-pink dolomite	.1
Sandstone; contains light-brown and dark-brown laminations	.5
Sandstone, dolomitic, grayish-purple, hard; contains dendrites	.1
Siltstone, dark-reddish-brown, sandy	.6
Sandstone, grayish-purple; contains dendrites	.1
Shale, dark-reddish-brown, sandy	.1
Sandstone, dolomitic, grayish-purple, hard, contains dendrites	.3
Sandstone, moderate-reddish-brown, silty	6.0
Sandstone, moderate-reddish-brown, silty, massive appearing but crossbedded on closer examination; bedding plane at top	10.0
Covered, probably shaly or silty sandstone	9.0
Sandstone, moderate-reddish-brown, silty, massive appearing but crossbedded on closer examination	±17.0
Sandstone, pale-reddish-brown, friable, crossbedded	8.5
Sandstone, pale-reddish-brown and grayish-green, fine-grained, in thin alternating beds less than 0.1-inch thick	2.0
Sandstone, pale-reddish-brown, hard, crossbedded; contains dendrites	.2
Sandstone, pale-reddish-brown with grayish-green spots $\frac{1}{4}$ inch in diameter, very fine-grained	5.5
Sandstone, grayish-green, very fine to fine-grained, hard, crossbedded	.7
Total exposed thickness of Marlow Formation	64.8

The Doe Creek Sandstone Member (pl. 1) forms a discontinuous linear outcrop pattern which trends perpendicularly to the regional structure. It has been mapped northeastward from sec. 5, T. 22 N., R. 20 W. (Woodward County), to sec. 20, T. 28 N., R. 16 W. (Woods County). Beyond these points the unit is covered by younger rocks of the Whitehorse Group.

The Doe Creek is resistant to weathering, and forms rugged outcrops that are further characterized by rough, vuggy surfaces. In its outcrop area the Doe Creek has a maximum thickness of about 50 feet. It consists of relatively thick beds of firmly cemented orange-pink to light-reddish-brown fine-grained sandstone containing many well-rounded and frosted particles of coarse- to very coarse-grained quartz, oölites, and unidentified marine fossils. In some outcrops the sandstone beds are distinctly crossbedded; in others the sand occurs in massive, indistinctly bedded units and as thin, slabby beds. Calcium carbonate, the principal cementing agent, also occurs as calcite filling casts or molds of fossils, and as thin veins filling crevices in the rocks. The cement makes up about 60 percent of the rock.

The two dolomite beds (Upper Relay Creek and Lower Relay Creek Dolomites of Evans, 1931) occurring at the top of the Marlow range in thickness from paper thin to about 4 inches and are separated by zero to about 25 feet of reddish-brown sandstone and shale. Locally the dolomite beds grade into gypsum, and at places one or both may be missing. As noted above, the upper dolomite marks the top of the Marlow; and where only one dolomite is found it cannot safely be identified as either the upper or the lower one. According to Fay (1962, p. 72) the best way to map the dolomites is to find both beds in the same outcrop and to plot their altitudes on a map. The altitude of an unidentified dolomite can be compared with the altitudes of the known beds and, after correcting for the regional dip of the beds (about 14 feet per mile), the identity of the unknown bed can usually be determined. Fay also reports (oral communication, March 1963) that where one of the Relay Creek Dolomite beds has been found, the missing bed or a dolomitic shale representing the missing bed usually can be found by carefully searching an area of 15 to 30 feet stratigraphically above or below the identified bed.

Rush Springs Sandstone

The Rush Springs Sandstone, the uppermost formation of the Whitehorse Group, conformably overlies the Marlow Formation. In a few places, especially north of Mooreland and southeast of Woodward (pl. 1), the Rush Springs is conformably overlain by dolomite, shale, and silty sandstone beds of the Cloud Chief Formation. In these areas the top of the Rush Springs is marked at the base of the Day Creek Dolomite. At most other places, the uppermost part of the formation has been removed by erosion. The base of the Rush Springs has been defined as the top of the Upper Relay Creek Dolomite of Evans (1931). This unit is not easily recognized in most parts of the county; therefore, where it was not definitely identified the Rush Springs and the underlying Marlow were mapped as the Whitehorse Group. See pl. 1.)

Where it has been differentiated, the Rush Springs Sandstone consists of about 130 feet of sandstone, siltstone, and shale which can be subdivided, on the basis of lithology, into a lower, rather evenly bedded sandstone unit and an upper shale unit.

The lower sandstone unit, 70 to 90 feet thick, is composed of an interbedded series of well-bedded reddish-brown and grayish-green fine-grained quartzose sandstone, silty sandstone, and sandy to silty shale. In most places, the top of the sandstone unit occurs near the base of a dolomitic shale; but in some places, especially in the SE¼ sec. 23, T. 23 N., R. 18 W., and in the SE¼ sec. 9, T. 24 N., R. 22 W., the dolomitic horizon is missing and the top of the sandstone unit is marked by a series of thin, platy siltstone beds.

The upper shale unit is 40 to 60 feet thick, and consists of reddish-brown clay shale containing occasional beds of reddish-brown and grayish-green silty shale, siltstone, and very fine-grained sandstone. A dolomitic zone containing from one to three thin beds of dolomite or dolomitic shale occurs near the base of the unit in most places.

Water-Bearing Properties of the Whitehorse Group

In Woodward County, the rocks of the Whitehorse Group are poor aquifers that are used only where no other is avilable. At most places the rocks are capable of yielding water in quantities sufficient for domestic and stock requirements, but they are too fine grained and too well consolidated to transmit water at rates sufficient to supply irrigation wells. In some places the permeability of the rocks may have been increased somewhat by the solution and removal of gypsum and gypsiferous cement. In such cases the water may be unfit for human consumption because of the disagreeable taste and laxative effect resulting from the dissolved gypsum.

The principal hydrologic function of the Whitehorse Group is to impede the downward movement of water from Tertiary and Quaternary deposits in the southern two-thirds of the county. Thus, the concealed erosion surface (pl. 4) of the relatively impermeable rocks of the Whitehorse Group serves as the base of the ground-water reservoir contained in the overlying deposits. When water percolating downward through the Tertiary and Quaternary deposits becomes impeded, it tends to move laterally toward areas of lower hydrostatic head. In this way, the percolating water fills troughs or depressions in the eroded surface of the Permian rocks and thus forms a saturated zone of varying thickness (pl. 5) in the lower part of the Tertiary and Quaternary deposits.

In some places, especially along creek valleys where the contact between the Permian surface and overlying deposits has been exposed, points of ground-water discharge are marked by springs, willow and cottonwood trees, and other water-loving vegetation.

Cloud Chief Formation

The Cloud Chief Formation overlies the Rush Springs Sandstone and is the youngest of the Permian rocks exposed in Woodward County. The formation, most of which has been removed by erosion, occurs principally as isolated outliers capping buttes, odd-shaped flat-topped ridges, and rounded hills located mostly in T. 24 N., Rs. 18 and 19 W., and T. 22 N., R. 20 W. (See pl. 1.) In these areas the Cloud Chief ranges from less than a foot to about 20 feet in thickness and contains at its base the Day Creek Dolomite and an overlying unnamed unit composed principally of dark-maroon shale and very fine-grained sandstone. The Day Creek is a dense light-gray, pink or white coarsely crystalline to very fine-grained crenulated dolomite or dolomitic limestone. Because of its resistance to erosion, it is the "cap rock" that supports may of the buttes, hills, and ridges along the divide between the North Canadian and Cimarron Rivers north of Mooreland and the hills and ridges south of North Canadian River. In some places, a reddish-brown or purplish dolomite, about 3 inches thick, occurs about 4 feet above the Day Creek.

The Cloud Chief, so far as is known, yields no water to wells in Woodward County. Because most of the formation has been removed by erosion, wells in outcrop areas probably would obtain most or all their water from the underlying Rush Springs Sandstone.

TERTIARY SYSTEM

Ogallala Formation

The Ogallala Formation of Pliocene age crops out in an area of about 320 square miles in the west-central and southwestern part of the county (pl. 1). This area is an extension of the broad area known as the High Plains, which extends from the southern end of the Texas Panhandle to South Dakota. The Woodward County topography does not resemble the High Plains, but is marked by flat upland ridges, gentle slopes, rounded escarpments, and large dune-covered areas. In the northern part of the outcrop area the upper part of the Ogallala has been stripped away so that the formation is thinner than elsewhere in the county. That part of the area has the appearance of a stream terrace partly covered by dunes, and the upland surface is about 100 to 150 feet lower than the general upland level in the main part of the outcrop area.

The Ogallala Formation was deposited by streams flowing southeastward from the southern part of the Rocky Mountains. The base lies on an eroded surface of the Permian rocks that is characterized by stream valleys, hills, and locally, sinkholes (pls. 4 and 7). Relief on the bedrock surface beneath the Ogallala is about 210 feet--from 1,940 feet in sec. 36,

T. 22 N., R. 20 W., to 2,150 feet in sec. 36, T. 20 N., R. 21 W. The bedrock-contour map (pl. 4) shows what appears to be a sinkhole at the site of the test hole in sec. 31, T. 21 N., R. 20 W. The base of the Ogallala is about 70 feet lower there than in adjacent areas. Fillings of Ogallala-type material in eroded sinkholes can be observed east of Sharon where the edge of the formation is exposed. Ogallala deposits also fill a stream valley that trends southeastward and eastward nearly through the middle of the outcrop area in Woodward County (pl. 4).

In Woodward County the Ogallala Formation has a maximum thickness of about 400 feet, as determined from test drilling, and averages about 210 feet. The thickness varies considerably from place to place because the upper part has been eroded and because of the irregular surface on which the formation lies (pl. 4).

The formation consists principally of semi-consolidated sand, silt, gravel, clay, caliche, and volcanic ash. It is not well exposed in most of the county, but its character can be determined from test-hole logs and from exposures in adjoining areas. Like other fluvial deposits, the beds are lenticular and discontinuous, and local erosional unconformities occur within the deposits. Individual beds range from a few inches to several feet in thickness and may interfinger or grade laterally into beds of different lithology. Much of the formation is poorly consolidated and some beds of sand are so loose the drillers refer to them as "quicksand." Other beds are partly cemented with calcium carbonate, and a few are so well cemented they form resistant layers of caliche or "mortar beds."

Test-hole logs (App. B) indicate that the principal lithology of the Ogallala in Woodward County is sand which is mostly quartz and ranges in size from very fine to very coarse. Much of the sand is loose or only very loosely cemented with calcium carbonate and the loose sand probably is the source of the dune sand that covers a large part of the Ogallala outcrop area. Much of the sand is buff in color, but gray, greenish-gray, and reddish beds also have been noted. Many of the sand beds are silty but a few are well sorted or contain gravel although gravel is not a very common lithology in Woodward County. In a few places silty sands cemented with calcium carbonate form "caliche" layers that hold up small buttes or form ledges along hill or valley slopes. Caliche also occurs as nodules or as thin impure beds of silty limestone. Opalized opaque chert is intermixed with the caliche in places.

Thick sections of clay, generally sandy or silty and locally containing caliche, were noted in the logs of several test holes. The thickest sections were in the lower part of the formation in test-holes 20N-22W-22ccc1, -31bcc1, -36add1, and 22N-22W-22bbb1. The clay is commonly silty or sandy, and in places is interbedded with caliche and thin beds of sand. It is generally buff or light-red, but in places is orange, brown, grayish-brown, or gray.

Volcanic ash, about 10 feet thick, is exposed in a pit in sec. 24, T. 23 N., R. 22 W., and has been mapped as part of the Ogallala Formation (pl. 1). The ash is bluish-gray, thinly stratified, and partly cemented with calcium carbonate. It is impure in part, containing much silt and fine sand, particularly in the lower part. In places, thin lenticular layers of bentonite, probably derived from weathering of the ash, are interbedded with it. Bentonite was noted in cuttings from several test holes, and volcanic ash was found in test-hole 23N-22W-22dcd3.

Although gravel is relatively uncommon in the Ogallala in Woodward County, the gravel furnishes valuable clues to the origin of the material composing the formation. The gravel contains fragments of igneous and metamorphic crystalline rocks from the Rocky Mountains and dark volcanic rock, quartz, jasper, petrified wood, chert, and pebbles and cobbles from the Permian and Cretaceous rocks, including pieces of water-worn Cretaceous shells and ironstone. These materials indicate that much of the detritus in the Ogallala was derived from sources far to the west, but that the material was mixed with fragments eroded from exposures of Cretaceous and Permian bedrock, probably near the areas of deposition.

Water-Bearing Properties of the Ogallala Formation

Because of its large areal extent and great thickness of saturated material, the Ogallala Formation contains the largest reservoir of ground water in Woodward County--about 3.6 million acre-feet. Its saturated thickness averages 180 feet and is more than 300 feet in the southwestern part of the county (pl. 5). Recharge to the formation is derived chiefly from precipitation absorbed by dune sand in the outcrop areas, where a high percentage of water infiltrates to the ground-water body. The formation probably receives recharge over most of its area but an important recharge area is shown by the north-trending water-table ridge, centered in T. 21 N., R. 22 W. (pl. 3).

The Ogallala is essentially undeveloped as an aquifer in Woodward County, although it supplies most of the water needs for the farms in the southwestern part of the county. Most wells tapping the formation produce only a few gallons of water per minute to supply domestic and stock needs. Because the depth to water in the formation ranges from less than 10 to nearly 140 feet, the wells also range widely in depth. Records of 10 irrigation wells are given in Appendix A. These wells range in depth from 23 feet for well 21N-20W-6add1, which is in a topographically low area, to 184 feet for well 21N-21W-16cdb2, in an upland area. The largest yield reported is 290 gpm for well 21N-21W-16cdb2 which penetrated about 125 feet of saturated sand. Specific capacity of the well was 10 gpm/ft.

Ground water seeping from the Ogallala maintains the dry-weather flow of Indian, Hackberry, North Persimmon, South Persimmon, and Sand Creeks, and small tributaries of Wolf Creek (table 6, pl. 3). During summer periods several of these streams flow for only short distances downstream from the seepage areas before the combined effects of evaporation and transpiration by plants along the channels remove all the seepage water.

The rate of pumping from the Ogallala is only a fraction of the rate at which the aquifer is being replenished, therefore pumping from the formation could safely be increased substantially. Other things being equal, the yield of properly constructed wells generally is proportional to the thickness and permeability of the saturated material tapped by the well. Hence the yield of wells in areas where the saturated thickness of the Ogallala is relatively thin (pl. 5) would be less than in areas where it is thick. Most of the test holes reported a high percentage of sand in the Ogallala, but in several test holes nearly 100 feet of clay was present. Because the lithology differs so much from place to place, test drilling is desirable to determine the character and thickness of the deposits in the formation and to select the most favorable site for a well. Packing the well with gravel of a diameter selected on the basis of the size of the sand to be screened also is desirable to prevent the pumping of sand.

It should be possible to develop additional wells yielding several hundred gallons per minute at many places in the outcrop area of the Ogallala, particularly near the southwestern corner of the county. Although the water is hard, it is suitable for drinking, for livestock, for irrigation, and for most other uses.

Quaternary System

A large part of the land surface in the central and southwestern parts of Woodward County is covered by unconsolidated deposits of Quaternary age. Fluvial deposits include the broad area of high-terrace deposits, mostly on the north side of the North Canadian River, and smaller areas of low-terrace deposits and alluvium adjacent to the principal streams. Eolian deposits include the dune sand that overlies large areas of the high-terrace deposits and Ogallala Formation, and several square miles of silt that has been mapped as loess near Mutual.

The Quaternary deposits unconformably overlie the Permian rocks and the Ogallala, and younger Quaternary deposits are channeled into, or conformably overlie, the older deposits. On the basis of their surface features, geomorphology, and relation to other deposits, the alluvium and dune sand are judged to be Recent. The high-terrace deposits are Pleistocene, probably Kansan to early Wisconsin in age, and the low-terrace deposits probably are late Wisconsin to Recent.

The Quaternary deposits have been mapped more on the basis of surface form or geomorphology than lithology. The surface of the dune sand is hummocky and undulating and is marked by "blowouts" and characteristic dune forms that are easily recognized on the ground or on aerial photographs. The surface of the alluvium and low-terrace deposits is nearly flat and little dissected except in and adjacent to modern stream channels, where it is irregular. The high-terrace deposits are more eroded than the low-terrace deposits and in most places their surface is gently sloping or irregular rather than flat. In most places the contact between the two terrace deposits is a pronounced break in slope, but in some places the contact is obscured by dune sand.

High-Terrace Deposits

The high terrace deposits of Woodward County occur mostly north of the North Canadian River. They extend eastward and southeastward in a band 3 to 10 miles wide from near the north bank of the river to the divide between the North Canadian and Cimarron Rivers. In places the deposits extend across the divide, and a small area occurs in the Cimarron drainage basin (pls. 1 and 7). In much of the area a thin layer of dune sand covers the terrace deposits and most of the area has been mapped as dune sand (pl. 1). The high-terrace deposits are so named because they occupy a terrace position that is elevated with respect to the adjacent river valley. These deposits are the most extensive and most important aquifer in the county.

The high-terrace deposits consist principally of unconsolidated sand, silt, clay, and gravel. The main source of this material was the Ogallala Formation to the northwest, and some material was eroded from local bedrock--the Permian and Cretaceous beds. The deposits overlie a surface eroded into the Permian redbeds and they fill channels and blanket hills on that bedrock surface (pl. 4). They are Pleistocene in age and may represent as many as three cycles of erosion and deposition. In places, three rather indistinct terrace levels can be identified within the area of terrace deposits. Volcanic ash and associated fossils in the deposits along the stream divide near their northern edge have been identified as Kansan in age (Myers, 1962). Because of their relation to the North Canadian River, it is believed that these deposits were laid down by an ancestral North Canadian River flowing somewhat north of and at a higher elevation than the present stream. If the deposits actually do represent several cycles of deposition, then during each succeeding cycle the older deposits probably were incised and reworked to form the next younger deposits.

Downstream, in Blaine County, Fay (1962, p. 94) recognized three terrace levels and postulated that deposits occupying a position similar to the high-terrace deposits of Woodward County were late Kansan to Wisconsin in age.

It was not deemed practical for this report to separate the deposits representing different Pleistocene cycles within the mass of high-terrace deposits. The entire mass forms a single aquifer wherein water moves from intake areas in topographically high areas toward discharge areas along the streams. Therefore, the deposits are treated as a unit in this report.

The high-terrace deposits consist mostly of unconsolidated sand, gravel, silt, and clay. Fine to coarse sand constitutes the greater part of the deposits (App. B) and quartz is the dominant mineral in the sand. The deposits also contain smaller amounts of clay, silt, very coarse sand, gravel, volcanic ash, bentonite, and soft caliche. Their color commonly is brown or buff, but some of the clay beds are red, orange, or gray; some of the sand beds are bright yellow; and where caliche occurs, the beds are light gray or grayish white. Much of the material is not well sorted and the sands commonly are silty or contain scattered gravel. Thin beds of gravel or sand and gravel occur in the basal part of the deposits, particularly where they fill buried channels. Locally, the basal sand and gravel is cemented to form a resistant conglomerate.

Individual beds in the deposits are lenticular and irregular. They may range in thickness from a few inches to several feet, and in some exposures sand beds as thick as 20 feet have been noted.

The thickness of the high-terrace deposits as a unit ranges widely from place to place. The maximum recorded was 145 feet in test-hole 24N-19W-19cdd1. This test hole was drilled in a dune area and several feet of dune sand may have been penetrated before the terrace deposits were reached. More than 120 feet was penetrated in several test holes, so the maximum thickness is judged to be 120 to 130 feet. The average thickness, as shown by test-hole logs (App. B) is about 70 feet, and thicknesses in excess of 100 feet occur where the bedrock channel (pls. 4 and 7) coincides with an area of relatively high topography.

Water-bearing properties--The high-terrace deposits are the most important and most developed aquifer in Woodward County. Ground water has been developed from these deposits because of its shallow depth, the relatively high permeability of the deposits, the moderate yield of wells, and the occurrence of the deposits near the county's two principal cities and near the areas of most productive agricultural land. In addition to municipal supplies for Woodward and Mooreland, water for the principal industries in the county, and for irrigation, the high-terrace deposits furnish much of the water for domestic and stock use on farms in their outcrop area. However, pumpage from the deposits is small compared to the quantity in storage--estimated to be nearly a million acre-feet in Woodward County.

The depth to water in the high-terrace deposits is less than 50 feet in large areas and less than 20 feet in a few places (pls. 1 and 6). Where the permeability of the deposits is relatively high and the saturated thickness is great, wells yield several hundred gallons per minute. The saturated thickness of the deposits is more than 60 feet at several places and more than 40 feet in about half the area (pl. 5).

Yields of many of the muncipal wells in the Woodward and Mooreland well fields and of the industrial and the irrigation wells are more than 100 gpm. Yields of 4 irrigation wells test pumped as part of this investigation ranged from 170 to 490 gpm (table 5). The most productive well (23N-19W-23cbd1) in the high-terrace deposits is an industrial well for the powerplant of Western Farmers Electric Cooperative near Mooreland. This well had a yield of 660 gpm with a drawdown of only 25 feet and a specific capacity of 26 gpm/ft when tested in 1962 (table 5).

Because of the large areas of dune sand and sandy soil developed on the terrace deposits, precipitation infiltrates readily and a large part percolates down to the ground-water body. In Woodward County, the North Canadian River has only one poorly developed tributary that drains the high-terrace deposits. Drainage for the rest of the area is underground through the high-terrace deposits. The water-level contour map (pl. 3) shows that the highest points of the water table in these deposits are near the North Canadian-Cimarron River divide. This corresponds closely with the topographic high and from this area ground water moves toward lower areas, principally along the North Canadian River. Some of the water seeps into the river, some moves downstream as underflow beneath the valley, and a large part is used by salt cedar, willow, cottonwood, and other plants that commonly grow adjacent to the river. Some of this water might be salvaged for use in the county if the streamward flow of water could be intercepted by wells.

Additional wells yielding 100 to 300 gpm could be developed in the high-terrace deposits at several places. The test-hole logs (App. B) and the saturated-thickness map (pl. 5) would be useful guides in selecting areas for more detailed testing. Test drilling would aid in determining the thickness and character of the deposits and in choosing the best well sites. Care should be taken to space wells of large yield properly so as to avoid interference between wells, local overdevelopment, and consequent depletion of the aquifer.

Low-Terrace Deposits

Relatively young alluvial deposits form terraces only a few feet higher than the flood plains of streams and have been mapped along the North Canadian River and Wolf, Bent, and Persimmon Creeks. The surface of these deposits is nearly undissected and slopes downstream. Thus, it contrasts with the surface of the adjacent high-terrace deposits which slopes toward the river and has been partly eroded. The low-terrace deposits have been channeled into and in part overlie the high-terrace deposits and in turn have been channeled into by the Recent alluvium that forms the present flood plain. The age of the low-terrace deposits has not been determined, but they evidently were formed during the erosional cycle immediately preceding the present cycle. Their geomorphic form suggests that they are only slightly older than the Recent alluvium, and they therefore probably are of late Pleistocene age.

From a point near Mooreland downstream to the county line the low-terrace deposits form a nearly continuous band along both sides of the North Canadian River (pl. 1). Including the flood plain of the river, which has cut out a band $\frac{1}{2}$ to $1\frac{1}{2}$ miles wide, the width of the deposits is 3 to 4 miles. Upstream from Mooreland only remnants of the low-terrace deposits are present. They have been eroded away completely where the river valley is constricted by the resistant Doe Creek Sandstone Member of the Marlow Formation just south of Boiling Springs State Park (pl. 1). In other places, such as just north of Woodward, they are obscured by dune sand, or they have been eroded away by the river, as in the northern part of T. 24 N., R. 21 W.

In addition to the areas along North Canadian River, narrow bands of low-terrace deposits were mapped along Wolf, Bent, and Persimmon Creeks in their lower reaches where it was possible to show them on the map without exaggeration. Elsewhere along these streams and along other tributaries these deposits were mapped together with the adjoining alluvium (pl. 1).

The low-terrace deposits consist principally of sand, generally buff and poorly sorted. Much of the sand is a mixture of fine to coarse; some layers contain silt, gravel, or clay. Although buff is the predominant color, gray, brown, red, and yellow beds have been reported. Gravel occurs near the base at most places (App. B), either in distinct beds or mixed with the sand. Silt and clay may occur in any part of the deposits, but seem to be most common in the upper zones. Bedding of the low-terrace deposits cannot be observed, but probably is similar to other fluvial deposits in being lenticular and irregular. Logs of test holes indicate that individual beds may range from less than a foot to several feet in thickness.

The low-terrace deposits may be channeled into the older high-terrace deposits in places, but at most places probably lie directly on the eroded surface of the Permian rocks. The bedrock-contour map (pl. 4) indicates that the bedrock surface in the southeastern part of the county is cut 40 to 60 feet lower than beneath the adjacent high-terrace deposits. In several places (pls. 1 and 4) Permian bedrock crops out or occurs at shallow depth near the contact of the two types of terrace deposits.

Test drilling has shown that the thickness of the low-terrace deposits in Woodward County averages more than 50 feet. The greatest thickness noted was 90 feet in test-hole 22N-19W-34dcc1, which evidently was drilled into the deep bedrock channel beneath the deposits.

Water-bearing properties--The low-terrace deposits furnish most of the water used by farms on the terrace area (pl. 1), including water for domestic, stock, and irrigation use. Most of the wells supply water for domestic and stock needs and have relatively low yields; however, the irrigation wells commonly yield several hundred gallons per minute.

Because of the flat topography and alluvial soil, the low-terrace areas are some of the most productive farmland in the county. An example is Moscow Flat, an area of several square miles on the terrace at the south side of the North Canadian River a few miles north of Mutual. Nine irrigation wells tap the low-terrace deposits in that area. The W. Cox irrigation well (22N-19W-35cca4) yielded 750 gpm with a drawdown of 20 feet. This well had the highest yield and highest specific capacity of all wells tested in the county (table 5).

The ground-water supply in the low-terrace deposits has been only partly developed in Woodward County, and other wells yielding several hundred gallons per minute could be obtained. Yields are likely to be highest where the deposits are thickest and most permeable, as, for instance, where they fill the bedrock channel beneath the low-terrace surface (pl. 4). Saturated thickness of the deposits is more than 60 feet just north of the North Canadian River from the center of T. 21 N., R. 18 W., downstream. More than 40 feet is saturated in Moscow Flat, near the mouth of Persimmon Creek, and near the river west and southwest of Mooreland (pl. 5). Large yields should be expected from wells in all these areas. Test drilling would aid in determining the thickest section of best water-bearing material and in selecting a well site. Screen size and gravel pack should be selected on the basis of the size of the material to be tapped by the well, to reduce the possibility of pumping sand or plugging the well screen.

Alluvium

The modern channels and flood plains along rivers and their major tributaries have been mapped as alluvium (pl. 1). These deposits represent the present cycle of erosion and deposition and are still being formed, eroded, and reworked. Therefore, they are Recent in age. Flood plains generally are 5 to 15 feet lower than the surface of the adjacent low terraces and the stream channels are cut into the flood plains.

Along the North Canadian River the alluvium is a band averaging about a mile in width, but in places it is about $1\frac{1}{2}$ miles wide. It is only 0.6 mile wide where the valley is constricted by the resistant Doe Creek Sandstone Member of the Marlow Formation near Boiling Springs State Park. The North Canadian River has a sandy shifting channel 1,000 to 2,000 feet wide. Phreatophytes, such as salt cedar, willow, and cottonwood trees, are common along the channel and on the flood plain of the river. The alluvium of Wolf Creek averages about half a mile in width. Upstream from Fort Supply Reservoir cattails, marsh grass, and other phreatophytes are common along the flood plain. The flood plains of other creeks generally are narrow; trees and brush commonly line streambanks of the larger ones.

The Cimarron River flood plain is mostly a sandy channel half a mile to $1\frac{1}{2}$ miles wide. The water in the Cimarron River alluvium is highly

Table 5--Summary of aquifer-test data

Well number	21N-21W-16cdb2	23N-22W-22dcd1	22N-19W-35cca4	23N-18W-30ddc1	23N-19W-23cbd1[a]
Geologic source	Ogallala Formation	Ogallala Formation	Low-terrace deposits and alluvium	High-terrace deposits	High-terrace deposits
Date of test	Oct. 1957	July 1957	Sept. 1957	Aug. 1957	Feb.-Mar. 1962
Duration of test (days)	3	3	8.4	3	2
Nonpumping (static) water level below land surface (ft)	28.13	30.33	16.97	44.75	19.70
Pump discharge (gpm)	290	160	750	490	660
Drawdown at pumped well (ft)	28	13	20	35	25
Specific capacity of pumped well (gpm/ft of drawdown)	10	12	37	14	26
Saturated thickness of aquifer (ft)	125	64	39	58	50
Coefficient of transmissibility (gpd/ft)	28,000	29,000	65,000	34,000	51,000
Average field coefficient of permeability (gpd/ft^2)	220	450	1,500	600	1,000
Storage coefficient of aquifer	....	0.07	0.03	....	0.03

Well number	23N-19W-28aca1	23N-20W-7dbd5	24N-19W-27cbb1	24N-20W-6cdb1
Geologic source	High-terrace deposits	High-terrace deposits	High-terrace deposits	High-terrace deposits
Date of test	July 1957	Feb. 1957	June 1957	Sept. 1957
Duration of test (days)	3	12	3	6
Nonpumping (static) water level below land surface (ft)	20.23	19.95	57.77	62.40
Pump discharge (gpm)	245	44	338	170
Drawdown at pumped well (ft)	19	2.5	32	34
Specific capacity of pumped well (gpm/ft of drawdown)	13	17	9	5
Saturated thickness of aquifer (ft)	35	22	43	42
Coefficient of transmissibility (gpd/ft)	47,000	25,000	....	16,000
Average field coefficient of permeability (gpd/ft^2)	1,300	1,100	....	350
Storage coefficient of aquifer	0.02	0.03	....	....

[a] Data from tests conducted by R. L. Vincent, Layne-Western Co., Wichita, Kansas

mineralized and unusable as a result of the salt water seeping into it and emerging from springs near Big and Little Salt Plains.

The alluvium consists principally of sand, but it probably also contains lenticular beds of silt and clay and some gravel in the lower part. The thickness ranges up to a maximum estimated to be about 30 feet. The alluvium is channeled into the Permian red beds at many places, but in other places along North Canadian River and the larger creeks it may be underlain by remnants of the low-terrace deposits.

Small quantities of water could be developed from the alluvium along all the larger creeks and the North Canadian River. Where the deposits are thickest and most permeable wells might yield as much as 100 gpm. Where the alluvium and low-terrace deposits have been mapped together, along streams such as Persimmon Creek, these deposits may be nearly 100 feet thick and permeable. Wells tapping those deposits might yield several hundred gallons of water per minute.

Ground water in the alluvium is erratic in quality. Where water seeps into the alluvium from the Permian or from surface streams draining the Permian rocks, the ground water is moderately mineralized, and is generally very hard. Where underflow is from high-terrace deposits or the Ogallala Formation the water in the alluvium is likely to be similar in quality to water from those deposits. Evapotranspiration probably concentrates the minerals in the ground water in the alluvium where depths to water are shallow.

Loess

Gray silt, resembling the late Pleistocene loess of central Kansas, has been mapped in an area of about 15 square miles near Mutual and about 5 square miles near the southeast corner of the county. Where it is exposed in road ditches the silt is structureless, friable, and in part sandy or clayey. Generally the lower part, which rests directly on the Permian red beds, is more clayey, and at places caliche has accumulated in the upper part of the clayey zone and at the contact with the Permian.

Near the southeast corner of the county, the silt caps the uplands and is draped like a mantle over the bedrock hills. The maximum thickness observed was about 6 feet, but it may be thicker near the hilltops where its base is not exposed. Near Mutual similar deposits underlie a plain about 3 miles across that has developed on the slope above the valley of Persimmon Creek. Similar deposits occurring in small patches on ridges upheld by the Blaine Gypsum, in the northeastern part of the county, and overlying high-terrace deposits along the divide between Cimarron and North Canadian Rivers were not mapped on plate 1.

The origin of the silt is in doubt, but it is judged to be loess because of its texture, general appearance, and topographic position. The silt is mostly unstratified and could not have been deposited on hilltops by streams. Because of its texture it could not have originated by weathering of Permian rocks. Its surface is relatively uneroded, hence it is relatively young--probably of late Pleistocene age.

The loess is above the water table, but because of its moderate permeability it may afford good opportunity for recharging underlying rocks.

Dune Sand

Dune sand covers the surface in large areas in the general outcrop area of the Ogallala Formation, the high-terrace deposits, and alluvium (pl. 1) This sand is believed to have been derived from the weathering of the underlying deposits; and it probably has been moved only a very short distance by the wind. Because the dune shapes are little eroded in most places, and some dunes and "blowouts" are still being formed, the age of the dunes is judged to be Recent. In large areas the dunes support a sparse cover of vegetation and seem to be stabilized. In some areas, however, sand is advancing upon older dunes, terrace deposits, and older rocks, and in these areas the size and shape of the dunes are being changed by the wind. In many places, particularly near North Canadian River, the dunes that were present during field mapping had no resemblance to those shown on the aerial photographs made 15 years earlier.

The dune sand consists largely of well-sorted fine to medium sand, principally quartz. Some silt and other fine material has accumulated, chiefly in the interdune depressions. Thickness of the dune sand is not known, but probably is very erratic over the area. In places dunes have been heaped to heights of 20 feet or more above adjacent interdune depressions. The sand may have a maximum thickness of about 30 feet, but the surface beneath the dunes probably is very irregular.

An interesting feature of the dune areas is the many small, more or less circular tracts, some as much as 50 feet in diameter, containing scrub oak or other small trees. The trees grow in dense clusters, are all about the same size, generally 10 to 15 feet high, and catch the blowing sand in a low mound. The origin of these tree clusters can only be postulated, but they may have started from a single tree and spread outward gradually as the sand around them became stabilized.

The dune sand lies above the water table and does not yield water to wells. Because of its high permeability and irregular, undrained topography, however, the dune sand facilitates recharge by readily absorbing precipitation and transmitting it downward to underlying rocks or deposits.

GROUND WATER

Occurrence

In Woodward County, ground water occurs principally in the terrace deposits and alluvium in the valley of the North Canadian River and its major tributaries--Wolf, Indian, Persimmon, and Bent Creeks--and in the Ogallala Formation which covers the southwestern part of the county. Ground water is present also in small or moderate quantities in the alluvium of the Cimarron River and its tributaries, in dune-sand deposits, and in the bedrock formations (red beds) beneath the younger deposits. For purposes of discussion, the Ogallala Formation, which covers the southwestern part of the county, and the terrace deposits and alluvium in the valley of the North Canadian River and its major tributaries will be referred to collectively as the Tertiary and Quaternary deposits; and the Permian sedimentary rocks will be referred to collectively as red beds or bedrock.

Ground water is the water beneath the land surface in the zone of saturation. In unconsolidated deposits and in loosely to moderately consolidated sedimentary rocks the water is contained chiefly in openings of primary origin, called voids, pores, or interstices. In tightly consolidated and well-cemented sedimentary rocks, and in igneous and metamorphic rocks, the water is contained chiefly in cracks, crevices, or cavities formed as a result of earth stresses, weathering processes, and solution. Water contained in openings of these types is the principal source for wells, springs, and most perennial streams.

Ground water is derived chiefly from local precipitation in the form of rain or snow. A part of this water runs off directly into streams, a part evaporates, and a part is absorbed into the soil. A part of the water that enters the soil is used and transpired by vegetation, and the part that is in excess of the soil-moisture requirement percolates through pore spaces and crevices in the soil and underlying rocks to the water table, where it enters the zone of saturation and becomes ground water. Within the zone of saturation, water percolates slowly through interstices or crevices in the water-bearing rocks from points of higher altitude in intake or recharge areas to points of lower altitude in the discharge areas. Eventually, part of the ground water is discharged as evapotranspiration in swampy areas; some seeps into streams; and a part leaves the area by underflow through water-bearing materials where physical conditions permit. Part of the ground water entering the zone of saturation goes into storage to replace water that has been pumped for use, seeped into streams, or otherwise been removed.

It is of great practical importance to distinguish water that is contained in the openings of rocks from water that will move through these openings. Rocks with large total pore space do not necessarily transmit water readily. Clay, for example, contains a great many microscopic openings, and hence may contain a large amount of water, but the water is held so tightly by molicular forces that it does not move easily. Coarse gravel, however, has a relatively small number of large intricately interconnected openings which allow water to move freely under the force of gravity. This property of rocks, which determines their capacity for transmitting fluids, is known as permeability, and will be discussed more fully under hydrologic properties of the water-bearing materials (See p. 50.)

Near the land surface the voids and crevices in rocks commonly are filled with air. Some water also is held in the smallest voids by capillary forces. At some depth, which differs from place to place, water will fill both large and small openings in the rocks. The contact between the zone where openings larger than capillary size are filled with water and the zone where these openings are filled with air is called the water table. The altitude of the water table differs from place to place, according to the shape and slope of the land surface and on the conditions of recharge, movement, and discharge of ground water. The altitude, configuration, and gradient of the water table is shown on plate 3 and is discussed later under source, movement, and discharge of ground water. (See p. 54.)

Recharge, movement, and discharge of ground water not only differ from place to place but also vary from time to time; and, as these factors change, the water table responds by rising or falling. This subject is discussed more fully under water-level fluctuations. (See p. 62.)

If the zone above the water table contains one or more relatively impermeable beds of silt or clay, they may impede the downward movement of water from the surface. Just above the poorly permeable beds, water may accumulate to form a water body, perhaps temporary, above the main zone of saturation. Such a water body is said to be perched, and its upper surface is called a perched-water table. In Woodward County, perched-water bodies are small, and most are temporary. Areas where such water bodies occur are shown on plate 3. Ordinarily, a well developed in a perched-water body cannot be depended upon as a permanent water supply.

Within the main zone of saturation, ground water occurs under either unconfined (water-table) or confined (artesian) conditions. The water table, as noted above, is the upper surface of the zone of saturation; it is the level at which the hydrostatic pressure is equal to atmospheric pressure. Above it is the capillary fringe, the lower part of which also may be saturated, but with water at less than atmospheric pressure. If anywhere within the zone of saturation an extensive, poorly permeable bed is situated so as to form a confining layer, water contained in more permeable deposits beneath the confining layer is said to be under artesian conditions. Under these circumstances, the water is under sufficient pressure to cause water levels in tightly cased wells to rise above the base of the confining layer. If the pressure is sufficient, the water level in a well will rise above the land surface, and the well will flow. Generally this water has a hydraulic connection with a water table that is some distance away and at a higher altitude than the top of the artesian aquifer.

Only nine flowing wells were found in Woodward County during this investigation. Eight of the wells discharged small quantities of water derived chiefly from solution cavities in the Blaine Gypsum. The water is highly mineralized and unfit for human consumption. One well discharges less than 1 gpm from the Ogallala Formation. Ground-water conditions in the Ogallala Formation and in the terrace deposits and alluvium in the stream valleys are generally unfavorable for flowing wells because there is no widespread system in which water is confined. Because of the heterogeneous character of most fluvial deposits, water may be confined locally by beds of clay or silt, but these confining beds generally are not extensive. Most fluvial deposits also have sufficient differences in horizontal and vertical permeability that water bodies which generally are unconfined may react to fluctuations in pressure due to pumping in much the same manner as confined-water bodies. During periods of little draft, however, pressure effects are minimized and the hydrostatic head adjusts to equilibrium with the water table.

Hydrologic Properties of Water-Bearing Materials

The quantity of water that a water-bearing material will yield to wells depends principally upon the thickness, permeability, and storage coefficient of the material. The permeability and storage coefficient vary with differences in the size, shape, and extent of the openings and with their degree of interconnection.

The *permeability* of a water-bearing material is its capacity for transmitting water under pressure. In ground-water hydraulics, the permeability of an aquifer generally is expressed as a *permeability coefficient*, which is the rate of flow of water in gallons per day through a cross-sectional area of 1 square foot under a hydraulic gradient of 1 foot per foot. The coefficient of permeability used in this report is called the *field coefficient of permeability* and is defined as the number of gallons of water per day that percolates, at the prevailing temperature of the water, through each mile of the aquifer (measured at right angles to the direction of flow) for each foot of thickness of the aquifer and for each foot per mile of the hydraulic gradient. The *coefficient of transmissibility* may be expressed as the number of gallons of water a day, at the prevailing temperature, transmitted through each mile strip by the entire saturated thickness of the aquifer under a hydraulic gradient of 1 foot per mile; hence, it is the product of the average coefficient of permeability and the saturated thickness of the aquifer.

The quantity of water that can be removed from storage in an aquifer depends upon its storage coefficient. The coefficient of storage[5] of an aquifer is defined as the volume of water it releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. Under artesian conditions the coefficient of storage is a small value, generally 10^{-3} to 10^{-5}, representing water derived by compaction of fine-grained materials, and by expansion of the water itself, as the head declines. Under water-table conditions the storage coefficient includes this small amount plus the generally much larger amount represented by the water that drains by gravity out of the uppermost material as the water table declines. This larger amount, called the specific yield, is defined as the ratio of the volume of water that a saturated aquifer will yield by gravity to the volume of the aquifer. It is therefore a measure of the quantity of water that a saturated aquifer will yield when drained by gravity. Not all water contained in the interstices of a material will be drained by gravity, because some will be retained by capillary action. The volume of retained water, expressed as a ratio of the total volume of material, is called the specific retention of the material. The specific yield and specific retention are together equal to the porosity, which is the percentage of the total volume of openings or interstices in a material. Thus, if 100 cubic feet of a saturated material will yield 8 cubic feet and retain 13 cubic feet of water when drained by gravity, the specific yield is 0.08 or 8 percent, the specific retention is 0.13 or 13 percent, and the porosity is 0.21 or 21 percent.

Aquifer Tests

An aquifer test, or so-called pumping test, is a method of determining the main hydrologic properties of an aquifer, the coefficients of permeability, transmissibility, and storage. These properties may be determined by a mathematical analysis of hydrologic data that reflects the behavior of the water table or piezometric surface around a pumped well. This analysis can be accomplished by means of formulas based on equilibrium and nonequilibrium conditions. In this report, the basic nonequilibrium formula (Theis, 1935), or one of its variations (Cooper and Jacob, 1946),

[5] The reader is referred to Ferris and others (1962, p. 74-78) for a detailed discussion of the storage-coefficient concept and its application to artesian and water-table aquifers in horizontal and inclined attitudes.

was used to determine the aquifer constants. The field coefficients of permeability were determined by dividing the coefficients of transmissibility by the saturated thickness of the aquifer near the pumped wells.

The Theis nonequilibrium formula can be applied to the drawdown or recovery in one or more observation wells to determine the coefficients of transmissibility and storage. The same formula can be applied also to the rate of recovery or drawdown in the pumped well to calculate the coefficient of transmissibility. However, it is not possible to calculate the coefficient of storage from the rates of drawdown or recovery in pumped wells unless the effective radius of the well, which is usually difficult to determine, is known.

During the period of field work for this report, aquifer tests involving 2 or more observation wells in addition to the pumped well were made at 8 sites. Six of the tests were made to determine the aquifer coefficients in the terrace deposits and alluvium of the North Canadian River valley, and two tests were made to determine the aquifer coefficients of the Ogallala Formation. The results are summarized in table 5.

The coefficients of transmissibility and storage determined by the tests, although locally representative, are not necessarily indicative of the values in all parts of the aquifer, because the coefficients differ considerably with changes in lithology and saturated thickness. Consequently, where computations involved ground-water movement, the values of permeability believed to be most representative of the particular area were used.

The storage coefficients shown in table 5 represent minimum values, because the apparent storage coefficient increases with time as additional water drains from that part of the aquifer within the cone of depression created by pumping. For example, Wenzel (1942, p. 135) states that the specific yield (coefficient of storage) as determined from a 24-hour aquifer test on an irrigation well near Gothenburg, Nebr., was only 16 percent of the specific yield determined in laboratory tests of the same material, where drainage was complete. The storage coefficient for the 12-day test reported in table 5 was about 5 times the coefficients for tests of 2 or 3 days' duration in the same type material. It is concluded, therefore, that a figure of 20 percent may fairly represent the coefficient of storage in the terrace deposits and alluvium of the North Canadian River valley; and that 10 percent may be a reasonable figure for the Ogallala Formation.

Behavior of Ground Water in the Vicinity of Discharging Wells

As soon as a pump begins discharging water from a well, the water table in the vicinity of the well is lowered and a hydraulic gradient toward the well is established. The water table around the well assumes the form of an inverted cone, called the cone of depression. At first, most of the water that is pumped from the well is derived from saturated material close to the well. As pumping continues, the material near the well is gradually dewatered and water is transmitted to the well from an ever-increasing distance. Thus, the cone of depression continues to expand, and the water table within the cone continues to decline. If no recharge occurs and if the quantity of water being pumped is greater than the capacity of the aquifer, the cone will continue to expand, at a decreasing rate, until the limits of the aquifer are reached, or until the water level in the well approaches the bottom of the well. The development of the cone may be altered if water is added to the aquifer by natural or artificial recharge, or if the expanding cone reaches a boundary that impedes the movement of ground water. If the cone of depression expands until it meets a boundary, further development depends on the nature of the boundary and the possibilities for recharge. If the boundary is a stream or lake from which water may enter the aquifer, an essentially stable hydraulic gradient will develop between the source of recharge and the pumped well, and much of the water supplied to the well will come from the source of recharge. If the supply for recharge is ample, the cone will stabilize, and the expansion will stop; but if the boundary is an impermeable barrier, no water will be available for recharge. Expansion of the cone will be stopped at such a boundary; but in other locations the expansion of the cone will be accelerated because more water must come from those areas if the discharge rate is to be maintained. At the same time, the drawdown[6] rate in the well being pumped will be accelerated.

After pumping is stopped, water continues to percolate toward the well so long as the hydraulic gradient is in that direction and gradually refills the well and the adjacent material that was dewatered by pumping. As the material near the well is refilled, the hydraulic gradient decreases and the recovery of the water level in the well becomes progressively slower. A general equalization of the water levels eventually takes place over the affected area, and the water table tends to assume its original form, although it may remain temporarily or permanently lower than before water was withdrawn.

In areas where large-capacity wells are closely spaced, the cones of depression, created as a result of pumping, commonly intersect and form

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[6] Drawdown is the difference between the static water level and the water level in a well being pumped.

a large depression in the water table. The overlapping of cones of depression or interference between wells may cause a serious decrease in the yields of the wells, an increase in pumping costs, or both.

The coefficient of transmissibility governs the shape and configuration of the cone of depression. If the coefficient is low, the hydraulic gradient will be relatively steep and the cone will be deep but not broad. If the coefficient is high, the cone will be broad but shallow.

The coefficient of storage is related to the volume of water withdrawn from the cone of depression. Theoretically, the volume of dewatered material within the cone of depression multiplied by the coefficient of storage should equal the total volume of water pumped. Water naturally drains slowly from the dewatered part of an aquifer, and the volume of the cone of depression, during the early stages of its development must exceed the theoretical volume in order to yield the water pumped. As pumping continues, the draining is more and more complete, and the actual volume of the cone of depression approaches more closely the theoretical volume.

An average drawdown curve that would be generally useful in planning the development of a well field cannot be prepared because the coefficients of transmissibility and storage of the principal aquifers differ greatly from place to place. When large quantities of water are sought, preliminary test drilling and test pumping are the best method to obtain facts on which to base specifications for wells, well spacing, pumps, and power.

Source, Movement, and Natural Discharge

Precipitation, in the form of rain or snow, is the source of fresh water in Woodward County. Infiltration of precipitation within the county accounts for most of the ground water, but some water enters the county as subsurface inflow from the alluvial deposits in the valleys of the North Canadian River and Wolf Creek, and from the Ogallala Formation. The bedrock formations (red beds) also contribute water to the younger deposits, but because of their low permeability the quantity is small.

The shape and slope of the water table and the general direction of ground-water movement in the Tertiary and Quaternary deposits, which are the principal water-bearing formations, are shown by contours on plate 3. The contours are lines of equal altitude of the water table, and ground water flows across the lines perpendicularly and toward areas where the altitude of the water table is lower. A casual inspection of the map will show that the water table is not level or uniform but is a warped, sloping surface. The irregularities in slope and in direction of slope are caused by differences in saturated thickness and permeability of the water-bearing deposits and by unequal additions or withdrawals of water from the ground-water reservoir.

Ground water moves in the direction of greatest slope of the water table, and the rate of movement is proportional to that slope (hydraulic gradient) and to the permeability of the water-bearing material. The water-table map (pl. 3) shows that in the North Canadian River valley the water table in the Quaternary deposits slopes diagonally downstream and toward the river. Therefore, ground water discharges into the river, making it a gaining stream. During periods of low flow, all or most of the water in the river is seepage from the ground-water reservoir. The slope of the water table in the direction of river flow is about the same as the gradient of the river, which is about 4 feet to the mile. (See p. 15.) This is not the slope of the water table toward the river but is the downstream component of that slope. The alluvial deposits adjacent to and beneath the river channel have sufficient thickness and permeability to serve as an underflow conduit which can accommodate most of the water supplied to the river from the ground-water reservoir. This is the reason that the North Canadian is dry in some months. Water will flow in the river channel only during periods when the quantity of water being discharged by surface and subsurface flow exceeds the capacity of the underflow conduit. Ponds that occur along certain reaches of the river during periods of no flow are fed by ground water that is forced upward in places where the underflow conduit is restricted by irregularities in the bedrock surface, or by changes in the relative permeability of the deposits composing the underflow conduit.

Plate 3 also shows that the general movement of ground water in the Ogallala Formation, which covers the southwestern part of the county, is northward and northeastward. The direction of movement, however, is modified by several streams that cause depressions in the water table. Ground water percolates toward these depressions, where it is discharged by subsurface flow into the alluvial deposits in the stream valleys, or emerges as springs at the base of the Ogallala and contributes to the flow of the streams.

Natural discharge from the principal ground-water body in the Tertiary and Quaternary deposits is in the form of springs and seeps and of subsurface flow into the alluvium of the larger streams. A few small springs and seeps discharge where perched-water bodies intersect the land surface, but most seeps are at favorable places along a line marking the contact between the Ogallala Formation and the red beds (bedrock). Seeps also discharge ground water in creek channels at times when the water table intersects the land surface there. Ground water in the alluvial deposits not only may enter streams but also may be evaporated directly or transpired by shrubs or other plants growing on the flood plains.

Evaporation of ground water from the land surface occurs mostly in low, flat areas adjacent to the larger streams, in waterlogged areas near springs and seeps, and in areas around ponds and reservoirs. The accumulation of substantial amounts of alkali on the land surface suggests that water is being drawn from the zone of saturation or from the capillary fringe above the water table by capillary action and discharged by evaporation. Much of the water taken into the roots of plants directly from the zone of saturation or from the capillary fringe above it, is discharged by a process known as transpiration--the giving off of moisture through the surfaces of leaves and stems of plants. The depths from which plants lift ground water differ greatly with the plant species, with the types of soil, and with the conditions of water supply.

Most of the loss of ground water by transpiration occurs in areas where the depth to water is less than 20 feet, and most loss of ground water by evaporation occurs where the depth to water is less than 10 feet. Water loss by evaporation and transpiration is known collectively as evapotranspiration and increases as the depth to water decreases. No attempt has been made to estimate the quantity of ground water lost by evapotranspiration in the county but it probably accounts for a major part of the water discharged from the zone of saturation.

Measurements of the base flow of streams draining the southwestern part of the county (table 6) indicate that the natural ground-water discharge from the Ogallala serves as a source of recharge to the Quaternary deposits in the stream valleys during dry periods. These base-flow measurements also show that the red beds, which the streams cross on their way to the North Canadian River (pl. 1), contribute little or no water to the flow of the streams. The relatively high base flows recorded during October, November, and December 1957 (table 6) reflect ground-water discharge from Quaternary deposits which had become saturated as a result of the above-normal rains of 1957. Water-level trends in the alluvial deposits of the tributary-stream valleys are illustrated by the hydrograph of well 21N-18W-31bba1 (fig. 6). The hydrograph shows the rapid recovery of water levels in response to precipitation and the steep declines caused chiefly by evapotranspiration during the summer. The recovery of water levels during the autumn and winter of 1957 resulted from a decline in evapotranspiration rates and an increase in precipitation during the autumn.

Computation of discharge--Rate of natural discharge from the Ogallala Formation has not been determined but may be estimated from computations of recharge or of ground-water movement. In the discussion of recharge (p. 66), recharge to the Ogallala Formation in 1957 in Woodward County was calculated to be 67,500 acre-feet. This figure plus inflow from Ellis County, 5,500 acre-feet, minus the increase in storage, 40,000 acre-feet, would be the total discharge from the aquifer in 1957--33,000 acre-feet.

Another estimate of the seepage part of the discharge could be made from the seepage measurements for streams draining the Ogallala. The total discharge measured in November and December 1957 of Indian Creek, a tributary of Indian Creek, and North and South Persimmon Creeks near the

Table 6.- Measurements of the base flow of streams draining the southwestern part of Woodward County

(Discharge in cubic feet per second)

Date	Roundup Creek 23N-21W-17, NW¼ [1]	Indian Creek 22N-20W-29, NE¼ [2]	Unnamed Creek 22N-20W-27, SE¼ [3]	Indian Creek 22N-19W-30, NE¼ [4]	Indian Creek 22N-19W-21, SE¼ [5]	North Persimmon Creek 21N-20W-27, SW¼ [6]	South Persimmon Creek 20N-20W-10, NW¼ [7]	Persimmon Creek 21N-19W-33, NE¼ [8]	Hackberry Creek 20N-20W-24, NE¼ [9]	Hackberry Creek 21N-19W-34, SW¼ [10]	Kizer Creek 20N-18W-33, SW¼ [11]	Bent Creek 22N-20W-22, NE¼ [12]
3/15/56	.....	2.84	0.19	2.76	1.62	1.61	1.61	1.46	.....	...	....	....
3/16/56	.....	....	....	....	....	....	....	....	.....	...	0.44	1.19
4/17/56	.....	2.31	.21	.15	0	.94	.94	1.37	0.04.	0	.36	....
4/18/56	0	....	....	....	....	....	....	....	.....	...	....	.74
5/22/56	.....	....	....	....	....	....	....	....	.....	...	0	0
5/23/56	0	.85	.07	0	0	.19	.19	.11	a .03	0	....	....
6/18/56	.....	....	....	....	....	....	....	....	....	...	....	0
6/19/56	0	.44	0	0	0	0	0	0	a .004	0	0	....
12/13/56	a .001	1.36	....	....	....	.77	.13	....	.....	...	....	....
2/26/57	.11	2.40	.05	....	.41	....	....	....	.....	0	....	.94
2/27/57	.....	....	....	....	....	2.90	1.48	.78	a .02	0	.24	....
2/28/57	.....	....	....	2.23	....	....	....	....	.....	...	....	....
4/11/57	.....	....	.04	....	....	2.82	2.34	5.50	.06	0	.49	....
4/12/57	.26	3.92	....	6.48	3.91	....	....	....	.....	...	....	1.62
7/10/57	.....	4.63	.15	....	....	1.57	.23	3.41	.05	0	.47	....
7/11/57	.05	....	....	5.60	4.48	....	....	....	.....	...	....	3.64
8/14/57	a .04	1.44	a .004	a .02	0	.38	0	.08	a .02	0	0	.13
9/11/57	a .04	2.42	.07	0	0	1.51	0	.42	.....	0	....	.11
9/12/57	.....	....	....	....	....	....	....	....	a .01	...	.05	....
10/17/57	.63	4.17	.29	5.52	6.57	2.29	1.52	5.69	.03	0	.10	1.32
11/12/57	1.10	4.39	.22	6.12	5.57	2.85	2.56	5.18	.08	0	.29	1.45
12/19/57	.80	4.54	.26	5.46	5.57	2.81	2.46	5.94	.08	0	.44	1.83

a/ Estimated

1/ Roundup Creek, tributary to North Canadian River; measured in the NW¼ sec. 17, T. 23 N., R. 21 W., at bridge on U.S. Highway 270, 5 miles northwest of Woodward

2/ Indian Creek, tributary to North Canadian River; measured in the NE¼ sec. 29, T. 22 N., R. 20 W., at bridge on State Highway 34, 5½ miles southeast of Woodward

3/ Unnamed tributary to Indian Creek; measured at county highway bridge on south line of the SE¼ sec. 27, T. 22 N., R. 20 W., 7 miles southeast of Woodward

4/ Indian Creek, tributary to North Canadian River; measured at county highway bridge on east line of the NE¼ sec. 30, T. 22 N., R. 19 W. 9 miles southeast of Woodward

5/ Indian Creek, tributary to North Canadian River; measured at county highway bridge on east line of the SE¼ sec. 21, T. 22 N., R. 19 W., 10 miles southeast of Woodward

6/ North Persimmon Creek, tributary to North Canadian River; measured in the SW¼ sec. 27, T. 21 N., R. 20 W., at bridge on State Highway 34, ½ mile south of Sharon

7/ South Persimmon Creek, tributary to North Persimmon Creek; measured at county highway bridge on north line of the NW¼ sec. 10, T. 20 N., R. 20 W., 3 miles south of Sharon

8/ Persimmon Creek, tributary to North Canadian River; measured on east line of the NE¼ sec. 33, T. 21 N., R. 19 W., at county highway bridge, 6 miles east of Sharon

9/ Hackberry Creek, tributary to Persimmon Creek; measured in the NE¼ sec. 24, T. 20 N., R. 20 W., at county highway bridge, 6 miles southeast of Sharon

10/ Hackberry Creek, tributary to Persimmon Creek; measured at county highway bridge along east line of the SW¼ sec. 34, T. 21 N., R. 19 W., 6 miles east of Sharon

11/ Kizer Creek, tributary to Bent Creek; measured in the SW¼ sec. 33, T. 20 N., R. 18 W., at county highway bridge, 6 miles southeast of Mutual

12/ Bent Creek, tributary to North Canadian River; measured in the NE¼ sec. 22, T. 20 N., R. 17 W., at county highway bridge, 10 miles southeast of Mutual edge of the Ogallala Formation was 10 cubic feet per second. At this rate, the annual seepage along those streams would have been 7,240 acre-feet. This is only part of the seepage from the Ogallala because water seeps out also along several other streams that drain the formation. As already noted, seepage accounts for only part of the discharge, and water is discharged also by subsurface outflow, by plants directly from the saturated zone, and by pumping. Hence, the total annual discharge from the Ogallala Formation in Woodward County is estimated to be about 30,000 acre-feet.

Most of the water in the Quaternary deposits is moving slowly toward the North Canadian River. Part of this water is discharged by evapotranspiration along the river valley, some seeps into the river, and some moves downstream as subsurface outflow. An estimate of the rate of discharge from these deposits can be made by computing the rate at which ground water is moving toward the river, using the formula:

$$Q = TIL$$

Where Q = rate of movement, in gallons per day;
T - coefficient of transmissibility, in gallons per day per foot;
I = average hydraulic gradient of the water table, in feet per mile;
L = length, in miles, along which movement toward the river takes place

Using a coefficient of transmissibility of 60,000 gpd per foot, an average gradient of 20 feet per mile toward the river, and a total length of 50 miles, the rate of movement is computed to be about 67,000 acre-feet for 1957. This compares reasonably well with 57,000 acre-feet difference between total recharge and increase in ground-water storage for these deposits for 1957.

Water Use and Pumpage

Wells have been a primary source of water for domestic and stock use in Woodward County since the first settlement there. Windmills have been and still are a major source of power, although many rural wells now are powered by internal-combustion engines or electric motors. Ordinarily, a yield sufficient for domestic or stock use can be obtained if the well taps the Tertiary or Quaternary deposits. Where the well taps the red beds (bedrock), the yield may not be sufficient. Information pertaining to well depths, depths to water, and adequacy of well yields in different parts of the county is summarized in plate 6. Most large-capacity wells in the county are used for irrigation, but a few are used for public-supply or industrial purposes.

Irrigation use--Most irrigation wells in Woodward County were drilled before 1955 (table 7). In the North Canadian River valley and in the valleys of Wolf, Indian, and Persimmon Creeks these wells commonly are drilled through the entire thickness of the alluvial deposits and bottom on top of the red beds. Wells drilled within the outcrop area of the Ogallala generally obtain sufficient water for irrigation without penetrating the entire thickness of the formation. The diameters of the holes range from 20 to 36 inches. Shutter or perforated well screen ranging in diameter from 10 to 18 inches is installed opposite the saturated section of the well, and blank casing is set opposite the unsaturated part. The annular space between the casing and the sides of the hole is then filled with gravel of uniform size, and the well is developed and tested. Trubine pumps are installed in most irrigation wells, and most are powered by internal-combustion engines using natural gas or liquefied petroleum gas for fuel, although a few wells are powered by electric or diesel units. Many of the wells were drilled during the 6-year dry period 1951-56. Since the drought-breaking rains of 1957 not all the wells have been used every year. Most of the wells are in three irrigated sections of the North Canadian River valley as follows: east of the river near Mooreland; along the west side of the river about 7 miles south of Mooreland (known locally as Moscow Flats); and along the east side of the river in the north half of T. 20 N., R. 17 W.

The area irrigated from wells and an estimate of the amount of ground water used for irrigation during each year from 1955 to 1960 are shown in table 7. In 1963 irrigated acreage was as follows: alfalfa, 2,500; sorghum, 2,100; small grain, 1,500; pasture, 700; corn, 250, and horticulture, 50. Surface water was used to irrigate 200 acres out of a total of 7,000 acres irrigated. The number of acres irrigated by surface water varies from year to year but has never exceeded 200 acres.

Although the amount of irrigation water applied varies from year to year, depending on the rainfall during the growing season, the average from 1955 to 1963 was about 1.4 acre-feet per acre.

Public-supply use--Only four towns in Woodward County have public water-supply systems, and all are supplied by wells. For many years the city of Woodward obtained a large part of its water supply from wells tapping alluvial deposits in sec. 19, T. 23 N., R. 20 W. In 1940 this source of supply was abandoned in favor of greater quantities of water of better quality derived from high-terrace deposits in secs. 7, 8, and 16, T. 23 N., R. 20 W. During the 24-year period 1940-63 the city well field was expanded to a total of 36 wells with a capacity of about 5 million gallons per day, or about 5,500 acre-feet per year. The annual municipal pumpage of Woodward since 1954 is shown in table 8. Water use is greatest during August, when about 57 million gallons (195 acre-feet) is pumped. The minimum use is in February, when about 12.5 million gallons (38 acre-feet) is pumped.

Table 7.--Pumpage of ground water for irrigation in Woodward County 1955-56

Year	Number of wells	Area irrigated	Pumpage[a] (acre-feet)
1955	61[b]	4,100[b]	5,000
1956	65[b]	6,100[b]	9,100
1957	62[b]	7,200[b]	1,800
1958	60[c]	6,400[b]	7,600
1959	60[b]	6,400[b]	7,400
1960	60[c]	6,500[c]	9,100
1961	60[c]	6,500[c]	9,600
1962	60[c]	6,500[c]	10,300
1963	65[b]	6,800[b]	12,400

[a] Computed by U.S. Geological Survey by subtracting precipitation during the growing season of various crops from the consumptive use determined for those crops by Garton and Criddle (1955, table 2) in Woodward County, and multiplying the result by the acreage given by Duffin in the Irrigation Survey Summaries referred to in footnote b. An irrigation efficiency of 70 percent was assumed, based on Garton and Criddle (1955, p. 9).

[b] From Irrigation Survey Summaries compiled by R. B. Duffin, Extension Irrigation Specialist, Oklahoma State University, Stillwater, Okla.

[c] Estimated by U.S. Geological Survey because irrigation summaries had not been compiled for those years.

Table 8.--Municipal pumpage at Woodward

Year	Acre-feet	Year	Acre-feet
1954	1,200	1959	690
1955	1,050	1960	1,000
1956	1,210	1961	1,020
1957	850	1962	1,210
1958	930	1963	1,480

Mooreland is supplied by two wells on the east side of town. Each well is capable of producing about 300 gpm of water from the high-terrace deposits. The annual use of water is not known, but an estimate of municipal pumpage was made by multiplying the urban population (870 in 1960) by 100 gpd per person. By this method municipal pumpage is estimated to be about 32 million gallons, or 96 acre-feet per year.

Western State Hospital near Fort Supply obtains its water supply from wells that tap alluvial deposits in the valley of Wolf Creek. The hospital wells also furnish water to the town of Fort Supply. The combined annual pumpage for Western State Hospital and the town of Fort Supply is estimated to be about 500 acre-feet per year.

Water for Quinlan is supplied by five wells of low yield which obtain water from red beds about a mile west of town. The water used by Quinlan is not metered, but a city official estimates that pumpage is about 3 million gallons, or 9 acre-feet per year.

Commercial and industrial use--Commercial use of water includes use for motels, gasoline stations, restaurants, and other business establishments. The amount of water used for commercial purposes in areas away from the principal towns is small, especially the amount not obtained from public supplies. Also, the demand for water for commercial purposes in outlying areas is similar to the demand for domestic needs and the wells are, for this reason, included in the domestic category.

Most water used for industrial purposes is purchased from municipal supplies. Some water, however, is pumped for use at a natural-gas compressor station; some is used during the washing and processing of sand and gravel aggregate; some is used during the drilling and testing of oil wells; and some is used for cooling purposes. The total self-supplied industrial use is estimated to be about 100 acre-feet per year.

Domestic and stock use--The greatest number of wells in Woodward County supply water for domestic and stock purposes. Most are small-diameter wells equipped with pumps operated by windmills, by gasoline engines, by electricity, or by hand. The yields of these wells generally are less than 5 gpm. Most of the wells obtain water from the Tertiary or Quaternary deposits, although many obtain it from the red beds. Yields of wells in the red beds are consistently reported to be inadequate.

Total pumpage for domestic and stock purposes is necessarily estimated and may indicate only an order of magnitude. An estimate of the domestic pumpage was made by multiplying the rural population (5,000 in 1960) by 35 gpd per person. By this method, the domestic pumpage is estimated to be about 190 acre-feet per year. By use of the same method for stock (65,000 head at 12 gpd, 4,000 dairy cows at 30 gpd, considering the amount of water used by other livestock to be negligible), an estimate of 1,000 acre-feet per year is obtained. The total rural domestic and stock requirement is about 1,200 acre-feet per year.

From the above estimates, the total ground-water pumpage in Woodward County for 1960 may be computed:

	Acre-feet
Irrigation	9,100
Public supply	1,600
Industrial	100
Domestic and stock	1,200
TOTAL (rounded)	12,000

Water-Level Fluctuations

Records of water-level fluctuations in wells are among the most useful means for determining the availability of ground water because the ground-water surface fluctuates in response to changes in the amount of ground water in the reservoir. The rise or decline of this surface depends upon the relation between recharge into and discharge from the ground-water reservoir. When withdrawal exceeds inflow the ground-water surface declines, and conversely, when inflow exceeds withdrawal, the ground-water surface rises. Thus, the fluctuations of water levels in wells are an index to the inflow and outflow of water from a ground-water reservoir, somewhat as the fluctuation of the water level in a surface reservoir indicates the amount of water in it. However, for the recharge or discharge of a given quantity of water, the ground-water surface fluctuates through a larger range than does the water level in a surface reservoir.

An analysis of the fluctuations of water levels in wells can yield valuable information about the water-bearing characteristics of a ground-water reservoir. Such an analysis may be used to (1) indicate the seasonal and long-term trends in ground-water storage; (2) provide an index of the net effects of recharge and discharge, both natural and artificial; (3) indicate the general direction of ground-water movement; (4) determine whether an aquifer is controlled by water-table or artesian conditions; (5) determine the relative permeability of the materials penetrated by wells in different parts of the aquifer; (6) indicate principal areas of recharge; and (7) determine the average permeability and specific yield of the saturated rocks when used in connection with records of pumping, precipitation, and the low (base) flow of unregulated streams.

To determine the character and magnitude of the water-level fluctuations in the principal aquifers of Woodward County, measurements of water levels in 50 to 60 wells were made at weekly, biweekly, or monthly intervals during 1956 and 1957, and automatic water-level recorders were installed on several wells ranging from 20 to 320 feet in depth. The period of record for wells equipped with water-level recorders ranged from a few days to about 18 months. From 1958 to 1963, measurements of the water level in

20 to 30 wells were made at monthly intervals, and detailed water-level fluctuations were recorded in a well tapping alluvial deposits in the North Canadian River valley and in a well tapping the Ogallala Formation.

Although few water-level measurements were made in Woodward County before the period of this investigation, the general water-level trend during the 1951-56 drought can be demonstrated from semiannual measurements. (See fig. 6.) The trend of the annual water-level fluctuations also can be predicted from a graph showing the cumulative departure from average precipitation if the lag in time between precipitation and a change in ground-water storage (rise or decline of ground-water levels) is considered. A casual inspection of the graph showing cumulative departure from average precipitation at Woodward (fig. 4) indicates that during the 6-year dry period (1951-56) the quantity of water available for recharge decreased sharply. Hence, ground-water levels recorded during 1956 probably reflect a relatively low-water table. Hydrographs (figs. 5 and 6) illustrate the trend and magnitude of fluctuations since 1956. Under the existing conditions, the pattern of fluctuations is unlikely to change from year to year, although the magnitude of seasonal change will vary with the volume and duration of recharge from precipitation and with the rates of evaporation and transpiration.

The hydrograph of well 21N-22W-23bbb1 (fig. 5) shows that the water level in a relatively undeveloped part of the Ogallala Formation rose abruptly in 1957 when the drought of 1951-56 was ended by above-normal precipitation. The graph indicates that ground-water levels in the Ogallala fluctuate in response to precipitation, but that changes in water levels lag from 2 to 3 months behind the rainfall that caused the changes. The time lag is determined principally by the necessity of satisfying the moisture requirements of the soil, and by the vertical permeability of the deposits in the interval between land surface and the zone of saturation.

The hydrograph of well 23N-19W-3aaa1 (fig. 5) illustrates water-level fluctuations typical of the high-terrace deposits in the North Canadian River valley. The graph shows that ground-water levels in the high-terrace deposits have risen from the 1956 low as a result of the above-average precipitation since 1957. Water-level fluctuations in wells tapping the low-terrace deposits and alluvium of the North Canadian River and its tributaries are closely related to local precipitation. (See fig. 6.) The graphs show that water levels rise rapidly in response to spring and early summer rains and then decline steeply during the summer in response to high evapotranspiration. The graphs also show that water levels recover slightly during the autumn and winter when evapotranspiration losses are at a minimum. The slight recovery probably reflects a decrease in the quantities of water lost by transpiration from vegetation and by evaporation of soil moisture from the shallow water table.

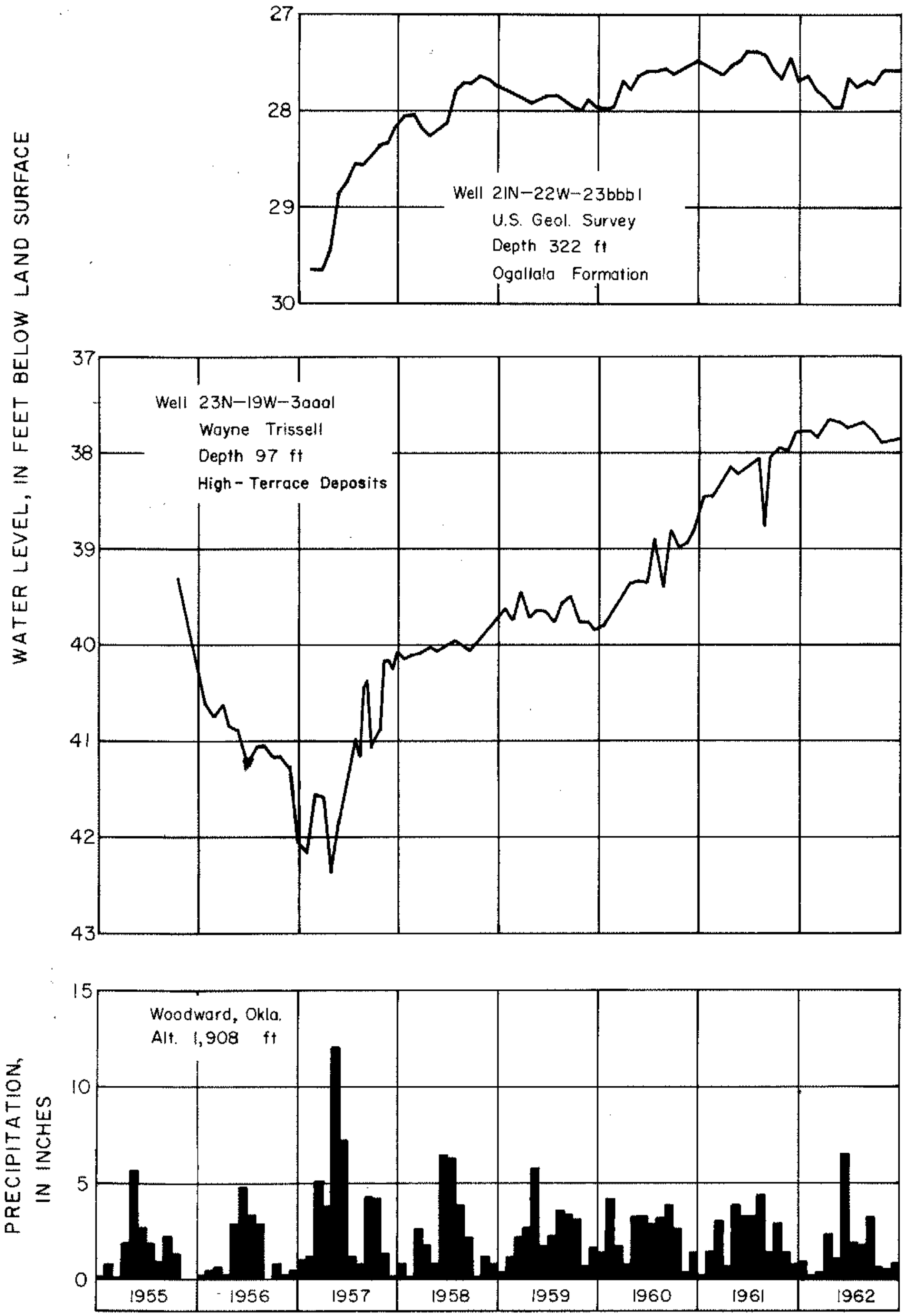

FIG. 5 -- GRAPHS SHOWING WATER-LEVEL FLUCTUATIONS IN REPRESENTATIVE WELLS TAPPING THE OGALLALA FORMATION AND THE HIGH-TERRACE DEPOSITS; AND PRECIPITATION AT WOODWARD

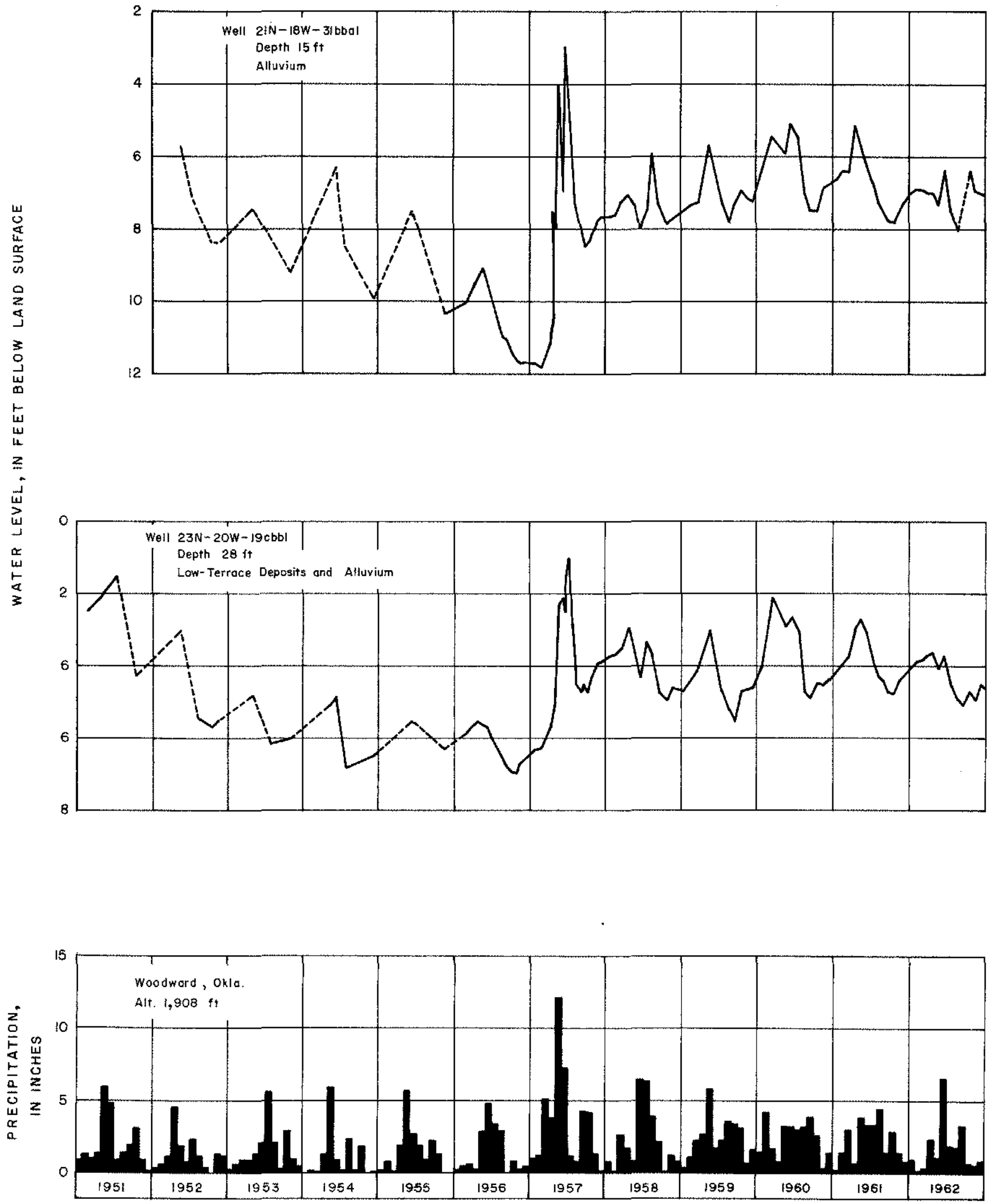

FIG. 6-- GRAPHS SHOWING WATER-LEVEL FLUCTUATIONS IN REPRESENTATIVE WELLS TAPPING THE LOW-TERRACE DEPOSITS AND ALLUVIUM; AND PRECIPITATION AT WOODWARD

Natural water levels in the red beds probably fluctuate only slightly. Although the red beds receive some recharge directly from precipitation, most of it probably comes by seepage from overlying unconsolidated deposits that absorb water rapidly from precipitation. The overlying unit, which may include the zone of weathered material in outcrop areas or deposits of Tertiary or Quaternary age in other areas, provides a relatively constant head of water for recharging the red beds. Thus, the character of water-level fluctuations in the red beds is similar to that in the overlying deposits, and the general trend of the annual fluctuations can be predicted from graphs showing the cumulative departure from average precipitation. (See fig. 4.)

Most deposits of dune sand are thin and are not saturated, but they readily absorb rainfall and transmit it to underlying rocks. If a record of water-level fluctuations were available for the dune sand, it probably would correlate closely with precipitation records, and the time lag between increased rainfall and a rise in water level would be small.

Recharge, Inflow, and Storage

Recharge to the ground-water body in the Tertiary and Quaternary deposits already has been discussed in general terms under the section entitled source, movement, and natural discharge. (See p. 54.) As noted earlier, the Tertiary and Quaternary deposits are underlain by Permian sedimentary rocks (red beds) whose low permeability prevents movement of large amounts of ground water. Thus, recharge by underflow from the red beds probably is negligible.

In many places, small ephemeral streams bring water into the alluvial deposits in the valleys of the North Canadian River and its major tributaries. However, the drainage areas of the individual streams is small, and the streams flow only for brief periods in response to precipitation. Thus, recharge from such sources is believed to be small.

The only significant sources of recharge for the Ogallala Formation, which covers the southwestern part of the county, are precipitation on the land surface and underflow from the south and southwest. The major streams draining this part of the county contribute no water to the Ogallala because the direction of ground-water movement is toward the streams (pl. 3).

Seeps are evident in places along the contact of the red beds and the Ogallala. Ground water is therefore being discharged from the Ogallala at favorable places along the contact. Where the Ogallala is in contact with the alluvial deposits in the valleys of the larger streams, such as Indian, North Persimmon, South Persimmon, and Hackberry Creeks, which drain the area, ground water can percolate by underflow from the Ogallala into the alluvium. In most places, however, the red beds are not far below the surface at the contact of the Ogallala and the alluvial deposits. Thus, the cross-sectional area through which ground water could move from the Ogallala into the alluvium probably is small and the amount of underflow likewise is small. Nevertheless, the quantity of water contributed by underflow and by springs is large enough to maintain the base flow of the streams in all except the driest seasons.

In the North Canadian River valley, north and northeast of the river, Quaternary deposits are notably lacking in surface drainage. (See pl. 1.) Only a few poorly defined and poorly integrated streams cross the area and empty into the river. The predominantly sandy soil, which covers much of the area, favors a high rate of infiltration and large tracts have no visible drains. In addition, many shallow depressions in areas covered by dune sand trap and hold water derived from precipitation until it evaporates or infiltrates into the underlying rocks. Because infiltration is rapid, relatively few of the depressions retain water for more than 1 or 2 days after precipitation ceases.

The amount of precipitation that reaches the ground-water reservoir in the Tertiary and Quaternary deposits depends on the amount, rate, and distribution of rainfall, the composition and physical character of the soil and underlying materials, the vegetation, the proximity of the water table to the land surface, and the shape and slope of the land surface. Water infiltrates more readily in areas mantled by permeable materials, such as dune sand or sandy soil, than in areas covered by less permeable materials, such as oils derived from silt, clay, or shale. Much of the area underlain by the Tertiary and Quaternary deposits is covered with dune sand. Thus, infiltration of local precipitation is an important source of recharge.

A comparison of water-level fluctuations in wells with the cumulative departure from average precipitation at Woodward suggests a relation between departure from normal rainfall and changes in ground-water levels. The rise of water level in response to local rains appears to be relatively rapid; thus, it is believed that fluctuations of ground-water levels in deposits of known specific yield could be used to provide a reasonable estimate of recharge resulting from precipitation.

The graphs in figure 4 show that the annual precipitation increased abruptly from an average of 17.2 inches for the 6-year dry period 1951-56 to an average of 28.5 inches for the 6-year period 1957-62. The graphs also show that most of the increase in precipitation occurred in 1957. During that year precipitation was 24.5 inches above the 1951-56 average. The water table began to rise in response to the increased precipitation (figs. 5 and 6), and during the period of rise recharge exceeded discharge, resulting in an increase in the quantity of ground water stored in the Tertiary and Qauaternary deposits.

The rise in water levels in observation wells tapping substantial thicknesses of the Ogallala Formation ranged from 0.2 foot to 5 feet and averaged 2 feet. Water-level rises in wells tapping alluvial deposits in the stream valleys ranged from 2 feet to 10 feet and averaged 3 feet. When the average annual precipitation increased by 11.3 inches for a period of 6 years, recharge exceeded discharge and ground-water storage increased, causing the water table to rise an average of 2 feet in the Ogallala Formation and an average of 3 feet in the Quaternary deposits. The greater part of this rise occurred during the summer and autumn of 1957 (figs. 5 and 6). From 1958 through 1961 water levels in most wells tapping the Ogallala rose from 0.01 foot to 0.05 foot per year, and in wells tapping the Quaternary deposits from 0.01 foot to 0.5 foot per year. Hence, recharge resulting from precipitation only slightly exceeded discharge from natural and artificial means for the period 1958-61.

In the following calculations of recharge derived from precipitation, the Ogallala Formation and the Quaternary deposits were assigned specific yields of 10 and 20 percent, respectively.

With a specific yield of 10 percent, the 2-foot rise of the water table in the Ogallala represented an addition to the ground-water body of 0.2 foot of water. This 0.2 foot, or 2.4 inches of water, was not the total recharge to the Ogallala, but only the amount of recharge in excess of discharge.

To account for the water added to storage, recharge had to be at least 2.4 inches, or 10 percent of the increase in precipitation (24.5 inches) during 1957 when most of the recharge occurred. Because ground water is being discharged continually from the ground-water reservoir, the total recharge must have been greater than 2.4 inches. The rate at which ground water would be discharged depends on the water table and the hydraulic gradient near points of discharge. As the water table rose in response to the increased recharge, the rate of discharge would increase. During 1957, recharge had to provide an amount of water equal to that discharging at low ground-water stages, plus an amount equal to the increased discharge caused by the higher water table, plus the 2.4 inches that was added to storage. Although 10 percent of the toal precipitation was added to ground-water storage, the percent of the total precipitation recharging the ground-water body in the Ogallala is not known. If, however, 10 percent of the total precipitation (41.7 inches) became recharge, then in 1957 recharge from precipitation would have been about 4 inches. Recharge over the part of the county underlain by the Ogallala (320 square miles) would then be about 67,500 acre-feet in 1957, and the increase in ground-water storage alone would have been about 40,000 acre-feet.

During the 4-year period 1958-61 rainfall remained above average and the quantity of ground water added to storage in the Ogallala was computed to be about 1,000 acre-feet per year.

The recharge rate and the amount of water added to storage in the Quaternary deposits was determined by the method described for the Ogallala Formation.

It was determined that the specific yield of the Quaternary deposits is 20 percent, and that water levels rose an average of 3 feet during 1957. This water-level rise represented an addition to the ground-water body of 0.6 foot, or 7.2 inches of water. As noted earlier, this increase in storage was not the total recharge but only the amount of recharge in excess of discharge. To account for the water added to storage, recharge would have had to be at least 7.2 inches, or 29 percent of the increase in precipitation (24.5 inches) during 1957 when most of the recharge occurred. Hence, the quantity of ground water added to storage in the part of the county underlain by the Quaternary deposits (340 square miles) would have been about 130,000 acre-feet. Owing to depressed water levels resulting from the extended drought, it was assumed that only 25 percent of the toal precipitation (41.7 inches) might become recharge. If that were true, then recharge derived from precipitation in 1957 would have been 10.4 inches. Recharge over the part of the county underlain by the Quaternary deposits (340 square miles) would have been about 187,000 acre-feet in 1957.

During the 4-year period 1958-61 rainfall remained above average and the quantity of ground water in storage increased about 22,000 acre-feet per year.

In addition to recharge from precipitation, some water is added to the ground-water body in Woodward County by subsurface inflow through the Ogallala Formation which extends westward and southward into Ellis County, and by inflow through Quaternary deposits in the valleys of the North Canadian River and Wolf Creek. An estimate of the amount of water entering the county from these sources may be made by the application of Darcy's law which may be written:

$$Q = TIW$$

Where Q = inflow, in gallons per day;
T = coefficient of transmissibility; in gallons per day per foot;
I = average hydraulic gradient of the water table, in feet per mile;
W = width, in miles, of the saturated part of the aquifer contributing inflow

Recharge to the Ogallala Formation by subsurface inflow from Ellis County (average coefficient of transmissibility, 28,000 gpd per foot; ground-water gradient in the southwest corner of Woodward County about 20 feet per mile; length of the 2,300-foot water-table contour about 9 miles) was calculated to be about 5,000,000 gpd, or about 5,500 acre-feet per year. Recharge resulting from subsurface inflow of water moving through the alluvial deposits in the valleys of the North Canadian River and Wolf Creek (average coefficient of transmissibility, 60,000 gpd per foot; ground-water gradient in North Canadian River valley near mouth of Wolf Creek, 5 feet per mile; width of the alluvial valley of North Canadian River near mouth of Wolf Creek, 1.5 miles) was calculated to be about 450,000 gpd, or about 500 acre-feet per year.

Although the figures given above do not represent all water added to the ground-water reservoir by subsurface inflow, they do indicate that ground-water inflow is not an important source of recharge.

For future planning it is useful to know the total amount of water available from storage in the Tertiary and Quaternary deposits, even though it would not be feasible to pump all the water. The method of calculation is to multiply the volume of saturated deposits by their specific yield. Thus, the Ogallala Formation, which covers about 320 square miles, has an average saturated thickness of 180 feet (pl. 5), a specific yield of 10 percent, and an estimated 3.6 million acre-feet of water in storage.

The Quaternary deposits, which cover about 340 square miles, have an average saturated thickness of 30 feet (pl. 5), a specific yield of 20 percent, and an estimated 1.3 million acre-feet of water in storage.

The recharge rate and volume of water in storage might be compared to the total pumpage in 1960, which was estimated to be 12,000 acre-feet.

QUALITY OF WATER

Mineral matter and organic substances are dissolved by (a) water at the land surface, (b) water that infiltrates the soil and seeps downward to the zone of saturation, and (c) water that moves through the rocks and deposits in the zone of saturation. In addition to natural factors, the quality of the ground water is influenced by human activities, such as pollution caused by industrial waste and domestic sewage and contamination resulting from the disposal of oil-field brines or ther industrial wastes. The kind and amount of dissolved materials are closely related to the mineral composition of the soil and rocks through which the water moves. For this reason, different geologic units commonly contain ground water of different chemical character. The quality of the water in the different units is described in a later section.

Chemical analyses of ground water from selected wells and springs in Woodward County are given in Appendix C. Analyses of water from streams draining the Tertiary and Quaternary deposits are given in Appendix D.

Quality with Respect to Source

The quality of the ground water in Woodward County varies considerably from place to place, the variance depending largely on the geologic unit in which it occurs. Water in the Permian rocks is the most mineralized because those rocks contain soluble minerals such as gypsum and halite and because water moves through them rather slowly. Water in the Ogallala Formation and high-terrace deposits is of the best quality because infiltration is rapid through the sandy soil developed on these deposits and because water moves through the deposits more readily than through the Permian rocks.

Permian rocks--Water in the Permian rocks is moderately to highly mineralized, is hard to very hard, and is of a calcium bicarbonate, calcium sulfate, or sodium chloride type, or a mixture of these types. Water from the Blaine Gypsum is very hard, as much as 3,180 ppm (parts per million) because of the sulfate dissolved from the gypsum beds. Water from the Whitehorse Group is a calcium bicarbonate type and is hard to very hard.

In the extreme northern part of the county, brine issuing from springs believed to originate in the Flowerpot Shale is much more mineralized than sea water. Water from a spring in sec. 33, T. 17 N., R. 19 W., contained 156,000 ppm chloride and had a total dissolved solids content of 262,000 ppm. Test drilling in the area has shown that bedded halite (rock salt) occurs in the Flowerpot at shallow depths beneath the alluvium of Cimarron River. Halite probably occurs also in the shale adjacent to the valley and is undoubtedly the source of the sodium chloride in the spring water.

Permian rocks, Blaine Gypsum--Samples of water from the Blaine Gypsum were collected from five flowing artesian wells and one windmill well. Although the windmill well (23N-17W-8abb1) was only 75 feet deep, the water from it had a dissolved-solids content of 2,790 ppm, a hardness of 2,050 ppm, 1,570 ppm of sulfate, and was of a calcium sulfate type. Water from one of the artesian wells (34N-17W-30ccc1), about 5 miles southeast of the windmill well, was of similar quality. However, water from the other four flowing wells, all in the southern part of the county, was of a sodium chloride type or a sodium chloride-calcium sulfate type. The dissolved-solids content of water from these four wells ranged from 5,000 to 11,400 ppm, and the water is too salty for most uses.

The calcium sulfate in the water from the Blaine results from the solution of gypsum in the formation. The wells containing sodium chloride water or a mixture of sodium chloride and calcium sulfate water are all deeper and farther from the outcrop of the formation than the wells containing water of the calcium sulfate type. The sodium chloride probably was derived from halite associated with the gypsum layers or disseminated in the shale beds of the Blaine.

Permian rocks, Whitehorse Group--Water from the Whitehorse Group is principally of a calcium bicarbonate type and moderately mineralized. Dissolved-solids content ranged from less than 300 to nearly 800 ppm and hardness from 160 to 405 ppm. Sulfate, chloride, and fluoride were low in the seven samples analyzed. These samples were collected from wells in the outcrop area of the group mostly in the eastern part of the county. In the western part of the county the Whitehorse Group contains disseminated and bedded gypsum and water in that area is likely to be more mineralized and of the calcium sulfate type.

Ogallala Formation--Water was obtained from seven wells tapping the Ogallala Formation. The depth of the wells ranged from 25 to 205 feet, but the quality of the water was remarkably similar in all. The water was of a calcium bicarbonate type and was relatively low in dissolved solids (278 to 339 ppm). The hardness averaged about 250 ppm, and sulfate, chloride, and fluoride contents were very low.

High-terrace deposits--Water from wells in the high-terrace deposits is of a calcium bicarbonate type, hard, and has a relatively low dissolved-solids content. Dissolved solids ranged from 172 to 464 and hardness from 104 to 305 ppm; the sulfate, chloride, and fluoride contents were very low.

Low-terrace deposits and alluvium--Water from the low-terrace deposits and the alluvium seems to be erratic in quality, probably because of the seepage of water into these deposits from other aquifers. In places these deposits also contain much detrital material derived from the Permian rocks, which would influence the quality. Where these deposits are adjacent to and receive recharge from areas of dune sand or high-terrace deposits the water is moderately mineralized, hard, and of a calcium bicarbonate type. Water collected in 1956 from well 20N-17W-7abd1, about 7 miles east of Mutual, had a dissolved-solids content of 609 ppm, hardness of 460 ppm, sulfate of 193 ppm, and chloride of 14 ppm. In contrast, a sample collected in 1952 from one of the Western State Hospital wells (24N-22W-10cab1), in the alluvium of Wolf Creek valley, had a dissolved-solids content of 1,100 ppm, hardness of 634 ppm, sulfate of 392 ppm, and chloride of 131 ppm. This water was of a calcium sulfate type, reflecting the influence of the Permian rocks which border Wolf Creek valley in that area.

Quality with Respect to Use

The chemical quality of the ground water in Woodward County affects its use for certain purposes. Hardness, dissolved solids, sulfate, and chloride generally are the most important constituents in water for drinking or other domestic use. Sodium, boron, and dissolved solids affect the suitability of the water for irrigation. Different industries have widely varying requirements concerning the quality of the water they use. If the water is used principally for cooling, it is possible for an industry to use water that is more mineralized and poorer in quality than water to be incorporated into a product.

Calcium and magnesium make water hard and are responsible for the scale formed in water heaters, steam radiators, pipes, valves, and other fixtures. Hardness in water also results in increased consumption of soap for laundry purposes and is responsible for the scummy deposit that accumulates in bathtubs, lavatories, and laundry equipment. The U.S. Geological Survey classifies water with respect to hardness as follows: less than 60 ppm, soft; 61-120 ppm, moderately hard; 121-180 ppm, hard; more than 180 ppm, very hard. Most of the ground water in Woodward County (Apps. C and D) is hard or very hard; water from the Blaine Gypsum is extremely hard.

The specific conductance of a water is a measure of its ability to conduct electricity and is expressed in micromhos per centimeter at 25°C. Because the salinity of water is closely related to the specific conductance, the specific conductance may be used as a measure of the salinity hazard of the water. As a rule, the higher the salinity of a water, the less suitable it is for use.

Sodium and potassium in concentrations of 50 to 100 ppm amy cause foaming if the water is used in the operation of steam equipment. Sodium also affects the usability of water for irrigation, and the sodium-adsorption ratio (SAR, in App. C) together with the specific conductance is used to classify water for irrigation use.

Drinking water-- The U.S. Public Health Service (1962) has recommended that certain constituents in water used for drinking on interstate carriers should not exceed the following limits: sulfate and chloride, 250 ppm; nitrate, 45 ppm; dissolved solids, 500 ppm (1,000 ppm permissible).

Sulfate and chloride generally will give the water a bitter or salty taste if they are present in amounts greater than 250 ppm. The sulfate content of water from most wells in Woodward County, except those tapping the Blaine Gypsum, was less than 250 ppm. Water from a few wells tapping the alluvium contained an excessive amount of sulfate, and water from one (24N-22W-6abb1) contained 270 ppm chloride.

Nitrate in water may cause methemoglobinemia (blue-baby's disease) if the water is used for drinking or the preparation of the infant's formula. The U.S. Public Health Service recommends that the public be warned of the potential dangers of using water containing more than 45 ppm nitrate. Water from two wells tapping the Whitehorse Group (App. C) contained 150 and 210 ppm nitrate, probably as a result of local contamination of the wells by organic matter.

Except for water from the Blaine Gypsum, the dissolved-solids content of ground water in Woodward County is within the permissible limits for drinking water.

Irrigation--The suitability of water for irrigation depends upon several factors in addition to the mineral content of the water. Among these are the type and drainage characteristics of the soil, the amount of water applied, and the amount and distribution of precipitation.

The U.S. Salinity Laboratory Staff (1954) has found that the usefulness of an irrigation water is determined by (1) total concentration of soluble salts (salinity hazard); (2) relative proportion of sodium to other cations (sodium or alkali hazard); (3) concentration of boron or other elements that may be toxic; and (4) under some conditions, the bicarbonate concentration as related to the concentration of calcium and magnesium.

The total concentration of soluble salts in irrigation water is most easily expressed in terms of specific conductance. The property varies with the amount and kinds of dissolved salts and the temperature. Nearly all irrigation waters that have been used successfully have specific conductances less than 2,250 micromhos. Water of higher specific conductance has been used occasionally; but crop production, except on very well-drained soil, has not been successful.

Most ground water in the county has a salinity hazard in the medium-to-high range. Special drainage and agricultural practices may be needed if water in the high range is to be used for irrigation.

The U.S. Salinty Laboratory staff (1954, p. 72-74) has shown that the sodium-adsorption ratio (SAR) of a water is a useful index of the sodium or alkali hazard, because it is related to the adsorption of sodium by a soil. The sodium-adsorption ratio (SAR) is calculated by dividing the sodium concentration by the square root of half the sum of the calcium and magnesium concentrations, in equivalents per million. The SAR is reported in Appendixes C and D for most of the samples of water analyzed. The sodium hazard is low in all water analyzed, except water from wells penetrating the Blaine Gypsum and older rocks.

Boron in small amounts is essential for the normal growth of practically all plants, but in amounts greater than about 2 ppm it may be toxic. The ground water in Woodward County does not contain boron in amounts great enough to be toxic to the crops generally grown in the area.

The ranges in specific conductance, sodium-adsorption ratio, and boron of water in Woodward County are summarized below.

Source of water	Specific conductance (micromhos at 25°C)	Sodium-adsorption ratio (SAR)	Boron (ppm)
Streams......................	601-2,640	0.4-5.7	....
Ogallala Formation...........	439-542	0.2-0.8	0.00-0.12
High-terrace deposits........	303-776	0.2-1.5	0.00-0.13
Low-terrace deposits and alluvium.................	882-1,690	0.6-3.2	0.02-0.08
Permian rocks overlying Blaine Gypsum	269-1,160	0.4-2.1	0.00-0.34
Blaine Gypsum and older rocks of Permian age......	2,760-17,300	0.6-30	0.09-0.46

Except for water from the Blaine Gypsum, ground water in Woodward County is suitable for irrigation. Some of the calcium sulfate water from the Blaine probably could be used where soil drainage is good and if good irrigation practices are followed.

CONCLUSIONS

In Woodward County the principal sources of ground water for municipal, industrial, and agricultural development are the Ogallala Formation in the southwestern part of the county and the terrace deposits and alluvium in the North Canadian River valley. The amount of water stored in these deposits is estimated to be about 5 million acre-feet (3.6 million acre-feet in the Ogallala and 1.3 million acre-feet in the alluvial deposits).

After drought-breaking rains in 1957, ground-water recharge from precipitation and subsurface inflow was estimated to be 260,000 acre-feet (73,000 acre-feet in the Ogallala, and 187,000 acre-feet in the alluvial deposits). Water added to the ground-water reservoir in 1957 replaced most of the water lost during the 1951-56 drought. Discharge from the aquifers in the county is estimated to total about 100,000 acre-feet per year. These magnitudes may be compared with the total pumpage in 1960, which was estimated to be 12,000 acre-feet. Ground water supplies most of the needs in the county for municipal, industrial, domestic, and irrigation supplies. Large quantities of additional ground water could be developed, principally from the terrace deposits and Ogallala Formation.

Although the ground-water supply in the Ogallala Formation and in the terrace deposits and alluvium is great and is being replenished continually, the concentration of large-capacity wells in small areas can result in local overdevelopment. A continuing program is needed to measure water levels periodically and to inventory ground-water withdrawals to insure the safe development and conservation of the ground-water resources.

A factor not mentioned previously, in determining the feasibility of developing ground water for irrigation, is the initial cost of the wells and the subsequent maintenance and pumping costs. These, together with other factors of interest to the individual water user, are discussed by Wood (1950). Furthermore, the generally close relationship of ground water and surface water emphasizes the need for clarification of the legal status of each in relation to the other, so that existing rights will be protected and the county's water resources will be fully developed.

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Well number: For explanation see text, p. 7 ; well locations shown on plate 2 .

Type of well: B, bored; D, dug; Dd, drilled; Dn, driven;

Pump and power: C, cylinder; Cf, centrifugal; J, jet, N, none; T, turbine; a, airlift; b, butane, e, electric; g, gasoline, h, hand; p, propane; w, wind.

Use: D, domestic; I, irrigation; Id, industrial; N, none (includes unused or destroyed wells); O, observation; P, public supply; S, stock; T, test hole.

Geologic source : Qal, low-terrace deposits and alluvium; Qt, high-terrace deposits; To, Ogallala Formation; Pwh, Whitehorse Group; Pdc, Dog Creek Shale; Pb, Blaine Gypsum; Pf, Flowerpot Shale.

Other data: C, chemical analysis shown in appendix C; L, well log shown in appendix B.

Well number	Location in section	Owner or tenant	Type of well	Pump and power	Use	Geologic source	Depth of well (feet)	Water level: Depth below land surface	Water level: Date of measurement	Altitude above mean sea level (feet): Land surface	Altitude above mean sea level (feet): Water level surface	Altitude above mean sea level (feet): Permian surface	Other data
20N-17W-1ddd1	SE¼SE¼SE¼ 1	W. A. Green	Dd	J, e	D,S	Qt	49	22.0	5-17-57	1,724	1,702	1,674	....
2bbb1	NW¼NW¼NW¼ 2	H. Shuck	Dd	C, W	D,S,O	Qal	..	33.8	8-13-57	1,751	1,717	1,707	....
2ddd1	SE¼SE¼SE¼ 2	A. L. Louthan	Dd	T, g	I	Qal	36	12.9	4-25-57	1,717	1,704	1,682	....
2ddd2	do.	US Geol. Survey	Dd	N	T	Qal	36	10.8	4-25-57	.....	.....	.....	L
2ddd3	do.	do.	Dd	N	T	Qal	30	10.5	4-25-57	.....	.....	.....	L
2ddd4	do.	do.	Dd	N	T	Qal	22	11.8	4-25-57	.....	.....	.....	L
2ddd5	do.	do.	Dd	N	T	Qal	22	10.0	4-25-57	.....	.....	.....	L
5cdc1	SW¼SE¼SW¼ 5	do.	B	N	T, O	Qal	11	3.8	5-13-57	1,727	1,723	.....	....
7abd1	SE¼NW¼NE¼ 7	R. Craighead	Dd	T, g	I	Qal	70	25.0	9-10-56	1,746	1,721	1,676	C, L
10bbb1	NW¼NW¼NW¼10	US Geol. Survey	Dd	N	T,O	Qal	56	12.0	5-13-57	1,723	1,711	1,667	L
12ccc1	SW¼SW¼SW¼12	do.	Dd	N	T	Qal	33	7.3	4-25-57	1,706	1,699	1,673	L
19dbc1	SW¼NW¼SE¼19	G. Laoshman	Dd	C, w	D,S	Pwh	64	50.7	10-26-55	.....	.....	.....	....
35cbc1	SW¼NW¼SW¼35	H. R. Grift.	Dd	C, w	D,S	Pwh	48	24.9	10-26-55	.....	.....	.....	....
20N-18W-3aaa1	NW¼NE¼NE¼ 3	E. L. Billingsliy	Dd	C, w	D,S	Pwh	71	37.0	5-21-57	1,794	1,757	.....	....
5aab1	NW¼NE¼NE¼ 5	D. Cooper	D	N	N	Pwh	50	36.3	5-21-57	.....	.....	.....	....
5cbc1	SW¼NW¼SW¼ 5	T. E. Hartley	Dd	J, e	D,S	Pwh	87	35.8	10-27-55	.....	.....	.....	....
11aad1	SE¼NE¼NE¼11	C. D. Neagle	D	C, w	D,S,O	Pwh	37	30.2	5-21-57	1,800	1,770	.....	....
21bba1	NE¼NW¼NW¼21	E. L. Billingslly	Dd	C, w	S	Pwh	43	8.3	5-21-57	.....	.....	.....	....
27bbb1	NW¼NW¼NW¼27	L. Donely	Dd	C, w	S	Pwh	50	21.0	5-21-57	.....	.....	.....	....
28daa1	NE¼NE¼SE¼28	....	Dd	C, w	S	Pwh	54	25.2	5-21-57	.....	.....	.....	....
30bbd1	SE¼NW¼NW¼30	O. Thompson	Dd	C, w	D,S	Pwh	80	34.0	8- 8-56	.....	.....	.....	....
20N-19W-1ddd1	SE¼SE¼SE¼ 1	J. E. Adams	Dd	C, h	D	Pwh	45	26.2	5-17-57	.....	.....	.....	....
7ada1	NE¼SE¼NE¼ 7	G. Converse	Dd	N	N	Pwh	46	11.4	8- 9-56	.....	.....	.....	....
16cdc1	SW¼SE¼SW¼16	....	Dd	C, w	S	Pwh	98	30.2	5-17-57	2,046	2,016	.....	....
29aaa1	NE¼NE¼NE¼29	E. C. Conine	Dd	C, w	S,O	To	54	24.3	5-17-57	2,119	2,095	.....	....
30ddd1	SE¼SE¼SE¼30	....	Dd	C, w	S	Pwh?	124	86.6	8- 9-56	.....	.....	.....	....
36bbb1	NW¼NW¼NW¼ 36	J. H. Jones	D	C, w	S	Pwh	57	41.2	5-17-57	.....	.....	.....	....
20N-20W-2aaa1	NE¼NE¼NE¼ 2	M B. Bieness	Dd	N	N	Pb	...	flowing	9-10-56	2,055	.....	.....	C
6ddd1	SE¼SE¼SE¼ 6	C. F. Keltch	Dd	C, w	S,O	To	56	34.0	5-15-57	2,137	2,103	.....	....
8daa1	NE¼NE¼SE¼ 8	E. E. Travers	D	N	S	To	25	flowing	9-10-56	.....	.....	.....	C
19daa1	do. 19	B. L. Mote	Dd	C, w	S,O	To	44	40.5	7- 2-57	2,196	2,155	.....	....
22bbb1	NW¼NW¼NW¼22	US Geol. Survey	Dd	N	T	To	101	....	....	2,163	.....	2,062	L
36bbb1	do. 36	School land	Dd	C, w	D,S,O	To	42	37.9	5-15-57	2,161	2,123	.....	....
20N-21W-1aaa1	NE¼NE¼NE¼ 1	....	Dd	C, h	N	To	70	63.4	5-19-57	2,180	2,117	.....	....
2dad1	SE¼NE¼SE¼ 2	....	Dd	N	N	To	106	91.3	5-10-57	.....	.....	.....	....
5aaa1	NE¼NE¼NE¼ 5	R. Bellows	Dd	C, h	D,O	To	17	5.5	5-13-57	2,165	2,160	.....	....
6aaa1	do. 6	....	Dd	N	N	To	82	54.3	5-16-57	2,226	2,171	.....	....
8bcc1	SW¼SW¼NW¼ 8	....	Dd	N	N	To	64	56.1	5- 9-57	2,236	2,180	.....	....
12dad1	SE¼NE¼SE¼12	C. L. Young	Dd	C, w	D,S	To	50	43.7	11- 8-55	2,174	2,130	.....	....
18ccb1	NW¼SW¼SW¼18	....	Dd	C, w	S	To	98	88.2	5- 9-57	2,279	2,191	.....	....
22dcc1	SW¼SW¼SE¼22	US Geol. Survey	Dd	N	T	To	196	104.8	4- 8-57	2,291	2,186	2,095	L
23cdd1	SE¼SE¼SW¼23	....	Dd	C, w	N	To	55	45.1	5-19-57	2,193	2,148	.....	....
26bcb1	NW¼SW¼NW¼26	R. E. Reaves	Dd	C, h	S,O	To	67	32.9	5-13-57	2,204	2,171	.....	....
30bcb1	do. 30	....	Dd	C, w	N	To	99	82.8	5-19-57	2,303	2,220	.....	....
36add1	SE¼SE¼NE¼36	US Geol. Survey	Dd	N	T	To	162	....	....	2,311	.....	2,153	L
20N-22W-5abb1	NW¼NW¼NE¼ 5	....	Dd	N	N	To	52	43.4	5- 9-57	.....	.....	.....	....
5cbc1	SW¼NW¼SW¼ 5	....	Dd	C, w	N	To	67	58.9	5-17-57	2,389	2,330	.....	....
6bbb1	NW¼NW¼NW¼ 6	Oil co. test hole	Dd	N	T	.....	830	....	....	2,361	.....	2,001	L
7daa1	NE¼NE¼SE¼ 7	....	Dd	C, w	N	To	96	85.4	5- 9-57	2,412	2,327	.....	....
17bab1	NW¼NE¼NW¼17	H. Hamilton	Dd	C, w	D,S	To	89	79.0	11- 9-55	.....	.....	.....	....
19add1	SE¼SE¼NE¼19	....	..	C, w	N	To	160	138.1	5- 9-57	2,452	2,313	.....	....
19ddd1	SE¼SE¼SE¼19	Shrodar	Dd	C, w	S	To	205	....	....	.....	.....	.....	C
22ccc1	SW¼SW¼SW¼22	US Geol. Survey	Dd	N	T	To	295	....	....	2,292	.....	2,000	L
24dcc1	SW¼SW¼SE¼24	E. R. Lucas	Dd	C, w	S,O	To	23	8.0	5-13-57	2,230	2,222	.....	....
29bbd1	SE¼NW¼NW¼29	W. M. Erlman	Dd	C, w	S	To	145	137.6	11- 9-55	2,457	2,319	.....	....
31bcc1	SW¼SW¼NW¼31	US Geol. Survey	Dd	N	T	To	402	....	....	2,513	.....	2,118	L
34aad1	SE¼NE¼NE¼34	....	Dd	N	N	To	15	12.5	5-19-57	2,309	2,297	.....	....
35abb1	NW¼NW¼NE¼35	....	Dd	C, w	S	To	38	9.7	5-19-57	2,291	2,281	.....	....
36add1	SE¼SE¼NE¼36	US Geol. Survey	Dd	N	T,O	To	402	95.2	5-13-57	2,374	2,279	1,997	L
36bba1	NE¼NW¼NW¼36	....	Dd	C, w	S	To	71	59.6	5-19-57	2,321	2,262	.....	....

Well number: For explanation see text, p. 7; well locations shown on plate 2.

Type of well: B, bored; D, dug; Dd, drilled; Dn, driven;

Pump and power: C, cylinder; Cf, centrifugal; J, jet, N, none; T, turbine; a, airlift; b, butane, e, electric; g, gasoline, h, hand; p, propane; w, wind.

Use: D, domestic; I, irrigation; Id, industrial; N, none (includes unused or destroyed wells); O, observation; P, public supply; S, stock; T, test hole.

Geologic source: Qal, low-terrace deposits and alluvium; Qt, high-terrace deposits; To, Ogallala Formation; Pwh, Whitehorse Group; Pdc, Dog Creek Shale; Pb, Blaine Gypsum; Pf, Flowerpot Shale.

Other data: C, chemical analysis shown in appendix C; L, well log shown in appendix B.

Well number	Location in section	Owner or tenant	Type of well	Pump and power	Use	Geologic source	Depth of well (feet)	Water level: Depth below land surface	Water level: Date of measurement	Altitude above mean sea level (feet): Land surface	Altitude above mean sea level (feet): Water level surface	Altitude above mean sea level (feet): Permian surface	Other data
21N-17W-2daa1	NE¼NE¼SE¼ 2	....	Dd	C, w	S	Pwh	138	120.0	5- 9-56	.....	.....	.....	....
9ccc1	SW¼SW¼SW¼ 9	US Geol. Survey	Dd	N	T	Qt	50	41.7	5-25-57	1,894	1,852	1,846	L
9ccc2	do.	....	Dd	C, w	N	Pwh	160	123.6	10-14-60	1,901	1,776	.....	....
12daa1	NE¼NE¼SE¼12	L. Clayton	Dd	C, w	S	Pwh	93	66.8	10-25-55	1,826	1,759	.....	....
13aaa1	NE¼NE¼NE¼13	US Geol. Survey	Dd	N	T	Qt	35	17.6	4-27-57	1,872	1,854	1,842	L
13ccc1	SW¼SW¼SW¼13	do.	Dd	N	T	Qt	50	30.0	4-25-57	1,874	1,844	1,826	L
17bab1	NW¼NE¼NW¼17	J. L. Duer	Dd	C, w	D,S	Qt	99	95.1	10-25-55	.....	.....	.....	....
19bac1	SW¼NE¼NW¼19	O. Best	Dd	T, g	I	Qal	53	18	....	1,762	1,744	1,709	L
22dcd1	SE¼SW¼SE¼22	I. Clayton	Dd	C, w	D,S	Pwh	79	75.6	5-17-57	1,814	1,739	.....	C
26bbb1	NW¼NW¼NW¼26	W. Brewer	Dd	C, w	D,S	Pwh	86	78.6	10-25-55	1,815	1,737	.....	....
27aaa1	NE¼NE¼NE¼27	US Geol. Survey	Dd	N	T	Qt	51	20.8	4-25-57	1,823	1,802	1,774	L
27ccc1	SW¼SW¼SW¼27	do.	Dd	N	T	Qt	50	34.7	4-25-57	1,758	1,723	1,710	L
29ccc1	do. 29	do.	Dd	N	T	Qal	40	12.0	5-25-57	1,740	1,728	1,704	L
29cdc1	SW¼SE¼SW¼29	W. Haynes	Dd	C, w	S	Qal	38	12.4	5- 9-56	1,734	1,722	.....	....
33ccc1	SW¼SW¼SW¼33	US Geol. Survey	Dd	N	T	Qal	60	22.8	4-25-57	1,741	1,718	1,685	L
35ddd1	SE¼SE¼SE¼35	A. L. Louthan	Dd	C, w	S	Qt	49	47.1	5-17-57	.....	.....	.....	....
36cdd1	SE¼SE¼SW¼36	US Geol. Survey	Dd	N	T	Qt	62	44.8	4-25-57	1,763	1,718	1,702	L
21N-18W-6add1	SE¼SE¼NE¼ 6	do.	Dd	N	T	Qal	51	.....	....	1,784	.....	1,736	L
7ccc1	SW¼SW¼SW¼ 7	F. Harper	Dd	C, w	S	Qal	58	25.7	5-21-57	1,803	1,777	.....	....
10abb1	NW¼NW¼NE¼10	US Geol Survey	Dd	N	T	Qt	55	31.8	4-25-57	1,821	1,789	1,770	L
14aaa1	NE¼NE¼NE¼14	....	Dd	N	O	Qal	24	23.3	5- 7-57	1,773	1,750	.....	....
21bbb1	NW¼NW¼NW¼21	US Geol. Survey	Dd	N	T,O	Qal	82	29.9	5-13-57	1,797	1,767	1,717	L
22ddd1	SE¼SE¼SE¼22	do.	Dd	N	T	Qal	40	25.6	1-23-57	1,774	1,749	1,741	L
27aaa1	NE¼NE¼NE¼27	....	Dd	C, w	N	Qal	46	38.8	5-21-57	1,793	1,754	.....	....
27bcb1	NW¼SW¼NW¼27	G. Ellington	Dd	C, w	S,O	Qal	53	42.6	5-21-57	1,805	1,763	.....	....
28add1	SE¼SE¼NE¼28	US Geol. Survey	Dd	N	T	Qal	55	43.5	1-23-57	1,804	1,761	1,749	L
29ddd1	SE¼SE¼SE¼29	J. Allison	D	C, e	D,S	Qal	35	28.9	5-21-57	1,821	1,792	.....	....
31bba1	NE¼NW¼NW¼31	US Geol. Survey	Dn	N	O	Qal	16	4.6	5-21-57	1,834	1,829	.....	....
32bbd1	SE¼NW¼NW¼32	....	Dd	T, e	I	Qal	64	20.9	12- 3-58	1,833	1,812	1,769	....
32dcc1	SW¼SW¼SE¼32	E. Cray	D	C, w	D,S	Pwh	39	18.5	5-21-57	1,817	1,799	.....	C
33ccd1	SE¼SW¼SW¼33	B. Nelson	B	N	N	Pwh	60	39.7	5-21-57	1,828	1,788	.....	....
36dcd1	SE¼SW¼SE¼36	H. Sanders	Dd	C, w	S,O	Qal	49	38.4	5-13-57	1,772	1,733	1,722	....
21N-19W-2cbd1	SE¼NW¼SW¼ 2	W. Cox	Dd	T, b	I	Qal	58	14.2	5-14-57	1,802	1,788	1,746	....
3dda1	NE¼SE¼SE¼ 3	E. T. Bailey	Dd	T, b	I	Qal	68	32.1	5-14-57	1,819	1,787	.....	....
7ddd1	SE¼SE¼SE¼ 7	H. Baker	D	C, w	S	Pwh	44	24.0	5-16-57	1,943	1,919	.....	....
8bba1	NE¼NW¼NW¼ 8	C. E. Britton	Dd	C, w	S	Pwh	36	3.6	5-16-57	1,877	1,873	.....	....
10dda1	NE¼SE¼SE¼10	R. Armstrong	Dd	T, b	I	Qal	59	.....	....	1,813	.....	1,756	....
11aca1	NE¼SW¼NE¼11	J. D. Elmore	Dd	T, b	I	Qal	48	13.1	5-14-57	.....	.....	.....	L
11ccb1	NW¼SW¼SW¼11	J. R. Merkling	Dd	T, b	I	Qal	56	21	....	1,812	.....	1,756	L
12cbd1	SE¼NW¼SW¼12	W. Harper	Dd	T, b	T	Qal	53	14.1	5-14-57	1,799	1,785	.....	....
12bbd1	SE¼NW¼NW¼12	J. S. Price	Dd	N	O	Qal	32	12.0	4-14-57	1,796	1,784	.....	....
12ddd1	SE¼SE¼SE¼12	US Geol. Survey	Dd	N	T	Qal	55	32.8	4-24-57	1,800	1,767	1,748	L
15adc1	SW¼SE¼NE¼15	Oil co. test hole	Dd	N	T	.....	1,485	flowing	9-10-56	1,820	.....		C,L
24baa1	NE¼NE¼NW¼24	A. W. Crawford	Dd	N	O	Qal	64	35.9	5-13-57	1,818	1,783	.....	....
25add1	SE¼SE¼NE¼25	US Geol. Survey	Dd	N	T	Qal	42	.....	....	1,847	.....	1,810	L
26ada1	NE¼SE¼NE¼26	....	Dd	C, w	S	Pwh	55	46.1	5-16-57	1,903	1,857	.....	....
28daa1	NE¼NE¼SE¼28	C. Phillips	Dd	N	N	Pwh	26	21.2	5-17-57	.....	.....	.....	....
30dac1	SW¼NE¼SE¼30	L. Clem	Dd	T, b	I	Qal	90	9.4	5-17-57	1,944	1,935	1,854	L
32bcc1	SW¼SW¼NW¼32	....	Dd	C, w	S,O	Qal	30	15.9	6-13-56	1,934	1,918	.....	....
36cbd1	SE¼NW¼SW¼36	....	Dd	C, w	S	Qal	31	12.4	6-13-56	1,858	1,845	1,827	....
21N-20W-3bbb1	NW¼NW¼NW¼ 3	US Geol. Survey	Dd	N	T	To	195	.....	....	2,060	.....	1,867	L
3abd1	SE¼NW¼NE¼ 3	B. Steadman	Dd	T, b	I	To	95	7.0	5-15-57	2,037	2,030	.....	....
6acb1	NW¼SW¼NE¼ 6	C. W. Hopkins	B	C, g	I	To	26	13.0	5-15-57	.....	.....	.....	....
6acc1	SW¼SW¼NE¼ 6	do.	B	C, g	I	To	29	13.1	5-15-57	.....	.....	.....	....
6add1	SE¼SE¼NE¼ 6	do.	B	C, g	I	To	23	12.9	5-15-57	.....	.....	.....	....
6daa1	NE¼NE¼SE¼ 6	M. P. Phillips	Dd	N	N	.....	500	flowing	9- 5-56	.....	.....	.....	C
8aab1	NW¼NE¼NE¼ 8	....	Dd	C, w	N	To	34	28.5	5-15-57	2,166	2,137	.....	....
12bbb1	NW¼NW¼NW¼12	R. J. Weber	Dd	J, e	D,S,O	To	50	37.8	5-15-57	2,030	1,992	.....	....
14aaa1	NE¼NE¼NE¼14	....	Dd	N	N	Pwh	29	21.9	5-15-57	.....	.....	.....	....
16acc1	SW¼SW¼NE¼16	P. Darden	Dd	C, w	S	To	34	28.6	11- 2-55	.....	.....	.....	....
20aaa1	NE¼NE¼NE¼20	US Geol. Survey	Dd	N	T	To	120	32.4	3-29-57	2,126	2,094	2,010	L
22ddd1	SW¼SE¼SE¼22	....	Dd	C, w	S	To	36	19.1	9- 5-56	.....	.....	.....	....
24aad1	SE¼NE¼NE¼24	....	Dd	N	N	.....	39	34.2	5-15-57	.....	.....	.....	....

Well number: For explanation see text, p. 7; well locations shown on plate 2.

Type of well: B, bored; D, dug; Dd, drilled; Dn, driven;

Pump and power: C, cylinder; Cf, centrifugal; J, jet, N, none; T, turbine; a, airlift; b, butane, e, electric; g, gasoline, h, hand; p, propane; w, wind.

Use: D, domestic; I, irrigation; Id, industrial; N, none (includes unused or destroyed wells); O, observation; P, public supply; S, stock; T, test hole.

Geologic source: Qal, low-terrace deposits and alluvium; Qt, high-terrace deposits; To, Ogallala Formation; Pwh, Whitehorse Group; Pdc, Dog Creek Shale; Pb, Blaine Gypsum; Pf, Flowerpot Shale.

Other data: C, chemical analysis shown in appendix C; L, well log shown in appendix B.

Well number	Location in section	Owner or tenant	Type of well	Pump and power	Use	Geologic source	Depth of well (feet)	Water level		Altitude above mean sea level (feet)			Other data
								Depth below land surface	Date of measurement	Land surface	Water level surface	Permian surface	
21N-20W--Continued													
26aaa1	NE¼NE¼NE¼26	....	D	C, h	N	Pwh	37	22.7	5-15-57	.....	.....	.....	....
31ccc1	SW¼SW¼SW¼31	US Geol. Survey	Dd	N	T	To	500	.....	....	2,186	.....	2,076	L
31ccd1	SE¼SW¼SW¼31	....	Dd	C, w	S	To	81	68.4	5-15-57	2,186	2,118	.....	....
33cdd1	SE¼SE¼SW¼32	....	D	N	N	To	55	40.3	5-15-57	2,126	2,085	.....	....
36bac1	SW¼NE¼NW¼36	School land	Dd	C, w	S	Qal	64	4.2	5-15-57	.....	.....	.....	....
21N-21W-2bbb1	NW¼NW¼NW¼ 2	J. P. Stewart	Dd	C, w	N	To	56	44.4	5-15-57	2,164	2,119	.....	....
3add1	SE¼SE¼NE¼ 3	Oil co. test hole	Dd	....	N	....	1,775	47.8	5-15-57	2,167	2,119	1,995	L
4cbc1	SW¼NW¼SW¼ 4	J. Wright	Dd	C, w	S	To	89	73.0	5-15-57	2,238	2,165	.....	....
4dad1	SE¼NE¼SE¼ 4	R. L. Chenoweth	Dd	C, w	S	To	55	20.4	10-18-55	.....	......	.....	....
7ddd1	SE¼SE¼SE¼ 7	....	Dd	C, w	S,O	To	68	61.4	6- 6-57	2,223	2,262	.....	....
9daa1	NE¼NE¼SE¼ 9	....	Dd	N	N	To	102	87.9	5-15-57	2,235	2,147	.....	....
12cbb1	NW¼NW¼SW¼12	....	Dd	C, w	S,O	To	31	15.8	5-13-57	2,109	2,093	.....	....
14aaa1	NE¼NE¼NE¼14	....	Dd	C, w	N	To	54	48.9	5-15-57	2,154	2,105	.....	....
16cdb1	NW¼SE¼SW¼16	C. Miller	Dd	N	N	To	196	27.5	10-21-57	2,194	2,166	.....	....
16cdb2	do.	do.	Dd	T, b	I	To	184	27.6	10-21-57	2,194	2,166	.....	C
16cdb3	do.	do.	Dd	C, w	S	To	.....	26.4	10-21-57	2,193	2,167	.....	....
16cdb4	do.	US Geol. Survey	Dd	N	T,O	To	150	20.1	10-21-57	2,186	2,166	2,041	L
16cdb5	do.	do.	Dd	N	T,O	To	50	28.1	10-21-57	2,194	2,166	.....	L
16dda1	NW¼SE¼SE¼16	C. Miller	Dd	C, w	O	To	19	10.5	6-17-57	2,162	2,152	.....	....
17aaa1	NE¼NE¼NE¼17	G. Hunt	Dd	N	N	To	......	53.5	5-13-57	2,237	2,184	.....	....
19aab1	NW¼NE¼NE¼19	....	Dd	C, w	N	To	82	42.7	5-20-57	.....	.....	.....	....
19dad1	SE¼NE¼SE¼19	M. B. Wyatt	Dd	C, w	S,O	To	66	48.7	1- 8-57	2,305	2,257	.....	....
23ddc1	SW¼SE¼SE¼23	....	Dd	C, w	N	To	90	78.5	5-16-57	2,193	2,114	.....	....
27daa1	NE¼NE¼SE¼27	C. Miller	Dd	T, e	I	To	173	46.2	5-16-57	2,176	2,130	.....	....
28bab1	NW¼NE¼NW¼28	L. Baird	Dd	C, w	S	To	73	55.4	5-16-57	2,213	2,157	.....	....
29dad1	SE¼NE¼SE¼29	....	Dd	C, w	S	To	125	114.0	5-16-57	2,281	2,167	.....	....
31dcc1	SW¼SW¼SE¼31	US Geol. Survey	Dd	N	T	To	295	.....	....	2,301	.....	2,010	L
32daa1	NE¼NE¼SE¼32	....	Dd	C, w	S	To	112	73.3	5-16-57	2,237	2,164	.....	....
35dcc1	SW¼SW¼SE¼35	....	Dd	C, h	N	To	79	69.5	5-20-57	2,197	2,128	.....	....
21N-22W-1ccc1	SW¼SW¼SW¼ 1	J. E. Leatherman	Dd	C, w	S	To	.....	37.7	5- 9-57	2,307	2,270	.....	....
6bbb1	NW¼NW¼NW¼ 6	V. Beisel	B	C, h	O	To	25	2.0	5-13-57	2,147	2,145	.....	....
6bbb2	do.	US Geol. Survey	Dd	N	T	To	455	3.3	4-27-57	2,146	2,143	2,046	L
9bab1	NW¼NE¼NW¼ 9	....	Dd	C, w	N	To	70	31.4	5- 9-57	2,295	2,264	.....	....
11bbb1	NW¼NW¼NW¼11	....	Dd	C, w	N	To	38	31.3	5- 9-57	2,300	2,269	.....	....
15bab1	NW¼NE¼NW¼15	....	D	C, w	N	To	22	3.8	5-17-57	2,256	2,252	.....	....
15ccd1	SE¼SW¼SW¼15	Barber	Dd	C, h	D	To	32	14.4	5-17-57	2,305	2,290	.....	....
15cdc1	SW¼SE¼SW¼15	do.	B	C, h	N	To	8	0.5	2-23-56	.....	.....	.....	....
16ccc1	SW¼SW¼SW¼16	....	Dd	C, w	N	To	64	50.3	5-17-57	2,327	2,276	.....	....
19bbb1	NW¼NW¼NW¼19	....	Dd	C, w	N	To	38	25.6	5- 9-57	2,228	2,202	.....	....
19dda1	NE¼SE¼SE¼19	....	Dd	C, w	N	To	31	26.9	5-17-57	2,254	2,227	.....	....
21bcb1	NW¼SW¼NW¼21	G. Marston, Jr.	Dd	T, e	I	To	.....	26.1	5-17-57	2,291	2,265	.....	C
22ddc1	SW¼SE¼SE¼22	F. O. Brown	Dd	C, w	S	To	57	41.1	5-17-57	2,341	2,300	.....	....
23bbb1	NW¼NW¼NW¼23	US Geol. Survey	Dd	N	T,O	To	322	29.2	5-13-57	2,335	2,306	2,014	L
25ccd1	SE¼SW¼SW¼25	....	Dd	C, w	N	To	82	70.8	5- 9-57	2,367	2,296	.....	....
26baa1	NE¼NE¼NW¼26	W. W. Montgomery	Dd	N	N	To	76	.....	....	2,372	.....	.....	....
30ddd1	SE¼SE¼SE¼30	O. L. Mitchell	D	C, e	D,S	To	50	18.4	8-15-56	2,304	2,285	.....	....
31ccc1	SW¼SW¼SW¼31	US Geol. Survey	Dd	N	T	To	322	....	......	2,377	.....	2,058	L
32aab1	NW¼NE¼NE¼32	....	Dd	C, h	N	To	60	30.6	5- 9-57	2,314	2,284	.....	....
34aaa1	NE¼NE¼NE¼34	....	Dd	C, w	S	To	101	73.2	5- 9-57	2,373	2,300	.....	....
34ccd1	SE¼SW¼SW¼34	....	Dd	C, w	S	To	31	16.0	8-15-56	.....	.....	.....	....
22N-17W-1bcc1	SW¼SW¼NW¼ 1	W. M. Vickery	Dd	C, w	S	Pb,Pf	92	83.1	11-29-55	.....	.....	.....	....
5bbb1	NW¼NW¼NW¼ 5	R. Gates	Dd	C, h	N	Pdc	72	52.8	5- 7-57	.....	.....	.....	....
14baa1	NE¼NE¼NW¼14	F. Buttel	Dd	C, w	S	Pb,Pf	97	60.9	11-29-55	.....	.....	.....	....
14cbb1	NW¼NW¼SW¼14	H. Clayton	Dd	C, w	S	Pdc	78	45.2	3-20-57	.....	.....	.....	....
16cbb1	do. 16	W. Johns	Dd	C, w	D,S	Pb	150	51.4	11-29-55	.....	.....	.....	....
21bdd1	SE¼SE¼NW¼21	O. Ford	Dd	C, e	S	Pdc	93	50.7	11-30-55	.....	.....	.....	....
22dbb1	NW¼NW¼SE¼22	M. T. Smith	Dd	N	N	Pdc	149	92.4	11-29-55	.....	.....	.....	....
29ddd1	SE¼SE¼SE¼29	O. Ford	Dd	C, w	S	Pwh	96	67.4	11-30-55	.....	.....	.....	....
34acb1	NW¼SW¼NE¼34	R. W. Finley	D	C, e	D,S	Pwh	74	27.8	10-19-55	.....	.....	.....	....

Well number: For explanation see text, p. 7; well locations shown on plate 2.

Type of well: B, bored; D, dug; Dd, drilled; Dn, driven;

Pump and power: C, cylinder; Cf, centrifugal; J, jet, N, none; T, turbine; a, airlift; b, butane, e, electric; g, gasoline, h, hand; p, propane; w, wind.

Use: D, domestic; I, irrigation; Id, industrial; N, none (includes unused or destroyed wells); O, observation; P, public supply; S, stock; T, test hole.

Geologic source: Qal, low-terrace deposits and alluvium; Qt, high-terrace deposits; To, Ogallala Formation; Pwh, Whitehorse Group; Pdc, Dog Creek Shale; Pb, Blaine Gypsum; Pf, Flowerpot Shale.

Other data: C, chemical analysis shown in appendix C; L, well log shown in appendix B.

Well number	Location in section	Owner or tenant	Type of well	Pump and power	Use	Geologic source	Depth of well (feet)	Water level: Depth below land surface	Water level: Date of measurement	Altitude above mean sea level (feet): Land surface	Altitude above mean sea level (feet): Water level surface	Altitude above mean sea level (feet): Permian surface	Other data
22N-18W-2ddc1	SW¼SE¼SE¼ 2	C. Newman	Dd	C, w	D,S	Pwh	39	34.2	2- 5-57	1,812	1,778	.....	....
3baa1	NE¼NE¼NW¼ 3	E. Dodge	Dd	C, h	N	.....	135	100.5	5-15-57	1,974	1,873	.....	....
3dcd1	SE¼SW¼SE¼ 3	do.	Dd	C, w	D,S	.....	149	126.0	5-15-57	1,940	1,814	.....	....
6daa1	NE¼NE¼SE¼ 6	D. Elwood	Dd	C, e	D,S	Qt	104	38.4	5-15-57	1,894	1,855	.....	....
8bcc1	SW¼SW¼NW¼ 8	E. Dodge	Dd	N	N	Qt	48	36.2	5-13-57	1,887	1,851	.....	....
9bbb1	NW¼NW¼NW¼ 9	do.	Dd	C, w	S	Qt	87	62.0	5-15-57	1,918	1,856	.....	....
14ddd1	SE¼SE¼SE¼14	US Geol. Survey	Dd	N	T	Qt	82	55.8	4-25-57	1,824	1,768	1,744	L
15aaa1	NE¼NE¼NE¼15	do.	Dd	N	T	Qt	55	41.8	4-25-57	1,836	1,794	1,784	L
17bbb1	NW¼NW¼NW¼17	....	Dd	C, w	D,S	Qt	48	30.0	5-13-57	1,878	1,848	1,834	
17cdc1	SW¼SE¼SW¼17	....	Dd	C, w	S	Qt	37	28.4	5- 7-57	1,874	1,845	.....	....
19dcd1	SE¼SW¼SE¼19	V. Harper	Dd	J, e	D,S	.....	45	30.0	5-15-57	1,864	1,834	.....	....
21bbb1	NW¼NW¼NW¼21	....	Dd	C, w	S	Qt	68	53.1	5- 7-57	1,898	1,845	.....	....
21aaa1	NE¼NE¼NE¼21	....	Dd	C, w	S	Qt	80	70.1	5- 7-57	1,913	1,843	.....	....
23ccd1	SE¼SW¼SW¼23	US Geol. Survey	Dd	N	T	Qt	67	18.2	4-25-57	1,842	1,824	1,778	L
27bbc1	SW¼NW¼NW¼27	....	Dd	C, w	S	Qt	92	67.0	5- 7-57	1,902	1,835	.....	....
29daa1	NE¼NE¼SE¼29	....	Dd	N	N	Qt	51	40.8	5- 7-57	1,878	1,837	.....	....
30dab1	NW¼NE¼SE¼30	....	Dn	N	N	QT	21	16.0	5- 8-57	1,860	1,845	.....	....
33ccc1	SW¼SW¼SW¼33	US Geol. Survey	Dd	N	T,O	Qt	62	25.8	5-13-57	1,840	1,814	1,780	L
36daa1	NE¼NE¼SE¼36	A. G. Hartley	Dd	C, w	S	Qt	134	87.1	5-15-57	1,938	1,851	.....	....
22N-19W-2bbd1	SE¼NW¼NW¼ 2	J. Hubbard	Dd	Cf, e	I	Qt	47	.....	....	.....	.....	.....	C
2ccc1	SW¼SW¼SW¼ 2	US Geol. Survey	Dd	N	T	Qt	30	.....	....	1,848	.....	1,821	L
2cda1	NE¼SE¼SW¼ 2	J. S. Price	Dd	T, p	I	Qt	57	.....	....	1,876	.....	.....	....
4aaa1	NE¼NE¼NE¼ 4	F. Eilers	Dd	T, e	I	Qal	55	11.0	12-14-56	1,848	.....	1,793	L
5bac1	SW¼NE¼NW¼ 5	O. Rutledge	Dd	C, w	S	Qal	26	5.5	5- 8-57	1,833	1,827	1,807	L
7ccb1	NW¼SW¼SW¼ 7	C. Sheldon	Dd	C, w	S	Pwh	122	58.0	5-15-57	2,042	1,984	.....	....
9baa1	NE¼NE¼NW¼ 9	J. Caldwell	Dd	N	N	Qal	52	.....	....	1,826	.....	1,774	L
11cbb1	NW¼NW¼SW¼11	W. C. Syms	Dd	J, E	D	Qal	49	6.7	10-20-55	1,838	.....	.....	....
11cdd1	SE¼SE¼SW¼11	US Geol. Survey	Dd	N	T	Qal	50	8.5	4-25-57	1,832	1,823	1,785	L
12baa1	NE¼NE¼NW¼12	do.	Dd	N	T	Qal	80	21.4	4-25-57	1,863	1,841	1,788	L
18ccc1	SW¼SW¼SW¼18	....	Dd	N	N	.....	....	flowing	5- 9-56	1,966	.....	.....	....
22bcc1	SW¼SW¼NW¼22	US Geol. Survey	Dd	N	T	Qal	55	.....	....	1,824	.....	1,773	L
25ada1	NE¼SE¼NE¼25	H. Harper	Dd	C, w	S	Qal	51	22.1	5- 8-57	1,820	1,798	1,780	L
26ada1	do. 26	C. Harper	Dn	N	N	Qal	23	6.2	5- 8-57	1,800	1,794	.....	....
27bcc1	SW¼SW¼NW¼27	A. Harper	Dd	J, e	D,S,O	Qal	43	31.2	8-28-56	1,828	1,796	.....	....
28dda1	NE¼SE¼SE¼28	E. Peach	Dd	T, b	I	Qal	75	31.7	5-14-57	1,825	1,793	1,757	L
31add1	SE¼SE¼NE¼31	C. Moser	B	C, w	D,S	Pwh	124	71.2	5-15-57	1,990	1,919	.....	....
33aaa1	NE¼NE¼NE¼33	N. Peach	Dd	T, g	I	Qal	83	36.0	5-14-57	1,829	1,793	1,746	L
33aac1	SW¼NE¼NE¼33	do.	Dd	N	N	Qal	57	38.3	5-14-57	1,832	1,793	1,775	
34ddb1	NW¼SE¼SE¼34	L. Keith	Dd	T, b	I	Qal	90	39.1	5-14-57	1,828	1,789	1,738	L
35cca1	NE¼SW¼SW¼35	US Geol. Survey	Dd	N	T,O	Qal	55	16.5	4-25-57	1,804	1,788	1,750	L
35cca2	do	do.	Dd	N	T,O	Qal	40	16.0	4-25-57	1,804	1,788	.....	L
35cca3	do.	do.	Dd	N	T,O	Qal	40	16.8	4-25-57	1,805	1,788	.....	L
35cca4	do.	W. Cox	Dd	T, b	I	Qal	60	.....	....	1,805	.....	.....	C
35cac1	SW¼NE¼SW¼35	do.	Dd	N	N	Qal	40	8.9	12- 2-58	1,801	1,792	.....	....
22N-20W-1baa1	NE¼NE¼NW¼ 1	E. A. Crites	Dd	N	N	Pwh	74	31.4	5-16-57	.....	.....	.....	....
3cbb1	NW¼NW¼SE¼ 3	G. Menten	B	C, w	N	Pwh	69	41.8	5-16-57	.....	.....	.....	....
6bcc1	SW¼SW¼NW¼ 6	L. Adams	D	C, w	N	Pwh	41	15.9	5-16-57	1,971	1,955	.....	....
7aba1	NE¼NW¼NE¼ 7	M. Bennett	Dd	N	N	Qal	22	3.5	5-16-57	1,952	1,949	.....	....
8ddc1	SW¼SE¼SE¼ 8	F. E. Millard	Dd	C, e	N	Pwh	45	29.7	5-16-57	.....	.....	.....	....
11cdd1	SE¼SE¼SW¼11	J. Fritts	Dd	C, h	N	.....	35	18.6	5-16-57	2,048	2,029	.....	....
14ccb1	NW¼SW¼SW¼14	W. W. White	D	J, e	D	Pwh	32	17.8	5-16-67	2,011	1,993	.....	....
15bba1	NE¼NW¼NW¼15	J. L. Smalling	Dd	J, e	D,O	.....	43	23.7	5-13-57	2,050	2,026	.....	....
17ccc1	SW¼SW¼SW¼17	G. E. Campbell	B	J, e	D,S	To	54	18.2	11- 1-55	2,072	2,054	.....	....
19aad1	SE¼NE¼NE¼19	A. Lehr	Dd	N	N	To	81	19.0	5-16-57	.....	.....	.....	....
22bbb1	NW¼NW¼NW¼22	K. Blakley	Dd	C, h	N	Pwh	86	36.5	5-16-57	.....	.....	.....	....
24abb1	NW¼NW¼NE¼24	C. Steadman	Dd	C, w	S,O	Pwh	84	28.4	5-13-57	1,964	1,936	.....	....
24ccb1	NW¼SW¼SW¼24	....	Dd	C, w	N	Pwh	.....	5.5	5-16-57	1,933	1,927	.....	....
25bba1	NE¼NW¼NW¼25	US Geol. Survey	Dn	N	O	Qal	9	2.1	5-13-57	1,904	1,902	.....	....
30dcd1	SE¼SW¼SE¼30	W. Meech	Dd	C, w	S	To	31	7.0	5-16-57	2,040	2,033	.....	....
22N-21W-2dad1	SE¼NE¼SE¼ 2	....	Dd	C, w	O	To	23	14.9	5-13-57	2,053	2,038	.....	....
4abb1	NW¼NW¼NE¼ 4	H. Wells	Dd	C, w	N	To	31	25.5	5-15-57	2,090	2,065	.....	....
4add1	SE¼SE¼NE¼ 4	V. Wells	D	N	T	To	72	25	9-14-56	.....	.....	.....	L
6aad1	SE¼NE¼NE¼ 6	K. Blakley	Dd	C, w	N	To	24	20.2	5-15-57	2,138	2,117	.....	....

Well number: For explanation see text, p. 7 ; well locations shown on plate 2 .

Type of well: B, bored; D, dug; Dd, drilled; Dn, driven;

Pump and power: C, cylinder; Cf, centrifugal; J, jet, N, none; T, turbine; a, airlift; b, butane, e, electric; g, gasoline, h, hand; p, propane; w, wind.

Use: D, domestic; I, irrigation; Id, industrial; N, none (includes unused or destroyed wells); O, observation; P, public supply; S, stock; T, test hole.

Geologic source : Qal, low-terrace deposits and alluvium; Qt, high-terrace deposits; To, Ogallala Formation; Pwh, Whitehorse Group; Pdc, Dog Creek Shale; Pb, Blaine Gypsum; Pf, Flowerpot Shale.

Other data: C, chemical analysis shown in appendix C; L, well log shown in appendix B.

Well number	Location in section	Owner or tenant	Type of well	Pump and power	Use	Geologic source	Depth of well (feet)	Water level: Depth below land surface	Water level: Date of measurement	Altitude above mean sea level (feet): Land surface	Altitude: Water level surface	Altitude: Permian surface	Other data
22N-21W--Continued													
7cbb1	NW¼NW¼SW¼ 7	....	Dd	C, w	N	To	48	35.5	5-15-57	2,228	2,192	......	....
8aaa1	NE¼NE¼NE¼ 8	K. Charmasson	B	C, w	S	To	26	13.7	8-18-56	.....	.....	.....	....
9bbb1	NW¼NW¼NW¼ 9	S. E. Washburn	Dd	N	N	To	17	6.9	5-15-57	2,121	2,114	.....	....
9bbc1	SW¼NW¼NW¼ 9	do.	B	C, w	N	To	27	14.8	8-18-56	.....	.....	.....	....
11ada1	NE¼SE¼NE¼11	....	D	N	N	To	35	27.3	8-18-56	2,092	2,064	.....	....
14aaa1	NE¼NE¼NE¼14	H. Fine	Dd	C, w	S	To	45	31.8	9-18-56	2,115	2,083	.....	....
15abc1	SW¼NW¼NE¼15	J. W. Braley	Dd	C, w	S	To	51	27.6	9-10-56	.....	.....	.....	C
16ddd1	SE¼SE¼SE¼15	US Geol. Survey	Dd	N	T	To	165	70.0	2-21-57	2,208	2,138	2,046	L
18bbb1	NW¼NW¼NW¼18	S. Semmel	Dd	C, w	S	To	33	24.0	5-15-57	2,251	2,227	.....	....
19aca1	NE¼SW¼NE¼19	H. Wells	Dd	C, w	S,O	To	88	50.2	5-13-57	2,268	2,218	.....	....
20dcd1	SE¼SW¼SE¼20	....	Dd	N	N	To	97	83.2	5-15-57	2,308	2,224	.....	....
22dda1	NE¼SE¼SE¼22	L. A. Campbell	Dd	C, w	N	To	141	91.0	5-15-57	2,223	2,132	.....	....
23ddc1	SW¼SE¼SE¼23	....	Dd	C, w	N	To	59	39.4	5-15-57	2,156	2,116	.....	....
25aaa1	NE¼NE¼NE¼25	L. Merrill	Dd	J, e	D,S	To	28	17.2	8- 8-56	.....	.....	.....	....
26cca1	NE¼SW¼SW¼26	H. Myers	Dd	C, w	S	To	60	39.0	5-15-57	2,169	2,130	.....	.....
27ccd1	SE¼SW¼SW¼27	C. R. Blaylock	Dd	C, w	S	To	72	56.7	5-15-57	2,206	2,149	.....	....
28baa1	NE¼NE¼NW¼28	....	Dd	C, w	S	To	45	40.2	5-15-57	2,248	2,208	.....	....
30dab1	NW¼NE¼SE¼30	R. Adams	Dd	C, w	S	To	82	76.2	10- 3-56	.....	.....	.....	....
31add1	SE¼SE¼NE¼31	M. H. Reger	Dd	N	N	To	.....	184.6	5-15-57	2,362	2,177	.....	....
32abb1	NW¼NW¼NE¼32	....	Dd	C, w	S	To	85	81.5	5-15-57	.....	.....	.....	....
33add1	SE¼SE¼NE¼33	R. L. Chenoweth	Dd	C, w	S	To	136	64.1	10-18-55	2,234	2,170	.....	....
22N-22W-2aba1	NE¼NW¼NE¼ 2	....	Dd	N	N	To	69	44.1	5-17-57	2,188	2,144	.....	....
3ccb1	NW¼SW¼SW¼ 3	....	Dd	C, w	S,O	To	40	24.5	5-13-57	2,162	2,137	.....	....
4ccc1	SW¼SW¼SW¼ 4	....	Dd	N	N	To	7	3.8	5-17-57	.....	.....	.....	....
7ccc1	do. 7	F. A. Moorehart	Dd	N	N	To	20	10.5	5-17-57	2,089	2,078	.....	....
7dda1	NE¼SE¼SE¼ 7	....	Dd	C, w	S	To	48	37.2	5-17-57	2,122	2,085	.....	....
9ddd1	SE¼SE¼SE¼ 9	....	Dd	C, w	N	To	74	60.9	4-12-56	2,208	2,147	.....	....
11bcc1	SW¼SW¼NW¼11	J. E. Hardy	Dd	C, w	N	To	87	59.4	5-17-57	2,215	2,156	.....	....
12cbc1	SW¼NW¼SW¼12	....	Dd	C, w	N	To	39	30.8	5-17-57	2,253	2,222	.....	....
18add1	SE¼SE¼NE¼18	....	Dd	C, w	S,O	To	58	54.0	5-13-57	2,161	2,107	.....	....
19ccc1	SW¼SW¼SW¼19	....	Dd	C, w	O	To	76	28.6	5- 7-57	2,163	2,108	.....	....
21cbc1	SW¼NW¼SW¼21	C. E. Williams	Dd	Cf, p	I	To	60	.....	....	2,155	.....	2,095	C, L
22bbb1	NW¼NW¼NW¼22	US Geol. Survey	Dd	N	T	To	225	.....	....	2,202	.....	1,982	L
22ddd1	SE¼SE¼SE¼22	....	Dd	C, w	N	To	43	30.4	5-17-57	2,264	2,233	.....	....
26ddd1	do. 26	....	Dd	C, w	O	To	52	46.6	5-13-57	2,283	2,236	.....	....
28dcc1	SW¼SW¼SE¼28	....	Dd	C, w	S	To	27	20.3	5-17-57	2,192	2,172	.....	....
31ccc1	SW¼SW¼SW¼31	US Geol. Survey	Dd	N	T	To	80	3.9	2-26-57	2,146	2,142	2,072	L
33dcc1	SW¼SW¼SE¼33	....	Dd	C, w	N	To	.....	18.0	6-15-56	.....	.....	.....	.....
34daa1	NE¼NE¼SE¼34	Sneed Estate	Dd	C, w	N	To	54	45.5	5-17-57	2,272	2,227	.....	....
36aaa1	NE¼NE¼NE¼36	US Geol. Survey	Dd	N	T	To	352	109.5	2-21-57	2,327	2,218	1,977	L
23N-17W-7bad1	SE¼NE¼NW¼ 7	L. Hinderliter	Dd	J, e	D	Pdc	50	32.3	11-15-55	.....	.....	.....	....
8ada1	NE¼SE¼NE¼ 8	G. Harper	Dd	C, w	D,S	....	59	27.6	11-15-55	.....	.....	.....	....
8abb1	NW¼NW¼NE¼ 8	J. Harper	Dd	C, w	S	....	75	.....	....	.....	.....	.....	C
14bbb1	NW¼NW¼NW¼14	C. E. Wilber	Dd	C, w	S	Pb	39	28.6	10-12-55	.....	.....	.....	....
17bcc1	SW¼SW¼NW¼17	R. C. Dauphin	Dd	J, e	D,S	....	115	60.5	11-15-55	.....	.....	.....	....
19bcc1	do. 19	City of Quinlan	Dd	C, e	P	Pwh	190	.....	....	.....	.....	.....	C
20bcb1	NW¼SW¼NW¼20	W. D. Huff	Dd	C, w	S	Pb	116	97.8	10-12-55	.....	.....	.....	....
27dba1	NE¼NW¼SE¼27	A. Farrand	Dd	C, w	S	Pb	29	9.4	10-13-55	.....	.....	.....	....
28cdc1	SW¼SE¼SW¼28	W. O. Mullins	Dd	C, w	S	Pb	59	47.5	11-15-55	.....	.....	.....	....
30ccc1	SW¼SW¼SW¼30	R. Roberts	Dd	N	S	Pb	133	flowing	9-11-56	1,724	.....	....	C

Well number: For explanation see text, p. 7 ; well locations shown on plate 2 .

Type of well: B, bored; D, dug; Dd, drilled; Dn, driven;

Pump and power: C, cylinder; Cf, centrifugal; J, jet, N, none; T, turbine; a, airlift; b, butane, e, electric; g, gasoline, h, hand; p, propane; w, wind.

Use: D, domestic; I, irrigation; Id, industrial; N, none (includes unused or destroyed wells); O, observation; P, public supply; S, stock; T, test hole.

Geologic source : Qal, low-terrace deposits and alluvium; Qt, high-terrace deposits; To, Ogallala Formation; Pwh, Whitehorse Group; Pdc, Dog Creek Shale; Pb, Blaine Gypsum; Pf, Flowerpot Shale.

Other data: C, chemical analysis shown in appendix C; L, well log shown in appendix B.

Well number	Location in section	Owner or tenant	Type of well	Pump and power	Use	Geologic source	Depth of well (feet)	Water level		Altitude above mean sea level (feet)			Other data
								Depth below land surface	Date of measurement	Land surface	Water level surface	Permian surface	
23N-18W-7bbc1	SW¼NW¼NW¼ 7	W. Ames	Dd	N	N	Qt	51	50.9	5-16-57	2,019	1,968	.....	....
7ccc1	SW¼SW¼SW¼ 7	US Geol. Survey	Dd	N	T	Qt	85	.....	....	1,993	.....	1,912	L
10ccc1	do. 10	State of Oklahoma	Dd	C, w	S	Pwh	142	118.0	1- 2-57	.....	.....	.....	....
19ddd1	SE¼SE¼SE¼19	M. Elwood	Dd	T, g	I	Qt	67	49.6	5-14-57	1,943	1,893	.....	....
20ccc1	SW¼SW¼SW¼20	US Geol. Survey	Dd	N	T	Qt	38	.....	....	1,940	.....	1,905	L
25add1	SE¼SE¼NE¼25	M. Morgan	Dd	C, e	D,S	Pwh	88	55.9	5-15-57	.....	.....	.....	....
27cdc1	SW¼SE¼SW¼27	O. Rutledge	Dd	C, w	S	.....	130	81.2	5-15-57	1,960	1,879	.....	....
28bcc1	SW¼SW¼NW¼28	A.T.&S.F. Ry.*	Dd	J, E	Id	.....	203	.....	....	.....	.....	.....	....
30ccc1	SW¼SW¼SW¼30	....	Dd	C, w	N	Qt	60	48.1	5-16-57	1,921	1,873	.....	....
30ccd1	SE¼SW¼SW¼30	O. Rutledge	Dd	N	N	Qt	65	48.8	5-16-57	1,928	1,876	.....	....
30ddc1	SW¼SE¼SE¼30	J. Phillips	Dd	T, b	I	Qt	106	48.1	5-15-57	1,918	1,873	1,814	C,L
30ddc2	do.	US Geol. Survey	Dd	N	T,O	Qt	102	42.2	8-23-57	1,917	1,874	1,817	L
30ddc3	do.	do.	Dd	N	T,O	Qt	60	41.9	8-23-57	1,916	1,875	.....	L
30ddc4	do.	do.	Dd	N	T,O	Qt	60	41.4	8-23-57	1,916	1,875	.....	L
30dcd1	SE¼SW¼SE¼30	do.	Dd	N	T,O	Qt	60	41.8	8-23-57	1,917	1,875	.....	L
31dcc1	SW¼SW¼SE¼31	do.	Dd	N	T	Qt	85	35.9	4-25-57	1,899	1,863	1,816	L
33ddd1	SE¼SE¼SE¼33	do.	Dd	N	T	Qt	60	46.2	4-25-57	1,953	1,907	1,896	L
36baa1	NE¼NE¼NW¼36	R. C. Campbell	Dd	C, w	D,S,O	Pwh	67	19.8	11-20-56	1,751	1,731	.....	....
23N-19W-2ddc1	SW¼SE¼SE¼ 2	J. W. Richmond	Dd	C, w	S	Qt	28	15.8	5-16-57	1,963	1,947	.....	....
3aaa1	NE¼NE¼NE¼ 3	W. Trissell	Dd	C, w	O	Qt	97	42.4	5-13-57	2,006	1,964	.....	....
3cbc1	SW¼NW¼SW¼ 3	Oil co. test hole	Dd	N	T	.....	2,500	.....	....	2,000	.....		
4bcb1	NW¼SW¼NW¼ 4	D. Miller	Dd	C, w	S	Qt	60	43.3	5-16-57	2,008	1,965	.....	....
6ccb1	NW¼SW¼SW¼ 6	R. E. Gilbert	Dd	C, w	S	Qt	80	43.6	5-16-57	2,014	1,970	.....	....
10bbb1	NW¼NW¼NW¼10	US Geol. Survey	Dd	N	T	Qt	117	.....	....	1,983	.....	1,868	L
10dcd1	SE¼SW¼SE¼10	L. M. Trissell	Dd	C, w	S	Qt	85	39.0	5-16-57	1,953	1,914	.....	....
14aac1	SW¼NE¼NE¼14	Cities Service Gas Co.	Dd	T, e	Id	Qt	105	.....	....	1,939	.....	1,834	L
15cca1	NE¼SW¼SW¼15	F. E. Dail	Dd	T, e	I	Qt	90	.....	....	.....	.....	.....	....
17cdd1	SE¼SE¼SW¼17	US Geol. Survey	Dd	N	T	Qt	65	.....	....	1,915	.....	1,852	L
20bab1	NW¼NE¼NW¼20	W. C. Richard	Dd	N	O	Qt	39	21.5	5-13-57	1,921	1,899	.....	....
21cca1	NE¼SW¼SW¼21	I. I. Caldwell	Dd	T, b	I	Qt	58	.....	....	.....	.....	.....	....
22aac1	SW¼NE¼NE¼22	A. A. West	Dd	T, b	I	Qt	79	32.4	5-14-57	1,922	1,890	1,844	L
22ddb1	NW¼SE¼SE¼22	F. E. Dail	Dd	T b	I	Qt	89	.....	....	.....	.....	.....	....
23adb1	NW¼SE¼NE¼23	T. B. Triplett	Dd	T, b	I	Qt	74	.....	....	1,921	.....	1,850	L
23bca1	NE¼SW¼NW¼23	do.	Dd	T, e	I	Qt	82	24.2	5-14-57	1,915	1,889	1,835	L
23cbd1	SE¼NW¼SW¼23	R. L. Triplett	Dd	T, e	I	Qt	79	23.2	5-14-57	1,908	1,885	1,829	L
23dbd1	SE¼NW¼SE¼23	J. E. Bouquot	Dd	T, g	I	Qt	75	.....	....	.....	.....	.....	....
25aaa1	NE¼NE¼NE¼25	US Geol. Survey	Dd	N	T	Qt	82	52.0	4-25-57	1,940	1,888	1,860	L
26dbd1	SE¼NW¼SE¼26	City of Mooreland	Dd	....	P	Qt	61	.....	....	.....	.....	.....	C
26dbb1	NW¼NW¼SE¼26	do.	Dd	....	P	Qt	61	.....	....	.....	.....	.....	....
27bab1	NW¼NE¼NW¼27	G. C. Davison	Dd	C, w	D,S	Qt	73	34.7	5-16-57	1,910	1,875	.....	....
27bab2	do	do.	Dd	N	N	Qt	38	34.9	5-16-57	.....	.....	.....	....
28aca1	NE¼SW¼NE¼28	T. Z. Wright	Dd	T, b	I	Qt	64	18.7	7- 8-57	1,892	1,873	1,837	C,L
28aca2	do.	US Geol. Survey	Dd	N	T,O	Qt	40	17.3	7- 8-57	1,890	1,872	.....	L
28aca3	do.	do.	Dd	N	T,O	Qt	56	18.7	7- 8-57	1,892	1,873	1,838	L
28aca4	do.	do.	Dd	N	T,O	Qt	40	18.2	7- 8-57	1,891	1,873	.....	L
28cab1	NW¼NE¼SW¼28	W. D. White	Dd	Cf, b	I	Qt	47	.....	....	.....	.....	.....	....
28cdb1	NW¼SE¼SW¼28	T. Z. Wright	Dd	J, e	D,I	Qt	39	11.6	5-14-57	1,873	1,861	.....	....
28dcb1	NW¼SW¼SE¼28	do.	Dd	T, b	I	Qt	51	13.1	5-14-57	1,874	1,861	1,831	L
33ddb1	NW¼SE¼SE¼33	E. Barton	Dd	N	O	Qt	30	3.1	5-16-57	1,861	1,858	.....	....
34ada1	NE¼SE¼NE¼34	C. M. Triplett	Dd	Cf, e	I	Qt	54	20.6	5-14-57	1,885	1,864	.....	....
34ddb1	NW¼SE¼SE¼34	K. M. Swigart	Dd	T, g	I	Qt	48	.....	....	1,871	.....	.....	....
35bbd1	SE¼NW¼NW¼35	C. Phillips	Dd	T, p	I	Qt	69	19.5	5-14-57	1,884	1,864	1,823	L
36aaa1	NE¼NE¼NE¼36	US Geol. Survey	Dd	N	T	Qt	95	46.9	4-25-57	1,920	1,873	1,828	L
23N-20W-1cdc1	SW¼SE¼SW¼ 1	R. F. Gilbert	Dd	C, w	N	Qt	52	39.0	9-25-56	.....	.....	.....	....
2baa1	NE¼NE¼NW¼ 2	US Geol. Survey	Dd	N	T	Qt	110	48.6	2-13-57	2,052	2,004	1,949	L
2cdd1	SE¼SE¼SW¼ 2	C. D. Ruttman	Dd	C, w	N	Qt	88	40.9	5-17-57	2,013	1,972	.....	....
3cdd1	do. 3	US Geol. Survey	Dd	N	T	Qt	100	42.0	2-14-57	2,017	1,975	1,922	L
3daa1	NE¼NE¼SE¼ 3	do.	Dd	N	T	Qt	110	45.7	2-14-57	2,026	1,981	1,918	L
5bba1	NE¼NW¼NW¼ 5	O. Foglesong	Dd	C, w	S,O	Qt	40	30.9	5-13-57	2,016	1,985	.....	....
7aca1	NE¼SW¼NE¼ 7	City of Woodward	Dd	N	T	Qt	57	26	1954	1,960	.....	1,903	L
7dbd1	SE¼NW¼SE¼ 7	US Geol. Survey	Dd	N	T,O	Qt	50	19.7	2- 5-57	1,947	1,928	1,903	L

*Atchison Topeka and Santa Fe Railway Co.

Well number: For explanation see text, p. 7 ; well locations shown on plate 2 .

Type of well: B, bored; D, dug; Dd, drilled; Dn, driven;

Pump and power: C, cylinder; Cf, centrifugal; J, jet, N, none; T, turbine; a, airlift; b, butane, e, electric; g, gasoline, h, hand; p, propane; w, wind.

Use: D, domestic; I, irrigation; Id, industrial; N, none (includes unused or destroyed wells); O, observation; P, public supply; S, stock; T, test hole.

Geologic source : Qal, low-terrace deposits and alluvium; Qt, high-terrace deposits; To, Ogallala Formation; Pwh, Whitehorse Group; Pdc, Dog Creek Shale; Pb, Blaine Gypsum; Pf, Flowerpot Shale.

Other data: C, chemical analysis shown in appendix C; L, well log shown in appendix B.

Well number	Location in section	Owner or tenant	Type of well	Pump and power	Use	Geologic source	Depth of well (feet)	Water level: Depth below land surface	Water level: Date of measurement	Altitude above mean sea level (feet): Land surface	Altitude: Water level surface	Altitude: Permian surface	Other data
23N-20W--Continued													
7dbd2	SW¼NW¼SE¼ 7	US Geol. Survey	Dd	N	T,O	Qt	[illegible]	19.4	2- 5-57	1,947	1,927	.....	L
7dbd3	do.	do.	Dd	N	T,O	Qt	[illegible]	20.5	2- 5-57	1,948	1,928	.....	L
7dbd4	do.	do.	Dd	N	T,O	Qt		20.8	2- 5-57	1,948	1,927	.....	L
7dbd5	do.	City of Woodward	Dd	T, e	P	Qt	[illegible]	18.7	1-22-57	1,946	1,928	.....	C
7dbd6	do.	do.	Dd	T, e	P	Qt	.....	25.6	2-18-57	1,954	1,928	.....	....
7dbd7	do.	do.	Dd	T, e	P	Qt	.....	18.8	2-25-57	1,945	1,926	.....	....
10ccc1	SW¼SW¼SW¼10	Oil co. test hole	Dd	N	T	.....	2,500	.....	....	1,978	.....	1,938	L
15cbb1	NW¼NW¼SW¼15	City of Woodward	Dd	N	T	Qt	61	36	1946	1,951	.....	1,890	L
15dcc1	SW¼SW¼SE¼15	do.	Dd	N	T	Qt	64	32	10-17-46	1,946	.....	1,882	L
17aaa1	NE¼NE¼NE¼17	do.	Dd	N	T	[illegible]	69	44	1954	1,967	.....	1,898	L
17bba1	NE¼NW¼NW¼17	do.	Dd	N	T	[illegible]	60	32	1954	1,957	.....	1,897	[illegible]
17bbb1	NW¼NW¼NW¼17	do.	Dd	N	T	Qt	52	26	1954	1,955	.....	1,903	[illegible]
17bcd1	SE¼SW¼NW¼17	do.	Dd	N	T	Qt	42	17	1954	1,941	.....	1,899	L
17cda1	NE¼SE¼SW¼17	do.	Dd	N	T	Qt	29	14	1946	1,936	.....	1,907	L
17daa1	NE¼NE¼SE¼17	do.	Dd	N	T	Qt	56	36	1946	1,953	.....	1,897	L
17ddc1	SW¼SE¼SE¼17	do.	Dd	N	T	Qt	38	20	1946	1,938	.....	1,900	L
18dcc1	SW¼SW¼SE¼18	do.	Dd	N	T	Qt	32	7	1954	1,878	.....	1,846	L
19baa1	NE¼NE¼NW¼19	do.	Dd	N	N	Qal	44	8	1954	1,878	.....	1,834	[illegible]
19bdb1	NW¼SE¼NW¼19	do.	Dd	N	T	Qal	28	8	1954	1,878	.....	1,850	L
19cba1	NE¼NW¼SW¼19	do.	Dd	N	N	Qal	27	5.7	5-29-41	.....	.....	.....	....
19cbb1	NW¼NW¼SW¼19	W. Erts	Dd	C, g	I	Qal	26	2.2	5-13-57	1,874	1,871	.....	....
21aba1	NE¼NW¼NE¼21	R. Reed	Dd	N	N	Qal	45	.....	....	1,944	.....	.....	....
21aba2	do.	do.	Dd	C, w	N	Qal	53	33.2	9-25-56	1,933	1,900	.....	....
22bbc1	SW¼NW¼NW¼22	City of Woodward	Dd	N	T	Qt	46	24	1946	1,931	.....	[illegible]	L
22bbd1	SE¼NW¼NW¼22	do.	Dd	N	T	Qal	83	19	1946	1,925	.....	1,842	L
22cbb1	NW¼NW¼SW¼22	do.	Dd	N	T	Qal		38	1946	1,924	.....	1,868	L
22dbb1	NW¼NW¼SE¼22	do.	Dd	N	T	Qal	[illegible]	42	1946	1,926	.....	[illegible]	
23bca1	NE¼SW¼NW¼23	....	Dd	C, w	S	Qt	[illegible]	17.9	5- 8-56	1,922	[illegible]	.....	....
31ddd1	SE¼SE¼SE¼31	City of Woodward	Dd	N	P	[illegible]		flowing	9- 7-56	1,900	.....	.....	C
36aab1	NW¼NE¼NE¼36	....	Dd	N	N	[illegible]		flowing	11-16-55	.....	.....	.....	....
23N-21W-3cab1	NW¼NE¼SW¼ 3	US Geol. Survey	Dd	N	T	[illegible]	[illegible]	27.1	2-27-57	1,959	1,932	1,904	L
4dcd1	SE¼SW¼SE¼ 4	do.	Dd	N	T		[illegible]	13.3	2-27-57	1,828	1,915	1,907	L
7ddc1	SW¼SE¼SE¼ 7	....	Dd	C, w	S	Pwh	91	72.0	5-15-57	2,001	1,929	.....	....
10cab1	NW¼NE¼SW¼10	US Geol. Survey	Dd	N	T	Qt	40	...	....	1,937	.....	1,901	L
27bab1	NW¼NE¼NW¼27	....	Dd	N	O	Pwh	61	26.0	5-13-57	1,952	1,926	.....	....
30ddd1	SE¼SE¼SE¼30	....	Dd	C, w	O	To	37	15.4	5-13-57	2,095	2,080	.....	....
34ccc1	SW¼SW¼SW¼34	H. Wells	Dd	C, w	S	To	26	20.5	5-15-57	2,076	2,056	.....	....
23N-22W-1bab1	NW¼NE¼NW¼ 1	US Geol. Survey	Dd	N	T	To	37	16.3	6- 6-57	2,034	2,017	1,998	L
1bbd1	SE¼NW¼NW¼ 1	Vludman	Dd	C, w	S	To	44	33.8	5- 9-57	.....	.....	.....	....
6cbb1	NW¼NW¼SW¼ 6	....	Dd	C, w	S,O	Pwh	53	41.1	5-13-57	.....	.....	.....	....
7cdd1	SE¼SE¼SW¼ 7	H. Wisner	Dd	C, w	S	Pwh	23	17.2	4-16-56	.....	.....	.....	....
11abc1	SW¼NW¼NE¼11	F. W. Devore	Dd	C, w	S	To	68	41.0	5-15-57	2,144	2,103	.....	....
14abb1	NW¼NW¼NE¼14	do.	Dd	C, w	S,O	To	69	41.8	5-15-57	2,136	2,095	.....	....
20daa1	NE¼NE¼SE¼20	....	Dd	J, e	D	To	14	6.0	3-23-56	2,076	2,070	.....	....
22dcc1	SW¼SW¼SE¼22	U. S. Air Force	Dd	N	T	To	73	...	....	2,130	.....	2,059	L
22dcd1	SE¼SW¼SE¼22	E. Peoples	Dd	T, b	I	To	51	29.4	7-13-57	2,133	2,104	.....	C
22dcd2	do.	do.	Dd	N	N	To	42	32.8	7-13-57	2,136	2,104	.....	....
22dcd3	do.	US Geol. Survey	Dd	N	T,O	To	100	28.9	7-13-57	2,134	2,105	2,039	L
22dcd4	do.	do.	Dd	N	T,O	To	52	28.4	7-13-57	2,132	2,104	.....	L
22dcd5	do.	do.	Dd	N	T,O	To	50	28.9	7-13-57	2,135	2,106	.....	L
25cbb1	NW¼NW¼SW¼25	U. S. Air Force	Dd	N	T	To	83	.....	....	2,163	.....	2,080	L
25dda1	NE¼SE¼SE¼25	do.	Dd	N	T	To	75	.....	....	2,078	.....	2,003	L
25ddb1	NW¼SE¼SE¼25	do	Dd	N	T	To	41	.....	....	2,081	.....	2,040	L
26bbb1	NW¼NW¼NW¼26	do.	Dd	N	T	To	72	.....	....	2,136	.....	2,064	L
26dab1	NW¼NE¼SE¼26	do.	Dd	T, e	P	To	70	45	1- 1-43	2,163	.....	.....	....
26ddd1	SE¼SE¼SE¼26	do.	Dd	N	T	To	110	.....	....	2,166	.....	2,056	L
28dda1	NE¼SE¼SE¼28	F. Norman	Dd	N	O	To	30	18.9	10-13-55	2,124	2,105	.....	....
29baa1	NE¼NE¼NW¼29	U. S. Air Force	Dd	N	T	Qal	27	.....	....	2,040	.....	2,014	L
36adb1	NW¼SE¼NE¼36	do.	Dd	N	T	To	57	.....	....	2,102	.....	2,045	L
36adc1	SW¼SE¼NE¼36	do.	Dd	N	T	To	61	.....	....	2,113	.....	2,052	L
36adc2	do.	C. O. Zimmerman	Dd	T, e	I	To	91	7	4-31-43	2,110	.....	.....	....
36dac1	SW¼NE¼SE¼36	U. S. Air Force	Dd	T, e	P	To	67	6	4-28-43	2,120	.....	.....	....
36dcd1	SE¼SW¼SE¼36	do.	Dd	N	T	To	96	.....	....	2,136	.....	2,040	L
36dcd2	do.	do.	Dd	T, e	P	To	91	9	4-20-43	2,135	.....	.....	....

Well number: For explanation see text, p. 7 ; well locations shown on plate 2 .

Type of well: B, bored; D, dug; Dd, drilled; Dn, driven;

Pump and power: C, cylinder; Cf, centrifugal; J, jet, N, none; T, turbine; a, airlift; b, butane, e, electric; g, gasoline, h, hand; p, propane; w, wind.

Use: D, domestic; I, irrigation; Id, industrial; N, none (includes unused or destroyed wells); O, observation; P, public supply; S, stock; T, test hole.

Geologic source : Qal, low-terrace deposits and alluvium; Qt, high-terrace deposits; To, Ogallala Formation; Pwh, Whitehorse Group; Pdc, Dog Creek Shale; Pb, Blaine Gypsum; Pf, Flowerpot Shale.

Other data: C, chemical analysis shown in appendix C; L, well log shown in appendix B.

Well number	Location in section	Owner or tenant	Type of well	Pump and power	Use	Geologic source	Depth of well (feet)	Water level: Depth below land surface	Water level: Date of measurement	Altitude above mean sea level (feet): Land surface	Altitude above mean sea level (feet): Water level surface	Altitude above mean sea level (feet): Permian surface	Other data
24N-17W-4bcc1	SW¼SW¼NW¼ 4	E. Matteson	Dd	C, w	D,S	Pb	36	32.8	12-18-56	.....	.....	.....	....
24N-18W-17ccc1	SW¼SW¼SW¼17	T. I. Caldwell	D	C, w	S	.....	33	28.8	5-16-57	2,095	2,066	.....	....
24ada1	NE¼SE¼NE¼24	Kohlar Estate	Dd	C, w	D,S	Pdc	49	24.1	1- 8-57	.....	.....	.....	....
29dba1	NE¼NW¼SE¼29	Oil co. test hole	Dd	N	T	.....	2,[illegible]	.....	....	2,079	.....	2,002	L
30bbc1	SW¼NW¼NW¼30	F. O. Daniels	Dd	C, w	S	.....	100	66.5	5-16-57	2,072	2,006	.....	....
24N-19W-13bbb1	NW¼NW¼NW¼13	....	D	C, h	N	Pwh	.....	18.4	1-17-61	1,887	.....	.....	....
14bbb1	do. 14	Oil co. test hole	Dd	N	T	.....	2,494	.....	....	1,887	.....	1,887	L
17add1	SE¼SE¼NE¼17	US Geol Survey	Dd	N	T	Qt	120	83.5	2-13-57	2,118	2,034	2,001	L
19cdd1	SE¼SE¼SW¼19	do.	Dd	N	T	Qt	150	.....	....	2,114	.....	1,969	L
19daa1	NE¼NE¼SE¼19	do.	Dd	N	T	Qt	125	64.3	2-13-57	2,091	2,027	1,969	L
20abb1	NW¼NW¼NE¼20	do.	Dd	N	T	Qt	120	88.5	2-13-57	2,110	2,021	1,992	L
22bb1	NW¼NW¼NW¼22	O. Barrick	Dd	C, w	S	Qt	123	61.4	5-16-57	2,103	2,042	.....	....
27cab1	NW¼NE¼SW¼27	US Geol. Survey	Dd	N	T,O	Qt	80	57.3	6-17-57	2,055	1,998	.....	L
27cba1	NE¼NW¼SW¼27	do.	Dd	N	T,O	Qt	90	55.9	6-17-57	2,054	1,998	.....	L
27cba2	do.	do.	Dd	N	T,O	Qt	80	57.3	6-17-57	2,054	1,996	.....	L
27cbb1	NW¼NW¼SW¼27	A. Richmond	Dd	T, b	I	Qt	101	56.6	6-17-57	2,055	1,998	1,954	C
29ccc1	SW¼SW¼SW¼29	G. Elwood	Dd	N	N	Qt	80	70.8	5-16-57	2,077	2,007	.....	....
30bcc1	SW¼SW¼NW¼30	US Geol. Survey	Dd	N	T	Qt	130	68.6	2-13-57	2,094	2,025	1,968	L
31ddb1	NW¼SE¼SE¼31	M. Ruttman	Dd	N	N	Qt	115	.....	....	2,047	.....	1,932	L
35dda1	NE¼SE¼SE¼35	N. B. Ames	Dd	N	N	Qt	67	23.9	5-16-57	1,992	1,968	.....	....
36aaa1	NE¼NE¼NE¼36	US Geol. Survey	Dd	N	T	Qt	58	.....	....	2,088	.....	2,037	L
36aba1	NE¼NW¼NE¼36	M. Healey	Dd	C, w	S	Qt	95	61.4	5-16-57	2,074	2,013	.....	....
24N-20W-2aad1	SE¼NE¼NE¼ 2	J. Foster	Dd	C, w	D,S	Pwh	189	99.8	10- 5-55	.....	.....	.....	....
2dcc1	SW¼SW¼SE¼ 2	....	Dd	C, w	N	Qt	69	50.4	5-17-57	2,138	2,088	.....	....
3aaa1	NE¼NE¼NE¼ 3	US Geol. Survey	Dd	N	T	Qt	35	.....	....	2,114	.....	2,083	L
3ddc1	SW¼SE¼SE¼ 3	B. Harrison, Jr.	Dd	C, w	S	Qt	81	64.6	5-17-57	2,116	2,051	.....	....
4ddd1	SE¼SE¼SE¼ 4	US Geol. Survey	Dd	N	T	Qt	100	.....	....	2,100	.....	2,002	L
5bbc1	SW¼NW¼NW¼ 5	D. VanDorn	Dd	C, w	N	Qt	90	69.1	9-25-56	2,044	1,975	.....	....
5dcc1	SW¼SW¼SE¼ 5	H. Munson	Dd	J, e	D,S	Qt	80	...	....	.....	.....	.....	L
6cdb1	NW¼SE¼SW¼ 6	L. A. Parsens	Dd	T, b	I	Qt	105	65.3	5-15-57	2,052	1,987	1,948	C,L
6cdb2	do.	US Geol. Survey	Dd	N	T,O	Qt	105	61.4	9-30-57	2,054	1,992	1,950	L
6cdb3	do.	do.	Dd	N	T,O	Qt	81	58.1	9-30-57	2,057	1,999	.....	L
6cdb4	do.	do.	Dd	N	T,O	Qt	102	55.7	9-30-57	2,056	2,001	1,956	L
7bbd1	SE¼NW¼NW¼ 7	L. A. Parsons	Dd	C, w	S	Qt	109	52.0	10- 6-55	2,049	1,997	.....	....
8abb1	NW¼NW¼NE¼ 8	H. Munson	Dd	C, w	S	Qt	73	66.0	9-21-56	2,054	1,988	.....	....
9abb1	do. 9	T. W. Collier	Dd	C, w	N	Qt	60	50.3	5-15-57	2,079	2,029	.....	....
11bab1	NW¼NE¼NW¼11	J. W. Kelsh	Dd	C, w	N	Qt	107	56.4	9-21-56	2,139	2,083	.....	....
12cbc1	SW¼NW¼SW¼12	T. E. Finch	Dd	C, w	S	Qt	84	54.8	5-15-57	2,144	2,089	.....	....
14aba1	NE¼NW¼NE¼14	M. Ward	Dd	C, w	S	Qt	77	57.8	5-15-57	2,146	2,089	.....	....
14cbb1	NW¼NW¼SW¼14	F. B. Frost	Dd	N	N	Qt	59	56.6	5-15-57	2,121	2,074	.....	....
14ddd1	SE¼SE¼SE¼14	US Geol. Survey	Dd	N	T,O	Qt	110	59.2	5-13-57	2,132	2,072	2,030	L
15ccc1	SW¼SW¼SW¼15	do.	Dd	N	T	Qt	115	58.9	2- 9-57	2,086	2,027	1,978	L
17aaa1	NE¼NE¼NE¼17	do.	Dd	N	T	Qt	110	61.8	2- 9-57	2,061	1,999	1,957	L
18bbb1	NW¼NW¼NW¼18	....	Dd	C, w	S	Qt	49	43.6	10- 6-55	2,031	1,987	.....	....
18ccc1	SW¼SW¼SW¼18	H. Munson	Dd	N	N	Qt	50	42.1	5-17-57	2,026	1,984	.....	....
18ddd1	SE¼SE¼SE¼18	do.	Dd	N	N	Qt	59	54.2	5-17-57	2,050	1,996	.....	....
18ddd2	do.	US Geol. Survey	Dd	N	T	Qt	100	47.0	2- 6-57	2,043	1,996	1,948	L
23bbb1	NW¼NW¼NW¼23	Oil co. test hole	Dd	N	T	.....	2,500	.....	....	2,116	.....	2,017	L
24add1	SE¼SE¼NE¼24	H. Ruttman	Dd	C, w	S	Qt	111	60.1	5-17-57	2,119	2,059	.....	....
25dca1	NE¼SW¼SE¼25	L. B. Triplett	Dd	C, w	N	Qt	135	66.1	5-16-57	2,091	2,025	.....	....
26dad1	SE¼NE¼SE¼26	W. G. Jordan	Dd	C, w	N	Qt	109	72.4	5-16-57	2,099	2,027	.....	....
30bbb1	NW¼NW¼NW¼30	US Geol. Survey	Dd	N	T,O	Qt	60	33.8	5-13-57	2,018	1,984	1,961	L
30bcc1	SW¼SW¼NW¼30	R. E. Rittenhouse	Dd	C, w	S	Qt	58	30.9	5-15-57	2,017	1,986	.....	....
31ccc1	SW¼SW¼SW¼31	E. Baker	Dd	C, w	S	Qt	69	54.2	5-15-57	2,023	1,969	.....	....
33dcc1	SW¼SW¼SE¼33	US Geol. Survey	Dd	N	T,O	Qt	115	48.2	5-13-57	2,036	1,988	1,928	L
35daa1	NE¼NE¼SE¼35	do.	Dd	N	T	Qt	102	50.7	2-13-57	2,069	2,018	1,971	L
36ccc1	SW¼SW¼SW¼36	M. Ruttman	Dd	C, w	S	Qt	93	58.4	5-16-57	.....	.....	.....	....
36abb1	NW¼NW¼NE¼36	US Geol. Survey	Dd	N	T	Qt	120	60.3	2-14-57	2,084	2,024	1,968	L
24N-21W-1aaa1	NE¼NE¼NE¼ 1	US Geol. Survey	Dd	N	T	Qt	75	58.0	2-11-57	2,052	1,994	1,983	L
1ccc1	SW¼SW¼SW¼ 1	I. H. Rutledge	Dd	C, w	S	Qt	37	5.4	5-15-57	2,052	2,046	.....	....
2abb1	NW¼NW¼NE¼ 2	R. C. Densmore	Dd	C, w	O	Pwh	69	33.9	5-13-57	2,094	2,160	......	....
3ccc1	SW¼SW¼SW¼ 3	US Geol. Survey	Dd	N	T	Qt	40	12.7	2- 6-57	2,052	2,039	2,015	L

Well number: For explanation see text, p. 7 ; well locations shown on plate 2.

Type of well: B, bored; D, dug; Dd, drilled; Dn, driven;

Pump and power: C, cylinder; Cf, centrifugal; J, jet, N, none; T, turbine; a, airlift; b, butane, e, electric; g, gasoline, h, hand; p, propane; w, wind.

Use: D, domestic; I, irrigation; Id, industrial; N, none (includes unused or destroyed wells); O, observation; P, public supply; S, stock; T, test hole.

Geologic source: Qal, low-terrace deposits and alluvium; Qt, high-terrace deposits; To, Ogallala Formation; Pwh, Whitehorse Group; Pdc, Dog Creek Shale; Pb, Blaine Gypsum; Pf, Flowerpot Shale.

Other data: C, chemical analysis shown in appendix C; L, well log shown in appendix B.

Well number	Location in section	Owner or tenant	Type of well	Pump and power	Use	Geologic source	Depth of well (feet)	Water level: Depth below land surface	Water level: Date of measurement	Altitude above mean sea level (feet): Land surface	Altitude: Water level surface	Altitude: Permian surface	Other data
24N-21W--Continued													
10ddd1	SE¼SE¼SE¼10	US Geol. Survey	Dd	N	T	Qt	55	22.8	2- 6-57	1,982	1,960	1,932	L
11ccc1	SW¼SW¼SW¼11	H. D. Jividen	Dd	N	N	Qt	33	22.1	5-15-57	1,894	1,962	.....	....
13ddc1	SW¼SE¼SE¼13	....	Dd	C, w	S,O	Qt	78	35.8	4-11-57	2,019	1,983	.....	....
14ddd1	SE¼SE¼SE¼14	US Geol. Survey	Dd	N	T	Qt	55	33.6	2- 6-57	2,006	1,972	1,955	L
18bbb1	NW¼NW¼NW¼18	H. Cooper	Dd	C, w	S	Qt	27	14.0	5- 9-57	1,992	1,977	.....	....
22aca1	NE¼SW¼NE¼21	P. F. Zimmerman	Dd	T, b	I	Qt	35	.....	....	1,970	.....	1,935	L
32baa1	NE¼NE¼NW¼32	P. Ferguson	Dd	C, w	S	.....	.....	.....	....	.....	.....	.....	C
34abb1	NW¼NW¼NE¼34	US Geol. Survey	Dd	N	T	Qt	60	26.3	2-12-57	1,973	1,947	1,916	L
34bba1	NE¼NW¼NW¼34	P. Ferguson	Dd	C, w	S,O	Qt	54	25.2	3-19-57	1,970	1,945	.....	....
34ddc1	SW¼SE¼SE¼34	US Geol. Survey	Dd	N	T,O	Qt	57	25.9	5-13-57	1,981	1,955	1,924	L
35aaa1	NE¼NE¼NE¼35	do.	Dd	N	T	Qt	86	28.3	2-12-57	1,999	1,970	1,918	L
24N-22W-3dcc1	SW¼SW¼SE¼ 3	Western State Hospital	Dd	N	N	Qal	26	8.1	3-21-56	.....	.....	.....	L
4add1	SE¼SE¼NE¼ 4	H. Cooper	Dd	N	N	Qal	37	13.9	5-14-57	1,977	1,963	1,942	....
6abb1	NW¼NW¼NE¼ 6	US Geol. Survey	B	N	T,O	Qal	11	2.3	5-13-57	1,979	1,976	.....	C
8cdd1	SE¼SE¼SW¼ 8	F. W. Devore	Dd	C, w	S	Pwh	97	19.2	5-14-57	2,031	2,012	.....	....
10cab1	NW¼NE¼SW¼10	Western State Hospital	Dd	C, a	P	Qal	90	.....	....	.....	.....	.....	C
10cba1	NE¼NW¼SW¼10	do.	Dd	N	T	Qal	40	16.2	3-21-56	.....	.....	.....	L
10ccc1	SW¼SW¼SW¼10	US Geol. Survey	Dn	N	O	Qal	17	10.9	5-13-57	1,976	1,965	.....	....
10ccd1	SE¼SW¼SW¼10	Western St. Hosp.	Dd	N	T	Qal	46	8.4	3-21-56	.....	.....	.....	L
10ccd2	do.	do.	Dd	T, e	P	Qal	45	8.2	5-14-57	.....	.....	.....	....
12bdd1	SE¼SE¼NW¼12	H. Cooper	Dd	C, w	S	Qt	28	15.7	5- 9-57	1,971	1,956	.....	....
14daa1	NE¼NE¼SE¼14	do.	Dd	C, w	S	Qt	32	27.2	5- 9-57	2,011	1,984	.....	....
15bab1	NW¼NE¼NW¼15	Western St. Hosp.	Dd	T, e	P	Qal	35	10.6	5-14-57	1,971	1,960	.....	....
15bac1	SW¼NE¼NW¼15	do.	Dd	T, e	P	Qal	34	.....	....	1,971	.....	.....	....
15bba1	NE¼NW¼NW¼15	do.	Dd	T, e	P	Qal	44	8.8	5-14-57	1,972	1,963	1,928	....
15bba2	do.	do.	Dd	T, e	P	Qal	36	10.5	5-14-57	1,971	1,961	1,935	....
15bdd1	SE¼SE¼NW¼15	Okla. Dept. Hwys.	Dd	C, h	P	Qt	24	19.1	5-14-57	1,982	1,963	.....	....
20aba1	NE¼NW¼NE¼20	US Army C. of E.	Dd	N	O	Pwh	49	24.4	5-13-57	2,034	2,010	.....	....
22add1	SE¼SE¼NE¼22	....	Dd	C, w	S	Qt	70	23.7	5- 9-57	2,026	2,003	.....	....
23cbb1	NW¼NW¼SW¼23	US Geol. Survey	Dd	N	T	Qt	32	26.7	6- 6-57	2,033	2,006	2,002	L
26caa1	NE¼NE¼SW¼26	W. Vludman	Dd	C, w	S	Qt	25	20.8	5- 9-57	2,069	2,048	.....	....
27bcd1	SE¼SW¼NW¼27	do.	Dd	C, w	S	Qt	21	13.3	5- 8-57	2,076	2,063	.....	....
33add1	SE¼SE¼NE¼33	do.	Dd	C, w	S	Qt	38	6.7	5- 8-57	2,059	2,052	.....	....
25N-17-W-26dcc1	SW¼SW¼SE¼26	L. Russell	Dd	C, w	S	Qal	14	7.6	1- 8-57	.....	.....	.....	....
36caa1	NE¼NE¼SW¼36	School land	Dd	C, w	S	Qal	35	16.4	1- 8-57	.....	.....	.....	....
25N-18W-3bdd1	SE¼SE¼NW¼ 3	Oil co. test hole	Dd	N	T	.....	2,137	.....	....	1,699	.....	.....	L
8ccb1	NW¼SW¼SW¼ 8	do.	Dd	N	T	.....	2,146	.....	....	1,724	.....	....	L
19ddd1	SE¼SE¼SE¼19	do.	Dd	N	T	.....	2,300	.....	....	1,700	.....	.....	L
22aaa1	NE¼NE¼NE¼22	do.	Dd	N	T	.....	2,193	.....	....	1,743	.....	.....	L
32ccd1	SE¼SW¼SW¼32	do.	Dd	N	T	.....	2,200	.....	....	1,831	.....	.....	L
25N-19W-10dcc1	SW¼SW¼SE¼10	Oil co. test hole	Dd	N	T	.....	2,300	.....	....	1,838	.....	.....	L
20baa1	NE¼NE¼NW¼20	S. Selman	Dd	C, w	S	Pwh	114	65.3	9-21-55	.....	.....	.....	....
22daa1	NE¼NE¼SE¼22	C. Lehr	Dd	C, w	S	Pwh	119	74.9	9-22-55	.....	.....	.....	....
28dcd1	SE¼SW¼SE¼28	A. Dutton	D	N	D	Pwh	26	21.4	9-22-55	.....	.....	.....	....
26N-18W-10bcb1	NW¼SW¼NW¼10	E. Blackmon	Dd	C, w	S	Pb	75	63.1	9-16-55	.....	.....	.....	....
21aaa1	NE¼NE¼NE¼21	Oil co. test hole	Dd	N	T	.....	105+	.....	....	1,693	.....	.....	L
22bba1	NE¼NW¼NW¼22	S. Walker	Dd	C, w	S	Pb	39	36.3	9-16-55	.....	.....	.....	....
28bbb1	NW¼NW¼NW¼28	P. Hepner	Dd	C, w	S	Pb	84	45.3	9-15-55	.....	.....	.....	....
30ddd1	SE¼SE¼SE¼30	Zerkle	Dd	N	N	Pb	70	flowing	9-13-55	.....	.....	.....	....
31aad1	SE¼NE¼NE¼31	Oil co. test tole	Dd	N	T	.....	2,199	.....	....	1,764	.....	.....	L
26N-19W-5bbb1	NW¼NW¼NW¼ 5	W. E. Williams	B	C, w	S	Qt	26	16.1	9-16-55	.....	.....	.....	....
16aaa1	NE¼NE¼NE¼ 6	Oil co. test hole	Dd	N	T	.....	2,400	.....	....	1,783	.....	.....	L
24acc1	SW¼SW¼NE¼24	G. Brunham	Dd	C, w	S	Pb	79	53.0	9-20-55	.....	.....	.....	....
31cbb1	NW¼NW¼SW¼31	J.B. Kornale	Dd	C, w	S	Pb	79	53.0	10- 5-55	.....	.....	.....	....
35cdc1	SW¼SE¼SW¼35	L. Devore	Dd	N	N	Pdc	79	76.3	9-21-55	.....	.....	.....	....
36dcc1	SW¼SW¼SE¼36	M. Overton	Dd	C, w	S	Pdc	79	32.1	10- 7-55	.....	.....	.....	....

Logs of wells and test holes in Woodward County, Oklahoma

Altitudes shown are in feet above mean sea level and refer to land surface at the mouth of the well or test hole, and to the concealed surface of the red beds (bedrock) at the well or test-hole site.
Thickness in feet. Depth in feet below land surface.

Description	Thickness	Depth
20N-17W-2ddd2. 60 feet north of irrigation well Sample log of observation well.		
Low-terrace deposits:		
Sand, fine to coarse	5	5
Sand, buff and yellow, fine to medium; thin layer caliche; thin layer gray silty clay	5	10
Sand, buff, very fine to medium; caliche	5	15
Sand, buff, and yellow, medium to coarse; trace of very coarse sand; trace of humus in lower part	10	25
Sand, buff, medium to coarse	5	30
Sand, buff, medium to very coarse; trace of fine gravel	6	36
Red beds (bedrock):	..	..
20N-17W-2ddd3. 100 feet north of irrigation well Sample log of observation well.		
Low-terrace deposits:		
Sand, light-brown, very fine to medium, silty	5	5
Sand, buff and yellow, fine to medium, calcareous	5	10
Sand, buff and yellow, fine to medium; trace of coarse sand	5	15
Sand, buff, fine to coarse; trace of very coarse sand	5	20
Sand, buff and yellow, medium to coarse, thin layer of gray, silty clay	5	25
Sand, buff, medium to very coarse; trace of fine gravel	5	30
(Test hole not drilled to bedrock)		
20N-17W-2ddd4. 175 feet north of irrigation well. Sample log of observation well.		
Low-terrace deposits:		
Sand, buff, fine to coarse; trace of very coarse sand	5	5
Sand, buff, medium to very coarse, trace of fine gravel; thin layer sandy caliche	5	10
Sand, buff, medium to very coarse; trace of fine gravel; gray silty clay in lower part	12	22
(Test hole not drilled to bedrock)		
20N-17W-2ddd5. 100 feet east of irrigation well. Sample log of observation well.		
Low-terrace deposits:		
Sand, buff, fine to coarse, traces of very coarse sand and gray silty clay	5	5
Sand, buff, very fine to coarse; trace of very coarse sand; thin layer of gray silty clay	5	10
Sand, buff, fine to medium; calcareous	5	15
Sand, buff, medium to very coarse; fine gravel	6	21
Clay, gray	1	22
(Test hole not drilled to bedrock)		
20N-17W-7abd1. Log obtained from Emil Grade, driller. Altitudes: land surface, 1,746; bedrock, 1,676.		
Low-terrace deposits:		
Soil	5	5
Sand, fine	20	25
Sand, coarse; and gravel	45	70
Red beds (bedrock):	..	..
20N-17W-10bbb1. 56 feet southwest of a fence corner near the SW cor. sec. 3. Sample log of water-test hole and observation well. Altitudes: land surface, 1,723; bedrock, 1,667.		
Low-terrace deposits:		
Sand, buff, fine to coarse	5	5
Sand, buff, medium to very coarse	5	10
Sand, buff, fine to very coarse	10	20
Sand, buff, medium to very coarse, trace of fine gravel	10	30
Sand, buff, medium to very coarse; fine gravel	10	40
Sand, buff, medium to coarse	5	45
20N-17W-10bbb1.--Continued		
Sand, buff, medium to very coarse; trace of fine gravel	5	50
Sand, buff, medium to very coarse; fine to medium gravel	6	56
Red beds (bedrock):	..	..
20N-17W-12ccc1. 16 feet south and 94 feet east of fence corner at the SW cor. sec. 12. Sample log of water-test hole. Altitudes: land surface, 1,706; bedrock, 1,673.		
Low-terrace deposits:		
Sand, gray, very fine to fine, silty	5	5
Sand, buff, fine to coarse, trace of very coarse sand	10	15
Sand, buff, medium to coarse	5	20
Sand, buff, medium to very coarse; trace of fine gravel	5	25
Sand, buff, coarse to very coarse; fine to medium gravel	8	33
Red beds (bedrock):	..	..
20N-20W-22bbb1. 26 feet south and 77 feet east of fence corner at NW cor. sec. 22. Sample log of water-test hole. Altitudes: land surface, 2,163; bedrock, 2,062.		
Ogallala Formation:		
Sand, buff, very fine to medium; trace of caliche	10	10
Clay, buff, silty to sandy	4	14
Sand, buff, very fine to medium; trace of coarse sand; caliche	11	25
Sand, buff, medium to very coarse; trace of fine gravel; thin streak of buff, sandy clay	10	35
Sand, buff, fine to coarse	10	45
Sand, buff, fine to medium; some coarse sand; caliche; thin layer of buff, silty to sandy clay in lower part	10	55
Sand, buff, fine to medium; trace of coarse sand; gray and buff silty clay	5	60
Sand, buff, very fine to medium; thin layer of caliche; thin layer of buff silty clay	5	65
Caliche, sandy	5	70
Sand, buff, fine to medium; sandy caliche	5	75
Sand, buff, medium to very coarse; thin layer of hard caliche	5	80
Sand, buff, medium to very coarse; traces of fine gravel and caliche	5	85
Sand, buff, medium to very coarse; thin layer of gray silty clay; trace of caliche	5	90
Sand, buff, medium to very coarse; trace of fine gravel and caliche	4	94
Caliche, hard	1	95
Caliche, hard; sandy caliche in layers	4	99
Sand, buff, medium to coarse; trace of fine gravel	1	100
Caliche, hard	1	101
Red beds (bedrock):	..	...
20N-21W-22dcc1. 17 feet south and 40 feet east of fence corner. Sample log of test hole. Altitudes: land surface, 2,291; bedrock, 2,095.		
Ogallala Formation:		
Sand, buff, very fine to fine; reddish-brown, silty clay	10	10
Sand, buff, fine to medium; thin layers of reddish-brown and gray silty clay	5	15
Sand, light-buff, very fine to medium, clean, trace of caliche	10	25
Sand, light-buff, fine to medium; trace of coarse sand; caliche	14	39
Sand, buff, very fine to medium; orange silty clay; caliche	11	50
Sand, buff, very fine to medium, orange silty clay	10	60
Sand, buff, very fine to medium, silty loosely cemented with caliche	5	65
Sand, buff, very fine to fine, silty, slightly cemented with caliche; thin layers of hard caliche	10	75
Sand, buff, very fine, silty; buff silty clay; thin layer of hard caliche	5	80

Description	Thick-ness	Depth
20N-21W-22dcc1.--Continued		
Sand, buff, very fine to fine, slightly silty; thin layer of gray silty clay; thin layer of hard caliche	5	85
Sand, buff, very fine, very silty	15	100
Sand, buff, very fine to medium, silty, loosely to well cemented with caliche	10	110
Sand, buff, very fine to medium, silty, loosely to well cemented with caliche; thin layer of hard caliche	5	115
Sand, buff, fine to medium, silty, with thin layers of loosely cemented caliche	5	120
Sand, buff, very fine to medium, trace of coarse sand, orange silty clay	5	125
Sand, buff, very fine to medium, silty	5	130
Sand, buff, very fine to medium, silty loosely to well cemented with caliche; thin layer of hard caliche	5	135
Sand, buff, very fine to medium	5	140
Sand, buff, very fine to medium, clean; thin layers of gray and orange clay	5	145
Sand, buff, fine to medium, clean	10	155
Sand, buff, fine to medium; thin layers of gray and grayish-maroon clay	10	165
Sand, buff, medium to very coarse; trace of clean fine gravel	5	170
Sand, light-buff, fine to medium, clean	5	175
Sand, light-buff, fine to coarse	5	180
Sand, light-buff, medium	5	185
Sand, light-buff, fine to coarse	5	190
Sand, buff, fine to coarse; thin layer of orange, silty clay; hard caliche	5	195
Sand, buff, fine to very coarse; thin layer of red silty clay; illmenite grains	1	196
Red beds (bedrock):	..	...
20N-21W-36add1. 76 feet north and 46 feet west of fence corner, sec. 31, T. 20 N., R. 20 W., 17 feet east of north-south fence on west side of road. Sample log of test hole. Altitudes: land surface, 2,311; bedrock, 2,153.		
Ogallala Formation:		
Sand, buff, very fine to medium, red silty clay	10	10
Sand, buff, fine to medium; thin layer light-reddish-gray, silty clay	10	20
Sand, buff, very fine to medium; light-red silty to sandy clay	10	30
Sand, buff, fine to very coarse; trace of fine gravel	10	40
Sand, buff, fine to very coarse; caliche particles	6	46
Clay, light-red, silty to sandy, alternating with buff, fine to coarse sand; fine to medium gravel	12	58
Sand, buff, fine to medium, very silty thin layer cemented; trace of fine to medium gravel	2	60
Sand, buff, very fine to medium; coarse sand; thin layer of buff silty clay	10	70
Sand, buff, very fine to coarse; thin layer of buff, silty to sandy clay; fine gravel	5	75
Sand, buff, very fine to medium, very silty	5	80
Sand, buff, very fine to medium; thin layer of buff, silty to sandy clay	5	85
Sand, buff, fine to medium, trace of coarse sand	5	90
Sand, buff, medium to very coarse; trace of fine gravel; thin layer of hard caliche	5	95
Sand, buff, fine to medium; thin layer of light-red silty clay	5	100
Sand, buff, very fine to coarse	10	110
Sand, buff, fine to coarse	10	120
Sand, buff, very fine to medium; thin layer of buff, silty clay	14	134
Clay, gray to light-red, silty to sandy	2	136
Sand, buff, fine to medium; trace of coarse sand; fine gravel	4	140
Sand, buff, fine to medium; thin layers of light-red, silty clay; layer of hard caliche	10	150
Sand, buff, very fine to medium; light-red, silty to sandy clay	8	158
Red beds (bedrock):	..	...

Description	Thick-ness	Depth
20N-22W-6bbb1. 180 feet south and 20 feet east of north-west section corner. Log of oil company test hole. Altitudes: land surface, 2,361; bedrock, 2,001.		
Ogallala Formation:		
Sand, white, fine to coarse, subangular	30	30
Limestone, sandy	10	40
Clay, pink and buff; coarse sand; conglomerate; gravel	50	90
Sand, fine to coarse	240	330
Clay, pink and buff	10	340
Conglomerate	20	360
Whitehorse Group (bedrock):		
Shale, red, sandy; conglomerate; fine orange sand	60	420
Sand, orange, fine red; sandy shale	110	530
Sand, orange, fine, gypsiferrous	30	560
Gypsum, white	10	570
Sand, fine; red sandy shale	20	590
Dog Creek Shale:		
Shale, red sandy; streaks of gypsum; blue and brown shale; trace of dolomite	113	703
Blaine Gypsum:		
Gypsum, white; red shale; selenite; trace of dolomite at base	66	769
Shale, red and gray	4	773
Gypsum, gray and white; underlain by very porous, gray dolomite	32	805
Shale, gray and brown	5	810
Gypsum	20	830
(Lost circulation at 829-830, hole abandoned)		
20N-22W-22ccc1. 48 feet north and 265 feet east of SW fence corner. Sample log of test hole. Altitudes: land surface, 2,292; bedrock, 2,000.		
Ogallala Formation:		
Sand, buff, very fine to medium; brown and gray, silty to sandy clay	10	10
Sand, buff, fine to medium; trace of coarse sand; caliche	10	20
Sand, buff, medium to coarse	5	25
Clay, brownish-gray, silty to sandy	10	35
Sand, buff, medium to very coarse	2	37
Clay, gray, silty	5	42
Sand, buff, fine to very coarse, clean	4	46
Clay, gray, silty	1	47
Sand, buff, coarse to very coarse; fine gravel	3	50
Clay, buff, silty	2	52
Sand, buff, medium to very coarse; trace of fine gravel	3	55
Clay, buff, silty	1	56
Sand, buff, medium to very coarse; trace of fine gravel	14	70
Sand, buff, medium to very coarse; trace of fine gravel; thin layer of buff, silty clay	10	80
Sand, buff, medium to very coarse	9	89
Clay, dark-buff, silty; powdery caliche scattered throughout; thin layers of hard caliche	6	95
Sand, buff, very fine, silty, loosely to well cemented with powdery caliche; thin layers of hard caliche	10	105
Caliche, powdery, sandy, thin layers of hard, slightly sandy caliche; thin layers of buff, partly silty clay	10	115
Caliche, hard	5	120
Sand, buff, very fine to fine, with powdery caliche, loosely cemented; thin layers of hard, pure caliche; thin layers of buff, silty clay	10	130
Sand, buff, very fine to fine with powdery caliche, loosely to well cemented; thin layers of hard pure caliche	20	150
Sand, buff, very fine to fine, with powdery caliche, loosely to well cemented; thin layers of hard pure caliche; thin layers of buff silty clay	20	170
Sand, buff, very fine to fine with powdery caliche, loosely to well cemented; hard, pure to sandy caliche; thin layers of buff, silty clay	15	185
Sand, buff, very fine to coarse, loosely cemented with powdery caliche; fine gravel; thin layers of buff, silty clay; thin layers of hard, pure to sandy caliche	10	195
Sand, buff, very fine to fine; loosely to well cemented with powdery caliche; thin layers of buff, silty clay	10	205

Description	Thick-ness	Depth
20N-22W-22ccc1.--Continued		
Sand, very fine to fine, well cemented with caliche; buff, coarse to very coarse sand; fine gravel; thin layer of brown, silty clay	10	215
Clay, light-red to gray, very silty to sandy	10	225
Clay, reddish-brown, silty to very silty	5	230
Clay, reddish-brown, silty to very silty; thin layers of brown clay; thin layer of hard caliche	5	235
Clay, light-red, very silty	5	240
Clay, light-red, silty to slightly sandy; thin layers of brown clay; thin layers of hard, sandy caliche	15	255
Clay, grayish-brown to light-red, stratified; thin layers of hard pure to sandy caliche	10	265
Clay, grayish-brown to light-red, silty; thin layers of hard, pure caliche; trace of buff, medium to very coarse sand	15	280
Clay, light-red to dark-gray, silty; thin layer of hard, pure caliche; trace of buff, medium to very coarse sand	12	292
Red beds (bedrock):	..	...
20N-22W-31bcc1. 300 feet north and 24 feet west of fence corner. Sample log of test hole. Altitudes: land surface, 2,513; bedrock, 2,113.		
Ogallala Formation:		
Sand, tan, fine to medium; brown silty clay	13	13
Sand, tan, fine to medium; reddish-brown clay; thin layers of gray silty clay in lower part	11	24
Clay, gray, silty to sandy; buff, fine to medium sand	6	30
Sand, buff, medium to very coarse; gray and tan sandy clay; trace of caliche	5	35
Sand, buff, fine to medium; gray and yellow-orange, sandy clay	10	45
Sand, buff, fine to medium; thin layers of gray sandy clay; trace of caliche	5	50
Sand, buff, very fine to medium; buff and gray sandy clay; trace of caliche	10	60
Clay, orange and gray, sandy	10	70
Clay, orange and gray, silty to sandy; buff, fine sand	10	80
Sand, buff, fine to medium; orange and gray, silty to sandy clay; trace of caliche	14	94
Sand, buff, medium; orange to light-red, nodules of sandy clay	6	100
Clay, orange to light-red and gray, sandy; trace of caliche	10	110
Clay, gray to buff, sandy; trace of caliche	5	115
Clay, gray to light-red, sandy; trace of buff; medium to very coarse sand	10	125
Sand, buff, medium to very coarse; thin layer of tan, silty clay; trace of caliche	5	130
Sand, buff, medium to coarse	5	135
Sand, buff, medium to very coarse; trace of fine angular gravel; pieces of graphic granite; trace of caliche	10	145
Sand, buff, very coarse; sand size, angular pieces of graphic granite; trace of fine gravel	5	150
Sand, buff, medium to very coarse; fine to coarse, granitic gravel	10	160
Sand, buff, fine to medium; trace of caliche	5	165
Sand, buff, medium to very coarse; trace of fine gravel in lower part; trace of caliche	10	175
Sand, buff, medium to very coarse; fine gravel; thin layer of gray, silty clay	5	180
Sand, buff, medium to coarse; trace of caliche	10	190
Sand, buff, medium to coarse; trace of illmenite; trace of caliche	5	195
Sand, buff, medium to very coarse; trace of fine gravel; trace of caliche	10	205
Sand, buff, fine to very coarse; trace of fine gravel; trace of caliche	5	210
Sand, buff, very coarse; fine gravel	5	215
Sand, buff, medium to very coarse; fine gravel, thin layer of tan sandy clay; trace of caliche	10	225
Sand, buff, medium to very coarse; fine gravel; thin layer of pure caliche; trace of illmenite	10	235
Sand, buff, medium to very coarse; trace of fine gravel; thin layer of caliche	4	239
Clay, gray and orange, silty to sandy	3	242
20N-22W-31bcc1.--Continued		
Sand, buff, medium to coarse; thin layer of caliche; thin layer of very fine-grained sandstone	8	250
Sand, buff, fine to medium; buff sandy clay; thin layer of caliche; trace of fine gravel	5	255
Clay, gray and orange, very silty to sandy; trace of caliche	5	260
Clay, buff, sandy; thin layers of caliche; thin layer of green, very silty clay	10	275
Sand, buff, medium; buff, green and brown, silty to sandy clay; thin layers of hard, pure caliche	5	280
Sand, buff, medium to coarse; tan, silty clay; soft caliche	10	290
Sand, buff, medium to coarse; trace of fine gravel; soft caliche; gray and buff, sandy clay in lower part	10	300
Sand, buff, medium to very coarse; gray and buff, silty clay, soft caliche; thin layers of hard caliche	5	305
Clay, buff, sandy; trace of caliche; trace of buff coarse sand; thin layer of hard caliche	5	310
Clay, buff, sandy; trace of caliche	5	315
Clay, buff, sandy; soft caliche; trace of buff, coarse to very coarse sand	10	325
Clay, buff to orange, sandy; buff, coarse to very coarse sand	5	330
Clay, buff, sandy; very coarse sand; thin layers of sandy caliche	5	335
Clay, gray and brown, sandy; thin layers of green, silty clay; trace of buff, very coarse sand; hard caliche	5	340
Clay, buff, very sandy, trace of caliche	5	345
Clay, buff, very sandy; thin layers of hard caliche; thin layers of brown silty clay; trace of buff, medium to coarse sand	10	355
Clay, buff, very sandy; thin layers of hard caliche; thin layers of brown, silty clay; trace of buff, coarse to very coarse sand	10	365
Clay, buff, very sandy; buff, fine to coarse sand; hard caliche	5	370
Clay, gray, brown and green, very silty, somewhat stratified; thin layer of soft, sandy caliche; trace of fine gravel in lower part	10	380
Clay, buff, very sandy, calcareous; trace of fine gravel; thin layers of green and brown, very silty clay	10	390
Clay, buff, very sandy, calcareous; trace of fine gravel; thin layers of green and brown, very silty clay	8	398
Sand, buff, medium to very coarse; fine gravel	2	400
Red beds (bedrock):	..	...
20N-22W-36add1. 119 feet north and 1 foot east of fence corner. Sample log of test hole and observation well. Altitudes: land surface, 2,374; bedrock, 1,997.		
Ogallala Formation:		
Sand, buff, fine to medium; light-red, silty clay	5	5
Sand, buff, medium; buff, silty clay; light-red, sandy clay	5	10
Sand, buff, fine to medium; light-red, sandy clay; particles of blue silty clay, silty caliche	5	15
Sand, buff, very fine to medium	10	25
Sand, buff, very fine to medium; light-red, sandy clay; trace of caliche	5	30
Sand, buff, fine to medium, red sandy clay; trace of caliche	5	35
Sand, buff, very fine to medium; trace of caliche	10	45
Sand, medium to coarse; trace of caliche	10	55
Sand, buff, fine to medium; trace of coarse sand; caliche	10	65
Sand, buff, fine to medium; trace of coarse sand; caliche particles scattered throughout	10	75
Sand, buff, very fine to medium; trace of coarse sand; orange, very sandy clay; caliche	10	85
Sand, buff, medium to coarse; gray silty clay; caliche	5	90
Sand, buff, very fine to medium; caliche	5	95
Sand, buff, medium to very coarse; trace of fine to medium gravel	7	102
Sand, buff, fine to medium; caliche particles throughout	3	105
Sand, buff, medium to coarse; caliche particles	6	111

Description	Thick-ness	Depth
20N-22W-36add1.--Continued		
Sand, buff, medium to very coarse; buff; very sandy caliche	9	120
Sand, very fine to medium; trace of very coarse sand; buff, sandy clay; caliche particles	10	130
Clay, buff to light-orange, sandy; thin layers of hard pure caliche; fine gravel in lower part	10	140
Sand, buff, medium; buff, sandy clay; silty to sandy caliche; thin layer of hard, pure caliche in lower part	10	150
Caliche; buff, medium sand	5	155
Caliche; buff, medium to coarse sand; trace of fine gravel; thin layers of hard caliche	10	165
Sand, buff, medium to very coarse; silty caliche	10	175
Sand, buff, medium; caliche, clayey; thin layers of hard caliche	10	185
Sand, medium to very coarse; thin layers of pure caliche; thin layers of orange, silty clay	10	195
Clay, gray, sandy, mixed with caliche; silty brown clay; thin layers of hard caliche; trace of fine gravel	5	200
Sand, buff, fine; caliche, silty; thin layers of hard caliche	5	205
Sand, buff, fine, some coarse sand; thin layers of hard, pure caliche; thin layer orange, sandy clay; fine gravel	10	215
Clay, orange sandy	5	220
Clay, orange, sandy; silty, brown clay; thin layers of hard pure caliche; trace of fine gravel; trace of reworked red-bed material	10	230
Clay, orange, sandy, mixed with caliche; trace of reworked red-bed material; trace of fine gravel	10	240
Clay, orange, sandy; fine to very coarse sand; small grayish-brown clay balls; layer of hard, pure caliche in lower part	10	250
Clay, orange, sandy; fine to very coarse sand; thin layers of caliche; clay with caliche in lower part	10	260
Clay, orange and gray, sandy; thin layers of pure caliche	5	265
Gravel, fine; trace of reworked red-bed material	5	270
Sand, buff, fine to coarse; orange sandy clay; thin layer of hard caliche	15	285
Sand, buff, fine to coarse, trace of very coarse sand; orange sandy clay; nodules of reworked red-bed material; thin layer of hard caliche in lower part	10	295
Clay, light-red, silty to sandy; buff fine to medium sand	10	305
Clay, light-red, silty; very fine to medium sand; thin layers of hard caliche	10	315
Clay, light-red, silty; trace of very fine to medium sand; thin layers of hard caliche	10	325
Clay, light-red, silty; trace of buff fine sand	10	335
Clay, light-red, silty; trace of buff fine to medium sand	10	345
Clay, light-red, few rusty zones, silty; trace of medium sand; thin layers of caliche	10	355
Clay, light-red, silty and sandy; trace of medium sand; thin layers of caliche	10	365
Clay, light-red, silty and sandy; thin layer of caliche in lower part; medium to coarse sand at base	12	377
Red beds (bedrock):	..	...

21N-17W-9ccc1. 15 feet north and 132 feet east of SW fence corner. Sample log of test hole. Altitudes: land surface, 1,894; bedrock, 1,846.

Description	Thick-ness	Depth
High-terrace deposits:		
Clay, light-red, very silty to sandy	5	5
Clay, light-red, very silty to sandy; buff, very fine to medium silty sand	5	10
Sand, buff, fine to medium; trace of coarse sand; thin layers of silty clay	10	20
Sand, buff, very fine to medium	10	30
Sand, buff, very fine to medium, trace of coarse sand	10	40
21N-17W-9ccc1.--Continued		
Sand, buff, fine to coarse, trace of very coarse sand	5	45
Sand, buff, medium to very coarse; fine gravel	3	48
Red beds (bedrock):	..	..

21N-17W-13aaa1. 225 feet south and 24 feet west of northeast fence corner. Sample log of test hole. Altitudes: land surface, 1,871; bedrock, 1,842.

Description	Thick-ness	Depth
High-terrace deposits:		
Sand, buff, fine to medium; trace of coarse sand	5	5
Sand, buff, very fine to medium	10	15
Sand, buff, medium	10	25
Sand, buff, medium to very coarse	5	30
Red beds (bedrock):	..	..

20N-17W-13ccc1. 25 feet south and 45 feet west of southwest fence corner. Sample log of test hole. Altitudes: land surface, 1,874; bedrock, 1,826.

Description	Thick-ness	Depth
High-terrace deposits:		
Sand, buff, fine to medium	10	10
Sand, buff, fine to medium, slightly clayey	5	15
Sand, buff, trace of yellow and red, very fine to medium, slightly clayey	5	20
Sand, buff, trace of yellow, fine to medium	10	30
Sand, buff and yellow, very fine to fine	5	35
Sand, buff, trace of yellow and pink, fine to very coarse	10	45
Sand, buff, coarse to very coarse; trace of fine gravel	3	48
Red beds (bedrock):	..	..

20N-17W-19bac1. Driller's log supplied by Ellis Caldwell. Altitudes: land surface, 1,762; bedrock, 1,709.

Description	Thick-ness	Depth
Low-terrace deposits:		
Sand	5	5
Clay	10	15
Sand, medium	38	53
Red beds (bedrock):	..	..

21N-17W-27aaa1. 43 feet south and 16 feet east of NE fence corner. Sample log of test hole. Altitudes: land surface, 1,823; bedrock, 1,774.

Description	Thick-ness	Depth
High-terrace deposits:		
Sand, buff, fine to medium	5	5
Sand, buff, medium to coarse	10	15
Sand, buff, medium to coarse; trace of very coarse sand	5	20
Sand, buff, very fine to medium; trace of coarse sand; gray, sandy clay	5	25
Sand, buff, medium to very coarse	5	30
Sand, buff, fine to medium; trace of coarse sand	10	40
Sand, buff, medium to coarse; trace of very coarse sand	5	45
Sand, buff, medium to very coarse; fine gravel	4	49
Red beds (bedrock):	..	..

21N-17W-27ccc1. 10 feet south and 7 feet east of southwest fence corner. Sample log of test hole. Altitudes: land surface, 1,758; bedrock, 1,710.

Description	Thick-ness	Depth
High-terrace deposits:		
Sand, buff, very fine to medium; thin layers of dark-gray silty clay	5	5
Sand, buff, very fine to medium, very silty; buff, silty clay	5	10
Sand, buff, fine to medium; trace of coarse sand	5	15
Sand, buff, medium to very coarse; trace of fine gravel	5	20
Sand, buff, medium to coarse; trace of very coarse sand	10	30
Sand, buff, medium to very coarse; fine gravel	10	40
Sand, buff, medium to very coarse	8	48
Red beds (bedrock):		
Sand, red, very fine	2	50

Description	Thickness	Depth
21N-17W-29ccc1. 15 feet south and 102 feet east of fence post on west end of east-west fence line. Sample log of test hole. Altitudes: land surface, 1,740; bedrock, 1,704.		
Low-terrace deposits:		
Sand, buff, very fine to medium; thin layer of gray, silty clay	5	5
Sand, buff, fine to medium	5	10
Sand, buff, fine to coarse; trace of very coarse sand	5	15
Sand, buff, medium to very coarse; fine to medium gravel; trace of humus	10	25
Sand, buff, fine to coarse	5	30
Sand, buff, medium to very coarse	5	35
Sand, buff, coarse to very coarse; fine gravel	1	36
Red beds (bedrock):	..	..
21N-17W-33ccc1. 61 feet south and 40 feet west of telephone pole; 0.95 mile south of northwest fence corner. Sample log of test hole. Altitudes: land surface, 1,741; bedrock, 1,685.		
Low-terrace deposits:		
Sand, buff, very fine to fine, silty	5	5
Sand, buff, fine to medium; trace of coarse sand	10	15
Sand, buff, very fine to medium	10	25
Sand, buff, medium to coarse	10	35
Sand, buff, medium to very coarse; trace of fine gravel	5	40
Sand, buff, medium	5	45
Sand, buff, medium to coarse	5	50
Sand, buff, medium to very coarse	5	55
Sand, buff, coarse to very coarse; fine to medium gravel	1	56
Red beds (bedrock).	..	..
21N-17W-36cdd1. 17 feet south and 40 feet west of power pole. Sample log of test hole. Altitudes: land surface, 1,763; bedrock, 1,702.		
Low-terrace deposits:		
Sand, buff, very fine to medium	15	15
Sand, buff, fine to medium	5	20
Sand, buff, fine to coarse; trace of gray and buff, sandy clay	5	25
Clay, buff, silty to sandy	10	35
Sand, buff, fine to coarse	5	40
Sand, buff, yellow and black, medium to coarse; trace of very coarse sand	10	50
Sand, buff, medium to very coarse; trace of fine gravel	5	55
Sand, buff, coarse to very coarse; fine gravel	6	61
Red beds (bedrock):	..	..
21N-18W-6add1. 118 feet north and 94 feet east of fence corner; 32 feet northeast of cottonwood tree. Sample log of test hole. Altitudes: land surface, 1,784; bedrock, 1,736.		
Low-terrace deposits:		
Sand, buff, fine to coarse, clean	10	10
Sand, buff, fine to coarse, trace of very coarse sand; thin layer of dark-gray, silty clay	10	20
Sand, buff, fine to medium; thin layers of dark-gray, silty clay	5	25
Sand, buff, medium to very coarse; trace of fine gravel	10	35
Sand, buff, medium to very coarse; fine to medium gravel	13	48
Red beds (bedrock):	..	..
21N-18W-10abb1. 4 feet north and 41 feet east of fence corner. Sample log of test hole. Altitudes: land surface, 1,821; bedrock, 1,770.		
High-terrace deposits:		
Sand, buff, very fine to coarse	5	5
Clay, buff, silty to sandy	15	20
Sand, buff, very fine to medium	5	25
Sand, buff, fine to medium; trace of coarse sand; thin layers of gray, silty clay	10	35
Sand, buff, and yellow, medium to very coarse; fine gravel	10	45
Sand, buff, medium to very coarse	6	51
Red beds (bedrock):	..	..

Description	Thickness	Depth
21N-18W-21bbb1. 5 feet south and 450 feet east of northwest fence corner. Sample log of test hole and observation well. Altitudes: land surface, 1,796; bedrock, 1,717.		
Low-terrace deposits:		
Sand, buff, fine to medium; trace of coarse to very coarse sand; clayey	5	5
Sand, buff, medium to coarse	8	13
Sand, buff, silty to sandy	3	16
Sand, buff, medium to very coarse; trace of fine gravel	4	20
Sand, buff, very fine to medium, slightly silty	5	25
Sand, buff, medium to very coarse; trace of fine gravel	10	35
Sand, buff, medium to very coarse; trace of black, silty clay; trace of fine gravel	5	40
Sand, buff, fine to medium	5	45
Sand, buff, coarse to very coarse; trace of fine gravel; thin layer of dark-gray silty clay in lower part	10	55
Sand, buff, medium to very coarse; trace of fine gravel	10	65
Sand, buff, medium to very coarse	5	70
Sand, buff, coarse to very coarse; fine to		
Sand, buff, coarse to very coarse; fine to medium gravel	10	80
Red beds (bedrock):		
Sand, red, very fine	2	82
21N-18W-22ddd1. 39 feet west and 10 feet south of southeast fence corner. Sample log of test hole. Altitudes: land surface, 1,774; bedrock, 1,741.		
Low-terrace deposits:		
Sand, brown, very fine to medium	5	5
Sand, buff, fine to medium	5	10
Sand, buff, fine, thin layer of reddish-brown, silty clay	5	15
Sand, buff, fine to medium; thin layer of reddish-brown silty clay	3	18
Clay, dark-gray, silty	2	20
Clay, gray, sandy	5	25
Clay, light-gray, silty; buff, fine sand	5	30
Sand, brown, very fine to medium	3	33
Red beds (bedrock):	..	..
21N-18W-28add1. 150 feet north and 22 feet east of fence corner. Sample log of test hole. Altitudes: land surface, 1,804, bedrock, 1,739.		
Low-terrace deposits:		
Sand, reddish-brown, very fine	5	5
Sand, buff, fine to medium	7	12
Clay, buff, silty	1	13
Sand, buff, very fine to fine	2	15
Sand, buff, fine to coarse; trace of fine gravel	5	20
Sand, buff, fine to coarse; thin layer of red, silty clay	5	25
Sand, buff, very fine to coarse	5	30
Sand, buff, very fine to medium	5	35
Sand, buff, very fine to fine; buff silty clay	5	40
Sand, fine to coarse	15	65
Red beds (bedrock):	...	...
21N-19W-11aca1. Driller's log supplied by Emil Grade.		
Low-terrace deposits:		
Soil	3	3
Clay	21	24
Sand, fine	6	30
Sand, coarse	18	48
Red beds (bedrock):		
21N-19W-11ccb1. Driller's log supplied by Emil Grade. Altitudes: land surface, 1,812; Bedrock, 1,756.		
Low-terrace deposits:		
Soil	4	4
Clay	16	20
Sand, fine	5	25
Clay	11	36
Sand, coarse	20	56
Red beds (bedrock):	..	..

21N-19W-12dddl. 17 feet south and 18 feet west of southeast fence corner. Sample log of test hole. Altitudes: land surface, 1,800; bedrock, 1,748.

Description	Thickness	Depth
Low-terrace deposits:		
Sand, buff, very fine to medium	4	4
Clay, gray	1	5
Sand, buff, fine to medium; gray clay	8	13
Clay, gray	2	15
Sand, buff, very fine to medium, very silty; thin layers of gray silty clay; trace of caliche	4	19
Clay, gray and light-brown	11	30
Clay, gray and light-blue, silty	9	39
Sand, buff, coarse to very coarse; fine gravel	1	40
Gravel, fine	12	52
Red beds (bedrock):		
Sand, red, very fine	3	55

21N-19W-15adcl. Partial driller's log supplied by an oil company. Altitude: land surface, 1,820.

Description	Thickness	Depth
Whitehorse Group, undifferentiated (bedrock):		
Red rock	45	45
Sand	15	60
Shale	20	80
Sand	60	140
Dog Creek Shale:		
Red rock	60	200
Shale, brown	10	210
Blaine Gypsum:		
Gypsum	70	280
Flowerpot Shale and older rocks, undifferentiated:		
Sand, broken	5	285
Red rock	25	310
Shale, sandy	85	715
Sand	18	733
Shale, red	7	740
Sand	8	748
Shale, red	5	753
Salt	150	903
Sand	4	907
Salt	46	953
Sand	50	1,003
Salt	57	1,060
Shale, red	10	1,070
Salt	10	1,080
Shale, sandy	55	1,135
Sand, red	15	1,150
Salt	18	1,168
Shale, sandy	12	1,180
Sand	10	1,190
Salt	78	1,268
Red rock	37	1,305
Shale	180	1,485

21N-19W-25addl. 341 feet north and 9 feet east of fence corner. Sample log of test hole. Altitudes: land surface, 1,847; bedrock, 1,810.

Description	Thickness	Depth
Low-terrace deposits:		
Sand, buff, very fine to medium	8	8
Clay, gray to reddish-brown, silty to sandy	7	15
Sand, buff, fine to medium; trace of coarse to very coarse sand; orange, silty clay	5	20
Sand, buff, very fine to medium	5	25
Sand, buff, medium to coarse	10	35
Sand, buff, medium to very coarse; fine gravel	2	37
Red beds (bedrock):	..	..

21N-19W-30dacl. Driller's log supplied by Ellis Caldwell. Altitudes: land surface; 1,944; bedrock, 1,854.

Description	Thickness	Depth
Low-terrace deposits:		
Soil, sandy	5	5
Clay	5	10
Caliche, sandy	5	15
Sand, medium	25	40
Gravel	25	65
Clay	5	70
Sand, fine	15	85
Gravel and sand	5	90
Red beds (bedrock):	..	..

21N-20W-3bbb1. 54 feet south and 13 feet west of northwest fence corner. Sample log of test hole. Altitudes: land surface, 2,060; bedrock, 1,867.

Description	Thickness	Depth
Ogallala Formation:		
Sand, buff, fine to medium	10	10
Sand, buff, very fine to fine	10	20

21N-20W-3bbb1.--Continued

Description	Thickness	Depth
Sand, buff, fine to medium; trace of caliche	10	30
Sand, buff, very fine to fine, silty; thin layer of gray sandy clay in lower part	10	40
Sand, buff, fine to medium; thin layers of soft sandy caliche	5	45
Sand, buff, fine to medium, loosely cemented with caliche	15	60
Sand, buff, fine to medium, caliche particles throughout	5	65
Sand, buff, fine to medium, loosely cemented with caliche	15	80
Clay, brown, silty to sandy	5	85
Sand, buff, fine, cemented with caliche	10	95
Clay, brown, silty; thin layers of hard caliche; buff fine sand, loosely cemented with caliche	10	105
Sand, buff, fine, loosely cemented with caliche; thin layers of hard caliche	35	140
Sand, buff, fine to medium; caliche particles throughout; thin layers of hard caliche	10	150
Sand, buff, fine to medium, loosely cemented with caliche; thin layers of hard caliche	20	170
Clay, gray, silty to sandy; thin layers of hard caliche	15	185
Sand, buff, medium to very coarse; trace of fine gravel	1	186
Clay, purplish-gray, silty; alternating with hard caliche	6	192
Gravel, fine to medium	1	193
Red beds (bedrock):	..	..

20N-20W-20aaa1. 600 feet south and 32 feet east of northeast fence corner. Sample log of test hole. Altitudes: land surface, 2,126; bedrock, 2,010.

Description	Thickness	Depth
Ogallala Formation:		
Sand, buff, fine to coarse	14	14
Clay, tan, silty	1	15
Sand, buff, medium to very coarse; thin layer of hard sandy caliche	5	20
Sand, buff, fine to coarse; buff, very silty clay; thin layer of caliche	5	25
Sand, buff, fine to medium, loosely cemented with caliche; thin layers of hard caliche	25	50
Sand, buff, fine to medium, silty	4	54
Caliche, hard	1	55
Sand, buff, medium to very coarse; trace of fine gravel; orange and gray silty to sandy clay	5	60
Sand, buff, medium to very coarse; thin layer of light-orange, silty to sandy clay	10	70
Sand, buff, medium to very coarse; trace of fine gravel	5	75
Gravel, fine to medium; reworked red-bed particles	5	80
Caliche, hard	1	81
Clay, gray and tan, silty	7	88
Caliche, hard	1	89
Sand, buff, fine to coarse; thin layers of gray silty clay	11	100
Sand, buff, medium to very coarse; fine gravel	5	105
Gravel, fine to medium; ironstone fragments	11	116
Red beds (bedrock):	..	...

20N-20W-31cccl. 6 feet south and 40 feet east of southwest fence corner. Sample log of test hole. Altitudes: land surface, 2,186; bedrock, 2,076.

Description	Thickness	Depth
Ogallala Formation:		
Sand, gray, very fine to medium, silty	5	5
Sand, buff, fine to coarse, trace of very coarse sand; orange, silty clay	5	10
Clay, light-red to orange, silty to very sandy; thin calcareous zones	10	20
Sand, buff, very fine to coarse; thin layer of orange clay; silty in lower part	10	30
Clay, orange, very silty to sandy; trace of caliche	10	40
Caliche, pure; buff, very fine silty clay; loosely cemented with caliche	10	50
Sand, buff, very fine, loosely cemented with caliche	10	60
Sand, buff, fine to coarse; thin zones of loosely cemented with caliche; thin layer of pure caliche	5	65

Description	Thick-ness	Depth
21N-20W-31ccc1.--Continued		
Sand, buff, fine to coarse, loosely cemented with caliche; thin layers of pure caliche	10	75
Sand, buff, fine to coarse, trace of very coarse sand; thin layers of pure to sandy caliche	10	85
Sand, buff, fine to coarse; thin layers of pure to sandy caliche	5	90
Sand, buff, medium to very coarse; trace of fine gravel; thin layer of caliche	5	95
Gravel, fine; yellowish-tan and gray, silty, calcareous clay	5	100
Caliche, pure, very hard to soft	5	105
Clay, light-red, silty calcareous, mixed with caliche	5	110
Whitehorse Group, undifferentiated (bedrock):		
Siltstone, light-red, soft, slightly sandy; thin calcareous zones	10	120
Siltstone, light-red, soft, slightly sandy; thin gypsum streaks	10	130
Siltstone, red, soft	10	140
Siltstone, red, soft to hard; thin streaks of white, sugary gypsum	10	150
Siltstone, red, soft; thin streaks of white, sugary gypsum	5	155
Siltstone, red, hard, slightly sandy; thin gypsum streaks	10	165
Siltstone, red, hard, slightly sandy; thin layers of sugary gypsum	10	175
Siltstone, red, soft, slightly gyppy	5	180
Siltstone, red, hard, gyppy; thin layers of white and red, sugary gypsum	5	185
Siltstone, red, soft to hard, slightly sandy; thin streaks of white, sugary gypsum	10	195
Siltstone, red, soft	5	200
Siltstone, red, hard, gyppy, slightly sandy	10	210
Siltstone, red, soft, gyppy	5	215
Siltstone, red, slightly sandy	7	222
Siltstone, red, soft	10	232
Siltstone, red, soft to hard, slightly sandy	8	240
Siltstone, red, soft to hard, slightly gyppy	10	250
Siltstone, red, soft, slightly clayey, gyppy; trace of dark-red siltstone	10	260
Siltstone, red, soft, slightly gyppy	10	270
Siltstone, red, soft to hard, slightly sandy	10	280
Dolomite, hard to sugary	2	282
Siltstone, red, hard, slightly sandy; thin streaks of sugary gypsum	8	290
Siltstone, red, hard	10	300
Siltstone, red, soft to hard	10	310
Siltstone, red, soft to hard, thin calcareous streaks	9	319
Dolomite, white, hard thin bedded	3	322
Siltstone, red, hard	16	338
Siltstone, red, hard, sandy	2	340
Siltstone, red, hard; streaks of very sandy siltstone	10	350
Siltstone, red, soft to hard, slightly sandy	10	360
Siltstone, red, soft, slightly sandy; thin streaks of gypsum	10	370
Siltstone, red, hard, slightly sandy; thin streaks of gypsum	12	382
Siltstone, red, hard, sandy, mixed with white, chalky gypsum	11	393
Siltstone, red, hard, slightly sandy; thin layers of very sandy siltstone	7	400
Siltstone, red, hard; trace of selenite	10	410
Siltstone, red, hard; trace of selenite	10	420
Siltstone, red, soft, slightly sandy	10	430
Siltstone, red, hard, slightly sandy, slightly gyppy	10	440
Siltstone, red, soft to hard, slightly to moderately sandy	10	450
Siltstone, red, hard, slightly sandy	10	460
Siltstone, red, hard, slightly sandy; thin zones of very sandy siltstone	10	470
Dog Creek Shale:		
Siltstone, red, sandy, mixed with white, chalky gypsum; trace of dark-red siltstone; streaks of blue-green clay; trace of selenite in lower part	10	480
Siltstone, dark-red, mixed with white chalky gypsum; streaks of blue-green clay; thin streaks of selenite	20	500

Description	Thick-ness	Depth
21N-21W-3add1. Partial driller's log supplied by an oil company. Altitudes: land surface, 2,167; bedrock, 1,995.		
Ogallala Formation:		
Sand, fine, silty	35	35
Sand	15	50
Sand, quick	122	172
Whitehorse Group, undifferentiated (bedrock):		
Clay, red; shale	150	322
Sand, red, soft	20	342
Dog Creek Shale:		
Clay, red; sand	118	460
Blaine Gypsum:		
Gypsum	13	473
Clay, red; sand	18	491
Gypsum	2	493
Clay, red; shale	2	495
Gypsum	34	529
Clay, red; shale	9	538
Gypsum	27	565
Clay, red-bro[illegible]	6	571
Gypsum	24	595
Flowerpot Shale:		
Shale, blue	75	670
Shale, brown	100	770
21N-21W-16cdb4. 400 feet east of irrigation well. Sample log of observation well. Altitudes: land surface, 2,186; bedrock, 2,041.		
Ogallala Formation:		
Sand, buff, very fine to medium; silty	5	5
Sand, buff, very fine to fine, very silty; very silty and very sandy caliche	5	10
Sand, buff, fine to medium, very silty; pinkish-gray, clayey to silty and sandy; calcareous clay	5	15
Sand, buff, very fine to medium	10	25
Sand, buff, fine to medium; trace of pure to silty caliche	5	30
Sand, light-brown, fine to medium, trace of coarse sand; brownish-maroon silty clay	5	35
Sand, light-brown, fine to coarse, trace of very coarse sand; thin layer of brownish-maroon, silty clay	5	40
Sand, buff, very fine to medium	5	45
Sand, buff, medium to very coarse; dark-gray silty clay; trace of hard, pure caliche	10	55
Sand, buff, fine to very coarse	5	60
Clay, light to dark-gray, silty to sandy; buff, very fine to coarse sand; thin layers pure,sandy caliche	5	65
Clay, gray and pink, silty to sandy, calcareous	5	70
Sand, buff, very fine to coarse; gray and pink, silty to sandy, calcareous clay	5	75
Clay, orange and gray, silty and sandy, calcareous	5	80
Sand, buff, very fine to medium; pure to sandy caliche	10	90
Caliche, pure to silty and sandy; buff, very fine to medium sand	10	100
Sand, buff, very fine to medium, very silty; silty and sandy caliche	15	115
Sand, buff, fine to very coarse; thin layer of pure to sandy caliche	10	125
Sand, buff, medium to very coarse; fine gravel	5	130
Sand, buff, fine to coarse; thin layers of hard pure caliche	5	135
Sand, buff, medium to very coarse; thin layer of pure hard caliche in lower part; thin layer of pink to gray, silty, slightly calcareous clay	10	145
Red beds (bedrock):	..	...
21N-21W-16cdb5. 500 feet south of irrigation well. Sample log of observation well. Altitude: land surface, 2,194.		
Ogallala Formation:		
Sand, brown, very fine to coarse	5	5
Sand, buff, very fine to medium, silty; silty to sandy caliche	5	10
Sand, buff, fine to medium	5	15
Sand, buff, fine to coarse, trace of very coarse sand	5	20
Sand, buff, very fine to coarse, silty; thin layer of pure to silty and sandy caliche	5	25
Caliche, pink, silty and sandy	5	30

Description	Thick-ness	Depth
21N-21W-16cdb5.--Continued		
Sand, buff, fine to medium; thin layer of pure caliche	5	35
Sand, buff, fine to coarse; thin layers of pure to silty caliche	5	40
Sand, buff, fine to medium; thin layer of pink clay in lower part	10	50
(Test hole not drilled to bedrock)		
21N-21W-31dcc1. 44 feet north and 50 feet east of northwest fence corner, sec. 6, T. 20 N., R. 21 W.; 25 feet south of east-west fence on north side of road. Sample log of test hole. Altitudes; land surface, 2,301; bedrock, 2,010.		
Ogallala Formation:		
Sand, buff, fine; clay, dark-gray, silty	10	10
Sand, buff, fine; thin layer of orange silty clay	5	15
Sand, buff, fine to medium, clean	10	25
Sand, buff, fine to medium; trace of coarse sand; trace of pink, silty clay	10	35
Sand, buff, fine to coarse; trace of very coarse sand; fine gravel	5	40
Sand, buff, very fine to fine; trace of gray silty clay	5	45
Sand, buff, very fine to fine; thin layers slightly cemented with caliche	5	55
Clay, brownish-gray, silty to sandy	7	62
Sand, buff, fine to medium; alternating with pink, silty clay	13	75
Sand, buff, medium to coarse	4	79
Clay, brownish-gray, silty to sandy	1	80
Sand, buff, medium to coarse	7	87
Clay, pinkish-gray, silty	3	90
Sand, buff, medium to coarse; alternating with pink, silty clay	5	95
Sand, buff, medium to very coarse	5	100
Sand, buff, medium to very coarse; thin layer	10	110
Clay, pinkish-gray, silty to sandy, mixed with soft caliche	10	120
Sand, buff, fine to medium, loosely cemented with caliche	10	130
Sand, buff, fine to medium, loosely cemented with caliche; thin stringers of hard caliche	20	150
Sand, buff, fine, loosely to firmly cemented with caliche; thin stringers of hard caliche	30	180
Sand, buff, fine to medium; thin layer of pink, silty clay	15	195
Sand, buff, medium to coarse, slightly silty; trace of caliche	5	200
Sand, buff, medium to very coarse, clean; thin layer of pink, silty clay	5	205
Sand, buff, very fine to medium, silty; thin layer of dark-gray, silty clay	5	210
Sand, buff, medium to coarse thin layers of soft, sandy and hard caliche	5	215
Sand, buff, medium to coarse; thin layer of pink, silty clay	5	220
Sand, buff, very fine to medium	5	225
Clay, grayish-pink, silty and compact, tough	5	230
Sand, buff, fine to medium; grayish-pink, silty clay	5	235
Sand, buff, fine to coarse	8	243
Sand, buff, medium to very coarse; pink, silty, compact clay	6	249
Caliche, very hard, silica zones	1	250
Sand, buff, medium to very coarse; thin layer of dark-gray, silty clay	10	260
Sand, buff, medium to very coarse; trace of fine gravel	5	265
Sand, buff, very coarse; fine gravel	5	270
Sand, buff, medium to very coarse; trace of fine gravel	10	280
Sand, buff, very coarse; fine gravel	8	288
Caliche, very hard crystalline; green and gray silty clay	3	291
Red beds (bedrock):	..	...
21N-22W-6bbb2. 56 feet south and 5 feet west of NW fence corner. Sample log of test hole. Altitudes: land surface, 2,146; bedrock, 2,046.		
Ogallala Formation:		
Sand, gray, fine to very coarse, black silt	5	5
Clay, dark-gray, thin layer of caliche; buff, fine to medium sand	5	10
Clay, gray, silty	5	15

Description	Thick-ness	Depth
21N-22W-6bbb2.--Continued		
Clay, dark-gray, silty; gray, fine to very coarse sand, trace of fine gravel	5	20
Sand, fine to coarse; trace of very coarse sand; trace of light to dark-gray, silty, slightly calcareous clay; trace of sandy bentonite	5	25
Sand, buff, fine to coarse, clean	5	30
Sand, buff, fine to coarse, trace of very coarse sand; trace of fine gravel	5	35
Sand, buff, medium to very coarse; trace of fine gravel; thin layer of light-gray, slightly calcareous clay	5	40
Sand, buff, fine to medium	5	45
Sand, buff, medium to very coarse; thin layers of light-gray calcareous clay	5	50
Sand, buff, fine to coarse, trace of very coarse sand; trace of light-gray calcareous clay	5	55
Caliche, soft, very silty to very sandy	15	70
Caliche, soft, very silty to very sandy; thin layers of pure caliche; buff, fine to very coarse sand	5	75
Sand, buff, medium to very coarse; trace of fine gravel; thin layer of hard pure caliche thin layer of light-gray silty calcareous clay	5	80
Sand, buff, medium to very coarse	5	85
Caliche, pure, hard to silty, soft, inter-bedded with gray, silty, calcareous clay	6	91
Sand, buff, medium to very coarse; thin layer of light-gray, si ty, calcareous clay	4	95
Sand, buff, medium to very coarse; fine gravel; thin layer of grayish-tan, silty clay	5	100
Whitehorse group, undifferentiated (bedrock):		
Siltstone, red, hard	10	110
Siltstone, red, soft, thin streaks of gray clay; trace of dolomite nodules	10	120
Siltstone, red, soft to hard, thin streaks of gray clay	10	130
Siltstone, red, hard; thin streaks of gray, very calcareous clay; dolomite nodules	10	140
Siltstone, red, hard, slightly sandy, few zones very sandy; trace of frosted, quartz grains; thin streaks of grayish-green, calcareous clay	10	150
Siltstone, red, hard, slightly sandy; thin layer of grayish-green, calcareous clay in upper part	10	160
Siltstone, red, hard, slightly sandy; thin streaks of grayish-green calcareous clay	10	170
Siltstone, red, hard, slightly sandy; thin streaks of grayish-green, calcareous clay	10	180
Siltstone, red, soft to hard	10	190
Siltstone, red, hard, slightly sandy in zones; trace of selenite; thin streaks of grayish-green, calcareous clay	10	200
Siltstone, red, hard, sandy; frosted quartz sand grains; thin streaks of grayish-green, calcareous clay	10	210
Siltstone, red, hard, sandy; thin streaks of grayish-green, calcareous clay	8	218
Dolomite, white, hard to chalky	5	223
Siltstone, red, hard, sandy; thin streaks of grayish-green, calcareous clay; trace of selenite	7	230
Siltstone, red, hard, slightly sandy	10	240
Siltstone, red, hard, slightly sandy; thin streaks of grayish-green, calcareous clay	9	249
Dolomite, white, soft, sandy to pure, hard	1	250
Siltstone, red, soft to hard, slightly sandy; thin streaks of soft white dolomite; thin layer of grayish-green calcareous clay in upper part	10	260
Siltstone, red, soft to hard, slightly sandy, thin streaks of grayish-green calcareous clay; selenite in lower part	10	270
Siltstone, red, hard, sandy in upper part; thin layer of bluish-gray, slightly calcar-eous clay; thin streaks of selenite	10	280
Siltstone, red, hard, slightly sandy; thin streaks of grayish-green calcareous clay; thin streaks of selenite	10	290
Siltstone, red, hard, slightly sandy; thin streaks of grayish-green calcareous clay	10	300
Siltstone, red, hard, slightly sandy; thin streaks of gray calcareous clay; selenite	10	310
Siltstone, red, hard, sandy; thin streaks of gray, calcareous clay	5	315

Description	Thick-ness	Depth
21N-22W-6bbb2.--Continued		
Dolomite, white, hard	1	316
Siltstone, red, hard, very sandy; thin streaks of soft dolomite	1	317
Dolomite, white, hard	1	318
Siltstone red, hard, slightly sandy	2	320
Siltstone, red, hard; thin streaks of gray calcareous clay; thin layer of dark-red, silty clay; selenite	10	330
Siltstone, red, hard, sandy; thin streaks of gray clay; thin layers of dark-red silty clay	5	335
Siltstone, red, hard, very sandy	5	340
Siltstone, red, hard, slightly to very sandy in zones; thin streaks of grayish-green clay; thin layers of selenite	10	350
Siltstone, red, hard; thin layers of grayish-green and dark-red clay; thin layers of selenite	10	360
Dog Creek Shale:		
Gypsum, white, chalky, interbedded with hard, red, sandy siltstone; thin layer of grayish-green clay; trace of selenite	12	372
Clay, grayish-green	2	374
Clay, dark-red, streaks of white, chalky gypsum	6	380
Clay, dark-red, interbedded with red, sandy siltstone; white sugary gypsum	10	390
Clay, dark-red, thin streaks of grayish-green interbedded with red siltstone, chalky to sugary gypsum; trace of selenite	20	410
Siltstone, dark-red, slightly sandy; thin layers of clay, dark-red clay; thin streaks of gray clay; trace of sugary gypsum	10	420
Siltstone, dark-red, slightly sandy	4	424
Gypsum, white, sugary	1	425
Clay, dark-red, silty; trace of selenite	5	430
Clay, dark-red, silty; thin streaks of gray clay; trace of selenite	9	439
Gypsum, white, sugary	1	440
Clay, dark-red, silty interbedded with siltstone, sandy in places; thin layers of grayish-green clay; thin layers of selenite; thin layers of white, sugary gypsum	10	450
Clay, dark-red, silty; thin streaks of grayish-blue and green clay; white sugary gypsum	5	455

21N-22W-23bbb1. 2 feet north and 131 feet east of northwest fence corner. Sample log of test hole and observation well. Altitudes: land surface, 2,335; bedrock, 2,014.

Description	Thick-ness	Depth
Ogallala Formation:		
Sand, buff, fine to coarse; pink to dark-gray silty clay	5	5
Sand, buff, medium to coarse; tannish-orange, silty clay; caliche	5	10
Sand, buff, medium to coarse; thin layer of purple, silty clay	10	20
Sand, buff, fine to medium; trace of caliche	5	25
Sand, buff, medium to coarse; trace of caliche; purple silty clay in lower part	5	30
Clay, purple and light-gray, silty to sandy; alternating with hard caliche	5	35
Caliche, hard; alternating with clay, purple, silty; buff, medium to coarse sand	15	50
Sand, buff, medium to coarse, silty; thin layers of hard caliche; thin layers of purple clay	10	60
Clay, purple, silty	4	64
Sand, buff, medium to coarse, clean	2	66
Clay, purple, silty	1	67
Sand, buff, medium to very coarse	3	70
Sand, buff, medium to very coarse; thin layers of hard caliche; thin layers of purple silty clay	5	75
Clay, purple and gray, silty	15	90
Sand, buff, medium to coarse	2	92
Clay, purple, silty	3	95
Sand, buff, medium to very coarse; purple silty clay	5	100
Sand, buff, fine to medium, silty; thin layers of purple, silty clay; thin layers of hard caliche	12	112
Sand, buff, medium to very coarse, clean; thin layer of brown silty clay	18	130
Sand, buff, fine to coarse; thin layer of light-brown, silty clay; caliche	10	140
Sand, buff, fine to medium; thin layer of gray silty clay; thin layer of hard caliche	20	160
Sand, buff, fine to medium; thin layers of purple and gray, silty clay; thin layers of hard caliche	10	170

Description	Thick-ness	Depth
21N-22W-23bbb1.--Continued		
Sand, buff, fine to medium, silty; purple and gray, silty clay	10	180
Sand, buff, fine to medium; thin layer of maroon, silty clay; layer of hard caliche	10	190
Sand, buff, fine to medium; thin layers of maroon, silty clay	20	210
Sand, buff, fine to medium; thin layer of soft caliche	10	220
Sand, fine to medium; thin layers of maroon, silty clay	10	230
Clay, grayish-maroon, very sandy; thin layers of hard caliche	10	240
Sand, buff, medium to coarse, silty; grayish-maroon, silty clay	10	250
Sand, buff, medium to coarse; pink, sandy clay; thin layer of hard caliche	5	255
Sand, buff, medium to coarse; clean; thin layers of maroon, silty clay	10	265
Sand, buff, fine to medium, clean; thin layers of maroon, silty clay; thin layer of hard caliche in lower part	10	275
Sand, buff, medium to coarse, slightly silty; thin layer of maroon, silty clay	5	280
Sand, buff, medium to very coarse, clean; thin layers of maroon, silty clay in lower part	11	291
Sandstone, light-red, cemented with silica	1	292
Sand, buff, medium to very coarse; fine gravel; thin layer of maroon, silty clay	13	305
Clay, light-orange, very silty; thin layer of hard caliche	5	310
Sand, buff, fine to medium; light-orange, very silty clay; thin layer of hard caliche	5	315
Sand, buff, fine to medium, silty; thin layer of light-orange, very silty clay	4	319
Caliche, very hard, and fine gravel	2	321
Red beds (bedrock):	..	...

21N-22W-31cccl. 9 feet south and 60 feet east of SW fence corner. Sample log of test hole. Altitudes: land surface, 2,377; bedrock, 2,058.

Description	Thick-ness	Depth
Ogallala Formation:		
Sand, pink and gray, loosely cemented with caliche, silty	10	10
Sand, buff, fine to medium, loosely cemented with caliche; thin layers of hard caliche; buff, very coarse sand in lower part	10	20
Sand, buff, fine to medium, loosely cemented with caliche	10	30
Sand, buff, fine to coarse; caliche particles scattered throughout; few cemented zones	10	40
Sand, buff, very fine to fine, loosely cemented with caliche; thin layers of caliche	10	50
Sand, buff, fine to coarse, loosely cemented with caliche; thin layers of hard caliche	5	55
Sand, buff, fine to medium; thin layers of hard caliche	10	65
Sand, buff, fine to coarse, silty; thin layers of hard caliche	10	75
Caliche, hard; tan, silty clay	20	95
Sand, buff, fine to medium; thin layer of hard caliche in lower part	5	100
Sand, buff, medium to very coarse; thin layer of hard caliche at 104 feet	5	105
Sand, buff, medium to very coarse; trace of fine gravel; thin layer of caliche at 109 feet	10	115
Sand, buff, medium to very coarse; fine gravel	10	125
Clay, green and reddish-tan, silty; thin layers of hard caliche	10	135
Sand, buff, fine to coarse	5	140
Sand, buff, fine to very coarse; tan and buff, silty clay	10	150
Sand, buff, medium to coarse	10	160
Sand, buff, fine to very coarse	5	165
Sand, buff, medium to very coarse; trace of fine gravel; thin layer of hard caliche; thin layer of tan, silty clay	5	170
Clay, brown and green, silty; buff, fine to medium sand	5	175
Sand, buff, fine to medium; thin layers of hard caliche	10	185
Clay, tan and gray, silty; trace of medium sand; thin layers of hard caliche	10	195
Sand, buff, fine to medium; thin layer of hard caliche	5	200
Clay, brown, silty; sand, buff, fine; hard caliche	5	205
Sand, buff, fine to medium; hard caliche; brown and gray, silty clay	10	215

Description	Thick-ness	Depth
21N22W-31ccc1.--Continued		
Clay, brown and gray, silty; buff, fine to medium sand, caliche	10	225
Sand, buff, fine; brown and gray, silty clay; thin layer of hard caliche in lower part	10	235
Clay, brown and gray, silty	10	245
Sand, buff, fine to medium; brown and gray, silty clay, thin layer of hard caliche	15	260
Sand, buff, very fine to fine	5	265
Clay, brown and gray, silty; thin layer of soft caliche	10	275
Sand, buff, very fine, silty; brown and gray clay; hard caliche	5	280
Clay, red and gray, silty	5	285
Sand, buff, medium to very coarse; trace of fine gravel; thin streaks of hard caliche	10	295
Sand, buff, coarse to very coarse; fine gravel; thin layer of hard caliche at 304 feet	10	305
Sand, buff, coarse to very coarse; fine gravel; fragments of ironstone	5	310
Caliche, very hard	3	313
Sand, buff, medium to very coarse; fine gravel	4	317
Caliche, very hard	1	318
Sand, buff, very coarse; fine gravel	1	319
Red beds (bedrock):	..	...
22N-18W-14ddd1. 10 feet north and 17 feet east of southeast fence corner. Sample log of test hole. Altitudes: land surface, 1,924; bedrock, 1,844.		
High-terrace deposits:		
Sand, buff, very fine to medium; thin layer of buff, silty clay	15	15
Sand, buff, very fine to medium, very silty; buff and gray, silty clay	15	30
Sand, buff, fine to medium; thin layer of buff sandy clay	20	50
Sand, buff, fine to medium; trace coarse sand	10	60
Sand, buff, medium to coarse, trace of very coarse sand	20	80
Red beds (bedrock):	..	..
22N-18W-15aaa1. 38 feet south and 49 feet west of southeast fence corner, sec. 10, T. 22 N., 18 W. Sample log of test hole. Altitudes: land surface, 1,836; bedrock, 1,784.		
High-terrace deposits:		
Sand, buff, very fine to medium; thin layer of buff silty clay	25	25
Sand, buff, very fine to medium, trace of caliche	10	35
Sand, buff, medium to coarse, fine gravel	17	52
Red beds (bedrock):	..	..
22N-18W-23ccd1. 0.75 mile west of southeast fence corner; 15 feet south and 17 feet east of south post of north-south fence. Sample log of test hole. Altitudes: land surface, 1,842; bedrock, 1,778.		
High-terrace deposits:		
Sand, buff, very fine to fine, brown silt	5	5
Sand, buff, very fine to medium	5	10
Sand, buff, fine to coarse; thin layers of gray, silty clay	5	15
Sand, buff, very fine to medium, trace of coarse sand	10	25
Sand, buff, fine to medium; trace of coarse sand; buff, silty clay in lower part	10	35
Sand, buff, fine to medium, trace of coarse sand	10	45
Sand, buff, fine to medium	10	55
Sand, buff, fine to coarse, trace of very coarse sand	9	64
Red beds (bedrock):	..	..
22N-18W-33ccc1. 2 feet north and 4 feet west of southwest fence corner. Sample log of test hole and observation well. Altitudes: land surface, 1,840; bedrock, 1,780.		
High-terrace deposits:		
Sand, buff, very fine to medium, silty	5	5
Sand, buff, very fine to medium	5	10
Clay, orange and dark-gray, silty to sandy	10	20
Sand, buff, very fine to medium, very silty; thin layer of dark gray, silty to sandy clay	5	25
Sand, buff, fine to medium	10	35
Sand, buff, fine to coarse	10	45
Sand, buff, fine to coarse, trace of very coarse sand	10	55
Sand, buff, medium to very coarse; fine gravel	5	60
Red beds (bedrock):	..	..

Description	Thick-ness	Depth
22N-19W-2ccc1. 8 feet south and 12 feet west of SW fence corner. Sample log of test hole. Altitudes: land surface, 1848; bedrock, 1,821.		
High-terrace deposits:		
Sand, buff, very fine to fine; brown silt; thin calcareous zones	10	10
Sand, buff, fine to very coarse; fine to medium gravel	5	15
Sand, buff, medium to very coarse	5	20
Sand, buff, fine to very coarse	7	27
Red beds (bedrock):		
Sand, red, very fine	3	30
22N-19W-4aaa1. Driller's log supplied by Ellis Caldwell. Altitudes: land surface, 1,848; bedrock, 1,793.		
Low-terrace deposits:		
Sand	10	10
Sand, fine	25	35
Sand, medium	20	55
Red beds (bedrock):	..	..
22N-19W-5bac1. Driller's log supplied by Ellis Caldwell. Altitudes: land surface, 1,833; bedrock, 1,807.		
Alluvium:		
Sand, fine	5	5
Sand, coarse	21	26
Red beds (bedrock):	..	..
22N-19W-9baa1. Driller's log supplied by Ellis Caldwell. Altitudes: land surface, 1,826; bedrock, 1,774.		
Low-terrace deposits:		
Sand, fine	10	10
Sand, medium	10	20
Sand, medium, sharp	20	40
Sand, coarse	5	45
Sand, coarse; gravel	5	50
Gravel, coarse	2	52
Red beds (bedrock):	..	..
22N-19W-11cdd1. 8 feet south and 350 feet west of fence corner. 8 feet south and 15 feet west of east gate. Sample log of test hole. Altitudes: land surface, 1,832; bedrock, 1,785.		
High-terrace deposits:		
Sand, buff, very fine to fine; dark-gray silty clay	5	5
Sand, buff, very fine to medium; trace of coarse sand; calcareous zones; thin layer of gray, silty clay in lower part	10	15
Sand, buff, very fine to fine; dark-gray, silty clay	5	20
Sand, buff, very fine to fine	5	25
Sand, buff, very fine to fine; thin layers of dark-gray, silty clay	10	35
Sand, buff, fine to medium, trace of coarse sand	5	40
Sand, buff, medium to coarse, trace of very coarse sand	5	45
Sand, buff, very coarse	2	47
Red beds (bedrock):		
Sand, red, very fine to fine	3	50
22N-19W-12baa1. 17 feet north and 95 feet west of fence corner. Sample log of test hole. Altitudes: land surface, 1,863; bedrock, 1,788.		
High-terrace deposits:		
Sand, buff, very fine to fine; gray, silty clay	5	5
Sand, buff, fine to medium; orange, silty clay	10	15
Sand, buff, fine to medium, trace of coarse sand	10	25
Sand, buff, very fine to fine; thin layers of buff, silty clay	10	35
Sand, buff, very fine to medium; thin calcareous zones	5	40
Sand, buff, very fine to fine, silty, very calcareous	10	50
Sand, buff, very fine to fine, silty, calcareous	10	60
Sand, buff, coarse to very coarse; fine gravel	10	70
Gravel, fine	5	75
Red beds (bedrock):	..	..

22N-19W-22bdd1. 35 feet north and 26 feet west of fence corner. Sample log of test hole. Altitudes; land surface, 1,824; bedrock, 1,773.

Description	Thickness	Depth
Low-terrace deposits:		
Sand, buff, fine to medium, trace of coarse and	10	10
Clay, dark-gray, silty	2	12
Sand, buff, fine to medium, trace of coarse sand thin layers of dark-gray, silty clay	8	20
Sand, buff, fine to coarse, trace of very coarse sand	5	25
Sand, buff, medium to very coarse; trace of fine gravel	5	30
Sand, buff, fine to coarse, trace of very coarse sand	5	35
Sand, buff, medium to very coarse; fine gravel in lower part	10	45
Sand, buff, coarse to very coarse; fine to medium gravel	6	51
Red beds (bedrock):		
Sand, red, very fine to fine	4	55

22N-19W-25ada1. Driller's log supplied by Ellis Caldwell. Altitudes. land surface, 1,820; bedrock, 1,780.

Description	Thickness	Depth
Low-terrace deposits:		
Sand, fine	10	10
Sand, medium	20	30
Sand, coarse	10	40
Red beds (bedrock):	..	..

22N-19W-28dda1. Driller's log supplied by Ellis Caldwell. Altitudes: land surface, 1,825; bedrock, 1,757.

Description	Thickness	Depth
Low-terrace deposits:		
Clay	30	30
Sand	10	40
Sand, medium	28	68
Red beds (bedrock):	..	..

22N-19W-33aaa1. Driller's log supplied by Ellis Caldwell. Altitudes: land surface, 1,829; bedrock, 1,746.

Description	Thickness	Depth
Low-terrace deposits:		
Sand, red	10	10
Clay	25	35
Sand, fine	5	40
Sand, medium	5	45
Sand, coarse	30	75
Sand, coarse; gravel	8	83
Red beds (bedrock):	..	..

22N-19W-34ddb1. Driller's log supplied by Emil Grade. Altitudes: land surface, 1,828; bedrock, 1,738.

Description	Thickness	Depth
Low-terrace deposits:		
Soil	3	3
Clay	19	23
Clay, sandy	23	45
Sand, coarse; gravel	45	90
Red beds (bedrock):	..	..

22N-19W-35cca1. 75 feet west of irrigation well. Sample log of observation well. Altitudes: land surface, 1,804; bedrock, 1,750.

Description	Thickness	Depth
Low-terrace deposits:		
Silt, dark-brown; very fine gray sand	3	3
Clay, dark-brown, silty and sandy	7	10
Clay, brown, very silty and sandy, thin calcareous zones	5	15
Clay, dark-gray, very silty to sandy; fine to very coarse sand in lower part	10	25
Sand, buff, medium to very coarse	5	30
Sand, buff, fine to very coarse; trace of fine gravel	5	35
Sand, buff, medium to very coarse; fine gravel; ironstone fragments	10	45
Sand, buff, medium to very coarse; fine gravel; ironstone fragments	14	54
Red beds (bedrock):	..	..

22N-19W-35cca2. 150 feet south of irrigation well. Sample log of observation well. Altitude: land surface, 1,804.

Description	Thickness	Depth
Low-terrace deposits:		
Silt, brown; very fine gray sand	3	3
Clay, brown, very silty	7	10
Clay, brown, silty, slightly sandy; thin calcareous zones	10	20

22N-19W-35caa2.--Continued

Description	Thickness	Depth
Sand, buff, fine to coarse; trace of very coarse sand; thin layers of brown, silty to sandy clay in lower part	10	30
Sand, buff, fine to medium, trace of coarse sand	5	35
Sand, buff, medium to very coarse	5	40
(Test hole not drilled to bedrock)		

22N-19W-35cca3. 300 feet west of irrigation well. Sample log of observation well. Altitude: land surface, 1,805.

Description	Thickness	Depth
Low-terrace deposits:		
Silt, dark-brown; very fine gray sand	3	3
Clay, brown, very silty to slightly sandy	7	10
Clay, gray to buff, very silty to sandy	5	15
Clay, gray, very silty to sandy, calcareous	5	20
Sand, buff, fine to very coarse; thin layer of silty gray clay in lower part	10	30
Sand, buff, medium to very coarse; fine gravel	10	40
(Test hole not drilled to bedrock)		

22N-21W-4add1. Drillers log supplied by Vernon Wells.

Description	Thickness	Depth
Ogallala Formation:		
Clay	15	15
Sand, fine	15	30
Clay	10	40
Sand, fine	10	50
Clay	10	60
Sand	5	65
Sand, coarse	5	70
Red beds (bedrock):	..	..

22N-21W-16ddd1. 394 feet north and 50 feet west of the southeast fence corner. Sample log of test hole. Altitudes: land surface, 2,207; bedrock, 2,046.

Description	Thickness	Depth
Ogallala Formation:		
Sand, buff, very fine to fine	13	13
Clay, buff, silty to sandy; trace of buff medium sand in lower part	7	20
Sand, buff, medium to coarse; trace of very coarse sand; caliche	10	30
Sand, buff, medium to coarse; thin layers of gray sandy clay; trace of caliche	5	35
Sand, buff, medium to very coarse; trace of caliche	10	45
Sand, buff, medium to very coarse; trace of fine gravel; thin layers of caliche	15	60
Sand, buff, very fine to coarse; trace of fine gravel; trace of caliche	10	70
Clay, brownish-gray, silty to sandy; thin layers of caliche	10	80
Clay, buff, silty to sandy; thin layers of caliche; trace of medium sand in lower part	14	94
Sand, buff, fine to medium	11	105
Sand, buff, fine to medium; thin layers of purplish-gray, silty to sandy clay	5	110
Sandstone, gray, very fine, cemented with caliche, hard, alternating in thin layers with buff, very sandy clay	5	115
Clay, buff and gray, silty to sandy; trace of caliche; buff fine sand in lower part	35	140
Sand, buff, fine to medium, trace of very coarse sand; thin layer of hard caliche	5	145
Sand, buff, medium to very coarse	5	150
Sand, very coarse; fine gravel, numerous black ironstone fragments; thin layer of hard caliche at 152 feet; thin layer of hard very fine-grained sandstone	12	162
Red beds (bedrock):	..	...

22N-22W-21cbc1. Driller's log supplied by Ellis Caldwell. Altitudes: land surface, 2,155; bedrock, 2,095.

Description	Thickness	Depth
Ogallala Formation:		
Clay, sandy	10	10
Sand, coarse	20	30
Clay	5	35
Sand, fine	5	40
Sand, coarse	15	55
Sand, coarse; gravel	5	60
Red beds (bedrock):	..	..

22N-22W-22bbb1. 60 feet south and 18 feet west of northwest corner. Sample log of test hole. Altitudes: land surface, 2,202; bedrock, 1,982.

Description	Thickness	Depth
Ogallala Formation:		
Sand, buff, fine to medium; trace of caliche	10	10
Sand, buff, fine to medium, trace of coarse sand; caliche	10	20
Sand, buff, very fine to fine; thin layer of gray and pink, silty clay in upper part; thin layer of hard caliche in lower part	5	25
Sand, buff, very fine to medium; thin layers of sandy caliche; thin layer of pink, silty clay in lower part	10	35
Sand, buff, fine to medium; caliche particles throughout	10	45
Sand, buff, medium to coarse	5	50
Sand, buff, medium to very coarse, trace of fine gravel	5	55
Caliche, hard, compact, alternating with sandy caliche	5	60
Sand, buff, very fine to medium; coarse sand in lower part; caliche particles throughout	10	70
Sand, buff, fine	5	75
Sand, buff, medium to very coarse; thin layer of gray silty clay in upper part	6	81
Caliche, hard	1	82
Sand, buff, medium to coarse	3	85
Sand, buff, very fine to medium; caliche nodules throughout	9	94
Caliche, hard, alternating with buff, very fine to fine sand	6	100
Sand, buff, fine to medium; thin layer of gray, silty clay	9	109
Caliche, hard	1	110
Sand, buff, fine to medium	7	117
Clay, gray, silty	3	120
Sand, buff, medium to coarse	13	133
Caliche, hard, alternating with buff, fine to medium sand	7	140
Sand, buff, fine to medium; trace of coarse sand	10	150
Sand, buff, medium to very coarse; thin layer of gray silty clay	5	155
Sand, buff, fine to very coarse; thin layers of hard caliche	5	160
Clay, gray, silty; buff, fine to medium sand	7	167
Caliche, hard, sandy	9	176
Clay, light-brown, very silty to sandy	6	182
Caliche, hard	1	183
Clay, light-brown; thin layers of hard caliche; buff, medium to coarse sand in lower part	12	195
Clay, light-brown, silty; buff, fine to medium sand	5	200
Clay, light-brown, silty to sandy, thin layers of hard caliche	5	205
Sand, buff, fine to medium, well cemented	1	206
Clay, brown, silty to sandy; trace of coarse sand	4	210
Sand, buff, fine to medium, well cemented; thin layers of gray, silty clay; trace of fine gravel	8	218
Clay, gray, hard	2	220
Red beds (bedrock):	..	...

22N-22W-31ccc1. 16 feet south and 36 feet east of southwest fence corner. Sample log of test hole. Altitudes: land surface, 2,146; bedrock, 2,072.

Description	Thickness	Depth
Ogallala Formation:		
Sand, buff, fine to coarse, mixed with soft caliche	5	5
Clay, gray, silty, very calcareous; soft, silty to sand caliche	5	10
Clay, dark-gray, silty; thin layer of hard caliche	5	15
Sand, buff, fine to very coarse; trace of fine gravel; thin layer of gray and orange, silty clay	5	20
Sand, buff, fine to coarse	10	30
Sand, buff, fine to very coarse; trace of fine gravel; thin layer of soft, pure caliche	5	35
Sand, buff, fine to coarse; thin layers of yellowish-tan and light-gray clay	10	45
Sand, buff, fine to coarse; trace of very coarse sand; thin layer of light and dark gray, silty clay	5	50
Sand, buff, fine to coarse, very silty; silty to sandy caliche	10	60

22N-22W-31ccc1.--Continued

Description	Thickness	Depth
Caliche, pure to silty	5	65
Caliche, pure, hard to soft, silty and sandy	5	70
Clay, gray, hard, pure caliche	4	74
Red beds (bedrock):	..	..

22N-22W-36aaa1. 13 feet north and 27 feet west of northeast fence corner. Sample log of test hole. Altitudes: land surface, 2,327; bedrock, 1,977.

Description	Thickness	Depth
Ogallala Formation:		
Sand, buff, very fine to medium; trace of caliche	10	10
Sand, buff, medium to very coarse; trace of caliche	4	14
Clay, brown and gray, silty to sandy	6	20
Sand, buff, fine to medium; trace of caliche; pink and gray, silty clay	15	35
Sand, buff, silty to fine; trace of caliche	5	40
Sand, buff, very fine to fine; trace of caliche; thin layer of pink, silty clay	5	45
Sand, buff, fine to medium; trace of caliche	3	48
Clay, pink, silty	2	50
Sand, buff, fine to coarse; thin layers of sandy caliche; thin layer of pink, silty clay	10	60
Clay, pink and gray, sandy; trace of caliche	5	65
Sand, buff, medium; trace of caliche, thin layer of pink, very silty clay	5	70
Caliche, sandy	5	75
Sand, buff, fine to medium; sandy caliche	5	80
Sand, buff, fine to coarse; trace of caliche	5	85
Sand, buff, medium to very coarse; hard caliche; pink, silty clay	5	90
Sand, buff, medium to very coarse; trace of fine gravel; fine particles of caliche throughout; illmenite particles in lower part	10	100
Sand, buff, medium to very coarse, trace of fine gravel; fine particles of caliche throughout; thin layer of pink, silty caly in lower part	10	110
Clay, pink, silty to sandy	3	113
Sand, buff, medium to very coarse; fine gravel; thin layer of hard caliche	2	115
Sand, buff, medium to very coarse; trace of caliche; trace of pink silty clay	10	125
Sand, buff, medium to very coarse; caliche; trace of pink, silty clay	10	135
Sand, buff, very fine to medium; caliche; pink, silty clay	14	149
Caliche, soft to hard	4	153
Sand, buff, very fine to medium; caliche; pink, silty clay	2	155
Caliche, sandy, hard layer in lower part	5	160
Sand, buff, very fine to medium; caliche	10	170
Sand, buff, fine to medium; sandy caliche	25	195
Sand, buff, fine to coarse, very coarse sand in lower part; thin layers of pink and gray silty clay	9	204
Caliche, hard compact	2	206
Sand, buff, very fine to medium; caliche; thin layer of gray silty clay	9	215
Sand, buff, very fine to medium, silty	5	220
Sand, buff, very fine to very coarse, silty; caliche; thin layer of gray silty shale in lower part	5	225
Sand, buff, very fine, silty; caliche	5	230
Sand, buff, medium to very coarse; thin layers of caliche; thin layers of pink and gray, silty clay	5	235
Caliche, very silty to sandy	5	240
Caliche, very silty to sandy, trace of very coarse sand; thin layers of pink, silty clay in lower part	10	250
Sand, buff, medium to coarse; silty to sandy caliche	5	255
Caliche, silty to sandy; trace of buff, medium to coarse sand	10	265
Caliche, silty to sandy; trace of buff, medium to coarse sand; hard caliche	5	270
Clay, tan and gray, silty	10	280
Sand, buff, fine to medium, trace of coarse sand; hard caliche	5	285
Sand, buff, very fine to medium silty; caliche; thin layer of gray, silty clay	5	290
Sand, buff, medium to very coarse, clean; thin layers of gray and tan silty clay	5	295
Sand, buff, medium to very coarse	4	299
Caliche, hard	1	300
Sand, buff, very fine to coarse; thin layers of tan and gray, silty clay	10	310

Description	Thick-ness	Depth
22N-22W-36aaa1.--Continued		
Sand, buff, medium to very coarse; thin layer of gray, silty clay	5	315
Sand, buff, fine to coarse; thin layers of ligh-gray, silty clay	10	325
Sand, buff, coarse to very coarse; fine gravel; thin layers of gray, silty clay	10	335
Caliche, hard	2	337
Clay, light-gray and tan, silty	1	338
Caliche, hard	2	340
Sand, buff, fine to medium; trace of coarse sand; thin layer of gray, silty clay	3	343
Caliche, hard	1	344
Sand, coarse to very coarse; fine gravel	5	349
Caliche, very hard, slightly crystalline	1	350
Red beds (bedrock):	..	...
23N-18W-7ccc1. 135 feet north and 23 feet west of SW fence corner. Sample log of test hole. Altitudes: land surface, 1,993; bedrock, 1,912.		
High-terrace deposits:		
Sand, buff, very fine to medium	10	10
Sand, buff, fine to medium; thin layer of buff, silty to sandy clay	10	20
Sand, buff, fine to medium; thin layer of orange, silty to sandy clay	10	30
Sand, buff, fine to medium; trace of coarse sand	10	40
Sand, buff, fine to medium	10	50
Sand, buff, very fine to fine	5	55
Sand, buff, fine to medium; trace of coarse	5	60
Sand, buff, fine to medium; thin layers of gray, silty clay	10	70
Sand, buff, fine to medium, trace of coarse sand	5	75
Sand, buff, medium to very coarse; thin layer of gray, silty clay	5	80
Sand, buff, coarse to very coarse; fine gravel	1	81
Red beds (bedrock):	..	..
23N-18W-20ccc1. 10 feet south of east-west fence on north side of road and 455 feet east of northwest fence corner, sec. 29, T. 23 N., R. 18 W. Sample log of test hole. Altitudes: land surface, 1,940; bedrock, 1,905.		
High-terrace deposits:		
Sand, buff, very fine to fine, very silty	2	2
Clay, dark-gray to brown, silty	3	5
Clay, gray, silty and sandy	5	10
Sand, buff, fine to medium; thin layers of gray silty clay	5	15
Sand, buff, very fine to fine, very silty; pinkish-orange, silty clay	5	20
Sand, buff, fine to medium	5	25
Sand, buff, medium to coarse; thin layers of gray silty clay	5	30
Sand, buff, medium to very coarse; fine gravel in lower part	5	35
Red beds (bedrock):	..	..
23N-18W-30ddc1. Driller's log supplied by Ellis Caldwell. Altitudes: land surface, 1,918; bedrock, 1,814.		
High-terrace deposits:		
Clay	20	20
Sand	10	30
Clay	5	35
Sand	5	40
Clay	5	45
Sand	5	50
Clay	10	60
Sand	5	65
Clay	10	75
Sand, medium to coarse	29	104
Red beds (bedrock):	..	..
23N-18W-30ddc2. 130 feet west of irrigation well. Sample log of observation well. Altitudes: land surface, 1,917; bedrock, 1,817.		
High-terrace deposits:		
Sand, buff and light-red, very fine to medium; trace of coarse sand; slightly clayey	5	5
Sand, buff, very fine to medium, trace of coarse sand; gray, silty to sandy clay; caliche	5	10
Sand, buff and yellow, very fine to medium; trace of coarse to very coarse sand	5	15
Sand, buff, fine to coarse	5	20
Sand, buff, fine to medium	5	25
Sand, gray to orange, fine, silty	15	40
23N-18W-30ddc2.--Continued		
Sand, buff, fine to medium, trace of coarse sand	10	50
Sand, buff, fine to medium, trace of coarse sand	12	62
Clay, gray and buff, silty to sandy; thin layers of sandy caliche	8	70
Clay, gray and orange, silty to sandy; thin layers of sandy caliche	5	75
Clay, reddish-brown, silty, slightly sandy	5	80
Clay, gray to buff, silty to sandy, very calcareous	5	85
Sand, buff, medium to very coarse; trace of fine gravel	5	90
Sand, buff, coarse to very coarse; fine gravel	5	95
Sand, buff, coarse to very coarse; fine to coarse gravel	5	100
Red beds (bedrock):	..	...
23N-18W-30ddc3. 200 feet west of irrigation well. Sample log of observation well. Altitude: land surface, 1,916.		
High-terrace deposits:		
Sand, buff, fine to medium, silty	5	5
Sand, buff, fine to medium, silty, clayey	10	15
Sand, buff, fine to medium, trace of coarse sand	11	26
Clay, buff, silty to sandy; thin layers of pure to sandy caliche	9	35
Sand, buff, fine to coarse	10	45
Sand, buff, very fine to medium	15	60
(Test hole not drilled to bedrock)		
23N-18W-30ddc4. 200 feet north of irrigation well. Sample log of observation well. Altitude: land surface, 1,916.		
High-terrace deposits:		
Sand, light-brown, very fine to medium, trace of coarse sand	5	5
Sand, light-brown, very fine to coarse, silty; thin layer of sandy caliche	5	10
Sand, buff, fine to medium; coarse sand	10	20
Sand, buff, fine to medium	6	26
Clay, gray, silty and sandy	9	35
Sand, buff, fine to coarse	5	40
Sand, buff, fine to medium, trace of coarse sand	10	50
Sand, buff, fine to medium	10	60
(Test hole not drilled to bedrock)		
23N-18W-30dcd1. 350 feet west of irrigation well. Sample log of observation well. Altitude: land surface, 1,917.		
High-terrace deposits:		
Sand, light-brown, very fine to coarse, silty	10	10
Sand, buff, fine to medium; thin layers of pure to sandy caliche	15	25
Sand, buff, fine to medium	5	30
Clay, pink, silty to sandy, calcareous; thin layers of sandy caliche	5	35
Sand, buff, fine to coarse	5	40
Sand, buff, fine to medium	20	60
(Test hole not drilled to bedrock)		
23N-18W-31dcc1. 19 feet south and 12 feet east of fence corner. Sample log of test hole. Altitudes: land surface, 1,899; bedrock, 1,816.		
High-terrace deposits:		
Sand, buff, very fine to fine	5	5
Sand, buff, very fine to medium; orange, silty to sandy clay	10	15
Sand, buff, very fine to medium	20	35
Sand, buff, very fine to fine	10	45
Sand, buff, very fine to fine; thin layer of brown, silty clay	8	53
Sand, buff, very fine to fine, silty; pink, silty to sandy clay	11	64
Sand, buff, very fine to fine, trace of medium sand	2	66
Caliche, sandy	1	67
Sand, buff, fine to medium; thin layer of pink, silty clay	3	70
Sand, buff, fine to coarse	5	75
Sand, buff, medium to very coarse; trace of fine gravel	5	80
Sand, buff, coarse to very coarse; fine gravel	3	83
Red beds (bedrock):	..	..

Description	Thick-ness	Depth
23N-18W-33ddd1. 21 feet south and 59 feet west of southeast fence corner. Sample log of test hole. Altitudes: land surface, 1,953; bedrock, 1,896.		
High-terrace deposits:		
Sand, buff, very fine to medium, silty; reddish-orange, silty clay	15	15
Sand, buff, very fine to medium, clean	10	25
Sand, buff, very fine to medium, clean;	10	35
Clay, gray and buff, very silty to very sandy	10	45
Clay, gray, very silty to very sandy	4	49
Sand, buff, very fine to medium	1	50
Sand, buff, medium to very coarse	5	55
Sand, buff, coarse to very coarse; fine gravel	2	57
Red beds (bedrock):	..	..
23N-19W-10bbb1. 11 feet north and 18 feet west of NW fence corner. Sample log of test hole. Altitudes: land surface, 1,983; bedrock, 1,868.		
High-terrace deposits:		
Sand, buff, very fine to medium; thin layer of brown, silty clay	10	10
Sand, buff, very fine to medium; trace of caliche; thin layer of orange, silty clay	10	20
Clay, brown, silty to sandy	5	25
Sand, buff, fine to medium; thin layer of orange, silty to sandy clay	10	35
Sand, buff, fine to medium	5	40
Sand, buff, very fine to fine; trace of caliche	10	50
Sand, buff, fine to medium; thin layer of dark-gray, silty clay	10	60
Sand, buff, very fine to medium, trace of very coarse sand	10	70
Sand, buff, fine to medium, trace of coarse sand	10	80
Sand, buff and yellow, fine to medium; trace of coarse to very coarse sand; ironstone fragments	35	115
(Lost circulation 82-115 feet, sample collected from bit)		
23N-19W-14aac1. Driller's log supplied by Cities Service Gas Co. Altitudes: land surface, 1,939; bedrock, 1,834.		
High-terrace deposits:		
Soil, sandy	13	13
Sand, fine	7	20
Clay, sandy	6	26
Sand, fine	2	28
Sand, clay	12	40
Sand, fine	13	53
Sand, fine; clay streaks	2	55
Clay, sandy	8	63
Sand, fine	30	93
Sand, coarse; trace of gravel	7	100
Sand, gravel	5	105
Red beds (bedrock):	..	..
23N-19W-17cdd1. 59 feet north and 57 feet west of fence corner, sec. 20, T. 23 N., R. 19 W. Sample log of test hole. Altitudes: land surface, 1,915; bedrock, 1,852.		
High-terrace deposits:		
Sand, buff, very fine to medium	10	10
Sand, buff, very fine to medium, trace of coarse sand	10	20
Sand, buff, very fine to fine	5	25
Clay, gray, silty to sandy	1	26
Sand, buff, very fine to medium	9	35
Sand, buff, very fine to medium; thin layer of gray, silty to sandy clay	10	45
Sand, buff, fine to medium; thin layers of gray, silty to sandy calcareous clay	10	55
Sand, buff, fine to medium	8	63
Red beds (bedrock):	..	..
23N-19W-22aac1. Driller's log supplied by Ellis Caldwell. Altitudes: land surface, 1,922; bedrock, 1,844.		
High-terrace deposits:		
Sand, fine	15	15
Clay	15	30
Sand, fine	20	50
Sand, coarse	9	59
Gravel	19	78
Red beds (bedrock):	..	..

Description	Thick-ness	Depth
23N-19W-23adb1. Driller's log supplied by Emil Grade. Altitudes: land surface, 1,921; bedrock, 1,850.		
High-terrace deposits:		
Soil	3	3
Caliche	43	46
Sand, fine	9	55
Sand, coarse	5	60
Clay	4	64
Sand, coarse	7	71
Red beds (bedrock):	..	..
23N-19W-23bca1. Driller's log supplied by Ellis Caldwell. Altitudes: land surface, 1919; bedrock, 1,835.		
High-terrace deposits:		
Clay	15	15
Sand, fine	5	20
Clay	25	45
Sand	5	50
Sand, coarse; clay	20	70
Sand, coarse	10	80
Red beds (bedrock):	..	..
23N-19W-23cbd1. Driller's log supplied by Emil Grade. Altitudes: land surface, 1,908; bedrock, 1,829.		
High-terrace deposits:		
Soil	3	3
Caliche	22	25
Clay, sandy	10	35
Sand, coarse	44	79
Red beds (bedrock):	..	..
23N-19W-25aaa1. 82 feet south and 25 feet west of northwest fence corner, sec. 30, T. 23 N., R. 18 W. Sample log of test hole. Altitudes: land surface, 1,940; bedrock, 1,860.		
High-terrace deposits:		
Sand, buff, very fine to fine, silty	5	5
Sand, buff, very fine to medium; thin layer of orange, silty clay	5	10
Clay, dark-gray, silty	5	15
Sand, buff, very fine to fine, very silty; trace of caliche; thin beds of orange and gray, silty clay	5	20
Sand, buff, very fine to fine, slightly silty; thin layer of orange, silty clay	5	25
Sand, buff, fine to medium; thin layers of orange, silty clay	5	30
Sand, buff, very fine to fine; orange, silty clay	5	35
Sand, buff, fine to medium; thin layers of gray, silty clay	5	40
Sand, buff, fine to medium, clean; trace of caliche; thin layer of orange, silty clay in lower part	10	50
Sand, buff, fine to medium	10	60
Sand, buff, fine to medium; trace of caliche	10	70
Sand, buff, very fine to fine; trace of medium sand	5	75
Sand, buff, fine to coarse; thin layer of silty clay in lower part	5	80
Red beds (bedrock):	..	..
23N-19W-28aca1. Driller's log supplied by Ellis Caldwell. Altitudes: land surface, 1,892; bedrock, 1,837.		
High-terrace deposits:		
Clay	15	15
Sand, medium	20	35
Clay	1	36
Sand, medium	14	50
Clay	1	51
Sand, medium	4	55
Red beds (bedrock):	..	..
23N-19W-28aca2. 150 feet south of irrigation well. Sample log of observation well. Altitude: land surface, 1,890.		
High-terrace deposits:		
Sand, buff, very fine to fine, silty	5	5
Sand, buff, very fine to medium; trace of coarse; caliche nodules	5	10
Sand, buff, very fine to medium; trace of coarse to very coarse sand; caliche	10	20
Sand, buff, fine to coarse; trace of very coarse sand	10	30
Sand, buff, medium to coarse, clean	5	35
Sand, buff, medium to very coarse, clean	5	40
(Test hole not drilled to bedrock)		

Description	Thick-ness	Depth
23N-19W-28aca3. 90 feet west of irrigation well. Sample log of observation well. Altitudes: land surface, 1,892; bedrock, 1,838.		
High-terrace deposits:		
Sand, buff, very fine to fine, silty	3	3
Clay, gray to buff, silty	2	5
Clay, buff, sandy; thin layer of hard, sandy caliche	5	10
Sand, buff, fine to medium, calcareous zones	5	15
Sand, buff, very fine; powdery to hard caliche	5	20
Sand, buff, medium to coarse; caliche particles	5	25
Sand, buff, medium to coarse; trace of very coarse sand	10	35
Sand, buff, medium to very coarse, clean; trace of fine gravel	10	45
Sand, buff, medium to coarse, clean	5	50
Sand, buff, medium to very coarse, clean, fine gravel	4	54
Red beds (bedrock):		
23N-19W-28aca4. 300 feet west of irrigation well. Sample log of observation well. Altitude: land surface, 1,891.		
High-terrace deposits:		
Sand, buff, very fine to fine, silty	2	2
Clay, grayish-brown, very silty to sandy	5	7
Clay, gray-sandy, calcareous zones; thin layer of hard caliche	3	10
Sand, buff, very fine, silty with powdery to hard caliche	15	25
Sand, buff, fine to medium, slightly silty	5	30
Sand, buff, medium to coarse	5	35
Sand, buff, medium to very coarse; trace of fine gravel	5	40
(Test hole not drilled to bedrock)		
23N-19W-28dcb1. Driller's log supplied by Ellis Caldwell. Altitudes: land surface, 1,874; bedrock, 1,831.		
High-terrace deposits:		
Caliche	10	10
Sand, fine	10	20
Sand, medium	4	24
Clay	1	25
Sand, coarse	18	43
Red beds (bedrock):	..	..
23N-19W-35bbd1. Driller's log supplied by Ellis Caldwell. Altitudes: land surface, 1,884; bedrock, 1,823.		
High-terrace deposits:		
Soil	10	10
Caliche	5	15
Sand, coarse	10	25
Sand, gravel	5	30
Sand, coarse	10	40
Sand, gravel	15	55
Sand, coarse	6	61
Red beds (bedrock):	..	..
23N-19W-36aaa1. 68 feet south and 17 feet east of northeast fence corner. Sample log of test hole. Altitudes: land surface, 1,920; bedrock, 1,828.		
High-terrace deposits		
Sand, buff, very fine to medium	9	9
Clay, orange silty to sandy	6	15
Sand, buff, fine to medium, thin layers of orange, silty clay	19	34
Clay, buff, silty to sandy; slightly sandy caliche	6	40
Sand, buff, very fine to medium; trace of coarse sand; thin layers of sandy caliche	10	50
Sand, buff, fine to medium; thin layers of sandy caliche	30	80
Sand, buff, fine to medium; trace of coarse sand	5	85
Sand, buff, medium to coarse, trace of very coarse sand	5	90
Sand, buff, medium to very coarse; fine gravel	2	92
Red beds (bedrock):	..	..

Description	Thick-ness	Depth
23N-20W-2baa1. 14 feet north and 167 feet west of fence corner. Sample log of test hole. Altitudes: land surface, 2,052; bedrock, 1,949.		
High-terrace deposits:		
Sand, light-brown, very fine to medium, very silty	5	5
Clay, light-gray, sandy, bentonitic; dark-gray to brown, silty to sandy clay	5	10
Sand, buff, fine to coarse; thin layer of brown, sandy clay	10	20
Sand, yellow, fine to medium; trace of coarse sand; thin layer of light-gray to buff, bentonitic clay	5	25
Sand, buff, very fine to medium	5	30
Sand, yellow, fine to coarse; thin layer of light-gray, sandy bentonitic clay	5	35
Sand, buff, fine to coarse; trace of very coarse sand	10	45
Sand, yellow, fine to medium; trace of bentonite	5	50
Sand, buff, medium to coarse	10	60
Sand, buff, fine to coarse; trace of bentonite	5	65
Sand, buff, fine to medium, trace of coarse sand; trace of bentonite	10	75
Sand, buff, fine to coarse	5	80
Sand, buff, medium to coarse	5	85
Bentonite, pure to sandy	5	90
Sand, buff, fine to coarse; trace of bentonite	5	95
Sand, buff, medium to very coarse; trace of bentonite; trace of illmenite grains	5	100
Sand, buff, medium to very coarse	3	103
Red beds (bedrock):	...	...
23N-20W-3cdd1. 43 feet north and 21 feet west of fence corner. Sample log of test hole. Altitudes: land surface, 2,017; bedrock, 1,922.		
High-terrace deposits:		
Clay, gray, silty	5	5
Clay, gray, silty to sandy; buff, fine to coarse, silty sand	5	10
Sand, buff, medium to coarse; trace of bentonite	5	15
Sand, buff, very fine to medium; thin layer of buff, silty to sandy clay	10	25
Sand, buff, medium to very coarse	5	30
Sand, buff, medium to coarse; light-gray to buff, sandy, bentonitic clay	5	35
Sand, buff, medium to coarse; trace of very coarse sand; bentonite	10	45
Sand, buff, fine to coarse; thin layers of light-gray, sandy, bentonitic clay	10	55
Sand, buff, fine to medium	10	65
Sand, buff, fine to medium, trace of coarse to very coarse sand; light-gray, sandy, bentonitic clay	5	70
Sand, buff, medium to very coarse	5	75
Sand, buff, medium to very coarse; fine to medium gravel	20	95
Red beds (bedrock):	..	..
23N-20W-3daa1. 152 feet south and 14 feet east of fence corner. Sample log of test hole. Altitudes: land surface, 2,026; bedrock, 1,918.		
High-terrace deposits		
Sand, brown, fine to medium, silty	5	5
Sand, light-brown, very fine to medium	5	10
Sand, buff, fine to coarse	10	20
Sand, buff, fine to medium; trace of coarse sand	10	30
Sand, buff, very fine to medium; trace of bentonite	10	40
Sand, buff, fine to coarse; thin layer of light-gray, bentonitic clay	5	45
Sand, buff, medium to coarse; trace of bentonite	10	55
Sand, buff, fine to coarse; light-gray to buff, sandy, bentonitic clay	5	60
Clay, red, silty to sandy; light-gray, sandy, bentonitic clay	10	70
Sand, buff, fine to coarse; thin layer of light-gray, sandy, bentonitic clay	5	75
Sand, buff, fine to medium, trace of coarse sand; trace of buff, bentonitic clay	10	85
Sand, buff and yellow, fine to coarse; thin layer of light-gray to buff, sandy, bentonitic clay	5	90

Description	Thick-ness	Depth
23N-20W-3daa1.--Continued		
Sand, buff, fine to coarse, trace of very coarse sand; trace of bentonite	5	95
Sand, buff, medium to very coarse; fine gravel	13	108
Red beds (bedrock):	..	...
23N-20W-7aca1. Driller's log supplied by Alexander Engineering Co. Altitudes: land surface, 1,960; bedrock, 1,903.		
High-terrace deposits:		
Sand, fine	32	32
Sand, coarse	18	50
Sand, coarse; gravel	7	57
Red beds (bedrock):	..	..
23N-20W-7dbd1. 50 feet south of public-supply well. Sample log of observation well. Altitudes: land surface, 1,947; bedrock, 1,903.		
High-terrace deposits:		
Sand, buff, fine to medium	5	5
Sand, buff, medium to very coarse	10	15
Sand, buff, fine	5	20
Sand, medium to coarse; trace of very coarse sand	10	30
Sand, fine to very coarse; trace of fine gravel	10	40
Gravel, fine	4	44
Red beds (bedrock):		
23N-20W-7dbd2. 150 feet south of public-supply well. Sample log of observation well. Altitude: land surface, 1,947.		
High-terrace deposits:		
Sand, buff, very fine to medium; trace of coarse sand	10	10
Sand, buff, medium to very coarse	15	25
Sand, buff, medium to very coarse; trace of fine gravel	15	40
(Test hole not drilled to bedrock)		
23N-20W-7dbd3. 100 feet east of public-supply well. Sample log of observation well. Altitude: land surface, 1,948.		
High-terrace deposits:		
Sand, buff, very fine to fine, very silty, trace of caliche	5	5
Sand, buff, fine to very coarse; trace of fine gravel; trace of caliche	5	10
Sand, buff, fine to very coarse; clean	5	15
Sand, buff, fine to medium; trace of coarse sand	10	25
Sand, buff, medium to very coarse; fine gravel	15	40
(Test hole not drilled to bedrock)		
23N-20W-7dbd4. 200 feet east of public-supply well. Sample log of observation well. Altitude: land surface, 1,948.		
High-terrace deposits:		
Sand, buff, very fine to medium; thin layer of gray, silty clay	10	10
Sand, buff, medium to coarse	5	15
Sand, buff, fine to medium; trace of coarse sand	10	25
Sand, buff, fine to coarse; trace of fine gravel	15	40
(Test hole not drilled to bedrock)		
23N-20W-10ccc1. 270 feet north and 20 feet east of southwest corner of section. Partial log of oil company test hole. Altitudes: land surface, 1,978; bedrock, 1,938.		
High-terrace deposits:		
Sand, white, medium to coarse, subrounded	20	20
Sand, coarse	10	30
Sand, white, fine	10	40
Whitehorse Group, undifferentiated (bedrock):		
Sand, orange, very fine; silt	80	120
Sand, orange, fine	60	180
Sand, orange, very fine; contains coarse, rounded, frosted sand grains	20	200
Sand, fine	20	220
Sand, fine, gypsiferous	30	250
Sand, very fine; silt	10	260
Dog Creek Shale:		
Shale, red; silt	10	270
Silt, orange	10	280
Shale, red; gray sand and silt	10	290
Shale, red, brick-red and gray; trace of dolomite	20	310
Silt, orange	10	320

Description	Thick-ness	Depth
23N-20W-10ccc1.--Continued		
Shale, red; orange, very fine sand	48	368
Blaine Gypsum:		
Gypsum, white, soft; selenite; overlain by streak of gray dolomite	12	380
Shale, gray, red, and brown; dark-gray dolomite	10	390
Flowerpot Shale:		
Shale, gray, red and brown; trace of gypsum	20	410
Shale, gray, red, and brown; silt and very fine, white sand	10	420
Shale, gray, red, and brown; gray silt, and gray dolomite	20	440
Shale, red, and gray; trace of gypsum at 460 feet; trace of salt at 530 feet	160	600
Shale, red, and gray; silt	30	630
23N-20W-15cbb1. Driller's log supplied by Alexander Engineering Co. Altitudes: land surface, 1,951; bedrock, 1,890.		
High-terrace deposits:		
Sand, brown, fine	4	4
Clay, white	3	7
Clay, sandy	8	15
Sand, brown fine	37	52
Sand, medium to coarse	3	55
Sand, coarse; gravel	6	61
Red beds (bedrock):	..	..
23N-20W-15dcc1. Driller's log supplied by Alexander Engineering Co. Altitudes: land surface, 1,946; bedrock, 1,882.		
High-terrace deposits:		
Sand, brown, fine; clay	24	24
Clay, sandy	11	35
Sand, fine	8	43
Sand, medium	12	55
Sand, coarse; gravel	9	64
Red beds (bedrock):	..	..
23N-20W-17aaa1. Driller's log supplied by Alexander Engineering Co. Altitudes: land surface, 1,967; bedrock, 1,898.		
High-terrace deposits:		
Sand, fine to medium	30	30
Clay	2	32
Sand, medium	18	50
Sand, coarse	6	56
Clay	1	57
Sand, coarse	12	69
Red beds (bedrock):	..	..
23N-20W-17bba1. Driller's log supplied by Alexander Engineering Co. Altitudes: land surface, 1,957; bedrock, 1,897.		
High-terrace deposits:		
Sand, fine	35	35
Sand, coarse, loose	25	60
Red beds (bedrock):		
23N-20W-17bbb1. Driller's log supplied by Alexander Engineering Co. Altitudes: land surface, 1,955; bedrock; 1,903.		
High-terrace deposits:		
Sand, fine	15	15
Sand, coarse	5	20
Sand, medium	20	40
Clay	2	42
Sand, coarse	8	50
Sand, coarse; gravel	2	52
Red beds (bedrock):	..	..
23N-20W-17bcd1. Driller's log supplied by Alexander Engineering Co. Altitudes: land surface, 1,941; bedrock; 1,899.		
High-terrace deposits:		
Sand, fine	22	22
Sand, coarse	15	37
Gravel; clay	2	39
Gravel	3	42
Red beds (bedrock):	..	..

Description	Thick-ness	Depth
23N-20W-17cda1. Driller's log supplied by Alexander Engineering Co. Altitudes: land surface, 1,936; bedrock, 1,907.		
High-terrace deposits:		
Sand, fine; soil	5	5
Clay	3	8
Sand, fine	7	15
Sand, coarse	14	29
Red beds (bedrock):	..	..
23N-20W-17daa1. Driller's log supplied by Alexander Engineering Co. Altitudes: land surface, 1,953; bedrock, 1,897.		
High-terrace deposits:		
Sand, fine; soil	20	20
Sand, brown, fine	10	30
Sand, brown, coarse	4	34
Sand, white, coarse	10	44
Sand, white, medium	8	52
Sand, brown, coarse	3	55
Gravel	1	56
23N-20W-17ddc1. Driller's log supplied by Alexander Engineering Co. Altitudes: land surface, 1,938; bedrock, 1,900.		
High-terrace deposits:		
Sand, fine	5	5
Clay, white	8	13
Sand, brown, fine	6	19
Sand, medium to coarse	4	23
Clay, red	4	27
Sand, brown, fine	6	33
Sand, coarse; gravel	5	38
Red beds (bedrock):	..	..
23N-20W-18dcc1. Driller's log supplied by Alexander Engineering Co. Altitudes: land surface, 1,878; bedrock, 1,846.		
Low-terrace deposits:		
Sand, yellow, fine	8	8
Sand, medium, clean	10	18
Sand, medium to coarse	7	25
Sand, coarse	7	32
Red beds (bedrock):	..	..
23N-20W-19baa1. Driller's log supplied by Alexander Engineering Co. Altitudes: land surface, 1,878; bedrock, 1,834.		
Low-terrace deposits:		
Sand, tan, fine	12	12
Sand, gray, medium	12	24
Sand, coarse	20	39
Sand, coarse; red mud	5	44
Red beds (bedrock):	..	..
23N-20W-19bdb1. Driller's log supplied by Alexander Engineering Co. Altitudes: land surface, 1,878; bedrock, 1,850.		
Low-terrace deposits:		
Sand, fine, clean	10	10
Sand, medium	15	25
Sand, coarse	3	28
Red beds (bedrock):	..	..
23N-20W-22bbc1. Driller's log supplied by Alexander Engineering Co. Altitudes: land surface, 1,931; bedrock, 1,885.		
High-terrace deposits:		
Sand, brown, fine	28	28
Clay, streaks of sand	13	41
Sand, medium	4	45
Sand, coarse; gravel	1	46
Red beds (bedrock):	..	..
23N-20W-22bbd1. Driller's log supplied by Alexander Engineering Co. Altitudes: land surface, 1,925; bedrock, 1,842.		
High-terrace deposits:		
Sand, brown, fine	24	24
Clay, white	11	35
Sand, brown, fine	4	39
Sand, coarse; gravel	6	45

Description	Thick-ness	Depth
23N-20W-22bbd1.--Continued		
Clay, yellow, sandy	10	55
Sand, medium	27	82
Clay	1	83
Red beds (bedrock):	..	..
23N-20W-22cbb1. Driller's log supplied by Alexander Engineering Co. Altitudes: land surface, 1,924; bedrock, 1,868.		
High-terrace deposits:		
Sand, brown, fine	24	24
Clay	11	35
Sand, medium; clay streaks	9	44
Sand, coarse; gravel	12	56
Red beds (bedrock):	..	..
23N-20W-22dbb1. Driller's log supplied by Alexander Engineering Co. Altitudes: land surface, 1,926; bedrock, 1,862.		
High-terrace deposits:		
Sand, brown, fine	28	28
Clay	12	40
Sand, brown, fine, well-packed	12	52
Sand, medium to coarse	12	64
Red beds (bedrock):	..	..
23N-21W-3cab1. 0.75 mile southwest along trail from gate in northeast corner of section, 10 feet west of center of trail. Sample log of test hole. Altitudes: land surface, 1,959; bedorck, 1,904.		
High-terrace deposits:		
Sand, gray, very fine to medium; trace of coarse sand	5	5
Sand, gray, very fine to coarse; thin layer of gray, silty, bentonitic clay	5	10
Sand, gray, very fine to medium; trace of coarse sand	5	15
Sand, gray, medium to very coarse	10	25
Sand, gray, fine to coarse; silty to slightly sandy, bentonitic caliche; pure bentonite	5	30
Sand, gray, fine to medium	5	35
Sand, gray, fine to very coarse; trace of silty, bentonitic caliche	5	40
Sand, gray, medium to coarse	5	45
Sand, gray, medium to very coarse; fine gravel	10	55
Red beds (bedrock):	..	..
23N-21W-4dcd1. 22 feet southeast of 18-inch elm tree, 29 feet southwest of 24-inch elm tree, 10 feet north of trail. Sample log of test hole. Altitudes: land surface, 1,928; bedrock, 1,907.		
High-terrace deposits:		
Sand, buff, fine to coarse	5	5
Sand, buff, very fine to medium; trace of light-gray, silty clay	10	15
Sand, buff, very fine to medium	6	21
Red beds (bedrock):	..	..
23N-21W-10cab1. 0.12 mile east of clump of trees, 271 feet east of first curve after trail heads east, 10 feet south of center of trail. Sample log of test hole. Altitudes: land surface, 1,937; bedrock, 1,901.		
High-terrace deposits:		
Sand, buff, very fine to coarse	5	5
Sand, buff, fine to very coarse; trace of dark-gray, silty clay	10	15
Sand, buff, fine to coarse	5	20
Sand, buff, and yellow, medium to coarse	10	30
Sand, buff, medium to very coarse; fine gravel	6	36
Red beds (bedrock):	..	..
23N-22W-1bab1. 6 feet northwest and 6 feet northeast of gate corner post; 0.8 mile northwest of section-line road. Sample log of test hole. Altitudes: Land surface, 2,034; bedrock, 1,998.		
High-terrace deposits:		
Sand, buff, fine to very coarse; trace of caliche	5	5
Sand, buff, medium to coarse; trace of very coarse sand; caliche	5	10
Sand, grayish-white, very fine to medium; trace of coarse sand; grayish-white, bentonitic clay	7	17

Description	Thick-ness	Depth
23N-22W-1babl.--Continued		
Sand, grayish-white, medium to very coarse; trace of fine gravel	8	25
Sand, grayish-white, medium to coarse; trace of very coarse sand; trace of fine gravel	5	30
Sand, grayish-white to buff, medium to very coarse; fine gravel	6	36
Red beds (bedrock):	..	..

23N-22W-22dcc1. 192 feet east of S¼ cor. sec. 22, and 38 feet north of center line of east-west section-line road. Driller's log of test hole supplied by Corps of Engineers, U.S. Army. Altitudes: land surface, 2,130; bedrock, 2,059.

Description	Thick-ness	Depth
Ogallala Formation:		
Soil, sandy	8	8
Sand, clayey	4	12
Sand, coarse	8	20
Sand, clayey	11	31
Sand, coarse	3	34
Sand, medium to coarse	5	39
Sand, fine to medium	5	44
Sand, medium to coarse	3	47
Sand, fine	2	49
Sand, fine to medium	5	54
Sand and rock	1	55
Sand, fine to medium	5	60
Sand, fine	5	65
Sand, fine to medium	4	69
Sand, medium to coarse	2	71
Red beds (bedrock):	..	..

23N-22W-22dcd3. 60 feet south of irrigation well. Sample log of observation well. Altitudes: land surface, 2,134; bedrock, 2,039.

Description	Thick-ness	Depth
Ogallala Formation:		
Caliche, silty to sandy; light to dark-gray, silty clay; thin layers of hard caliche	5	5
Caliche, pure to silty and sandy	5	10
Caliche, very silty to very sandy; thin layer of light-gray, silty bentonitic clay	5	15
Clay, light-gray, silty to sandy, bentonitic; thin layer of hard pure caliche	5	20
Caliche, very silty; hard, pure caliche	5	25
Clay, gray to buff, silty, slightly bentonitic	4	29
Sand, buff, fine to coarse	6	35
Sand, buff, medium to very coarse	5	40
Sand, buff, medium to very coarse; fine gravel	11	51
Sand, buff, very fine to fine, alternating with hard, pure caliche	3	54
Sand, buff, fine to coarse; trace of very coarse sand; light-gray silty to sand, bentonitic clay; pure bentonite	6	60
Sand, buff, very fine to coarse; volcanic ash	5	65
Sand, buff, fine to very coarse; pure to silty and sandy caliche; light-gray, silty, bentonitic clay; volcanic ash	5	70
Caliche, very silty and sandy, soft	10	80
Caliche, very silty and sandy; trace of pure, soft caliche	7	87
Sand, buff, medium to very coarse; thin layer of volcanic ash; thin layer of hard, pure caliche	4	91
Caliche, silty to sandy	3	94
Caliche, hard, pure	1	95
Red beds (bedrock):	..	..

23N-22W-22dcd4. 100 feet northwest of irrigation well. Sample log of observation well. Altitude: land surface, 2,132.

Description	Thick-ness	Depth
Ogallala Formation:		
Caliche, silty to sandy; light to dark-gray, silty to sandy clay	5	5
Caliche, pure and silty; gray to light-maroon clay	10	15
Clay, light-gray, silty to sandy, slightly bentonitic; thin layers of hard, pure caliche	5	20
Clay, light-gray, silty to very sandy; trace of hard, pure caliche	5	25
Sand, buff, fine to very coarse; thin layer of light-gray, silty to sandy, slightly bentonitic clay	5	30
Sand, buff, fine to coarse, slightly silty; trace of fine gravel	5	35

Description	Thick-ness	Depth
23N-22W-22dcd4.--Continued		
Sand, buff, very fine to very coarse; thin layer of gray to light-maroon, silty, bentonitic clay; pure caliche	5	40
Sand, buff, medium to coarse; trace of very coarse sand	5	45
Sand, buff, medium to very coarse; trace of fine gravel; hard, pure caliche	7	52
(Test hole not drilled to bedrock)		

23N-22W-22dcd5. 150 feet south of irrigation well. Sample log of observation well. Altitude: land surface, 2,135.

Description	Thick-ness	Depth
Ogallala Formation:		
Sand, buff, fine to coarse; gray, silty clay; hard pure caliche	5	5
Caliche, silty to pure; thin layers of dark-gray, silty and sand clay	5	10
Clay, light-gray, sandy, bentonitic	5	15
Clay, light-gray, silty to sandy, bentonitic; thin layer of hard, pure caliche; buff, fine to coarse sand	5	20
Sand, light-gray to pink, fine to medium, very silty; hard, pure to silty and sandy caliche	5	25
Sand, buff, fine to coarse; thin layers of hard, pure caliche; thin layer of light-gray, calcareous clay	10	35
Sand, buff, fine to medium	5	40
Sand, buff, fine to coarse; trace of very coarse sand; pink, silty, bentonitic clay	5	45
Sand, buff, medium to very coarse; fine gravel	5	50
(Test hole not drilled to bedrock)		

23N-22W-25cbb1. 600 feet east of center line of north-south road and 27 feet south of east-west ½ section-line fence. Driller's log of test hole supplied by Corps of Engineers, U.S. Army. Altitudes: land surface, 2,163; bedrock, 2,080.

Description	Thick-ness	Depth
Ogallala Formation:		
Loam, sandy	3	3
Sand, fine	23	26
Sand, clayey	6	32
Sand, fine	20	52
Sand, fine to medium	4	56
Sand, medium to coarse	11	67
Clay, sandy	10	77
Sand, coarse	5	83
Red beds (bedrock):	..	..

23N-22W-25dda1. 300 feet west and 1,200 north of SE cor. sec. 25. Driller's log of test hole supplied by Corps of Engineers, U.S. Army. Altitudes; land surface, 2,078; bedrock, 2,003.

Description	Thick-ness	Depth
Ogallala Formation:		
Top soil	2	2
Sand, medium to coarse	32	34
Sand, medium to coarse, contains very little yellow clay	6	40
Sand, medium to coarse, clean	25	65
Sand, coarse	10	75
Red beds (bedrock):	..	..

23N-22W-25ddb1. 660 feet west and 1,200 feet north of SE cor. sec. 25. Driller's log of test hole supplied by Corps of Engineers, U.S. Army. Altitudes: land surface, 2,081; bedrock, 2,040.

Description	Thick-ness	Depth
Ogallala Formation:		
Top soil, sandy	2	2
Sand, fine to medium	14	16
Sand, coarse, clean	24	40
Sand, coarse, gravelly	1	41
Red beds (bedrock):	..	..

23N-22W-26bbb1. 91 feet east of center line of north-south road and 10 feet south of center line of east-west road. Driller's log of test hole supplied by Corps of Engineers, U.S. Army. Altitudes: land surface, 2,136; bedrock, 2,064.

Description	Thick-ness	Depth
Ogallala Formation:		
Soil, sandy	5	5
Gravel, clayey	3	8
Clay, sandy	2	10
Clay	10	20
Clay, sandy	5	25
Clay	25	50

Description	Thick-ness	Depth
23N-22W-26bbb1.--Continued		
Sand, clayey	4	54
Sand, fine to medium	5	59
Sand, clayey	2	61
Sand, medium to coarse	11	72
Red beds (bedrock):	..	..

23N-22W-26ddd1. 500 feet west of center line of north-south road and 175 feet north of center line of east west road. Driller's log of test hole supplied by Corps of Engineers, U.S. Army. Altitudes: land surface, 2,166; bedrock, 2,056.

Description	Thick-ness	Depth
Ogallala Formation:		
Loam, sandy	2	2
Soil, sandy	4	6
Sand, fine	12	18
Sand, clayey	3	21
Sand, medium to coarse	2	23
Sand, fine	3	26
Sand, fine to medium	3	29
Sand, clayey	3	32
Sand, fine	4	36
Sand, clayey	4	40
Sand, fine to medium	3	43
Sand, medium to coarse	12	55
Sand, clayey	2	57
Clay, sandy	3	60
Sand, clayey	3	63
Rock, sandy and clayey	1	64
Sand, clayey	7	71
Gravel, clayey	9	80
Sand, clayey	12	92
Sand, fine	8	100
Sand, clayey	2	102
Sand, fine	8	110
Red beds (bedrock):	..	...

23N-22W-29baa1. 87 feet south of east-west fence and 95 feet west of north-south fence. Driller's log of test hole supplied by Corps of Engineers, U.S. Army. Altitudes: land surface, 2,040; bedrock, 2,014.

Description	Thick-ness	Depth
Ogallala Formation:		
Sand, fine to medium	10	10
Sand, medium to coarse	16	26
Red beds (bedrock):	..	..

23N-22W-36adb1. 1,350 feet south and 700 feet west of north-east corner of section. Driller's log of test hole supplied by Corps of Engineers, U.S. Army. Altitudes: land surface, 2,102; bedrock, 2,045.

Description	Thick-ness	Depth
Top soil, sandy	2	2
Clay, yellow, sandy	8	10
Sand, fine, clayey	20	30
Sand, fine to medium, contains very little yellow clay	8	38
Sand, medium to coarse, contains very little yellow clay	19	57
Red beds (bedrock):	..	..

23N-22W-36adc1. 3,000 feet south and 700 feet west of north-east corner of section. Driller's log of test hole supplied by Corps of Engineers, U.S. Army. Altitudes: land surface, 2,113; bedrock, 2,052.

Description	Thick-ness	Depth
Ogallala Formation:		
Top soil	2	2
Sand, fine to medium	12	14
Sand, medium to coarse	6	20
Sand, fine to medium, contains very little clay	14	34
Clay, brown, soft; equal amount of sand	4	38
Sand, medium to coarse, clean	12	50
Sand, medium to coarse; very little clay	11	61
Red beds (bedrock):	..	..

23N-22W-36dcd1. 15 feet north and 1,340 feet west of south-east corner of section. Driller's log of test hole supplied by Corps of Engineers, U.S. Army. Altitudes: land surface, 2,136; bedrock, 2,040.

Description	Thick-ness	Depth
Ogallala Formation:		
Top Soil	2	2
Sand, medium to coarse	30	32
Sand, medium to coarse, contains little yellow clay	28	60
Sand, medium to coarse	5	65
Sand, rock, hard	3	68
Clay, yellow	6	74
23N-22W-36dcd1.--Continued		
Sand, fine, contains yellow clay	16	90
Sand, coarse; gravel	6	96
Red beds (bedrock):	..	..

24N-18W-29dba1. 2,750 feet south and 1,350 feet west of northeast section corner. Partial log of oil company test hole. Altitudes, land surface, 2,079; bedrock, 2,002.

Description	Thick-ness	Depth
High-terrace deposits:		
Sand, white, medium to coarse, buff and pink clay	20	20
Sand, white, fine	10	30
Sand, medium to coarse	10	40
Sand, coarse	10	50
Sand, fine	10	60
Sand, coarse to very coarse	17	77
Whitehorse Group, undiffernetiated (bedrock):		
Dolomite, white and pink	1	78
Sand, orange and gray, very fine	12	90
Silt, orange	10	100
Sand, orange, very fine to fine	20	120
Sand, orange, very fine; contains coarse, rounded, frosted sand grains	10	130
Sand, orange, very fine; contains silt	210	340
Sand, orange, very fine; contains coarse, rounded, frosted sand grains	10	350
Sand, fine, orange, gypsiferous, very fine sand at base	60	410
Dog Creek Shale and Blaine Gypsum, undifferentiated:		
Shale, red; silt	35	445
Shale, red; silt; trace of anhydrite at 455 feet	15	460
Shale, blue-gray	10	470
Flowerpot Shale, and older rocks, undifferentiated:		
Shale, red; silt	15	485
Shale, red and brick-red; some gray shale; trace of gypsum	80	565
Shale, red and brick-red; gray, sandy shale, trace of gypsum	80	645
Shale, red, brick-red, and gray; white and red, very fine, sand; trace of gypsum	105	750
Silt, red	10	760

24N-19W-14bbb1. 100 feet south and 200 feet east of north-west section corner. Partial log of oil company test hole. Altitudes: land surface, 1,887; bedrock, 1,887.

Description	Thick-ness	Depth
Whitehorse Group, undifferentiated (bedrock):		
Sand, orange, fine, angular	30	30
Sand, orange, fine angular, contains coarse, rounded, frosted sand grains	20	50
Sand, orange, very fine to fine	15	65
Sand, orange, medium, angular, gypsiferous; some medium and coarse, rounded, frosted sand grains	10	75
Dog Creek Shale:		
Shale, red; silt; streaks of white very fine very fine sand and gray shale	35	110
Shale, red and brick-red; silty; trace of gypsum	20	130
Blaine Gypsum:		
Gypsum, white, soft; selenite; streaks of red and gray shale; streaks of thin dolomite or dolomitic silt at 180 feet, 202 feet, and at base	98	228
Flowerpot Shale:		
Shale, red, brick-red and gray	15	243

24N-19W-17add1. 6 feet north and 29 feet east of fence corner. Sample log of test hole. Altitudes: land surface, 2,118; bedrock, 2,001.

Description	Thick-ness	Depth
High-terrace deposits:		
Sand, buff, very fine to fine	10	10
Sand, buff, fine to medium	3	13
Clay, buff, silty and sandy	7	20
Sand, buff, fine; buff, very sandy clay	5	25
Sand, buff, fine to medium, clean	10	35
Sand, buff, medium, clean	10	45
Sand, buff, fine to medium; thin layers of light-gray, sandy clay	10	55
Sand, buff, fine to medium; thin layers of light-gray, sandy clay	13	68
Clay, light-gray, sandy	12	80
Sand, buff, fine to medium; trace of coarse sand	10	90

Description	Thickness	Depth
24N-19W-17add1.--Continued		
Sand, buff, medium to coarse; trace of fine gravel; thin layers of light-gray, sandy clay	5	95
Clay, light-gray and red, sandy	10	105
Clay, light-gray, sandy; trace of fine gravel; thin layer of pure caliche	5	110
Clay, light-gray, sandy; buff, fine to coarse sand; medium gravel	7	117
Red beds (bedrock):	..	...
24N-19W-19cdd1. 14 feet south and 6 feet west of fence corner. Sample log of test hole. Altitudes: land surface, 2,114; bedrock, 1,969.		
High-terrace deposits:		
Sand, buff to light-brown, very fine to medium; buff, sandy clay	12	12
Clay, light-brown, sandy	3	15
Clay, gray, silty	3	18
Sand, ubff, fine to medium; buff and gray, sandy clay	7	25
Sand, buff, fine to medium; trace of caliche	5	30
Sand, buff, medium to coarse; gray, sandy, bentonitic clay	10	40
Sand, buff, fine to medium	9	49
Clay, buff, and gray, sandy, bentonitic	5	54
Sand, buff, very fine to medium	4	58
Clay, buff, and gray, very sandy, bentonitic	7	65
Sand, buff, fine to medium; trace of coarse sand, bentonite	10	75
Sand, buff, fine to coarse, clean; trace of caliche and bentonite	10	85
Sand, buff, medium to coarse; thin layers of buff to gray, sandy bentonitic clay	10	95
Sand, buff, medium to coarse; thin layers of gray, silty bentonitic clay	10	105
Sand, buff, medium to very coarse; thin layers of buff and orange, sandy bentonitic clay	10	115
Sand, buff, very fine to coarse; thin layers of buff, sandy bentonitic clay	10	125
Sand, buff, medium to coarse; thin layers of buff, sandy bentonitic clay	5	130
Sand, buff, coarse to very coarse	10	140
Sand, buff, fine to medium; trace of very coarse sand	5	145
Red beds (bedrock):	..	...
24N-19W-19daa1. 330 feet south and 11 feet east of fence corner. Sample log of test hole. Altitudes: land surface, 2,091; bedrock, 1,969.		
High-terrace deposits:		
Sand, buff, very fine to medium, silty tan, silty to sandy clay	5	5
Sand, buff, fine to medium	5	10
Sand, white, fine to medium; trace of coarse sand	30	40
Sand, buff, to white, very fine to medium	10	50
Sand, white, fine to coarse	5	55
Sand, white, very fine to medium, silty; light-gray, sandy bentonitic clay	10	65
Sand, white, very fine to medium; trace of coarse sand; light-gray, sandy bentonitic clay	5	70
Sand, white, fine to coarse; trace of very coarse sand; thin layers of very light-gray, sandy, very bentonitic clay	10	80
Sand, white, very fine to coarse, silty; thin layers of light-gray, sandy bentonitic clay	10	90
Bentonite, slightly sandy; red clay	5	95
Clay, light-red, silty to sandy, slightly bentonitic	5	100
Clay, red, compact	5	105
Clay, red, silty to sandy; bentonite	3	108
Sand, buff, medium to coarse; trace of very coarse sand	2	110
Sand, buff, medium to very coarse	5	115
Sand, buff, medium to very coarse; fine gravel	7	122
Red beds (bedrock):	..	...
24N-19W-20abb1. 15 feet north and 70 feet east of fence corner. Sample log of test hole. Altitudes: land surface, 2,110; bedrock, 1,992.		
High-terrace deposits:		
Clay, brown, silty to sandy	5	5
Sand, light-brown, fine to medium; light-brown silty to sandy, calcareous clay	5	10
Clay, light-gray, very sandy, bentonitic; trace of caliche	5	15

Description	Thickness	Depth
24N-19W-20abb1.--Continued		
Sand, buff, fine; thin layers of light-gray, sandy bentonitic clay; caliche	5	20
Sand, white, fine to medium; thin layers of light-gray, sandy bentonitic clay	10	30
Sand, white, fine to medium; thin layers of light-gray, sandy bentonitic clay	5	35
Sand, buff to white, fine to medium; thin layers of light-gray to pink, sandy bentonitic clay	5	40
Clay, light-brown, very sandy	5	45
Sand, buff, fine to medium; thin layers of light-gray to light-brown, very sandy clay	5	50
Clay, light-red, very silty and sandy	10	60
Sand, buff, very fine to medium; thin layers of pink, silty to sandy clay	10	70
Sand, buff, fine to medium; gray and pink, silty to sandy clay	5	75
Clay, gray and pink, very sandy	5	80
Sand, buff, fine to medium	5	85
Sand, buff, fine to medium; gray, very sandy clay	10	95
Sand, buff, fine to medium; trace of coarse sand	5	100
Sand, buff, medium to very coarse; trace of fine gravel in lower part	10	110
Sand, buff, medium to very coarse; fine gravel	8	118
Red beds (bedrock):	..	..
24N-19W-27cab1. 200 feet southeast of irrigation well. Sample log of observation well. Altitude: land surface, 2,055.		
High-terrace deposits:		
Clay, dark-gray, silty, slightly sandy	10	10
Sand, buff, very fine to medium; thin yellow, calcareous silty zones	5	15
Clay, gray to orange, silty to sandy, bentonitic	13	28
Sand, buff, fine to medium	7	35
Sand, buff to white, very fine to medium; t in layers of dark-gray silty clay	10	45
Sand, buff to white, very fine to medium, trace of coarse sand	10	55
Sand, buff, medium to coarse	10	65
Sand, buff, fine to coarse, thin bentonitic zones	5	70
Sand, buff, fine to medium, bentonitic zone; coarse sand; thin layer of dark-gray, silty clay	5	75
Sand, buff, fine to medium, thin bentonitic zones	5	80
(Test hole not drilled to bedrock)		
24N-19W-27cba1. 100 feet southwest of irrigation well. Sample log of observation well. Altitude: land surface, 2,054.		
High-terrace deposits:		
Sand, buff, very fine to medium, trace of coarse sand	12	12
Clay, orange, silty	3	15
Sand, buff, fine to medium	10	25
Clay, orange, silty to sandy	12	37
Sand, buff, fine to medium	8	45
Sand, buff, medium to coarse	5	50
Sand, buff, fine to medium	14	64
Clay, gray, very silty and sandy; buff, very fine to medium sand	11	75
Sand, buff, very fine to medium; thin layer of sandy bentonite	7	82
Clay, light to dark-gray, silty	8	90
(Test hole not drilled to bedrock)		
24N-19W-27cba2. 300 feet southwest of irrigation well. Sample log of observation well. Altitude: land surface, 2,054.		
High-terrace deposits:		
Clay, gray, silty	7	7
Sand, buff, fine to medium	3	10
Clay, gray, silty	3	13
Sand, orange, fine to medium	12	25
Sand, buff to yellow, fine to medium	5	30
Sand, buff, fine to medium; thin layer of orange, silty clay	5	35
Sand, buff, fine to medium	5	40
Sand, buff, very fine to medium	10	50
Sand, buff, fine to medium; trace of coarse sand	15	65

Description	Thick-ness	Depth
24N-19W-27cba2.--Continued		
Sand, buff, fine to medium; thin layer of sandy bentonite	5	70
Sand, buff, medium, bentonitic	5	75
Bentonite, sandy; buff, fine to medium sand; gray, silty clay	5	80
(Test hole not drilled to bedrock)		
24N-19W-30bcc1. 117 feet north and 19 feet west of fence corner. Sample log of test hole. Altitudes: land surface, 2,094; bedrock, 1,968.		
High-terrace deposits:		
Sand, light-brown, very fine to fine, silty	5	5
Sand, light-brown, fine to medium, silty; light- to dark-gray, silty clay	5	10
Sand, buff, fine to medium, silty; light-gray to tan, sandy bentonitic clay	5	15
Sand, buff to yellow, fine to medium; thin layer of brown, silty clay	5	20
Sand, buff, very fine to medium; trace of gray, bentonitic clay in lower part	10	30
Sand, buff, fine to medium; thin layers of light-gray, bentonitic clay	10	40
Sand, buff, fine to medium; thin layer of dark-gray, silty clay	5	45
Sand, buff, medium to coarse	35	70
Sand, buff, fine to coarse; light-gray, bentonitic clay	10	80
Clay, light-gray, very sandy, bentonitic; thin layers of bentonite	10	90
Sand, buff to white, fine to coarse; thin layers of sandy, bentonitic clay; pure bentonite	5	95
Sand, buff to white, very fine to medium; thin layer of light-gray, sandy bentonitic clay	5	100
Sand, buff and yellow, medium to coarse; very coarse sand; thin layer of brown, silty clay	5	105
Sand, buff, medium to very coarse; fine gravel; trace of bentonite	21	126
Red beds (bedrock):	..	...
24N-19W-31ddb1. Driller's log supplied by Ellis Caldwell. Altitudes: land surface, 2,047; bedrock, 1,932.		
High-terrace deposits:		
Sand, fine	15	15
Clay	5	20
Sand, fine	10	30
Clay	5	35
Sand, fine	80	115
Red beds (bedrock):	..	...
24N-19W-36aaa1. 62 feet south and 22 feet east of NE fence corner. Sample log of test hole. Altitudes: land surface, 2,088; bedrock, 2,037.		
High-terrace deposits:		
Sand, buff, fine to medium; trace of caliche	4	4
Clay, brown and dark-gray, silty to sandy	3	7
Sand, buff, fine to medium, silty; gray, silty clay	8	15
Sand, buff and yellow, fine to medium; thin layer of gray, silty clay	5	20
Sand, buff, medium to coarse	5	25
Sand, buff, medium to coarse; very coarse sand; gray, silty clay	4	29
Sand, buff, medium to very coarse	4	33
Clay, brown, silty	2	35
Volcanic ash, pure to sandy; alternating with thin layers of buff, fine sand	7	42
Sand, buff, medium to coarse	3	45
Sand, buff, medium to very coarse; thin layer of orange, silty clay; fine to medium gravel	5	50
(Lost circulation)	1	51
Red beds (bedrock):	..	..
24N-20W-3aaa1. 15 feet north and 64 feet west of NE fence corner. Sample log of test hole. Altitudes: land surface, 2,114; bedrock, 2,081.		
High-terrace deposits:		
Sand, buff, very fine to medium, silty, thin layer of dark-gray, silty clay; sandy bentonite	5	5
Sand, buff, very fine to medium, silty; coarse sand; thin layer of pink and gray, silty bentonitic clay	5	10
24N-20W-3aaa1.--Continued		
Sand, buff, fine to very coarse; fine gravel; trace of caliche	5	15
Sand, buff, medium to very coarse; light-gray, silty bentonitic clay	5	20
Sand, buff, medium to very coarse, silty; fine gravel; pink, silty bentonitic clay	10	30
Sand, buff, coarse to very coarse; fine gravel	3	33
Red beds (bedrock):	..	..
24N-20W-4ddd1. 18 feet south and 45 feet west of southeast fence corner. Sample log of test hole. Altitudes: land surface, 2,100; bedrock, 2,002.		
High-terrace deposits:		
Sand, buff, very fine to medium, silty	5	5
Sand, buff, fine to medium silty; thin layer of light-red, silty clay; caliche	5	10
Sand, buff, fine to medium	15	25
Sand, buff, very fine to fine, thin bentonitic zones	5	30
Sand, buff, fine to medium, thin bentonitic zones	20	50
Sand, buff, very fine to medium, thin bentonitic zones; trace of caliche	10	60
Sand, buff, fine to medium; trace of caliche	5	65
Sand, buff and yellow, fine to coarse; trace of caliche	5	70
Sand, buff, medium to very coarse	5	75
Sand, buff, coarse to very coarse; fine gravel	10	85
Sand, buff and yellow, medium to very coarse	5	90
Sand, buff, coarse to very coarse; fine gravel	8	98
Red beds (bedrock):	..	..
24N-20W-5dcc1. Driller's log supplied by Ellis Caldwell.		
High-terrace deposits:		
Sand	5	5
Sand; clay	5	10
Clay	35	45
Sand, medium	20	65
Clay	10	75
Sand, medium	5	80
Red beds (bedrock):	..	..
24N-20W-6cdb1. Driller's log supplied by Emil Grade. Altitudes: land surface, 2,052; bedrock, 1,948.		
High-terrace deposits:		
Sand, fine	15	15
Clay	5	20
Sand	5	25
Clay	5	30
Sand	5	35
Sand, fine	40	75
Clay	20	95
Gravel	9	104
Red beds (bedrock):	..	...
24N-20W-6cdb2. 100 feet south of irrigation well. Sample log of observation well. Altitudes: land surface, 2,054; bedrock, 1,950.		
High-terrace deposits:		
Sand, brown, very fine to fine; thin layers of brown, sandy clay	10	10
Clay, buff, silty to sandy; thin layer of sandy caliche	5	15
Sand, buff, very fine to fine; buff, sandy clay	10	25
Sand, buff, fine to medium; thin layers of buff, sandy clay	20	45
Sand, buff, very fine to fine, medium sand; clay streaks throughout	25	70
Clay, purplish-brown, silty; fine gravel	10	80
Clay, buff, very sandy	5	85
Clay, purplish-brown, silty and sandy	14	99
Sand, buff, very coarse; fine to medium gravel	5	104
Red beds (bedrock):	..	...
24N-20W-6cdb3. 200 feet south of irrigation well. Sample log of observation well. Altitude: 2,057.		
High-terrace deposits:		
Sand, buff, very fine; dark-gray, silty clay	5	5
Sand, buff, very fine to fine; orange, silty clay	10	15
Sand, buff, fine, clayey	5	20
Sand, buff, very fine to fine; medium sand; thin layers of orange and gray, sandy clay	40	60

Description	Thickness	Depth
24N-20W-6cdb3.--Continued		
Sand, buff, very fine	5	65
Sand, buff, fine to medium, very clayey	10	75
Clay, orange, sandy	5	80
Clay, orange, silty	1	81
(Test hole not drilled to bedrock):	..	..

24N-20W-6cdb4. 300 feet south of irrigation well. Sample log of observation well. Altitudes: land surface, 2,056; bedrock, 1,956.

Description	Thickness	Depth
High-terrace deposits:		
Sand, buff, very fine to fine, clayey, with few particles of caliche	10	10
Clay, gray, and buff, sandy	5	15
Sand, buff, very fine, clayey	5	20
Sand, buff, very fine to fine	5	25
Sand, buff, fine; trace of medium sand; thin layers of dark-gray, silty clay	30	55
Sand, buff, fine to medium	11	66
Sand, buff, fine to medium, very clayey	14	80
Clay, buff, sandy	18	98
Sand, buff, very coarse; fine to medium gravel	2	100
Red beds (bedrock):		

24N-20W-14ddd1. 4 feet south and 87 feet west of SE fence corner. Sample log of test hole, and observation well. Altitudes: land surface, 2,132; bedrock, 2,030.

Description	Thickness	Depth
High-terrace deposits:		
Sand, buff, fine	5	5
Sand, buff, fine to medium; buff, sandy clay; caliche	10	15
Sand, buff, fine to medium; trace of caliche; thin layers of buff, sandy clay	10	35
Clay, buff, very sandy	10	45
Sand, buff, medium to coarse; thin layers of buff, very sandy clay	10	55
Sand, buff, medium to coarse, clean	5	60
Sand, buff, fine to medium; trace of caliche	10	70
Sand, medium to coarse; thin layers of buff, very sandy clay	5	75
Sand, buff, very fine to medium; trace of coarse sand	5	80
Sand, buff, fine to medium; buff, and maroon, sandy clay	5	85
Sand, buff, medium to coarse; buff, sandy clay, caliche	10	95
Sand, buff, and yellow, medium to coarse; very coarse sand	5	100
Sand, buff, medium to very coarse	2	102
Red beds (bedrock):	..	...

24N-20W-15ccc1. 8 feet south and 2 feet east of southwest fence corner. Sample log of test hole. Altitudes: land surface, 2,086; bedrock, 1,978.

Description	Thickness	Depth
High-terrace deposits:		
Sand, buff, very fine	10	10
Sand, buff, fine to medium; orange silty clay	5	15
Sand, buff, fine to medium; caliche particles throughout	10	25
Sand, buff, medium to coarse	15	40
Sand, buff, fine; thin layer of red clay in lower part	5	45
Sand, buff, fine to coarse; caliche particles throughout	5	50
Sand, buff, and yellow, medium to very coarse	15	65
Sand, buff, very coarse; yellow, and light-gray, bentonitic clay	5	70
Clay, light-gray, and yellowish-orange, very sandy, bentonitic	10	80
Sand, buff, and yellow, very fine to medium	5	85
Sand, buff, and yellow, medium to very coarse; fine gravel	14	99
Gravel, fine to medium, clean	2	101
Sand, buff, fine to medium	4	105
Sand, buff, medium to very coarse; fine to medium gravel	3	108
Red beds (bedrock):	..	...

24N-20W-17aaa1. 123 feet south and 11 feet east of northeast fence corner. Sample log of test hole. Altitudes: land surface, 2,061; bedrock, 1,957.

Description	Thickness	Depth
High-terrace deposits:		
Clay, gray, silty	10	10
Sand, buff, fine to medium, loosely cemented with caliche	15	25
24N-20W-17aaa1.--Continued		
Sand, buff, medium to coarse, loosely cemented with caliche	10	35
Sand, buff, fine to medium, cemented with caliche	5	40
Sand, buff, fine to coarse, thin layers cemented with caliche	10	50
Sand, buff, fine to coarse; caliche particles scattered throughout	15	65
Sand, buff, fine to medium; thin layers of very sandy, orange, and gray clay	5	70
Sand, buff, very fine to fine; coarse sandy caliche particles; thin layers of buff, very sandy clay	10	80
Sand, buff, very fine to fine; thin layers of orange and gray, sandy clay	10	90
Sand, buff, fine to medium; thin layers of orange, sandy clay	10	100
Sand, buff, medium to very coarse; fine gravel	4	104
Red beds (bedrock):	..	..

24N-20W-18ddd2. [illegible] feet west and 13 feet south of southeast fence corner. Sample log of test hole. Altitudes: land surface, 2,043; bedrock, 1,948.

Description	Thickness	Depth
High-terrace deposits:		
Sand, buff, very fine to coarse; trace of caliche	10	10
Sand, buff, fine to coarse; trace of caliche	15	25
Sand, buff, coarse; buff, sandy clay	5	30
Clay, buff, sandy; trace of caliche	5	35
Sand, buff, medium, trace of coarse sand; clay, buff, sandy; trace of caliche	10	45
Sand, buff, medium to coarse; trace of caliche	5	50
Sand, buff, medium to very coarse	5	55
Sand, buff, very fine to medium	5	60
Sand, buff, medium	5	65
Sand, buff, medium to coarse; trace of caliche	10	75
Sand, buff, very coarse; fine gravel	5	80
Sand, buff, fine to medium	5	85
Sand, buff, medium to very coarse	5	90
Sand, buff, coarse to very coarse; fine to medium gravel	5	95
Red beds (bedrock):	..	..

24N-20W-23bbb1. 280 feet south and 100 feet east of northwest section corner. Partial log of oil company test hole. Altitudes: land surface, 2,116; bedrock, 2,017.

Description	Thickness	Depth
High-terrace deposits:		
Sand, white, fine to medium, subrounded	50	50
Sand, medium to coarse	49	99
Whitehorse Group, undifferentiated (bedrock):		
Sand, red, very fine; silt	11	110
Sand, orange, fine	20	130
Sand, very fine; white sand and silty; red shale	20	150
Sand, orange, fine	10	160
Sand, orange, very fine	10	170
Shale, red	10	180
Sand, orange, very fine; silty	30	210
Sand, orange, very fine; silt; trace of coarse, rounded, frosted, sand grains	30	240
Sand, orange, fine	40	280
Sand, orange, very fine, silty	20	300
Sand, orange, fine; trace of coarse, rounded, frosted, sand grains	40	340
Sand, orange, fine, gypsiferous; coarse, rounded, frosted, sand grains	30	370
Dog Creek Shale:		
Silt, orange; red shale	10	380
Shale, red; gray silt; streaks of gray, fine sand	51	431
Blaine Gypsum:		
Limestone, dolomitic	2	433
Shale, gray and brown	7	440
Gypsum, white; selenite	20	460
Shale, dark-red	4	464
Gypsum, white, soft; selenite	14	478
Shale, dark-gray	2	480
Gypsum	1	481
Shale, gray, dolomitic	1	482
Flowerpot Shale:		
Shale, brick-red, and gray	80	562
Shale, brick-red, and gray; gray silt	5	567
Shale, brick-red, and gray; trace of gypsum; orange, fine sand, trace of anhydrite	113	680

24N-20W-30bbb1. 71 feet south and 4 feet west of northwest fence corner. Sample log of test hole. Altitudes: land surface, 2,018; bedrock, 1,961.

Description	Thickness	Depth
High-terrace deposits:		
Sand, buff, very fine to fine, clayey	5	5
Sand, buff, fine; gray, sandy clay	5	10
Sand, buff, very fine to fine, clean	5	15
Sand, buff, medium	5	20
Sand, buff, fine to medium; trace of coarse sand	10	30
Clay, buff, very sandy	10	40
Sand, buff, fine to medium; gray, sandy clay; trace of caliche	5	45
Clay, light-gray, sandy, bentonitic	5	50
Sand, buff, medium; coarse sand; light-gray, sandy, bentonitic clay	7	57
Red beds (bedrock):	..	..

24N-20W-33dcc1. 4 feet south and 8 feet west of west gate. Sample log of test hole and observation well. Altitudes: land surface, 2,036; bedrock, 1,928.

Description	Thickness	Depth
High-terrace deposits		
Sand, light-brown, fine to medium, silty; coarse sand	5	5
Sand, light-brown, fine to coarse; trace of very coarse sand	5	10
Sand, buff, fine to coarse, silty; buff, silty, slightly bentonitic clay	5	15
Sadn, buff, medium to coarse; thin layer of light-brown to buff, silty, slightly bentonitic clay	5	20
Sand, buff, fine to medium; thin layer of light-gray, bentonitic clay	5	25
Sand, buff, medium to coarse; trace of bentonite	5	30
Sand, buff, fine to coarse; buff to light-gray, silty to sandy, bentonitic clay	10	40
Sand, white, fine to coarse; trace of very coarse sand	10	50
Sand, buff, medium to very coarse	5	55
Sand, buff, fine to medium, thin layer of buff, silty, bentonitic clay	10	65
Bentonite, pure to sandy	5	70
Sand, buff, fine to medium; coarse sand; silty to sandy, bentonitic clay	10	80
Sand, buff, fine to coarse; trace of bentonite	5	85
Clay, light-gray to buff, silty to sandy, bentonitic; buff, fine to medium, silty sand	5	90
Sand, buff, medium to very coarse	5	95
Sand, buff, medium to very coarse; fine gravel	13	108
Red beds (bedrock):	..	...

24N-20W-35daa1. 217 feet south and 12 feet east of fence corner. Sample log of test hole. Altitudes: land surface, 2,069; bedrock, 1,971.

Description	Thickness	Depth
High-terrace deposits:		
Sand, light-brown, very fine to fine, very silty	5	5
Sand, light-brown, very fine to fine, silty; brown, silty clay	5	10
Sand, buff, fine to medium; thin layer of buff, bentonitic clay	5	15
Sand, buff to white, very fine to medium; thin layer of gray, bentonitic clay	5	20
Sand, buff, fine to medium	5	25
Sand, buff to white, medium to coarse	10	35
Sand, buff, fine to medium	5	40
Sand, buff, fine to coarse; thin alyer of orange, sandy bentonitic clay	10	50
Sand, buff, medium to coarse; very coarse sand; bentonite	10	60
Sand, buff, fine to coarse	5	65
Sand, buff, medium to very coarse	10	75
Sand, buff, fine to medium; light-gray to buff; bentonitic clay	5	80
Sand, buff, very fine to medium; trace of bentonite	10	90
Sand, white, fine to medium	5	95
Sand, buff, medium to very coarse	3	98
Red beds (bedrock):	..	..

24N-20W-36abb1. 14 feet north and 275 feet east of fence corner. Sample log of test hole. Altitudes: land surface, 2,084; bedrock, 1,968.

Description	Thickness	Depth
High-terrace deposits:		
Sand, buff, very fine to medium; buff, very sandy clay	10	10
Clay, buff, and orange, silty and sandy, bentonitic	12	22
Sand, buff, very fine to medium	3	25

24N-20W-36abb1.--Continued

Description	Thickness	Depth
Clay, buff, sandy, bentonitic; buff medium sand	10	35
Sand, buff, medium	10	45
Sand, buff, and yellow, very fine to medium; trace of caliche	10	55
Sand, buff, medium to coarse	10	65
Sand, buff, medium to coarse; trace of caliche	10	75
Sand, buff, and yellow, fine to coarse; trace of bentonite	10	85
Sand, buff, very fine to medium; thin layer of light-gray, sandy, bentonitic clay	10	95
Sand, buff, fine to medium; trace of bentonite	15	110
Sand, buff, medium to very coarse; fine to medium gravel	6	116
Red beds (bedrock):		

24N-21W-1aaa1. 18 feet east of telephone pole in road island. Sample log of test hole. Altitudes: land surface; 2,052; bedrock, 1,983.

Description	Thickness	Depth
High-terrace deposits:		
Sand, buff, very fine; silt, black	5	5
Sand, buff, very fine to fine; trace of medium sand	16	21
Clay, buff, sandy	4	25
Caliche, very silty	5	30
Clay, buff, sandy; silty caliche	15	45
Clay, buff, sandy; silty caliche; buff, fine to medium sand	10	55
Sand, buff, medium, clayey; caliche	7	62
Sand, buff, medium to very coarse; fine gravel	3	65
Gravel, fine to medium	4	69
Red beds (bedrock):	..	..

24N-21W-3ccc1. 41 feet north and 8 feet east of southwest fence corner. Sample log of test hole. Altitudes: land surface, 2,052; bedrock, 2,015.

Description	Thickness	Depth
Alluvium:		
Sand, red, very fine to fine, silty	5	5
Sand, buff, very fine to fine	5	10
Sand, buff, very fine to coarse; trace of caliche	10	20
Sand, buff, fine to very coarse, clean	10	30
Sand, buff, medium to very coarse; fine gravel	5	35
Gravel, fine to medium	2	37

24N-21W-10ddd1. 11 feet north and 4 feet east of SE fence corner. Sample log of test hole. Altitudes: land surface, 1,982; bedrock, 1,932.

Description	Thickness	Depth
High-terrace deposits:		
Clay, buff, sandy; trace of caliche	5	5
Caliche, silty; buff, sandy clay	20	25
Clay, buff, and dark-gray, sandy	5	30
Sand, buff, fine to very coarse, clean	5	35
Sand, buff, very coarse; fine gravel with ironstone fragments	5	40
Sand, buff, fine to coarse with ironstone fragments		
Sand, buff, very coarse; fine to medium gravel	10	50
Red beds (bedrock):	..	..

24N-21W-14ddd1. 7 feet south and 4 feet east of southeast fence corner. Sample log of test hole. Altitudes: land surface, 2,006; bedrock, 1,955.

Description	Thickness	Depth
High-terrace deposits:		
Sand, buff, fine to medium; buff, silty, calcareous clay	5	5
Sand, buff, very fine to medium, very silty calcareous; thin layer of buff, silty clay	5	10
Sand, light-brown, fine to coarse; trace of caliche	15	25
Sand, buff, medium to coarse; thin layer of gray, silty clay	5	30
Sand, buff, medium to coarse	5	35
Sand, buff, medium to coarse	5	35
Sand, buff, fine to coarse; thin layer of light-red, silty clay	5	40
Sand, buff, and yellow, fine to coarse	5	45
Sand, yellow, medium to very coarse	6	51
Red beds (bedrock):	..	..

Description	Thickness	Depth
24N-21W-22aca1. Driller's log supplied by Ellis Caldwell. Altitudes: land surface, 1,970; bedrock, 1,935.		
High-terrace deposits:		
Sand, fine	10	10
Clay	5	15
Caliche	5	20
Sand, fine	5	25
Sand, medium	5	30
Sand, coarse	5	35
Red beds (bedrock):	..	..
24N-21W-34abb1. 124 feet south of section-line fence, 66 feet south of center of east-west section-line road, 14 feet west of north-south trail, 0.4 mile west of northeast fence corner. Sample log of test hole. Altitudes: land surface, 1,973; bedrock, 1,916.		
High-terrace deposits:		
Sand, buff, fine to coarse	10	10
Sand, buff, fine to coarse; trace of very coarse sand	10	20
Sand, buff, medium to very coarse; thin layers of dark-gray, and light-gray, sandy bentonitic clay	5	25
Sand, buff, medium to very coarse; fine gravel; thin layer of reddish-brown clay; trace of caliche	10	35
Sand, buff, fine to very coarse; fine gravel	5	40
Sand, buff, coarse to very coarse; fine to medium gravel	17	57
Red beds (bedrock):	..	..
24N-21W-34ddc1. 4 feet north of section-line fence, 20 feet east of gate, approximately 1,300 feet west of southeast fence corner. Sample log of test hole. Altitudes: land surface, 1,981; bedrock, 1,924.		
High-terrace deposits:		
Sand, light-brown, fine to coarse	5	5
Sand, buff, fine to very coarse; thin layer of dark-gray, silty clay	5	10
Sand, buff, fine to medium; light-gray, sandy clay; thin layer of dak-gray clay	5	15
Sand, buff, fine to medium	10	25
Sand, buff, fine to coarse; thin layer of light-gray, silty to sand, bentonitic clay	5	30
Sand, buff, medium to very coarse; fine to medium gravel	10	40
Sand, buff, medium to very coarse; fine to medium gravel; thin layer of light-red clay	10	50
Gravel, fine to medium	7	57
Red beds (bedrock):	..	..
24N-21W-35aaa1. 55 feet south of section-line fence, 44 feet north of center section-line road, 88 feet east of telephone pole, 1.1 miles west of State Highway 34. Sample log of test hole. Altitudes: land surface, 1,999; bedrock, 1,918.		
High-terrace deposits:		
Sand, light-buff, fine to medium, silty	5	5
Sand, light-buff, fine to medium; dark-gray silty clay	10	15
Sand, buff, fine to medium; trace of coarse sand	5	20
Sand, buff, very fine to medium	5	25
Sand, buff, fine to medium: thin layer of gray, silty to sandy clay	5	30
Sand, light-gray to buff, fine to medium; light-gray, bentonitic clay	5	35
Sand, buff, fine to very coarse; fine gravel	10	45
Sand, buff, fine to very coarse; fine gravel	10	55
Sand, buff, medium to very coarse; fine gravel; reddish-brown clay	10	65
Sand, buff, medium to very coarse; fine gravel	5	70
Sand, coarse to very coarse; fine gravel	3	73
Clay, light-red, silty; buff, coarse to very coarse sand; fine gravel in lower part	8	81
Red beds (bedrock):	..	..
24N-22W-3dcc1. 60 feet east and 150 feet north of fence corner. Driller's log of test hole supplied by Western State Hospital.		
Low-terrace deposits:		
Sand, fine to coarse; silt	10	10
Sand, fine to coarse	10	20
Sand, fine to coarse; fine gravel; gray clay	6	26
Red beds (bedrock):	..	..
24N-22W-10cba1. 33 feet northeast of pump house. Sample log of test hole.		
Low-terrace deposits:		
Sand, fine	25	25
Sand, coarse	5	30
Sand, coarse; fine gravel	10	40
Red beds (bedrock):	..	..
24N-22W-10ccd1. 28 feet north of hackberry trees. Sample log of test hole supplied by Western State Hospital.		
Low-terrace deposits:		
Sand, fine to coarse; brown silt in upper part	10	10
Sand, fine to coarse; gravel	10	20
Sand, fine; coarse sand	10	30
Sand, fine; coarse sand; gravel, small amount of gray silt	10	40
Sand, fine to coarse	6	46
Red beds (bedrock):	..	..
24N-22W-23cbb1. 6 feet southwest of southeast concrete gate post on northeast side of U.S. Highway 270. Sample log of test hole. Altitudes: land surface, 2,033; bedrock, 2,002.		
High-terrace deposits:		
Sand, buff, fine to coarse, silty	5	5
Sand, buff, very fine to coarse; very coarse sand	10	15
Sand, buff, fine to coarse	5	20
Sand, buff to grayish-white, medium to coarse; trace of very coarse sand	5	25
Sand, buff to grayish-white, medium to very coarse	6	31
25N-18W-3bdd1. 3,300 feet west and 2,100 feet south of northeast section corner. Partial log of oil company test hole. Altitudes: land surface, 1,699; bedrock, 1,699.		
Blaine Gypsum (bedrock):		
Shale, gray, sandy	10	10
Shale, red; sandy	14	24
Gypsum, white; selenite	11	35
Flowerpot Shale:		
Shale, red; trace of gray shale and silt	45	80
25N-18W-8ccb1. 1,120 feet north and 80 feet east of southwest section corner. Partial log of oil company test hole. Altitudes: land surface, 1,724; bedrock, 1,724.		
Blaine Gypsum (bedrock):		
Shale, red; covered by weathered shale	30	30
Anhydrite, white; underlain by gray shale	23	53
Flowerpot Shale:		
Shale, red and brick-red	17	70
25N-18W-19ddd1. 300 feet north and 150 feet west of southeast section corner. Partial log of oil company test hole. Altitudes: land surface, 1,700; bedrock, 1,700.		
Blaine Gypsum (bedrock):		
Gypsum, white; covered by red weathered shale; underlain by gray dolomite	17	17
Flowerpot Shale:		
Shale, red, brown and gray	68	85
25N-18W-22aaa1. 100 feet west and 60 feet south of section corner. Partial log of oil company test hole. Altitudes: land surface, 1,743; bedrock, 1,743.		
Dog Creek Shale (bedrock):		
Shale, red; silt; streaks of gray sand and fine, orange sand	57	57
Blaine Gypsum:		
Gypsum, white; underlain by dark-gray, thin dolomite	27	84
Flowerpot Shale:		
Shale, red and brick-red; silt; orange, thin sand streak at top	21	105
25N-18W-32ccd1. 750 feet east and 360 feet north of southwest section corner. Partial log of oil company test hole. Altitudes: land surface, 1,831; bedrock, 1,831.		
Whitehorse Group, undifferentiated (bedrock):		
Sand, orange, very fine	40	40
Sand, orange, very fine; contains coarse, rounded, frosted, sand grains, slightly gypsiferous	50	90

Description	Thick-ness	Depth
25N-18W-32ccd1.--Continued		
Dog Creek Shale:		
Shale, red; silt; some very fine sand	30	120
Sand, orange, fine	10	130
Shale, red; silt	10	140
Sand, orange, fine, slightly gypsiferous	15	155
Blaine Gypsum:		
Shale, red; gray shale; streaks of white gypsum	30	185
Flowerpot Shale:		
Shale, brick-red and gray; trace of gypsum	65	250
Silt, gray	5	255
Shale, red; purplish shale; silt; gray shale	120	375
25N-19W-10dcc1. 2,760 feet east and 20 feet north of southwest section corner. Partial log of oil company test hole. Altitudes: land surface, 1,838; bedrock, 1,838.		
Dog Creek Shale (bedrock):		
Shale, red; very fine sand and silt; trace of white gypsum	24	24
Sand, gray, very fine, gypsiferous	4	28
Blaine Gypsum:		
Gypsum, white; selenite; streaks of red shale and gray silt	32	60
Dolomite, gray, oolitic	2	62
Shale, red; silt; brick-red and gray shale	13	75
Gypsum, white; selenite	21	96
Dolomite, gray	3	99
Shale, brick-red; silt; gray shale; streaks of gypsum	7	106
Gypsum, white; underlain by gray dolomite	21	127
Flowerpot Shale, and older rocks, undifferentiated:		
Shale, dark-gray	3	130
Shale, brick-red and gray; red silt; trace of gypsum and gray silt	110	240
Shale, red; trace of gray shale	10	250
Shale, brick-red and gray; silt, trace of gypsum	40	290
Shale, brick-red and gray; silt; salt; trace of anhydrite	60	350
Shale, red	10	360
Shale, red; silt; salt; trace of white, very fine, sand	40	400
26N-18W-21aaa1. 130 feet south and 70 feet west of northeast section corner. Partial log of oil company test hole. Altitudes: land surface, 1,693; bedrock, 1,693.		
Dog Creek Shale (bedrock):		
Shale, red	20	20
Blaine Gypsum:		
Gypsum, white	10	30
Shale, red	9	39
Gypsum, white	26	65
(No sample, lost circulation)	5	70
Flowerpot Shale:		
Shale, red and gray	35	105
26N-18W-31aad1. 1,290 feet south and 140 feet west of northeast section corner. Partial log of oil company test hole. Altitudes: land surface, 1,764; bedrock, 1,764.		
Dog Creek Shale (bedrock):		
Sand, orange, very fine; red shale; coarse, rounded, frosted, sand grains; trace of gray silt at base	55	55
Blaine Gypsum:		
Gypsum, white	25	80
Shale, brown and red	7	87
Gypsum, white; selenite; some anhydrite; trace of gray dolomite at base	28	115
Flowerpot Shale:		
Shale, gray; brick-red shale	3	118
Shale, red; silt; gray; very fine sand; trace of gypsum	142	260
26N-19W-16aaa1. 260 feet west and 40 feet south of northeast section corner. Partial log of oil company test hole. Altitudes: land surface, 1,783; bedrock, 1,783.		
Blaine Gypsum (bedrock):		
Shale, red; trace of gray shale; very fine sand and silt	15	15
Gypsum, white, soft; selenite; underlain by 1-foot gray, sandy, porous, oolitic dolomite	25	40
Shale, red; white very fine sand	10	50
Gypsum, grayish-white; selenite	15	65
Shale, brick-red; gray shale	10	75
Gypsum, white; selenite; underlain by buff dolomite	30	105
Flowerpot Shale:		
Shale, gray	5	110
Shale, brick-red and gray	10	120

C-1

Appendix C.--Chemical analyses of water from wells and springs in Woodward County, Okla.

Location: See text p. 4 for explanation of well-numbering system; well locations shown on plate 1.
Aquifer: Qal, low-terrace deposits and alluvium; Qt, high-terrace deposits; To, Ogallala Formation; Pwh, Whitehorse Group; Pb, Blaine Gypsum.

[Analytical results in parts per million except as indicated]

Location	Depth (feet)	Aquifer	Date of collection	Temperature (°F)	Silica (SiO_2)	Total iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Residue on evaporation at 180°C	Dissolved solids: Sum	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH	Sodium adsorption ratio (SAR)
20N-17W-7abd1	70	Qal	9-10-56	63	29	0.01	128	34	32	1.2	346	0	193	14	0.4	7.3	0.02	....	609	460	176	13	882	7.2	0.6
20N-20W-2aaa1	.....	Pb	9-10-56	65	14	.01	943	201	1,910	7.8	68	0	2,900	3,080	.8	.....	.60	....	9,090	3,180	3,120	57	12,900	6.8	15
20N-20W-8daa1	25	To	9-10-56	60	30	.00	75	9.2	11	1.6	246	0	15	6.0	.1	22	.02	....	291	225	24	10	439	7.3	.3
20N-22W-19ddd1	205	To	9-10-56	63	32	.01	62	9.6	26	2.3	244	0	19	14	.1	6.4	.00	....	291	194	0	22	442	7.8	.8
21N-17W-22dcd1	79	Pwh	3-24-58	..	30	.00	100	23	16	...	140	0	18	50	.0	210	.34	....	516	345	230	9	803	7.5	.4
21N-18W-32dcc1	39	Pwh	9-10-56	63	25	.01	102	37	97	1.3	372	0	111	64	.2	150	.20	....	771	405	100	34	1,160	7.4	2.1
21N-19W-15adc1	1,485	...	9-10-56	64	26	.03	14	102	3,210	5.8	147	0	1,800	5,340	.5	.....	.22	....	11,300	2,200	2,080	76	17,300	7.3	30
21N-20W-6daa1	.....	...	8-31-56	66	24	.01	750	104	1,070	5.8	80	0	2,120	1,650	.8	.....	.40	....	5,760	2,300	2,230	50	7,950	7.0	9.7
[a]21N-20W-21, SE¼	.....	Pwh	6- 9-53	..	28	.00	58	17	27	2.5	236	0	29	26	.3	1.7	....	....	......	216	22	..	321	7.7	....
21N-21W-16cdb2	184	To	9- 7-56	64	34	.00	91	12	13	1.6	302	0	8.8	15	.3	24	.00	....	349	275	28	9	542	7.5	.3
21N-22W-21bcb1	.....	To	9-10-56	62	32	.01	82	11	23	1.7	314	0	8.2	5.2	.4	20	.12	.....	338	250	0	17	517	7.3	.6
22N-19W-2bbd1	47	Qt	8-11-59	..	..	....	90	20	58		318	0	74	62	...	8.4	.13	....	469	305	44	29	776	7.7	1.5
22N-19W-35cca4	60	Qal	9-19-56	62	28	.01	110	35	151	2.0	344	0	162	200	.4	8.5	.08	....	866	420	138	44	1,430	7.4	3.2
22N-21W-15abc1	51	To	9-10-56	62	30	.01	8.7	8.0	20	1.8	308	0	9.3	9.5	.4	14	.00	....	331	250	0	15	525	7.3	.6
22N-22W-21cbc1	60	To	9-14-56	62	36	.01	94	11	8.1	0.9	328	0	7.4	6.2	.3	9.9	.00	....	335	280	11	6	517	7.2	.2
23N-17W-8abb1	75	...	9-11-56	67	26	.00	660	98	65	2.6	516	0	1,570	36	.6	28	.18	....	2,740	2,050	1,630	6	2,910	7.2	.6
23N-17W-19bcc1	190	Pwh	9-11-56	66	34	.01	59	28	35	2.4	340	0	17	28	.2	2.9	.03	....	374	264	0	22	598	7.3	.9
[b]23N-17W-20	.....	...	12-12-52	..	24	.09	54	26	32	1.8	309	0	16	29	.1	2.4	....	....	337	242	0	..	566	7.6	....
23N-17W-30ccc1	133	Pb	9- 1-56	67	14	.01	600	69	84	1.9	132	0	1,610	90	.7	0.2	.09	....	2,530	1,780	1,670	9	2,760	7.4	.9
23N-18W-30ddc1	106	Pwh	9-11-56	63	33	.01	33	5.2	16	1.5	128	0	6.2	8.2	.1	16	.00	....	182	104	0	25	269	6.8	.7
23N-19W-26dbd1	61	Qt	7-16-51	..	26	.00	58	11	32	1.6	231	0	24	26	.3	12	....	....	305	190	0	27	501	7.7	....
23N-19W-28aca1	64	Qt	9-11-56	63	32	.01	40	10	1.5	1.5	194	0	13	16	.4	5.4	.00	....	240	162	3	20	368	7.7	.7
23N-20W-7dbd5	.....	Qt	3-13-57	63	32	.00	71	13	54	2.9	111	0	151	70	.1	3.0	....	....	452	232	141	33	713	6.7	1.5
[c]23N-20W-7, 8, 16	.....	Qt	2-20-51	..	26	.02	34	5.3	18	1.7	104	0	23	26	.0	6.1	....	....	197	107	21	26	303	7.3	....
[d]23N-20W-23, SE¼	.....	Pwh	9-10-56	60	30	.02	49	9.1	38	1.4	160	0	31	49	.1	5.1	.00	....	292	160	29	34	470	7.3	1.3
23N-20W-31ddd1	320	Pb	9- 7-56	66	24	.01	740	62	806	4.4	126	9	1,890	1,220	.6	.....	.19	....	4,810	2,100	2,000	45	6,410	7.7	7.7
23N-22W-22dcd1	51	To	9-10-56	65	38	.01	82	9.8	18	2.2	292	0	9.5	7.0	.2	22	.00	....	333	245	6	14	500	7.3	.5
24N-19W-27cbb1	101	Qt	9-11-56	64	50	.02	41	9.1	20	2.6	192	0	7.4	10	.1	7.8	.00	....	242	140	0	23	350	6.9	.7
24N-20W-6cdb1	105	Qt	9- 7-56	64	33	.01	64	17	7.4	2.5	260	0	8.2	7.0	.1	22	.03	....	289	230	17	6	430	7.6	.2
24N-21W-32baa1	.....	...	9- 7-56	64	25	.02	570	274	1,150	5.0	356	0	1,550	2,200	1.0	.....	.46	....	5,950	2,550	2,260	49	8,730	7.0	9.9
24N-22W-6abb1	11	Qal	7-11-47	..	..	...	.....	.....	....	...	106	0	250	270	...	.0	....	....	......	490	.....	..	1,690	...	....
24N-22W-10cab1	.....	Qal	10- 8-52	..	25	.10	160	57	100	2.6	334	0	392	131	.5	1.1	....	....	......	634	360	..	1,550	7.6	....

[a] Town of Sharon
[b] Town of Quinlan, composite sample of three wells taken from tap
[c] City of Woodward, composite sample of 21 wells taken from tap
[d] Boiling Springs, sample taken from discharge pipe at main spring in Boiling Springs State Park

Appendix D.--Chemical analyses of water from streams in Woodward County, Okla.

(Analytical results in parts per million except as indicated)

Stream and location	Date of collection	Discharge (cfs)	Temperature (°F)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Chloride (Cl)	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Sodium adsorption ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
Bent Creek, 20N-17W-22, NE¼, at county-highway bridge.	4-18-56	0.74	51	352	98	41	226	1,150	1,280	1,100	7	0.5	2,130	8.2
Kizer Creek, 20N-18W-33, SW¼, west line of section at county-highway bridge.	4-17-56	.36	55	552	117	38	232	34	1,860	1,670	4	.4	2,640	8.1
South Persimmon Creek, 20N-20W-10, NW¼, north line of section at county-highway bridge.	4-17-56	.94	57	122	12	32	316	20	355	96	16	.7	853	7.7
Do.	5-23-56	.19	67	106	26	22	328	13	372	103	11	.5	746	7.7
Hackberry Creek, 20N-20W-24, NE¼, north line of section at county-highway bridge.	4-17-56	.04	..	200	44	41	296	36	680	438	12	.7	1,300	7.9
Persimmon Creek, 21N-18W-30, SE¼, at bridge on U.S. Highway 270.	9- 5-51	....	74	128	50	..	706	118	524	0	..	...	1,450	7.9
Sand Creek, 21N-19W-4, SW¼, at bridge on U.S. Highway 270.	6- 5-56	1.51	..	71	19	30	156	44	255	127	20	.8	638	7.1
Persimmon Creek, 21N-19W-33, NE¼, east line of section at county-highway bridge.	4-17-56	1.37	58	130	17	52	310	48	395	141	22	1.1	934	7.8
North Persimmon Creek, 21N-20W-27, SW¼, west line of section at bridge on State Highway 34.	4-17-56	1.15	61	104	8.6	38	304	42	295	46	22	1.0	791	7.8
Do.	5-23-56	.64	67	78	20	31	240	38	276	80	20	.8	655	7.9
Indian Creek, 22N-19W-21, SE¼, east line of section at county-highway bridge.	4-17-56	No flow	59	72	17	59	138	83	250	137	34	1.6	746	7.5
Indian Creek, 22N-19W-30, NE¼, east line of section at county-highway bridge.	4-17-56	.15	64	196	42	336	136	435	660	548	53	5.7	2,620	7.6
Unnamed tributary to Indian Creek, 22N-20W-27, SE¼, south line of section at county-highway bridge.	4-17-56	.21	64	68	11	37	230	34	215	26	27	1.1	601	7.7
Do.	5-23-56	.07	67	77	17	37	286	37	260	26	24	1.0	660	8.1
Indian Creek, 22N-20W-29, NE¼, east line of section at bridge on State Highway 34.	3-28-56	2.57	67	138	28	125	192	195	460	320	37	2.5	1,420	7.8
Do.	5-23-56	.85	66	144	28	161	270	126	475	254	42	3.2	1,160	7.6
North Canadian River, 23N-20W-25, SE¼, at bridge on State Highway 15.	5- 9-55	42.5	65	50	13	67	152	102	180	56	45	2.2	761	8.1
Wolf Creek, 24N-22W-9, SE¼, at bridge on U.S. Highway 270.	2-23-56	31.5	60	69	21	73	216	107	260	83	38	2.0	816	8.1
Do.	3-28-56	15.9	60	90	18	96	236	120	300	106	41	2.4	1,000	7.3

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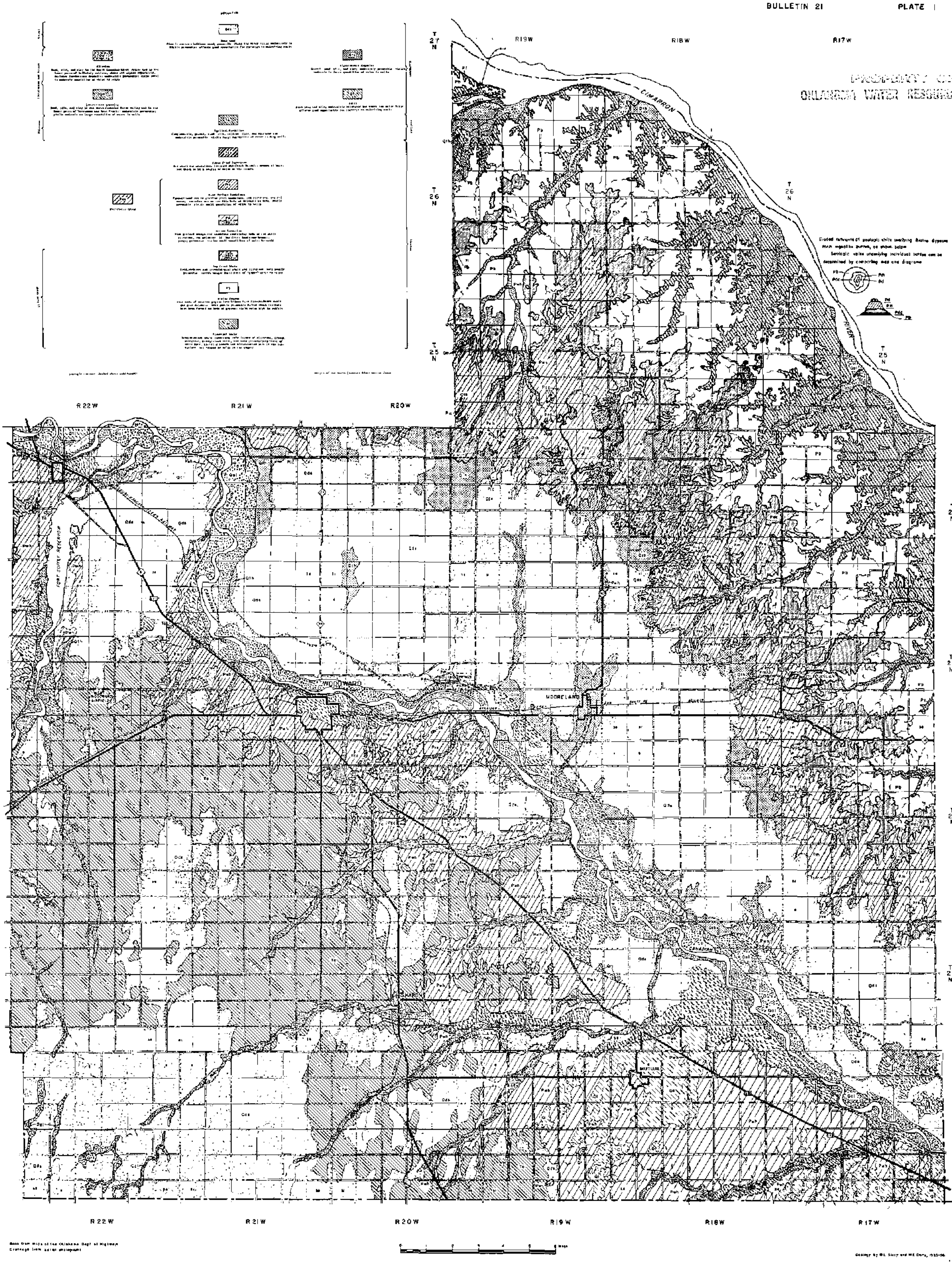
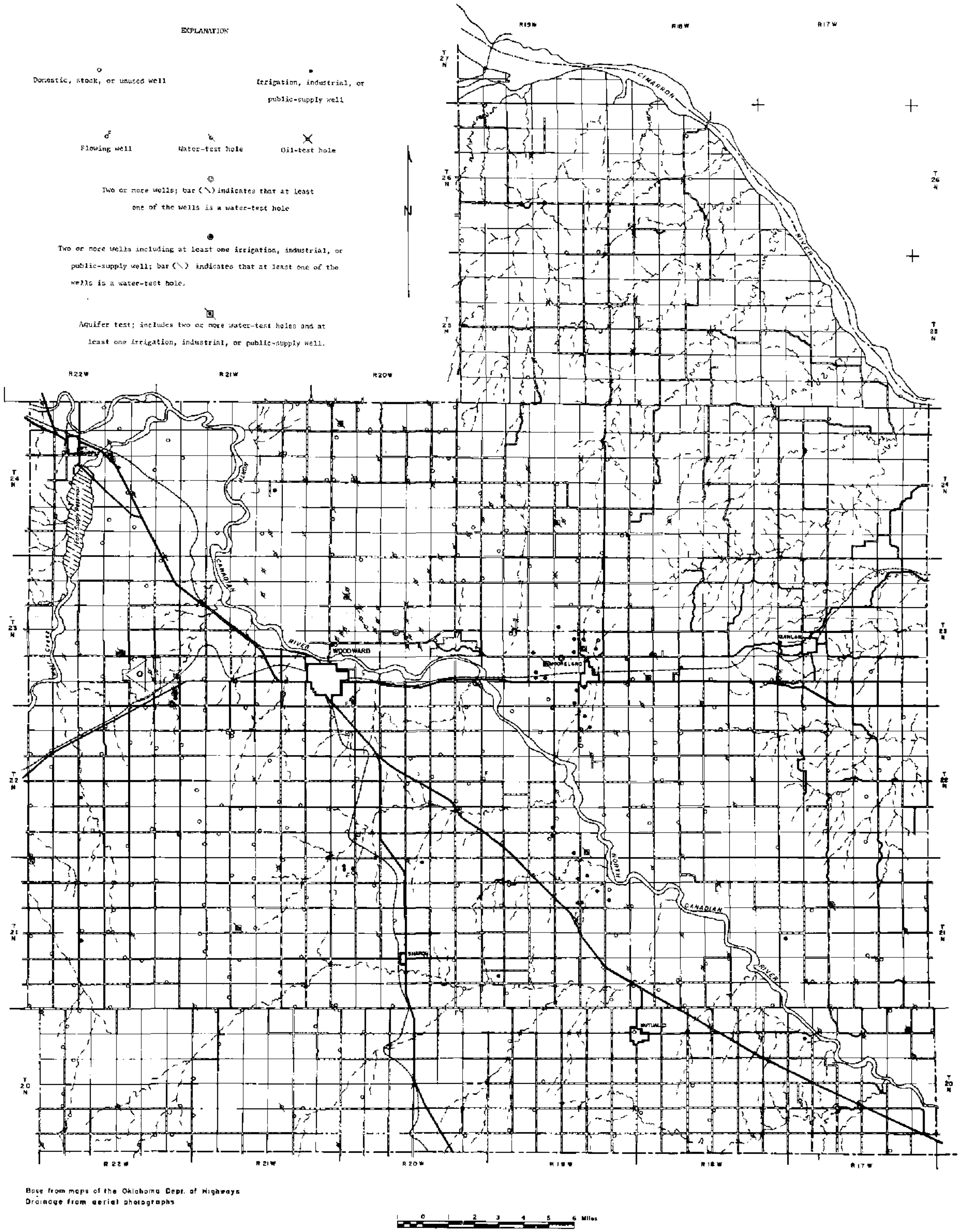
OKLAHOMA WATER RESOURCES BOARD
BULLETIN 21 PLATE 1



GEOLOGIC MAP OF WOODWARD COUNTY, OKLAHOMA

UNITED STATES GEOLOGICAL SURVEY

OKLAHOMA WATER RESOURCES BOARD
BULLETIN 21 PLATE 2



MAP OF WOODWARD COUNTY, OKLAHOMA, SHOWING THE LOCATION OF SELECTED WELLS AND TEST HOLES

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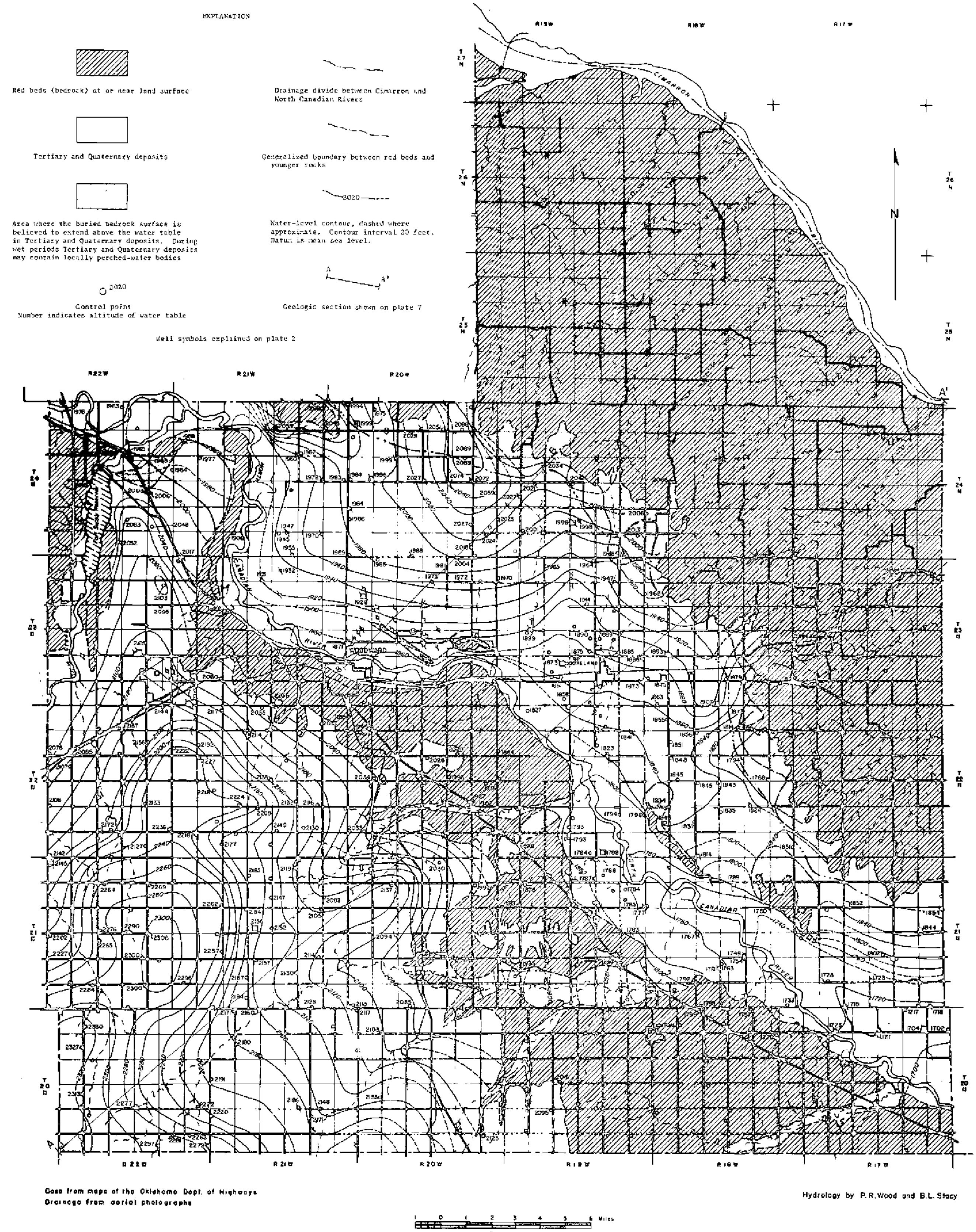
OKLAHOMA WATER RESOURCES BOARD
BULLETIN 21 PLATE 3



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

Hydrology by P.R. Wood and B.L. Stacy

Scale

MAP OF WOODWARD COUNTY, OKLAHOMA, SHOWING WATER-LEVEL CONTOURS FOR MAY, 1957

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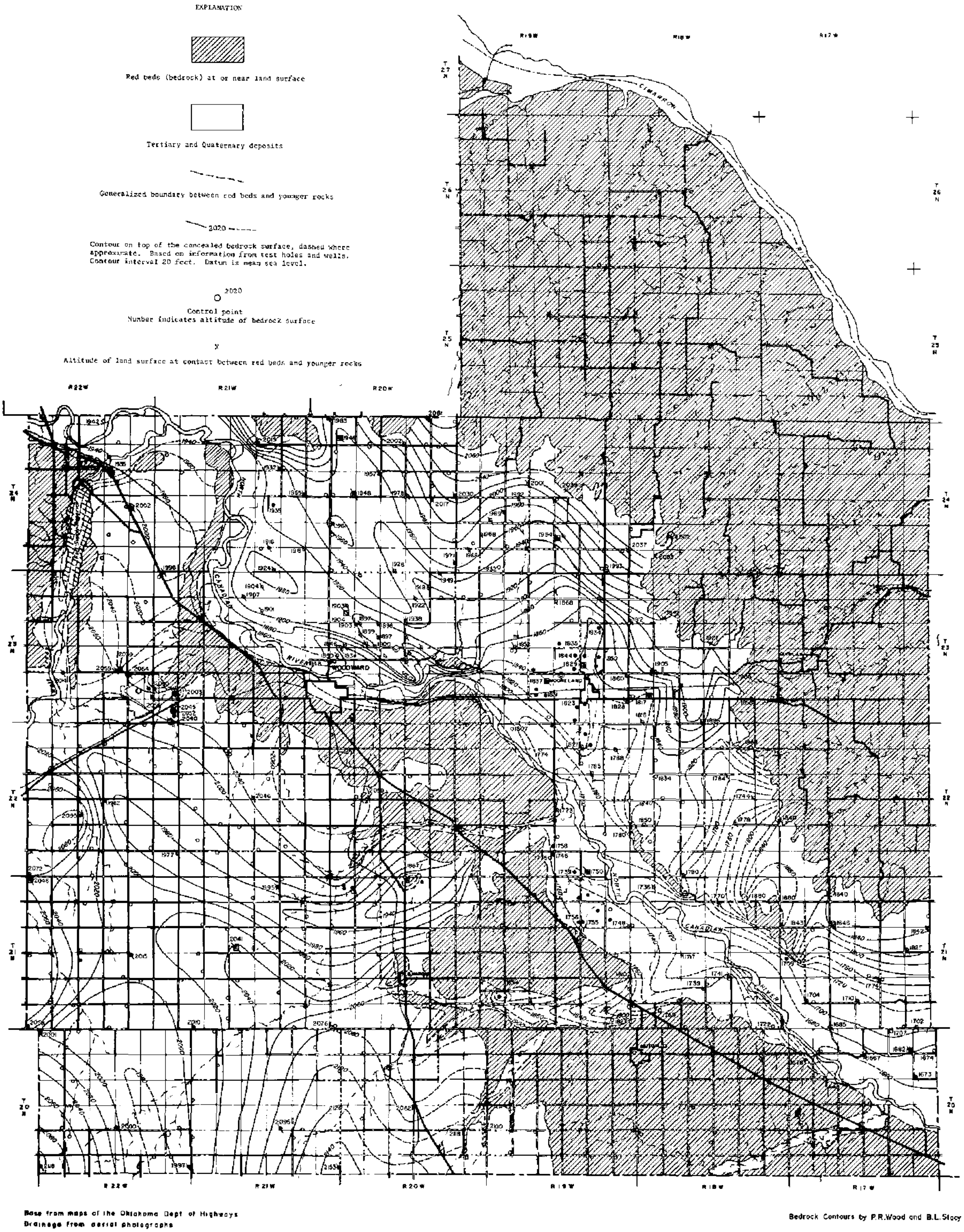
OKLAHOMA WATER RESOURCES BOARD

BULLETIN 21 PLATE 4



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

Bedrock Contours by P.R.Wood and B.L.Stacy

1 0 1 2 3 4 5 6 Miles
Scale

MAP OF WOODWARD COUNTY, OKLAHOMA, SHOWING GENERALIZED TOPOGRAPHY OF THE REDBEDS (Bedrock) BENEATH THE TERTIARY AND QUATERNARY DEPOSITS.

EXPLANATION

Red beds (bedrock) at or near land surface

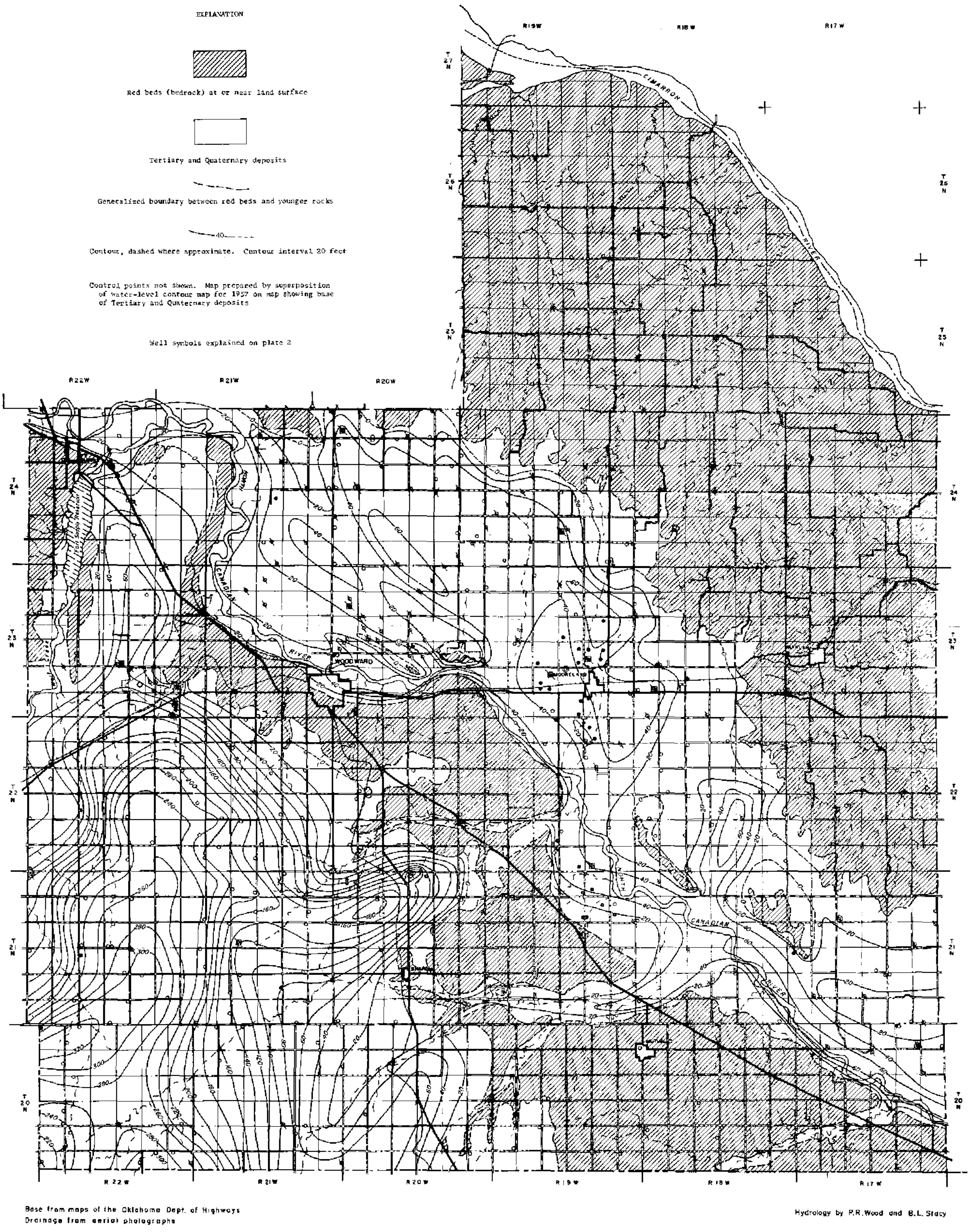
Tertiary and Quaternary deposits

Generalized boundary between red beds and younger rocks

Contour, dashed where approximate. Contour interval 20 feet

Control points not shown. Map prepared by superposition of water-level contour map for 1957 on map showing base of Tertiary and Quaternary deposits

Well symbols explained on plate 2



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

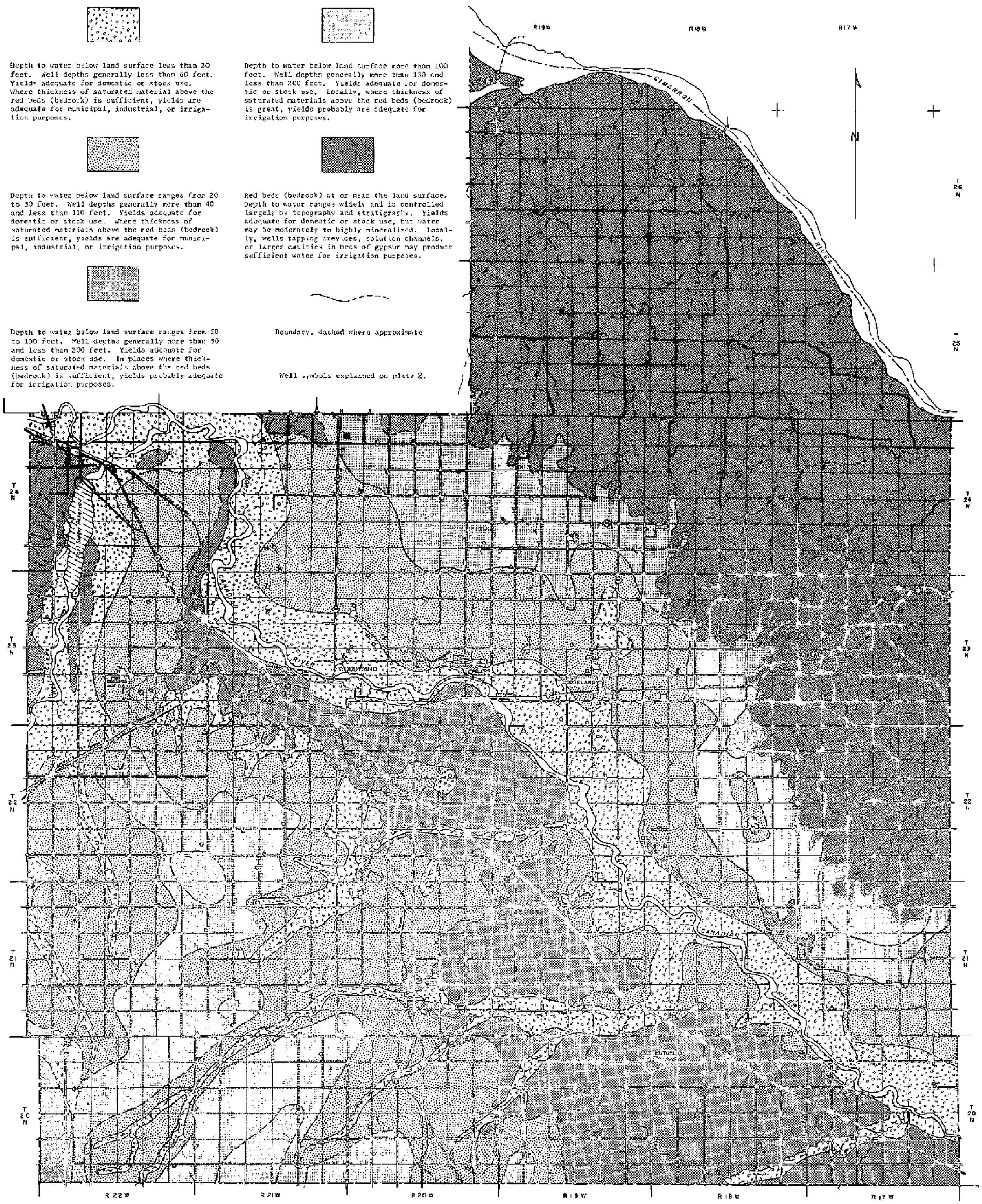
Hydrology by P.R. Wood and B.L. Stacy

MAP OF WOODWARD COUNTY, OKLAHOMA, SHOWING SATURATED THICKNESS OF TERTIARY AND QUATERNARY DEPOSITS

UNITED STATES GEOLOGICAL SURVEY

OKLAHOMA WATER RESOURCES BOARD

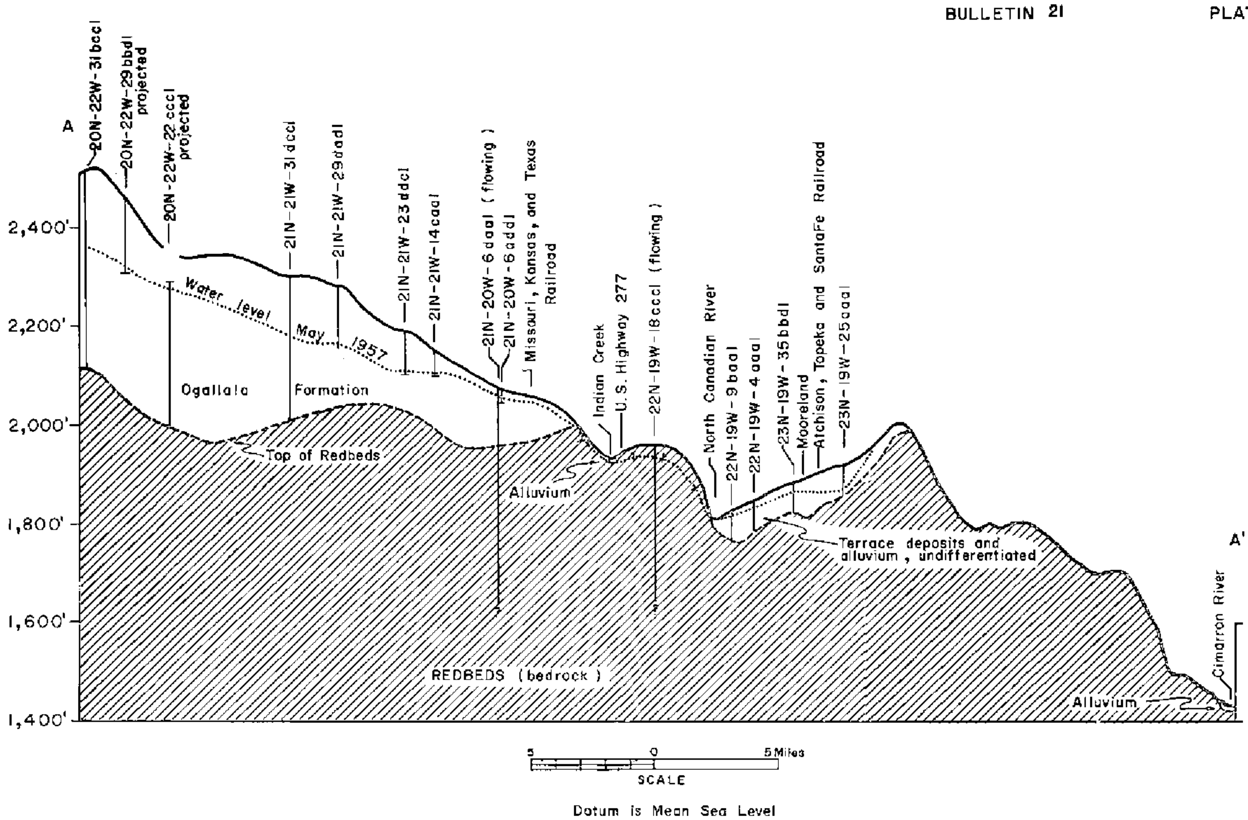
BULLETIN 21 PLATE 6

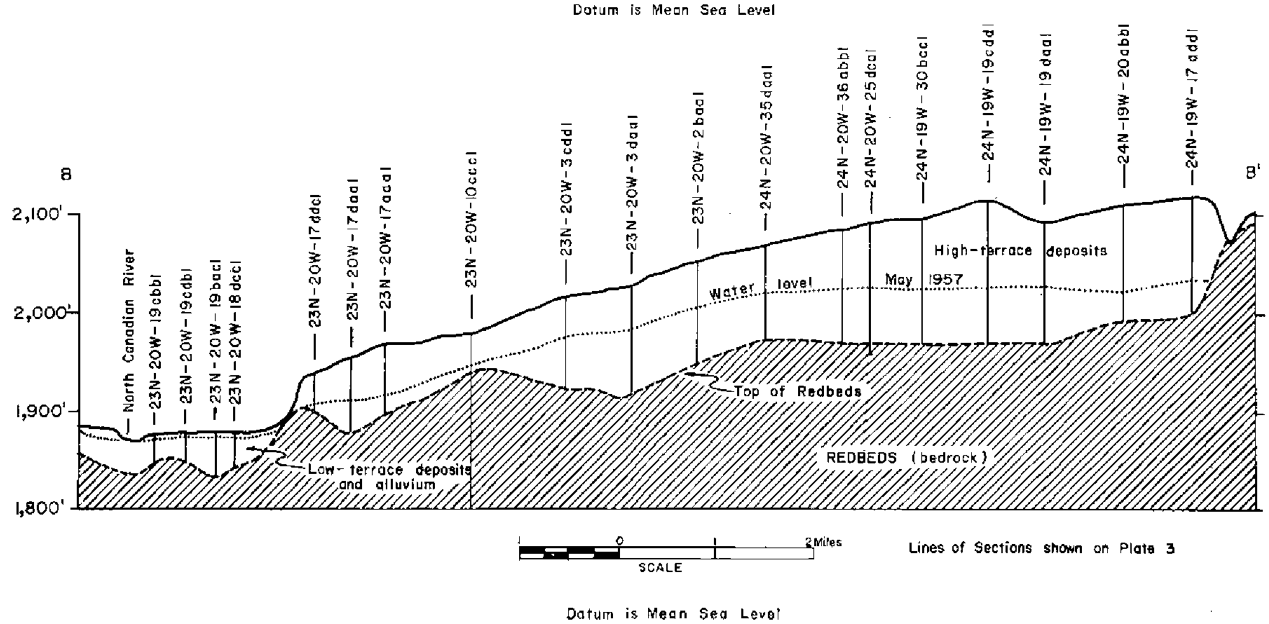


Base from maps of the Oklahoma Dept. of Highways
Drainage from aerial photographs

1 0 1 2 3 4 5 6 Miles

MAP OF WOODWARD COUNTY, OKLAHOMA, SHOWING AVAILABILITY OF GROUND WATER





GENERALIZED GEOLOGIC SECTIONS A-A' AND B-B', WOODWARD COUNTY, OKLAHOMA