Geohydrology of Sedgwick County, Kansas

By Charles W. Lane
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CONTENTS

ILLUSTRATIONS

TABLES

ERRATUM

On Plate 4, Bulletin 174 should read Bulletin 176.

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ABSTRACT

Sedgwick County has an area of about 1,000 square miles and lies within the Arkansas River Lowlands of the Central Lowland physiographic province. It is drained by the Arkansas River, Little Arkansas River, Ninnescah River, and tributaries of the Walnut River. The normal annual precipitation at Wichita, the principal city, is 30.70 inches, but it is subject to wide extremes.

The County contains about 15.7 percent of the State's population, and Wichita is the largest city in the State, with a population of about 254,700. It is the most heavily industrialized area of the State. The principal industry is the fabrication of private and military aircraft. The processing of agricultural products and petroleum, metal fabrication, and chemical manufacture are also important industries.

The rocks that crop out in the County are of sedimentary origin and range in age from Permian to Recent. The Wellington Formation of Permian age is the oldest rock cropping out. The surficial materials over much of the County are unconsolidated deposits of clay, silt, sand, and gravel of Neogene age. The unconsolidated deposits are thickest and are areally most extensive underlying the broad alluvial plain flanking the Arkansas River. The geologic history of the Arkansas Valley is discussed in detail in a section of this report.

Ground water is the most important mineral resource of Sedgwick County. It constitutes essentially all water used in the County. The quantity of ground water withdrawn cannot be determined accurately, but water rights in the amount of about 190,800 acre-feet have been approved or are pending approval in the County for all uses. The principal source of the ground water is the unconsolidated deposits underlying the Arkansas Valley where well yields of from a few gallons per minute to over 2,000 gallons per minute are readily obtained. The chemical quality of the ground water ranges from moderately hard to extremely hard, depending on the source of the water. Ground water in the Arkansas Valley is generally of moderate hardness, but locally it contains undesirable quantities of dissolved salt and iron. Water from the Permian rocks is generally extremely hard and of limited usefulness owing to its high content of chloride and sulfate ions.

The ground-water reservoir is recharged by precipitation in Sedgwick County and adjacent areas. Subsurface inflow and outflow are about balanced. Ground water discharge is principally by seepage into streams and by evaporation and transpiration, and withdrawal by wells has reached significant proportions.

Maps of Sedgwick County included in this report show the outcrop areas of the rocks, the lines of geologic cross sections, the configuration of the Permian bedrock surface, the shape and slope of the water table and location of wells, springs, and test holes for which records are given, generalized ground-water areas, thickness of sand and gravel deposits in the Arkansas Valley, the estimated transmissibility of the unconsolidated rocks in the Arkansas Valley, the distribution of chlorides in the ground water, the distribution of dissolved solids in the ground water, and areas where additional large ground-water supplies might be developed.

INTRODUCTION

PURPOSE AND SCOPE OF INVESTIGATION

This report is part of a continuing program of ground-water investigations in Kansas begun in 1937 by the U. S. Geological Survey and the State Geological Survey of Kansas in cooperation with the Environmental Health Services of the Kansas State Department of Health, the Division of Water Resources of the Kansas State Board of Agriculture, and the City of Wichita. The present status of the program is shown in Figure 1.

The investigation of the geology and ground-water resources of Sedgwick County was made to determine the availability and quality of ground water for domestic, stock, municipal, industrial, and irrigation use and to determine the geologic and hydrologic factors that control the occurrence of ground water in the County. Ground water is one of the County's principal natural resources, and though supplies are adequate in most parts of it at present withdrawal rates, there is a need for definitive information on the distribution, quantity, and quality of the available water supply.

This report presents many of the basic geologic and hydrologic data needed to evaluate the quantity, quality, and distribution of

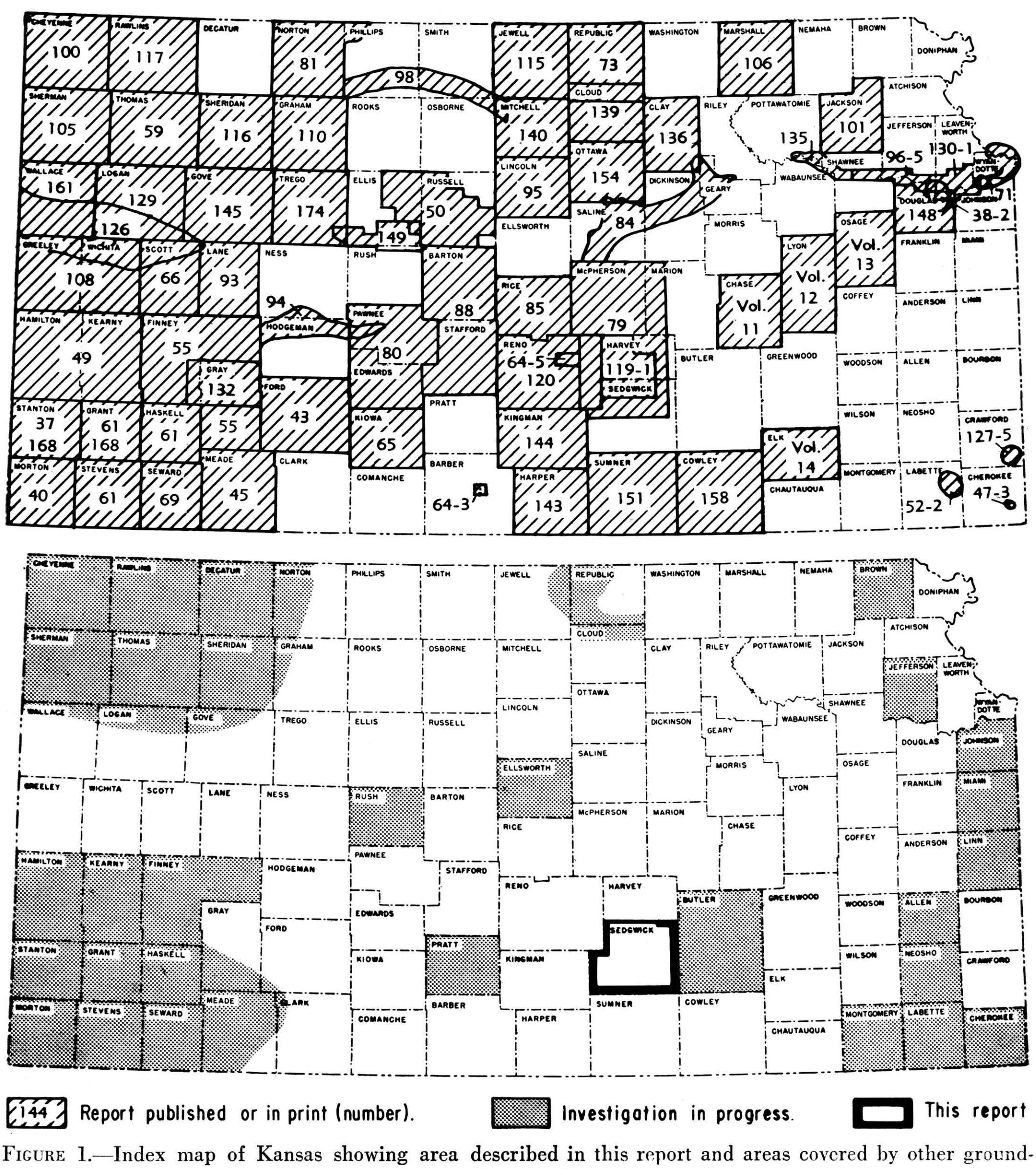


FIGURE 1.—Index map of Kansas showing area described in this report and areas covered by other ground-water reports.

ground water in the County and to enable sound engineering and administrative decisions to be made on the development and management of the resource.

LOCATION AND EXTENT OF AREA

Sedgwick County, in south-central Kansas, is bounded on the north by Harvey County, on the east by Butler County, on the south by Sumner County, and on the west by Kingman and Reno counties. The County contains 28 townships and has an area of about 1,000 square miles (Fig. 1).

PREVIOUS GEOLOGIC AND HYDROLOGIC WORK

Permian System.—Prosser (1897) discussed the history of geologic investigations of the Upper Permian rocks in Kansas and the stratigraphy of the Permian rocks in the Sedgwick County area. The lithologic character and stratigraphy of the Permian rocks have been described by Moore (1920), Bass (1929), Ver Wiebe (1937), Norton (1939), Swineford (1955), and Kulstad (1959).

Neogene System.—A Pleistocene age for the unconsolidated silt, sand, and gravel in Sedgwick County and adjacent areas (Udden, 1891; Harnly, 1895) was established in the late 1800's by means of vertebrate fossils which were found in them (Cope, 1889, 1895; Udden, 1891; Lindahl, 1892; Williston, 1897). These deposits were called "Sheridan beds" (Scott, 1897) or "*Equus* beds" and were described by Haworth and Beede (1897) and Beede (1898). Additional vertebrate and invertebrate fossils of Neogene age from the area were collected and described (Deere, 1908; Hay, 1917, 1924; Nininger, 1928; Harnly, 1934; Mohler, 1938; Frye and Hibbard, 1941; Hibbard, 1948, 1956; and Taylor, 1960). Little geologic work was done in the area after the work of Haworth and Beede in 1897-98 until cooperative ground-water investigations were started by the State and Federal Geological Surveys in 1937. Preliminary results of this cooperative work were reported by Frye (1939), Lohman and Frye (1940), Moore, *et al.* (1940), and Frye and Hibbard (1941). A comprehensive report on the geology and ground-water resources of a part of south-central Kansas included the northern part of Sedgwick County (Williams and Lohman, 1949). A report on the Pleistocene geology of Kansas (Frye and Leonard, 1952) discussed Sedgwick County and the surrounding area. The geology and ground-water resources of adjacent counties have been described by Bayne (1956, 1960, 1962), Lane (1960), and Walters (1961).

Hydrologic studies.—The quality and availability of water in Sedgwick County and adjacent areas were studied and reported on by Parker (1911). Meinzer (1914) prepared a preliminary report on the availability of ground water for irrigation in the vicinity of Wichita. Lohman, *et al.* (1942) reported on the availability of ground-water supplies for national defense industries in south-central Kansas and included a brief description of the ground-water resources of Sedgwick County. Williams and Lohman (1947) summarized the methods used in estimating the ground-water supply in the Wichita well-field area, which includes a part of Sedgwick County. A progress report (Stramel, 1956) on the hydrology of the *Equus*-beds area covered a part of the County. An investigation of salt-water contamination in Wichita was made by the Kansas State Board of Health (Jones, 1938). An observation-well program that included wells in Sedgwick County and adjacent areas was begun in 1937. Records of water-level observations made during the program were published annually by the U. S. Geological Survey (U. S. Geological Survey, 1938 to 1956) and since that time have been published annually by the State Geological Survey of Kansas (Fishel and Mason, 1957, 1958; Fishel, *et al.*, 1959; Fishel and Broeker, 1960; Broeker and Fishel, 1961, 1962).

METHODS OF INVESTIGATION

Field work for this report was begun in April 1957 and was completed in the 1959 field season. Intermittent field work has been carried on since that time as additional data from newly developed water supplies became available. Data were collected on 460 wells and springs in the County and these include the depth of the well, depth to water in the well, method and type of construction used, and the type and size of pumping equipment installed. Information concerning the yield of the well, adequacy of the supply, quality, and use of the water were obtained from the owners of the wells. Information on use of water in the County was obtained from well owners, when known, and from records of the Division of Water Resources of the State Board of Agriculture.

A total of 315 test holes were drilled during this investigation to determine the thickness and character of the water-bearing material. Of the test holes, 294 were drilled with a power auger and 21 with an hydraulic rotary drill. In addition to the test holes drilled for this investigation 17 drillers' logs and 23 sets of well cuttings from previous investigations (Williams and Lohman, 1949) were reexamined. Drillers' logs of 93 wells and 35 sets of drill cuttings were obtained from private contractors working in the area. Drill cuttings were examined and logged in the field and later examined microscopically in the office and then used to prepare lithologic strip logs. The location of all wells and test holes were determined by means of an automobile odometer, and the altitude of the land surface and measuring points at all sites were determined with a plane table and alidade.

The stage of the Arkansas River and its tributaries was measured at 43 points and the Ninnescah River and its tributaries at 14 points, to aid in preparation of the water-table contour map of the County (Pl. 1).

Samples of water were collected from 94 wells and test holes, 3 springs, and 10 surface streams for complete mineral analysis, and 130 samples for chloride analysis were collected from test holes. All water samples collected during this investigation were analyzed in the Water and Sewage Laboratory of the Kansas State Department of Health under the supervision of Howard A. Stoltenberg, Chief Chemist. In addition to the above water samples, analyses of all municipal and suburban water supplies in the County were obtained from the State Board of Health. Many complete and partial water analyses were obtained from Wichita and are so acknowledged.

The geology was mapped on aerial photographs obtained from the Agricultural Adjustment Administration, U. S. Department of Agriculture, or on topographic maps of the U. S. Geological Survey, and later transferred to a base map using a focalmatic projector for reduction.

The base map used was modified from one obtained from the Wichita—Sedgwick County Metropolitan Area Planning Commission. The roads shown on the base map were brought up-to-date from field observation. The drainage system was delineated from aerial photographs.

WELL-NUMBERING SYSTEM

The wells, test holes, springs, and surface-water sampling points reported here are numbered according to their location as determined by the General Land Office surveys and according to the following number-sequence: township, range, section, quarter section, quarter-quarter section, and quarter-quarter-quarter section (10-acre tract). The subdivisions of a section are designated *a, b, c,* or *d* in a counterclockwise direction starting in the northeast corner. All townships in the County are south of the base line, hence no letter designation of north or south is necessary; however, the sixth principal meridian passes through the County and range numbers are followed by "E" or "W" with respect to this line. In the text of this report, only the east ranges are designated by letter. An example of the well-numbering system is given in Figure 2.

ACKNOWLEDGMENTS

Appreciation is expressed to the many residents of the County who supplied information on their wells and to the officials of the cities who furnished information regarding the municipal water supplies. Special acknowledgment is made to R. H. Hess, Director of Water and Sewage Treatment, to O. K. Brandon, Water Production and Treatment Superintendent, and to G. J. Stramel, Hydrologist, all of the City of Wichita, for making available all geologic and hydrologic data on the Wichita water-supply system.

D. R. Soder, Vice President, Layne-Western Drilling Company, and personnel under his

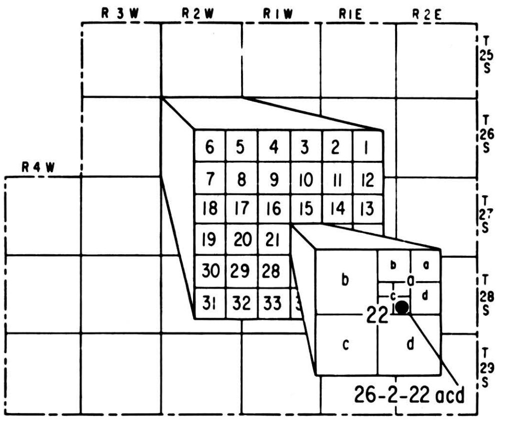


FIGURE 2.—Outline map of Sedgwick County, Kansas, illustrating the well-numbering system used in this report. Location is Section 22, Township 26 South, Range 2 West, showing the method of dividing sections into quarter sections, quarter-quarter sections, and quarter-quarter-quarter sections.

supervision were especially cooperative in providing logs of many wells and test holes drilled in the County and in permitting formation samples to be collected during drilling operations. Special thanks are extended to officials of the Kansas Gas and Electric Company and to the U. S. Air Force, who supplied much information and many logs of wells and test holes drilled for their respective organizations.

The manuscript of this report has been reviewed critically by several members of the Federal and State Geological Surveys; by R. V. Smrha, Chief Engineer, and H. L. Mackey, Engineer, Division of Water Resources, Kansas State Board of Agriculture; and by J. L. Mayes, Chief Engineer, and Bruce Latta, Geologist, Environmental Health Services, Kansas State Department of Health.

GEOGRAPHY

TOPOGRAPHY AND DRAINAGE

Sedgwick County, with the exception of the northeast corner, lies within the Arkansas River Lowlands section of the Central Lowland physiographic province (Schoewe, 1949). The location of the County with respect to other physiographic areas of the State is shown in Figure 3. The topography of the County is characterized by the extreme flatness of the broad Arkansas River valley and the gently rolling slopes rising to the uplands adjacent to the valley. The highest point in the County, about 1,540 feet above sea level, is on its west edge, about 5 miles southwest of Andale. The lowest point, about 1,220 feet above sea level, is where the Arkansas River leaves the County to the south.

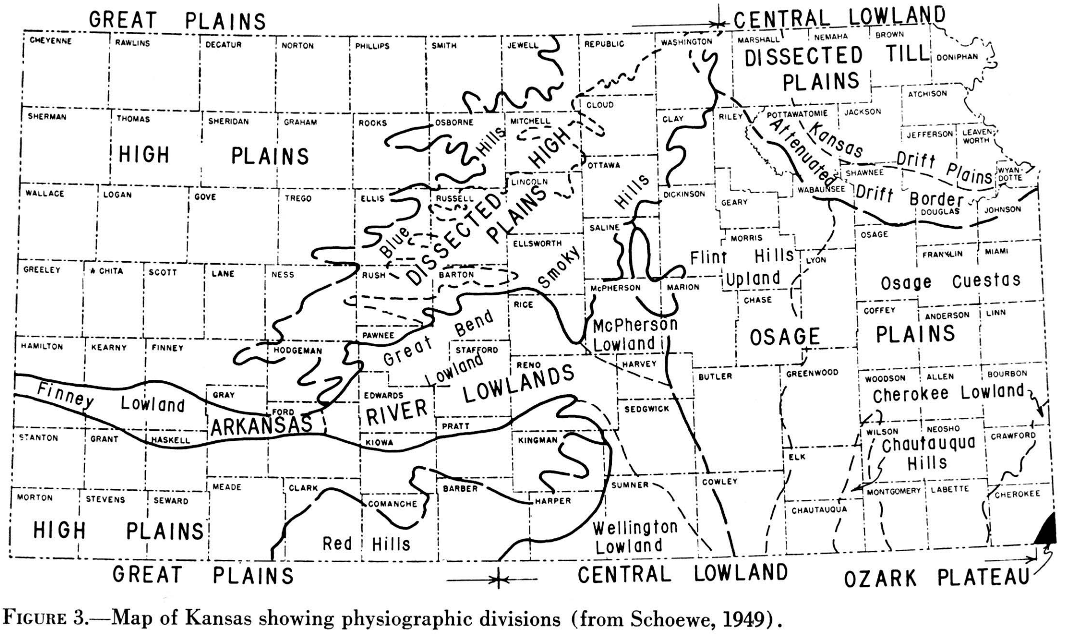


FIGURE 3.—Map of Kansas showing physiographic divisions (from Schoewe, 1949).

Modern 7½-minute topographic maps are available for all of the County except the southwestern one-third, for which 15-minute maps, reprinted in 1922 from earlier editions, are available (Fig. 4).

Drainage of the County is by way of the Arkansas River and its tributaries. The Arkansas River enters the County at the northwest corner, flows in a southeasterly direction to a point north of Wichita where it turns south, and leaves near the southeast corner. The Little Arkansas River enters the County near the center of the north boundary, flows east-southeast, and joins the Arkansas River at Wichita. South of the Arkansas River, drainage is by Big Slough, Cowskin Creek, the Ninnescah River, and all their tributaries. Big Slough and Cowskin Creek head in the northwestern part of the County and parallel the course of the Arkansas to join it near Derby and in northeast Sumner County, respectively. The North Fork and South Fork Ninnescah rivers join in the southwestern part of the County to form the Ninnescah River which flows to the southeast and leaves the County near Clearwater. A narrow strip along the eastern edge of the County, ranging in width from 6 miles at the north county line

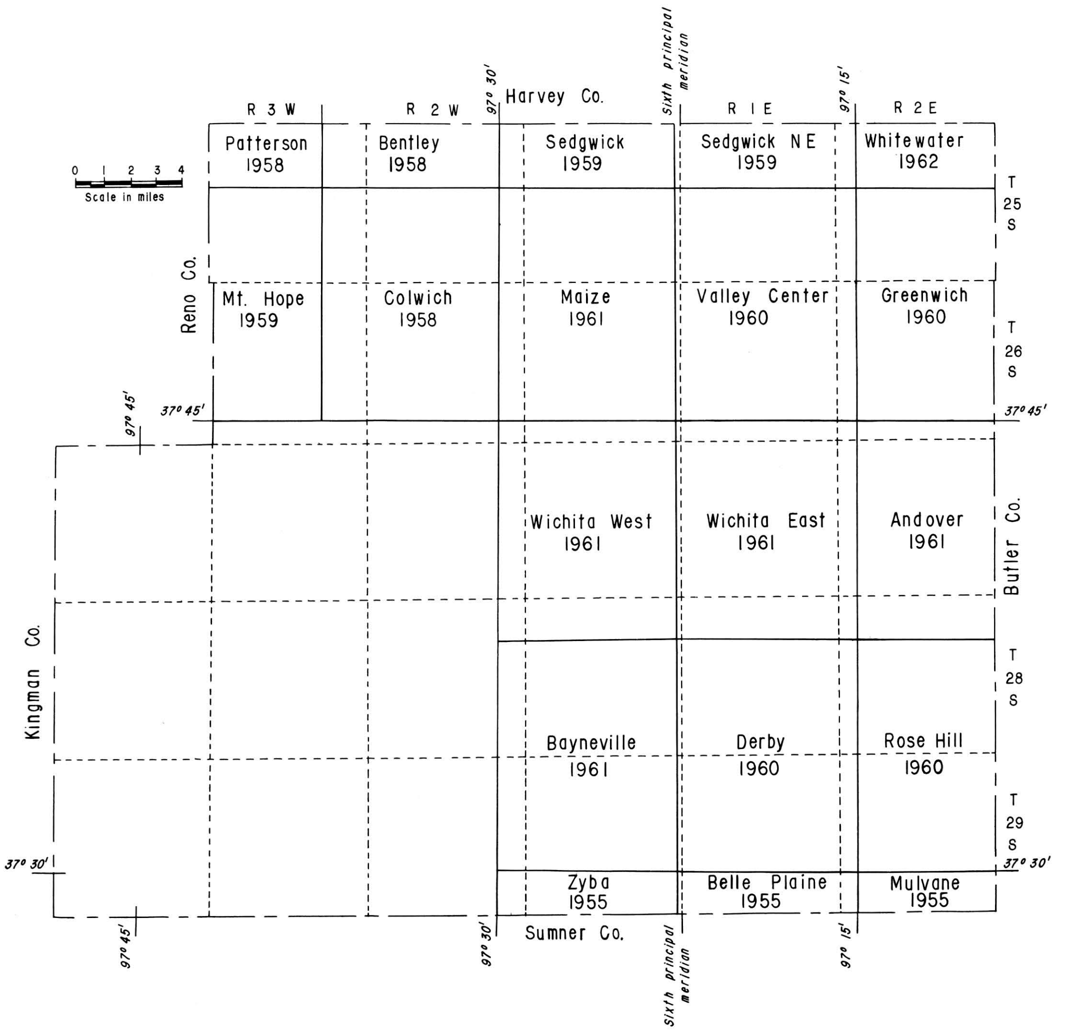


FIGURE 4.—Outline map of Sedgwick County, Kansas, showing areas covered (1963) by modern 7½-minute quadrangle topographic maps. Names are official quadrangle names of the U. S. Geological Survey and dates are those of last revision of sheets.

to 1 mile at the south county line, is drained by east-flowing tributaries of the Walnut River.

Much of the flat land adjacent to the Arkansas River is very poorly drained, and artificial drains have been installed on much of the agricultural land. An extensive flood diversion system has been constructed around Wichita to alleviate recurrent flooding of urban areas by the Little Arkansas and Arkansas rivers and their tributaries. (*See* Pl. 1.)

CLIMATE

The following climatic data were compiled from a 72-year record of the U. S. Weather Bureau for the Wichita station and are presented as an aid in interpreting and correlating water-level fluctuations due to weather phenomena.

Sedgwick County lies in the path of warm, moist air masses moving northward from the Gulf of Mexico that alternate with cold, dry air moving southward from the polar regions. Consequently, the weather is subject to frequent abrupt changes. Summers are generally hot, and strong southerly winds are common. Winters are usually mild, but snow flurries are common, with snow usually remaining on the ground for a short time only. The mean annual temperature at Wichita is 57° F and has ranged from –22° F on February 12, 1899, to 114° F on July 12, 1936. The average date of the first killing frost in the fall is October 31 and of the last killing frost in the spring April 6, with an average growing season of 208 days.

The normal annual precipitation in Wichita is 30.70 inches (period of record 1921-1950). Most of the precipitation falls during the growing season in the form of brief, heavy thunderstorms. The distribution of precipitation throughout the year and from year to year is quite irregular. The wettest year on record at Wichita was 1951 when 50.48 inches of precipitation were recorded. The driest year on record was 1956 when only 12.73 inches were recorded. The monthly precipitation, normal monthly precipitation, and cumulative departure from normal precipitation for the Wichita station are shown in Figure 5.

POPULATION

Sedgwick County contains about 15.7 percent of the State's population and has been an area of rapid growth in the past two decades. The County was organized in 1870 when it had a population of 1,095, and by 1960 it had a population of 343,231, according to records of the Bureau of the Census. About 91 percent of the County's population is classed as urban and most are inhabitants of Wichita. Table 1 gives the population of Wichita since the year 1880 as reported by the Bureau of the Census.

TABLE 1.—Population of Wichita.

Year	Population	Year	Population
1880	4,911	1930	111,110
1890	23,853	1940	114,966
1900	24,671	1950	168,279
1910	52,450	1960	254,698
1920	72,217		

AGRICULTURE

In 1959 there were about 2,150 farms in Sedgwick County with 376,190 acres in cropland. Small grain farming, raising of livestock, and dairying are the principal agricultural pursuits in the County. Wheat is the principal crop raised, and in 1959 the County ranked third in the State in wheat production, second in barley, and sixth in grain sorghums.

MINERAL RESOURCES

The mineral resources of Sedgwick County in addition to ground water include oil, gas, salt, gypsum, sand, and gravel. The distribution of the mineral resources of the County other than ground water is shown in Figure 6.

Oil and gas.—Oil was first discovered in the County in 1928 when a well 3,367 feet deep located in sec. 12, T 26 S, R 1 W was completed in the Viola Limestone of Middle Ordovician age. Development in the County has continued, and in 1960 oil and gas were being produced from 631 wells. The cumu-

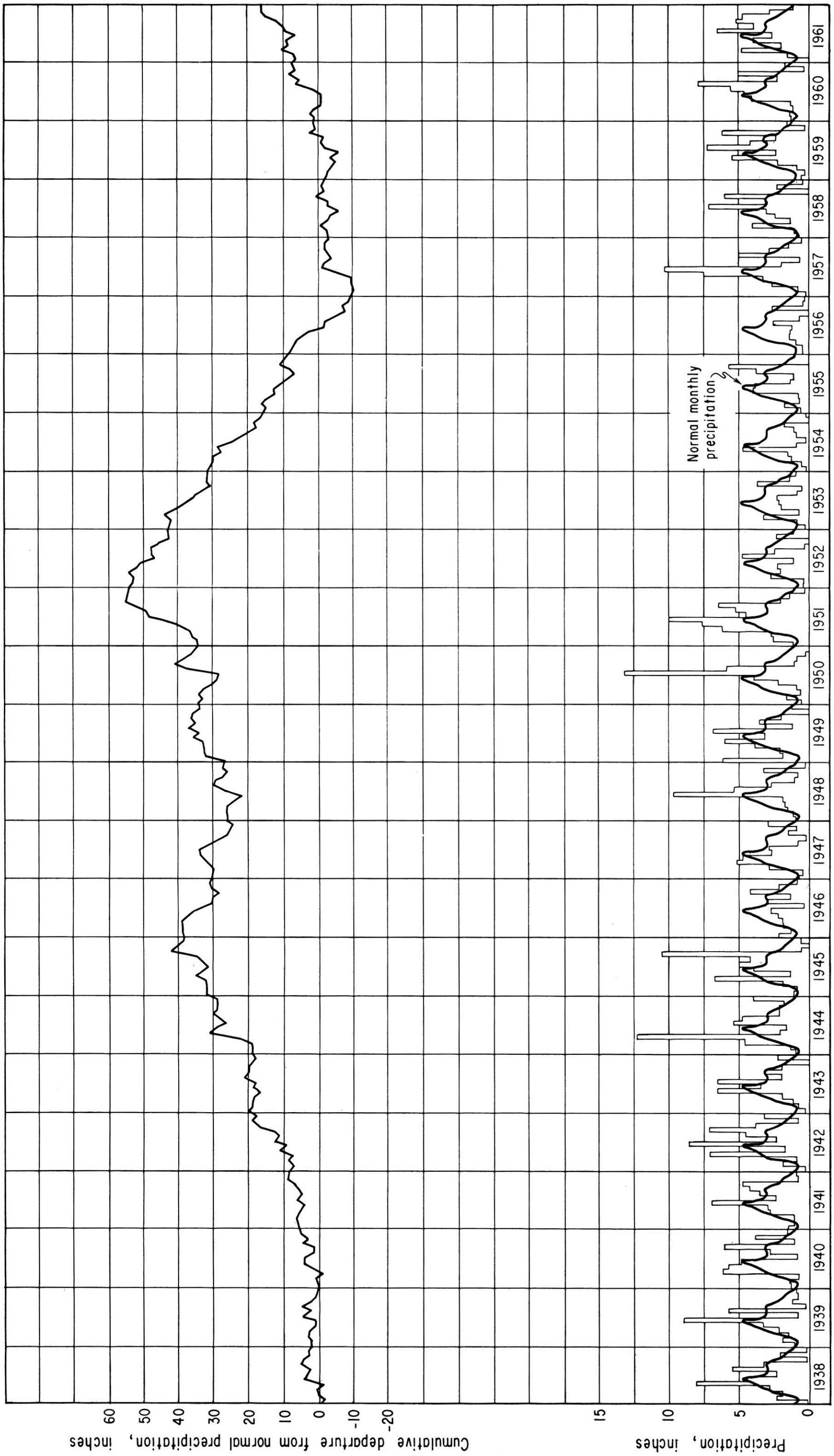


FIGURE 5.—Monthly precipitation, normal monthly precipitation, and cumulative departure from normal precipitation at Wichita, Kansas.

lative production in Sedgwick County has been 72.76 million barrels of oil and 2.26 billion cubic feet of gas. The cumulative production, number of wells, producing zones, and depth to producing zones for all fields in the County are given in annual reports by the Oil and Gas Division, State Geological Survey of Kansas.

Salt.—Salt deposits in the Wellington Formation of early Permian age underlie about the western half of Sedgwick County. The deposits range in thickness from a featheredge near the center of the County to about 300 feet along the western edge. They are interbedded with thin shales, anhydrite, and limestone. Salt is being extracted for use as a raw material by a chemical company near Wichita. Originally the salt was extracted as a natural brine from a solution zone along the eastern margin of the salt beds. Current salt production is from brine which is artificially produced by water injection into wells located in the southwestern part of the County.

Gypsum.—The presence of gypsum and anhydrite in the Wellington Formation east of the Arkansas River valley in Sedgwick County has been known for many years and was reported originally by Grimsley and Bailey (1899, p. 68). A gypsum deposit northeast of Mulvane was worked commercially from 1899 to 1901, but there has been no commercial production of gypsum in the County since that date. Little information is available concerning the extent and quality of the gypsum in the County, but it is thought to be present in much of the area east of the Arkansas Valley.

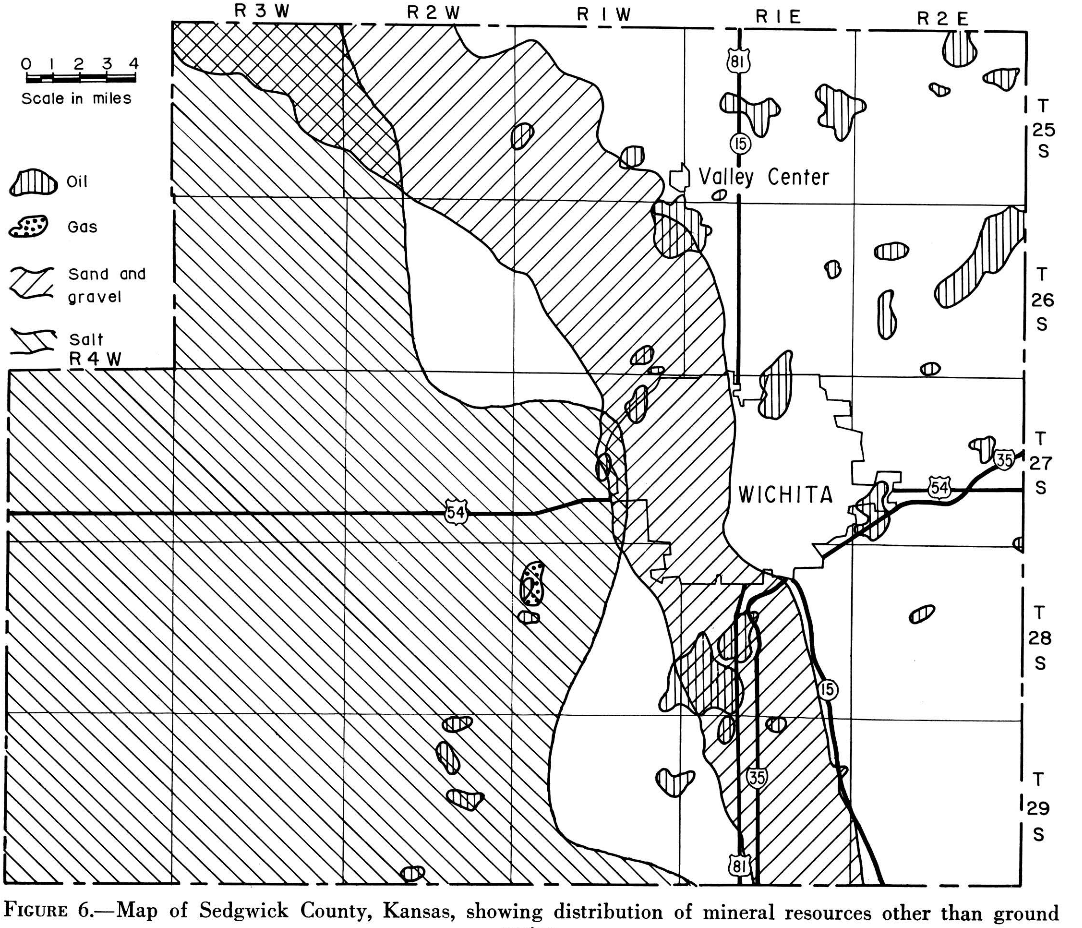


FIGURE 6.—Map of Sedgwick County, Kansas, showing distribution of mineral resources other than ground water.

Sand and gravel.—Sand and gravel deposits of Pleistocene age underlie about one-third of the County and have been worked commercially for many years. Most of the pits are located near the Arkansas and Little Arkansas rivers where the overburden is thin. The water table is shallow adjacent to the rivers, and the sand and gravel is quarried hydraulically. These are used extensively for concrete aggregate and as road metal. The location of active sand and gravel pits in the County is shown on Plate 1.

INDUSTRIES

The metropolitan area of Wichita is the most heavily industrialized area in the State and is the most important transportation and distribution center. The area is nationally prominent in the manufacture of military and private aircraft. Other important industries include the production and refining of petroleum products, chemical manufacture, the milling and storage of grain, meat packing, metal fabrication, and the manufacture of foundry products.

GENERAL GEOLOGY

SUMMARY OF STRATIGRAPHY [1]

The rocks that crop out in Sedgwick County are of sedimentary origin and range in age from Permian to Recent. Rock exposures in the County are poor owing to the nature of the rocks and the lack of topographic relief. Much of the interpretation presented in this report is based on subsurface data and knowledge of geology in nearby areas.

The oldest rocks cropping out in the County are a part of the Wellington Formation of the Cimmaronian Stage of the Permian System. The Wellington forms the bedrock surface in about the eastern two-thirds of the County and is exposed at the surface along streams east of the Arkansas River valley and along the southern edge of the County where it is not covered by younger rocks. The Ninnescah Shale, also of the Cimmaronian Stage, forms the bedrock surface in about the western one-third of the County. It conformably overlies the Wellington Formation in this area. Topographic relief in this part of the County is more pronounced, and the Ninnescah Shale is exposed at many places in the valley walls of the Ninnescah River and its tributaries. However, the Ninnescah Shale is covered by younger rocks in the uplands.

The unconsolidated deposits of south-central Kansas, particularly north of Sedgwick County, in McPherson, Harvey, and Reno counties, described by Haworth and Beede (1897) and by Beede (1898) were named the "McPherson *Equus* beds." On the old edition of the geologic map of Kansas (Moore and Landes, 1937) the unconsolidated rocks are shown as alluvium, Quaternary deposits, and, in the upland west of the Arkansas Valley, as Ogallala (Tertiary). Williams and Lohman (1949) and Hibbard (1952) recognized the presence of Tertiary deposits, which they called the Delmore Formation, in a part of McPherson County. All deposits of Pleistocene age there except the alluvium and dune sand were included in the McPherson Formation. Frye, Leonard, and Swineford (1956, p. 57) recognized that the Delmore Formation had a local source, but they included these beds within the Ash Hollow Member of the Ogallala Formation on the basis of fossil evidence. In subsequent geologic work in conjunction with ground-water investigations in Kansas members of the Federal and State Geological Surveys have established a sequence of Pleistocene events that can be correlated with the classic glacial section of the Mississippi Valley. The stratigraphic sequence thus established will be used in this report insofar as possible, although the term "*Equus* beds" is well established by local usage to include all unconsolidated water-bearing deposits in Sedgwick County and adjacent areas irrespective of age.

Unconsolidated deposits of clay, silt, sand, and gravel believed to be equivalent to a part of the Pliocene Ogallala Formation unconformably overlie Permian rocks in the basal part of the valley fill of the Arkansas River. Similar deposits are present as isolated remnants underlying loess on the uplands west of the Arkansas Valley. These rocks are known to be exposed at only one locality in the

1. The classification and nomenclature of the rock units used in this report are those of the State Geological Survey of Kansas and differ somewhat from those of the U. S. Geological Survey.

County—in a creek channel in the uplands north of the city of Goddard—but they have been penetrated by many water wells in the valley.

Deposits representing at least four major depositional cycles of the Pleistocene Series are present in Sedgwick County. These deposits range in age from the Early Pleistocene Holdrege Formation of the Nebraskan Stage to Recent alluvium and consist of unconsolidated clay, silt, sand, and gravel. The sediments of Pleistocene age unconformably overlie Neogene(?) and Permian rocks in the Arkansas Valley and Permian rocks in other stream valleys and the upland areas of the County.

A generalized section of the rocks significant to the occurrence of ground water in Sedgwick County is given in Table 2.

The areal geology of the County and the geologic cross sections of it are shown on Plates 1 and 2 respectively.

SUMMARY OF GEOLOGIC HISTORY

PALEOZOIC ERA

During Paleozoic time marine rocks of Cambrian and Ordovician age were deposited in central Kansas over igneous and metamorphic basement rocks. Rocks of Silurian and Devonian age probably were deposited over these older rocks and later removed by erosion after the pre-Mississippian uplift of the Ellis Arch (Central Kansas Arch). This arch extends from Chautauqua County on the Oklahoma line to the northwest through Ellis County. Rocks of Mississippian age were deposited over the arch and are unconformable upon Cambrian and Ordovician rocks. After deposition of Mississippian rocks, the area was again uplifted and part of the upper Mississippian rocks were deeply eroded. Following erosion, the area was again submerged, forming the Sedgwick Basin where Pennsylvanian and Permian rocks, about 3,500 feet thick, were deposited. After deposition of the Permian rocks, the area was again uplifted and subjected to a long period of erosion.

MESOZOIC ERA

Central Kansas, including Sedgwick County, was probably a land area during Triassic and Jurassic time, and no deposits of these periods are known in the area. Deposition was resumed in the area in Cretaceous time and Cretaceous rocks probably were deposited in Sedgwick County and removed by later erosion. No Cretaceous rocks are known to be present in the County, but they are present to the north in McPherson and Rice counties and to the west in Pratt and Stafford counties.

CENOZOIC ERA

Neogene Period

PLIOCENE EPOCH

Uplift in the Rocky Mountains and tilting of older rocks in adjacent areas at the close of the Mesozoic Era started a long period of erosion by streams which flowed eastward from the mountains across Kansas, at least as far as the western edge of the Flint Hills, where they turned to the south and flowed in a depression formed in a belt of easily eroded Permian shales. The presence of thick, readily soluble salt beds in the Wellington Formation of Permian age was the controlling factor in the location of the major Neogene streams in Sedgwick and adjacent counties and in later deposition of sediments by these streams. The maximum eastward extent of salt beds in the Wellington is not known, but it was probably not farther east than the present city of Wichita. The salt beds probably did not crop out owing to their solubility, but must have been close to the surface over a large area, and Neogene streams cutting into the salt would have rapidly widened or deepened their valleys. The salt beds thicken and dip to the west, and the streams that were actively dissolving the salt would have shifted to the west at a decreasing rate as the salt beds became more deeply buried. Circulating ground water as well as stream action must have played an important role in development of the large north-south-trending depressional area in the Wellington

TABLE 2.—Generalized section of geologic formations * in Sedgwick County, Kansas, and their water-bearing properties.

System	Series	Subseries	Stratigraphic units used in this report	Maximum thickness, feet	Physical character	Water supply
Neogene	Pleistocene	Upper Pleistocene	Dune sand (Recent)	5	Composed of fine to medium, silty sand.	Lies above the water table and thus yields no water to wells.
			Alluvium and terrace deposits (Wisconsinan to Recent)	45	Composed of fine to coarse sand and fine to very coarse arkosic gravel containing only minor amounts of silt and clay that grade upward into clayey silt. Clay balls up to one foot in diameter are common in the sand and gravel.	Comprises the most widely used aquifer in the County and yields large supplies of very hard water to many wells. Well yields up to 2,000 gpm can be developed locally. Adjacent to the Arkansas River the water is too highly mineralized for many uses.
			Colluvium (Illinoisan to Recent)	30	A heterogeneous mixture of silt, clay, sand, gravel, and bedrock fragments deposited by slope processes.	Generally above the water table and thus yields no water to wells. Where deposits are thick and contain sand and gravel lenses, wells yielding a few gpm may be possible but would be subject to failure in dry years.
			Loess (Illinoisan to Recent)	74	Wind-deposited tan to pink-tan, calcareous silt, containing zones of caliche nodules and some sandy zones.	Generally above water table, but locally the basal part is saturated and sandy zones may yield some water to wells.
			Terrace deposits (Illinoisan)	75	Composed of fine to coarse sand and fine to coarse arkosic gravel that grades upward into sandy silt. Sand and gravel beds locally contain silt and clay lenses, and clay balls up to one foot in diameter are common.	Well yields of 500 gpm of good quality water are generally available from the deposits, and locally yields up to 1,000 gpm can be obtained.
		Lower Pleistocene	Undifferentiated deposits (Nebraskan and Kansan)	157	Composed of light tan to light gray, commonly sandy, silt and clay, fine to coarse sand, and fine to coarse arkosic gravel. Locally contains a lenticular bed of volcanic ash, the Pearlette ash bed of late Kansan age.	Yield large quantities of good quality water to wells in the Arkansas Valley that are screened in multiple porous zones and penetrate the complete section of unconsolidated rocks. The water is highly mineralized locally near the Arkansas River. Where present in the uplands west of the Arkansas Valley, well yields up to 50 gpm are possible locally.
	Pliocene		Ogallala(?) Formation	150 ±	Composed of lenticular beds of calcareous, gray to pink-tan silt and clay, fine to coarse sand, and fine to coarse gravel. The sediments reflect two sources; arkosic sand and gravel beds derived from the west are interfingered in the northern part of the County with sand and gravel beds composed of gray to tan quartz and ironstone derived from Cretaceous rocks to the north. In subsurface only.	Contributes large supplies of good quality water to many municipal, irrigation, and industrial wells screened in multiple porous zones and penetrates the complete section of unconsolidated rocks.
Permian	Lower Permian		Ninnescah Shale	175 ±	Composed of alternating beds of brownish-red silty shale and siltstone, and a few thin beds of gray-green silty shale in lower part. Some gypsum is present as thin, cross-cutting and intersecting vein fillings.	Yields small quantities of water to many stock and domestic wells in the western part of the County. Water obtained from the weathered zone in the formation is generally of good quality. Water from deeper zones is generally highly mineralized but usable.
			Wellington Formation	550 ±	Calcareous gray and blue shale containing several thin beds of impure limestone and thin beds of gypsum and anhydrite. Some beds of maroon and gray-green shale near top of Formation. The thick Hutchinson Salt Member is present near the middle of the Formation in the western part of the County.	Yields small quantities of highly mineralized water to many stock and domestic wells east of the Arkansas River valley and in south-central part of County. Moderately large water supplies of as much as 350 gpm are available from solution zones in gypsum beds near east County line. The water is highly mineralized but usable.

* The classification is that of the State Geological Survey of Kansas.

Formation, for a closed depression about 300 square miles in area is present on the buried surface of the Wellington in parts of Sedgwick, Reno, and Harvey counties. The southern end of this closed depression in Sedgwick County corresponds with the 1,200-foot contour on Plate 3 which closes on both the north and south sides of a topographic saddle on the bedrock surface southwest of Wichita. Solution of salt by ground water with resultant settling of the overlying rocks is still taking place along the western edge of this broad depressional area as is attested to by a line of sinks that extends from near McPherson on the north to just northwest of Wichita. The sinks in Sedgwick County are shown as small lakes on the base maps of Plates 1 and 3.

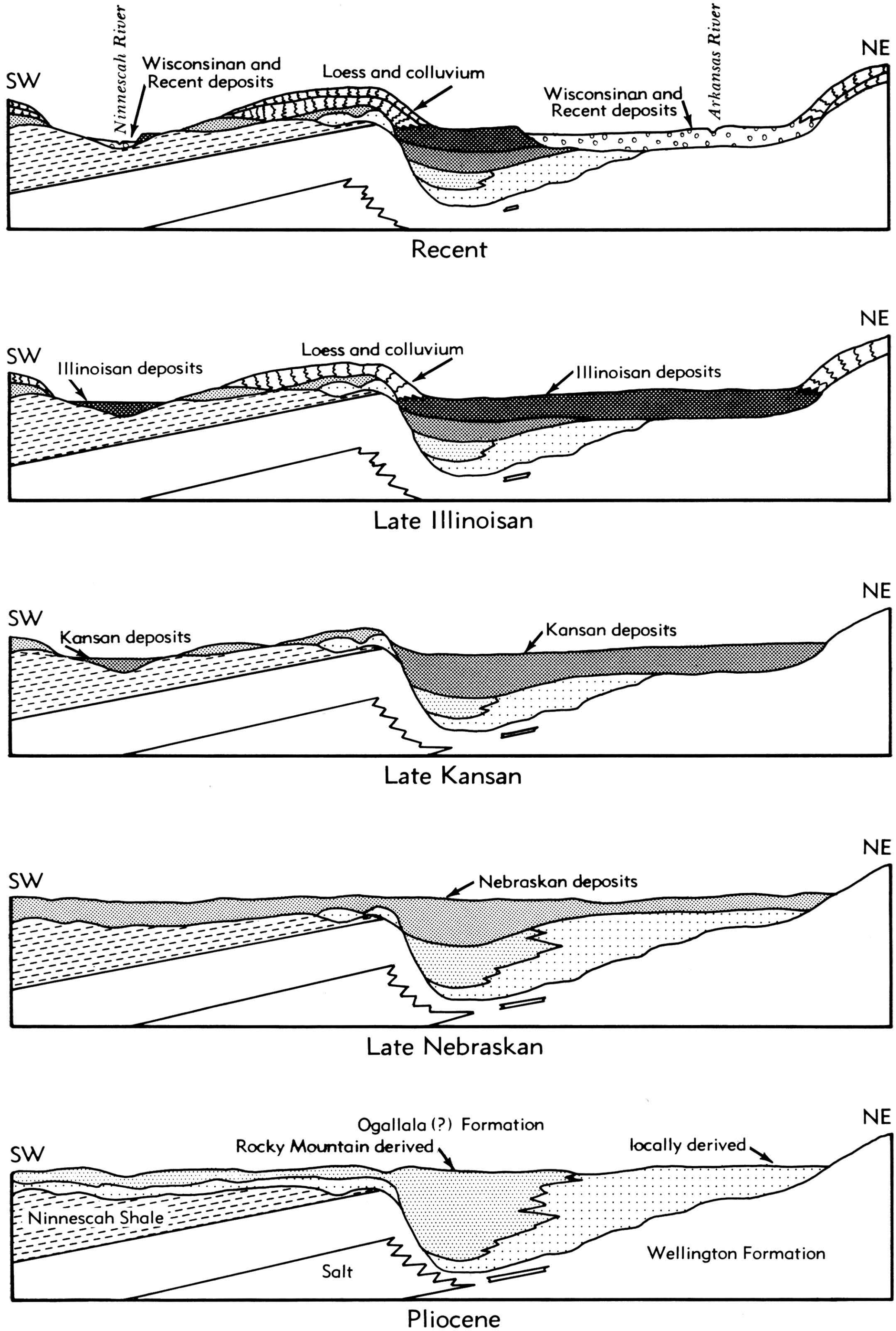
The ancestral Arkansas River was the master stream in the area, flowing into Sedgwick County from the northwest. It probably integrated many of the streams flowing from the Rocky Mountains into the southern half of Kansas. One or more streams apparently not connected with drainage from the west were eroding the Permian and Cretaceous rocks to the north of Sedgwick County and joined the master stream northwest of Wichita.

Erosion predominated over deposition during the Neogene until the deposition of the Pliocene Series. Available evidence, although meager and in part deductive, indicates that the large depressional area in the Wellington Formation was completely filled with Pliocene sediments and formed a nearly continuous alluvial plain that extended from eastern Sedgwick County westward over all of western Kansas. The Pliocene Epoch ended with renewed but minor uplift in the Rocky Mountain area. A sketch of the geologic development of Sedgwick County in Neogene time is shown in Figure 7.

PLEISTOCENE EPOCH

The minor uplift in the Rocky Mountain area that marked the end of the Pliocene Epoch was followed by a gradual climatic cooling in North America that resulted in the formation of great continental ice sheets and mountain glaciers that distinguish the Pleistocene Epoch. Four major ice sheets invaded the northern Midcontinent Region, two advancing as far south as northeastern Kansas. The climatic changes accompanying the advance and retreat of the ice affected areas far beyond the ice fronts, causing changes in stream regimen and major drainage changes in some areas. Throughout Kansas, in areas remote from the ice, events associated with each major glaciation seem to have followed a cyclic pattern that differed only in detail. A cooler and more moist climate than prevails in Kansas today preceded the accumulation and advance of each major ice sheet, and streams that were at or near base level were rejuvenated. A period of downcutting in stream valleys was followed by deposition of coarse alluvium that graded into finer material as the ice retreated and the climate became warmer and dryer. Eolian deposition was probably important during the late phase of each glacial cycle, but only deposits of late Pleistocene loess can be distinguished today. Each major glacial advance and retreat was followed by an interglacial period in which the climate was not much different than that of Kansas today, and soil formation was the dominant geologic process.

Early Pleistocene.—Early Pleistocene time in Kansas included the time and events associated with the first two continental glaciations and the interglacial periods that followed each. Events associated with the Nebraskan Glaciation and the Aftonian Interglaciation in Sedgwick County are not well defined, and most of the sediments deposited at this time have been removed by later erosion or are buried under younger sediments. However, much can be deduced regarding the deposits of Nebraskan streams from evidence available in adjacent areas and from surface and subsurface data within the County. Sediments of late Nebraskan to Aftonian age (Lane, 1960, Taylor, 1960, Hibbard, 1956) form the highest topographic elements in southeastern and northeastern Kingman County. These are remnants of the fill in an extensive southeast-trending valley system cut in Permian rocks (cross section E-E′, Pl. 2). Sediments of similar character and topographic position underlie late Pleistocene loess high on the flanks of the bedrock ridge forming the divide between the Arkansas and Ninnescah River


SW
NE
Ninnescah River
Wisconsinan and Recent deposits
Loess and colluvium
Wisconsinan and Recent deposits
Arkansas River
Recent
SW
NE
Illinoisan deposits
Loess and colluvium
Illinoisan deposits
Late Illinoisan
SW
NE
Kansan deposits
Kansan deposits
Late Kansan
SW
NE
Nebraskan deposits
Late Nebraskan
SW
NE
Ogallala (?) Formation
Rocky Mountain derived
locally derived
Ninnescah Shale
Salt
Wellington Formation
Pliocene

valleys. The master stream in the area must have flowed along the west edge of the broad depressional area now forming the Arkansas Valley but at a level only slightly below the present upland surface. Scattered remnants of a high-level terrace of presumed Nebraskan and or Aftonian age along the Smoky Hill Valley in western and central Kansas (Frye, Leonard, and Hibbard, 1943) strongly suggest the presence of a major stream in that area. This stream may have turned south along the west edge of the broad depressional area in McPherson and Harvey counties to join the master stream in northwestern Sedgwick County. If this indirect evidence of earliest Pleistocene streams flowing at altitudes near those of the present uplands is correct, then the large depressional area in Sedgwick, Harvey, McPherson, and Reno counties must have been filled to near the present upland level prior to the beginning of Pleistocene time.

Events associated with the second continental glaciation (the Kansan) and the Yarmouthian Interglacial Stage that followed, are much better known in most of the State, owing to better preservation of the sediments deposited during this time, than are the events of the first continental glaciation (the Nebraskan) and the Aftonian Interglacial Stage. The deposition of the lenticular, petrographically distinct Pearlette ash bed in latest Kansan time provides a useful stratigraphic marker.

During Kansan and Yarmouthian time a major stream flowed southward through the depressional area in Sedgwick County. The master stream was located west of the present Arkansas Valley and probably meandered over a wide area during a part of its life. This stream undoubtedly extended well into western Kansas near the course of the present Arkansas River and was joined in north-central Sedgwick County by a major tributary that carried the ancestral Smoky Hill River drainage southward along the west side of the depressional area in McPherson and Harvey counties. Drainage from the Rocky Mountains probably reached into south-central Kansas during the Kansan glacial cycle, and during the depositional phase that followed spread a thick sheet of coarse alluvium that forms the high plains surface over much of the area west of central Kingman and Reno counties and south of the present Arkansas River. The nature of the streams that deposited this material is not clear but may well have been a distributary system flowing on a gently eastward-sloping plain underlain by older sediments. The large stream flowing through Sedgwick County and adjacent areas to the north and west probably integrated this drainage and flowed out of Kansas near the present course of the Arkansas River.

The gradient of the large stream flowing through Sedgwick County was less than that of the present Arkansas River. The sediments that filled this stream valley during late Kansan time are buried under younger sediments in Sedgwick County and to the north and northwest, but rise southward with respect to the present Arkansas River. In Sumner County to the south and where the Arkansas River leaves the State in Cowley County remnants of these sediments are perched well above the present flood plain.

Late Pleistocene.—Late Pleistocene time in Kansas included events associated with the last two major glaciations in North America, from the Illinoisan and Wisconsinan to the Recent. The Illinoisan ice sheet reached no farther south than southeastern Iowa and the Wisconsinan only to central Iowa, but the climatic changes accompanying these ice invasions affected the regimen of Kansas streams. The Illinoisan Glaciation was followed by the Sangamon Interglacial Stage. Wisconsinan time included two major ice advances, but events associated with each advance cannot be distinguished in Sedgwick County. Recent time includes the time since the Wisconsinan ice sheet ceased to be an active force in modifying the climate of the area.

During Illinoisan time a major stream once again flowed in the depressional area in Sedgwick County. Early in Illinoisan time a number of major drainage changes occurred in

FIGURE 7.—Generalized cross section showing geologic development during Neogene time along the Arkansas and Ninnescah river valleys, Sedgwick County, Kansas. (Horizontal scale, approximately 5 miles per inch.)

the area, and these had a profound effect upon this stream, establishing it as a through drainage from the Rocky Mountains. The tributary that had carried the ancestral Smoky Hill River drainage southward into Sedgwick County was captured by a tributary to the Kansas River probably near Lindsborg in McPherson County. Streams flowing from the mountains into south-central Kansas apparently were not strongly developed and shifted laterally over the high plains surface or discharged through a widespread distributary system. Headward erosion by the Arkansas River during Illinoisan time probably integrated this weakly developed stream system, forming a through drainage system from the mountains near the present course of the Arkansas River. Sediments deposited by this stream during late Illinoisan and Sangamonian time underlie a broad terrace surface west of the Arkansas River in Sedgwick County. The present gradient of the Arkansas River through the County is greater than that of the last Illinoisan or Sangamonian stream to occupy the valley, and the surface of the terrace rises topographically with respect to the river from about 10 feet above the river where it enters the northwest corner of the County to about 40 feet where it leaves the County.

A minor drainage change affecting the Ninnescah River probably took place during Illinoisan time. A small abandoned and partially filled valley crosses the extreme southwestern corner of Sedgwick County and connects the South Fork Ninnescah Valley in Kingman County with Slate Creek valley in Sumner County. The topographic position of this abandoned valley (Pl. 2, section H-H′) with respect to the present Ninnescah River and Slate Creek valleys strongly suggests the capture of the headwaters of Slate Creek by a tributary of the Ninnescah River in Illinoisan time. The point of capture is thought to have been near the junction of the South Fork Ninnescah River and Smoots Creek in eastern Kingman County (Lane, 1960). Locally along the Ninnescah River in southern Sedgwick County sediments correlated with Illinoisan and Sangamonian deposition underlie terrace remnants well above the present river flood plain. These terrace remnants are particularly well preserved near the town of Clearwater.

Events associated with Wisconsian time in Kansas followed closely the pattern of previous glacial cycles. Most streams in Kansas experienced two periods of erosion, each followed by deposition. In many streams in the State, sediments deposited at this time underlie terraces at two distinct levels (Frye and Leonard, 1952). The depositional sequence in Sedgwick County was probably the same as in much of Kansas, but sheet erosion and slope processes in Recent time have obliterated most surface expression, and sediments associated with the Wisconsinan depositional cycles together with Recent sediments are considered as a single unit in this report. Sediments associated with Wisconsinan and Recent deposition along the Arkansas River underlie a broad, extremely flat surface adjacent to the river. This surface attains a maximum width in the County of about 9 miles. The slope of this broad depositional plain is about the same as that of the present river and is graded very slightly toward it. The Arkansas River meandered widely over this surface during Wisconsinan time, and old meander scars are discernable on aerial photographs as far as 7 miles from the present river channel, but these are not easily seen from the ground.

The Little Arkansas River was probably established in its present course in Sedgwick County during Recent time. Old meander scars on the Wisconsinan terrace surface associated with this stream show that the mouth of the river has changed positions many times. From the mouth of the river north to about Halstead, in Harvey County, the river channel is entrenched only slightly below the terrace surface and has developed no valley. Northward from this area the land surface rises and the river has eroded a narrow valley that is well below the general land surface.

Eolian activity was widespread in Late Pleistocene time, and in parts of Kansas widespread deposition of loess took place late in each glacial cycle and probably into the early part of the following interglacial period. Loess was probably deposited over all of

Sedgwick County. It is thickest on the slopes and uplands bordering the Arkansas River valley and thins away from the valley. Much of the loess has been removed by erosion along the small creek valleys in eastern and southwestern Sedgwick County.

Sand dunes were formed in some areas of the County in Late Pleistocene and Recent time. Many small, rounded dunes were formerly present on the flood plain of the Arkansas River both north and south of Wichita. Agricultural activity and later urban development in these areas have obliterated these dunes except in a few places. Only two small dune tracts are now present in the County, one southeast and one northwest of the town of Bentley. These dunes are subdued in form and are planted to crops in most years.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

PALEOZOIC ROCKS

Permian System—Lower Permian Series

SUMNER GROUP

The Permian rocks of Sedgwick County are a part of the Sumner Group of the Lower Permian Series. The rocks of the Sumner Group that crop out at the surface include parts of the Wellington Formation and the Ninnescah Shale. The Wellington and Ninnescah are covered by younger sediments in most of the County and surface exposures are scarce. However, they are easily recognized in the subsurface by their distinctive color, the Wellington being gray to grayish-green and the Ninnescah reddish-brown. The distribution of the Permian rocks in the County is shown on the geologic map (Pl. 1).

Wellington Formation

Character.—The lithology of the Wellington Formation has been described by Bass (1929), Ver Wiebe (1937), Norton (1939), and Swineford (1955). The part of the Wellington that crops out in Sedgwick County consists mostly of calcareous gray and blue-gray shale containing several thin beds of impure limestone, and thin beds of gypsum and anhydrite. Some beds of maroon and gray-green shale occur near the top of the Formation. The gypsum beds in the Wellington are most common in the lower part and crop out at a few places east of the Arkansas Valley. Near the surface, solution of the gypsum has taken place, and the Wellington is characterized by local deformation that has resulted from differential compaction in solution areas. These small-scale structures are best exposed in cuts along the Kansas Turnpike northeast of Wichita. A thick salt bed containing some shale and anhydrite is present in the subsurface near the middle of the Wellington Formation. The salt has been removed by solution in the area now occupied by the Arkansas Valley and to the east. However, it underlies the area west of the valley and attains a thickness of about 350 feet near the west county line (Kulstad, 1959). The Milan Dolomite Member (Norton, 1937) forms the top of the Wellington Formation in southern Kansas, and it is exposed in a creek bank in the center of the west side sec. 9, T 28 S, R 3 W. At the stratigraphic position of the Milan the gray color of the Wellington gives way to the red-brown of the overlying Ninnescah Shale. The color change from gray to red is considered by most workers to mark the top of the Wellington Formation.

Distribution and thickness.—The Wellington Formation forms the bedrock under about the eastern four-fifths of the County and underlies the Ninnescah Shale in the remainder of the County. Where the Wellington Formation is near the surface east of the Arkansas Valley, the relatively soft shale and evaporites yield easily to erosion, and as a result the topography is gently rolling and rounded. In most of the County younger sediments cover the Wellington and surface exposures are scarce. The Formation ranges in thickness from about 80 feet along the east county line to about 550 feet along the west county line where the full thickness of the salt bed is present.

Water Supply.—The Wellington Formation is the only source of usable ground water in that part of the area where it is present and is not overlain by younger water-bearing beds.

Most domestic and stock wells in the area east of the Arkansas Valley and many wells in the south-central part of the County derive water from the Formation. The quantity and quality of the water available differs with both the location and the method of construction of a well. In most cases the water is very hard or has other objectionable properties. Large-diameter dug wells finished in the weathered zone of the Wellington are common east of the Arkansas River. These wells are subject to failure during prolonged droughts, and when water is available from them, a high nitrate content in the water is commonly a problem. Where gypsum and anhydrite beds are present at shallow depths along parts of the east county line, solution has been active, and the Wellington contains water under artesian pressure. Moderately large well yields are obtainable from this zone (see wells 27-2E-13cccl, 2, 3, 4, Table 13), and a few large springs issue from it where exposed along small streams. The water from the evaporite zone is quite hard and has a high sulfate content, but it is used for domestic and stock purposes. The westward extent of the evaporite solution zone in the lower part of the Wellington is not known. However, meager information obtained from interviews with local residents indicates that as the evaporites become more deeply buried to the west, solution has been less active, and enough salt is present in parts of the shale to make the water from this zone unusable.

West of the Arkansas Valley where thick salt beds near the middle of the Wellington are present in the subsurface, an active solution zone along the east margin of the salt contains saturated brine. The extent of the solution zone or the quantity of brine available are not known, but in the past the brine has been used by one company as a raw material for the manufacture of chemicals.

Ninnescah Shale

Character. — The Ninnescah Shale was named by Norton (1939) from exposures on the North and South Forks of the Ninnescah River in Reno and Kingman counties. The formation conformably overlies the Wellington Formation and is composed of alternating beds of brownish-red silty shale and siltstone. A few thin beds of gray-green silty shale occur in the lower part. Some gypsum is present in the Ninnescah and occurs as thin intersecting veins that were deposited secondarily in the red and green shales.

Distribution and thickness. — The Ninnescah Shale forms the bedrock under about the western one-fifth of the County. In a part of its outcrop area the Ninnescah is covered by younger sediments, but it is exposed in the valley walls of North Fork Ninnescah River and its tributaries. The formation ranges in thickness from a featheredge along the eastern edge of the outcrop area to about 175 feet along parts of the west county line.

Water supply.—The Ninnescah Shale yields water to many stock and domestic wells in its outcrop area where it is not overlain by younger water-bearing beds. Large yields from wells are not known to be available from the formation. The water-bearing properties of the formation are not well understood, but most of its water is probably obtained from the weathered surface zone. There is some evidence, though unconfirmed, that solution openings or fractures containing water occur at depths of 100 feet or more in the Ninnescah. The water from the weathered part of the Ninnescah is of generally good chemical quality although it commonly has large concentrations of nitrate. Water from deeper parts of the formation, though usuable, usually contains a large concentration of dissolved solids with sulfate being the most objectionable constituent.

CENOZOIC ROCKS

Neogene System

PLIOCENE SERIES

Ogallala(?) Formation

Rocks believed to be equivalent in age to a part of the Ogallala Formation underlie younger sediments in much of the broad depressional area now occupied by the Arkansas River valley. These older sediments are best preserved in the deeper parts of the depression to the north and northwest of Wichita and are thought to be the remnants of much more extensive Neogene valley fill deposits.

The presence of pre-Pleistocene sediments in the fill of the depressional area in McPherson County was recognized by Lohman and Frye (1940), Frye and Hibbard (1941), Hibbard (1948) and Williams and Lohman (1949). The name "Delmore Formation" was proposed by Williams and Lohman (1949) for lithologically distinct sediments in McPherson County where they crop out at the surface. They did not recognize pre-Pleistocene sediments in northern Sedgwick County and considered all the unconsolidated sediments in the area to be of Pleistocene or Recent age and assigned them either to their all-inclusive McPherson Formation or to the Recent alluvium. Frye, Leonard, and Swineford (1956) correlated the sediments of McPherson County with the Ash Hollow Member of the Ogallala Formation on the basis of the contained fossils, recognizing that they were in part derived from sources different than the Ogallala of western Kansas. More recent work in Sedgwick and adjacent counties, including extensive test drilling and a restudy of formation samples from earlier work, has more clearly defined the nature and development of the extensive depressional area and the sediments filling it.

Character.—The Ogallala(?) Formation is composed of calcareous, gray to pink-tan silt and clay, fine to coarse sand, and fine to coarse gravel. These deposits strongly reflect two different sources of the sediments. Calcium carbonate is common in the silt and clay beds in the form of nodules, root tubes, thin layers, and small crevice fillings. The sand and gravel beds are poorly sorted and vary in thickness within short distances owing to the uneven bedrock floor and the interbedded silt and clay layers. The sand and gravel is composed dominantly of well-worn grains and pebbles of quartz, feldspar, some mica, and other dark minerals. The sand and gravel that has a definite aspect of Rocky Mountain derivation is interbedded in parts of the Arkansas Valley with sand and gravel derived from Cretaceous and Permian rocks to the north and east. The sand and gravel derived from the Rocky Mountains generally is pink. The locally derived deposits are finer and are composed almost entirely of tan and gray quartz and contain pebbles of ironstone, chert, and shale. The Ogallala(?) sand and gravel is finer, contains more silt, and is less permeable than that of overlying younger beds. Northward from the Arkansas River the percentage of granitic gravels in the Formation becomes less, and in most of Harvey and McPherson counties granitic gravels are rare or entirely absent.

Silt and clay beds in the Ogallala(?) Formation similarly show a difference in character and distribution that is quite marked. In the Arkansas Valley the fine clastics are predominantly sandy silt, containing some clay, that is pink-tan to buff colored. Northward from the Arkansas River the silt and clay beds are less sandy, contain a very high percentage of clay, and are predominantly light to dark gray. In Harvey and McPherson counties fine clastics compose a larger part of the Formation, and this is probably a reflection of the type of material available in the source area of the depositing streams.

Origin.—The rocks comprising the Ogallala(?) Formation were deposited by streams having two distinct sources of sediment. The stream judged to be the master stream entered Sedgwick County near the northwest corner and followed the depression in the bedrock surface that lies to the south and west of the present Arkansas River (see Pl. 3). The course of this stream to the west of Sedgwick County is not known with certainty, but it probably was near the present course of the Arkansas River with its headwater region extending into western Kansas near the present Pawnee and Walnut River valleys. Such a stream would have provided an outlet to the east and south for some of the heavily laden Neogene streams carrying sediment eastward from the Rocky Mountains. This stream was joined in northern Sedgwick County by one or more streams draining the broad depressional area in Harvey and McPherson counties.

These northern streams and their tributaries were actively eroding the Cretaceous and Permian rocks in the uplands to the north, east, and west and depositing sediments in the lower parts of the area. The sediments deposited strongly reflect their source area, and the sand and gravel were obviously derived from the Kiowa and Dakota formations that crop out to the north of the area. Sharks' teeth and fragments of *Inoceramus* derived from the Cretaceous rocks can be found in the sand and gravel obtained from well and test-hole cuttings. The silt and clay derived from the Cretaceous and Permian rocks bear a marked resemblance to the black and gray shale of the Kiowa, Dakota, and Wellington formations in the surrounding areas. The absence of granitic gravels indicate that the streams did not carry drainage from the west and that Pliocene streams crossing northern Kansas found outlets to the east or north.

Streams transporting sediments derived from the west and those derived locally joined in northern Sedgwick County, where two lithologically distinct types of sediment can be seen to interfinger. This contrast in lithology can easily be seen in the cuttings from the wells and test holes.

Distribution and thickness. — The Ogallala(?) Formation does not crop out in Sedgwick County but is deeply buried under younger sediments in the broad depressional area of the Arkansas Valley to a point southwest of Wichita. The nearest known outcrop of the Formation is about 20 miles north in southwestern Marion County, but the distinctive lithology of the sediments in this area can be traced in the subsurface into northern Sedgwick County. As the Arkansas River is approached, sediments derived from the Rocky Mountains make up the bulk of the Formation, and it is difficult to distinguish them from overlying younger sediments. Owing to the lithologic similarity of the Ogallala(?) to overlying younger sediments in the northwestern part of the County, the maximum thickness of the Formation cannot be determined accurately, but it is thought to be about 150 feet. The Formation thins to a featheredge to the south and along the west edge of the depressional area. It has been removed by later erosion along the Little Arkansas River and the Arkansas River southward from Wichita.

Age and correlation.—Much of the available evidence for assigning the sediments described above to the Ogallala(?) Formation is indirect but nevertheless quite strong. The silt and clay beds of the Ogallala(?) in Sedgwick County are fossiliferous, but because they are deeply buried, only fragmentary material has thus far been recovered from wells and test holes, and accurate dating of the sediments is not possible. Fossils of middle Pliocene age collected from the Ogallala Formation in McPherson County have been reported by Frye and Hibbard (1941) and Hibbard (1952). The distinctive lithology and stratigraphic position of the sediments from which these fossils were collected has been traced into Sedgwick County in the subsurface and this evidence strongly suggests the sediments are a part of the same formation.

Other evidence pointing to the Pliocene age is the position of this formation in relation to younger sediments of known age. In the depressional area occupied by the Arkansas River valley, the Ogallala(?), where present, forms the lowest part of the fill and is overlain in part of the area by Early Pleistocene sediments of late Kansan age. The age of the latter sediments was determined by the presence of the Pearlette ash bed which was penetrated by several wells and test holes in the County (see logs 26-2W-15add, 26-2W-26aaa, and 29-1W-9aaa). In southeastern Kingman County, deposits of late Nebraskan or early Aftonian age (Hibbard, 1956, Taylor, 1960, and Lane, 1960) form the highest topographic elements in the area. These deposits are remnants of sediments in the filled valley of a stream that flowed toward and was presumably a tributary to a stream flowing near the present course of the Arkansas River but at a level near the present uplands. Sand and gravel underlying loess near the upland level in central Sedgwick County are believed to be correlative with the deposits in Kingman County (section E-E′, Pl. 2). If the earliest Pleistocene streams in the area flowed at a level near the present uplands, it follows that the large depressional area in Sedgwick and adjacent counties to the north and northwest was filled with sediments prior to Pleistocene time which have been in part removed by Pleistocene stream erosion. From the known record of Pliocene events in Kansas, a Pliocene (Ogallala) age would best fit the pre-Pleistocene unconsolidated sediments in Sedgwick County.

Water supply.—The material comprising the Ogallala(?) Formation in Sedgwick

County is finer grained and more poorly sorted than the sediments overlying it. However, the Formation is hydraulically connected with the more permeable overlying beds and supplies a part of the water obtained from many municipal, industrial, and irrigation wells drilled through it. Most wells of large yield penetrate the complete section of unconsolidated rocks and are screened through most of the permeable zones, making it difficult to determine by methods presently available the water supply available from any one formation. However, water samples obtained by special sampling techniques indicate the water from the Ogallala is only moderately hard, and that it is suitable for most uses. Locally the water in the basal part of the Formation contains undesirable quantities of dissolved salt, but the known areas of contaminated water are of small areal extent and are thought to be confined to the lowest elevations on the bedrock surface.

PLEISTOCENE SERIES

The Pleistocene Series in Kansas is divided into four glacial stages and three interglacial stages (Table 2). Events during each of the stages of continental glaciation and deglaciation followed a similar pattern. The cycle in the zone marginal to the glaciated area is characterized by downcutting in stream valleys and some local deposition of sediment during the southward advance of the glacial ice, then deposition of coarse clastics that became finer grained as the glacial front retreated northward, and finally the development of soil over large areas during the interglacial period that followed.

Deposits representing all the glacial stages of the Pleistocene are present in the County, but these cannot be clearly differentiated in parts of the area. Sediments of the Holdrege and Fullerton formations (Late Nebraskan age) were not recognized in the Arkansas Valley, and the Grand Island and Sappa formations are buried under younger sediments. These formations are considered under a single heading as Lower Pleistocene, undifferentiated, in the following section of the report and on the geologic map (Pl. 1), although they are discussed separately and, where possible, are differentiated on geologic sections (Pl. 2) and well logs.

Sediments of Late Pleistocene age are better exposed and thus more readily distinguished in the field and are discussed separately except for the Wisconsinan terrace deposits and Recent alluvium which are combined as a single unit.

Lower Pleistocene Subseries

Lower Pleistocene Deposits, Undifferentiated

Two distinct periods of erosion and deposition are represented by sediments of late Nebraskan, late Kansan, and Yarmouthian age in Sedgwick County. The sediments of late Nebraskan age, probably equivalent to a part of the Holdrege Formation, unconformably overlie Permian rocks near the upland level on the west and south of the divide between the Arkansas and Ninnescah rivers. Equivalent deposits were not recognized in the Arkansas Valley, although they were probably deposited there and removed by later erosion. Sediments of late Kansan and Yarmouthian age underlie younger deposits in the Arkansas Valley, except where removed by erosion near the Arkansas River, and unconformably overlie upper Paleozoic (Permian) and Neogene rocks. Equivalent deposits were not recognized in other parts of the County and, if once deposited, they have been removed by later erosion.

Character.—The material comprising the Lower Pleistocene deposits is stream-laid silt, clay, sand, and gravel, and, locally, a thin bed of volcanic ash. The silt and clay beds are generally sandy and vary in color from shades of light tan to light gray. Caliche pebbles are common throughout the silt and clay beds but are best developed in the upper beds. The beds of sand and gravel are composed predominantly of quartz but contain much feldspar, some mica, and other darker minerals. The sand and gravel exhibit some minor differences in lithology, which probably reflect the source areas from which they were derived. The sand and gravel of the Nebraskan deposits lie on Permian rocks and contain many fragments of Permian shale, some ironstone derived from Cretaceous rocks, and a high percentage of quartz. The degree of weathering of the feldspars suggests that the gravels were reworked from older gravels, probably in the Ogallala Formation to the west. The sand and gravel in the deposits of Kansan age in the Arkansas Valley also show differences in lithology that suggest different source areas. The stream that entered the County from the direction of Harvey County deposited granitic gravels that show a more advanced degree of weathering than those deposited by the stream entering the County from the northwest. The gravels from the north contain much less feldspar and are grayish-pink in color, while those from the northwest are bright pink.

The gravels from the two source areas are mixed below the junction of the two streams and lose their distinctive appearance, but their characteristics suggest that the gravels from the north were reworked from older gravels while those from the northwest were at least in part derived directly from the Rocky Mountains. The sand and gravel in the Lower Pleistocene deposits are coarser and better sorted than those of the Ogallala(?) Formation but less coarse and less well sorted than those of the Upper Pleistocene deposits with which they are associated.

Origin.—The Lower Pleistocene deposits are the result of stream deposition during the Nebraskan and Kansan stages. Throughout much of south-central Kansas the early Pleistocene drainage pattern was much different than that of today, but the master stream then, as now, was probably in the broad depressional area now occupied by the Arkansas Valley. During Nebraskan time several major tributaries with eastward gradients less than those of later Pleistocene streams drained the area to the west and at least one of these streams entered west-central Sedgwick County near the present North Fork of the Ninnescah Valley. This stream followed a southeasterly course paralleling the present North Fork of Ninnescah and the Ninnescah valleys and probably joined the master stream near the southern boundary of the County. During late Nebraskan time this stream and others draining south-central Kansas were unable to transport the heavy loads of coarse clastics they formerly carried. To the west of Sedgwick County the streams filled their bedrock valleys and coarse alluvial material was spread over former divides to form an almost coalescing sheet of alluvium over the entire area. These deposits may have once extended over most of Sedgwick County as far east as the Arkansas Valley and were subsequently removed by erosion. Present streams in the County, having steeper gradients than the Nebraskan streams, have incised their valleys much below the level of the Nebraskan streams, and sediments deposited by the early streams are found only near the present upland level. No sediments associated with the Nebraskan Stage have been recognized in the Arkansas Valley. Alluviation of the valley must have been widespread, with later erosion completely removing the sediments.

Stream deposits associated with the Kansan Stage of glaciation were recognized only in a part of the Arkansas Valley where they are buried by younger rocks. During early Kansan time the stream flowing near the present course of the Arkansas River deeply entrenched its valley and removed a large volume of older sediments. This stream was joined in northern Sedgwick County by a large tributary carrying the ancestral Smoky Hill River southward through western McPherson and Harvey counties. This stream may have extended well into west-central Kansas near the course of the present Smoky Hill River with a major tributary flowing from the Saline Valley through the abandoned Wilson Valley (Frye, Leonard, and Hibbard, 1943). Perhaps the Ogallala Formation in western Kansas could have provided sediment to this stream. The drainage pattern to the west of the County during this period is not clear but appears to have been initially a widespread distributary system carrying a large volume of water and sediment from the mountains. Tributaries to the master stream in Sedgwick County may have integrated a part of this drainage. During late Kansan time alluviation was widespread as streams became incompetent to carry their heavy load of sediment. West of the County and south of the great bend of the Arkansas River a thick sheet of coarse sediment was deposited, and this forms the present high plains surface in much of the area. This sheet deposit may have coalesced with the Kansan deposits now buried in the Arkansas Valley, but, if so, it has been removed by later erosion as far west as central Kingman County (Lane, 1960).

Distribution and thickness.—Deposits of Early Pleistocene age are found in the Arkansas Valley and near the upland level on the west and south sides of the bedrock divide between the Arkansas and Ninnescah River valleys (Pl. 2, sections E-E′ and F-F′). The sediments associated with the Nebraskan glaciation were recognized only near the upland level flanking the Ninnescah Valley where they underlie late Pleistocene loess. These deposits are remnants of a filled high-level valley system that has been greatly dissected by later stream erosion. Exposures are poor but are found in road cuts and stream channels. The areal extent of the rocks was determined principally from subsurface data obtained by extensive test drilling. Sediments of similar age were probably deposited over a large part of the Arkansas Valley but were removed by later erosion. The Nebraskan deposits range in thickness from a featheredge to about 19 feet in the area near test hole 27-2W-29bbb.

Deposits associated with the Kansan glaciation were recognized only in a part of the Arkansas Valley where they underlie younger sediments. The areal extent of these sediments cannot be definitely ascertained owing to the similarity of lithology of underlying and overlying deposits. They were probably deposited over the entire valley, but the thickest deposits were west of the present Arkansas River where valley cutting by Kansan streams was greatest. The Arkansas River now flows along the east edge of the valley from the north edge of Wichita southward through the County and has removed any older sediments that once may have been present in this area. The topographic position of the Kansan deposits rises with respect to the present level of Arkansas River southward through the County but not sufficiently to be exposed at the surface. To the south of the County, near the state border, the Kansan sediments are perched well above river level and underlie the highest elements of the topography. The maximum thickness of the Kansan deposits is not known, but it is estimated to be about 28 feet in the northwestern corner of the County.

Age and correlation.—A Nebraskan age for the older part of the Lower Pleistocene deposits is based primarily on their topographic position near the upland surface, their history of deposition, their relation to adjacent younger sediments, and their equivalence to Nebraskan sediments in nearby areas that have been dated by fossils and stratigraphic evidence.

The Kansan age of a part of the sediments filling the depressional area of the Arkansas Valley is based primarily on the presence of the late Kansan Pearlette ash bed which was penetrated by several test holes drilled in the County and in adjacent areas (logs 26-2W-15add, 26-2W-26aaa, and 29-1W-9aaa). The ash bed was also found in cuttings from several test holes in Harvey and McPherson counties that were restudied during the investigation for this report. The silt and clay beds in the Kansan sediments are commonly fossiliferous, but they do not crop out in the County, and only fragmentary fossil material, unsuitable for identification, was recovered from drill cuttings. Deposits of Kansan age were not recognized outside the Arkansas Valley and if deposited elsewhere in the County, have been removed by erosion.

Water supply.—The early Pleistocene sand and gravel deposits of Nebraskan age are relatively thin, and in most of the area where present, they are covered by late Pleistocene loess that probably reduces the rate of recharge. However, near the upland level where the deposits are thickest, they are saturated and yield water to many stock and domestic wells. The town of Goddard is supplied by wells screened in these deposits, which yielded about 50 gpm (gallons per minute) when test pumped. The water is moderately hard but suitable for most uses.

The deposits of Kansan age in the Arkansas Valley are overlain and in part underlain by water-bearing sediments, and wells are seldom screened in only one water-bearing bed. The complete saturated section responds to long-term pumping as if it were a single unit, and the water supply of individual formations is difficult to determine. However, based on the lithology of the Kansan sediments, it is estimated that they would yield 500 to 1,000 gpm to wells, depending on the thickness of sand and gravel beds.

Upper Pleistocene Subseries

The Upper Pleistocene in Kansas includes all sediments younger than those of the Yarmouth interglacial period, and in Sedgwick County includes Illinoisan terrace deposits, Wisconsinan terrace deposits, Recent alluvium, undifferentiated loess deposits, colluvium or slope deposits, and dune sand. The Wisconsinan terrace deposits and Recent alluvium are difficult to distinguish from each other and are combined as a single unit in the section that follows.

Illinoisan Terrace Deposits

Character.—Deposits of silt, sand, and gravel of Illinoisan age underlie an extensive terrace surface west of the Arkansas River and locally along the north side of the Ninnescah River valley westward to the mouth of Spring Creek. A part of the fill in an abandoned valley crossing the extreme southwestern corner of the County is believed to be of similar age. The terrace deposits consist of fine to coarse sand and fine to coarse gravel that grades into sandy silt in the upper part. The sand and gravel is composed predominantly of quartz but contains much feldspar and other minerals typical of igneous rocks derived from the Rocky Mountains. Thin beds of gray to tan silt interbedded with the sand and gravel are common but are local in extent. The sand and gravel is generally more coarse and better sorted than the older underlying sand and gravel deposits. Clay balls up to one foot in diameter are common in the sand and gravel beds. The silt in the upper part of the terrace deposits is sandy and is tan to reddish-tan in color.

Origin.—The Illinoisan terrace deposits present in the County are remnants of extensive valley fill deposited by streams flowing near the present stream courses. In early Illinoisan time the Arkansas River was probably established near its present course as a through stream from the mountains, and its principle tributaries were actively extending their drainage area by headward erosion. The former tributary carrying the Smoky Hill River southward into Sedgwick County was captured by a tributary of the Kansas River, and its former course through McPherson and Harvey counties was abandoned. Valley deepening by the Illinoisan streams evidently was not pronounced in the Arkansas River valley because the easily eroded Kansan sediments underlie the terrace deposits, and they appear to have remained intact. The stream shifted laterally over a wide area, depositing a sheet of coarse alluvium that originally may have been as much as 15 miles wide. The reason for the widespread deposition is thought to have been a reduction in the gradient of the stream as it flowed through the broad depressional area in Sedgwick and Harvey counties. The present slope of the terrace surface is less than that of the present river and the topographic position of the surface with respect to the river rises perceptibly downstream. In the Ninnescah River valley the Illinoisan terrace deposits rest on Permian rocks, and if older sediments were present on the valley floor, they were removed by erosion before the deposition of the Illinoisan or were not recognized.

Distribution and thickness.—The Illinoisan terrace deposits along the Arkansas River underlie a broad terrace west of the river and may be present under younger deposits adjacent to the river. The eastern edge of the terrace is marked by a distinct scarp and the terrace surface abuts against the bedrock walls of the valley on the west. Along the western edge of the terrace late Pleistocene loess overlaps the valley wall onto the terrace making the contact indistinct. Sand and gravel underlying loess along the east valley wall in the vicinity of Derby is believed to be a part of the Illinoisan terrace deposits. Southwest of the town of Maize the terrace deposits reach a maximum width of about 7 miles.

The Illinoisan terrace deposits in the Arkansas valley range in thickness from 0 against the valley wall to a maximum of about 75 feet near test hole 26-2W-15aad.

Illinoisan terrace deposits underlie the surface of a terrace north of the Ninnescah River that is accordant with that in the Arkansas Valley. The terrace is graded toward the river, is less distinct than that in the Arkansas Valley, but is continuous to a point about 3 miles west of Clearwater. Remnants of this terrace are also present adjacent to the mouth of Clearwater Creek. The terrace deposits along the Ninnescah River range in thickness from 0 along the valley wall to about 56 feet near the town of Clearwater.

A small abandoned valley crosses the extreme southwestern corner of the County in T 29 S, R 4 W (Pl. 1 and 3). The basal part of the fill in this valley is believed to be equivalent in age to the Illinoisan terrace deposits. These basal deposits attain a maximum thickness of about 50 feet and are overlain by recent slope deposits.

Age and correlation.—An Illinoisan age for the terrace deposits is based on the relative position of the sediments in the Arkansas Valley where they unconformably overlie sediments of late Kansan age containing the Pearlette ash bed and are in part topographically higher than late Pleistocene sediments adjacent to them. The terrace surface is drained by Cowskin Creek which has cut a narrow valley in the surface. In the lower reaches of Cowskin Creek valley a terrace surface well below the Illinoisan surface is present and is accordant with terrace deposits adjacent to the Arkansas River that are judged to be Wisconsinan in age from the contained fossils. The Illinoisan deposits contain both vertebrate and invertebrate fossils. Surface exposures are rare, and the fossils are known only from fragmentary material obtained from drill cuttings.

Water supply.—The Illinoisan terrace deposits supply water to many stock and domestic wells in the County and to some municipal, irrigation, and industrial wells. As in most of the Arkansas Valley, wells of high yield located on the terrace surface commonly penetrate the entire section of unconsolidated rocks, and the water supply of any individual unit of the section is difficult to determine. However, well yields of 500 gpm are readily available in most of the area in the Arkansas Valley underlain by the terrace deposits, and yields of 1,000 gpm or more might be obtained at favorable locations. In the Ninnescah Valley the deposits are thinner, the saturated thickness is less, and well yields are correspondingly smaller. Many stock and domestic wells in the Ninnescah Valley obtain water from these deposits, and the town of Clearwater is supplied by four wells, each capable of yielding about 270 gpm. In the small abandoned valley in the southwestern corner of the County only a few domestic and stock wells obtain water from the buried Illinoisan deposits, but it is estimated that well yields of 50 to 100 gpm might be available in the thicker parts of the valley fill.

Wisconsinan Terrace Deposits and Recent Alluvium, Undifferentiated

Character.—The Wisconsinan terrace deposits and Recent alluvium are combined as a single unit in this report owing to their lithologic similarity, their hydraulic continuity, and the difficulty of separating the deposits in the field. A narrow deposit of alluvium is present in most of the small tributary valleys in the County, but it is not shown on the geologic map (Pl. 1). The deposits adjacent to the Arkansas River consist of fine to coarse sand and fine to very coarse gravel containing only minor amounts of silt and clay. The sand and gravel grade upward into clayey silt. The sand and gravel are mostly quartz fragments but the gravel contains much pink feldspar and other minerals typical of the Rocky Mountains. Clay balls are common in the sand and gravel, some attaining a maximum diameter of more than 12 inches. The clayey silt forming the upper part of the deposits is gray to light grayish-tan in color, is sandy, and contains much caliche in the lower part. The caliche occurs as thin bands, root tubes, and small crevice fillings, and is believed to have been deposited in the zone of water-table fluctuation. These deposits are well exposed in many gravel pits in the area.

The terrace deposits and Recent alluvium in the Ninnescah Valley contain much silt and fine sand and only minor amounts of fine to medium gravel. Gravel is most common in these deposits in and near the present river channel.

Origin.—The Wisconsinan terrace deposits and Recent alluvium are the result of deposition by streams following a period of erosion associated with the Wisconsinan glaciation. In the Arkansas Valley much of the Illinoisan deposits were removed and an inner valley was cut as much as 70 feet below the surface of these deposits. Lateral planation was an important feature of this erosional period, for the Wisconsinan terrace deposits and Recent alluvium now cover an area as much as 9 miles wide in the County. Following this period of erosion the stream transported into the area a large volume of coarse clastics derived from older sediments to the west and from the Rocky Mountains. The stream became incompetent to carry its load, and widespread deposition took place.

In the Ninnescah Valley and smaller tributary valleys in the County a similar but less extensive period of erosion and deposition took place. The stream regimen in these areas was controlled to a large extent by the climatic changes in the area, and the deposits in the valley were derived entirely from sediment available to the streams within their drainage basins.

Distribution and thickness.—The Wisconsinan terrace deposits and Recent alluvium in the Arkansas Valley underlie a broad, flat surface adjacent to the present river channel. The slope of this surface is the same as that of the river, and north and west of the mouth of the Little Arkansas River the channel is about 5 feet below it. Downstream from the junction of Arkansas and Little Arkansas rivers the channel is more deeply entrenched and is about 10 feet below the terrace surface where the river leaves the County. The deposits attain a maximum width of about 9 miles normal to the river in the north-central part of the County but narrow to about 4 miles along the south county line. The deposits average about 45 feet in thickness.

In the Ninnescah Valley the deposits are more restricted but attain a maximum width of about 2 miles. Above the junction of the North Fork and the South Fork of the Ninnescah River the deposits become more restricted in areal extent. They range in thickness from a featheredge to a maximum of about 45 feet. In the smaller tributary valleys in the County, the Wisconsinan terrace deposits and the alluvium are confined to a very narrow strip adjacent to the stream channels and are not shown on the geologic map (Pl. 1). However, these deposits attain a thickness of as much as 40 feet in some small stream valleys.

Age and correlation.—A Wisconsinan age for most of the sediments included in the Wisconsinan terrace deposits and Recent alluvium is based on the relative abundance of large vertebrate remains recognized as latest Pleistocene in age. Remains of horses, bison, and elephants are commonly recovered during screening operations at the many gravel pits operating in the County. Smaller forms are probably present in the deposits, also, but are not recovered by the screening process. The deposits are very poorly exposed and fossils are seldom found except in excavations. In much of the area bordering the Arkansas River where the surface has not been modified by overflows from the present river channel, complex patterns of meander scars mark the terrace surface. These features are seldom visible when observed from the ground but they show up well on aerial photographs. Some of these surface markings are as far as 7 miles from the present river channel and are believed to be traces of the channel during the waning phases of Wisconsinan deposition.

Water supply.—The Wisconsinan terrace deposits and Recent alluvium are the most widely used source of ground water in the County and yield water to many stock, domestic, municipal, industrial, and irrigation wells. The deposits in the Arkansas Valley are the most permeable in the County and are readily recharged by precipitation. Wells of moderate depth penetrating the entire thickness of the deposits are capable of large yields. In most of the area underlain by the deposits the water table is less than 10 feet below the land surface, and centrifugal pumps operated at the surface produce 500 gpm or more. Large-diameter wells with pumping equipment not limited by suction lift can yield 1,500 to 2,000 gpm. The chemical quality of the water varies with the location in the County. At normal and low stages the Arkansas River water is of poor quality and in parts of the area is freely interchanged with ground water. Generally the quality of the water improves with distance from the river, although a high iron content is common and often troublesome. In the Ninnescah Valley the deposits are much less permeable, but moderately large yields are possible at favorably located well sites.

Undifferentiated Loess Deposits

Origin.—Wind-deposited silt (loess) forms the surficial material over a large part of the County but it is most extensive on the valley slopes and uplands bordering the Arkansas Valley. The loess probably represents two major periods of deposition and may be correlative with the Loveland and Peoria formations of late Illinoisan and Wisconsinan age that are widespread in north-central and western Kansas. Exposures of the loess are few and its thickness and character are known primarily from test-hole data. No attempt was made to differentiate the loess, because fossil soils that are well developed and have been used for correlation in northwestern Kansas and fossil mollusks that have been studied at many localities in the State were not recognized in the test-hole cuttings in Sedgwick County. However, caliche zones found at several horizons in the loess may indicate that deposition was not continuous and that surface stability may have prevailed, allowing some leaching. The loess is thought to have been derived from the flood plain of the Arkansas River during late Pleistocene time and carried by the wind to the site of deposition. The late Pleistocene streams in the Arkansas Valley probably carried much more water than the present river, and seasonal floods would have left widespread silt deposits on the flood plain. Strong gusty winds during part of the year were probably prevalent then as now and would have easily picked up and transported the silt.

Distribution and thickness.—Loess was probably deposited over most of the County, but it has been removed by erosion along much of the Ninnescah Valley and the smaller tributary valleys remote from the Arkansas Valley. The loess is thickest on the slopes and uplands bordering the valley and thins rapidly away from it. The greatest thickness penetrated was 74 feet in test hole 27-3-12aaa. East of the Arkansas River about 60 feet of silt overlying sand and gravel was penetrated by test hole 29-2E-18ccc. Most of the contacts of the loess on older rocks shown on the geologic map (Pl. 1) are indicated by a dashed line and represent the point where the thickness of the loess is believed to be about 4 feet or more.

Age and correlation.—A late Illinoisan through Wisconsinan age is assumed for the loess in Sedgwick County as it is believed to be equivalent to the Loveland and Peoria formations in adjacent parts of the State. The lower part of the loess along the west side of the Arkansas Valley is interfingered with the Illinoisan terrace deposits, which are overlapped by the upper part of the loess. The loess is rarely exposed and in only a few places could the leached zone immediately below the surface be examined in the field. No fossils were found.

Water supply.—The loess is very fine-grained, well sorted, and has a low permeability and, therefore, would not ordinarily be considered as an aquifer. However, in parts of the County where the loess is thick, the lower part is saturated and may contribute some water to wells from the sandy zones or to wells completed in the weathered bedrock immediately below it. Many stock and domestic wells in the upland areas of the County are drilled through the loess into bedrock and supply adequate water for farm use, but the contribution of water from the loess to these wells is not known.

Undifferentiated Colluvial Deposits

Colluvial deposits as described in this report are those sediments transported and deposited by slope processes, primarily sheet wash and soil creep. They are most commonly found near the base of long gentle slopes developed on relatively weak, easily eroded rocks. Colluvial deposits are present in Sedgwick County overlying the Ninnescah Shale and Wellington Formation in the Ninnescah River valley and in the small abandoned valley in the southwestern corner. The colluvium consists mostly of silt but normally includes a heterogeneous mixture of silt, bedrock fragments, and sand and gravel, if these materials are present upslope from the deposit. The deposits normally grade imperceptibly downward into the terrace deposits, effectively masking the outer limit of the terrace. Deposition of the colluvium may have started as early as Illinoisan time, and it continues to the present time. The deposits generally are thin and probably do not exceed a maximum of 30 feet in thickness. In much of the area the deposits are above the water table and thus yield no water to wells. However, where the deposits are thick and contain local accumulations of sand and gravel, wells yielding a few gallons per minute might be obtained.

Dune Sand

Fine to medium sand containing some silt has been accumulated by wind action into low rounded dunes at a few locations in the County. Two small dune areas are located northwest and southeast of the town of Bentley, but these are not shown on Plate 1. A few small areas of dune accumulation were formerly found northwest and south of Wichita adjacent to the channel of the Arkansas River. Expansion of the city and agricultural activity have now obliterated these features. Where present, the dunes form low rounded mounds only a few feet thick and support field crops in most years. The dune sand readily absorbs precipitation, but its areal extent is so small that it is not considered significant as a recharge medium in the County.

GROUND WATER

EXPLANATION OF TERMS

The fundamental principles governing the occurrence of ground water have been discussed by many authors (Meinzer, 1923a; Moore, *et al.*, 1940) and the reader is referred to their reports for a detailed discussion of the subject. These principles as they apply to Sedgwick County will be discussed in the sections that follow, and the following explanations of technical terms commonly used in describing ground water are presented as an aid to those not familiar with the subject. Most of the explanations are adapted from Meinzer (1923b).

Aquifer—a rock formation, group of formations, or part of a formation that is water-bearing. Commonly used synonyms are ground-water reservoir, water-bearing bed, and water-bearing deposit.

Artesian water—ground water under sufficient pressure to rise above the level at which the water-bearing bed is tapped in a well. The pressure is often called artesian pressure and the rock containing artesian water is called an artesian aquifer (Fig. 8).

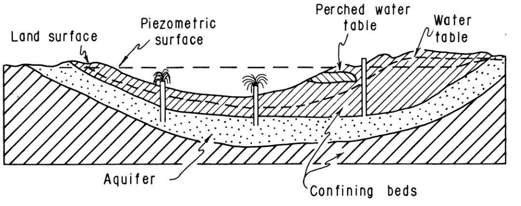


FIGURE 8.—Sketch illustrating the occurrence of artesian and water-table conditions, and a perched water table.

Capillary fringe—the zone directly above the water table in which water is held in the pore spaces by capillary action (Fig. 9).

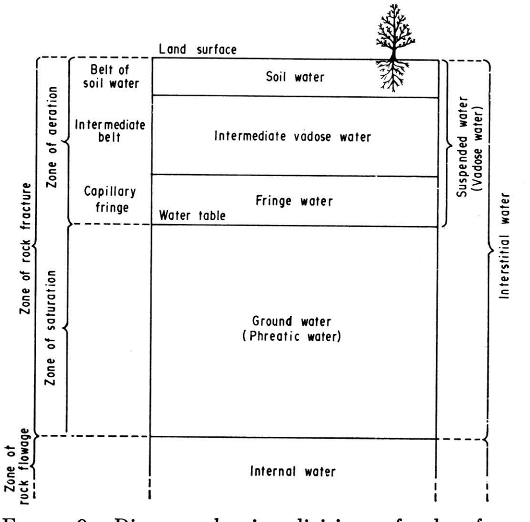


FIGURE 9.—Diagram showing divisions of subsurface water (after Meinzer, 1923b).

Coefficient of storage—the coefficient of storage of an aquifer is 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.

Cone of depression—a cone-shaped depression of the water table developed in the vicinity of a pumping well. Also called the cone of influence of a well (Fig. 10).

Confined water—water under artesian pressure.

Confining bed—a relatively less permeable rock layer that overlies or underlies an artesian aquifer and confines water in the aquifer under pressure (Fig. 8).

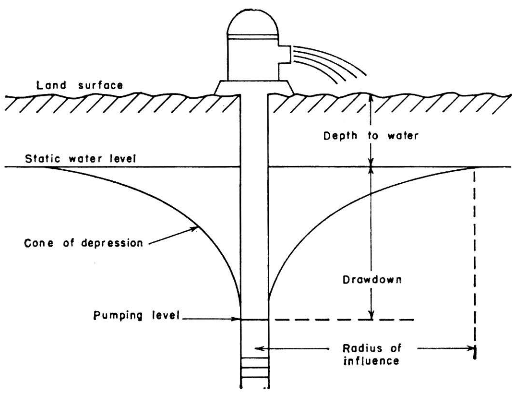


FIGURE 10.—Diagrammatic section of a pumping well showing drawdown, cone of depression, and radius of influence.

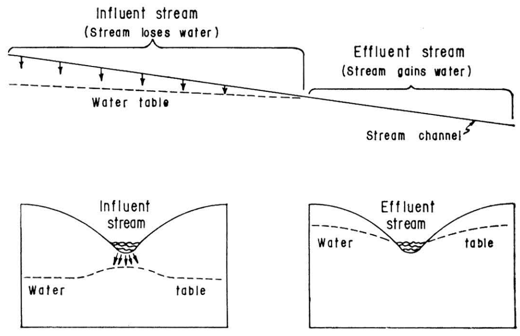


FIGURE 11.—Diagrammatic sections showing influent and effluent streams. Longitudinal section showing (right) how an effluent stream gains water and (left) how an influent stream loses water. Transverse section across influent part of a stream (lower left). Transverse section across effluent part of a stream (lower right). (After Meinzer, 1923a, fig. 26.)

Drawdown—the lowering of the water level in a well or nearby wells during pumping (Fig. 10).

Discharge—the removal of water from the zone of saturation.

Effluent stream—a stream into which water is discharged from the ground-water reservoir, sometimes called a gaining stream (Fig. 11).

Flowing well—an artesian well having sufficient head to discharge water above land surface (Fig. 8).

Ground water—water in the zone of saturation, or below the water table (Fig. 9).

Ground-water movement—the movement of ground water in an aquifer. The movement of ground water through an aquifer is extremely slow, generally on the order of inches per day or feet per year.

Hydraulic gradient—gradient of the water table measured in the direction of the greatest slope, generally expressed in feet per mile. The hydraulic gradient in an artesian aquifer is called the pressure gradient and is measured on the piezometric surface.

Hydrologic cycle—the complete cycle of phases through which water passes, commencing as atmospheric water vapor, passing into liquid and solid form as precipitation, thence along or into the ground, and finally returning to the form of atmospheric water vapor by means of evaporation and transpiration (Fig. 12).

Hydrologic properties—the properties of an aquifer that control the occurrence and movement of ground water.

Hydrologic system—a series of interconnected aquifers.

Hydrostatic pressure—pressure exerted by water at any point in a body of water at rest. In an artesian system the hydrostatic pressure is the artesian pressure.

Impermeable rock—an impervious rock; that is, a rock through which movement of water is negligible under subsurface pressure differentials commonly found in nature.

Infiltration—the process whereby water enters the soil and moves downward toward the water table.

Influent stream—a stream that contributes water to the ground-water reservoir (Fig. 11).

Intermittent stream—a stream that flows only following precipitation or when receiving water from springs, ground-water seepage, or melting snow.

Interstice—an opening or void in a rock. Interstices may be filled with any type of gas or liquid but in an aquifer are usually filled with water (Fig. 13).

Mutual interference—the drawdown caused in a pumping well by other pumping wells in close proximity. At any given point between two or more pumping wells the drawdown will be the sum of the drawdowns produced by each well at that point (Fig. 14).

Nonflowing artesian well—an artesian well in which the pressure is sufficient to cause the water level to rise above the top of the artesian aquifer but not above the land surface (Fig. 8).

Perched water—ground water separated from the underlying water by a zone of unsaturated rock. A perched water table is distinguished from the main water table (Fig. 8).

Perennial stream—a stream that flows continuously, such as the Little Arkansas River. (The Arkansas River is considered a perennial stream although on rare occasions it has been dry in some reaches.)

Permeable rock—rock that has a texture permitting water to move through it readily under pressure differentials ordinarily found in nature.

Permeability—the capacity of a rock to transmit water. The *field coefficient of permeability* of an aquifer may be expressed as the rate of flow of water at the prevailing temperature, in gallons a day, through a cross sectional area having a thickness of 1 foot and a width of 1 mile for each foot per mile of hydraulic gradient.

Piezometric surface—as generally used, the pressure indicating surface of an artesian aquifer.

Porosity—the ratio (expressed as percent) of the volume of openings in the rock to the total volume of the rock.

Recharge—the process by which water infiltrates and is added to the zone of saturation. Also used to designate the quantity of water added to the ground-water reservoir.

Runoff—the discharge of water by surface streams. It includes both surface-water runoff and ground-water seepage. Also used to designate the quantity of water discharged as runoff.

Specific capacity—the yield of a well generally expressed in gallons a minute per foot of drawdown after a specified time of pumping.

Specific yield—the ratio of the volume of water a saturated rock will yield by gravity drainage to its own volume.

Storage—water stored in openings in the zone of saturation is said to be in storage. Discharge of water from an aquifer that is not replaced by recharge is said to be from storage.

Subsurface inflow—the movement of ground water into an area in response to a hydraulic gradient.

Transmissibility—the transmissibility of a rock is its capacity to transmit water under pressure. The *coefficient of transmissibility* is the field coefficient of permeability multiplied by the saturated thickness, in feet, of an aquifer.

Transpiration—the process by which water vapor is given off into the atmosphere by living plants.

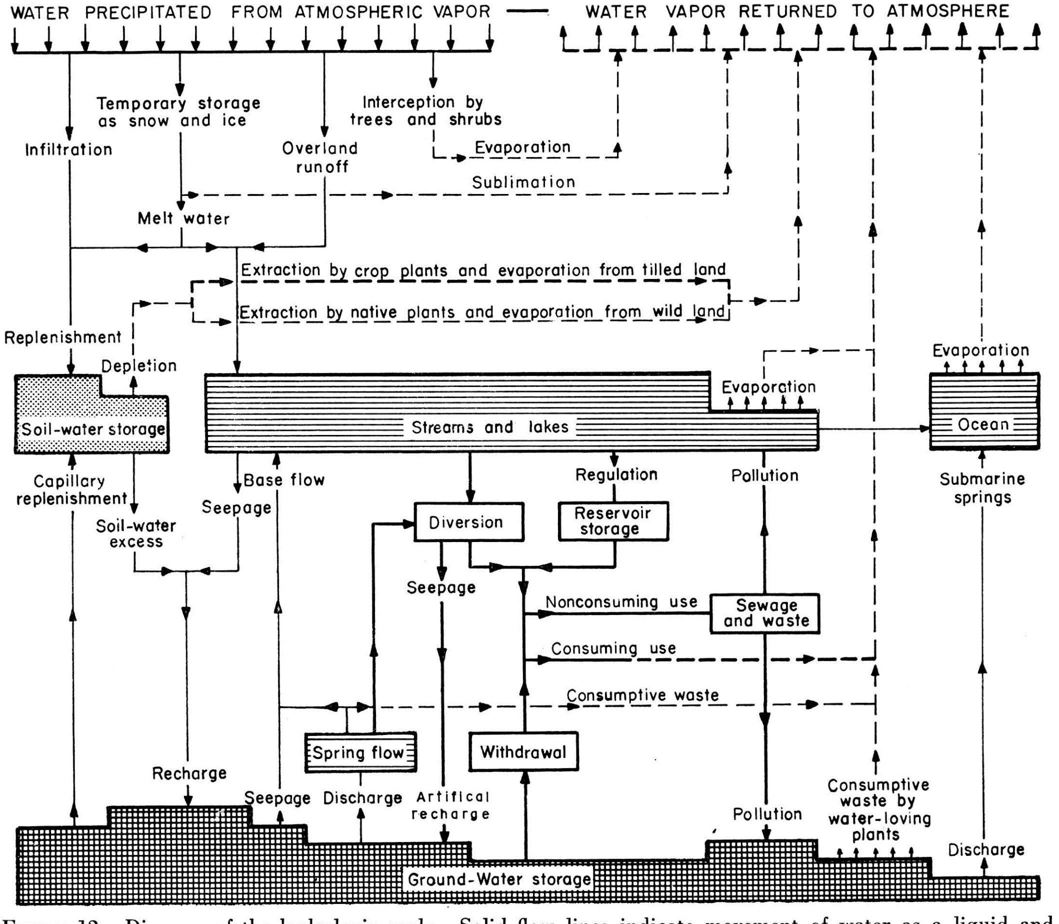


FIGURE 12.—Diagram of the hydrologic cycle. Solid flow lines indicate movement of water as a liquid and broken lines movement as vapor. Heavy flow lines indicate man's principal interruption of the natural cycle (after Piper, 1953).

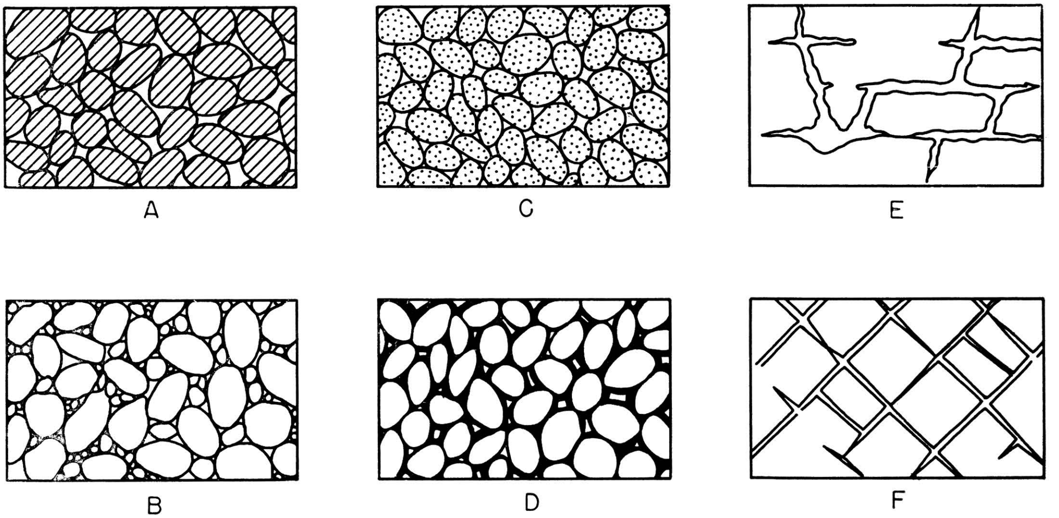


FIGURE 13.—Diagram showing several types of rock interstices and the relation of rock texture to porosity. *A,* Well-sorted sedimentary deposit having high porosity; *B,* poorly sorted sedimentary deposit having low porosity; *C,* well-sorted sedimentary deposit consisting of pebbles that are themselves porous, so that the deposit as a whole has a very high porosity; *D,* well-sorted sedimentary deposit whose porosity has been diminished by the deposition of mineral matter in the interstices; *E,* rock rendered porous by solution; *F,* rock rendered porous by fracturing. (From Meinzer, 1923a.)

Water table—the water table is the upper surface of the zone of saturation where that surface is not formed by an impermeable rock. The water table is not a plane surface, but has irregularities much like the land surface. The configuration of the water table in a part of Sedgwick County is shown on Plate 1 by means of contours.

Zone of aeration—the zone between the land surface and the water table (Fig. 9).

Zone of saturation—the zone of permeable rocks saturated with water under hydrostatic pressure (Fig. 9).

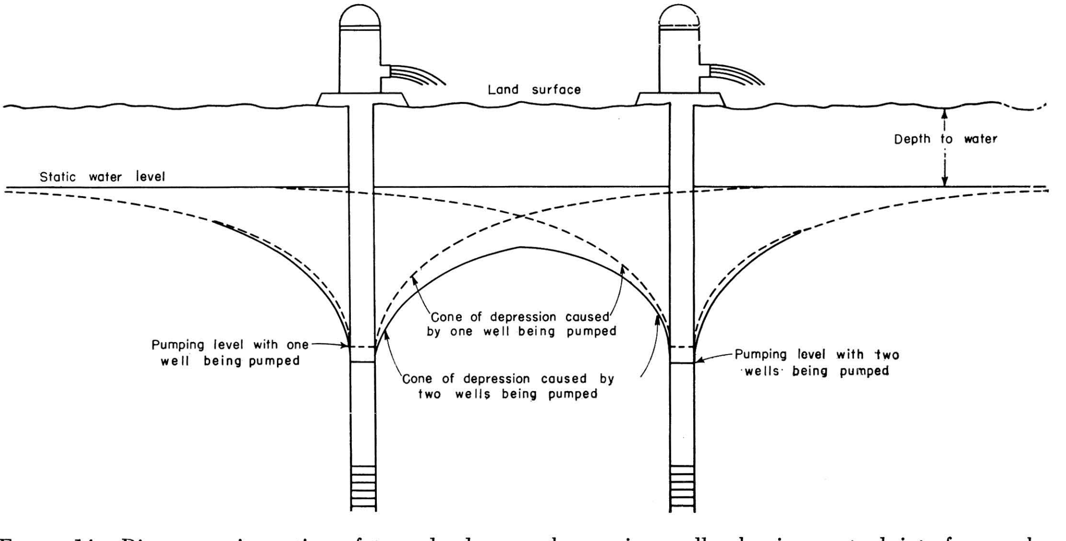


FIGURE 14.—Diagrammatic section of two closely spaced pumping wells showing mutual interference between wells and the resulting cones of depression.

THE WATER TABLE AND MOVEMENT OF GROUND WATER

The water table is not a flat surface but has irregularities that are related to and strongly affected by the topography, geology, and hydrology of the area. The shape of the water table in parts of Sedgwick County is shown on Plate 1 by means of contours. All points along a contour line have the same altitude, and the lines show the shape and slope of the water table in the same manner as the land surface is shown on a topographic map. The configuration of the water table where shown is very similar to the surface topography but is more subdued. In those parts of the County where the water-table contours are not shown on Plate 1 it lies beneath the surface of the consolidated bedrock. Contours are omitted where control is inadequate. The water table may be discontinuous or absent in some areas. The ground water in the bedrock is under artesian pressure in some areas and the relationship of the piezometric surface to the water table is not known.

The water table in the Arkansas Valley has a rather uniform slope to the southeast that averages about 7 feet per mile. Locally the slope of the water table may be as low as 5 feet or as high as 10 feet per mile. Ground-water movement is in the direction of water-table slope, or at right angles to the water-table contours. In the valley, ground-water movement is, in general, toward the Little Arkansas River and the Arkansas River below the junction of the two. At any particular point in the valley and at different depths below the land surface, the direction of ground-water movement may be slightly different from that indicated by the water-table gradient, owing to local conditions. In stratified and lenticular deposits of different permeability such as are present in the Arkansas Valley, the water pressure at a given depth below the surface may be slightly different than at other depths and the pressure gradients in a different direction than indicated by the water table. However, the resultant direction of water movement will be as indicated by the gradient on the water table.

The smooth surface of the water table in the Arkansas Valley is marked by a number of anomalies most of which are related to discharge of ground water. Along the Arkansas River northwest of Wichita the water-table contours show no flexure as they cross the river, indicating that at normal river stage the water table is in equilibrium with the river and the ground-water reservoir neither receives nor discharges water in this reach of the stream. Along the Little Arkansas River, the Arkansas River from Wichita south, and the larger tributary creeks west of the river, the water-table contours turn sharply upstream, indicating discharge of ground water to these streams. The southern end of the Wichita municipal well field is in the northern part of T 25 S, R 2 W, and the northwest corner of T 25 S, R 1 W, and withdrawals of ground water in this area have affected the shape of the water table. In the area of largest withdrawal near the northeast corner of T 25 S, R 2 W, the water table is flattened or depressed and the gradient reduced, shifting the direction of ground-water movement toward the well field. West of this pumping center the gradient is appreciably steepened in the direction of the well field. A noticeable distortion of the water-table contours in T 25 S, R 3 W, is probably caused by withdrawal of ground water by irrigation wells, causing water to move from the river in a small area; but it may be due, in part, to inadequate control on the water-table altitude. Other areas where withdrawals from wells have changed to some extent the direction of ground-water movement are located in Wichita and southwest of it, but these are not well defined by the water-table contours.

The water table in the alluvium and terrace deposits of the Ninnescah Valley shows the direction of ground-water movement to be downstream but with a strong component of movement toward the river. The Ninnescah River is influent throughout its course in Sedgwick County.

The water-table gradient becomes markedly steeper west of the Arkansas Valley as the land surface rises to the upland level. Within this zone, about 2 miles wide, the water table passes from the sand and gravel of the valley into loess mantling the valley slope. The water-table gradient in this zone is as much as 50 feet per mile locally and indicates the low permeability of the loess. Sand and gravel underlie the loess in a part of the upland area southwest of Goddard, and the water-table gradient is much less than in the loess-covered slopes. The configuration of the water table in this area shows the ground water to be moving from the uplands toward the Arkansas and Ninnescah valleys.

The rate of movement of ground water is very low compared to the movement of surface water. Typical rates of movement in the County are not known, but in unconsolidated materials such as are common there, the rate may range from a fraction of an inch per day in silt and clay to several feet per day in well-sorted sand and gravel.

FLUCTUATIONS OF THE WATER TABLE

Natural Fluctuations

If a ground-water reservoir was in equilibrium with its environment, that is, if recharge to and discharge from the reservoir at all places and at all times remain the same, the water table would remain in a fixed position. Such conditions are rare in nature, however, and in practically all places the water table fluctuates up and down in response to additions to or withdrawals from the ground-water reservoir. However, under natural conditions the changes in ground-water storage reflected by water-table fluctuations should balance out over a period of years or during a climatic cycle. Fluctuations of the water table in Sedgwick County have been determined by periodic measurements of the depth to water in selected wells since 1937. The results have been published annually by the U. S. Geological Survey through 1955 (see *References*) and thereafter by the State Geological Survey of Kansas (Fishel and Mason, 1957, 1958; Fishel, *et al.*, 1959; Fishel and Broeker, 1960; Broeker and Fishel, 1961; Broeker and Winslow, 1962). A list of the wells in which water levels are currently being measured and those that are no longer being measured but for which some record is available are given in Table 3.

Figure 15 is a hydrograph showing fluctuations of the water level in selected wells in the County and the monthly precipitation, monthly precipitation normals, and the cumulative departure from normal precipitation at Wichita. These wells are remote from centers of pumping and are believed to reflect natural fluctuations of the water table caused by recharge from precipitation and natural discharge. If the distribution of precipitation in the area were always normal, the hydrographs would display a cyclic pattern much like that shown by the monthly precipitation normals. However, during the period of record shown in Figure 15 the climatic pattern has gone from the severe drought in the late 1930's to a period of above normal precipitation through the 1940's, a severe drought during the early 1950's, and a return to normal or above-normal precipitation during the late 1950's to the present. This pattern is well displayed by the curve showing cumulative departure from normal precipitation, and the water-table fluctuations due to recharge and discharge closely follow the same pattern. This relationship should be expected if the ground-water reservoir is full and in equilibrium for the normal conditions of its environment. The amount of water-table fluctuation at a particular point resulting from a given volume of recharge to or discharge from an aquifer is determined by the specific yield of the aquifer in the zone of fluctuation at that point. This may account for some of the differences in the degree of water-table fluctuations on the hydrographs shown in Figure 15. These differences could also be caused, in part, by uneven distribution of precipitation in the area, local differences in the infiltration rate, location of wells with respect to areas of natural discharge, and depth to the water table below land surface.

Fluctuations Caused by Pumping

When a well begins to discharge water from a water-table aquifer, the water table adjacent to the well is lowered, establishing a hydraulic gradient toward the well. The water table around the well soon assumes a form similar to that of an inverted cone, with the apex at the well. For a short time most of the water pumped from a well is derived from the aquifer close to the well. As pumping continues, more of the aquifer is dewatered, and a gradient is established toward the well sufficient to move to the well the quantity of water that is being pumped. Most

TABLE 3.—Observation wells in Sedgwick County, Kansas.

Well number this report	Well number City of Wichita*	Depth of well, feet below land surface	Period of record
25–1W–26dbb	12	54	1937–62†
27–1E–18ccc	26	47	1937–62†
25–2W–7aaa	114	32	1954–62
25–2W–22bbb	115	32	1954–62
25–1W–17bbb	116	30	1954–60‡
25–1W–20ccc	117	39	1954–62
25–1W–5ddd	124	70	1955–62
25–1W–10ccc	125	69	1956–62
25–1W–22bbb	126	40	1955–62
25–2W–1cbb	307	92	1937–54; 1956–62
26–1W–16ddd	804	26	1938–62
26–1W–19abb	805	41	1938–62
26–2W–10bbb	807	37	1938–62
26–3W–18bcc	808	49	1938–53; 1958–62
26–1E–21bbb	809	32	1938–62
25–1W–35daa	810	25	1938–62
25–1W–33ddd	811	25	1938–58‡
25–1W–27bbb	812	25	1938–62
25–1W–14ddd	814	31	1938–62
25–1W–17aaa	815	31	1938–62
25–1W–7ccc	816	31	1938–62
25–1W–3aaa	825	25	1938–62
25–1W–5aaa	826	18	1939–49; 1955–62
25–2W–30ccc	830	57	1938–62
25–3W–9ccc	834	18	1938–62
25–3W–33baa	838	49	1938–53; 1955; 1958–62
25–2W–3ccc	840a	26	1952–62
25–2W–16bbb	842	15	1939–62
27–1E–6dcc	847	25	1939–62
25–2W–18aab	870	19	1939–62
25–2W–4aaa	1171	30	1950–62
25–1W–5ccc	1176	33	1950–62
25–3W–1ddd	3004	20	1949–62
25–2W–11cbc	3030	32	1950–62
25–3W–3ddd	3041	17	1953–62
25–2W–14ccc	3044	24	1953–62
25–2W–13bbc	3045	65	1954–62
25–2W–24ddd	3050	....	1952–62
25–2W–1baa	M25b	51	1939–62
25–2W–2bbb	M27	215	1947; 1949–62
25–2W–3aaa	M27b	80	1947–62
25–2W–2baa	M28	220	1947; 1949–62
25–2W–2abb	M28b	82	1947–62
25–2W–11bbb1	M29	225	1947; 1949–62
25–2W–11bbb2	M29b	103	1947–62
25–2W–11baa	M30	225	1947; 1949–62
25–2W–11abb	M30b	61	1947–62
25–2W–12bbb1	M31	197	1947; 1949–62
25–2W–12bbb2	M31b	62	1947–62
25–2W–12baa1	M32	185	1947; 1949–62
25–2W–12baa2	M32b	71	1947–62
25–2W–1daa	M33	170	1947; 1949–62
25–2W–1add	M33b	75	1947–62
25–1W–6ccc1	M34	150	1947; 1949–62
25–1W–6ccc2	M34b	85	1947–62

Well number this report	Well number City of Wichita*	Depth of well, feet below land surface	Period of record
25–1W–7baa	M35	130	1947; 1949–62
25–1W–6caa	M35b	86	1947–62
25–1W–7bcc1	M36	184	1958–62
25–1W–7bcc2	M36b	51	1958–62
25–1W–7bcc3	M36d	180	1958–62
25–1W–18abb1	M37	170	1958–62
25–1W–18abb2	M37b	53	1958–62
25–1W–18abb3	M37d	160	1958–62
25–1W–18aaa1	M38	128	1958–62
25–1W–18aaa2	M38b	46	1958–62
25–1W–18aaa3	M38d	127	1958–62
25–1W–17cbb1	M39	154	1958–62
25–1W–17cbb2	M39b	52	1958–62
25–1W–17cbb3	M39d	143	1958–62
25–1W–17ccc1	M40	127	1958–62
25–1W–17ccc2	M40b	41	1958–62
25–1W–17ccc3	M40d	121	1958–62
25–2W–5bbb1	M51	185	1958–62
25–2W–5bbb2	M51b	38	1958–62
25–2W–5bbb3	M51d	162	1958–62
25–2W–5bcc1	M52	40	1958–62
25–2W–5bcc2	M52b	40	1958–62
25–2W–5ccd1	M53	92	1958–62
25–2W–5ccd2	M53b	36	1958–62
25–2W–5dbb1	M54	80	1958–62
25–2W–5dbb2	M54b	38	1959–62
25–2W–5dcd1	M55	47	1958–62
25–2W–5dcd2	M55b	40	1958–62
27–1W–26ddd	....	87	1959–62†
28–1W–2cb	....	30	1959–62
28–1W–36adc	....	58	1959–62

* Well number is also used in State Geological Survey of Kansas Bulletins of ground-water levels in observation wells.
† Continuous water-stage recorder installed on well.
‡ Measurements discontinued.

of the water being pumped is derived from an ever increasing distance from the well, and as the cone of depression expands, the water table within the cone of depression continues to decline gradually. The cone of depression around the well will continue to increase in size until sufficient recharge is added to the aquifer or until the natural discharge of the aquifer is decreased, by an amount equal to that removed by pumping.

After discharge from the well has ceased, water will continue to move toward the well, for the water table gradient remains in that direction, but instead of being discharged from the well the water refills the cone of depression created by pumping. As the aquifer near the well is refilled the hydraulic gradient toward the well is gradually decreased, and the recovery of the water level becomes progressively slower. Near the edge of the cone of depression the water level may continue to decline for a time after pumping has stopped, because the water continues to move toward the well. In time there is a general equalization of water levels over the area affected, and the water table will assume its original form, although it may temporarily remain slightly lower than before water was withdrawn.

In general, in a group of pumping wells the hydrologic events are similar to those described above for a single well, but the effect on the water table is much more widespread. Figure 16 is a hydrograph of selected observation wells in the Wichita well field, the annual pumpage from the well field, and the cumulative departure from normal precipita-

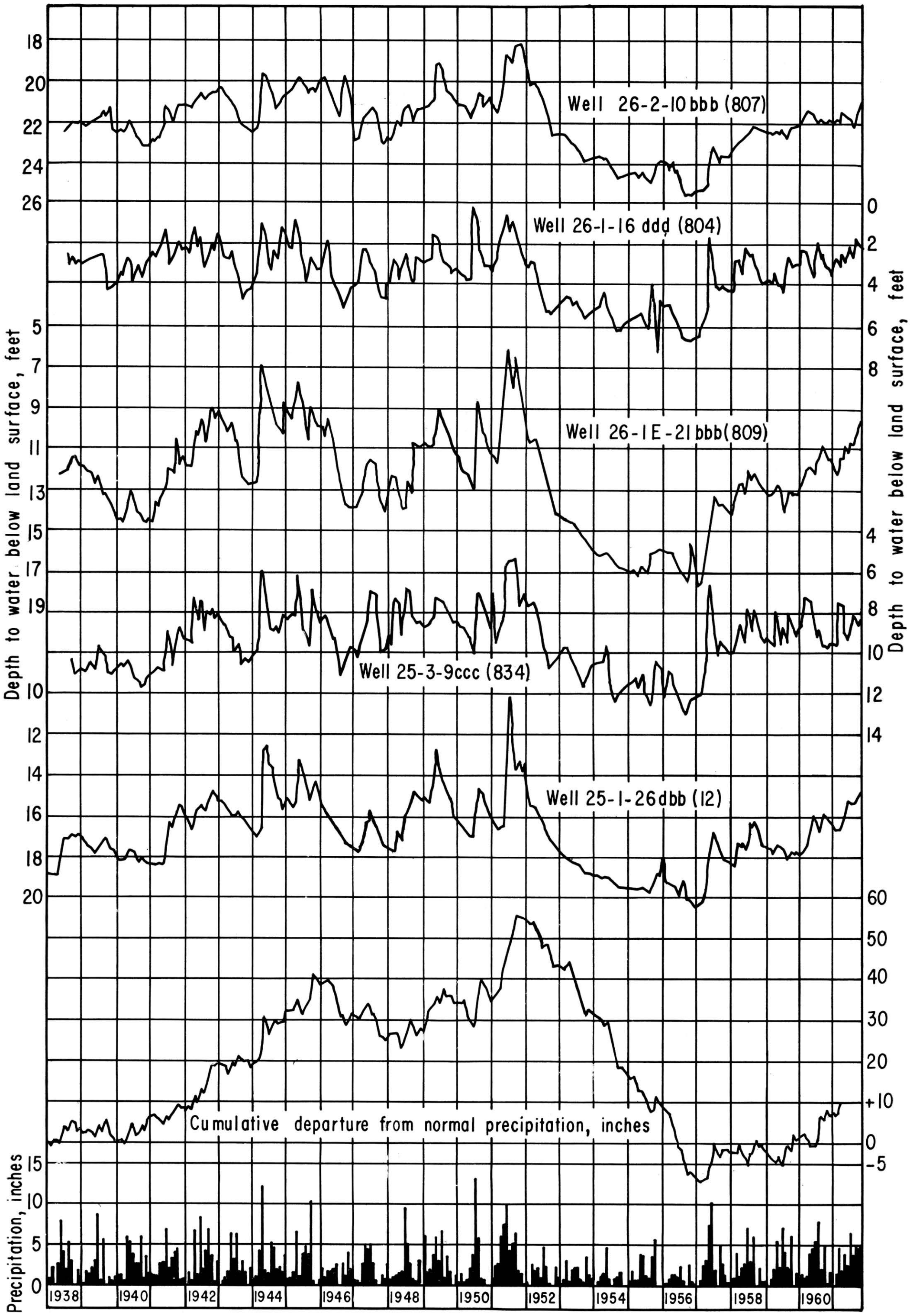


FIGURE 15.—Hydrographs showing fluctuations of the water table in selected wells not affected by pumping, monthly precipitation, and cumulative departure from normal monthly precipitation at Wichita, Kansas.

tion at Newton, Kansas. About the southern one-third of the well field, containing 19 wells, is in northern Sedgwick County and the remaining 36 wells are in Harvey County. The well field was constructed in three stages to meet increasing water demand: the original 25 wells in Harvey County were placed in production in 1940; in 1949, 10 wells, nine of them in Sedgwick County, were added; and in 1959, 20 additional wells, 10 of them in Sedgwick County, were added to the system. All of the hydrographs of wells shown in Figure 16 except one are from wells in Sedgwick County, and these most strongly reflect the water-level fluctuations caused by pumping since 1949. Well 24-2-9ccc is near the center of the pumping wells in Harvey County and shows the pattern of water-level changes in the well field since pumping began in 1940.

Inspection of the hydrograph shows the water table to be sensitive to changes in the hydrologic regimen of the area. The history of water-level fluctuations in the well-field area prior to 1938 is not known, but water levels were probably near normal or very slightly below normal following the drought of the 1930's. When pumping started in Harvey County in 1940, precipitation was near or slightly above normal, but the water table dropped steadily. The trend of the decline follows very closely the trend of increasing pumpage from the well field. During this period of development most of the water being pumped was coming from storage within the aquifer as a water-table gradient toward the well field was being established. By 1946 the downward trend of water levels in the well field ceased, owing to a combination of above-normal precipitation, a leveling off in pumpage from the field, and establishment of a water-table gradient toward the well field sufficient to balance withdrawals from and recharge to the aquifer. Withdrawals from the field increased steadily from 1947 through 1953, but water levels in the Harvey County area remained fairly steady through 1951, owing to above-normal precipitation. In 1949, 10 new wells were added to the well field, nine of them in Sedgwick County. Pumpage from the new wells caused a steady decline of the water table in adjacent areas that was reversed briefly during the very wet year of 1951. From 1952 through 1956 the area experienced the most severe drought on record. Pumpage from the well field increased greatly and water levels declined sharply until 1957 when precipitation returned to normal. Pumping from the field has decreased since 1957 and water levels have risen steadily through 1961. In 1959 20 wells were added to the well field, 10 in Harvey County and 10 in Sedgwick County, and a part of the water-level rise is probably due to spreading the withdrawal of water over a larger area. If pumpage from the well field does not increase and precipitation remains near normal, the water table in the well field will stabilize. Thereafter only minor fluctuations will take place as the pattern of pumping in the field is changed to spread withdrawals over the field. An increase in withdrawals or return to drought conditions would cause another period of declining water levels in the well field.

Water-table fluctuations in the Wichita well field have been measured regularly in a large number of observation wells since the installation of the field, and careful records of pumpage have been kept by the city. Maps are prepared periodically that show by means of contours, or lines of equal water-table change, the progressive change in shape and extent of the cone of depression created by pumping in the well-field area since pumping started in 1940. From these maps are prepared graphs showing the amount of decline plotted against the area in which the decline has taken place. Figure 17, *A* shows a change map and 17, *B* shows an areal decline curve between August 30, 1940, when pumping started, and October 1, 1956. The latter date is near the end of the severe drought of the 1950's, and Figure 17, *B* shows the maximum decline of the water table in the well field. In October 1956 the maximum decline of the water table was 32 feet in an area of less than 1 square mile in Harvey County. Measurable drawdown attributed to pumping affected an area of about 100 square miles. Figure 18, *A* shows a water-level change map and 18, *B*, areal decline curve between August 30, 1940, and January 1, 1960. The latter date follows a period of 3 years in which precipitation was normal or above normal and pumpage from

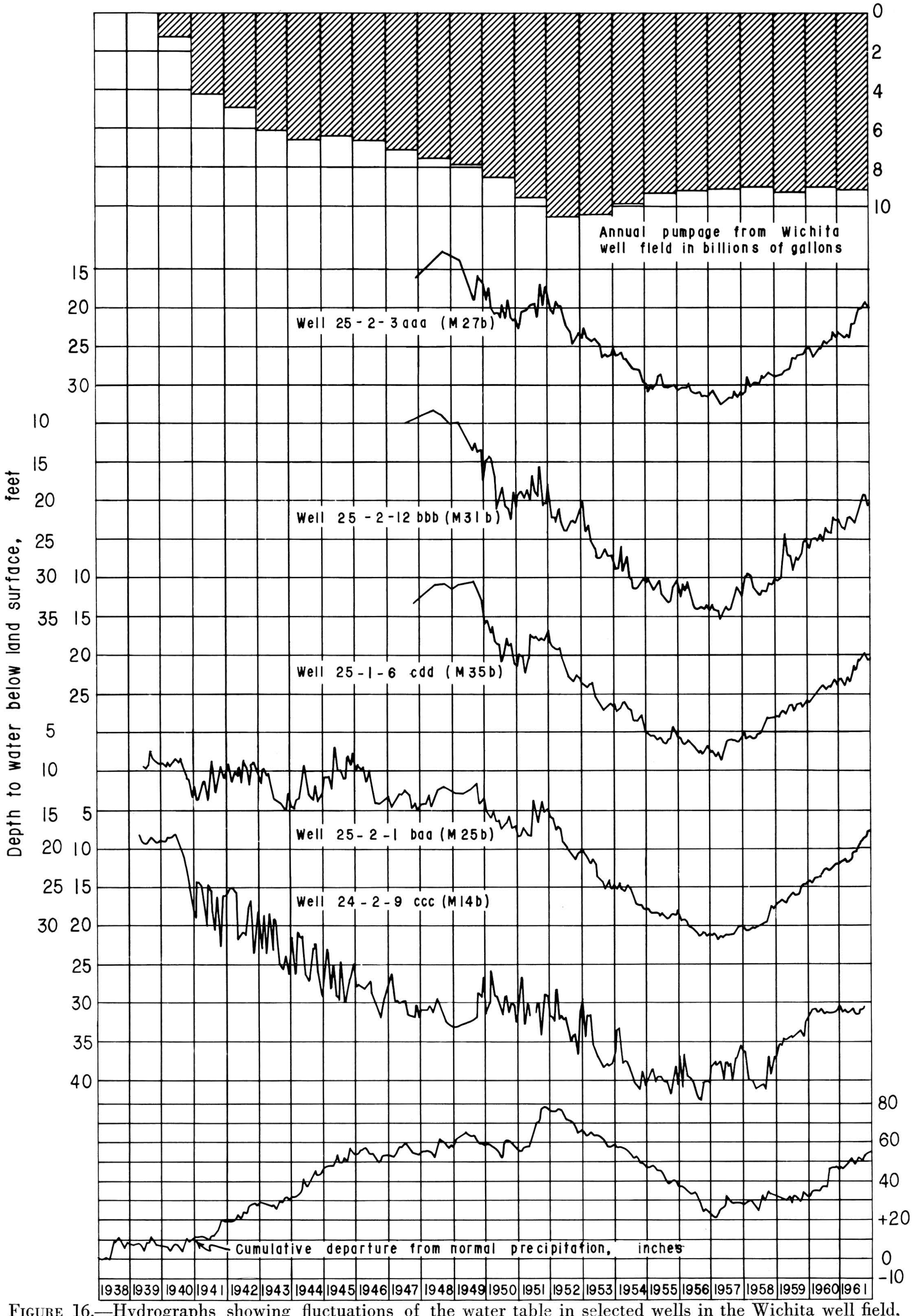


FIGURE 16.—Hydrographs showing fluctuations of the water table in selected wells in the Wichita well field, annual pumpage from the well field, and cumulative departure from normal precipitation at Newton, Kansas.

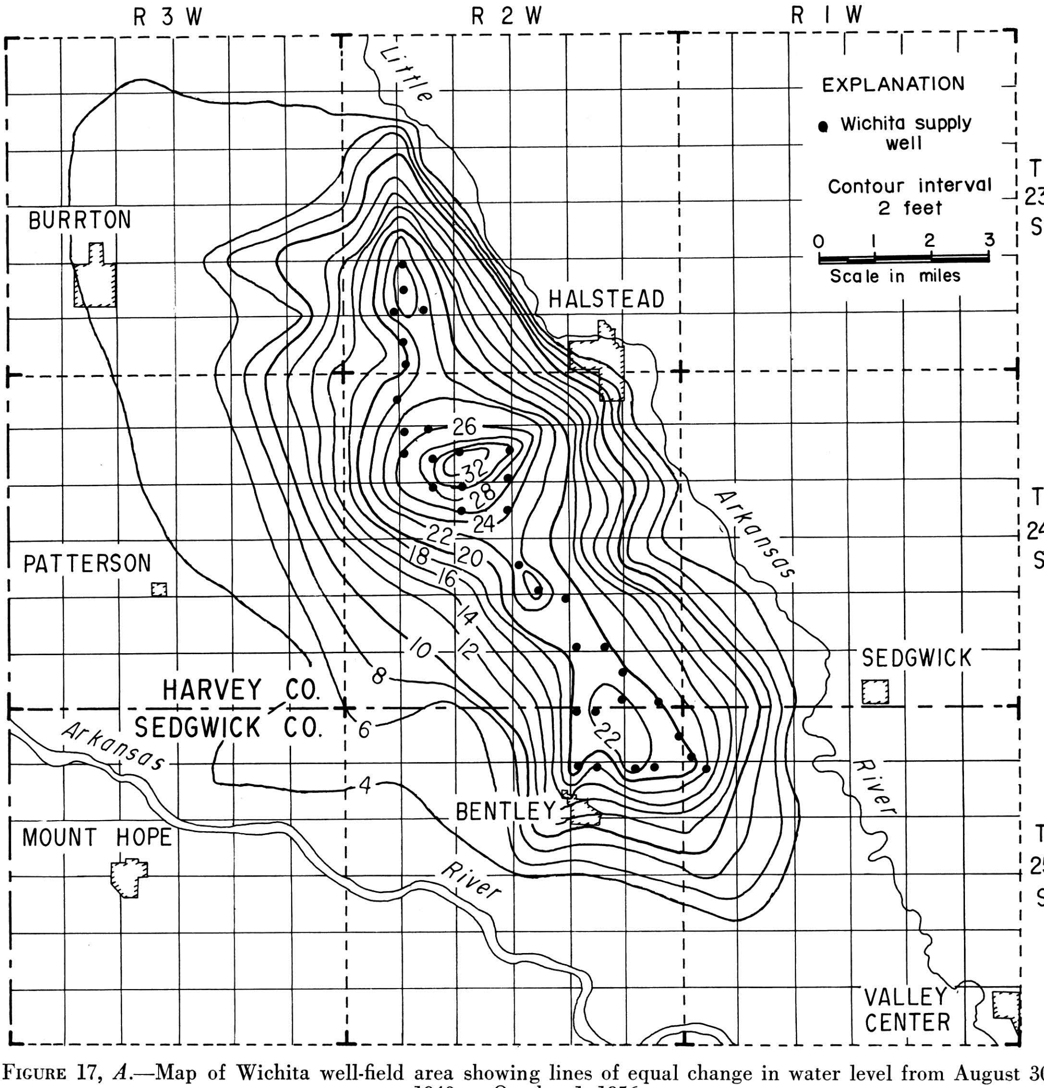


FIGURE 17, *A*.—Map of Wichita well-field area showing lines of equal change in water level from August 30, 1940, to October 1, 1956.

the well field was relatively stable. In January 1960 the maximum decline of the water table was 22 feet in an area of about 1 square mile. The area in which measurable drawdown due to pumping could be determined had decreased to about 90 square miles, and throughout this area water levels showed an appreciable rise above the lowest level of 1956. The maximum fluctuation of the water table in the well-field area under natural conditions of recharge and discharge through a climatic cycle is believed to be about 8 feet, but it is not uniform owing to local conditions.

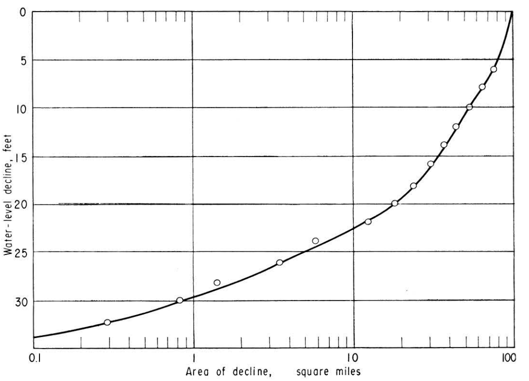


FIGURE 17, *B*.—Area decline curve for October 1, 1956, Wichita well-field area.

Fluctuations Caused by Changes in Atmospheric Pressure

In addition to the fluctuations of the water-table caused by addition or withdrawal of water from a ground-water reservoir, minor fluctuations caused by changes in atmospheric pressure are observed in some wells. In wells that penetrate water-bearing beds having a relatively impervious confining bed above the zone of saturation the water level may fluctuate inversely with the atmospheric pressure. The pressure on the water surface in a well changes directly in proportion to the change in atmospheric pressure. If the change in pressure is not transmitted uniformly to the ground-water body, but acts only on the exposed water surface in the well, the water level in the well fluctuates according to the changes in pressure. If the pressure is transmitted freely to the water table through the pore spaces of the soil, the water level in the well will reflect no appreciable barometric effect.

A hydrograph of well 27-1W-26ddd obtained from an automatic water-stage recorder and an inverted barograph trace obtained from a recording microbarograph at the same location are shown in Figure 19. On the hydrograph the fluctuations caused by barometric changes are superimposed on a gradually declining water level, but they correlate very closely. The rapid barometric fluctuations occurring on September 29 and October 2 produced a greater water-level fluctuation than more slowly occurring barometric fluctuations of the same magnitude and may indicate some leakage of air through the clayey silt overlying the aquifer with gradual changes in air pressure.

GROUND-WATER RECHARGE

Recharge to the ground-water reservoir at any particular place may occur in several ways, but the ultimate source of all ground water of quality suitable for use is precipitation in an area or in nearby areas. Of the total precipitation, a part runs off directly across the land surface to streams, a part is dissipated by evaporation from the land surface or from vegetation, a part is transpired by plants from the zone of soil moisture, and a part percolates downward to the zone of saturation. In addition to the direct infiltration of precipitation, the ground-water reservoir may be recharged locally by the infiltration of water from stream channels above the water table or by subsurface inflow from nearby areas. Under favorable conditions recharge may be effected artifically by such means as injection through wells, infiltration from recharge pits, or from water spreading, or by inducing the infiltration of river water into the reservoir by lowering the water table below the level of an adjacent stream.

Recharge from Precipitation

Precipitation is the source of most of the ground-water recharge in Sedgwick County, but the quantity of recharge at a particular site is strongly affected by local conditions. The amount and distribution of precipitation, the depth to the water table below the land surface, the slope of the land surface, the physical character and composition of the soil and subsoil, the condition and moisture content of the soil and subsoil, the type and density of vegetation, and the presence of soil cracks, roots, animal burrows, or other openings in the soil have a marked effect on recharge.

In the Arkansas Valley, conditions for recharge are very favorable and reasonably uniform, although local variations do exist. In areas of concentrated pumping, such as the Wichita well field, recharge conditions have probably changed in response to the changed conditions in the ground-water reservoir. Williams and Lohman (1949) estimated the recharge in the well-field area to be about 20 percent of the precipitation, or an average rate of about 320 acre-feet (1 acre-foot equals 325,850 gallons) per year per square mile. Although the amount of recharge varies from year to year in response to precipitation, later work in the area (Stramel, 1956) has shown these estimates to be of the right order of magnitude for the effective recharge in the well-field area. Table 4 is a tabulation of the quantity of recharge that has taken place for selected periods since the development of the well field. These computations were obtained from pumpage records and maps of water-level change. Specific yield was assumed to

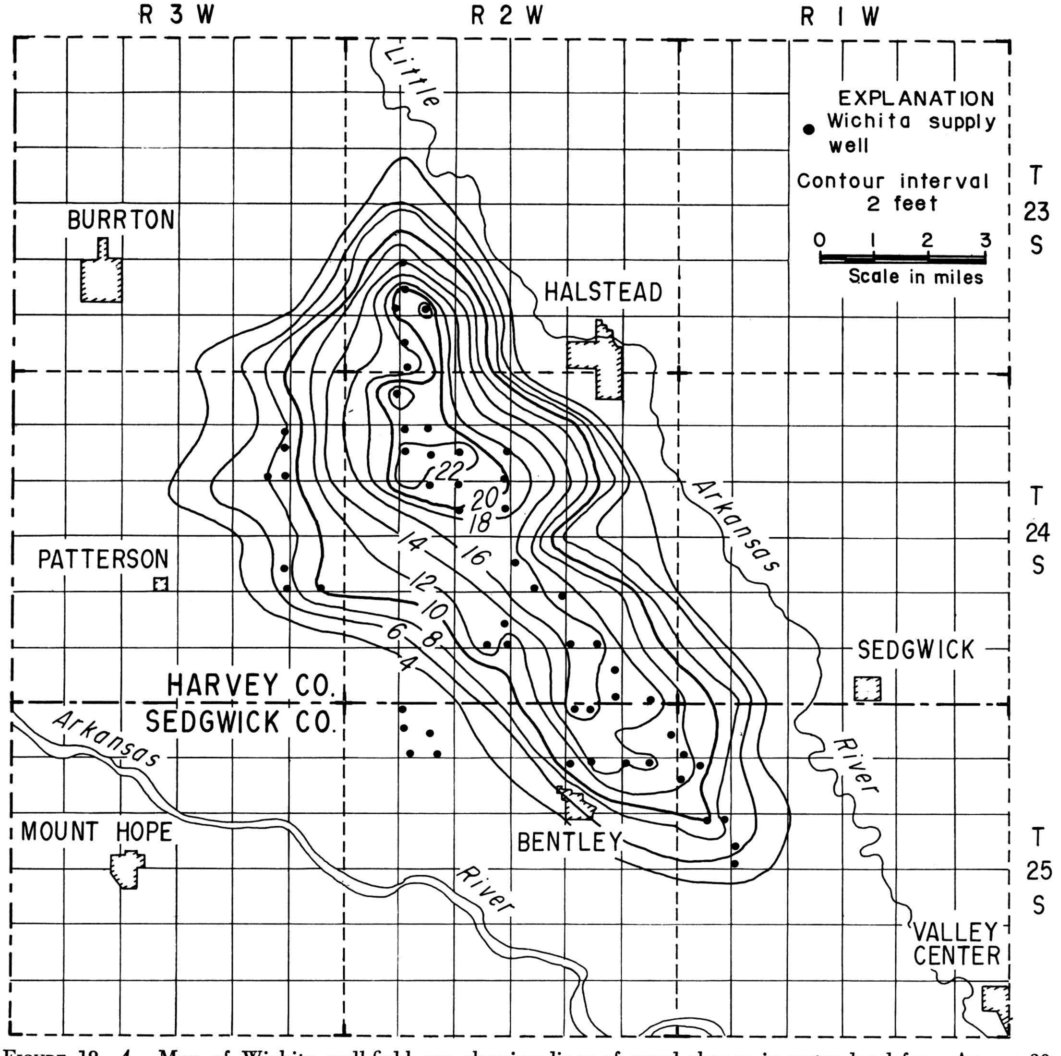


FIGURE 18, *A*.—Map of Wichita well-field ara showing lines of equal change in water level from August 30, 1940, to January 1, 1960.

be 20 percent for the dewatered sediments. Similar recharge conditions would probably apply to much of the Arkansas Valley under similar conditions of development. In much of the Arkansas Valley within the County withdrawals of water by pumping are not large, and the water table is within a few feet of the land surface. In such areas there is little or no recharge.

In areas where bedrock is at the surface, conditions for recharge from precipitation are much less favorable, but recharge can occur through fractures and solution openings de-

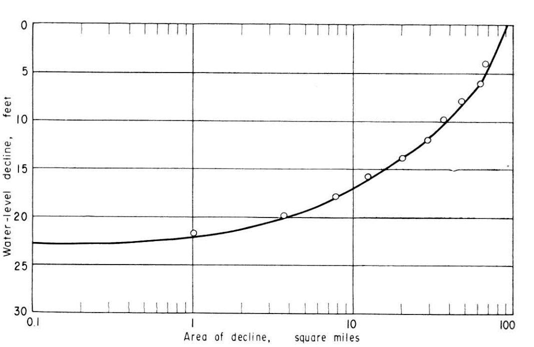


FIGURE 18, *B*.—Area decline curve for January 1, 1960, Wichita well-field area.

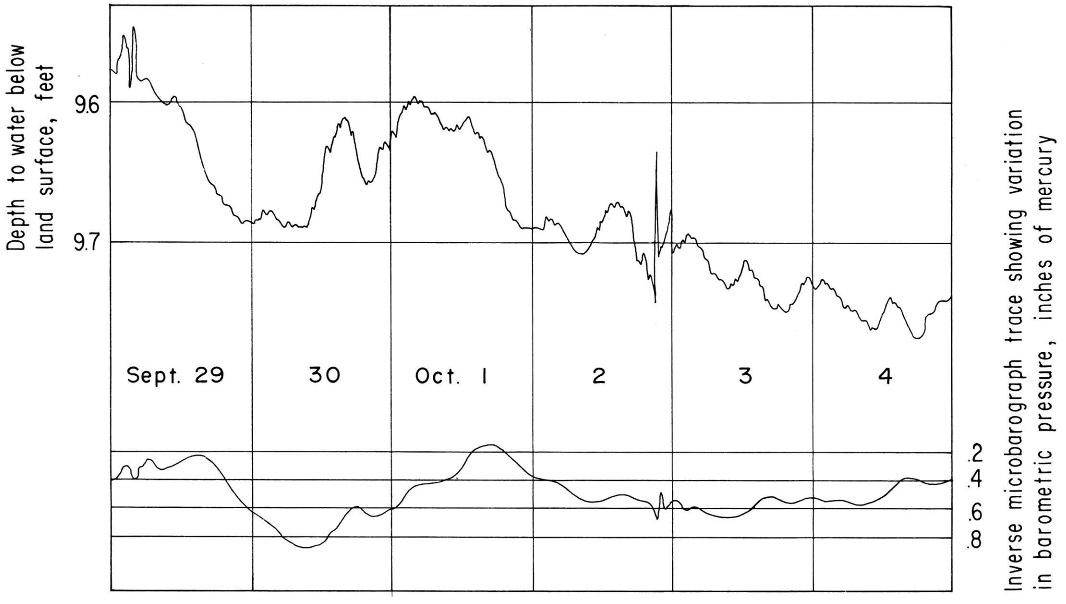


FIGURE 19.—Water-level fluctuations in well 27-1W-26ddd caused by changes in atmospheric pressure, September 29 to October 4, 1960.

veloped by weathering of these rocks. Where loess overlies bedrock or permeable sand and gravel, the loess retards the downward percolation of precipitation but it is believed to be more receptive to infiltration than the bedrock. The porosity of the loess is very high, and because it is very fine grained its permeability is low. The loess probably retains most of the infiltrated water within the soil zone and transmits water to the zone of saturation only during excessively wet periods.

Recharge from Streams

The Arkansas, Little Arkansas, and Ninnescah rivers and the lower reaches of their larger tributaries are all gaining or effluent streams within Sedgwick County and derive a

TABLE 4.—Summary of recharge in the Wichita Well Field.*

Period from August 30, 1940 to	Area affected by pumping, acres	Net reduction in storage, acre-feet	Quantity of water pumped, acre-feet	Quantity of water derived from recharge, acre-feet	Percent of total water pumped derived from recharge
January 1, 1944	32,300	33,900	51,600	17,700	34
January 1, 1948	34,700	49,800	135,800	86,000	63
January 1, 1952	32,400	50,200	230,000	179,800	79
January 1, 1955	66,000	111,000	330,300	219,000	67
January 1, 1958	47,400	115,000	409,000	294,000	72
January 1, 1960	57,000	107,000	462,000	355,000	77

* Data from files of the Water Department, Wichita, Kansas.

part of their flow from the discharge of ground water. The Arkansas River above Wichita is nearly in equilibrium with the ground-water reservoir, neither receiving nor contributing water to it. The gradient of the river in this reach is nearly the same as and in the same direction as the slope of the water table.

During periods of flood when the streams run bankfull or spill onto their flood plains, some of the surface water enters the ground-water reservoir. When the streams return to normal stages, the ground water stored in the alluvium adjacent to the streams is returned to them, and ground-water levels return to a normal stage.

Pumping from the Wichita well field has reduced the water-table gradient toward the Little Arkansas River but has not lowered water levels sufficiently to cause the river water to recharge the ground-water reservoir.

The upper reaches of small tributary streams in the County lie above the water table generally and may contribute some recharge to the underlying rocks. Parts of the courses of these streams are near the level of the uplands and carry water only after periods of precipitation, so that the opportunity for recharge is of short duration, and the quantity of recharge is probably insignificant.

Recharge from Subsurface Inflow

Ground water moving into an area in the direction of the water-table gradient from an adjacent area is commonly referred to as "inflow." The water-table contours shown on Plate 1 indicate that some ground water derived from precipitation on adjacent areas moves into Sedgwick County. The principal areas where inflow occurs is along the north half of the west county line. Some minor contributions occur adjacent to the North and South Fork Ninnescah rivers where they enter the County. The water-table gradient seems to parallel the north county line toward the Wichita well field and probably very little inflow takes place in this area. The water-table contours along the southern edge of the County show ground water to be flowing from the County in this area, and it is believed that the inflow and outflow are very nearly the same and that the net effect of inflow from adjacent areas is negligible. No attempt was made to compute the net quantity of inflow, but compared to recharge from precipitation, it is probably insignificant.

Artificial Recharge

Artificial recharge, whereby water is added to the zone of saturation by other than natural means, is one method of storing surplus surface water for later use and alleviating the adverse effects on the ground-water reservoir of concentrated pumping. The principal methods of artificially recharging a ground-water reservoir are water spreading or flooding, recharge through pits and other excavations, injection of water through wells, and induced infiltration of river water by pumping. Each method has advantages and disadvantages dependent on local conditions of climate, surface and subsurface geology, and the quality of the water available for recharging. With other conditions being favorable for artificial recharge, the two prime requirements for successfully recharging would be a water supply suitable in quantity and quality and at the right place for the purpose, and storage space in the ground-water reservoir adequate for conducting the added water away from the recharge site.

Artificial recharge is not intentionally practiced in the Arkansas Valley although geologic conditions are favorable in much of the area for some form of artificial recharge. The ground-water reservoir is nearly full in most of the area where artificial recharge might be practiced, and little storage space is available in the reservoir for additional water with the exception of the Wichita well field. Pilot studies of several methods of artificial recharge have been conducted by G. J. Stramel, hydrologist of the Wichita Water Department, to evaluate the feasibility of some form of artificial recharge in the city well field in Harvey and Sedgwick counties. The data collected during these studies are in the files of the Wichita Water Department and will not be presented here, but a brief summary of these studies and the pertinent results follows, as they are believed applicable to much of the Arkansas Valley in Sedgwick County.

The feasibility of recharging surface water to the ground-water reservoir through a well was studied, using an idle water-supply well in the SW SW SW sec. 26, T 24 S, R 2 W, in Harvey County. The water supply was from a small intermittent creek passing near the well. A conduit containing a trash screen and gravel filter was installed between the creek and the well so that water would flow into the well by gravity when available in the creek. The quantity of flow into the well was measured by a recording gage and the water level around the well was measured in nearby observation wells. The intake rate showed a steady decline although several million gallons of water could be injected before the well became badly plugged. The well could be cleaned by pumping, and investigation of the discharged water showed a high content of clay-size particles in the initial discharge from the well, indicating that the gravel filter was not satisfactorily removing the smaller particles of suspended sediment of the creek water. It was concluded that to operate the recharging well satisfactorily for a reasonably long period, the water injected would have to be of a biological, physical, and chemical quality that would have permitted direct use of the water.

A recharge pit was constructed near Kisiwa Creek in T 24 S, R 2 W, Harvey County, to utilize the intermittent flows of that creek as a source of water to study the feasibility of using untreated surface flows as a recharge source. The pit was excavated to a depth that exposed the sand and gravel of the aquifer, and an inlet structure suitable for measuring inflow to the pit was provided. The configuration of the water table under and near the pit was measured in observation wells. The initial outflow from the pit was quite rapid but the bottom and sides of the pit plugged within a short time. The bulk of the plugging material proved to be particles of clay size that could not be easily removed by gravity settling alone but would require flocculation for removal. It was concluded that for successful operation of this recharge pit some pre-treatment of the water to remove most of the suspended sediment would be necessary.

Two experiments to determine the feasibility of inducing water from the Little Arkansas River to recharge the underlying aquifer were conducted at a site in SW sec. 23, T 25 S, R 1 W in Sedgwick County. Geologic conditions are more favorable for this type of recharge along the Arkansas River, but the quality of the river water is unsatisfactory for municipal supply most of the time.

The first experiment involved the installation of a horizontal well screen in the stream channel with a vertical riser pipe at one end for installation of pumping equipment. The well screen was 50 feet in length, 16 inches in diameter, and was buried about 8 feet below the bottom of the river bed. The excavation was back-filled with coarse sand and gravel as a filter medium. Attempts to develop the well screen by conventional methods encountered serious difficulties, and the yield of the well, about 400 gallons per minute, was disappointing. Inability to adequately develop the well screen and probably silting of the stream bed over the screen indicated that this type of installation was not satisfactory under the conditions at this well site.

The second experiment involved installation of a vertical well adjacent to the stream channel to induce the flow of water from the river into it. The well, about 75 feet from the stream channel, was 16 inches in diameter with a 3-inch gravel pack surrounding a 20-foot length of screen. The well extended 34 feet below the river bed. Observation wells were installed on both sides of the river to determine the configuration of the water table around the well. The well was pumped continuously for 32 days at an average rate of about 800 gallons per minute. The pumping test demonstrated that significant infiltration of river water would take place, but that even after 32 days of pumping not all of the water was being derived from the river.

No economic feasibility studies were made in conjunction with the artificial recharge studies, but of the three methods investigated, induced infiltration of river water is believed to be the most practical at the present time.

GROUND-WATER DISCHARGE

When water derived from precipitation or other sources reaches the zone of saturation, it moves down gradient in the direction of the slope of the water table. The water remains a part of the ground-water body until removed or discharged by natural or artificial means. Water may be discharged from an aquifer by evaporation, plant transpiration, seepage into streams, as discharge from springs, or by pumping from wells. Discharge from the ground-water reservoir takes place by one or more of these methods most of the time. Over a period of years, or a climatic cycle, the quantity of ground-water discharge is about equal to the quantity of recharge, although this balance may be upset locally in areas of heavy pumping.

Discharge by Evaporation and Transpiration

Plants normally derive their water supply from water stored within the soil zone but under favorable conditions may take up water directly from the zone of saturation or from the capillary fringe above it and discharge it into the atmosphere by the process of transpiration. The depth from which plants lift water varies with the plant species and the type of soil in which the plant grows. Most grasses and field crops common to this area lift water only a few feet; however, alfalfa and certain types of water-loving trees and shrubs of arid regions have been known to extend roots to depths of as much as 60 feet to reach a water supply. Where the water table or the capillary fringe is near the land surface, significant quantities of ground water are discharged by direct evaporation from the ground-water reservoir.

Within the County a significant quantity of ground water is discharged by evaporation and transpiration and this quantity probably exceeds that by all other forms of discharge. Throughout most of the Arkansas Valley, the depth to water is less than 20 feet, and in the area of Recent alluvium and Wisconsinan terrace deposits (Pl. 1) the water table is commonly less than 10 feet below the land surface. A large quantity of ground water is evaporated and transpired along the Arkansas, Little Arkansas, and Ninnescah rivers, and along Cowskin and Big Slough creeks by the dense growth of vegetation along these streams that intercepts water that would normally be discharged into these streams. Lesser, but still significant, quanties of ground water are discharged by this means along the smaller tributary streams and the floodway west of Wichita. Within the Wichita well field in Harvey and Sedgwick counties a large part of the apparent recharge is believed to be water that would have been discharged by evaporation and transpiration had the water table not been lowered to a degree that reduces their effectiveness as a means of discharge.

Discharge into Streams

Stream flow at low stages of the Little Arkansas, the Arkansas, and the Ninnescah rivers and their larger tributaries in the County is maintained by ground-water discharge. Discharge into the streams occurs mainly through seeps in and along the stream channels. Upstream from near the mouth of the Little Arkansas River, where the Arkansas River is in approximate equilibrium with the water table, very little or no seepage enters the river. During prolonged droughts flow ceases because the water table drops below the river bed and any flow that might come from upstream percolates down to the water table. Seepage maintains the water level in several small lakes occupying sinks in the north-central part of the County by replacing water lost by evaporation from the water surface.

The quantity of seepage into streams is not known, but it is believed to be quite large. Most of the ground water moves toward the Little Arkansas and Arkansas rivers below the junction of the two, and any water not discharged by evaporation, transpiration, or by wells, eventually reaches these streams. Seepage measurements on the Little Arkansas River above Valley Center were made in September 1961, by the Surface Water Branch, U. S. Geological Survey. Some transpiration losses were probably taking place adjacent to the river, but these losses were probably slight as most vegetation either had ceased growing or was approaching dormancy. Unpublished data from two measuring stations in Sedgwick County, located in SE SW sec. 4, T 25 S, R 1 W., and NW SW sec. 36, T 25 S, R 1 W, showed an increase in flow of about 20 cubic feet per second or 12.93 million gallons per day. The distance between the two stations normal to the direction of ground-water flow is about 5.5 miles, and the discharge to the river was about 2.35 million gallons per day per mile. The discharge by seepage varies greatly depending upon river stage, ground-water stage, time of the year, and probably time of day, so that the seepage figure given above cannot be applied without some qualification. However, it does give a suggestion of the magnitude of seepage into the streams.

Discharge by Springs

The distinction between seeps and springs is not sharp, but ground water issuing from well-defined openings in rocks is properly classed as a spring. Several large springs are present in the drainage basin of Four Mile Creek east of Wichita and these issue from the Wellington Formation. Two of these springs, located in SW SW SW sec. 13, T 27 S, R 2 E, and SW NE NE sec. 36, T 27 S, R 2 E, were visited during the course of field work for this report. The springs issue from a gypsiferous zone in the Wellington Formation that has been exposed by erosion near the creek channels. This zone contains water under artesian pressure. The discharge of the spring in section 36 could not be measured, but that in section 13 was measured at 235 gpm. Local residents report that the discharge of the springs fluctuates in response to precipitation, but the range of fluctuation is not known.

Other springs are known to issue during wet periods near creek channels along the east wall of the Arkansas Valley and in T 28 S, R 2 W, and T 28 S, R 3 W. In both areas the springs issue at the contact between the unconsolidated deposits and the underlying, impermeable shale. The discharge from springs in these areas is not large and ceases during dry periods.

Discharge by Wells

Most of the water used in the County is obtained from wells. Water is pumped for municipal, industrial, irrigation, stock, and domestic use. The largest withdrawals take place in the Arkansas Valley where the Wichita well field and most of the industries are located. Most of the farms are supplied with water from wells, although some water for livestock is derived from ponds. The quantity of water pumped for each of these uses, insofar as it is known, is presented in the section of the report on utilization of water.

GROUND-WATER AREAS

Generalized ground-water areas and subareas within the County are shown on Figure 20 and are explained in the section of the report that follows. There are four major ground-water areas: the Arkansas Valley, the Ninnescah Valley, the Wellington Upland, and the Ninnescah-Wellington Upland. Where ground-water conditions are not uniform within an area, it has been divided into subareas.

Arkansas Valley (Area A)

The Arkansas Valley is characterized by its extreme flatness and the poorly developed surface drainage of the land flanking the Arkansas River. The area is underlain by alluvial sediments of Pliocene to Recent age that are the most productive water-bearing rocks in the County. Although the deposits are stratified and lenticular (Pl. 2), the sand and gravel beds containing most of the ground water are interconnected, and the complete sequence of silt, clay, sand, and gravel beds responds to long-term withdrawals of water as a singe aquifer.

The Arkansas River valley contains most of the usable ground water in the County, and most of the large ground-water supplies are obtained from this area. The quantity of ground water in storage within the sediments of the valley is about 6.1 million acre-feet if an assumed specific yield of 20 percent for the sediments is correct. This volume of water does not represent the amount that could ultimately be withdrawn from the area, but rather a reserve that could be regulated to provide a perennial yield without progressive depletion of storage if other hydrologic factors affecting the aquifer are known. Ultimately, the perennial yield will depend on the average annual recharge. Williams and Lohman (1949, p. 129) estimated the net average recharge in the Arkansas Valley to be about 20 percent of the annual precipitation or about 320 acre-feet per square mile per year in years of normal precipitation. Experience has shown this recharge rate to be approximately correct for the Wichita well-field area of Harvey County (Stramel, 1956). However, this figure does not take into account the concurrent natural discharge by seepage into streams and evapotranspiration, and if these losses from the ground-water reservoir could be salvaged for use, the effective recharge rate would be much greater. In much of the Arkansas Valley adjacent to the principal streams the depth to water below the land surface is less than 10 feet (Pl. 1) and discharge by evapotranspiration in this area is thought to exceed all other forms of natural discharge. In much of the remaining area of the valley the water table is deeper but is in clayey silt or other fine-grained sediments underlying the surface, and the capillary rise of water in these sediments may bring a large volume of water close enough to the surface for evapotranspiration to become an effective means of discharge. No studies of this phenomenon have been made in the area, but random observations of soil moisture conditions and crop growth strongly suggest that the capillary fringe above the water table may contribute significantly to ground-water discharge. Much of the natural discharge of ground water in the Arkansas Valley could be salvaged by pumping strategically spaced wells to lower the water table below the level where evapotranspiration is effective and to intercept ground water that is now discharged to streams. Maximum utilization of the ground-water supply by this method, while feasible, might cause some water quality problems owing to movement of poor quality water from the Arkansas River and social and economic problems in regard to established water rights and agricultural practices.

The yields of wells in the Arkansas Valley

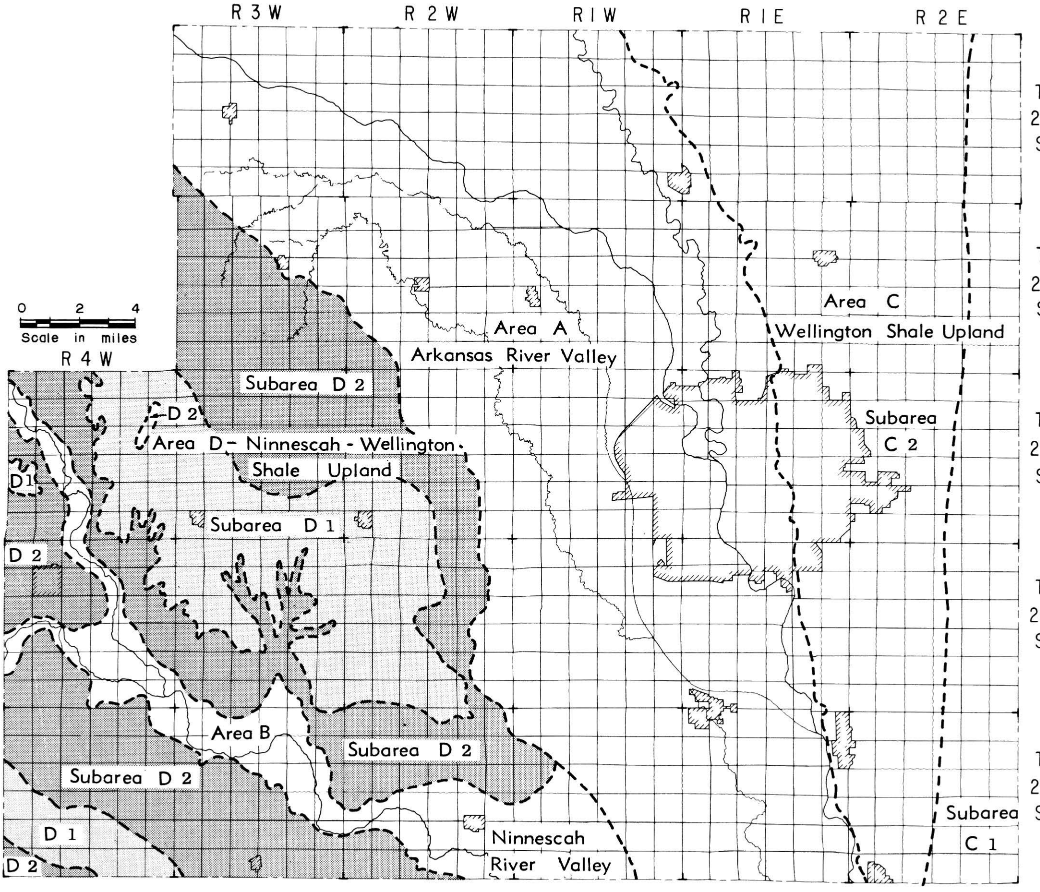


FIGURE 20.—Map of Sedgwick County, Kansas, showing generalized ground-water areas and subareas.

range from a few gallons per minute for small domestic and livestock wells to about 1,500 gpm for large municipal and industrial wells. In favorable areas, well yields of 2,500 gpm should be possible without excessive drawdown. The yield of individual wells designed and developed for maximum yield is dependent on several geologic and hydrologic factors. Maximum well yields will be obtained generally where the saturated thickness, sand and gravel thickness, and transmissibility of the sediments are greatest. These properties of the sediments in the Arkansas Valley are shown by means of contours on Figures 21 to 23. The saturated thickness map was prepared by superimposing the water-table contour map (Pl. 1) over the bedrock contour map (Pl. 3) and drawing contours through points of equal saturated thickness. The sand thickness contour map was prepared by contouring points of equal sand thickness obtained from logs of wells and test holes and does not include silt and clay beds that were present at the well site. The transmissibility map was prepared by applying permeability values obtained from selected pumping tests in the area to the sand and gravel thickness as recorded in the logs of wells and test holes for those formations for which samples were available. In much of Arkansas Valley, particularly where the total sand and gravel thickness is greatest, the permeability of these sediments decreases with depth. The permeability value applied to an individual sand and gravel bed at a well or test-hole site was based on a comparison of the lithology of the

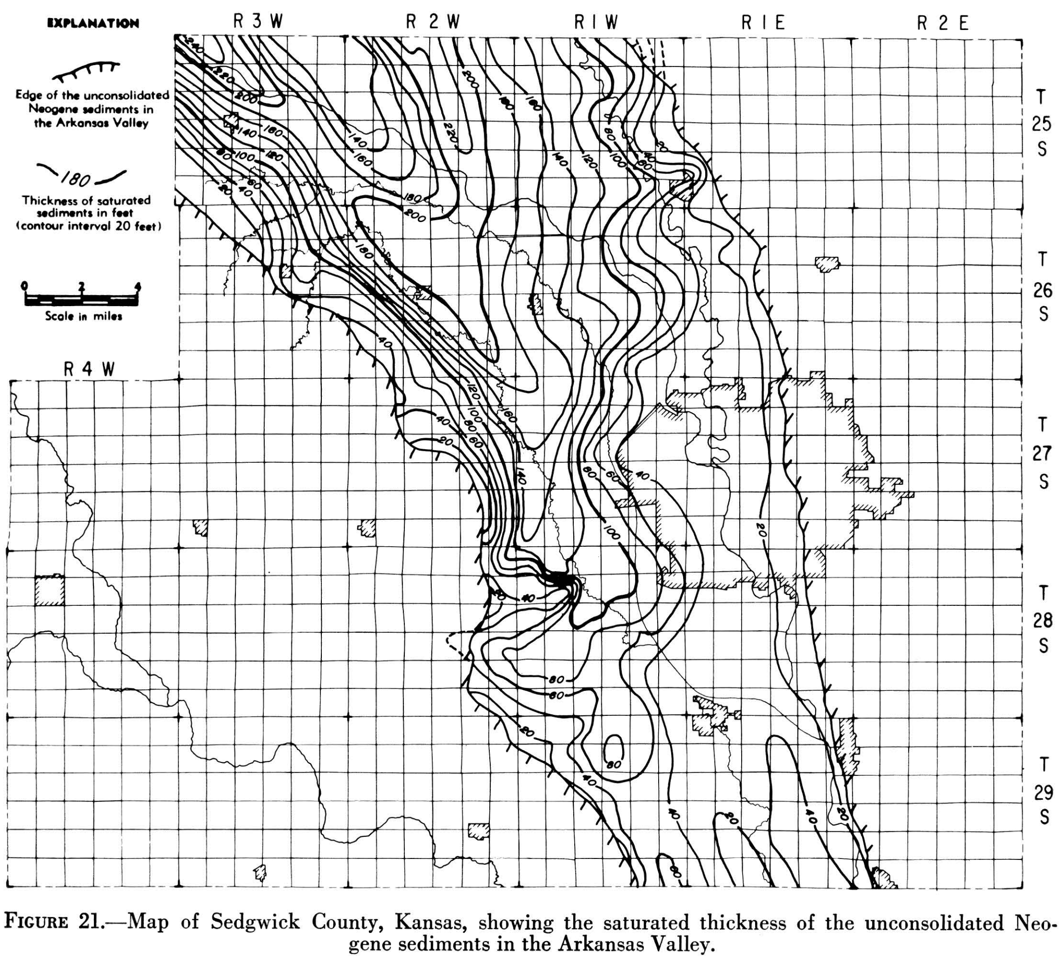


FIGURE 21.—Map of Sedgwick County, Kansas, showing the saturated thickness of the unconsolidated Neogene sediments in the Arkansas Valley.

bed with that of similar sediments from wells where permeability data derived from pumping tests were available.

The preparation of maps such as those shown on Figures 21, 22, and 23 require the exercise of some personal judgment in interpretation of available data, and the maps should be used with this thought in mind. However, the data presented on these maps are sufficiently accurate to provide a useful guide in selecting areas for water-supply developments. Although local geology at a well site and the well construction method will strongly influence the yield obtained, an estimate of the well yield can be made from the transmissibility map. Where the transmissibility is less than 50,000 gpd (gallons per day) per foot, water adequate for farm use and for lawn or garden irrigation is readily obtained. Where transmissibility is between 50,000 and 150,000 gpd per foot, well yields of 500 to 1,000 gpm can be expected, and where transmissibility is over 150,000 gpd per foot, yields of over 1,000 gpm are commonly available. The saturated thickness and sand thickness at a well site will affect the long-term yield of a well and should be considered when estimating well yields. In parts of Arkansas Valley, particularly along the sides, the transmissibility is relatively high but the aquifer is thin, and lowering the water level near a well more than a few feet by pumping will reduce the transmissibility and thus the well yield.

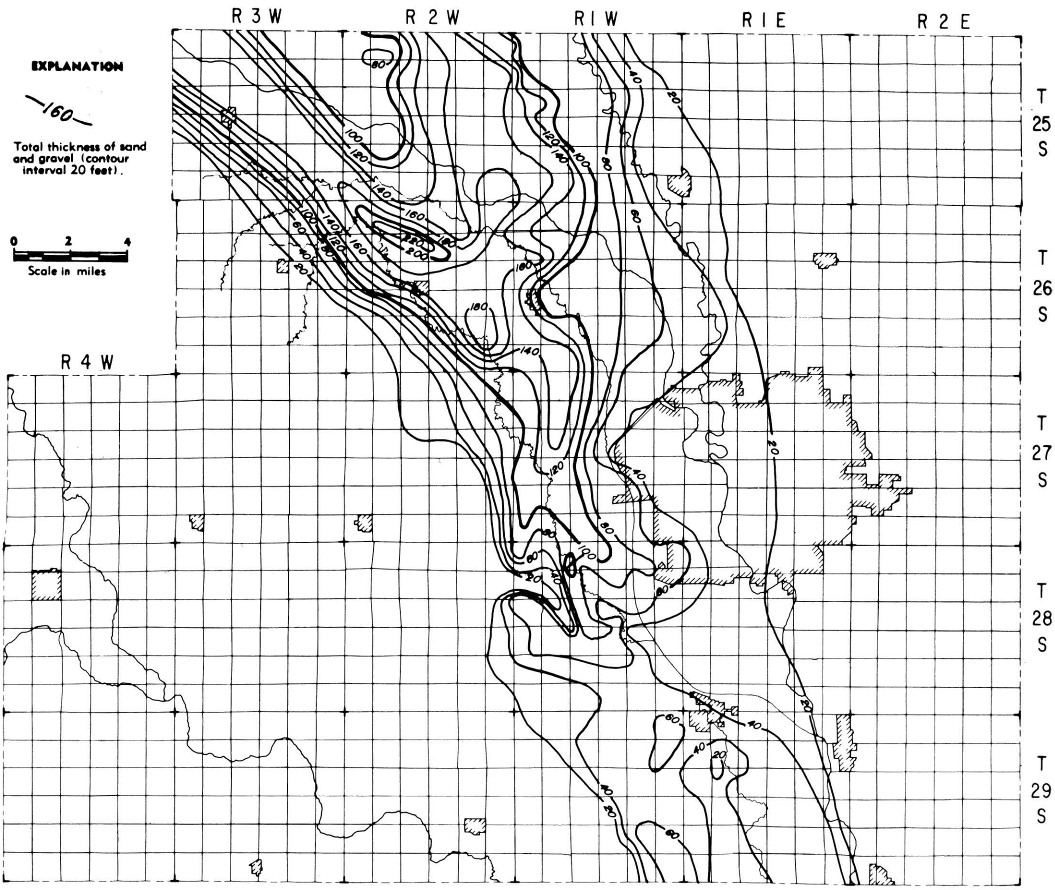


FIGURE 22.—Map of Sedgwick County, Kansas, showing the total thickness of sand and gravel in the unconsolidated Neogene sediments in the Arkansas Valley.

Ninnescah Valley (Area B)

The Ninnescah Valley area as shown on Figure 20 includes the lowlands flanking the Ninnescah River and its principal tributaries, the North and South Fork Ninnescah rivers. The area is underlain by silt, sand, and gravel that locally yields up to 250 gpm to properly constructed wells. The deposits underlying the valley range in thickness from a featheredge along the margin to about 55 feet, but average about 45 feet. The depth to water below land surface in the valley ranges from less than 10 feet adjacent to the rivers to as much as 25 feet along the valley sides.

The lithology of the sediments underlying the valley is quite heterogeneous, and generalizations regarding favorable sites for ground-water developments cannot be made from the data available. Locally the complete section may be composed of silt, and a short distance away sand and fine gravel may predominate. Where the river channel is cut into sand and gravel beds, wells close to the channel could produce moderately large yields by induced infiltration of river water. However, the location of favorable sites for such wells would require exploratory drilling, and wells would need protection from periodic flooding by the river.

Few details are known regarding recharge and discharge of ground water in the Ninnescah Valley. However, the Ninnescah River is effluent throughout its course in the County. The river is flanked by a dense growth of large trees and brush throughout most of its course, and during part of the year ground-

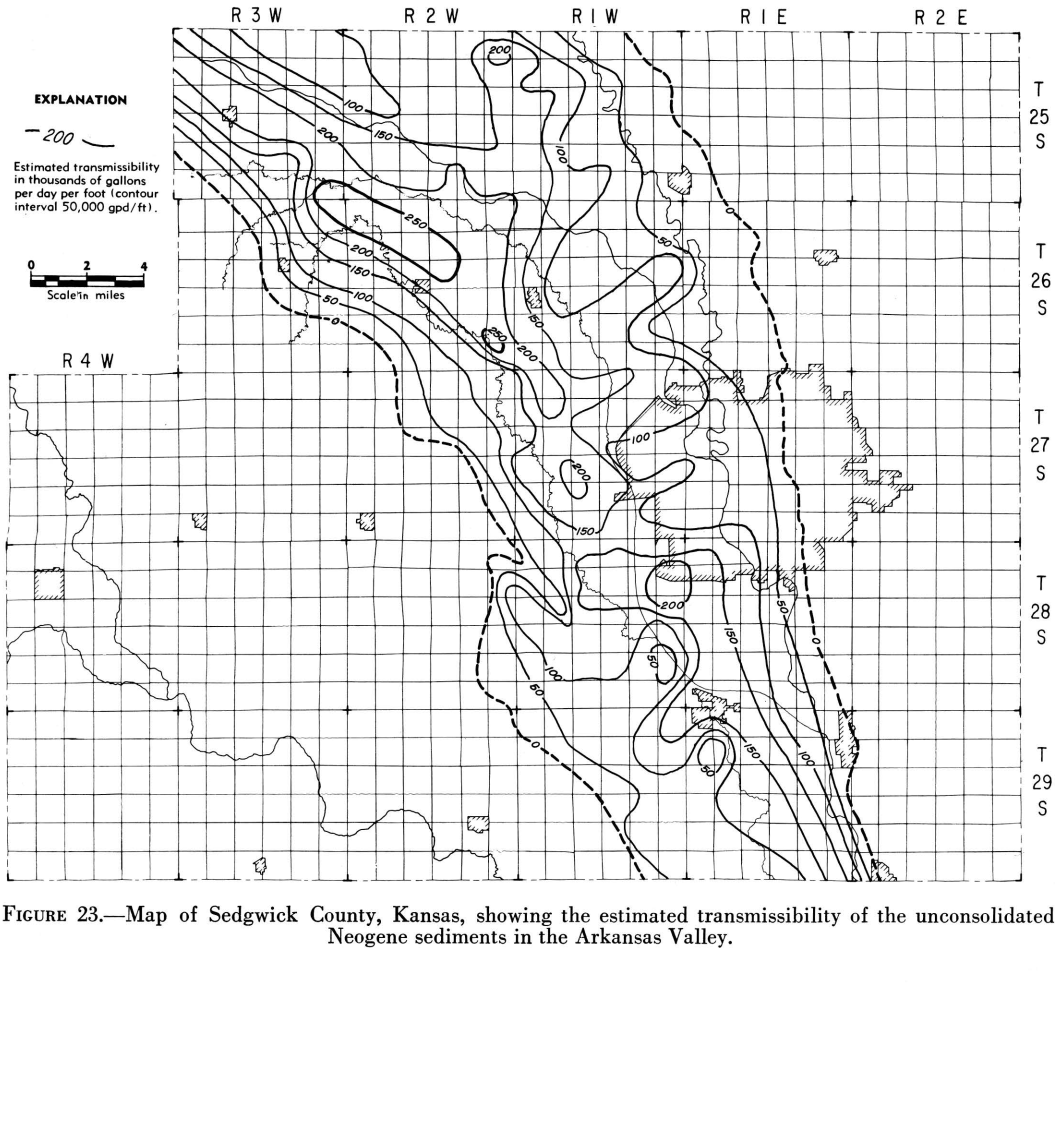


FIGURE 23.—Map of Sedgwick County, Kansas, showing the estimated transmissibility of the unconsolidated Neogene sediments in the Arkansas Valley.

water discharge by evapotranspiration probably exceeds discharge to the stream.

Wellington Upland (Area C)

The Wellington Upland area includes all of the uplands east of the Arkansas Valley. Low, rolling hills are typical geomorphic features. Thin loess mantles the divides between the many small creeks draining the area, and the Wellington Formation is exposed on most of the slopes bordering the creeks. The eastern two-thirds of the area is within the Walnut River drainage basin.

The area has been divided into two subareas on the basis of the occurrence of ground water, and the subareas are shown on Figure 20 as the Gypsum Subarea (C1) and the Loess-shale Subarea (C2). The line dividing the two subareas is arbitrarily placed at about the point where the type of well ordinarily used indicates the source of the ground water supplying the well.

Within Subarea C1, drilled wells less than 150 feet deep obtain water from solution openings in gypsum and anhydrite beds in the lower part of the Wellington Formation. The water is commonly under artesian pressure but flows at the surface in only a few places. Several creeks in the subarea have cut into or near the water-bearing zone, and large springs and seeps provide a perennial flow in the creeks. The water-bearing gypsum beds dip to the west and may underlie Subarea C2, but within this subarea the water from the gypsum beds is believed to be too salty for use. Wells yielding as much as 350 gpm have been drilled in Subarea C1, but the water is too highly mineralized for many uses without dilution with better quality water. However, where no other source is available, the water is used for domestic and stock wells.

Subarea C2 is the most difficult area in the County in which to obtain a ground-water supply, and wells yielding more than a few gallons per minute were not observed. Water supplies for domestic and stock use are obtained generally from large-diameter dug wells less than 40 feet deep that provide storage volume for the small quantity of water moving through the rocks. The water is thought to occur in small solution openings and crevices in the weathered upper part of the Wellington Formation. Thin loess deposits cover much of the subarea and although the loess has a low permeability, it may be more permeable than the underlying shale, and, therefore, retard the rate of surface runoff, allowing some recharge. Wells within this subarea are subject to failure during prolonged drought periods.

Ninnescah-Wellington Upland (Area D)

The Ninnescah-Wellington Upland includes all of the County west of the Arkansas Valley except that occupied by the Ninnescah River valley. This area includes the broad slopes flanking the Arkansas and Ninnescah valleys and the relatively flat, undissected interstream divide between the two valleys. The surface of most of the Ninnescah-Wellington Upland is underlain by loess, which overlies sand and gravel in part of the area. The bedrock surface is the Wellington Formation in about the eastern one-third and the Ninnescah Shale in the western two-thirds.

The area has been divided into two subareas on the basis of the occurrence of ground water. The two subareas are shown on Figure 20 as the Loess-sand Subarea (D1) and the Loess-shale Subarea (D2). Subarea D1 is largely confined to the uplands but does include the small abandoned valley in the southwest corner of the County where ground-water conditions are similar. Within Subarea D1 the surface material is loess that ranges in thickness from a featheredge to about 40 feet. The loess is underlain by deposits of sand and gravel containing some silt. These deposits attain a maximum thickness of about 35 feet. The sand and gravel beds are best developed in the area between and south of the towns of Goddard and Garden Plain and thin to zero near the edge of the area. Well yields of as much as 50 gpm can be developed where the sand and gravel beds are thickest, but during prolonged periods of drought the yields probably would decrease sharply. Where the sand and gravel thins, well yields become less, and near the edge of the area the sand and gravel may be completely dry.

The occurrence of ground water within Subarea D2 is not uniform; in general well yields are small, but adequate for farm and domestic use. The land surface within the subarea slopes toward the major streams and is underlain in part by loess and some colluvium and locally by only a soil over bedrock. The northeastern part of the subarea flanking the Arkansas Valley is underlain by loess that locally attains a thickness of about 75 feet and contains sandy zones near the base. The lower part of the loess is saturated, and wells penetrating sandy zones obtain adequate water for domestic and stock use. In those parts of Subarea D2 flanking the Ninnescah Valley, the loess and colluvium are thin, and the water table is commonly in bedrock. Wells penetrating the Ninnescah Shale are usually less than 100 feet in depth, and the water is believed to occur in crevices, solution openings, and bedding planes within the weathered part of the formation. Well yields from the Ninnescah Shale generally are larger than from the Wellington Formation, and may range from 1 gpm to as much as 75 gpm depending on the number of openings penetrated by the well. The well yield that might be expected at a particular location cannot be predicted, but a supply adequate for domestic and stock use can be developed in most of the subarea.

CHEMICAL CHARACTER OF GROUND WATER

The chemical character of the ground water in Sedgwick County is indicated by analyses or partial analyses of 297 samples of water collected from wells, test holes, springs, and municipal water systems. The results of the analyses are given in Tables 5 to 8. The analyses were made by the Water and Sewage Laboratory of the Kansas State Department of Health, the Wichita Water Department, and the Wichita Chemical and Testing Laboratory. The laboratory which made the analyses is given in the tables. In general, the analyses do not indicate the sanitary condition of the water (U. S. Public Health Service, 1962).

Chemical Constituents in Relation to Use

Dissolved solids.—When water is evaporated the residue consists mainly of those mineral constituents listed in the table of analyses (Tables 5, 6, and 7). In addition to the mineral constituents, the residue generally includes small quantities of organic matter and a small amount of water of crystallization. Water containing less than 500 ppm (parts per million) of dissolved solids is suitable for domestic use, except for difficulties resulting from hardness or the presence of iron in excessive amounts. Water containing more than 1,000 ppm of dissolved solids is likely to contain enough of certain constituents to cause noticeable taste or otherwise make the water undesirable or unsuitable for use. The dissolved solids in water samples collected in Sedgwick County ranged from 203 to 4,080 ppm.

The distribution of dissolved solids in the ground water in Sedgwick County is shown on Figure 24 and is closely related to the geology and hydrology of the County. The largest concentrations of dissolved solids are in water from the Wellington Formation in the eastern part of the County where the shale contains much gypsum and anhydrite and locally thin seams of salt. West of the Arkansas Valley in the area where loess overlies the Wellington Formation and Ninnescah Shale, the water is highly mineralized, but the dissolved solids are less than in the eastern part of the County. Recharge conditions are more favorable in the loess-covered area, and some dilution of the highly mineralized water in the bedrock may take place. Within the Arkansas Valley a zone of highly mineralized water is present adjacent to the Arkansas River and between Big Slough Creek and the river. The dissolved solids content of the water is quite variable with location and depth, but it is usually over 750 ppm. The high mineralization of the water adjacent to the Arkansas River is attributed to movement of highly mineralized water from the river into the aquifer. The Arkansas River above its junction with the Little Arkansas is normally in equilibrium with the water table, and the water-table gradient is parallel to the general direction of river flow (Pl. 1). Thus water in the river moves freely into the aquifer where its direction of flow locally is different from the direction of the water-table gradient. In Wichita ground water has been pumped from many municipal, industrial, and small irrigation wells for many years and has probably caused the movement of highly mineralized water into the aquifer from the Arkansas River and Big Slough Creek. In the southwestern part of the County where ground water is obtained from sand and gravel on the uplands and in stream valleys and from the Ninnescah Shale, the dissolved solids content of the water is only moderately large. The Ninnescah Shale does not contain an abundance of readily soluble minerals as does the Wellington Formation and thus does not contribute as greatly to the mineralization of the ground water.

Hardness.—The hardness of water is most commonly recognized by its effect when soap is used in the water. Salts of calcium and magnesium cause nearly all the hardness of ordinary water. These constituents also are the active agents in the formation of scale in steam boilers and in other containers in which water is heated or evaporated.

The total hardness, carbonate hardness, and noncarbonate hardness of water samples from Sedgwick County are given in Tables 5 and 6 and total hardness only in Tables 7 and 8. The carbonate hardness, or "temporary hardness," is caused by calcium and magnesium carbonates and can be almost entirely removed by boiling the water. The noncarbonate hardness, or "permanent hardness," is caused by sulfates and chlorides of calcium and magnesium and other salts and cannot be removed by boiling. Carbonate hardness and noncarbonate hardness react in the same manner in relation to the addition of soap. In boilers, water that has noncarbonate hardness forms a harder scale than water that has only carbonate hardness.

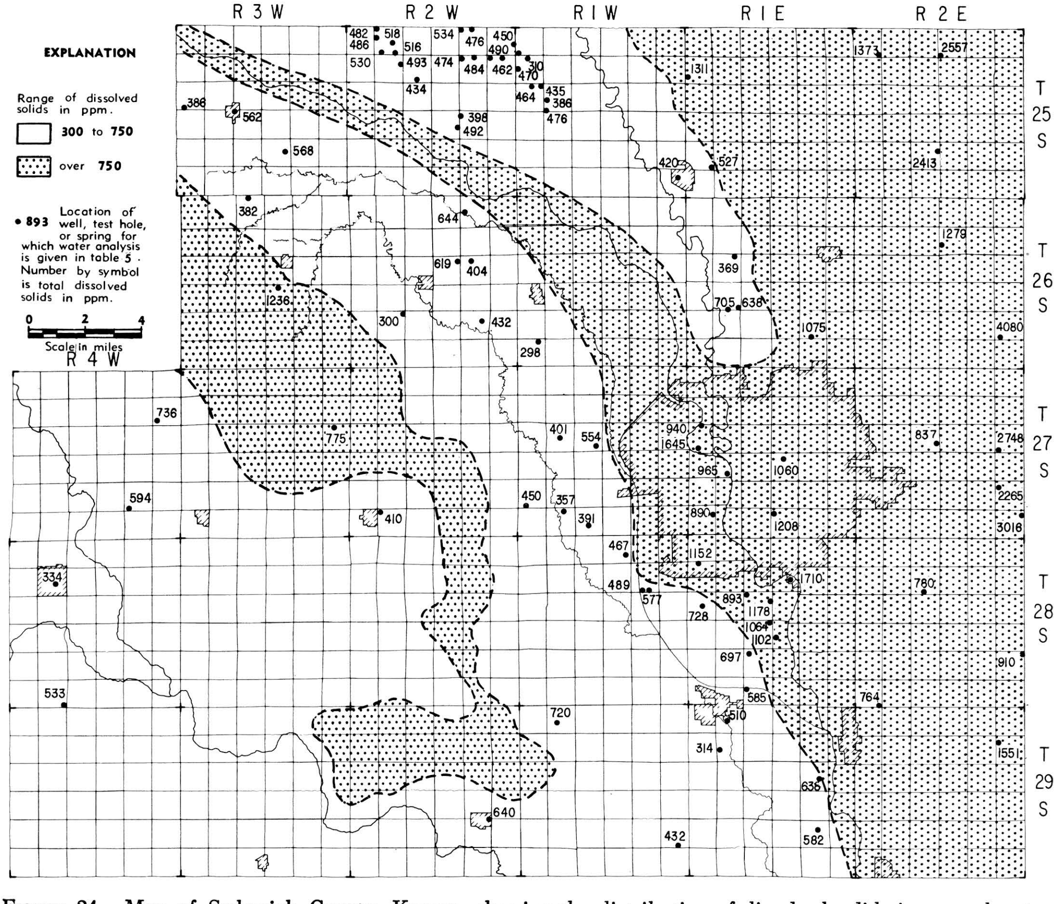


FIGURE 24.—Map of Sedgwick County, Kansas, showing the distribution of dissolved solids in ground water.

TABLE 5.—Analyses of water from wells and springs in Sedgwick County, Kansas (in parts per million,* except as otherwise indicated).

(Samples analyzed by H. A. Stoltenberg.)

Well number	Date of collection	Depth of well, feet	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Carbonate	Hardness as $CaCO_3$: Noncarbonate
25-2E-6ddd	11-20-58	28	56	17	0.10	—	243	104	20	334	74	201	0.2	549	1,370	270	760
3ccc	11-22-58	19	58	18	.36	—	592	79	83	316	1,550	77	.8	1.9	2,560	259	1,540
28ada	11-19-58	40	53	17	.50	—	561	90	47	324	1,510	19	.8	9.7	2,410	266	1,500
25-1E-7ccb	5-22-59	65.0	65	16	.33	—	240	78	72	383	654	51	.6	11.0	1,310	314	606
22aad	12-1-58	Sp	61	20	.03	—	46	7	16	185	11	7.5	.4	4.2	203	144	0
30ddd	9-11-58	20.0	—	25	1.6	—	71	11	102	339	44	54	.2	53	527	222	0
25-1W-6ccc (M34)†	1-60	150	—	—	.02	0.01	76	13	41	—	65	30	—	1.40	354	216	28
7baa (M35)	1-60	130	—	—	.02	.06	68	9	37	—	70	25	—	3.0	310	198	10
7bcc (M36)	1-60	184	—	—	.04	.10	76	16	71	—	49	70	—	.15	470	246	0
17cbb (M39)	1-60	154	—	—	.03	.07	71	21	51	—	47	35	—	1.80	386	218	0
17ccc (M40)	1-60	127	—	—	.16	.02	77	14	61	—	47	50	—	.01	476	252	0
18aaa (M38)	1-60	128	—	—	.01	.08	74	16	69	—	49	65	—	2.00	435	246	4
18abb (M37)	1-60	170	—	—	.02	.05	78	16	68	—	49	70	—	.30	464	258	0
25-2W-1daa (M33)	1-60	170	—	—	.04	.02	64	17	68	—	68	45	—	.01	450	230	0
2baa (M28)	1-60	220	—	—	.20	.00	75	14	74	—	54	70	—	.00	476	244	0
2bbb (M27)	1-60	215	—	—	.26	.15	74	12	64	—	64	70	—	.10	534	228	0
5bbb (M51)	1-60	185	—	—	.30	.25	76	15	84	—	61	85	—	.20	482	250	0
5bcc (M52)	1-60	40	—	—	.04	.01	73	9	68	—	71	65	—	.06	486	224	2
5ccd (M53)	1-60	92	—	—	.12	.00	78	9	84	—	78	82	—	6.0	530	181	0
5dbb (M54)	1-60	85	—	—	.02	.00	89	16	64	—	72	30	—	2.4	518	246	41
5dcd (M55)	1-60	47	—	—	.06	.00	70	15	62	—	67	80	—	4.0	516	212	26
8adb	8-14-58	40	60	19	.52	—	76	15	83	293	69	80	.5	6.6	493	240	11
9cdd	8-14-58	40	62	17	.03	—	69	14	71	288	50	61	.5	9.7	434	230	0
11baa (M30)	1-60	225	—	—	.02	.10	82	15	57	—	87	50	—	.54	484	242	25
11bbb (M29)	1-60	225	—	—	.02	.01	76	15	66	—	28	70	—	.30	474	252	0
12baa (M32)	1-60	185	—	—	.02	.00	81	11	66	—	63	60	—	.20	462	249	0

12bbb (M31)	1-60	197	—	—	.30	.05	83	10	56	—	96	50	—	.03	490	238	10
22daa.......	8-14-58	32	63	17	.02	—	74	14	84	276	64	81	.50	21	492	226	16
23bbc.......	8-14-58	35	62	17	.04	—	66	12	61	246	47	58	.50	15	398	202	12
25-3W-18cdc.......	8-14-58	100	65	22	.01	—	80	16	35	315	43	16	.2	19	386	258	8
27adc.......	8-14-58	100	64	19	.03	—	52	13	141	231	59	166	.6	3.5	568	183	0
26-2E-10cbb.......	11-25-58	30.0	56	18	.03	—	223	94	49	451	269	121	.2	283	1,280	370	573
25ccd.......	11-25-58	62.0	59	17	.16	—	672	130	595	339	802	1,690	.7	1	4,080	278	1,930
26-1E-20dcc.......	5-22-59	40	58	16	.14	—	141	42	45	383	200	70	.2	2.4	705	314	210
26cdd.......	5-21-59	66	63	34	.10	—	194	59	65	434	166	104	.1	239	1,080	356	370
26-1W-31aac.......	9- 4-58	40	60	24	3.9	—	2.9	6.7	69	212	21	31	.4	12	298	100	0
26-2W-2bcc........	1-12-61	16.0	—	0.5	26.0	—	22	17	202	151	81	251	.4	.4	649	124	1
14bac.......	9- 4-58	55.0	60	23	.35	—	49	12	84	290	29	57	.4	6.2	404	172	0
15aad.......	8- 3-59	229.0	—	17	.09	—	47	5.6	184	334	48	151	.6	1.6	619	140	0
26acd.......	9- 5-58	—	62	25	.04	—	61	14	83	390	21	32	.3	3.6	432	210	0
29aaa.......	1-12-61	83	—	1.5	10.0	—	41	20	47	229	37	26	.1	.4	300	184	0
26-3W-4baa........	8-15-58	75	64	23	.03	—	74	14	45	331	30	18	.1	15	382	242	0
22baa.......	4-27-60	100	59	14	.06	—	280	28	74	400	14	209	.1	420	1,240	328	486
27-2E-13ccc1......	5-18-59	Sp	55	12	.33	—	624	74	152	332	1,370	345	.8	2.2	2,750	272	1,590
13ccc2......	5-18-59	38.0	55	13	2.5	—	562	69	164	303	1,150	422	.8	1.5	2,530	248	1,440
16dad.......	11-25-58	70.0	59	20	.28	—	161	65	11	420	46	61	.1	266	837	344	324
25bbc.......	11-26-58	31.5	56	15	1.0	—	536	67	76	324	1,300	113	.9	1.0	2,270	266	1,350
36aad.......	5-20-59	Sp	62	18	.06	—	645	77	219	271	1,440	484	.8	2.8	3,020	222	1,700
27-1E-20cda.......	9-24-57	39.5	60	12	.9	—	132	18	191	244	200	290	.5	1.2	965	200	204
22bda.......	10- ?-57	29.1	—	24	.05	—	195	67	56	400	404	68	.2	49.	1,060	328	434
31ada.......	9-24-57	38.0	59	10	2.6	—	130	21	166	373	183	195	.4	.7	890	306	105
34bbc.......	9-24-57	27.0	59	11	.54	—	229	37	131	329	428	205	.6	4.4	1,210	270	454
27-1W-24cda.......	9-24-57	55.0	59	8	4.8	—	41	3.8	86	127	105	63	.6	1.0	371	104	14
30cdc.......	8-20-58	50.0	—	25	.79	—	88	16	58	406	34	29	.1	.4	450	286	0
32abb.......	5-22-59	56.0	62	18	.17	—	48	12	71	324	14	25	.1	9.3	357	170	0
33dad.......	9-24-57	115.0	59	17	.05	—	29	5.7	113	294	26	48	.2	7.5	391	96	0
27-3W-13bab.......	8-22-57	60	—	20	.15	—	161	33	51	351	52	126	.2	159	775	288	249
27-4W-12ccb.......	12-17-58	49.0	53	16	.48	—	152	37	14	237	13	68	.2	319	736	194	337

TABLE 5.—Analyses of water from wells and springs in Sedgwick County, Kansas (in parts per million,* except as otherwise indicated).—*Concluded.*

Well number	Date of collection	Depth of well, feet	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Carbonate	Hardness as $CaCO_3$: Noncarbonate
27-4W-26ccd	12-17-58	50.0	52	16	0.28	—	110	26	27	83	72	90	0.1	212	594	68	314
28-2E- 9cdd	5-25-59	35.0	62	34	.05	—	184	22	35	395	50	65	.1	195	780	324	226
25aaa	11-26-58	35.0	60	16	.03	—	202	49	15	386	23	105	.3	310	910	316	390
31ddd	11-29-58	90.0	47	21	.71	—	179	25	41	381	284	15	.2	11	764	312	238
28-1E- 7bab	9-24-57	48.0	—	13	2.4	—	130	25	265	351	149	396	.4	.7	1,150	288	140
10dbd	5- 6-57	22	—	—	.33	1.30	356	41	213	839	365	320	.2	1.5	1,710	688	368
16ada	5- 6-57	25	—	—	.81	.56	172	30	213	382	293	280	.6	1.0	1,180	313	239
16bbb	5- 6-57	45	—	—	.06	1.20	149	27	133	366	149	184	.4	71	893	300	183
21aaa	5- 6-57	30	—	—	.10	.06	154	31	190	354	236	270	.50	8.9	1,064	290	221
28bbd	8-15-58	36.0	65	16	.66	—	99	19	131	336	114	150	.8	1.7	697	276	49
33cbd	7-24-58	80.0	63	15	.22	—	80	17	109	290	107	108	.6	5.3	585	238	32
28-1W-3dac	9-16-55	109.0	—	18	.07	—	34	4.2	140	309	37	74	.3	9.7	467	102	0
3dca	9- 2-55	124.0	—	18	.08	—	30	1.2	171	357	41	82	.3	1.5	520	80	0
11ccd	8-20-55	108.0	—	21	.1	—	28	6.1	177	173	54	100	—	—	577	96	0
11cdd	8-10-55	114.0	—	19	.04	—	32	6.8	146	334	36	78	.2	4.4	489	108	0
28-4W-32ddd	1-22-59	64.0	62	17	.08	—	75	41	55	373	89	32	.1	40	533	306	50
29-2E- 12bba	11-29-58	32.0	53	20	.05	—	266	76	111	395	24	292	.1	567	1,550	324	652
20cdd	5-21-59	93.0	65	23	.14	—	63	10	39	257	30	18	.1	19	329	198	0
36aaa	12- 1-58	34.0	58	19	.15	—	107	50	14	410	14	83	.3	44	533	336	136
29-1E- 8cbb	5-25-59	36	61	23	.04	—	51	11	46	260	23	15	.1	17	314	172	0
26acb	5-21-59	39.0	63	14	.12	—	133	16	50	320	143	65	.5	2.7	582	262	136
29-1W-5dab	5-25-59	35.0	62	29	3.0	—	115	11	140	598	25	57	.1	49	720	332	0
25dcd	5-25-59	45.0	65	27	.10	—	94	12	43	310	24	56	.1	23	432	254	30

* One part per million is equivalent to one pound of substance per million pounds of water or 8.33 pounds per million gallons of water.

† Wichita municipal well number.

TABLE 6.—Analyses of water from municipal water systems in Sedgwick County, Kansas (in parts per million,* except as otherwise indicated).

(Samples analyzed by Kansas State Department of Health.)

District and well number	Date of collection	Source of sample	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Carbonate	Hardness as $CaCO_3$: Noncarbonate	Hardness as $CaCO_3$: Total
Bel Aire Improvement District (26–1E–20dd)	11–17–59	Residence tap	—	11	0.12	0.00	115	39	57	318	139	111	0.5	0.4	638	261	185	446
City of Cheney (28–4W–8db)	10–14–59	City well no. 3	—	25	.13	.00	63	24	13	218	34	23	.2	44	334	179	77	256
City of Clearwater (29–2W–23dd)	1– 4–60	Well no. 1	—	24	.03	.00	115	41	54	234	49	224	.2	17	640	192	264	456
Country Acres Improvement District (27–1W–16d)	7–22–59	Residence tap	—	15	.10	.00	28	6.3	178	332	42	115	.4	5.3	554	96	0	96
City of Derby (29–1E–14db)	7– 9–59	do	—	15	.06	.19	122	26	72	372	126	91	.7	2.1	638	305	107	412
Glenville Improvement District (28–1E–17cac)	1960	Well no. 1	—	—	.55	.54	—	—	—	—	—	144	.5	.4	—	—	—	379
City of Goddard (27–2W–32bb)	6–29–59	North well	—	20	.03	.00	94	14	39	339	13	57	.2	6.2	410	278	14	292
City of Haysville (29–1E–5caa)	5–10–60	Tap at water plant	—	12	.05	.00	33	12	127	12	149	154	.4	2.8	510	34	98	132
Jayhawk Improvement District (28–1E–22cb)	4–26–60	Residence tap	—	11	.42	.16	206	34	129	349	347	201	.5	2.5	1,100	286	368	654
City of Mount Hope (25–3W–center)	4–11–60	do	—	14	.06	.00	59	15	128	246	60	155	.5	4.2	562	202	6	208
Oaklawn Improvement District (28–1E–22ab)	1960	do	—	—	.40	.30	—	—	—	—	—	67	.7	.7	—	—	—	378
Park City Improvement District (26–1E–17aa)	2–24–60	do	—	16	4.1	.32	77	17	29	256	83	20	.3	.5	369	52	210	262
Purcell's 1st Improvement District (28–1E–18dbb)	2–10–60	do	—	16	.83	.41	83	17	164	332	112	172	.5	.5	728	272	5	277
Sunflower Improvement District (28–1E–32aa)	1960	do	—	—	.59	.23	—	—	—	—	—	164	.8	2.5	—	—	—	304
City of Valley Center (25–1W–36acd)	2– 1–60	Well no. 4		17	.60	.13	91	21	32	356	74	9.0	.4	1.0	420	292	22	314
Westlink Improvement District (27–1W–17 center)	1– 7–60	Residence tap	—	16	.07	.00	55	9.5	87	361	19	30	.3	7.1	401	176	0	176
City of Wichita	—	Average analysis of treated water for 1959	60	18	.00	.00	23	12	77	95	79	80	—	.9	372	96	10	106

* One part per million is equivalent to one pound of substance per million pounds of water or 8.33 pounds per million gallons of water.

Water having a hardness of less than 50 ppm is classified as soft, and treatment for reduction of hardness is not necessary for ordinary uses. Hardness between 50 and 150 ppm does not seriously interfere with the use of water for most purposes, but does increase the consumption of soap. Laundries and other industries using large quantities of soap, or using water for purposes in which this amount of hardness is objectionable in other ways, may find it profitable to soften the water. Water of this range of hardness forms scale in steam boilers so it generally is softened before being used for this purpose. Hardness of more than 150 ppm is universally noticeable. The hardness of water samples collected in Sedgwick County ranged from 49.9 to 2,211.0 ppm.

Iron.—Next to hardness, iron is the constituent in natural waters that generally is the most objectionable. The quantity of iron in water seemingly differs greatly from place to place, even in the same aquifer. If the water contains more than 0.3 ppm of iron in solution, the iron, upon oxidation, may settle out as a reddish sediment. Iron, if present in sufficient quantity, gives a disagreeable taste to water, stains clothing, cooking utensils, and plumbing fixtures, and is objectionable in foods and beverages. Iron generally can be removed by aeration and filtration, but some waters require chemical treatment for removal of iron.

The iron content of water samples collected in Sedgwick County ranged from 0 to 26 ppm. Iron in the ground water is a problem

TABLE 7.—Partial analyses of water from wells in Wichita "Bentley Reserve" and "local" well fields (in parts per million,* unless otherwise indicated).

(Samples analyzed by Wichita Water Department.)

Well number		Date of collection	Depth of well, feet	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Sodium and Potassium (Na+K)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Total hardness as $CaCO_3$
25–2W–35bb4	(B4)†	6– 8–56	126	—	—	—	—	328	686	—	—	439
35bb5	(B5)	5–22–56	137	—	—	—	—	304	610	—	—	483
35bb6	(B6)	6–19–56	212	—	—	—	—	162	523	—	—	385
27–1E–18baa	(N2)	5–60	48	0.001	0.00	96	202	248	260	6.0	940	330
18bac	(N3)	5–60	46	.00	.00	130	232	427	370	4.0	1,440	465
18bcc	(S7)	5–60	48	.00	.00	122	260	270	350	.60	1,230	421
18cbb	(S6)	5–60	47	.00	.00	98	208	200	332	1.60	1,060	342
18cbc	(S5)	5–60	52	.30	.00	205	208	205	340	.80	1,120	358
18cca	(S4)	5–60	49	.30	.00	123	258	230	375	.12	1,300	450
18cda	(S2)	5–60	54	.02	.00	135	317	322	575	4.0	1,640	450
18cdb	(S3)	5–60	50	.00	.00	118	306	270	503	4.0	1,460	409
18cdd1	(S1)	5–60	51	.00	.00	93	204	182	268	4.0	1,010	314
18dca1	(E9)	5–60	—	.00	.00	120	130	140	245	1.5	920	388
18dca2	(E3)	5–60	43	.00	.00	114	160	98	240	.08	740	372
18dca3	(E4)	5–60	42	.00	.00	128	150	139	270	.60	916	411
18dca4	(E5)	5–60	42	.00	.00	126	145	137	245	.08	844	412
18dcb1	(E2)	5–60	43	.00	.00	109	165	146	220	.35	752	360
18dcb2	(E1)	5–60	41	.00	.00	125	160	139	245	.60	906	373
18dcb3	(E8)	5–60	40	.00	.00	114	143	122	245	.90	906	360
18dcd2	(E7)	5–60	39	.00	.00	117	145	119	230	.60	940	373
18ddc	(E6)	5–60	42	.00	.00	116	134	109	225	.50	852	363

* One part per million is equivalent to one pound of substance per million pounds of water or 8.33 pounds per million gallons of water.

† Well number assigned by Wichita Water Department.

TABLE 8.—Partial analyses of water from wells in Sedgwick County, Kansas (in parts per million,* unless otherwise indicated).

(Samples analyzed by Wichita Chemical and Testing Laboratory.)

Well number	Depth of well, feet	Total alkalinity $CaCO_3$	Sulfate (SO_4)	Chloride (Cl)	Total hardness as $CaCO_3$
26-1W-20bbb	160	205	240	1,060	598
30bb	170	244	138	553	182
30dd	163	239	94	271	135
33aa	103	201	305	1,400	674
26-2W-34dd	130	290	93	35	247
36bb	193	304	90	35	240
27-1W-4dd	103	249	131	326	115
8bb	163	292	42	125	127
15dd	33	267	69	174	150
16dd	43	271	51	35	105
26dd	43	248	133	337	276
27cc	103	411	51	38	72
30dd	111	443	103	18	285
32cc	123	308	147	12	349
32dd	83	430	57	24	97
34dd	72	264	75	38	80
35dd	63	280	215	170	334
27-2W-1cc	105	304	147	28	272
10bb	70	301	126	42	270
24bb	38	215	44	24	195
26aa	28	307	78	49	182
28-1E-7ccc	56	252	180	291	200
11ddd	38	246	147	87	323
15aa	27	212	170	222	400
16aa	24	160	197	122	312
28-1E-18aa	55	275	175	383	264
28-1W-8bb	111	298	346	17	364
9aa	130	308	127	28	200
9abb	130	253	117	50	70
9ccb	129	308	188	28	255
10aa	84	308	102	106	50
10abb	125	180	51	35	45
10add	120	298	131	92	50
10cbb	60	208	160	28	100
11abb	72	276	148	135	90
12bcc	91	270	168	163	115
12cc	71	257	188	177	147
13cbb	73	286	173	206	150
13cdd	50	286	125	276	190
14ddd	51	289	115	99	80
15cc	84	305	149	28	182
15cdd	115	260	179	35	132
15dd	84	321	277	114	95
16aa	40	228	181	53	92
16aa	100	298	101	71	95
16cbb	105	321	277	114	95
16cc	94	208	427	57	349
16dcc	84	253	138	14	142
17aa	60	308	153	43	190
17aa	130	283	112	35	210

* One part per million is equivalent to one pound of substance per million pounds of water or 8.33 pounds per million gallons of water.

throughout the County, but the exceptionally high iron content of the water obtained from wells 26-1E-17ab, 26-2W-2bcc, 26-2W-29aaa, and 27-1W-24cda are thought to be due in part to contamination of the sample by rust or scale from associated plumbing. The chemistry of iron in natural waters is quite complex and beyond the scope of this report, but several factors related to the geology and hydrology of the County seem to influence the occurrence of iron in ground water. The iron content of water seems to be related to such factors as depth in the aquifer, the type of rocks comprising the aquifer, the length of time the water has been in the aquifer, the pH of the water, the dissolved gases in the water (which may affect the pH), the presence or absence of iron bacteria, and many other factors. Some iron problems seem to be associated with the well construction and the pumping schedule of the well. Wells using galvanized iron casing commonly produce water with a high iron content within a few months after installation, particularly when the pumping periods of the well are intermittent and of short duration. Wells with steel casings commonly develop similar problems with respect to iron in the water when pumped intermittently but not as soon as wells with galvanized casing. Wells with high yields that are pumped regularly, such as municipal and industrial wells, do not commonly produce water excessively high in iron, and the iron content of water from such wells probably is more nearly representative of the dissolved iron content of the water in the aquifer.

Manganese in ground water has properties similar to iron except that the manganese is more difficult to remove and stains plumbing fixtures black. Iron and manganese are considered together in evaluating the usefulness of water, and on some water analyses are reported together as iron. The manganese content of ground water in Sedgwick County is shown on the water analyses in Tables 5, 6, and 7.

Chloride.—Chloride ions are very abundant in nature. They are found in quantity in sea water and oil-field brines and are dissolved in small quantities as sodium chloride from many rock materials. Sodium chloride has little effect on the suitability of water for use unless it is present in such concentrations as to make the water unpotable or corrosive. The removal of sodium chloride from water is difficult and too costly for most water uses.

The chloride content of water samples collected in Sedgwick County ranged from 4 to 1,695 ppm. Plate 4 shows the distribution of chloride in the ground water of the County as determined from the water samples collected. The depth from which the individual water samples were obtained is plotted with the chloride concentration on Plate 4. Within the aquifer underlying the Arkansas Valley the highest chloride concentrations are found adjacent to the Arkansas River on the south and west side of the river channel. An increase in chloride concentration with depth occurs locally within the area south and west of the Arkansas River, but the reason for this has not been definitely determined.

The Arkansas River water normally has a chloride concentration that averages about 600 ppm, and the river is in equilibrium with the water table most of the time. If this equilibrium were lost, the direction of ground-water movement near the river as indicated by the water-table contours shown in Plate 1 would enable river water in the reach of the stream northwest of Wichita to move into the aquifer and thence to the southeast. The area in which movement of water from the river would take place is also an area where the water table is near the land surface and evapotranspiration would tend to concentrate the dissolved minerals in the ground water.

Ground water in the area adjacent to Big Slough Creek in T 26 S, R 1 W also has a high chloride content. The low land bordering the creek is swampy and seepage of ground water into the creek takes place most of the time. The above conditions are indicative of a ground-water discharge area, and the creek is down gradient from the reach of the Arkansas River where seepage of river water into the aquifer takes place. Concentration of dissolved minerals in the ground water by evapotranspiration probably accounts for the high chlorides in this area.

The solution zone in the salt beds of the Wellington Formation west of the Arkansas Valley contains saturated brine of unknown quantity and extent and may have hydraulic communication with the aquifer underlying the Arkansas Valley. The hydraulic head in the solution zone is reported to be about equivalent to the water-table altitude in the Arkansas Valley. Available data indicate that no water moves from the solution zone into the valley. If the reported relationship between the head in the solution zone and the water table in the valley is correct, the greater density of the brine and the low permeability of the sediments separating the two would probably prevent upward movement of the brine under natural conditions.

Fluoride.—Fluoride is present in ground water only in small quantities, but a knowledge of the fluoride content of water is important because the use of water containing fluoride in excess of 1.5 ppm by children during formation of their permanent teeth may cause mottling of the tooth enamel. If the fluoride content is as great as 4 ppm, about 90 percent of the children using the water may have mottled tooth enamel (Dean, 1936). Although too much fluoride in water is undesirable, a fluoride concentration of about 1 ppm in drinking water lessens the incidence of tooth decay (Dean, *et al.*, 1941). The fluoride concentration in samples of water collected in Sedgwick County ranged from 0 to 0.9 ppm.

Nitrate.—Investigations in the last two decades into the effect of nitrate in drinking water have shown that large concentrations of nitrate in water may cause cyanosis in infants (so-called "blue babies") when the water is used for drinking and in the preparation of formulas for feeding. Infant cyanosis is usually not fatal if diagnosed in time but may be fatal with continued use of water containing excessive nitrate. Water that contains more than 90 ppm of nitrate is regarded by the Kansas State Department of Health as likely to cause infant cyanosis (Metzler and Stoltenberg, 1950). Moderate nitrate concentrations are seemingly not harmful to older children or adults. Nitrate cannot be removed from water by boiling. The nitrate concentration in samples of water collected in Sedgwick County ranged from 0 to 567 ppm. The exceptionally high concentration of nitrates in ground water were found in water samples obtained from wells in the Wellington Formation in the eastern part of the County. In all cases the wells were large-diameter dug or bored farm wells that were not adequately cased or sealed to prevent surface water from seeping into the well.

Chemical Constituents in Relation to Irrigation

The following discussion of the suitability of water for irrigation use is adapted from Agriculture Handbook 60 of the U. S. Department of Agriculture (U. S. Salinity Laboratory Staff, 1954).

The development and maintenance of successful irrigation projects involve not only the supplying of irrigation water to the land but also the control of salt and alkali in the soil. The quality of irrigation water, irrigation practices, and drainage conditions are involved in salinity and alkali control. Soil that was originally nonsaline and nonalkaline may develop saline and alkaline character if excessive soluble salts or exchangeable sodium are allowed to accumulate in the soil as the result of improper irrigation or soil-management practices, or inadequate drainage.

In areas of sufficient rainfall and ideal soil conditions the soluble salts originally present in the soil or added to the soil with water are carried downward by the water and ultimately reach the water table. The process of solution and transportation of soluble salts by water moving through the soil is called "leaching." If the amount of water applied to the soil is not in excess of the amount needed by plants, there will be no downward percolation of water below the root zone and mineral matter will accumulate at that level. Impermeable zones in the soil near the surface can retard the downward movement of water, resulting in waterlogging of the soil and deposition of salts. Unless drainage is adequate, attempts at leaching may not be successful, because leaching requires the free passage of water through and away from the root zone.

The characteristics of water for irrigation that seem to be most important in determining its quality are: (1) total concentration of soluble salts; (2) relative proportion of sodium to other principal cations (magnesium, calcium, and potassium); (3) concentration of boron or other elements that may be toxic to plants; and (4) the bicarbonate concentration, under some conditions, as related to the concentration of calcium plus magnesium.

The total concentration of soluble salts in irrigation water can be adequately expressed in terms of electrical conductivity for purposes of diagnosis and classification. Electrical conductivity is a measure of the ability of the ionized inorganic salts in solution to conduct an electric current, and is usually expressed in micromhos per centimeter at 25° C. The electrical conductivity can be determined accurately in the laboratory, or an approximation of the electrical conductivity can be obtained by multiplying the total equivalents per million (epm) of calcium, magnesium, sodium, and potassium by 100 (Table 9). In general, water having a conductivity below 750 micromhos per centimeter is satisfactory for irrigation insofar as salt content is concerned, although salt-sensitive crops may be adversely affected by irrigation water having an electrical conductivity in the range of 250 to 750 micromhos per centimeter. Water having a range of 750 to 2,250 micromhos

TABLE 9.—Factors for converting parts per million of mineral constituents to equivalents per million.

Cation	Conversion factor	Anion	Conversion factor
Ca^{++}	0.0499	HCO_3^-	0.0164
Mg^{++}	.0823	SO_4^{--}	.0208
Na^+	.0435	Cl^-	.0282
		NO_3^-	.0161
		F^-	.0526

per centimeter is widely used, and satisfactory crop growth is obtained under good management and favorable drainage conditions, but saline conditions will develop if leaching and drainage are inadequate. Use of water having a conductivity of more than 2,250 micromhos per centimeter is not common, and very few instances can be cited where such waters have been used successfully.

In the past, the relative proportion of sodium to other cations in irrigation water usually has been expressed simply as the percentage of sodium among the principal cations (expressed in epm)—the percent sodium, so called. According to the U. S. Department of Agriculture the sodium-adsorption ratio (SAR), used to express the relative activity of sodium ions in exchange reactions with soil, is a better measure of suitability of water for irrigation with respect to the sodium (alkali) hazard. The sodium-adsorption ratio may be determined by the formula

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}},$$

where the ionic concentrations are expressed in equivalents per million.

The sodium-adsorption ratio may be determined also by use of the nomogram shown in Figure 25. In using the nomogram to determine the sodium-adsorption ratio of water, the concentration of sodium expressed in equivalents per million is plotted on the left-hand scale, and the concentration of calcium plus magnesium expressed in equivalents per million is plotted on the right-hand scale.

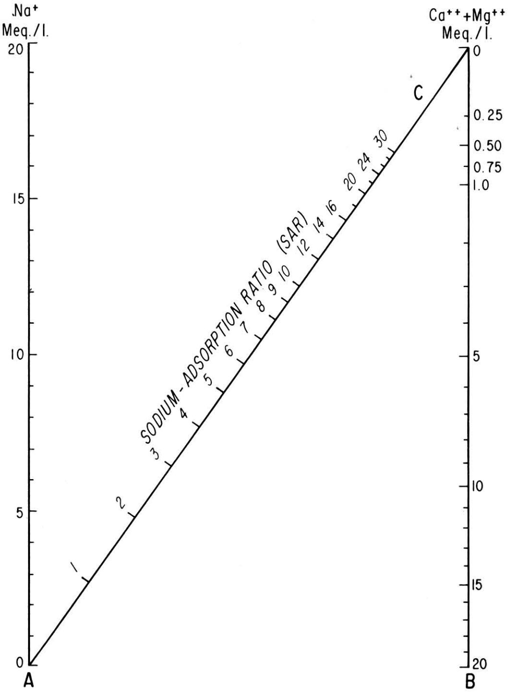


FIGURE 25.—Nomogram for determining sodium-adsorption ratio of water.

The point at which a line connecting these two points intersects the scale for the sodium-adsorption ratio indicates the sodium-adsorption ratio of the water. When the sodium-adsorption ratio and the electrical conductivity of a water are known, the classification of the water for irrigation can be determined by plotting these on the diagram shown in Figure 26. Table 10 gives the sodium-adsorption ratio and electrical conductivity of selected water samples from Sedgwick County that are plotted on Figure 26 and for which analyses are given in Table 5. Low-sodium water (S1) can be used for irrigation on almost all soils with little danger of developing harmful levels of exchangeable sodium. Medium-sodium water (S2) will present an appreciable sodium hazard in certain fine-textured soils, especially poorly leached soils. Such water may be used safely on coarse-textured or organic soils having good permeability. High-sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management such as good drainage and leaching and addition

TABLE 10.—Sodium-adsorption ratios (SAR) and conductivities of selected water samples from Sedgwick County, Kansas. These are plotted on Figure 26 and analyses are given in Table 5.

Well number	Sodium-adsorption ratio	Conductivity (Micromhos per centimeter)
25–2E–28ada......	0.5	2,740
25–2W–8adb......	2.2	880
25–2W–12bbb.....	1.6	740
26–1W–31aac......	3.0	510
27–2E–13ccc2......	1.8	3,540
27–1W–33dad.....	5.1	700
28–4W–32ddd.....	1.3	880
29–2E–36aaa......	0.3	1,050

of organic matter. Very high sodium water (S4) is generally unsatisfactory for irrigation unless special action is taken, such as addition of gypsum to the soil.

Low-salinity water (C1) can be used for irrigation of most crops on most soils with little likelihood that soil salinity will develop. Medium-salinity water (C2) can be used if a moderate amount of leaching occurs. Crops of moderate salt tolerance can be irrigated with C2 water without special practices. High-salinity water (C3) cannot be used on soils of restricted drainage. Very high salinity water (C4) is not suitable for irrigation water under ordinary circumstances. It can be used only on crops that are very tolerant of salt and then only if special practices are followed, including the provision for a high degree of leaching.

Boron is essential to normal plant growth, but the quantity required is very small, and large quantities are harmful. Crops vary greatly in their boron tolerance, but, in general, crops ordinarily grown in Kansas are not adversely affected by boron concentrations of less than 1 ppm.

In water having a high concentration of bicarbonate, there is a tendency for calcium and magnesium to precipitate as the water in the soil becomes more concentrated as a result of evaporation and plant transpiration. This reaction ordinarily does not go to completion, but when it does, there is a reduction in the concentration of calcium and magnesium, and, therefore, a relative increase in sodium. The calcium and magnesium are precipitated as carbonates, and any residual carbonate or bicarbonate is left in solution as sodium carbonate. The potential amount of such residual sodium carbonate may be computed

$(Na_2CO_3) = (CO_3^{--} + HCO_3^{-}) - (Ca^{++} + Mg^{++})$,

where the ionic concentrations are expressed as milliequivalents per liter or equivalents per million.

On the basis of limited data and using the concept of residual sodium carbonate described above, the Department of Agriculture has concluded that water having more than 2.5 epm of residual sodium carbonate is not suitable for irrigation. Water containing 1.25 to 2.50 epm of residual sodium carbonate is marginal, and water containing less than 1.25 epm can be safely used for irrigation.

In appraising the quality of an irrigation water, first consideration must be given to salinity and alkali hazards by reference to Figure 26. Then consideration should be given to other characteristics such as content of boron and other toxic elements and of

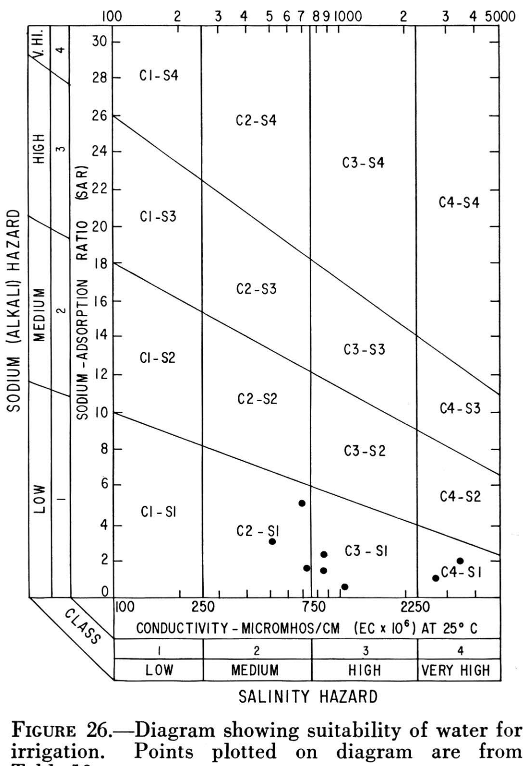


FIGURE 26.—Diagram showing suitability of water for irrigation. Points plotted on diagram are from Table 10.

bicarbonate, any one of which may change the quality rating. The use of water of any quality must take into account such factors as drainage and management practices.

UTILIZATION OF GROUND WATER

All water supplies in the County with the exception of a small amount of irrigation water and some stock-water supplies are obtained from ground-water sources. Water use for many purposes cannot be determined accurately, for many ground-water users do not keep accurate records of pumpage. The magnitude of potential ground-water withdrawals can be judged to some extent by the quantity of water for which water rights have been approved or are pending approval by the State. A tabulation of water rights by use is given in Table 11.

TABLE 11.—Volume of ground-water rights by use in Sedgwick County, Kansas, approved or pending approval by the State (1960).

Water use	Volume of water rights (acre-feet per year)*
Public supply	109,800
Industrial	45,300
Irrigation	30,200
Rural domestic†	5,500
Total	190,800

* One acre-foot = 325,850 gallons.

† Water rights are not required for domestic water supplies. Amount given here is an estimate.

Water rights for public supply are normally several times greater than the average rate of use. Peak water demands of short duration normally exceed average use by 2 to 3 times, and some allowance is made for increased use due to normal growth of urban areas. The average use of water for public supply in Sedgwick County is about 26 percent of the water rights that have been approved or are pending approval.

Public Water Supplies

Eight cities and nine improvement districts in the County provide municipal water service for about 90 percent of the population. The location of the cities and improvement districts providing municipal water service and the areas served are shown on Figure 27. Table 12 gives data on each water system. The peak water demands experienced by these water systems are not shown on Table 12 but are commonly 2 to 3 times the average daily demand.

The water-supply system for Wichita is the largest in the State and is quite complex, but it is very flexible in operation. The system is supplied by three well fields located in Sedgwick and Harvey counties. The location of the well fields and the principal pipelines connecting the system are shown on Figures 28 and 29. The 55 wells in the "*Equus* beds" well field (includes 36 wells in adjacent Harvey County), the 6 wells in the "Bentley reserve" well field, and the 27 wells in the "local" well field have a maximum combined yield of about 95 million gallons per day (mgd). The "*Equus* beds" well field is the principal source of water and is capable of yielding 55 mgd. The "Bentley reserve" well field, capable of yielding 10 mgd, and the "local" well field, capable of yielding 30 mgd, are used mainly to meet peak demands.

Water from the "*Equus* beds" and "Bentley reserve" well fields is delivered to the treatment plant through 66-inch and 48-inch pipelines. These pipelines are cross-connected and are about 25 miles in length. The combined capacity of these pipelines is about 100 mgd. Water that is stored in a 3-million gallon surge tank in the "*Equus* beds" well field and in the pipelines and treatment basins would provide about 2 days water supply for the city.

Wichita in cooperation with the U. S. Bureau of Reclamation began construction in 1962 of a dam on the North Fork Ninnescah River to impound water mainly as a supplemental water supply for the city. The dam is located in sec. 6, T 27 S, R 4 W, about 25 miles west of the water treatment plant. A 60-inch pipeline will deliver the water to the plant for treatment and distribution. When completed the reservoir will have a firm yield of 38 mgd.

Industrial Supplies

Sedgwick County is the most heavily industrialized area of the State, and industry is the greatest single user of water. Water demand by industries does not fluctuate as greatly as that for public supply and irrigation.

Water use by industry is believed to be about 53,000 acre-feet per year. Of this quantity, about 45,300 acre-feet is self-supplied and from 7 to 8 thousand acre-feet is supplied by the Wichita water system to industries located in the city. The water supplied to industry by the city is about 25 percent of the water produced by the city system. The largest use of water by industry is for power generation (steam boilers) and in all cases recirculation of the water is practiced. Wichita could supply an additional 30 mgd to industry in excess of peak demands on the city water system.

Irrigation Supplies

Irrigation with ground water has been practiced to a limited extent in Sedgwick County for many years, mostly as supplemental irrigation to provide needed water for crops during growth periods. The drought years from 1952 through 1956 caused a rapid expansion of irrigation in the County. Most irrigation remains supplemental in nature and results in a large fluctuation from year to year in the use of ground water for this purpose. Records of pumpage for irrigation are very sparse, but water rights have been approved or are pending approval by the State (1960) for 30,200 acre-feet of ground water to irrigate about 15,000 acres. Irrigation by flooding and by sprinkler methods are both practiced, the method used being determined by the topography and by the quantity of water available in the area to be irrigated.

Rural Domestic Supplies

Most rural domestic and stock water supplies in Sedgwick County are obtained from wells. Ponds are used in parts of the County

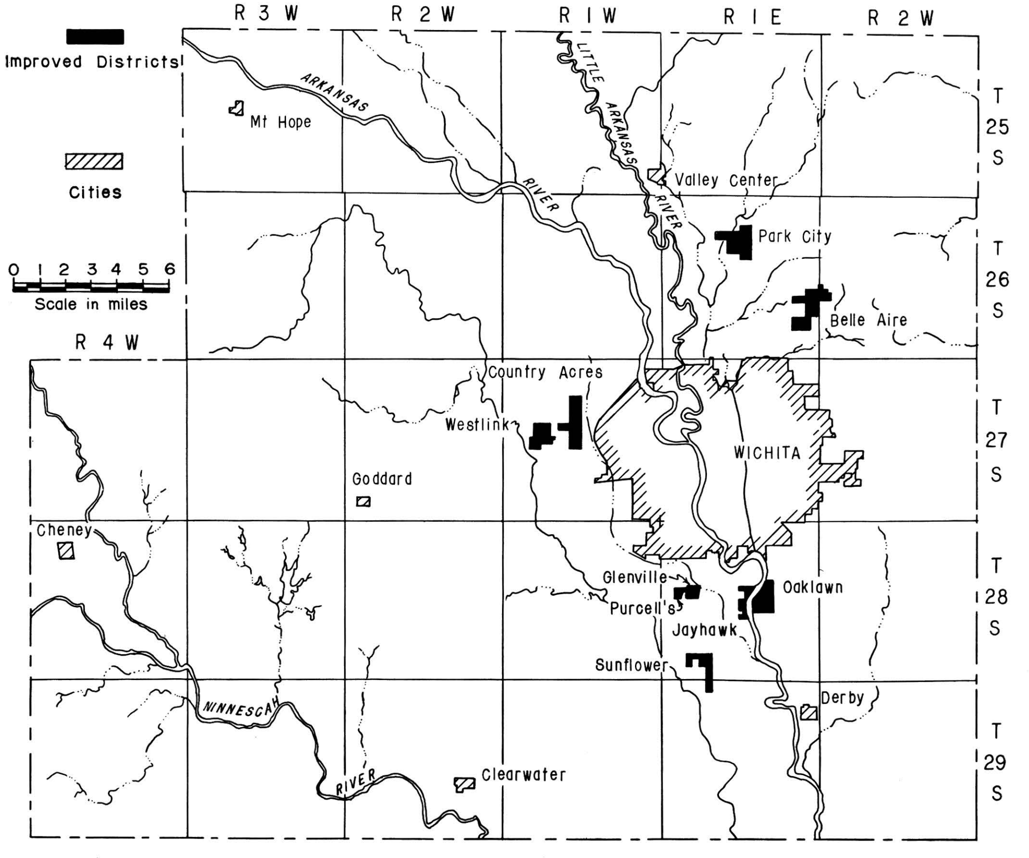


FIGURE 27.—Map of Sedgwick County, Kansas, showing cities and improvement districts providing municipal water service.

TABLE 12.—Public water-supply systems in Sedgwick County, Kansas, 1960.

(Data obtained from publications of the Kansas State Department of Health, unpublished data from the Wichita-Sedgwick County Department of Health, and from interviews with city officials.)

City or improvement district	Source of water	Raw water pumping capacity (mgd)	Raw water storage (millions of gallons)		Water treatment	Capacity of treatment plant (mgd)	Finished water storage (millions of gallons)		Service pumping capacity (mgd)	Average water use (thousands of gallons per day)		Emergency power source	Remarks
			Ground	Elevated			Ground	Elevated		Annual	High monthly		
Belle Aire Improvement District	4 wells	1.4	N	N	C, Cg	N	N	0.07	1.4	64.2	128.4	N	
Chaney	5 wells	.97	N	N	C	N	N	.04	.97	77.7	155.4	G	One well equipped with gasoline engine for emergency use.
Clearwater	4 wells	.97	N	N	C	N	N	.06	.97	85.8	175	N	
Country Acres Improvement District	2 wells	1.2	N	N	C	N	N	.05	1.2	177	408	N	
Derby (El Paso)	5 wells	2.4	N	N	C, Cg	N	0.50	.10	1.7	349.3	506.5	N	
Glenville Improvement District	2 wells	1.2	N	N	I, C, S, F	0.63	.02	.10	.72	132.3	264.6	N	
Goddard	2 wells	.14	N	N	C	N	N	.05	.14	22.3	32.1	N	
Hayesville	3 wells	1.8	N	N	H, I, Al, L, Sa, M, R, S, R, C, F	1.4	.62	.10	.94	295.4	437.2	N	
Jayhawk Improvement District	3 wells	1.1	N	N	C, Cg	N	N	N	1.1	112.4	258.5	N	
Mt. Hope	4 wells	.94	N	N	C	N	N	.05	.94	52.2	120.1	N	One pump equipped with power takeoff for direct drive by auxiliary engine.
Oaklawn Improvement District	12 wells	1.7	N	N	C, Cg	N	N	.05	1.7	245.5	368.3	N	
Park City Improvement District	4 wells	1.0	N	N	C, Cg	N	.40	.05	1.4	200	400	N	
Purcells 1st Improvement District	2 wells	.72	N	N	C, Cg	N	N	.05	.72	60.2	126.4	N	
Sunflower Improvement District	2 wells	.58	N	N	C, Cg	N	N	N	.58	43.7	65.6	N	
Valley Center	3 wells	1.5	N	N	C, Cg	N	N	.28	1.5	173.9	316.5	E	300 kw generator for emergency use.
Westlink Improvement District	4 wells	1.8	N	N	C	N	N	.10	1.8	337	674	N	

Wichita	55 wells (*Equus* beds field).	55.0	35.0	N	H, A, Is, L, N, C, M, S, C, F, Cg	112.0	14.8	2.30	95.0	26,500	35,500	D, Ng, E	Raw water storage includes a 3 million gallon surface tank and the capacity of the transmission lines and treatment basins. Emergency power sources could distribute about 30 mgd. No emergency power for wells is available.
	6 wells (Bentley reserve field).	10.0		N									
	27 wells (Local well field).	30.0	N	N									

Raw water pumping capacity: Capacity given in table is a total for all wells and pumping equipment and in many cases exceeds the capacity of transmission lines.

Raw water storage: *N*, none.

Water treatment: Type of treatment plant: *H*, softening; *I*, iron and manganese removal; *P*. purification. Treatment device: *A*, aeration; *Al*, alum; *C*, chlorination; *Cg*, polyphosphate; *F*, filter; *Is*, iron salts; *L*, lime; *M*, mixing; *Nh*, ammoniation; *R*, recarbonation; *S*, sedimentation; *Sa*, soda ash; *T*, taste and odor control.

Capacity of treatment plant: *N*, no treatment plant; where chlorination and polyphosphate addition are the only treatment these reagents are commonly added automatically at the well pump.

Finished water storage: *N*, none.

Emergency power source: *D*, diesel engine; *DE*, diesel electric; *E*, portable motor generator; *G*, gasoline engine; *N*, none; *Ng*, natural gas.

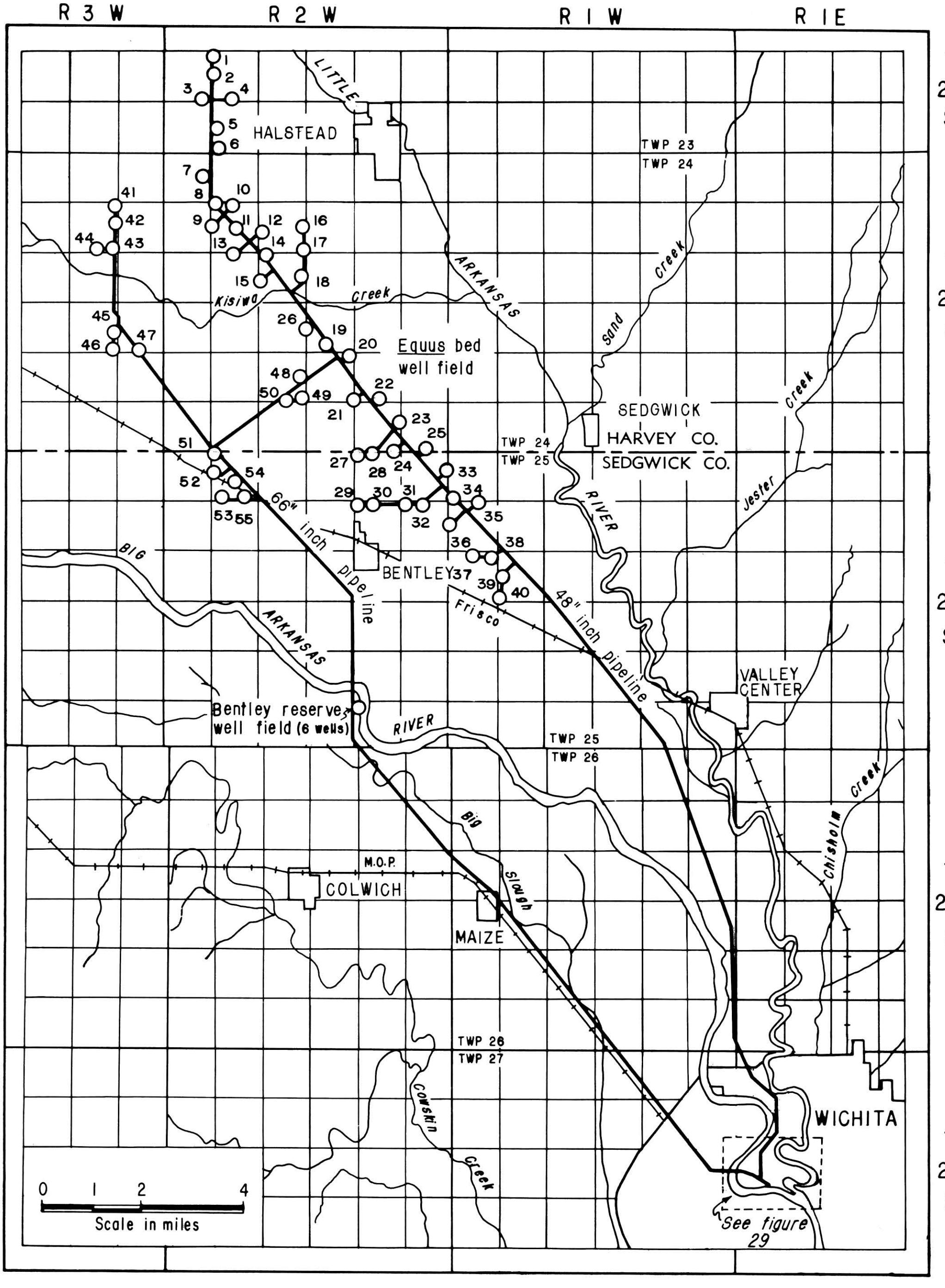


FIGURE 28.—Map showing location of Wichita "*Equus*-beds" and "Bentley reserve" well fields and pipelines from these fields. (Well-field names are those used by the Wichita Water Department.)

to supply stock water, but most of the ponds that provide a perennial water supply are constructed on small spring-fed streams or have been excavated below the water table. The amount of ground water used for rural domestic supplies is not known but is estimated to be about 5,500 acre-feet per year. About 2,500 acre-feet of the total is from private wells in Wichita that are used principally for lawn and garden irrigation, but which are also used to some extent for domestic supply. Ground water is generally available in quantities adequate for domestic supplies in all parts of the County, and in those areas where the water is obtained from bedrock, the quality is commonly poor, but the water is usable.

DEVELOPMENT OF ADDITIONAL LARGE GROUND-WATER SUPPLIES

Additional large ground-water supplies of from one to several million gallons per day for municipal, industrial, or irrigation use could be developed in parts of Sedgwick County. However, where a large-scale development is contemplated, consideration should be given to existing water rights and the availability of ground water as determined by the permeability and thickness of the water-bearing deposits. Figure 30 shows the volume of existing ground-water rights in the County by townships and the areas considered most favorable for developing wells yielding 500 gpm or more without unduly affecting existing water supplies. In outlining the favorable

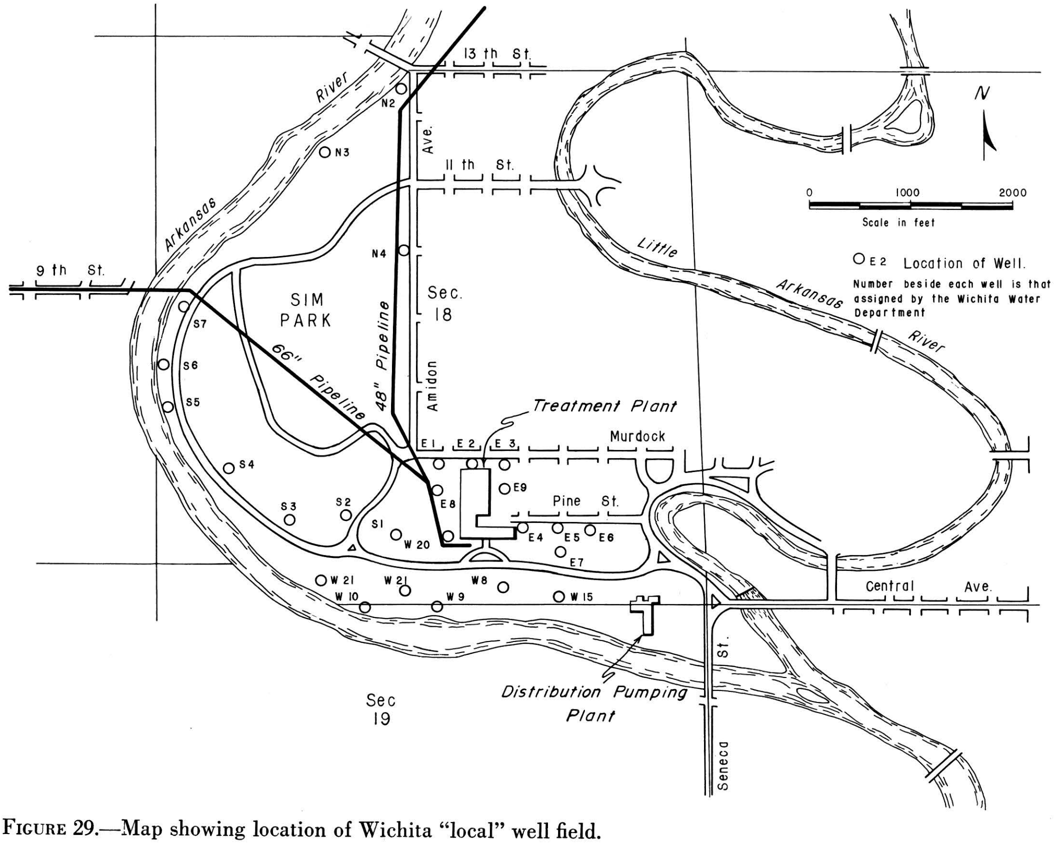


FIGURE 29.—Map showing location of Wichita "local" well field.

areas as shown on Figure 19, consideration was given to existing water rights and the transmissibility of the water-bearing deposits. The areas in and adjacent to T 25 S, R 3 W, T 26 S, R 1 W, and T 27 S, R 1 W, are the most favorable for development of large water supplies. South of Wichita, in T 28 S, R 1 W, and T 29 S, R 1 E, the water-bearing deposits thin and extensive development of large water supplies might lower water levels, thus causing a decline in well yields.

Large quantities of ground water could be developed by inducing infiltration of water from the Arkansas, Little Arkansas, and Ninnescah rivers with wells located adjacent to the river channels. Water thus derived from the Arkansas River would be inferior in quality for many uses, but it might serve as cooling water.

RECORDS OF WELLS AND SPRINGS

Information pertaining to 458 wells and 2 springs in Sedgwick County is given in Table 13. The well-numbering system used is described on page 8.

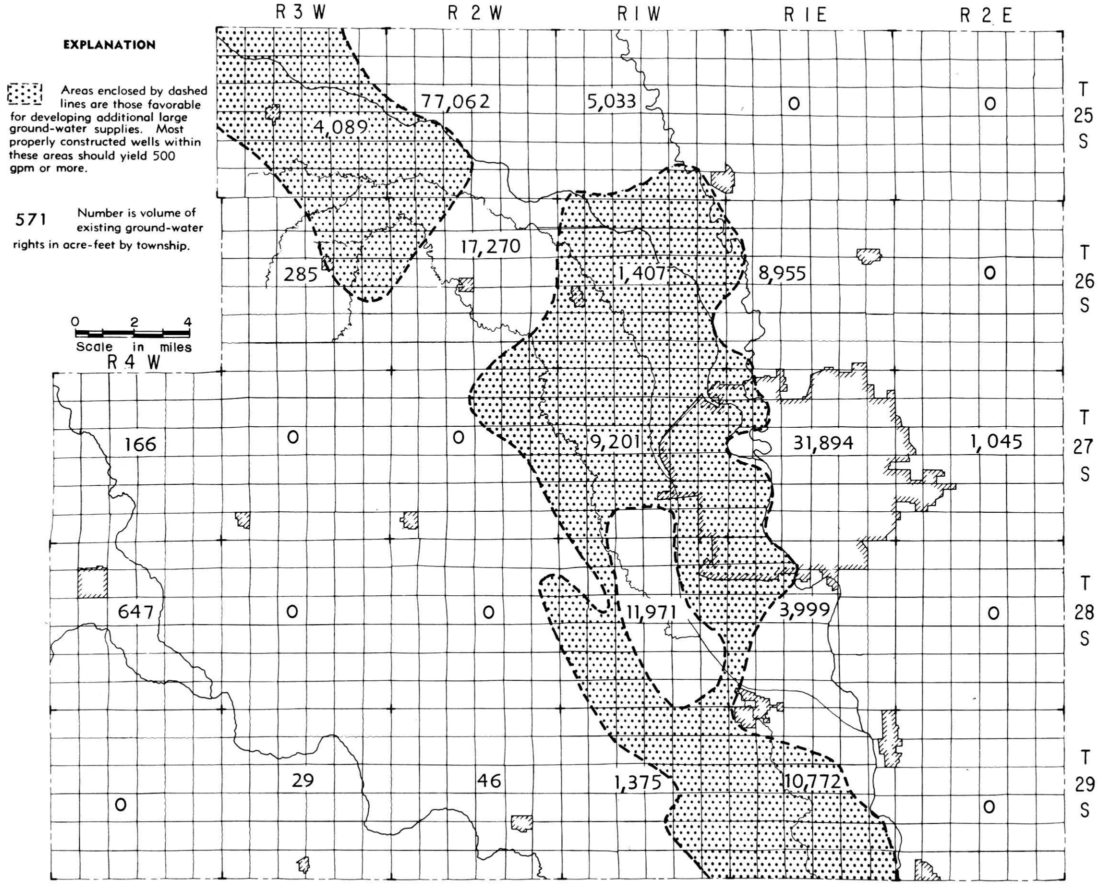


FIGURE 30.—Outline map of Sedgwick County, Kansas, showing volume of existing (1960) ground-water rights in acre feet by township, and areas favorable for developing additional large ground-water supplies.

TABLE 13.—Records of wells and springs in Sedgwick County, Kansas.

Well No.	Owner or tenant	Type of well†	Depth of well, feet‡	Diameter of well, inches	Type of casing§	Principal water-bearing unit: Character of material	Principal water-bearing unit: Geologic source	Method of lift¶	Use of water#	Depth to water level below land surface, feet	Date of measurement	Height of land surface above mean sea level, feet	Remarks (Yield given in gallons/minute; drawdown in feet)
25-2E-1ccb	O. J. Eilert	D	38.9	4	—	Shale	Wellington Formation	Ce, E	D, S	28.8	11-19-58	1,355.7	
3ccc*	—	D	19	8	S	do.	do.	N	N	—	11-22-58	—	Flowing about 15-20.
6ddd*	R. A. Ulbrick	Du	28	—	—	do.	do.	Ce, E	D, S	11.8	11-20-58	1,470.0	
13add	Gordon Waldemuth	Du	90	—	—	do.	do.	Cy, W	S	21.9	11-22-58	1,337.1	
15baa	John Ulbrick	Du	42	42	—	do.	do.	Cy, W	S	31.1	11-20-58	1,384.4	
17ccd	Lloyd Potter	Du	45	48	—	do.	do.	Cy, W	S	26.2	11-19-58	1,457.1	
25ada	W. W. Whitson	D	59	8	GI	do.	do.	Ce, E	S	9.5	11-22-58	1,321.4	
28ada*	John Nosiman	Du	40	—	—	do.	do.	J, E	S	29.5	11-19-58	1,378.2	
30cbc	J. Richardson, Jr.	Du	—	48	—	do.	do.	Cy, E	D	14.4	11-19-58	1,431.0	
25-1E-7ccb*	Leslie Smith	D	65	8	GI	do.	do.	J, E	D	21.8	5-22-59	1,373.1	
20abb	E. H. Ellingboe	D	50	4	GI	Sand and gravel	Pleistocene(?) deposits	Ce, E	I	—	6- 6-58	—	Reported yield 75.
22aad*	Harry Fryar	Sp	—	—	—	Shale	Wellington Formation	N	N	—	12- 1-58	—	Spring flowing about 7.
30cdd	Alma McLaughlin	D	30	8	GI	Sand and gravel	Alluvium	Ce, G	I	—	10- 9-58	—	Irrigates 5 acres.
25-1W-3aaa	City of Wichita	Dn	25.1	1¼	GI	do.	Pleistocene deposits	N	O	9.5	9- 3-58	1,383.2	Wichita well no. 825.
5aaa	do.	Dn	18.2	1¼	GI	do.	do.	N	O	10.6	9- 3-58	1,362.8	Wichita well no. 826.
5ccc	do.	Dn	32.5	1¼	GI	do.	do.	N	O	20.0	9- 3-58	1,375.0	Wichita well no. 1176.
5ddd	do.	D	70.0	1¼	GI	do.	Pleistocene and Pliocene(?) deposits	N	O	17.1	9- 2-58	1,370.7	Wichita well no. 124.
6ccc1*	do.	D	150.0	18	S	do.	do.	T, E	P	64.5	9- 2-58	1,381.6	Wichita well no. M34. Yield 1,490. Drawdown 39.5 30-in. gravel pack.
6ccc2	do.	D	85.0	1¼	GI	do.	do.	N	O	—	—	—	Wichita well M34a.
6ccc3	do.	D	85.0	1¼	GI	do.	do.	N	O	26.7	9- 2-58	1,379.9	Wichita well no. M34b.
7baa1*	do.	D	130.0	18	S	do.	do.	T, E	P	54.0	9- 2-58	1,381.1	Wichita well no. M35. Yield 1,500. Drawdown 50. 30-in. gravel pack.
7baa2	do.	D	85.0	1¼	GI	do.	do.	N	O	—	—	—	Wichita well no. M35a.
7baa3	do.	D	86.0	1¼	GI	do.	do.	N	O	28.7	9- 2-58	1,382.6	Wichita well no. M35b.
7bcc1*	do.	D	184.0	18	S	do.	do.	T, E	P	26.8	1-27-58	1,383.4	Wichita well no. M36. Screens at 108-118 ft., 125-140 ft., and 169-184 ft.
7bcc2	do.	D	180.0	1¼	GI	do.	do.	N	O	26.2	4-22-58	1,381.1	Wichita well no. M36a. Screens set at 116-119 ft., 133-136 ft., and 177-180 ft.
7bcc3	do.	D	51.0	1¼	GI	do.	do.	N	O	25.5	4-22-58	1,380.9	Wichita well no. M36b.
7ccc	do.	Dn	31.1	1¼	GI	do.	do.	N	O	21.2	9- 3-58	1,380.6	Wichita well no. 816.
10ccc	do.	D	68.5	1¼	GI	do.	do.	N	O	11.7	9- 2-58	1,360.7	Wichita well no. 125.
13bcd	M. C. Wilson	Du	47.0	6.0	GI	do.	Pleistocene deposits	Ce, B	I	18.0	5-17-58	1,364.1	
14ddd	City of Wichita	Dn	31.1	1¼	GI	do.	do.	N	O	15.1	9- 3-58	1,360.3	Wichita well no. 814.
17aaa	do.	Dn	30.7	1¼	GI	do.	do.	N	O	15.2	9- 2-58	1,370.2	Wichita well no. 815.
17acb	J. G. Dick	D	72.0	12	—	do.	Pleistocene and Pliocene(?) deposits	Ce, E	I	12.2	5-16-58	1,366.1	
17bbb	City of Wichita	A	30.0	1¼	GI	do.	Pleistocene deposits	N	O	19.0	9- 2-58	1,375.4	Wichita well no. 116.
17cbb1*	do.	D	154.0	18	S	do.	Pleistocene and Pliocene(?) deposits	T, E	P	14.4	12-31-58	1,377.7	Wichita well no. M39. Screens set at 97-107 ft., 117-127 ft., and 134-154 ft.
17cbb2	do.	D	144.0	1¼	GI	do.	do.	N	O	14.2	1-10-58	1,370.7	Wichita well no. M39a. Screens set at 100-103 ft., 121-124 ft., and 139-144 ft.
17cbb3	do.	D	52.0	1¼	GI	do.	do.	N	O	14.2	1-10-58	1,370.8	Wichita well no. M39b.
17ccc1*	do.	D	127.0	18	S	do.	do.	T, E	P	13.5	1-15-58	1,371.7	Wichita well no. M40. Screen set at 92-127 ft.

17ccc2	do	D	121.0	1¼	GI	do	do	N	O	13.0	1-16-58	1,370.3	Wichita well no. M40d. Screens set at 94-97 ft., 107-110 ft., and 120-123 ft.
17ccc3	do	D	43.0	1¼	GI	do	Pleistocene deposits	N	O	12.6	1-16-58	1,370.2	Wichita well no. M40b. Screens set at 40-43 ft.
18aaa1*	do	D	128.0	18	S	do	Pleistocene and Pliocene(?) deposits	T, E	P	17.0	1-17-58	1,373.4	Wichita well no. M38. Screens set at 93-128 ft.
18aaa2	do	D	129.0	1¼	GI	do	do	N	O	20.1	1-17-58	1,375.4	Wichita well no. M38d. Screens set at 98-101 ft., 112-115 ft., and 126-129 ft.
18aaa3	do	D	48.0	1¼	GI	do	Pleistocene deposits	N	O	19.2	7- 1-58	1,375.2	Wichita well no. M38b. Screen set at 45-48 ft.
18abb1*	do	D	170.0	18	S	do	Pleistocene and Pliocene(?) deposits	T, E	P	17.6	1-22-58	1,375.2	Wichita well no. M37. Screens set at 114-124 ft., 139-159 ft., and 165-170 ft.
18abb2	do	D	160.0	1¼	GI	do	do	N	O	18.5	5-14-58	1,375.2	Wichita well no. M37d. Screens set at 121-124 ft., 149-152 ft., and 157-160 ft.
18abb3	do	D	52.5	1¼	GI	do	Pleistocene deposits	N	O	18.7	5-14-58	1,375.3	Wichita well no. M37b. Screen set at 49.5-52.5 ft.
19dbd	Don Jacob	Du	55.0	6	—	do	do	Ce, G	I	15.2	5-20-58	1,372.0	
20ccc	City of Wichita	A	38.5	1¼	GI	do	do	N	O	11.2	9- 2-58	1,371.6	Wichita well no. 117.
22bbb	do	D	40.4	1¼	GI	do	do	N	O	11.3	9- 3-58	1,358.6	Wichita well no. 126.
25bac	B. Updegraph	D	28	8	S	do	do	Ce, B&G	I	—	—	—	Well not in use (sealed).
25bba	do	D	27	8	S	do	do	Ce, B&G	I	—	—	—	do
25bca	do	D	25.0	8	S	do	do	Ce, B&G	I	13.6	10- 8-58	1,354.5	
25cad	do	D	29	8	S	do	do	Ce, B&G	I	—	—	—	Well not in use (sealed).
25cdb	do	D	30	8	S	do	do	Ce, B&G	I	—	—	—	do
25dca	R. C. Wilson	D	51.0	—	GI	do	do	Ce, B	I	77.6	5-17-58	1,350	
26db	Dr. A. D. Updegraph	D	54.0	24.0	Cn	do	do	N	O	16.5	9- 3-58	1,353.9	City of Wichita recorder installed in 1937; well no. 12.
27bbb	City of Wichita	Dn	25.3	1¼	GI	do	do	N	O	11.5	9- 3-58	1,362.1	Wichita well no. 812.
30bba	Homer Jacob	Du	32.0	6	GI	do	do	N	N	7.9	6- 6-58	1,369.9	Well not in use.
30bdb	do	D	32.0	6	GI	do	do	Ce	I	—	—	—	Sealed system.
33ddd	City of Wichita	Dn	25.1	1¼	GI	do	do	N	O	8.3	9- 3-58	1,355.1	Wichita well no. 811.
35daa	do	Dn	24.8	1¼	GI	do	do	N	O	12.3	9- 3-58	1,347.5	Wichita well no. 810.
36acd1	City of Valley Center	D	50.6	—	S	do	do	T, E	P	17	—	1,346	City well 3. Yield of well about 350.
36acd2*	do	D	50.6	—	S	do	do	T, E	P	17	—	1,346	City well 4. Yield of well about 350.
36acd3	do	D	50.6	—	S	do	do	T, E	P	17	—	1,346	City well 5. Yield of well about 350.
25-2W-1baa	City of Wichita	D	51.0	1¼	GI	do	do	N	O	29.6	9- 2-58	1,383	Wichita well no. M25b.
1cbb	J. R. Clark	D	92.0	6	Cn	do	Pleistocene and Pliocene(?) deposits	N	O	31.6	9- 3-58	1,388.0	Wichita well no. 307.
1daa1*	City of Wichita	D	170.0	18	S	do	do	T, E	P	56.0	9- 2-58	1,381.0	Wichita well no. M33. Yield 1,000. Drawdown 46.5 after pumping 12 hrs.
1daa2	do	D	54.0	1¼	GI	do	Pleistocene deposits	N	O	—	—	—	Wichita well no. M33a.
1daa3	do	D	75.0	1¼	GI	do	Pleistocene and Pliocene(?) deposits	N	O	23.7	2- 2-59	1,379.3	Wichita well no. M33b.
2baa1*	do	D	220.0	18	S	do	do	T, E	P	66.0	9- 2-58	1,389.6	Wichita well no. M28. Yield 1,050. Drawdown 58 after pumping 12 hrs. 30-in. gravel pack.
2baa2	do	D	80.0	1¼	GI	do	do	N	O	—	—	—	Wichita well no. M28a.
2baa3	do	D	82.0	1¼	GI	do	do	N	O	29.0	3- 2-59	1,390.3	Wichita well no. M28b.
2bbb1*	do	D	215.0	18	GI	do	do	T, E	P	60.0	9- 2-58	1,391.3	Wichita well no. M27. Yield 2,000. Drawdown 61 after pumping 15 hrs. 30-in. gravel pack.
2bbb2	do	D	82.0	1¼	GI	do	do	N	O	—	—	—	Wichita well no. M27a.
3aaa	do	D	80.0	1¼	GI	do	do	N	O	29.2	9- 2-58	1,393.0	Wichita well no. M27b.
4aaa	do	Dn	20.1	1¼	GI	do	Pleistocene deposits	N	O	17.5	9- 3-58	1,400.2	Wichita well no. 1171.
4bca	C. L. Collins	Du	32.0	6	GI	do	do	Ce, G	I	10.8	5-21-58	1,401.1	Well not in use.

TABLE 13.—Records of wells and springs in Sedgwick County, Kansas.—*Continued.*

Well No.	Owner or tenant	Type of well†	Depth of well, feet‡	Diameter of well, inches	Type of casing§	Principal water-bearing unit: Character of material	Principal water-bearing unit: Geologic source	Method of lift¶	Use of water#	Depth to water level below land surface, feet	Date of measurement	Height of land surface above mean sea level, feet	Remarks (Yield given in gallons/minute; drawdown in feet)
25-2W-5bbb1*	City of Wichita	D	185.0	18	S	Sand and gravel	Pleistocene and Pliocene(?) deposits	T, E	P	19.5	1-31-58	1,407.3	Wichita well no. M51. Screens set at 88-108 ft., 155-165 ft., and 175-185 ft.
5bbb2	do	D	164.0	1¼	GI	do	do	N	O	23.0	2- 2-58	1,407.7	Wichita well no. M51d. Screen set at 160-163 ft.
5bbb3	do	D	39.0	1¼	GI	do	Pleistocene deposits	N	O	9.0	2-14-58	1,407.7	Wichita well no. M51b.
5bcc1*	do	D	40.0	18	S	do	do	T, E	P	6.9	2- 3-58	1,405.9	Wichita well no. M52. Gravel pack.
5bcc2	do	D	40.3	1¼	GI	do	do	N	O	9.7	2-11-58	1,407.9	Wichita well no. M52b. Screen set at 37-40 ft.
5ccd1*	do	D	92.0	18	S	do	Pleistocene and Pliocene(?) deposits	T, E	P	6.7	2- 7-58	1,403.5	Wichita well no. M53. Screens set at 36-41 ft., 50-70 ft., and 82-92 ft. Gravel pack.
5ccd2	do	D	37.0	1¼	GI	do	Pleistocene deposits	N	O	6.5	2-11-58	1,402.4	Wichita well no. M53b.
5dac	H. Collins	Du	35.0	6	GI	do	do	Ce, B	I	—	—	—	
5dbb1*	City of Wichita	D	85.0	18	S	do	Pleistocene and Pliocene(?) deposits	T, E	P	7.7	2-13-58	1,402.8	Wichita well no. M54. Screens set at 38-48 ft., and 70-80 ft., Gravel pack.
5dbb2	do	D	40.0	1¼	GI	do	Pleistocene deposits	N	O	8.2	4- 1-58	1,404.0	Wichita well no. M54b.
5dcd1*	do	D	47.0	18	S	do	do	T, E	P	10.1	2- 4-58	1,403.9	Wichita well no. M55. Screen set at 37-47 ft.; 30-in. gravel pack.
7aaa	do	D	32.0	1¼	S	do	do	N	O	4.8	9- 2-58	1,402.0	Wichita well no. 114.
8adb*	L. Morris	D	40.0	12	GI	do	do	Ce, G	I	5.6	8-14-58	1,400	
9aaa	City of Wichita	D	61.0	1¼	GI	do	—	N	O	11.2	9- 3-58	1,400.2	Wichita well no. 840.
9abb	J. C. Alley	D	39.0	12	GI	do	Pleistocene deposits	Ce	I	10.1	5-17-58	1,401.9	
9cba	C. C. Elliott	D	37.0	6	GI	do	do	Ce, B	I	4.4	6- 6-58	1,396	
9cca	do	D	36.6	6	GI	do	do	Ce, B	I	5.7	5-13-58	1,396.0	
9cdd*	do	D	40.0	8	GI	do	do	Ce, B	I	—	—	—	500 (est).
11baa1*	City of Wichita	D	225.0	18	S	do	Pleistocene and Pliocene(?) deposits	T, E	P	60.0	9- 2-58	1,387.0	Wichita well no. M30. Yield 1,850. Drawdown 57 after pumping 12 hrs. 30-in. gravel pack.
11baa2	do	D	72.0	1¼	GI	do	do	N	O	—	—	—	Wichita well no. M30a.
11baa3	do	D	61.0	1¼	GI	do	do	N	O	24.8	4- 1-59	1,386.8	Wichita well no. M30b.
11bbb1*	do	D	225.0	18	S	do	do	T, E	P	52.0	9- 2-58	1,390.7	Wichita well no. M29. Yield 2,000. Drawdown 52 after pumping 24 hrs. 30-in. gravel pack.
11bbb2	do	D	97.0	1¼	GI	do	do	N	O	27.5	9- 2-58	1,390.0	Wichita well no. M29a.
11bbb3	do	D	103.0	1¼	GI	do	do	N	O	22.3	7-31-59	1,391.0	Wichita well no. M29b.
11cbc	do	D	32.0	1¼	GI	do	Pleistocene deposits	N	O	12.8	9- 3-58	1,389	Wichita well no. 3030.
12baa1*	do	D	185.0	18	S	do	Pleistocene and Pliocene(?) deposits	T, E	P	28.0	9- 2-58	1,383.4	Wichita well no. M32. Yield 1,840. Drawdown 51 after pumping 12 hrs. 30-in. gravel pack.
12baa2	do	D	72.0	1¼	GI	do	do	N	O	—	—	—	Wichita well no. M32a.
12baa3	do	D	61.0	1¼	GI	do	do	N	O	25.5	7-31-59	1,383.4	Wichita well no. M32b.
12bbb1*	do	D	197.0	18	S	do	do	T, E	P	60.5	9- 2-58	1,385.9	Wichita well no. M31. Yield 2,000. Drawdown 40 after pumping 18 hrs. 30-in. gravel pack.

12bbb2	do	D	87.0	1¼	GI	do	do	N	O	—	—	—	Wichita well no. M31a.
12bbb3	do	D	62.0	1¼	GI	do	Pleistocene deposits	N	O	26.7	6- 1-59	1,386.5	Wichita well no. M31b.
13bbc	Frisco R. R.	D	65.0	6	GI	do	do	N	O	16.5	10- 5-58	1,383.4	Wichita well no. 3045. Recorder well.
14ccc	City of Wichita	D	—	1¼	GI	do	—	N	O	6.9	9- 3-58	1,384.6	Wichita well no. 3044.
16bbb1	do	D	15.0	1¼	GI	do	Pleistocene deposits	N	O	6.2	9- 3-58	1,397.0	Wichita well no. 842.
16bbb2	Fred Wolf	Dn	50.0	6	S	do	do	N	N	—	—	—	Well not in use.
16bdc	do	Du	30.0	6	S	do	do	N	N	1.0	7-10-58	1,392.5	Well not in use.
16bdd	do	Du	—	6	S	do	—	N	N	—	—	—	do
16dac	E. R. Hand	D	50.0	6	GI	do	Pleistocene and Pliocene(?) deposits	Ce, G	I	3.0	7-10-58	1,390.0	
18aab	W. Williams	Dn	19.0	1¼	GI	do	Pleistocene deposits	Ce	S, O	6.6	9- 3-58	1,404.1	Wichita well no. 870.
22bbb	City of Wichita	Dn	32.0	1¼	GI	do	do	N	O	5.1	9- 2-58	1,388.4	Wichita well no. 115.
22daa*	G. H. Jacob	D	32.0	6	GI	do	do	Ce, G	I	7.0	5-13-58	1,384.5	
23acc	C. Stamback	D	35.0	6	GI	do	do	Ce, G	I	—	—	—	Closed irrigation system.
23bbc*	do	D	35.0	6	GI	do	do	Ce, G	I	—	—	—	do
24ddd	City of Wichita	Dn	—	1¼	GI	do	—	N	O	7.5	10- 2-58	1,373.3	Wichita well no. 3050.
30ccc	do	Dn	57.0	1¼	GI	do	Pleistocene and Pliocene(?) deposits	N	O	23.6	12- 1-58	1,417.9	Wichita well no. 830.
35bb	do	D	199.0	26	S	do	do	T, E	P	5.0±	Spring '56	1,376.6	Wichita well no. Bentley R. no. 2. Gravel pack.
35bb	do	D	141.0	26	S	do	do	T, E	P	—	—	1,378.7	Wichita well no. Bentley R. no. 3. Gravel pack.
35bb*	do	D	126.0	26	S	do	do	T, E	P	—	—	1,376.9	Wichita well no. Bentley R. no. 4. Gravel pack.
35bb*	do	D	137.0	26	S	do	do	T, E	P	—	—	1,376.7	Wichita well no. Bentley R. no. 5. Gravel pack.
35bb*	do	D	212.0	26	S	do	do	T, E	P	—	—	1,374.8	Wichita well no. Bentley R. no. 6. Gravel pack.
35bc	do	D	212.0	26	S	do	do	T, E	P	4.0±	Spring '56	1,374.7	Wichita well no. Bentley R. no. 1. Gravel pack.
36aac	W. C. Wilbur	Du	36.0	6	GI	do	Pleistocene deposits	Ce	I	—	—	—	
36ddb	do	Du	35.0	6	GI	do	do	Ce	I	—	—	—	
25-3W-1cac	H. Blubaugh	Du	33	6	GI	do	do	Ce, B	I	3.7	3-24-58	1,412	
1cca	do	Du	36	6	GI	do	do	Ce, B	I	4.7	3-24-58	1,415	
1cdb	do	Du	34	6	GI	do	do	Ce, B	I	3.7	3-24-58	1,411.9	
1ddd	City of Wichita	Dn	20	1¼	GI	do	do	N	O	7.5	9- 3-58	1,412	Wichita well no. 3004.
3ddd	do	D	17.2	1¼	GI	do	do	N	O	10.5	9- 3-58	1,422	Wichita well no. 3041.
5abc	R. A. Howard	D	67.0	6	—	do	do	Ce, E	I	2.3	4- 7-58	1,430.0	
9ccc	City of Wichita	Dn	18.5	1¼	GI	do	do	N	O	9.0	9- 3-58	1,429.5	Wichita well no. 834.
11adb	Charles Reed	D	96.0	12	S	do	Pleistocene and Pliocene(?) deposits	T, G	I	15.4	4- 3-58	1,415	
11adc	do	D	90.0	12	GI	do	do	H	S	7.6	4- 3-58	1,415	
11bbd	E. Grimsman	D	77.0	12	—	do	do	T	I	13.4	4- 3-58	1,422.3	
11dac	Charles Reed	D	110.0	12	S	do	do	T, G	I	2.4	4- 3-58	1,410	
12ddb	Cecil Lewis	Du	37.0	6	GI	do	Pleistocene deposits	Cy, W	S	0.4	5-13-58	1,411.0	
15dac	L. Bardshar	D	170.0	12	S	do	Pleistocene and Pliocene(?) deposits	T, G	I, S	19.6	4- 7-58	1,430.5	
16ccc*	City of Mount Hope	D	100.0	12	S	do	do	T, E	P	25	10-10-58	1,441	City well 3. Yield about 200.
18cdc*	M. Moreland	D	100.0	12	—	do	do	T, G	I	26.2	4- 7-58	1,451.4	
20aad1	City of Mount Hope	D	74.0	12	S	do	do	T, E	P	28	—	1,441	City well 1. Yield about 120.
20aad2	do	D	74.0	12	S	do	do	T, E	P	25	10-10-59	1,441	City well 2. Yield about 120.
20bbd	H. O. Morris	D	105	12	—	do	do	T, G	I	35.4	4- 4-58	1,449.7	
21abd	C. Christensen	Du	40	—	GI	do	Pleistocene deposits	Ce, G	I	20.0	7- 8-58	1,426.3	
21bbc	City of Mount Hope	D	100	10	S	do	Pleistocene and Pliocene(?) deposits	T, E	P	25	—	1,438	City well 4. Yield about 300.
26cab	N. B. Martin	Du	59	12	GI	do	Pleistocene deposits	Ce, B	I	19.2	3-31-58	1,415	
26cad	do	D	100	18	S	do	Pleistocene and Pliocene(?) deposits	T, B	I	19.3	3-31-58	1,417.9	
27adc*	do	D	100	18	S	do	do	T, B	I	19.4	3-31-58	1,420	
28aac	Paul Dick	D	90	12	GI	do	do	T, B	I	19.1	5- 5-58	1,429	
29dbd	J. Marshall	D	89.0	12	GI	do	do	T, B	I	33.6	5- 5-58	1,446.4	
33baa	City of Wichita	Dn	49.3	1¼	GI	do	Pleistocene deposits	N	O	25.0	1- 2-59	1,433.1	Wichita well no. 838

TABLE 13.—Records of wells and springs in Sedgwick County, Kansas.—*Continued.*

Well No.	Owner or tenant	Type of well†	Depth of well, feet‡	Diameter of well, inches	Type of casing§	Principal water-bearing unit: Character of material	Principal water-bearing unit: Geologic source	Method of lift¶	Use of water#	Depth to water level below land surface, feet	Date of measurement	Height of land surface above mean sea level, feet	Remarks (Yield given in gallons/minute; drawdown in feet)
26-2E-1dad	Lloyd Edson	Du	30	48	R	Shale	Wellington Formation	Cy, W	S	16.7	11-25-58	1,329.4	
7bab	M. D. Matson	Du	22	48	R	do.	do.	Cy, W	S	12.8	11-25-58	1,409.5	
10cbb*	J. L. Lindel	Du	30	48	R	do.	do.	Ce, E	D	22.0	11-25-58	1,368.2	
13bcb	C. B. Mitchell	D&Du	97.0	—	R&GI	do.	do.	Cy, W	S	41.1	11-25-58	1,370.9	Bad water; gray and oily, probably oil field polluted.
19ccd	T. N. Pearson	Du	30.0	48	R	do.	do.	J, E	S	11.8	11-25-58	1,402.7	
25ccd*	K. Yourdon	D	62.0	6	GI	do.	do.	Ce, E	D	37.2	11-25-58	1,363.2	
27ada	A. D. Schnoor	D	35.0	48	R	do.	do.	P, E	D	18.1	11-25-58	1,369.9	
31ccc	G. F. Allen	D	15.0	60	R	do.	do.	Cy, W	S	5.0	11-25-58	1,355.8	
26-1E-17aab1	Park City Imp. Dist.	D	42	15	S	Sand and gravel	Pleistocene deposits	T, E	P	16	—	1,336	Yield 200. Drawdown 5 after pumping 8 hrs.
17aab2	do.	D	42	15	S	do.	do.	T, E	P	16	—	1,336	do
17aba	do.	D	42	21	S	do.	do.	T, E	P	16	—	1,336	Yield 240. Drawdown 6 after pumping 8 hrs.
17abb	do.	D	42	21	S	do.	do.	T, E	P	16	—	1,336	do
19bca	Howard Hall	D	42.0	6	GI	do.	do.	Ce, E	I	13.9	6- 3-58	1,330.5	
20cdd	Ark Valley Gardens	Du	40.0	8	GI	do.	do.	Ce, G	I	15.7	10-10-58	1,326.6	
20dca	Bel Aire Impr. Dist.	D	40	—	S	do.	do.	T, E	P	14	—	1,312	Individual wells yield about 300. Combined discharge of 4 wells about 1,000.
20dcc*	Abe Meyer	Du	40.0	8	GI	do.	do.	Ce, E	I	13.8	10-10-58	1,325.7	
20dcd	Bel Aire Impr. Dist.	D	40	—	S	do.	do.	T, E	P	14	—	1,312	Individual wells yield about 300. Combined discharge of 4 wells about 1,000.
20ddb	do.	D	40	—	S	do.	do.	T, E	P	14	—	1,312	do
20ddc	do.	D	40	—	S	do.	do.	T, E	P	14	—	1,312	do
21bbb	City of Wichita	Dn	32.2	1¼	GI	do.	do.	N	O	12.4	9- 3-58	1,330.3	Wichita well no. 809.
26cdd*	W. Tjaden	D	66.0	6	GI	do.	do.	J, E	S	27.6	5-21-59	1,384.4	
31baa	L. E. Gould	Du	35.0	12	—	do.	do.	Ce, E	I	—	—	—	
26-1W-15cbc	G. H. Holmes	D	40	—	GI	do.	do.	T	I	—	—	—	
15dbd	J. W. Kessler	D	60	—	GI	do.	do.	T	I	—	—	—	
15ddb	M. H. Adams	D	35.0	6	GI	do.	do.	Ce, G	I	4.8	6- 2-58	1,337.9	
16ddd	City of Wichita	Dn	25.7	1¼	GI	do.	do.	N	O	2.4	9- 3-58	1,339.6	Wichita well no. 804.
17aac	C. E. Switzer	D	—	6	GI	do.	—	Ce	I	—	—	—	
18dbd	C. A. Nicks	D	34.2	6	GI	do.	Pleistocene deposits	Ce	I	5.4	7- 1-58	1,353	
19aaa	do.	D	35.0	6	GI	do.	do.	Ce	I	6.2	9- 5-58	1,348.9	
19abb	City of Wichita	Dn	41.0	1¼	GI	do.	do.	N	O	3.4	9- 5-58	1,351.7	Wichita well no. 805.
19ddd	J. Torkleson	D	100	18	GI	do.	Pleistocene and Pliocene(?) deposits	N	N	26.3	7- 1-58	1,366.0	Well not in use.
29bdb	Gail Woodward	D	45	6	GI	do.	do.	Ce, B	I	—	—	—	
31aac*	N. R. Wells	D	40.0	12	GI	do.	do.	T, G	I	17.7	7- 2-58	1,355	
26-2W-2bcc*	A. B. Wetta	Dn	16.0	1¾	GI	do.	Pleistocene deposits	Cy, H	S	3.0	6- 4-59	1,369	Well not in use.
2cbb	Kansas Gas and Electric Co.	D	127	1¼	GI	do.	do.	N	O	—	—	1,373.1	
2cca	A. B. Wetta	Du&D	63.0	12	GI	do.	do.	Ce, G	I	9.5	6- 4-59	1,375	
3add	F. M. Simon	D	27.0	8	GI	do.	do.	N	N	8.6	6- 5-59	1,375.4	
8ddd	Paul Spexarth	Du	40	6	GI	do.	do.	Cy, H	S	25.7	9- 5-58	1,396.5	
10bbb	City of Wichita	Dn	37.2	1¼	GI	do.	do.	N	O	22.4	9- 3-58	1,392.1	Wichita well no. 807.
10bcd	John A. Wetta	D	52.0	6	GI	do.	do.	Cy, E	I	16.9	6- 3-59	1,387	
10bdc	do.	Dn	22.0	1¾	GI	do.	do.	N	O	15.5	6- 3-59	1,383	
10dcd	Frank Voegeli	D	26.0	12	GI	do.	do.	—	R	13.4	6- 1-59	1,378.7	

10ddd	do.	Dn	35.0	1¾	GI	do.	do.	J, E	D	17.0	6- 1-59	1,379.9	
13dac	Belt & Wetta Sales	D	40.0	8	GI	do.	do.	N	N	12.7	6- 5-59	1,365.1	
14bac*	W. B. Linnabur	D	55.0	6	GI	do.	do.	Ce, E	I	17	—	—	
14bba	Donald Linnabur	D	38.0	8	GI	do.	do.	N	N	17.1	6- 1-59	1,376.2	
14ddb	Dennis Nigg	D	90.0	12	GI	do.	Pleistocene and Pliocene(?) deposits	Ce	I	14.0	6- 5-59	1,371.7	
15dad	KAKE T.V. Transmitter	D	44.2	12	GI	do.	Pleistocene deposits	J, E	Ind	10.0	6- 3-59	1,369.6	Well used for air-conditioning; water recirculated.
16daa	J. H. Rau	D	35.0	6	GI	do.	do.	Ce, E	I	21.0	6-10-59	1,385	
16dcc	Sacred Heart Cemetery	D	60.0	8	GI	do.	Pleistocene and Pliocene(?) deposits	Ce, E	I	16.1	6- 9-59	1,381.2	
16dda	City of Colwich	D	35.0	6	GI	do.	Pleistocene deposits	N	N	21.5	6- 8-59	1,384.8	
16ddc	do.	D	50.0	8	—	do.	Pleistocene and Pliocene(?) deposits	T, G	P	21.3	6- 8-59	1,387	
18bcc	City of Wichita	Dn	49.3	1¼	GI	do.	Pleistocene deposits	N	N	23.6	12- 1-58	1,401.2	Wichita well no. 808.
22acd	A. J. Stolz	D	45.0	6	GI	do.	do.	Ce, G	I	—	—	—	
23aac	Dennis Nigg	D	31.5	6	GI	do.	do.	—	I	15.4	5-28-58	1,373.2	
24bdb	A. B. Anthony	D	40.0	6	GI	do.	do.	Ce, G	I	—	—	—	
25bdb	A. G. Bogner	D	—	—	GI	do.	—	Ce, G	I	18	6- 7-58	—	
26acd*	Starlight Club Co.	D	—	12	GI	do.	—	T, G	R	—	—	—	
26daa	Gene Reynolds	Du	17.2	6	GI	do.	Pleistocene deposits	—	R	7.7	7- 1-58	1,358.5	
29aaa*	Kansas Gas and Electric Co.	D	83	1¼	GI	do.	do.	N	O	—	—	1,383.8	
29aad	J. Strunk	D	35.0	6	GI	do.	do.	J, E	D	23.1	3-16-58	1,385.4	
26-3W-4baa*	Mary Lingg	D	75.0	12	S	do.	do.	T, B	I	32.2	5-21-58	1,435.5	
7ccd	P. G. Betzen	D	54.0	6	GI	do.	do.	J, E	D	23.4	3-11-59	1,515.1	
12bba	C. C. Winter	D	32.0	8	GI	do.	do.	N	N	14.3	3-10-59	1,408.6	
22baa*	V. Smithz	Du	100.0	48	R	Shale	Permian shale	Cy, H	D & S	45.0	9- 5-58	1,495.9	
25bab	M. M. Lies	Du	60.0	48	R	do.	do.	Cy, W	S	31.0	3- 9-59	1,460.4	
27-2E-5ccd	C. D. Miller	Du	31.0	36	R	do.	Wellington Formation	J, E	D	18.9	11-25-58	1,378.7	
11bbb	Vornado Club, Inc.	D&Du	98.0	18	GI	do.	do.	N	N	54.5	11-25-58	1,383.8	
13ccc1	Beech Aircraft Co.	D	80	10	S	Shale and gypsum	do.	T, E	Ind	3.0	5-18-57	1,313.5	Measured discharge 488 with draw-down 12.8.
13ccc2*	do.	D	38	10	S	do.	do.	T, E	Ind	3.0	5-19-57	1,313.0	Measured discharge 323 with draw-down 16.4.
13ccc3	do.	D	39	10	S	do.	do.	N	N	—	—	1,310.8	Well sealed.
13ccc4	do.	Sp	—	—	—	do.	do.	N	N	—	5-18-57	—	Measured discharge 235.
13cdd	G. M. Fisher	D	40.0	48	R	do.	do.	Cy, W	D & S	26.4	11-25-58	1,333.1	
16dad*	E. L. Wolf	Du	70.0	6	GI	Shale	do.	Ce, E	D	43.0	11-25-58	1,371.4	
20ccd	Mrs. L. E. Ruth	D	43.0	—	GI	do.	do.	N	N	20.5	11-25-58	1,341.4	
25bbc*	L. W. Landis	Sp	31.5	12	GI	do.	do.	N	R	0	11-26-58	1,303.3	Cased spring; flowing 5-10.
28ddd	R. T. McCrea	Du	60.0	6	GI	do.	do.	N	N	24.9	11-25-58	1,343.6	
35ddc	C. L. Crow	D	80.0	6	GI	do.	do.	—	I	7.0	11-25-58	1,340±	
27-1E-6acb	J. Smith	Du	40.0	—	—	Sand and gravel	Pleistocene deposits	Ce, G	I	—	—	—	
6cca	City of Wichita	D	48.0	—	S	do.	do.	T, E	P	18.8	9-24-57	1,315	
6dcc	do.	Dn	25.2	1¼	GI	do.	do.	N	O	16.0	9- 3-58	1,314.7	
10cdd	Ellie Greenhouse	D	60.0	8	GI	do.	do.	Ce, E	I	—	—	—	
15baa	Williamson Greenhouse	Du	30.0	6	GI	do.	do.	Ce, E	I	—	—	—	
15cbb	C. E. Heite, Jr.	Du	28.0	24	—	do.	do.	Ce, E	I	14.1	10-21-58	1,302	
17bbb	City of Wichita	D	42.5	—	S	do.	do.	T, E	P	—	—	—	
17cba	M. Drowatsky	D	38.0	12	GI	do.	do.	Ce, E	I	9.2	10-21-58	1,301	
17cdb	City of Wichita	D	35.0	12	S	do.	do.	T, E	P	—	—	1,300	
18baa*	do.	D	48	26	S	do.	Alluvium	T, E	P	17	—	—	City well N2. Yield about 800.
18bac*	do.	D	46	26	S	do.	do.	T, E	P	17	—	—	City well N3. Yield about 800.
18bcc*	do.	D	48	26	S	do.	do.	T, E	P	18	—	—	City well S7. Yield about 1,600.
18bcc	do.	D	45	26	S	do.	do.	T, E	P	16	—	—	City well N4. Yield about 800.
18ca	do.	D	45	—	S	do.	do.	T, E	I	14	—	—	Well is in Sim Park. Yield about 500.
18cbb*	do.	D	47	26	S	do.	do.	T, E	P	14	—	—	City well S6. Yield about 1,600.
18cbc*	do.	D	52	26	S	do.	do.	T, E	P	15	—	—	City well S5. Yield about 1,480.
18cc	do.	D	47.0	26	S	do.	Pleistocene deposits	N	O	12.9	9- 5-58	1,298.3	

TABLE 13.—Records of wells and springs in Sedgwick County, Kansas.—*Continued.*

Well No.	Owner or tenant	Type of well†	Depth of well, feet‡	Diameter of well, inches	Type of casing§	Principal water-bearing unit: Character of material	Principal water-bearing unit: Geologic source	Method of lift¶	Use of water #	Depth to water level below land surface, feet	Date of measurement	Height of land surface above mean sea level, feet	Remarks (Yield given in gallons/minute; drawdown in feet)
27-1E-18cca*	City of Wichita	D	49	26	S	Sand and gravel	Alluvium	T, E	P	15	—	—	City well S4. Yield about 1,740.
18cda*	do	D	54	26	S	do	do	T, E	P	9	—	—	City well S2. Yield about 1,930.
18cdb*	do	D	50	26	S	do	do	T, E	P	17	—	—	City well S3. Yield about 1,900.
18cdc	do	D	46	26	S	do	do	T, E	P	17	—	—	City well W12. Yield about 1,040.
18cdd1*	do	D	51	26	S	do	do	T, E	P	15	—	—	City well S1. Yield about 1,690.
18cdd2	do	D	51	26	S	do	do	T, E	P	20	—	—	City well W21. Yield about 1,390.
18dca1*	do	D	—	—	S	do	do	T, E	P	16	—	—	City well E9. Yield about 1,500.
18dca2*	do	D	43	18	S	do	do	T, E	P	18	—	—	City well E3. Yield about 750.
18dca3*	do	D	42	18	S	do	do	T, E	P	17	—	—	City well E4. Yield about 1,380.
18dca4*	do	D	42	18	S	do	do	T, E	P	17	—	—	City well E5. Yield about 1,190.
18dcb1*	do	D	43	18	S	do	do	T, E	P	17	—	—	City well E2. Yield about 1,160.
18dcb2*	do	D	41	18	S	do	do	T, E	P	17	—	—	City well E1. Yield about 870.
18dcb3*	do	D	40	18	S	do	do	T, E	P	16	—	—	City well E8. Yield about 1,440.
18dcc	do	D	50	26	S	do	do	T, E	P	22	—	—	City well W20. Yield about 1,390.
18dcd1	do	D	43	26	S	do	do	T, E	P	17	—	—	City well W8. Yield about 560.
18dcd2*	do	D	39	18	S	do	do	T, E	P	16	—	—	City well E7. Yield about 1,080.
18dcd3	do	D	43	26	S	do	do	T, E	P	17	—	—	City well W15. Yield about 840.
18ddc*	do	D	42	18	S	do	do	T, E	P	18	—	—	City well E6. Yield about 1,010.
19abb	do	D	43	26	S	do	do	T, E	P	17	—	—	City well W9. Yield about 1,660.
19baa	do	D	49	26	S	do	do	T, E	P	18	—	—	City well W10. Yield about 1,740.
20cda*	do	D	39.5	—	S	do	Pleistocene deposits	T, E	P	14.4	9-24-57	1,298	
22bda*	O. K. Brandon	Dn	29.1	1¼	GI	do	do	—	D	21.7	9-29-57	1,305	
31ada*	City of Wichita	D	38.0	—	S	do	do	T, E	P	16	—	1,290	
34bbc*	do	D	27.0	—	S	do	do	T, E	P	15.7	9-24-57	1,285	
27-1W-10bda	E. R. Hund	D	70.0	6	GI	do	Pleistocene and Pliocene(?) deposits	Ce, E	R	—	—	—	
15aba	L. Clupny	Du	40.0	6	GI	do	Pleistocene deposits	Ce, G	I	9.6	10-13-58	1,315.8	
16dbb	Country Acres Imp. Dist.	D	115.0	12	S	do	Pleistocene and Pliocene(?) deposits	T, E	P	28.0	—	1,343	District well 2. Yield about 400.
16dcb	do	D	122.0	12	S	do	do	T, E	P	32.0	8- -56	1,343	District well 1. Yield about 400.
17acc	Westlink Imp. Dist.	D	100	12	S	do	do	T, E	P	—	—	1,335	District well 4. Yield about 400.
17bdc	do	D	100	12	S	do	do	T, E	P	—	—	1,350	District well 3. Yield about 400.
17cdd	do	D	100	12	S	do	do	T, E	P	—	—	1,335	District well 1. Yield about 400.
20bac	do	D	100+	12	S	do	do	T, E	P	25.8	—	1,338	District well 2. Yield about 400.
24cda*	City of Wichita	D	55.0	—	—	do	Pleistocene deposits	T, E	P	13.1	9-24-57	1,304	
26ddd	U.S.G.S. and K.G.S.	D	87.0	6-2	P	do	do	N	O	8.4	10- 6-59	1,301	
28cda	C. R. Reed	Du	38.4	—	GI	do	do	N	N	34.9	9-22-58	1,333.1	
30ccd	Rest Haven Cemetery	D	—	6	GI	do	—	Ce, E	I	—	—	—	
30cdc*	A. W. Gilchrest	A	50.0	6	GI	do	Pleistocene deposits	J, E	D	19.4	9-11-58	1,330.1	
30daa1	Rufus Kirk	D	70.0	12	GI	do	do	T, E	R & I	17.6	2- 4-56	1,320	
30daa2	F. M. Miles	D	67.0	—	GI	do	do	Ce, E	D	—	—	—	
32aaa	C. R. Reed	D	112.0	10	S	do	do	T, E	I	24	—	1,321	Screens set at 58–78 ft. and 102–112 ft. Gravel packed.
32abb*	W. M. Wood	D	56.0	8	GI	do	do	Cy, E	D	16.5	5-22-59	1,316.1	
33dad*	City of Wichita	D	115	—	S	do	do	T, E	P	22.0	9-24-57	1,320.0	
27-2W-5bad	A. Strunk	D	115.0	8	GI	do	do	Ce, E	D	41.1	9-22-58	1,449.3	
12acb	M. M. Eberley	D	49.0	12	GI	do	do	—	I	7.6	6- 4-58	1,339.1	
15cdc	Julius Koblitz	Du	40.0	48	R	do	do	Cy, W	S	35.6	3-17-59	1,414.1	
32bbb1	City of Goddard	D	54	12	S	do	do	T, E	P	36.7	11- -56	1,457.0	City well 1. Yield about 50.
32bbb2	do	D	56	12	S	do	do	T, E	P	36	—	1,457	City well 2. Yield about 50.

27-3W-2bab	Paul Seivert	Du	—	8	GI	—	—	Cy, H	D	31.4	9- 5-58	1,480.9	
13bab*	Alfred Meyer	D	60.0	6-5	S	Silty sand and shale	Pleistocene deposits and Permian shale	J, E	D & S	30	8-22-57	1,440	
15bab	Francis Leis	Du	62.0	—	R	do.	do.	Cy, E	S	43.3	3- 9-58	1,509.5	
27-4W-5cdc	William Welty	Du	40.0	48	R	Shale	Permian shale	Cy, W	S	12.2	12-11-58	1,399.2	
12ccb*	John Lorg	D	49	6	GI	do.	do.	J, E	D	17.0	12-17-58	1,467.3	
17bba	T. L. Northcutt	D	—	8	GI	Sand	Pleistocene deposits	Ce, G	I	—	—	—	
20ddd	J. Albers	Du	12-15	6	GI	do.	do.	Ce, E	I	—	—	—	
26ccd*	C. L. Lawrence	Du	50.0	6	GI	Sand(?) and shale	Pleistocene(?) deposits and Permian shale	Cy, W	S	17.3	12-17-58	1,446.1	
28-2E-2ccb	J. T. Ingalls	Du	35.0	48	R	Shale	Wellington Formation	Cy, W	S	18.3	11-26-58	1,344.0	
4bba	A. Collinson	D	92.0	6	GI	do.	do.	N	N	53.1	11-26-58	1,383.9	
9cdd*	M. W. Wilson	Du	35.0	—	R	do.	do.	J, E	D & S	26.3	5-25-58	1,346.4	
13aab	Gene Turner	Du	28	48	R	do.	do.	W	S	25.7	11-26-58	1,345.1	
16dab	Eugene Lee	D	—	8	GI	do.	do.	N	N	5.3	11-26-58	1,352.6	
19ddd	H. J. Haley	D	91	6	GI	do.	do.	N	N	40.8	11-29-58	1,373.3	
25aaa*	E. D. Blue	D	35	48	R	do.	do.	J, E	D	17.0	11-26-58	1,326.1	
31ddd*	M. C. McBride	D	90.0	8	GI	do.	do.	Cy, W	S	45.9	11-29-58	1,334.3	
34aab	C. J. Moors	Du	92	36	R	do.	do.	Cy, W	S	45.1	11-26-58	1,344.4	
28-1E-5aad	City of Wichita	D	37.0	—	S	Sand and gravel	Pleistocene deposits	T, E	P	9.7	9-24-57	1,284	
7bab*	do.	D	48.0	—	S	do.	do.	T, E	P	—	—	1,283	
9cba	Campbell Greenhouse	Du	40.0	12	GI	do.	do.	Ce, G	I	7.7	10-13-58	1,279.1	
9cbb1	do.	Dn	40	1¼	GI	do.	do.	Ce, E	I	14.0	10-13-58	1,279	
9cbb2	Ralph Warne	D	—	—	GI	do.	do.	Ce, E	I	—	—	—	
15d	Oaklawn Imp. Dist.	D	25	12	S	do.	do.	T, E	P	14.0	—	1,270	Five wells in same general area. All wells similarly constructed. Combined yield about 500.
16abb	B. Lohkamp	Du	48.0	6	GI	do.	do.	Ce, G	I	8.2	8-13-58	1,278.4	
16baa	J. Lohkamp	D	34.0	6	GI	do.	do.	N	N	8.5	8-13-58	1,279.1	
17cac1*	Glenville Imp. Dist.	D	58.0	12	S	do.	do.	T, E	P	—	—	1,277	District well 1. Yield about 400.
17cac2	do.	D	58	12	S	do.	do.	T, E	P	—	—	1,277	District well 2. Yield about 400.
18dbb1	Purcell's 1st Imp. Dist.	D	50	18	S	do.	do.	T, E	P	12	—	1,276	District well 1. Yield about 250.
18dbb2	do.	D	50	18	S	do.	do.	T, E	P	12	—	1,276	District well 2. Yield about 250.
21aaa1	S. Riverside School Dist.	D	—	8	GI	do.	do.	Ce, E	D	—	—	—	
21aaa2	do.	D	—	8	GI	do.	do.	T, E	D	—	—	—	
21bcc	L. A. Borst	Du	38.0	6	GI	do.	do.	Ce, G	I	—	—	—	
21bcd	do.	Du	40.0	6	GI	do.	do.	Ce, G	I	—	—	—	
21dac	Meyers & Son Nursery	D	30.0	6	GI	do.	do.	Ce, G	I	—	—	—	
21dbd	do.	D	30.0	6	GI	do.	do.	Ce, G	I	10.6	10-14-58	1,270.3	Screen set at 20-30 ft.
21ddc	do.	D	30.0	6	GI	do.	do.	Ce, G	I	9.4	10-14-58	1,269.6	
22a	Oaklawn Imp. Dist.	D	30	12	S	do.	do.	T, E	P	14	—	1,265	Seven wells in same general area. All similarly constructed. Combined yield about 700.
22bcb	Jayhawk Imp. Dist.	D	25	—	—	do.	do.	T, E	P	—	—	1,270	District well 3. Yield about 250.
22cbb	do.	D	25	—	—	do.	do.	T, E	P	—	—	1,267	District well 1. Yield about 250.
22cbc	do.	D	25	—	—	do.	do.	T, E	P	—	—	1,267	District well 2. Yield about 250.
28bbd*	G. Bruinhorst	D	36	5	GI	do.	do.	Ce, G	I	11.0	—	1,271	
28bca	do.	D	38	5	GI	do.	do.	Ce, G	I	—	—	—	
28ccc1	E. R. Blood	D	40.0	—	GI	do.	do.	Ce, G	I	12.0	7-24-58	1,268.3	
28ccc2	F. E. Blood	D	36.0	6	GI	do.	do.	Ce, G	I	12.2	7-24-58	1,267.1	
28dca	G. Nicholson	D	32.0	—	GI	do.	do.	Ce, G	I	—	—	—	
28dcb	do.	D	31.0	—	GI	do.	do.	Ce, G	I	7.9	—	1,261.5	
29abd	G. Bruinhorst	D	40.0	5	GI	do.	do.	N	N	—	—	—	
29adc	do.	D	40.0	5	GI	do.	do.	N	N	—	—	—	
29cda	E. R. Blood	D	40.0	—	GI	do.	do.	Ce, G	I	7.3	7-24-58	1,266	
29dbd	do.	D	40.0	—	GI	do.	do.	Ce, G	I	6.7	7-24-58	1,265	
30ada	Simmons Turf Grass Farm	D	39.0	8	GI	do.	do.	Ce, E	I	8.3	7-14-58	1,270.5	
32aaa1	Sunflower Imp. Dist.	D	50	—	S	do.	do.	T, E	P	—	—	1,265	District well 1. Yield about 220.
32aaa2	do.	D	50	—	S	do.	do.	T, E	P	—	—	1,265	District well 2. Yield about 180.
32dcb	C. J. Hurley	Du	50.0	8	GI	do.	do.	Ce	I	—	—	—	
32dcd	do.	Du	36.0	8	GI	do.	do.	Ce	I	9.0	7-12-58	1,259.3	
33cbc	C. E. Benner	Du	40	—	GI	do.	do.	Ce	I	9.5	7-24-58	1,261.0	

TABLE 13.—Records of wells and springs in Sedgwick County, Kansas.—*Concluded.*

Well No.	Owner or tenant	Type of well†	Depth of well, feet‡	Diameter of well, inches	Type of casing§	Principal water-bearing unit: Character of material	Principal water-bearing unit: Geologic source	Method of lift¶	Use of water #	Depth to water level below land surface, feet	Date of measurement	Height of land surface above mean sea level, feet	Remarks (Yield given in gallons/ minute; drawdown in feet)
28-1E-33cbd*	Sunnyside Nursery	D	80.0	12	—	Sand and gravel	Pleistocene deposits	T, E	I	10.1	7-24-58	1,266.5	
33ccaa	W. R. Cain	Du	44.0	—	GI	do	do	Ce, G	I	10.6	7-24-58	1,260.9	
33cdc	do	Du	48.0	—	GI	do	do	Ce, G	I	10.8	7-24-58	1,259.9	
34ccd	do	Du	35	—	GI	do	do	N	N	11.7	8-15-58	1,255	
28-1W-2cbb	Wm. Vanderhaff	Dn	30.0	1½	GI	do	do	—	D, S, O	11.2	4-29-59	1,295	
10aca	J. V. Newby	D	36.5	6	GI	do	do	Ce, G	I	13.9	5-27-58	1,298.7	
11ccc	Sedgwick Co. Hwy. Dept.	Dn	28.5	—	GI	do	do	Cy, H	Ind	10.7	9- 9-57	1,287.0	
12bbc	M. Tamboer	Du	40.0	8	GI	do	do	Ce, G	I	—	—	—	
36adb	W. Wright	D	—	—	—	do	do	T	I	—	—	—	
36adc	Geo. Lipke	D	58.0	10	S	do	do	T	I, O	29.8	4-29-59	1,330	
36bab	John Hay	D	55.0	12	S	do	do	T, NG	I	36.0	9-28-58	1,345	
28-3W-4bab	W. Wheeler	D	63.0	6	GI	Sand and shale	Pleistocene(?) deposits and Permian shale	N	N	33.3	2- 6-59	1,418.8	
14cdc	H. Perkins	D	115.0	12	GI	Shale	Permian shale	J, E	D & S	47.1	2-23-59	1,406.2	
28aaa	Albert Rausch	Du	20.0	48	R	do	do	Cy, W	D	9.7	2-16-59	1,367.2	
31aaa	Ralph Pauly	D	30.0	6	GI	do	do	Ce, E	D	17.2	2-16-59	1,346.7	
28-4W-3baa	Mrs. L. Timmisch	Du	22.0	48	R	do	do	Cy, W	S	11.1	1-29-59	1,378.0	
5dcd	City of Cheney	—	84	—	—	do	do	T, E	P	—	—	—	City well 4. Yield about 200.
8bab	do	—	80	—	—	do	do	T, E	P	—	—	—	City well 1. Yield about 185.
8bcd	do	—	64	—	—	do	do	T, E	P	—	—	—	City well 2. Yield about 110.
8cab	do	—	82	—	—	do	do	T, E	P	—	—	—	City well 5. Yield about 100.
8dba*	do	—	68	—	—	do	do	T, E	P	—	—	—	City well 3. Yield about 80.
22aac	Charles Wolf	D	40.0	18	Cn	Sand, gravel (?)	Pleistocene deposits	Ce, G	I	7.5	10- 1-57	1,329.8	
32ddd*	Ralph Barker	Du	64.0	6	GI	Shale	Permian shale	Ce, E	D	27.5	1-22-59	1,371.5	
35dda	Geo. Hillman	D	60.0	—	GI	do	do	Ce, E	S	17.0	1-22-59	1,329.8	
29-2E-7dad	W. L. Ainsworth, Jr.	Du	32.0	36	R	do	Wellington Formation	J, E	D	26.2	11-29-58	1,337.6	
10ccc	C. M. Woods	Du	25.0	48	R	do	do	N	N	8.5	11-29-58	1,341.2	
12bba*	Frank Gordin	Du	32.0	60	R	do	do	Cy, H	D	20.1	11-29-58	1,315.5	
20cdd*	E. Shaffter	D	93	6	GI	do	do	N	N	70.3	11-29-58	1,317.8	
24baa	G. E. Williamson	D	73.0	4	GI	do	do	N	N	47.8	11-29-58	1,334.2	
32aba	J. R. Farber	Du	51.0	6	GI	do	do	J, E	S	45.1	12- 1-58	1,283.4	
34dad	Robert Mayfield	Du	38.0	48	R	do	do	Cy, W	S	15.7	12- 1-58	1,288.9	
36aaa*	C. L. Keller	D	34.0	6	GI	do	do	J, E	D	23.5	11-29-58	1,298.6	
29-1E-3ccb	R. L. Hancock	D	—	6	GI	Sand and gravel	Pleistocene deposits	Ce, G	I	—	—	—	
3cdc	T. L. Hess	D	—	—	—	do	do	Ce, G	I	—	—	—	
3dac	R. L. Hancock	D	40.0	6	GI	do	do	Ce, G	I	10.0	7-18-58	1,252.4	
4bcb	David Crammer	D	40.0	—	GI	do	do	Ce, G	I	7.8	8-15-58	1,256.4	
4cbb	L. O. Bell	D	43.0	7	—	do	do	Ce, G	I	8.5	9- 4-58	1,255.5	
4ddb	R. L. Hancock	D	40.0	6	GI	do	do	Ce, G	I	9.9	7-14-58	1,254.2	
4ddc	do	D	40.0	6	GI	do	do	Ce, G	I	12	7-14-58	1,255.0	
5caa	City of Haysville	D	54.0	12	S	do	do	T, E	P	24	10-17-58	1,261.1	City well 1. Yield about 250.
5daa	R. S. Bean	Du	22.0	12	GI	do	do	Ce, E	I	9.9	9- 4-58	1,256.2	
5dbb1	City of Haysville	D	54.0	12	S	do	do	T, E	P	24	10-17-58	1,258.4	City well 2. Yield about 300.
5dbb2	do	D	54.0	12	S	do	do	T, E	P	24	10-17-58	1,258.0	City well 3. Yield about 500.
8cbb*	M. R. Hemphill	D	36.0	8	GI	do	do	J, E	R	22.5	5-25-58	1,273.7	
9acd	L. J. Johnson	D	40.0	4	GI	do	do	Ce, G	I	6.7	6-21-58	1,247.6	
9ada	do	D	45.0	6	GI	do	do	Ce, G	I	—	—	—	
9dab	C. A. Youngmeyer	D	40.0	6	GI	do	do	Ce	I	7.4	6-21-58	1,247.2	
9dca	do	Du	40.0	6	GI	do	do	Ce	I	7.4	6-21-58	1,247.2	
9ddb	do	D	60.0	6	GI	do	do	Ce	I	6.4	6-21-58	1,246.2	
10bac	M. E. Johnson	D	—	6	GI	do	do	Ce, G	I	—	—	—	
10bad	H. L. Somers	Du	44.0	6	GI	do	do	Ce, G	I	—	—	—	

10bcd	L. J. Johnson	D	40.0	6	GI	do.	do.	Ce, G	I	6.5	7–21–58	1,250	
10bdc	H. L. Somers	Du	40.0	6	GI	do.	do.	Ce	I	6.4	7–21–58	1,250	
10dcd	A. B. Costin	Du	40.0	8	GI	do.	do.	—	I	9.6	10– 3–58	1,246.4	
11aca	E. C. Ripple	Du	12.0	—	GI	do.	do.	—	I	—	—	—	Well plugged.
11acc	L. Snider	Du	13.0	8	GI	do.	do.	Ce, G	I	8.9	—	1,249	
11cca	R. E. Costin	D	40.0	8	GI	do.	do.	Ce, G	I	—	—	—	
11dbd	El Paso Water Co.	D	40.0	12	S	do.	do.	T, E	P	12	—	1,249.7	City well 2. Yield about 200.
12cbc	do.	D	40.0	12	S	do.	do.	T, E	P	12	—	1,251.3	City well 4. Yield about 300.
13bdd	R. E. McHenry	D	20	8	GI	do.	do.	Ce, G	I	—	—	—	
14bbc	A. F. Bowman	Du	40	8	GI	do.	do.	Ce, B	I	11.3	10– 3–58	1,246.1	
14dbc1	El Paso Water Co.	D	40.0	12	S	do.	do.	T, E	P	12	—	1,244.3	City well 5. Yield about 500.
14dbc2	do.	D	40.0	12	S	do.	do.	T, E	P	12	—	1,243.0	City well 6. Yield about 500.
14dcb	do.	D	40.0	12	S	do.	do.	T, E	P	12	—	1,242.5	City well 7. Yield about 500.
16bbc	Alice R. Hudson	Du	30.0	6	GI	do.	do.	Ce, G	I	6.3	—	1,249	
16bbd	do.	Du	32.0	6	GI	do.	do.	Ce, G	I	6.1	10– 3–58	1,249	
16ccd	Earl Cox	Du	60.0	—	GI	do.	do.	Ce, G	I	—	—	—	
18dcd	Charles Brown	D	—	—	—	do.	do.	Ce, G	I	—	—	—	
23abd	Ted E. Church	Du	—	—	—	do.	do.	Ce, P	I	—	—	—	
23bdb	R. A. Bachman	D	38.0	6	GI	do.	do.	Ce, B	I	—	—	—	
25aca	W. Cain	Du	35.0	8	GI	do.	do.	Ce, G	I	9.7	10– 1–58	1,232.7	
25bac	E. Shoemaker	Du	—	—	—	do.	do.	Ce, G	I	—	—	—	
25bcc	do.	Du	28.0	6	GI	do.	do.	Ce, G	I	10.6	9–29–58	1,234.7	
25ccd	Heerche Bros.	Du	40.0	8	GI	do.	do.	Ce, B	I	—	—	—	
26acb*	O. N. Laurie	Du	39.0	10	GI	do.	do.	Ce, B	I	11.6	9–29–58	1,235.1	
26adc	do.	Du	38.0	6	GI	do.	do.	Ce, B	I	—	—	—	
26daa	Geo. Gosney	Du	32.0	8	GI	do.	do.	Ce, B	I	—	—	—	
27bcb	D. D. Jones	Du	35.0	—	—	do.	do.	Ce, B	I	4.7	8–29–58	1,234.5	
27bdb	do.	Du	35.0	—	—	do.	do.	Ce, B	I	—	—	—	
28add	J. T. McAdams	Du	40.0	14	GI	do.	do.	Ce, B	I	7.4	8–25–58	1,236.5	
28dca	B. R. Gosney	Du	49.0	6	GI	do.	do.	Ce, B	I	8.0		1,234	
29db	C. B. Morgan	D	—	—	—	do.	do.	Ce, B	I	—	—	—	
30ddb	C. J. Ott	D	49.8	8	GI	do.	do.	T, G	I	31.4	6– 5–58	1,272.0	
35aac	Heerche Bros.	Du	40.0	8	GI	do.	do.	Ce, B	I	6.2	10– 1–58	1,228.3	
35adc	do.	Du	40.0	—	—	do.	do.	Ce, B	I	7.0	10– 1–58	1,229.6	
35dbd	C. P. Butts	D	56.0	12	GI	do.	do.	—	I	8.4	3–23–58	1,226.5	
29–1W–5dab*	A. D. Wise	Du	35.0	48	R	—	—	Cy, W	S	20.6	5–25–59	1,308.4	
25aca	Lloyd Orrell	D	72.0	16	S	—	—	T, G	I	32.0	6– 9–58	1,279.8	
25cad	F. Orrell	D	81.0	18	S	—	—	T, G	I	19.3	8–25–58	1,259.6	
25dcd*	Lloyd Orrell	D	45.0	8	GI	—	—	J, E	D	33.2	5–25–59	1,275.8	
26abb	do.	D	82.0	16	S	—	—	T, G	I	32.1	6– 9–58	1,277.4	
29–2W–10bab	R. M. Colver	Du	23	48	R	Sand and gravel	Pleistocene deposits	N	N	9.5	2–27–59	1,343.2	
23ddd1	City of Clearwater	D	54	12	S	do.	do.	T, E	P	24	—	—	
23ddd2	do.	D	54	12	S	do.	do.	T, E	P	24	—	—	
23ddd3	do.	D	56	12	S	do.	do.	T, E	P	24.5	1960	—	
26bab	do.	D	54	10	S	do.	do.	T, E	P	—	—	—	
28ab	W. Rochette	Du	40	6	GI	do.	do.	Ce, G	I	6.8	—	1,260	
28abd	do.	Du	40	6	GI	do.	do.	Ce, G	I	6.9	—	1,260	
28ac	do.	Du	40	6	GI	do.	do.	Ce, G	I	5.8	—	1,260	
28aca	do.	Du	40	6	GI	do.	do.	Ce, G	I	5.8	—	1,260	
29–3W–2dcd	V. Pauley	D	22.8	6	GI	Silty sand and shale(?)	Colluvium and Permian shale(?)	J, E	D, S	9.9	2–26–59	1,313.0	
17bba	L. J. More	Du	32.0	48	R	do.	do.	Cy, W	D	26.0	2–24–59	1,325.1	
19ddd	John Porter	D	40.0	48	R	do.	do.	Cy, W	S	17.3	2–26–59	1,349.7	
28dad	G. W. Porter	D	51.0	6	GI	do.	do.	N	N	12.3	2–27–59	1,328.5	
29–4W–8cbb	J. M. Fearey	D	35.0	—	—	do.	do.	Cy, W	S	24.6	2– 2–59	1,403.7	
14bab	Wm. St. Clair	D	36.0	6	GI	do.	do.	Cy, W	N	10.3	1–30–59	1,344.9	
22aba	B. Brammer	D	25.0	6	GI	do.	do.	N	N	16.5	2– 6–59	1,363.9	

* Asterisk following well number indicates analysis of water is given in Tables 5 or 6.
† Type: *A*, augered; *D*, drilled; *Dn*, driven; *Du*, dug; *Sp*, spring.
‡ Reported depths below land surface are given in feet; measured depths below land surface are given in feet and tenths.
§ Type of casing: *Cn*, concrete; *GI*, galvanized iron; *N*, none; *R*, rock; *S*, steel.
¶ Method of lift: *Ce*, centrifugal; *Cy*, cylinder; *J*, jet; *N*, none; *P*, pitcher pump; *T*, turbine.
Type of power: *B*, butane; *E*, electirc; *G*, gasoline; *H*, hand; *W*, wind.
\# Use: *D*, domestic; *Ind*, industrial; *I*, irrigation; *N*, none; *O*, observation; *P*, public supply; *R*, recreation; *S*, stock.

LOGS OF WELLS AND TEST HOLES

The logs of 32 wells and test holes are given on the following pages. There are logs of 13 auger holes and 8 hydraulic-rotary test holes, all put down by the State Geological Survey of Kansas. A log is given for 1 well drilled by the city of Wichita. Drillers' logs are given for 1 well and 9 test holes drilled by private contractors. The samples from test holes drilled by the State Geological Survey and a part of those drilled by private contractors and the city of Wichita were examined and logged in the field. The logs that are designated "sample logs" were prepared after microscopic examination of the samples in the laboratory and comparison with the field log. The letter (T) following an altitude of land surface figure indicates that the altitude of the test hole was determined from a topographic map.

Logs of 369 additional wells and test holes in Sedgwick County are available on request from the State Geological Survey of Kansas as Special Distribution Publication 22. The locations of these logs are shown on Plate 1.

25-1E-5bbb.—Sample log of test hole in NW NW NW sec. 5, T 25 S, R 1 E., on east side of road, 60 feet south of center line of east-west road, augered September 1958. Altitude of land surface, 1,378.3 feet; depth to water, 10.1 feet.

	Thickness, feet	Depth, feet
Soil	2	2
NEOGENE		
Upper Pleistocene Subseries		
Wisconsinan and Ilinoisan Stages (loess)		
Silt, sandy, dark tan	3	5
Silt, sandy, light grayish-tan	4	9
Pliocene(?) Series and Lower Pleistocene Subseries, undifferentiated		
Sand, fine to coarse, very silty, grayish-tan; quartzose	8	17
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, gray	1	18

25-1W-5ddd2.—Sample log of observation well 124 in SE SE SE sec. 5, T 25 S, R 1 W, drilled by the City of Wichita, July 1955. Altitude of land surface, 1,370.7 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Upper Pleistocene Subseries		
Wisconsinan and Recent Stages (terrace deposits and alluvium)		
Silt, sandy, light- to medium-gray; some caliche	6	6
Sand, fine to coarse, with fine to coarse gravel; arkosic	16	22
Silt, sandy, clayey, gray	9	31
Sand, fine to coarse, gray; quartzose	1	32
Sand, fine to coarse, fine to medium gravel, gray; quartzose, some white feldspar	3	35
Sand, fine to coarse, fine to coarse gravel; arkosic, much quartz	15	50
Pliocene(?) Series and Lower Pleistocene Subseries, undifferentiated		
Silt, very sandy, tan	2	52
Sand, fine to coarse, fine to coarse gravel; arkosic, much quartz	8	60
Sand, fine to coarse, fine gravel, gray; mostly quartz with some feldspar	10	70
Silt, very sandy, clayey, grayish-tan; many caliche pebbles,	12	82
Sand, fine to coarse, grayish-tan; quartzose	4	86
Silt, sandy, light tannish-gray; some caliche	3	89
Sand, fine to coarse, gray; quartzose	16	105
Sand, fine to coarse, gray; quartzose with sandy, gray-tan silt streaks	5	110
Silt, sandy, gray-tan; some caliche	2	112
Sand, fine to coarse; quartzose, some rubble derived from the Dakota Formation	3	115
Silt, sandy, clayey, tan; some caliche	6	121
Sand, fine to coarse, some fine gravel; quartzose	7	128
Silt, sandy, tannish-gray	1	129
Silt, clayey, very sandy, light-gray; caliche pebbles present,	5	134
Sand, fine to coarse; quartzose	4	138
PERMIAN		
Lower Permian Series		
Wellington Shale		
Shale, hard, gray	0.5	138.5

25-1W-7bcc.—Sample log of test hole M36t in SW SW NW sec. 7, T 25 S, R 1 W, drilled by Layne-Western Co. for the City of Wichita, December 1957. Altitude of land surface, 1,385.4 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Upper Pleistocene Subseries		
Wisconsinan and Recent Stages (terrace deposits and alluvium)		
Silt, sandy, grayish-tan	6	6
Sand, fine to coarse, fine to coarse gravel; arkosic	24	30
Sand, fine to coarse, fine to medium gravel; arkosic, contains silt streaks	5	35
Sand, fine to coarse, fine to medium gravel; arkosic	13	48

	Thickness, feet	Depth, feet
Pliocene(?) Series and Lower Pleistocene Subseries, undifferentiated		
Sand, fine to coarse, fine gravel; 100 percent quartz, streaks of clayey gray silt	9	57
Sand, fine to coarse, fine to medium gravel, gray; 95 percent quartz	8	65
Sand, fine to coarse, fine to medium gravel; 95 percent quartz, thin streaks of sandy, gray silt	14	79
Silt, clayey, some sand, gray, contains caliche	11	90
Silt, sandy, grayish-tan	4	94
Sand, fine to coarse, some fine gravel, yellowish-gray; 95 percent quartz	14	108
Silt, sandy, clayey, gray to grayish-tan	4	112
Sand, fine to coarse, some fine gravel, yellowish-gray; 100 percent quartz	3	115
Sand, fine to coarse, much fine to medium, some fine gravel, yellowish-gray; some arkose	5	120
Sand, fine to coarse, fine gravel, yellowish-gray; some feldspar and quartzite	21	141
Silt, clayey, grayish-tan to gray,	2	143
Sand, fine to coarse, mostly fine to medium, grayish-tan	7	150
Sand, fine to coarse, yellowish-gray; little arkosic, some fine gravel	5	155
Sand, fine to coarse; some fine gravel, thin streaks of clayey, tannish-gray silt	5	160
Sand, fine to coarse, yellowish-tan; some fine gravel, thin silt streaks, much material derived from the Dakota Formation	10	170
Sand, fine to coarse, yellowish-tan; streaks of tan, sandy silt,	5	175
Sand, fine to coarse, yellowish-tan; some fine gravel, some tan silt streaks	6	181
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, gray	4	185

25-1W-18aaa.—Sample log of test hole 38T in NE NE NE sec. 18, T 25 S, R 1 W, drilled by Layne-Western Co. for the city of Wichita, December 1957. Altitude of land surface, 1,375.4 feet; depth to water, 19.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Upper Pleistocene Subseries		
Wisconsinan and Recent Stages (terrace deposits and alluvium)		
Silt, sandy, dark tan	3	3
Sand, fine to coarse, rusty tan	2	5
Sand, fine to coarse, fine to coarse gravel; arkosic	9	14
Silt, sandy, light gray to grayish-tan	8	22
Sand, fine to coarse, some fine to coarse gravel; arkosic	6	28
Sand, fine to coarse, fine to coarse gravel; arkosic, rust stains; 0.5 foot of dark gray silt at top	12	40
Sand, fine to coarse, and fine to coarse gravel; arkosic, rust-stained; dark gravel present	10	50
Pliocene(?) Series and Lower Pleistocene Subseries, undifferentiated		
Silt, clayey, sandy, grayish-tan to tan; sand streak at 53.0 feet	5	55
Sand, fine to coarse; some fine gravel, gray-tan; some feldspar, mostly quartz	5	60
Sand, fine to coarse, fine gravel; mostly quartz, some feldspar, some ironstone pebbles; caliche pebbles in lower 5.0 feet,	10	70
Sand, fine to coarse, fine gravel; some siltstone fragments	6	76
Silt, clayey, gray to tan	2	78
Sand, fine to coarse, fine to medium gravel; mostly quartz, some feldspar; streaks of clayey, sandy, light gray to tan silt	7	85
Sand, fine to coarse, and fine gravel; quartzose, some ironstone pebbles; some siltstone fragments in lower 7.0 feet	12	97
Silt, sandy, grayish-tan to tan	1	98
Sand, fine to coarse, and fine gravel, silty, gray to tan; clay streak at 102.0 feet	6	104
Clay, gray	1	105
Sand, fine to coarse, and fine gravel; quartzose, some feldspar, and some dark pebbles,	5	110
Sand, fine to coarse, and fine to medium gravel; quartzose, some feldspar, some sandstone and siltstone fragments, lower 10.0 feet less coarse material,	15	125
Silt, sandy, clayey, gray to tan; contains soft caliche	5	130
Silt, sandy, grayish-tan; some tan clay streaks	13	143
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, gray; some limestone fragments	3	146

25-1W-29ddd.—Sample log of test hole in SE SE SE sec. 29, T 25 S, R 1 W, 200 feet west of section corner, 100 feet east of the end of hedge row, 5 feet from center of roadside ditch, drilled September 1958. Altitude of land surface, 1,362.0 feet; depth to water, 8.4 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Upper Pleistocene Subseries		
Wisconsinan and Recent Stages (terrace deposits and alluvium)		
Silt, sandy, grayish-tan	5	5
Sand, fine to coarse; arkosic	5	10

	Thickness, feet	Depth, feet
Sand, fine to coarse, some fine gravel	5	15
Sand, fine to coarse, and fine to medium gravel; arkosic	15	30
Sand, fine to coarse, gray; arkosic, silt streak at 34.0 feet contains many snail fragments	5	35
Sand, fine to coarse, and fine to medium gravel; arkosic	5	40
Sand, fine to coarse, and fine gravel; arkosic, much gray silt with snail fragments to 44.0 feet	5	45
Sand, fine to coarse, and fine gravel; arkosic, some dark gravel; streaks of gray and tan silt	5	50
Pliocene(?) Series and Lower Pleistocene Subseries, undifferentiated		
Sand, fine to coarse, and fine gravel; less arkosic than above, more coarse material in lower 5.0 feet	10	60
Sand, fine to coarse, fine to medium gravel; arkosic	10	70
Sand, fine to coarse, and fine gravel, grayish-tan; some arkosic material	10	80
Sand, fine to coarse, and fine to medium gravel; arkosic (much lag gravel may be present)	10	90
Sand, fine to coarse, and fine to medium gravel, grayish-tan; quartzose with streaks of gray and tan silty clay; gravel finer in lower 7.0 feet	17	107
Silt, clayey, tan	3	110
Sand, fine to coarse, and fine gravel, grayish-tan; quartzose with thin streaks of tan silt	15	125
Sand, fine to coarse, and fine to medium gravel; quartzose with streaks of clayey, grayish-tan silt	15	140
Sand, fine to coarse, and fine gravel, grayish-tan; quartzose; much tan silty clay, less silt in lower 10.0 feet	15	155
Sand, gravel, silt and clay	5	160
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, gray, weathered	10	170

25-2W-1add.—Sample log of test hole 33T in SE SE NE sec. 1, T 25 S, R 2 W, drilled by Layne-Western Co. for the City of Wichita, 1947. Altitude of land surface, 1,383.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Upper Pleistocene Subseries		
Wisconsinan and Recent Stages (terrace deposits and alluvium)		
Silt, sandy, tan; fine to medium sand at base	20	20
Sand, fine to coarse, and fine gravel; arkosic	5	25
Sand, fine to coarse, and fine to coarse gravel; some silt streaks	10	35
Sand, fine to coarse, and fine to coarse gravel; arkosic	25	60
Pliocene(?) Series and Lower Pleistocene Subseries, undifferentiated		
Sand, fine to coarse, gray; quartzose, streaks of sandy, grayish-tan silt; caliche present	10	70
Sand, fine to coarse, some fine gravel, gray; streaks of sandy, tan silt; rubble derived from Dakota Formation in lower 5.0 feet	10	80
Silt, sandy, with some fine gravel, light grayish-tan to medium-gray; contains some caliche	20	100
Sand, fine to coarse, gray; quartzose, some streaks of sandy, gray silt in lower 15.0 feet	20	120
Sand, fine to coarse, some fine gravel; quartz, some streaks of sandy, gray silt; caliche in lower 5.0 feet	10	130
Sand, fine to coarse, and fine gravel, gray; quartzose, with streaks of sandy, grayish-tan silt in lower 10.0 feet	20	150
Sand, fine to coarse, and some fine gravel, grayish-tan; quartzose, many streaks of sandy tan and gray silt in lower 5.0 feet	25	175
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, gray	5	180

25-2W-2baa.—Sample log of test hole 28T in NE NE NW sec. 2, T 25 S, R 2 W, drilled by Layne-Western Co. for the City of Wichita, 1947. Altitude of land surface, 1,391.6 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Upper Pleistocene Subseries		
Wisconsinan and Recent Stages (terrace deposits and alluvium)		
Silt, sandy, dark tan	3	3
Sand, fine to coarse, and fine to medium gravel	7	10
Sand, fine to coarse, and fine to coarse gravel; arkosic, few streaks of sandy, clayey, tan silt in lower 10.0 feet	25	35
Sand, fine to coarse, and fine to coarse gravel; arkosic, with streaks of gray to grayish-brown sandy silt in lower 5.0 feet	25	60
Pliocene(?) Series and Lower Pleistocene Subseries, undifferentiated		
Sand, fine to coarse, and fine gravel, tannish-gray; quartzose, few streaks of sandy, grayish-tan silt in lower 10.0 feet	20	80
Silt, very sandy, light gray; some caliche, snails present	5	85

	Thickness, feet	Depth, feet
Sand, fine to coarse, and fine gravel, gray; quartzose	8	93
Silt, very sandy, clayey, light gray	7	100
Silt, sandy, grayish-tan; contains caliche, lower 18.0 feet clayey,	33	133
Sand, fine to coarse, gray; quartzose, streaks of very sandy light gray silt; many snail and vertebrate fragments in lower 5.0 feet	17	150
Silt, very sandy, grayish-tan to light gray; some caliche	40	190
Silt, sandy, gray; sand is quartz,	5	195
Sand, fine to coarse; some fine gravel in lower 18.0 feet; lower 3.0 feet contains silt streaks	23	218
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale	2	220

25-2W-5dcd.—Sample log of test hole 55T in SE SW SE sec. 5, T 25 S, R 2 W, drilled by Layne-Western Co. for the City of Wichita, January 1958. Altitude of land surface, 1,405.9 feet.

	Thickness, feet	Depth, feet
Soil	3	3
NEOGENE		
Upper Pleistocene Subseries		
Wisconsinan and Recent Stages (terrace deposits and alluvium)		
Sand, fine to coarse, much fine to medium	2	5
Sand, fine to coarse, and fine gravel; arkosic	5	10
Sand, fine to coarse, and fine to coarse gravel; arkosic; silt streak at 13.0 feet	5	15
Sand, fine to coarse, and fine to coarse gravel; arkosic	32	47
Pliocene(?) Series and Lower Pleistocene Subseries, undifferentiated		
Silt, sandy, reddish-tan	11	58
Silt, sandy, light grayish-tan and tan; some carbonaceous specks and sand streaks	100	158
Sand, fine to medium, tan; arkosic	13	171
Silt, very sandy to sandy, grayish-tan and red-tan; contains caliche and has carbonaceous specks in lower 15.0 feet	29	200
Sand, fine	2	202
Silt, sandy, tan; contains caliche and carbonaceous specks	3	205
Sand, fine to medium, tan	11	216
Silt, sandy, tan; some caliche in lower 8.0 feet	27	243
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, grayish-green	4	247

26-2W-14bbb.—Sample log of test hole in NW NW NW sec. 14, T 26 S, R 2 W, augered 1944. Altitude of land surface, 1,364.3 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Upper Pleistocene Subseries		
Illinoisan Stage (terrace deposits)		
Silt, sandy, dark gray to tan; clayey in upper 4.0 feet	13	13
Sand, fine to coarse, and fine to medium gravel, gray-pink; arkosic, some dark gravel; streaks of sandy, grayish-tan silt in lower 10.0 feet	37	50
Sand, fine to coarse, and fine gravel; arkosic with streaks of sandy tan silt	16	66
Pliocene(?) Series and Lower Pleistocene Subseries, undifferentiated		
Silt, sandy, gray and tan; some snail fragments in lower 14.0 feet	18	84
Sand, fine to coarse, and fine gravel; arkosic, some medium and coarse gravel; thin streaks of clayey, sandy tan silt; some caliche in lower 23.0 feet	69	153
Silt, sandy, grayish-tan to dark tan; many snail fragments	7	160
Sand, fine to coarse, and fine to medium gravel; arkosic, streaks of tan to gray sandy silt	10	170
Silt, sandy, tan to gray; some caliche; streaks of fine to coarse sand in lower 10.0 feet,	25	195
Sand, fine to coarse, and fine to medium gravel; arkosic; finer gravel and more quartz in lower 10.0 feet	31	226
Silt, clayey, sandy, light to dark gray; snails and caliche	4	230
Sand, fine to coarse, and fine to medium gravel; quartzose with much rubble derived from Dakota Formation; little arkose	25	255
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, gray	10	265

26-2W-15aab.—Sample log of well no. 1 in NW NE NE sec. 15, T 26 S, R 2 W, drilled by Layne-Western Co. for the Kansas Gas and Electric Co., July 1959. Altitude of land surface, 1,378.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Upper Pleistocene Subseries		
Illinoisan Stage (terrace deposits)		
Silt, sandy to very sandy, light gray to grayish-tan	15	15
Sand, fine to coarse, and fine to coarse gravel; arkosic, tan to gray silt streaks in lower 5.0 feet	25	40
Sand, fine to coarse, and fine to coarse gravel, grayish-pink; arkosic, much quartz	10	50

	Thickness, feet	Depth, feet
Sand, fine to coarse, and fine to medium gravel, grayish-pink; arkosic, much quartz grayish-tan silt streaks	10	60
Sand, fine to coarse, and fine gravel, tan; arkosic, some tan silt	10	70
Pliocene(?) Series and Lower Pleistocene Subseries, undifferentiated		
Sand, fine to coarse, and fine gravel, tan; arkosic, many tan silt streaks	5	75
Silt, sandy, tan to gray	5	80
Silt, very sandy, grayish-tan to dark gray; possible soil zone with snails	5	85
Sand, fine to coarse, and fine to medium gravel, grayish-tan; arkosic with abundant quartz; limestone fragments in lower 5.0 feet	35	120
Sand, fine to coarse, and fine gravel; arkosic with abundant quartz; coarser gravel in lower 10.0 feet with tan silt and material derived from the Dakota Formation	15	135
Silt, sandy, clayey, light grayish-tan; contains caliche pebbles,	10	145
Sand, fine to coarse, tan; arkosic; fine to coarse gravel in lower 30.0 feet with streaks of tan calcareous clay and gray-tan silt	35	180
Sand, fine to coarse, and fine to medium gravel; arkosic; streaks of sandy tan silt near base	5	185
Silt, sandy, tan; some thin sand streaks	7	192
Sand, fine to coarse, and fine gravel; predominantly quartz, some arkose and silt	2	194
Sand, fine to coarse, and fine to coarse gravel; arkosic with rubble derived from the Dakota Formation, streaks of sandy tan silt in lower 10.0 feet with no gravel in lower 5.0 feet	26	220
Sand, fine to coarse, and fine to coarse gravel; arkosic with streaks of sandy tan silt and silty, light-gray clay	10	230
Silt, sandy, clayey, gray to tan; streaks of fine to coarse sand, and fine to medium gravel; arkosic with abundant rubble derived from the Dakota Formation	5	235
Sand, fine to coarse, and fine to coarse gravel; gravel derived from the Dakota; some silty clay streaks	10	245
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, gray	5	250

26-2W-15add.—Sample log of test hole in SE SE NE sec. 15, T 26 S, R 2 W, drilled by Layne-Western Co. for the Kansas Gas and Electric Co., 1959. Altitude of land surface, 1,375.3 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Upper Pleistocene Subseries		
Illinoisan Stage (terrace deposits)		
Silt, sandy, tan and dark tan	15	15
Sand, fine to coarse, some fine gravel, tan; arkosic with some tan silt	15	30
Sand, fine to coarse, and fine to medium gravel; arkosic with some silt; fine to coarse gravel in lower 15.0 feet	20	50
Pliocene(?) Series and Lower Pleistocene Subseries, undifferentiated		
Silt, sandy, light-gray to dark-tan and pinkish-tan; caliche pebbles present with some clay	15	65
Silt, light grayish-tan; some arkosic sand and gravel; contains volcanic ash	5	70
Sand, fine to coarse, and fine to medium gravel, grayish-pink; arkosic with abundant quartz and some tan silt	10	80
Sand, fine to coarse, and fine to coarse gravel; streaks of sandy tan and pink silt	5	85
Sand, fine to coarse, and fine to medium gravel; arkosic; streaks of sandy, tan to gray silt with gray ash fragments	30	115
Sand, fine to coarse, and fine to coarse gravel; arkosic with shale fragments; fine to medium gravel and caliche in lower 5.0 feet	15	130
Sand, fine to coarse and fine gravel; arkosic with tan to gray silt and caliche; lower 10.0 feet has carbonaceous specks in the silt	15	145
Sand, fine to coarse, and fine to medium gravel, grayish-pink; arkosic with streaks of clayey, tan and gray silt with caliche,	20	165
Silt, very sandy, tan to gray; sand and gravel streaks	15	180
Sand, fine to coarse, and fine gravel; arkosic; some sandy, grayish-tan silt with caliche; fine to medium gravel and rubble derived from the Dakota Formation in lower 10.0 feet	45	225
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, gray, hard	5	230

26-4W-36ccc.—Sample log of test hole in SW SW SW sec. 36, T 26 S, R 4 W, in ditch on north side of road, 40 feet east of center line of north-south road, augered August 1957. Altitude of land surface, 1,497.6 feet; depth to water, 12.7 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Upper Pleistocene Subseries		
Wisconsinan and Illinoisan Stages (loess)		
Silt, sandy, tan; much caliche	5	5
Silt, sandy, grayish-tan	5	10
Sand, fine, very silty, grayish-tan to reddish-tan	7	17
Silt, clayey, sandy, reddish-tan; has carbonaceous specks	3	20
Silt, sandy, reddish-tan; some caliche pebbles	10	30
Wisconsinan and Illinoisan Stages (slope deposits)		
Sand, fine to coarse, very silty, reddish-tan; streaks of cemented material and some caliche	4	34
PERMIAN		
Lower Permian Series		
Ninnescah Shale		
Shale, red	3	37

27-2W-1ccc.—Drillers' log of test hole no. 60 in SW SW SW sec. 1, T 27 S, R 2 W, drilled by Layne-Western Co. for the U. S. Air Force, July-August 1955. Altitude of land surface, 1,355.8 feet; depth to water, 17.8 feet.

	Thickness, feet	Depth, feet
Soil	5	5
NEOGENE		
Upper Pleistocene Subseries		
Illinoisan Stage (terrace deposits)		
Clay, red, sandy	17	22
Clay, gray	13	35
Clay, brown, sandy	11	46
Sand, coarse	4	50
Sand, medium to coarse, and gravel; some clay streaks	16	66
Pliocene(?) Series and Lower Pleistocene Subseries, undifferentiated		
Clay, brown	1	67
Sand, coarse, and gravel; clay streaks	38	105
Clay, brown	2	107
Sand, coarse, and gravel	3	110
Clay, brown	19	129
Sand, fine to medium	7	136
Clay, brown	3	139
Sand, fine to coarse, and gravel; clay streaks	11	150
Sand, fine to coarse	5	155
Sand, fine to coarse, and gravel; clay streaks	10	165
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, blue	5	170

27-2W-29bbb.—Sample log of test hole in NW NW NW sec. 29, T 27 S, R 2 W, augered August 1957. Altitude of land surface, 1,449(T) feet; depth to water, 27.7 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Upper Pleistocene Subseries		
Wisconsinan and Illinoisan Stages (loess)		
Silt, dark brownish-gray	4	4
Silt, sandy, light tannish-gray	8	12
Silt, sandy, light grayish-tan	4	16
Silt, very sandy, rusty-tan	2	18
Lower Pleistocene Subseries, undifferentiated		
Sand, fine to medium, silty	5	23
Sand, fine to coarse, and fine gravel, silty, arkosic	14	37
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, gray	1	38

27-2W-31abb.—Drillers' log of test hole no. 6 in NW NW NE sec. 31, T 27 S, R 2 W, drilled by Layne-Western Co. for the city of Goddard, July 1959. Altitude of land surface, 1,477.0 feet.

	Thickness, feet	Depth, feet
Soil	5	5
NEOGENE		
Pleistocene Subseries, undifferentiated		
Clay, brown	30	35
Clay, yellowish-brown	10	45
Clay, brown	5	50
Clay, reddish-brown	9	59
Sand, fine	1	60
Sand, fine to coarse, and fine gravel	4	64
PERMIAN		
Lower Permian Series		
Ninnescah Shale		
Shale, red and green	4	68

27-3W-1bbb.—Sample log of test hole in NW NW NW sec. 1, T 27 S, R 3 W, in ditch on south side of road, 30 feet east of center line of north-south road, augered August 1957. Altitude of land surface, 1,467(T) feet; depth to water, 32.2 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Upper Pleistocene Subseries		
Wisconsinan and Illinoisan Stages (loess)		
Silt, sandy, gray	5	5
Silt, sandy, tan	5	10
Silt, tan; some fine sand	10	20
Silt, pinkish-tan; some sand	5	25
Silt, very sandy, tan; material derived from the Dakota Formation in lower 5.0 feet	10	35
Silt, sandy, tan	5	40
Silt, sandy, tan; some green shale fragments; with carbonaceous specks in lower 5.0 feet	10	50
Silt, sandy, tan	5	55
Silt, sandy, tan; some caliche	12	67
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, gray	2	69

27-4W-2bbb.—Sample log of test hole in NW NW NW sec. 2, T 27 S, R 4 W, in ditch on south side of road, 40 feet east of center line of north-south road, augered August 1957. Altitude of land surface, 1,501.6 feet; dry hole.

	Thickness, feet	Depth, feet
NEOGENE		
Upper Pleistocene Subseries		
Wisconsinan and Illinoisan Stages (loess)		
Silt, sandy, grayish-brown	5	5
Silt, sandy, light tannish-gray; some caliche pebbles	5	10
Silt, tan, sandy; many caliche pebbles	10	20
Silt, very sandy, grayish-tan to tan; many caliche pebbles	5	25
Wisconsinan and Illinoisan Stages (slope deposits, colluvium)		
Sand, fine to coarse, and fine gravel; much reddish-tan silt,	2	27
PERMIAN		
Lower Permian Series		
Ninnescah Shale		
Shale, red	3	30

28-2E-19baa.—Sample log of test hole in NE NE NW sec. 19, T 28 S, R 2 E, drilled 1944. Altitude of land surface, 1,358 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Upper Pleistocene Subseries		
Wisconsinan and Illinoisan Stages (loess)		
Silt, dark grayish-brown	3	3
Silt, very clayey, sandy, reddish-tan; much caliche	7	10
Silt, very clayey, sandy, very light tannish-gray; much caliche	5	15
Wisconsinan and Illinoisan Stages (slope deposits, colluvium)		
Silt, clayey, sandy, light tannish-gray; sand and gravel derived from the Dakota Formation	6	21
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, gray	4	25

28-1E-25abb.—Sample log of test hole drilled in NW NW NE sec. 25, T 28 S, R 1 E. Altitude of land surface, 1,342 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Upper Pleistocene Subseries		
Wisconsinan and Illinoisan Stages (loess)		
Silt, sandy, dark grayish-brown,	2	2
Silt, sandy, clayey, grayish-tan; much caliche; carbonaceous specks in lower 10.0 feet	18	20
Silt, sandy, very clayey, light grayish-tan; caliche	27	47
Illinoisan Stage (terrace deposits)		
Sand, fine to coarse, and fine gravel; mostly quartz; some sandy, clayey, tan silt, and lime-cemented streaks	10	57
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, maroon and gray	3	60

28-1W-17aaa.—Drillers' log of test hole no. 34 in NE NE NE sec. 17, T 28 S, R 1 W, drilled by Layne-Western Co. for the U. S. Air Force, July-August 1955. Altitude of land surface, 1,314.1 feet; depth to water, 30.4 feet.

	Thickness, feet	Depth, feet
Soil	5	5
NEOGENE		
Upper Pleistocene Subseries		
Illinoisan Stage (terrace deposits)		
Clay, red	5	10
Clay, sandy, red	11	21
Sand, coarse; with clay streaks,	9	30
Sand, medium to coarse, and gravel; a few clay streaks	10	40
Sand, coarse, and gravel; a few clay streaks	27	67
Lower Pleistocene Subseries, undifferentiated		
Clay, sandy, brown	4	71
Sand, medium to coarse, with clay streaks	16	87
Clay, sandy, brown	8	95
Clay, bluish-gray	31	126
Sand, fine to coarse; with clay streaks	14	140
Sand, fine to coarse, and gravel; a few clay streaks	6	146
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, blue	5	151

28-1W-28ccc.—Sample log of test hole in SW SW SW sec. 28, T 28 S, R 1 W, in ditch on east side of road at north edge of field drive; 40 feet north of east-west road, augered August 1957. Altitude of land surface, 1,309.5 feet; depth to water, 27.1 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Upper Pleistocene Subseries		
Illinoisan Stage (terrace deposits)		
Silt, dark gray; some sand	5	5
Silt, sandy, light tannish-gray; some caliche pebbles	5	10
Sand, fine to coarse, and fine gravel, grayish-tan; very silty,	3	13
Sand, fine to medium, grayish-tan	2	15
Sand, fine to coarse, and fine to medium gravel; arkosic, much quartz and thin silt streaks	5	20
Sand, fine to coarse, and fine to coarse gravel; arkosic with thin, grayish-tan silt streaks	5	25
Sand, fine to coarse, and fine to medium gravel; arkosic, streaks of reddish-tan and grayish-tan, clayey silt in lower 5.0 feet	10	35
Silt, clayey, sandy, reddish-tan to grayish-tan; some fine sand streaks	15	50

	Thickness, feet	Depth, feet
Sand and gravel; no return from auger	20	70
Lower Pleistocene Subseries, undifferentiated		
Sand and gravel, no return from auger	5	75

28-2W-24ddd.—Sample log of test hole in SE SE SE sec. 24, T 28 S, R 2 W, drilled September 1958. Altitude of land surface, 1,341.7 feet; depth to water, 25.9 feet.

	Thickness, feet	Depth, feet
Soil	5	5
NEOGENE		
Upper Pleistocene Subseries		
Illinoisan Stage (terrace deposits)		
Silt, very sandy, reddish-tan; some fine to medium sand	5	10
Silt, sandy, tan; some fine sand,	10	20
Sand, fine to medium; 80 percent quartz with some feldspar and other minerals	5	25
Sand, fine to coarse, and fine gravel; some tan sandy silt	8	33
Sand, fine to coarse; mostly quartz	2	35
Lower Pleistocene Subseries, undifferentiated		
Silt, sandy, tan to light gray	5	40
Silt, very sandy, tan; some thin gray limey streaks in lower 5.0 feet	10	50
Silt, sandy, tan; many limey streaks and has carbonaceous spots in lower 20.0 feet	25	75
Silt, sandy, reddish-tan, limey; a hard lime-cemented streak at 84.0 feet	15	90
Silt, very sandy, very limey, grayish-tan	8	98
Sand, fine to medium; arkosic	2	100
Sand, fine to coarse, and fine gravel; arkosic, with thin tan silt streaks in lower 7.0 feet	17	117
Silt, sandy, grayish-tan; some lime	3	120
Silt, sandy, reddish-tan; limey	8	128
Sand, fine to coarse, and fine gravel; mostly quartz	7	135
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, light- to medium-gray	5	140

28-3W-34ccc.—Sample log of test hole in SW SW SW sec. 34, T 28 S, R 3 W, on north side of road, 100 feet east of the north-south road, augered August 1957. Altitude of land surface, 1,323.2 feet; depth to water, 7.7 feet.

	Thickness, feet	Depth, feet
Road fill	2	2
NEOGENE		
Upper Pleistocene Subseries		
Wisconsinan and Illinoisan Stages (slope deposits, colluvium)		
Silt, sandy, grayish-brown	3	5
Silt, sandy, reddish-tan	2	7
Sand, fine to coarse, and fine gravel, silty, reddish-tan	2	9
Silt, sandy, reddish-brown	1	10
Illinoisan Stage (terrace deposits)		
Sand, fine to coarse, silty; some fine gravel	5	15
Silt, very sandy, dark tan	8	23
Sand, fine to coarse, and fine gravel, silty	9	32
PERMIAN		
Lower Permian Series		
Ninnescah Shale		
Shale, green	1	33

29-2E-18ccc.—Sample log of test hole in SW SW SW sec. 18, T 29 S, R 2 E, in triangle at road intersection, 25 feet north of power pole, drilled September 1958. Altitude of land surface, 1,309.4 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Upper Pleistocene Subseries		
Wisconsinan and Illinoisan Stages (loess)		
Silt, and fine sand, dark tan	10	10
Silt, sandy, calcareous, tan; has carbonaceous material	5	15
Silt, clayey, reddish-tan; has carbonaceous material; sandy in lower 10.0 feet	15	30
Silt, sandy, tan; carbonaceous specks; clayey in lower 10.0 feet	15	45
Silt, sandy, tan; caliche; cemented streak at 47.0 feet	5	50
Silt, very sandy, tan; some caliche with carbonaceous specks in lower 5.0 feet	10	60
Lower Pleistocene Subseries, undifferentiated		
Silt, sandy, tan; caliche and some gray silt, possible soil zone	7	67
Sand, fine to medium, silty	3	70
Sand, fine to coarse, and some fine gravel, yellowish-tan; mostly quartz with some feldspar	14	84
Clay, very silty, gray to grayish-white (weathered shale)	6	90
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, gray, weathered	5	95
Shale	5	100

29-1E-7aaa.—Sample log of test hole in NE NE NE sec. 7, T 29 S, R 1 E, in ditch on south side of road, 125 feet west of the north-south road, 75 feet west of school drive, augered August 1957. Altitude of land surface, 1,257.0 feet; depth to water, 16.9 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Upper Pleistocene Subseries		
Wisconsinan and Recent Stages (terrace deposits and alluvium)		
Silt, sandy, dark tan	5	5
Sand, fine to medium; abundant mica and magnetite	5	10

	Thickness, feet	Depth, feet
Sand, fine to coarse, and fine gravel, tan; arkosic	5	15
Sand, fine to coarse; much tan sandy silt	5	20
Sand, fine to coarse, silty, tan; streaks of gray silt	15	35
Sand, fine to coarse, and fine gravel, grayish-tan; arkosic with abundant quartz	7	42
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, gray	1	43

29-1E-19aaa.—Sample log of test hole in NE NE NE sec. 19, T 29 S, R 1 E, on south side of road, 15 feet west of large elm tree, 300 feet west of north-south road, augered August 1957. Altitude of land surface, 1,285.9 feet; depth to water, 39.9 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Upper Pleistocene Subseries		
Illinoisan Stage (terrace deposits)		
Silt, sandy, clayey, brown to tan,	5	5
Silt, sandy, dark tan to reddish-tan; very sandy near base	15	20
Silt, clayey, tan; some sand; grades into fine, silty, arkosic sand in lower 5.0 feet	10	30
Sand, fine, silty; arkosic; grades into sandy tan silt	5	35
Sand, fine to coarse, and fine to medium gravel, silty; arkosic; sand is predominantly fine to medium	5	40
Sand, fine to coarse, and fine to coarse gravel, silty; arkosic, no coarse gravel in lower 15.0 feet	20	60
Sand, fine to coarse, fine to coarse gravel; arkosic	3	63
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, gray	2	65

29-1W-1ccc.—Sample log of test hole in SW SW SW sec. 1, T 29 S, R 1 W, 10 feet south, 50 feet west of power pole, 15 feet north of road, drilled September 1958. Altitude of land surface, 1,288.6 feet.

	Thickness, feet	Depth, feet
Soil	3	3
NEOGENE		
Upper Pleistocene Subseries		
Illinoisan Stage (terrace deposits)		
Silt, sandy, tan	2	5
Silt, sandy, dark tan	5	10
Sand, fine to coarse; arkosic, some silt	5	15
Sand, fine to coarse, and fine gravel; arkosic, with thin streaks of silty tan clay	15	30
Sand, fine to coarse, and fine to coarse gravel	10	40
Sand, fine to coarse, and fine to medium gravel; arkosic, some tan silt; some coarse gravel in lower 5.0 feet	10	50
Sand, fine to coarse, and fine to medium gravel, silty to clean; arkosic	10	60
Sand, fine to coarse, and fine gravel	5	65
Sand, fine to coarse, and fine to medium gravel, silty; arkosic, with tan clay in lower 1.0 foot	5	70
Lower Pleistocene Subseries, undifferentiated		
Sand, fine to coarse, and fine gravel; streaks of silty, tan clay; sand is 95 percent quartz	15	85
Clay, yellowish-tan	1	86
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, bluish-gray	4	90

29-1W-9aaa.—Sample log of test hole in NE NE NE sec. 9, T 29 S, R 1 W, 8 feet from center of road, 100 feet west of the northeast corner of sec. 9, drilled September 1958. Altitude of land surface, 1,291.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Upper Pleistocene Subseries		
Illinoisan Stage (terrace deposits)		
Silt, sandy, dark tan; much sand and fine gravel near base	9	9
Sand, fine to coarse, yellowish-tan; predominantly quartz, derived from the Dakota Formation; some fine gravel	6	15
Sand, fine to coarse, and fine to medium gravel; arkosic with streaks of light grayish-tan clayey silt	5	20
Sand, fine to coarse, and fine gravel; arkosic	5	25
Sand, fine to coarse, and fine to medium gravel; arkosic, with streaks of tan, sandy silt; finer gravel in lower 5.0 feet	10	35
Sand, fine to coarse, and fine to medium gravel; arkosic with streaks of tan, sandy, clayey silt	5	40
Lower Pleistocene Subseries, undifferentiated		
Silt, clayey, sandy, reddish-tan; with caliche pebbles	5	45
Silt, clayey, sandy, light gray; some caliche	10	55
Silt, sandy, very light gray to gray; calcareous; scattered amounts of volcanic ash	15	70
Silt, very sandy, gray; some volcanic ash	5	75

	Thickness, feet	Depth, feet
Silt, sandy, grayish-tan to tannish-gray; much volcanic ash	15	90
Silt, and sand, grayish-tan	5	95
Sand, fine to coarse, very silty, gray; predominantly quartz	10	105
Sand, fine to coarse, and fine gravel; gravel is arkosic; grayish-tan silt	10	115
Sand, fine to coarse, and fine gravel; very arkosic	7	122
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, gray	8	130

29-1W-22ddd.—Sample log of test hole in SE SE SE sec. 22, T 29 S, R 1 W, drilled 1944. Altitude of land surface, 1,264 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Upper Pleistocene Subseries		
Illinoisan Stage (terrace deposits)		
Silt, sandy, dark grayish-tan	2	2
Silt, light gray; some sand, caliche pebbles; very little sand and some snail fragments in lower 14.0 feet	22	24
Silt, sandy, light grayish-tan; caliche and carbonaceous specks	12	36
Sand, fine to coarse, and fine to medium gravel; arkosic	14	50
Lower Pleistocene Subseries, undifferentiated		
Sand, fine to coarse, and fine gravel; arkosic, some streaks of clayey, light grayish-tan silt with caliche; silt becomes sandy in lower 10.0 feet	20	70
Sand, fine to coarse, and fine gravel; arkosic; gravel is fine to medium in lower 14.0 feet	24	94
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, dark gray	6	100

29-2W-13ddd.—Sample log of test hole in SE SE SE sec. 13, T 29 S, R 2 W, on north side of road, 60 feet west of center line of north-south road, augered August 1957. Altitude of land surface, 1,306.0 feet; depth to water, 16.2 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Upper Pleistocene Subseries		
Wisconsinan and Illinoisan Stages (slope deposits, colluvium)		
Silt, dark gray, sandy	5	5
Silt, tan; much sand and fine gravel	5	10
Silt, greenish-gray; some sand	5	15
Silt, grayish-green	4	19
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, grayish-green	1	20

29-3W-13cdd.—Sample log of test hole in SE SE SW sec. 13, T 29 S, R 3 W, on south side of road, 75 feet west of half-section fence, augered July 1957. Altitude of land surface, 1,287.9 feet; depth to water, 3.4 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Upper Pleistocene Subseries		
Wisconsinan and Recent Stages (terrace deposits and alluvium)		
Silt, sandy, brown	3	3
Silt, sandy, tan	5	8
Sand, fine to medium, very silty, reddish-tan	2	10
Sand, fine to coarse, and fine gravel; arkosic with fragments of green shale	5	15
PERMIAN		
Lower Permian Series		
Wellington Formation		
Shale, grayish-green	1	16

29-4W-18bcc.—Sample log of test hole in SW SW NW sec. 18, T 29 S, R 4 W, on east side of road at half-section line, augered July 1957. Altitude of land surface, 1,405.5 feet; depth to water, 20.4 feet.

	Thickness, feet	Depth, feet
Road fill	3	3
NEOGENE		
Upper Pleistocene Subseries		
Wisconsinan and Illinoisan Stages (loess and terrace deposits), undifferentiated		
Silt, sandy, grayish-tan	4	7
Silt, very sandy, reddish-tan	3	10
Silt, sandy, reddish-tan	5	15
Sand, fine to medium, very silty, reddish-tan	5	20
Sand, fine to coarse, silty, reddish-tan; some fine gravel in lower 32.0 feet and shale fragments in lower 27.0 feet	37	57
PERMIAN		
Lower Permian Series		
Ninnescah Shale		
Shale, red	1	58

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INDEX

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