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GEOLOGY AND GROUND-WATER RESOURCES OF LANE COUNTY, KANSAS

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Prepared by the State Geological Survey of Kansas and the United States Geological Survey, with the co-operation of the Division of Sanitation of the Kansas State Board of Health and the Division of Water Resources of the Kansas State Board of Agriculture

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GEOLOGY AND GROUND-WATER RESOURCES OF LANE COUNTY, KANSAS

By Glenn C. Prescott, Jr.

ABSTRACT

This report describes the geography, geology, and ground-water resources of Lane County in western Kansas. Lane County has an area of 720 square miles and in 1946 had a population of 2,626. The area consists of nearly flat to gently rolling upland plains, dissected on the north, east, and southeast by streams which have eroded away surficial materials exposing the underlying Cretaceous shale and limestone. A small basin in southwestern Lane County extends southwestward into Finney County where it may join the Scott-Finney Basin. A small area in the southwestern part of the county is mantled by dune sand. The climate is subhumid to semiarid, the average annual precipitation being about 19 inches. Farming and cattle raising are the principal occupations in the area. There is a very small amount of irrigation from deep wells in the north-central part of the county.

The outcropping rocks are sedimentary and range in age from Upper Cretaceous to Recent. A map showing the rock formations that crop out is included in the report. Much of the area is underlain by deposits of the Ogallala formation of Tertiary age, which is generally covered by wind-blown silts of the Sanborn formation of Pleistocene age. Cretaceous rocks have been exposed by stream erosion on the northern, eastern, and southeastern borders of the county. Thin deposits of Recent alluvium occur along some of the stream valleys.

Lane County has no permanently flowing streams, but contains the head-water areas of Walnut Creek and also is drained by tributaries to Smoky Hill River on the north and tributaries to Pawnee River on the south.

The Ogallala is the principal water-bearing formation in Lane County. The Meade (?) deposits in the southwestern part of the county furnish water for a few wells and the alluvium along some of the streams yields small amounts of water. A few wells may obtain a little water from the Niobrara formation, and deep wells in the Dakota yield water where shallow supplies cannot be obtained.

The report contains a map of the area showing the locations of wells for which information was obtained and showing, by means of shading, the depth to water level. The water table ranges in depth from about 110 feet in the northwest to less than 5 feet in the center of a basin in southwestern Lane County. A map, showing by means of contours the shape and slope of the water table, demonstrates that ground water moves in a general easterly direction with an average gradient of about 10 feet to the mile. A map showing the thickness of saturated water-bearing materials indicates that shallow ground-water supplies available to wells are scarce throughout much of the county.

The ground-water reservoir is recharged principally by precipitation that falls within the area and from precipitation that falls in adjacent areas to the west and enters Lane County as underflow. Ground water is discharged from the ground-water reservoir by transpiration and evaporation in areas of shallow water table, by movement into adjacent areas, by springs, and by wells. Most of the domestic, stock, public, and irrigation supplies are obtained from wells.

Irrigation is not practiced extensively in Lane County, as geologic and hydrologic conditions prohibit any great development. The area most favorable for the development of irrigation supplies lies in T. 17 S. and extends from the Scott County line eastward for about 16 miles.

The ground water in Lane County, though generally hard, is suitable for most purposes. Waters from Ogallala, Meade (?), and alluvial deposits are similar in chemical character, although Ogallala waters are higher in fluoride content. Dakota waters are high in dissolved solids but are soft, probably owing to a natural base-exchange process. Waters from both the Ogallala and Dakota are generally high in fluoride. The Dakota waters are unfit for irrigation.

The report contains a section in which character, thickness and distribution, age and correlation, and water supply of the rock formations are described. These are also briefly summarized in tabular form.

The field data upon which most of this report is based are given in tables; they include records of 303 wells, chemical analyses of water from 31 representative wells, and logs of 41 test holes and wells, including 33 test holes drilled by the State Geological Survey.

INTRODUCTION

Purpose and Scope of the Investigation

The investigation upon which this report is based was begun in July 1948 as part of a program of ground-water studies in Kansas by the United States Geological Survey and the State Geological Survey of Kansas in cooperation with the Division of Sanitation of the Kansas State Board of Health and the Division of Water Resources of the Kansas State Board of Agriculture. Several similar investigations have been completed since this program was begun in 1937 and several are now being made in other areas in Kansas.

Ground water is one of the principal natural resources of Lane County as well as of much of the western half of Kansas. Nearly all public, domestic, railroad, and stock supplies are obtained from wells. Several irrigation wells were completed in Lane County in 1948, and it is probable that the use of ground water for irrigation will increase as new wells are drilled. At the present rate of withdrawal, the danger of seriously depleting the ground-water supply seems very slight, but there is a definite need for an adequate understanding of the quantity and quality of the available supply, where additional supplies can be obtained, and what measures may be necessary to safeguard their continuance.

The investigation was made under the general direction of A. N. Sayre, Geologist in Charge of the Ground-Water Branch of the United States Geological Survey; and under the immediate supervision of V. C. Fishel, District Engineer in charge of ground-water work in Kansas.

Location and Extent of the Area

Lane County, on the eastern edge of the High Plains, is bounded on the north by Gove County, on the east by Ness County, on the west by Scott County, and on the south by Finney County. It is in the fourth tier of counties east of the western border of the State and is about midway between the north and south borders. It contains 20 townships, from T. 16 S. to T. 20 S. and from R. 27 W. to R. 30 W.; it has an area of 720 square miles. The location of this county and other areas in which cooperative ground-water investigations have been made are shown in Figure 1.

Previous Investigations

No detailed geologic reports on Lane County have been published previously, but several reports that apply to the county in a general way or in which the county has been referred to have been published. In 1897 Haworth (pp. 34-35) in a report on the physiography of western Kansas discussed Walnut Creek which rises in Lane County. In the same year Haworth contributed a report on the physical properties of Tertiary rocks in Kansas (1897a). A report of the Board of Irrigation Survey and Experiment to the State Legislature of Kansas for the years 1896 and 1897 also was published in 1897 and contained a log of and other information about a State-financed test well (Sutton, 1897). The same report contained a chapter on

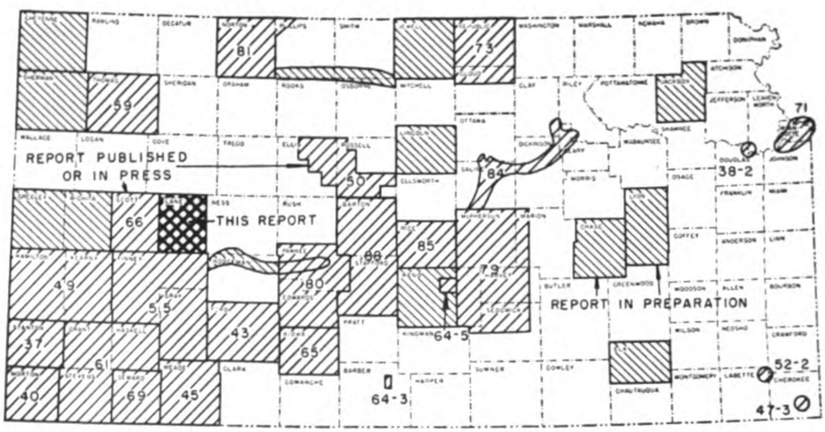


FIG. 1.—Index map of Kansas showing area covered by this report and other areas for which cooperative ground-water reports have been published or are in preparation.

the geology of underground water in western Kansas in which several specific references were made to the geology and hydrology of Lane County (Haworth 1897b). In a report in 1897 on the Pleistocene of Kansas, Williston (1897, pp. 301-302, 304) made references to vertebrate fossils found in Lane County. In another report the same year he (Williston, 1897a) discussed the Niobrara formation of Kansas. Johnson (1901, 1902), in his reports on the utilization of the High Plains, made special reference to the source, availability, and use of ground water in western Kansas. In 1905 Darton (p. 306) published a preliminary report on the geology and ground-water resources of the central Great Plains in which he made brief reference to Lane County. A report on the quality of water supplies in Kansas published in 1911 by Parker contained analyses of waters from Lane County (p. 124) and made brief reference to the geology of Lane County (pp. 123-124, 290). A report by Coffey and Rice (1912) contains results of a reconnaissance soil survey in western Kansas, including Lane County. In a special report on well waters in Kansas, Haworth (1913) devoted a chapter to the Tertiary area of western Kansas.

In 1931, Elias, in a bulletin on the geology of Wallace County, Kansas, mentioned two localities in Lane County where he had found algal limestone capping exposures of the Ogallala formation (p. 141). Moss (1932, p. 8) made reference to the geology of Lane County in a report on Ness and Hodgeman Counties. In a short report on the ground-water resources of the Shallow Water Basin in Scott and Finney Counties, Moss (1933, p. 4) again briefly mentioned Lane County. In 1935 Theis, Burleigh, and Waite described the water-bearing formations and availability of ground water in the southern High Plains. A report on the geology and oil and gas resources of Logan, Gove, and Trego Counties contained a graphic log of a test well drilled in Lane County (Landes and Keroher, 1939, Pl. 3). Latta (1944) made a study of the geology and ground-water resources of Finney and Gray Counties, Finney bordering Lane on the south. In 1940 Moore and others prepared a generalized report on the ground-water resources of Kansas. In 1946 the State Geological Survey of Kansas published a subsurface geologic cross section that extended through Lane County (Maher, 1946). In 1939 and 1940 Waite did the field work for a report, published in 1947, on the geology and ground-water resources of Scott County, which adjoins Lane to the west. In 1949, Frye and Swineford published a discussion on the physiographic provinces in which Lane County is located. In 1949 a popular bulletin on the ground-water resources in southwestern Kansas was prepared by Frye and Fishel. In addition, several reports by Ver Wiebe contain paragraphs summarizing the results of test drilling done for oil and gas in Lane County (Ver Wiebe, 1938, p. 13; 1939, p. 105; 1945, p. 108; 1946, pp. 104-105; Ver Wiebe and others 1949, p. 100).

Methods of Investigation

Four months in the summer and fall of 1948 and two weeks in September 1949 were spent in the field collecting the data upon which this report is based. A total of 303 wells in the county were visited and the total depth and depth to water level were measured in most of them. Well owners and drillers were interviewed regarding the nature and thickness of water-bearing formations penetrated by the wells and all available logs were collected. Information regarding the yield, drawdown, temperature, chemical character, and use of ground water was obtained.

Samples of water from 30 representative wells were collected; they were analyzed in the Water and Sewage Laboratory of the Kansas State Board of Health at Lawrence by Howard A. Stoltenberg, chemist.

During the investigation the surficial geology was studied and the geologic map (Pl. 1) was prepared. To determine the character of the material beneath the surface, 33 test holes were drilled by William T. Connor, Kenneth L. Walters, and Max Yazza, using the portable hydraulic-rotary rig owned by the State Geological Survey. Samples from the test holes were collected and studied in the field by Mr. Walters and were later examined by me in the office with a binocular microscope. Logs of five irrigation wells and of several irrigation test holes were supplied by George Weishaar of the Weishaar and Son Drilling Company of Scott City.

Pumping tests on three irrigation wells (17-28-15cb, 17-28-22aaa, and 16-29-28dab) were made by Woodrow W. Wilson of the Federal Geological Survey. These tests were made to determine the yield of the wells and the permeability of the water-bearing materials. The altitudes of the surface at the test holes and of the measuring points of the wells were determined by C. K. Bayne and William A. Carlson, using a plane table and alidade. The water-table contour map (Pl. 1) is based upon these altitudes together with the measured depths to water level in these wells. Wells shown on this map and the depth to water map were located within the sections by use of the odometer. The base map used for Plates 1 and 2 was prepared by Woodrow W. Wilson from a county map compiled by the State Highway Commission of Kansas. Drainage was adapted from maps obtained from the United States Department of Agriculture, Soil Conservation Service. Geologic mapping was on a base map compiled by the State Highway Commission of Kansas. This field mapping was greatly aided by the use of aerial photographs supplied by the Soil Conservation Service and the Agricultural Adjustment Administration offices in Dighton. Frequent references to the geologic map of Kansas (Moore and Landes, 1937) were made during the mapping.

WELL-NUMBERING SYSTEM

The well and test-hole numbers in this report give the location of wells according to General Land Office Surveys and according to the following formula: township, range, section, 160-acre tract within that section, the 40-acre tract within that quarter section, and the 10-acre tract within the quarter-quarter section if this subdivision can be accurately made. If two or more wells are within

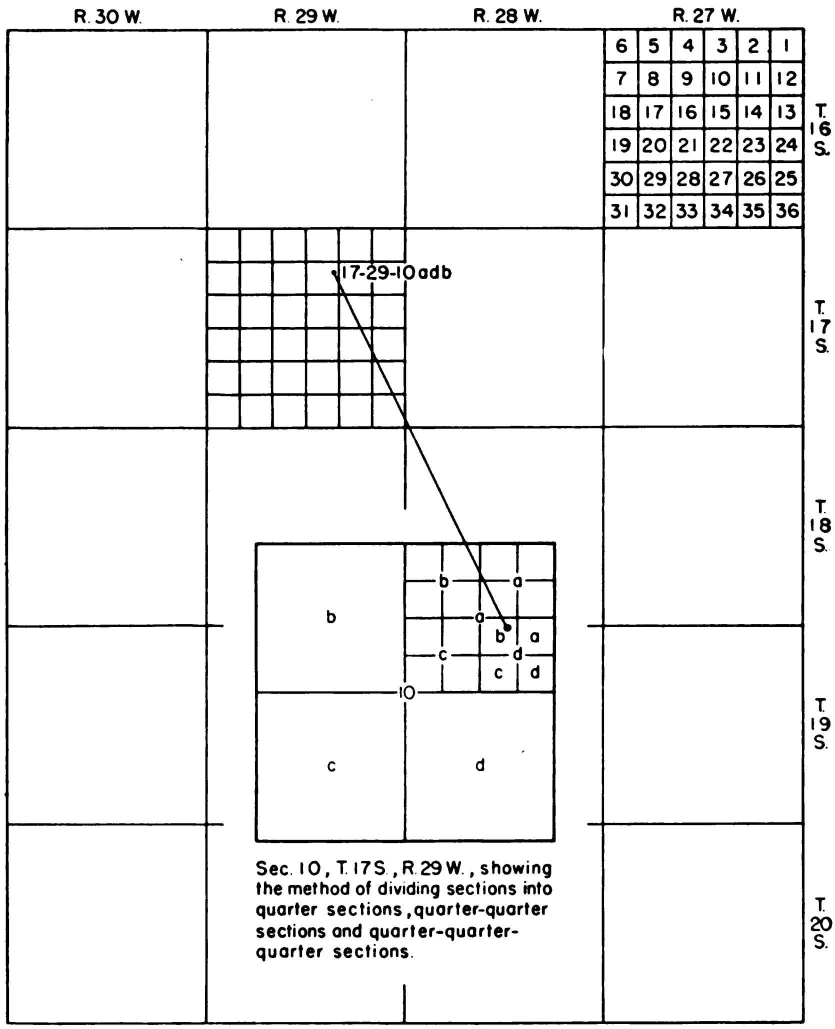


FIG. 2.—Map of Lane County illustrating the well-numbering system used in this report.

a 10-acre tract the wells are numbered serially beginning with the deepest well. An example of this well-numbering system is shown in Figure 2.

Acknowledgments

I am indebted to many residents of Lane County who readily gave permission to measure their wells, and who supplied helpful data about them. Special thanks are extended to the owners of irrigation wells who permitted pumping tests to be made, and to George Weishaar of Scott City who furnished several logs of irrigation test holes and wells. Silas Stone, Soil Conservationist, Ralph F. Burrell, Agricultural Adjustment Administration Supervisor, and Warren J. Tillotson, retired rancher, supplied information concerning geology and ground water. Harold Biggs, well driller from Healy, also supplied additional information.

The manuscript for this report has been reviewed critically by several members of the Federal and State Geological Surveys; George S. Knapp, Chief Engineer, and Robert Smrha, Senior Engineer, of the Division of Water Resources of the Kansas State Board of Agriculture; and Dwight Metzler, Director, and Willard Hilton, Geologist, of the Division of Sanitation of the Kansas State Board of Health. The illustrations were drafted by Woodrow W. Wilson of the Federal Geological Survey.

GEOGRAPHY

Topography and Drainage

Lane County is entirely in the High Plains section of the Great Plains physiographic province except for a small area on the eastern edge of the county which is included in the Smoky Hills Upland section (Adams, 1903, p. 113; Frye and Swineford, 1949). The county consists of nearly flat to gently rolling uplands dissected in several places by relatively shallow valleys (Pl. 3A). In the southwest corner of the county is an enclosed depressional basin, the origin of which is uncertain. The upland plains surface slopes gradually eastward at the rate of about 10 feet to the mile. The relief in the county is approximately 450 feet. The highest point is about 9 miles south of Amy and has an altitude of more than 2,930 feet. The lowest point, where Hackberry Creek enters Ness County in southeastern Lane County, has an altitude less than 2,480 feet.

A common feature of nearly flat upland plains is the occurrence of numerous shallow undrained depressions, ranging in diameter

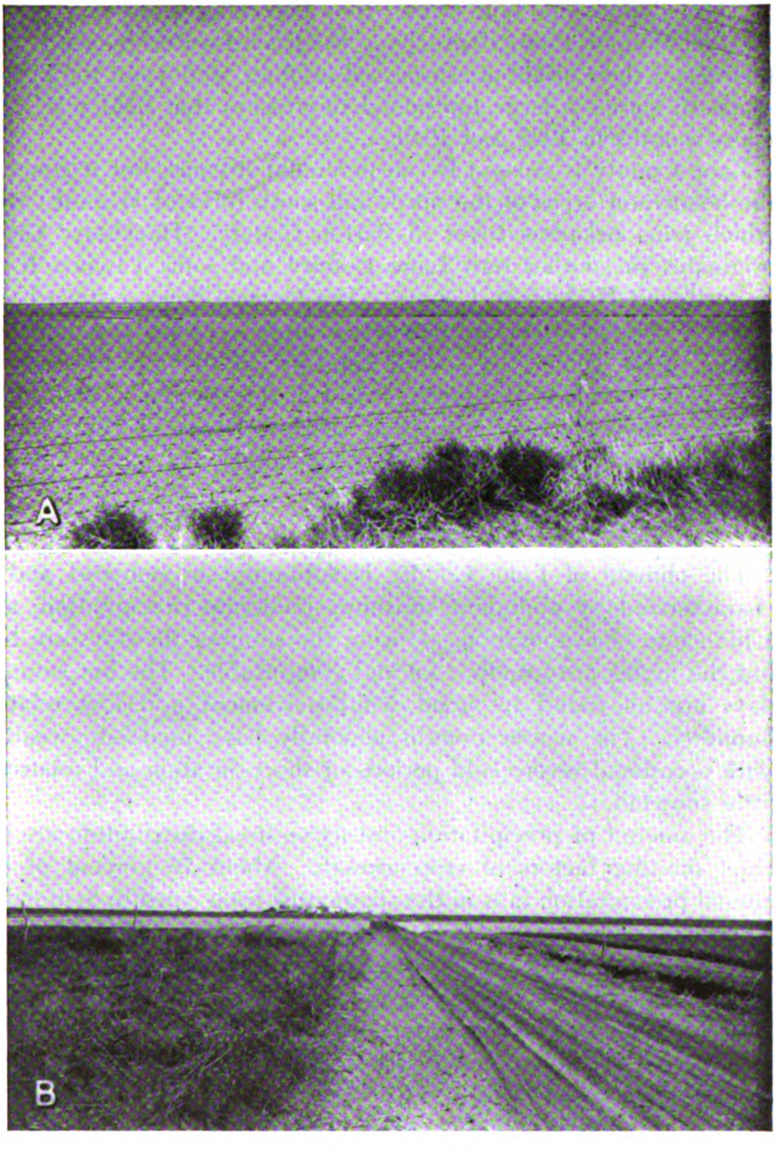


PLATE 3—Views of the High Plains surface in Lane County. *A*, High Plains surface, underlain by Ogallala formation covered by silts of the Sanborn formation. View looking northwest 2 miles east of Dighton. Photograph by J. C. Frye. *B*, Undrained upland depression filled with water. Looking north on section line separating secs. 33 and 34, T. 17 S., R. 29 W.

from a few tens of feet to nearly a mile. After a heavy rain, many of these depressions hold water, thus becoming temporary ponds. The relation of these depressions to ground-water recharge and theories of their origin are discussed in other sections of the report. Plate 3B shows a large undrained depression that held water for many months in 1948 and 1949.

Lane County is crossed by no perennial streams, but it contains the headwater areas of the north and south forks of Walnut Creek which joins Arkansas River in Barton County. Hackberry Creek originates in southeastern Lane County and joins Pawnee River in northwest Hodgeman County. The Pawnee flows eastward and meets Arkansas River in Pawnee County. Along the northern border of the county are several short creeks that are tributary to Smoky Hill River to the north. Most of the tributaries have deep rugged canyons where dissecting streams have cut through the Ogallala formation into the underlying Smoky Hill chalk member of the Niobrara formation.

Climate

The climate of Lane County is subhumid to semiarid and is characterized by abundant sunshine, moderate precipitation, and a high rate of evaporation. During the summer the days are hot, but the nights are usually cool and comfortable. The hot summer days are alleviated by good wind movement and low relative humidity. The winter months generally have moderate weather with occasional severe cold periods of short duration and relatively little snowfall.

The amount of precipitation and its seasonal distribution are the chief limiting factors of crop growth. About 76 percent of the annual precipitation falls in the six months from April to September when the growing season is at its height and moisture is needed.

According to the U. S. Weather Bureau, the normal annual precipitation is 18.77 inches at Healy. The precipitation has ranged from a minimum of 9.79 inches in 1916 to a maximum of 36.71 inches in 1923. The annual precipitation and the cumulative departure from normal precipitation at Healy are shown in Figure 3; the normal monthly precipitation is shown in Figure 4.

The normal annual mean temperature as recorded at Healy is 53.6° F. The lowest temperature on record is —31° F. which occurred on January 11, 1918, whereas the highest temperature is 116° F. on July 13, 1913. The average length of the growing season is 167 days and has ranged from extremes of 132 to 199 days. Killing frosts have occurred as late as May 27 and as early as September 12.

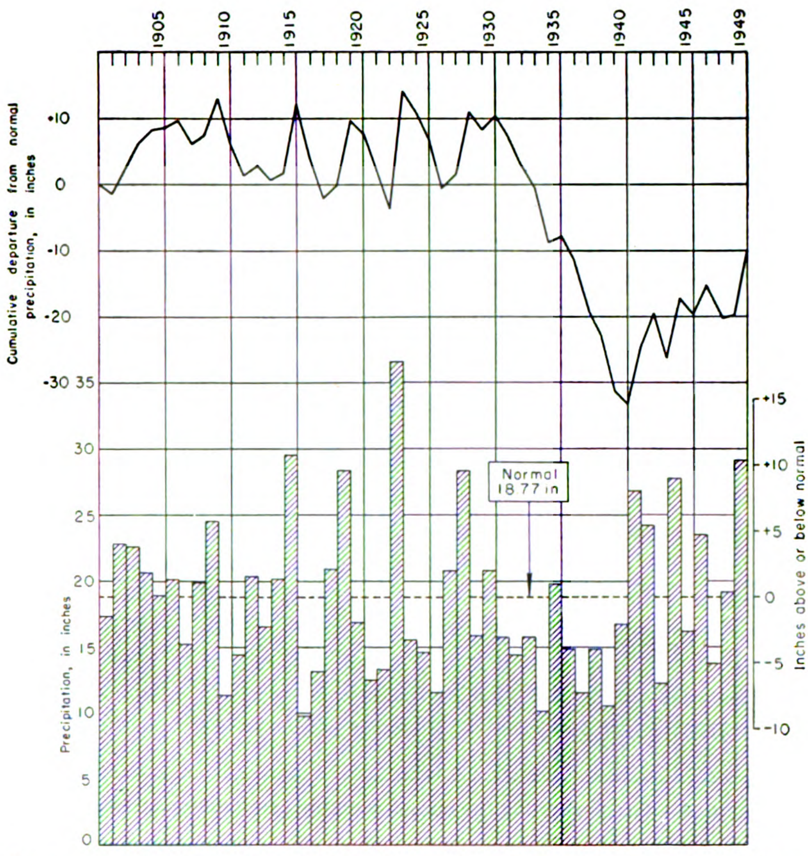


FIG. 3.—Graphs showing annual precipitation and cumulative departure from normal precipitation at Healy, Kansas.

POPULATION

According to the census of 1940, Lane County had a population of 2,821 and an average density of population of 3.9 persons to the square mile as compared with 21.9 for the entire state. The 1940 figure is a decrease of 16.3 percent from 3,372 in 1930. The population of the county was 2,060 in 1890; it declined to 1,563 in 1900, and then increased to 2,603 in 1910 and to 2,848 in 1920.

The Thirty-fifth Biennial Report of the Kansas State Board of Agriculture reports a population of 2,626 in 1946. It also lists the population of Dighton, the county seat of Lane County, as 1,037, an increase of 63 over the 1940 census figure of 974. Lane County ranks 96th in population within the State.

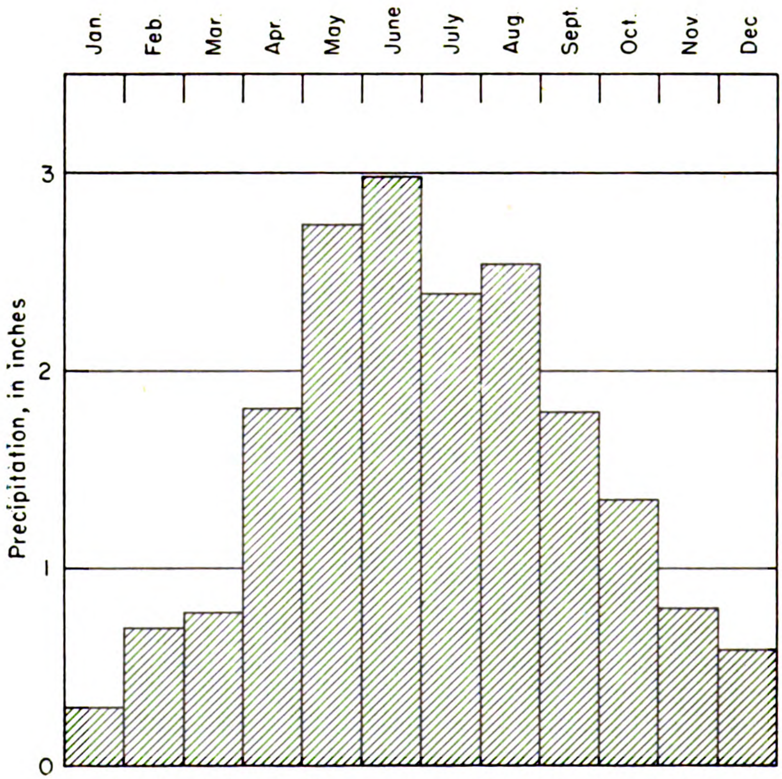


FIG. 4.—Graph showing the normal monthly precipitation at Healy.

TRANSPORTATION

Lane County is crossed by the main line of the Missouri Pacific Railway as well as by a branch line of the Atchison, Topeka, and Santa Fe Railway. The Missouri Pacific Railway enters the county about 4.5 miles east of Pendennis, and continues diagonally southwest through Shields and Healy to the county line. The Great Bend and Garden City branch of the Atchison, Topeka, and Santa Fe Railway enters the county about 3.5 miles southeast of Alamota, continues northwestward to Dighton, thence due west to the Scott County line.

State Highway 96 bisects the county from east to west and passes through Dighton and Amy. State Highway 23 extends from north to south across the county and passes through Dighton. State Highway 4 (gravel-surfaced) parallels the Missouri Pacific Railway as far as Healy, whence the highway continues on west whereas the railroad trends southwestward. Several of the county roads have been graded and graveled, and many other county and township roads have been improved.

Agriculture

Agriculture is the chief occupation in Lane County which has 454 farms comprising 460,800 acres (1946 census figures). Virtually all the land is in farms. According to the Kansas State Board of Agriculture, 190,185 acres of major crops were harvested in 1946. About 93 percent of the farmed acreage was used for the production of wheat; sorghums, barley, and hay were other principal crops. A large percentage of the land area was used for grazing. The acreage of principal crops harvested in 1946 is shown in Table 1.

Mineral Resources

Lane County has no known mineral resources of great economic importance. A small amount of sand and gravel may be obtained from the Ogallala formation (Pl. 4A), and caliche beds in the Ogallala are worked to a small extent for road-surfacing material. In southeastern Lane County the Fort Hays limestone member of the Niobrara formation has been quarried and used for building homes (Pl. 4B). A limited amount of exploration for oil and gas has been done, but until the present, it has been unsuccessful.

Table 1.—*Acreage of principal crops grown in Lane County, Kansas, in 1946*

Crop	Acres
Wheat	176,000
Corn	40
Oats	560
Barley	1,600
Rye	280
Sorghum:	
For grain	2,390
For forage	8,350
For silage	110
Irish potatoes	5
All hay	850
Total	190,185

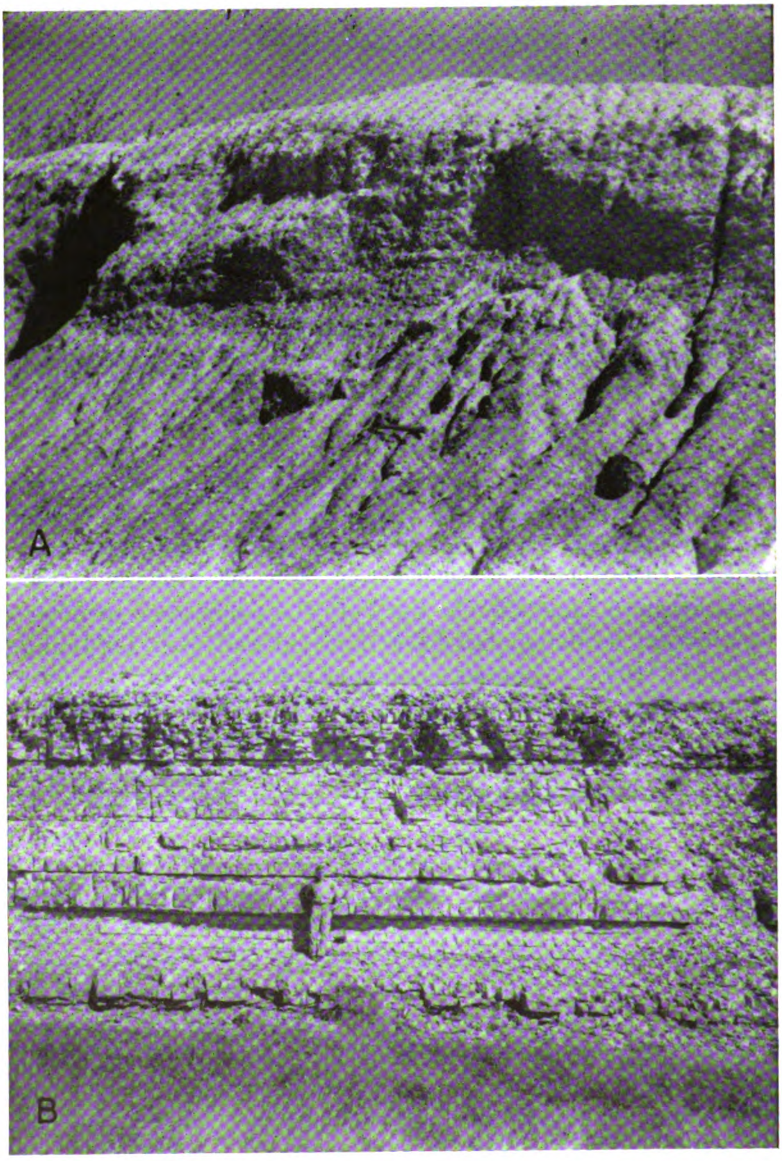


PLATE 4.—*A*, Gravel pit in Ogallala formation in the SE¼ sec. 12, T. 16 S., R. 27 W. Gravel is poorly sorted. *B*, Fort Hays limestone member of the Niobrara formation in the SW¼ sec. 2, T. 20 S., R. 27 W. Blocks have been quarried here for building stone. Photograph by H. G. O'Connor.

GEOLOGY

Summary of Stratigraphy

The rocks cropping out in Lane County are of sedimentary origin and range in age from Upper Cretaceous to Recent. The areal distribution of the rocks is shown in Plate 1. The oldest rocks exposed in the county belong to the Blue Hill shale member of the Carlile shale, which is found in a few isolated outcrops in the southeastern corner of the county. The Carlile is overlain by the Fort Hays limestone member of the Niobrara formation. Typical exposures of the Fort Hays limestone are found in the southeastern part of the county (Pl. 5A). The Smoky Hill chalk member of the Niobrara is next in ascending order and is found in excellent outcrops along tributaries to Smoky Hill River in the northern part of the county (Pl. 5B). It also crops out on the south side of the north and south forks of Walnut Creek as well as along several other intermittent drainageways. The Pierre shale which overlies the Niobrara formation in other areas is absent in Lane County.

The Ogallala formation of Pliocene age overlies the Cretaceous beds in the uplands over most of the county. It is exposed on the sides of many of the stream valleys, and several small hills are capped by the "Algal limestone" (Elias, 1931, pp. 136-141) which is the uppermost bed in the Ogallala section. A basinlike depression in southwestern Lane County contains sediments thought to belong to the Meade formation of Pleistocene age. Over a large part of the county, the Ogallala is overlain by the Pleistocene Sanborn formation which consists predominantly of eolian silt. Locally a small amount of sand and gravel occurs at the base of the Sanborn formation (Fig. 6). Colluvial materials derived in part from Pliocene and Cretaceous rocks and in part from the upland loess of the Sanborn formation mantle many slopes. These colluvial slope deposits are included with the Sanborn formation on the geologic map (Pl. 1). A small area in the southwest corner of the county is covered by dune sand, which is thought to be late Pleistocene in age. The most recent deposits are narrow bands of alluvium that occupy parts of the valleys of the several small creeks that head in Lane County.

The character and ground-water supply of the geologic formations are briefly described in Table 2, and more detail is given in the section on geologic formations and their hydrologic properties.

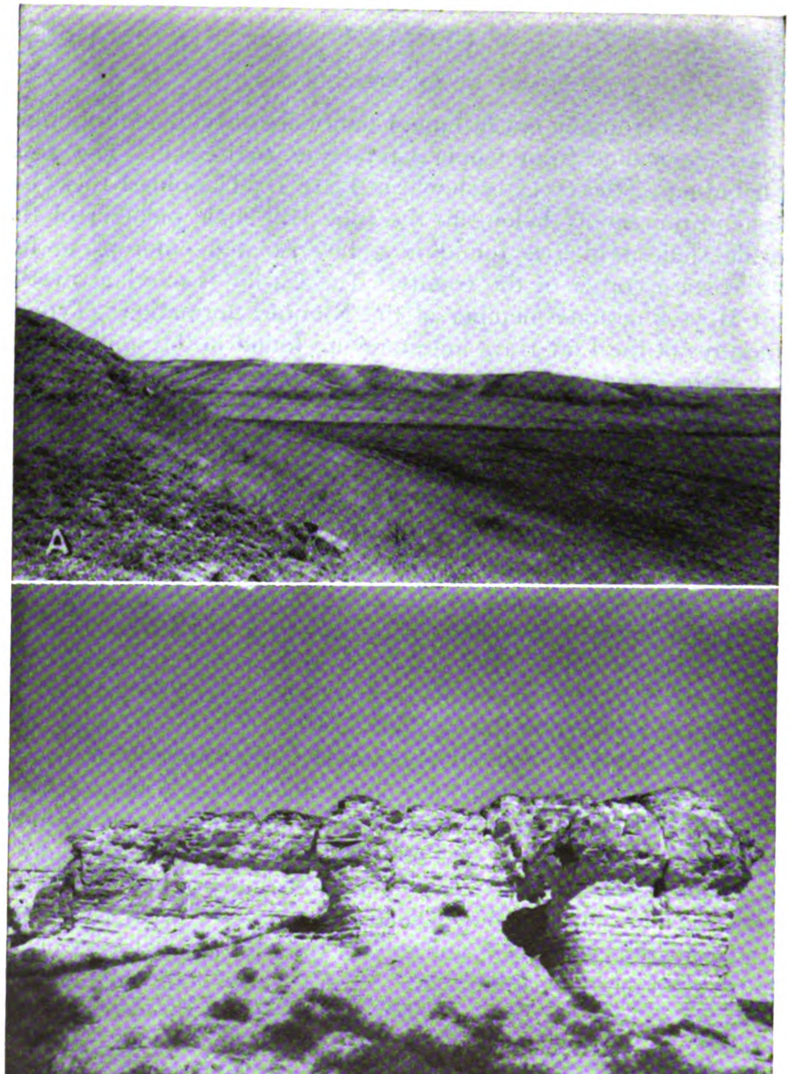


PLATE 5.—The Niobrara formation in Lane County. *A*, Bluffs formed by exposures of Fort Hays limestone member of the Niobrara formation; view looking southwest in sec. 25, T. 20 S., R. 27 W. *B*, Outcrop of Smoky Hill chalk member of the Niobrara formation showing massive beds at top and shaly beds below; sec. 8, T. 16 S., R. 30 W.; view looking north.

TABLE 2. *Generalized section of the geologic formations of Lane County, Kansas*[a]

System	Series	Formation	Member	Thickness, feet	Character	Water supply
Quaternary	Pleistocene	Alluvium		0-35	Sand, gravel, and silt comprising narrow bands of stream deposits along the forks of Walnut Creek and along the tributaries to Smoky Hill and Pawnee Rivers.	Yields small supplies of moderately hard water to wells.
		Unconformable on older formations				
		Dune sand		0-40±	Fine to medium-grained wind-blown sand. Covers a small area in southwestern corner of county.	No wells known to derive water directly from the dunes. Dunes are important as catchment areas for recharge from local precipitation.
		Unconformable on older formations				
		Sanborn formation (includes slope deposits)	Peoria silt member and Loveland silt member	0-25	Tan to brownish massive silt. Locally contains some sand and gravel at the base.	The Sanborn formation usually occurs above the water table but yields small supplies of water to a few wells.
		Unconformable on older formations				
		Meade (?) formation	Sappa member Grand Island member	0-110	Silt, clay, and very fine sand with a small amount of sand and gravel at the base.	Contains a large amount of water but because of fineness of material, yields are not large. Occurs in southwestern corner of county.
		Unconformable on older formations				
Tertiary	Pliocene	Ogallala formation		0-160	Gravel, sand, silt, clay, and caliche; predominantly calcareous. May be consolidated or unconsolidated.	The Ogallala is the principal water-bearing formation in Lane County. It yields moderate to large supplies of water to domestic and stock wells. The city of Dighton derives its water supply from the Ogallala as do several irrigation wells.
		Unconformity				

TABLE 2. *Generalized section of the geologic formations of Lane County, Kansas*[a]*—Concluded*

System	Series	Formation	Member	Thickness, feet	Character	Water supply
Cretaceous	Gulfian	Niobrara formation	Smoky Hill chalk member	0-350±	Alternating beds of chalk and chalky shale.	Yields only small supplies of water to very few wells in areas where Tertiary deposits are thin.
			Fort Hays limestone member	0-50±	Massive chalk beds separated by chalky shale layers.	Not an important aquifer. Yields a small amount of water to some wells in southeastern Lane County. Water occurs in fractures.
		Carlile shale	Blue Hill shale member	175-225	Sandstone and sandy shale comprising the Codell sandstone zone in the upper part; bluish-gray noncalcareous shale, containing gypsum seams and septarian concretions.	Not known to yield water to wells in Lane County.
			Fairport chalky shale member		Calcareous shale with thin limestone beds. Not exposed in Lane County.	Not known to yield water to wells in Lane County.
		Greenhorn limestone		100-105±	Alternating beds of thin chalky limestone and chalky shale. Not exposed in Lane County.	Yields no water to wells in Lane County.
		Graneros shale		50-55±	Gray noncalcareous shale containing lenses of sandstone. Not exposed in Lane County.	Not known to yield water to wells in Lane County.
		Dakota formation		250-300±	Sandstone, shale, and clay.	Yields moderate amounts of very soft water to several wells in areas where Tertiary deposits are thin or absent.

[a] The stratigraphic classification used in this report is that of the State Geological Survey of Kansas.

Geologic History

PALEOZOIC ERA

Cambrian and Ordovician Periods

Logs of test wells for gas and oil indicate that Lane County is underlain by at least 4,000 feet of sediments deposited during the Paleozoic era. During early Cambrian time Lane County, along with a large part of west-central United States, was a land surface. In middle Cambrian time an interior sea developed and persisted through most of the Ordovician Period. During the submergence there was extensive deposition of calcareous sediments, which are recognized in well cuttings and logs as the Arbuckle group of Cambrian and Ordovician age and the Viola limestone of Ordovician age. In a well in the NE¼ sec. 25, T. 16 S., R. 29 W., the Arbuckle was encountered at 4,900 feet and penetrated to a total depth of 5,032 feet.

Silurian and Devonian Periods

Rocks of Silurian and Devonian ages are not known to underlie Lane County. A shallow sea or a low land mass may have been present but no evidence of either erosion or deposition is left.

Mississippian and Pennsylvanian Periods

During early Mississippian time there was extensive deposition of marine dolomitic limestone, along with some shale and cherty limestone. Well logs indicate that Mississippian strata are encountered at approximately 4,500 feet. Rock types found in formations of Mississippian age include oölitic limestone, dolomite, cherty limestone, and cherty dolomite. In later Mississippian time there was a period of uplift during which the early Mississippian strata were subjected to erosion. During Pennsylvanian time subsidence and uplift alternated several times, and both marine and continental sedimentary rocks, consisting of sandstone, limestone, coal, and shale, were formed. Pennsylvanian rocks are approximately 1,000 feet thick in Lane County. In a test well, the top of the Lansing and Kansas City groups was logged at 3,973 feet, the top of the Marmaton group at 4,428, and the top of the Mississippian at 4,574 (the James Farm No. 1 well in the NE¼ NE¼ sec. 25, T. 16 S., R. 29 W.)

Permian Period

During early Permian time alternating submergence and emergence of late Pennsylvanian rocks continued and limestone, dolomite, and shale were deposited. During the latter part of the period shallow basins and low plains were areas of continental deposition. Most of the deposition took place in shallow water, so that subsidence must have kept pace with deposition during this period. The climate must have been arid and evaporation probably occurred in shallow basins, giving rise to extensive deposits of salt, anhydrite, and gypsum. Shale and sandstone were the predominant formations resulting from Permian continental deposition. According to Ver Wiebe (1939, p. 105) two anhydrite zones were found in one well—the Blaine at 1,620 feet and the Stone Corral at 2,170 feet. Both formations are in the Leonardian Series. Logs of deep tests show that Lane County is underlain by at least 2,000 feet of Permian sedimentary rocks.

MESOZOIC ERA

Triassic and Jurassic Periods

It is possible that some deposition occurred in the early part of Triassic time, but in the latter part of the Triassic Period this region was above sea level. Triassic deposits, if any, were removed by erosion and Permian rocks were also eroded. During Jurassic time, however, the area again was under water and deposition of sediments was resumed. The study of drill cuttings from an oil well test in the NW¼ NE¼ sec. 16, T. 16 S., R. 28 W. indicates that the Jurassic Morrison formation is represented by about 100 feet of gray to light-green shale in the subsurface of northern Lane County.

Cretaceous Period

During late Comanchean (early Cretaceous) time a shallow sea transgressed northward across central and western Kansas. The Cheyenne sandstone was deposited near the shore of this advancing sea and the Kiowa shale, which overlies it, in the deeper waters that subsequently covered the area. The sandstone, shale, and clay of the Dakota formation were deposited in a near-shore area at the beginning of Gulfian (late Cretaceous) time. The top of the Dakota is reported to have been encountered at depths ranging from 650 to 990 feet in Lane County. The combined thickness of the Cheyenne, Kiowa, and Dakota in Lane County is more than 500 feet.

After the deposition of the Dakota formation marine conditions prevailed throughout most of the remainder of Cretaceous time. Hundreds of feet of shale, limestone, and chalk were deposited. These formations in order of deposition are: Graneros shale, Greenhorn limestone, Carlile shale, and Niobrara formation. Thin beds of bentonite in these formations indicate that at different times volcanic ash was blown into the seas in which the sediments were being deposited. The ash settled in layers and was subsequently altered to bentonite.

The Pierre shale, which is the youngest Cretaceous formation in Kansas, is not found in Lane County. It was probably deposited during late Cretaceous time and subsequently was removed by erosion. In Gove County, immediately north of Lane County, the Pierre formation crops out in one small area.

CENOZOIC ERA

Tertiary Period

Prior to the deposition of Tertiary sediments in western Kansas there was a period of uplift and at the beginning of Tertiary time there was an extensive land surface. While streams were laying down widespread sheets of sand, gravel, and silt in the plains to the north, the land surface of western Kansas was being subjected to erosion and great thicknesses of Upper Cretaceous sediments were stripped off. In Lane County the Pierre shale, if ever deposited, was removed as were variable thicknesses of the Niobrara. According to Smith (1940, p. 80) the erosion surface on which the Ogallala formation was deposited was by no means a peneplain, but was characterized by considerable relief, locally as much as 200 feet (Figs. 5 and 6).

During the Pliocene Epoch a reversal from stream erosion to stream deposition occurred in the area of western Kansas. Widely shifting streams from the Rocky Mountains made extensive deposits of sand, gravel, silt, and clay over the High Plains surface. By the end of the Tertiary period the sediments of the Ogallala formation extended in a broad alluvial plain from the Rockies perhaps as far as the Flint Hills in Kansas (Smith 1940, p. 86).

Quaternary Period

Pleistocene Epoch.—During early Quaternary time uplift of the land occurred and streams were rejuvenated. A period of erosion followed but it was less severe than that preceding the deposition of the Ogallala for the resulting surface had slight relief as compared to the pre-Ogallala surface. Later, sedimentation was resumed and valleys cut in the Ogallala were filled with sediments that comprise the Meade formation. Deposits lying in a slightly southwesterly

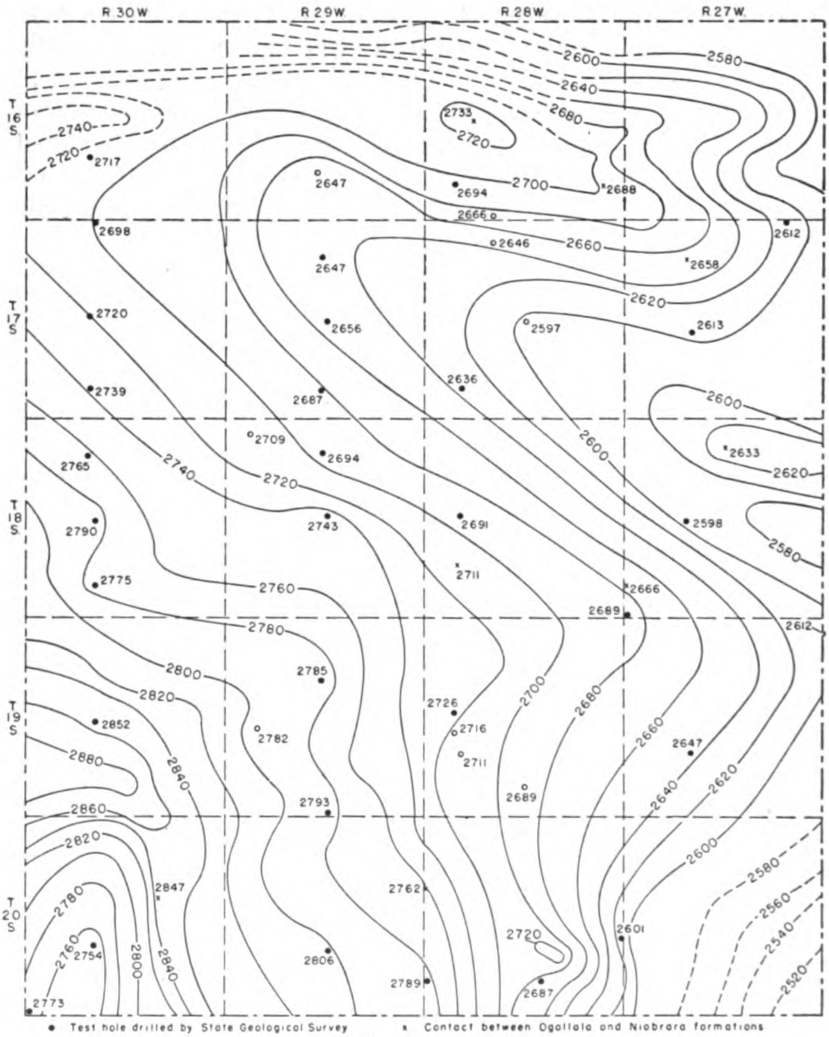


FIG. 5.—Map of Lane County showing the configuration of the bedrock surface beneath the Ogallala by means of contours, the locations of test holes, and the altitudes at which bedrock was encountered in test holes.

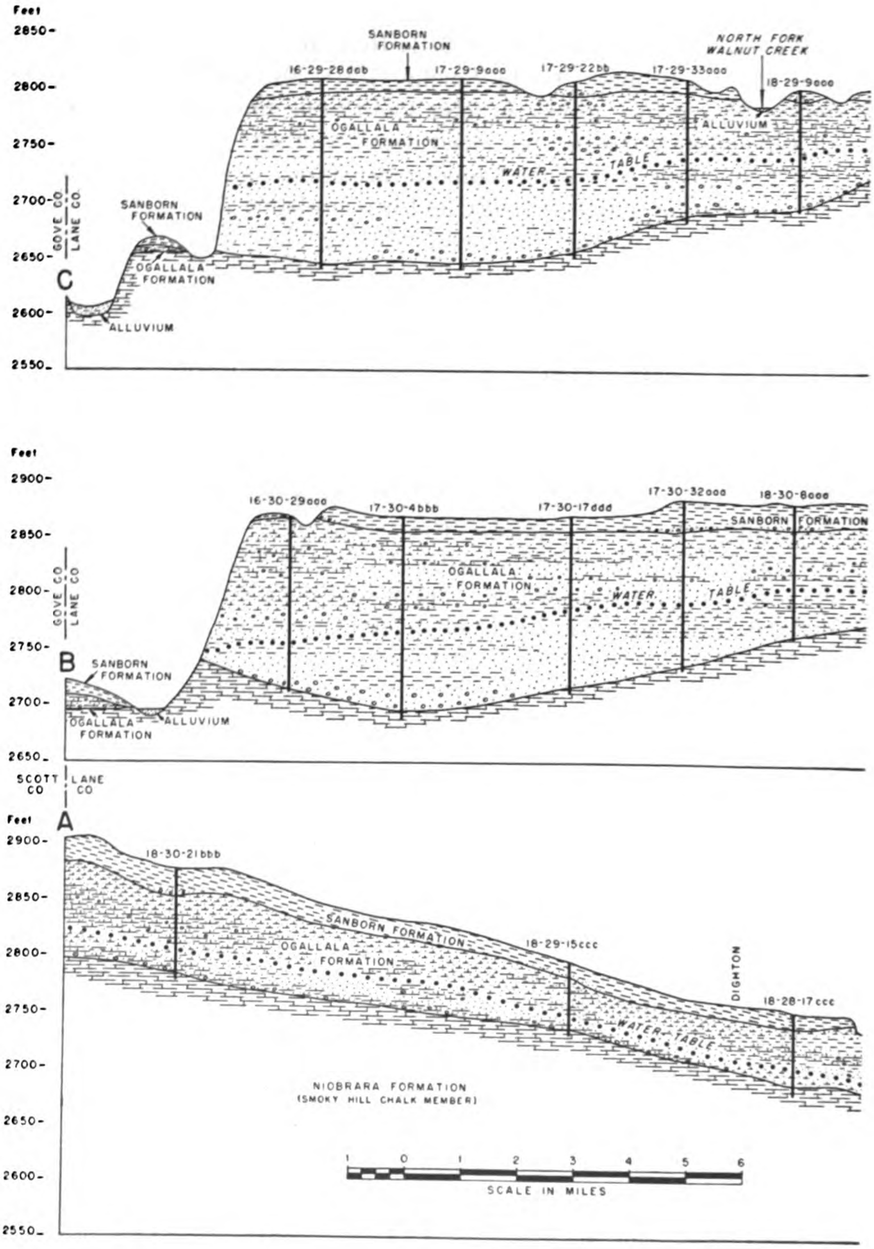
trending basin or depression in southwestern Lane County are tentatively classified as the Meade formation. Here the formation consists mainly of silt and clay, with a small amount of sand and gravel at the base. In the NW¼ of sec. 3, T. 16 S., R. 29 W. a terrace remnant along a tributary to the Smoky Hill is also tentatively classified as Meade formation. In later Pleistocene time aggrading and laterally shifting streams produced deposits of silt, sand, and gravel which constitute part of the Sanborn formation. These deposits are not extensive over Lane County and it is probable that no through-flowing streams crossed the county during Pleistocene time. Apparently in the latter part of the Pleistocene Epoch there was a climatic change and winds became very strong. A layer of wind-blown silt (loess) was deposited over the area to depths as much as 25 feet. The loess and underlying sand and gravel were named Sanborn formation by Elias (1931, p. 163).

In a small area in southwestern Lane County and in adjacent Finney and Scott Counties, the surface is mantled by dune sand. Its age is not known but it is probable that accumulation of the sand started in late Pleistocene time. The sand was probably derived from Pliocene and Pleistocene deposits and carried to its present location by strong winds. Much of the sand may have been derived from the strand flats of a lake that formerly occupied a depression in southeastern Scott County now known as Dry Lake. There is a similar depression in southwestern Lane County and it is likely that much sand was derived from the shores of the lake that it probably once contained.

During Recent time the county has undergone erosion that has formed much of the present topography. Some of the small intermittent streams, which flow periodically in Lane County, have cut down through Pleistocene and Pliocene deposits and deeply into the underlying Cretaceous rocks, exposing the Niobrara formation in many places and the Carlile shale in small, isolated outcrops in the southeast corner. A narrow band of alluvium has been deposited along most of these streams.

During Recent time many shallow depressions have developed on the surface of Lane County and of surrounding areas in the High Plains. The depressions range in diameter from a few yards to about half a mile and may or may not contain water. Most of them hold water after periods of heavy rainfall until the water has evaporated or moved downward to the water table.

The origin of the depressions is not known, but three main theories of origin have been offered. Darton (1916, pp. 36, 37)


Feet
2850-
2800-
2750-
2700-
2650-
2600-
2550-
SANBORN FORMATION
16-29-28dab
17-29-9aaa
17-29-22bb
17-29-33aaa
NORTH FORK WALNUT CREEK
18-29-9aaa
OGALLALA FORMATION
WATER TABLE
ALLUVIUM
GOVE CO
LANE CO
C
SANBORN FORMATION
OGALLALA FORMATION
ALLUVIUM
Feet
2900-
2850-
2800-
2750-
2700-
2650-
16-30-29aaa
17-30-4bbb
17-30-17ddd
17-30-32aaa
18-30-8aaa
SANBORN FORMATION
OGALLALA FORMATION
WATER TABLE
GOVE CO
LANE CO
B
SANBORN FORMATION
OGALLALA FORMATION
ALLUVIUM
SCOTT CO
LANE CO
Feet
A
2900-
2850-
2800-
2750-
2700-
2650-
2600-
2550-
18-30-21bbb
SANBORN FORMATION
OGALLALA FORMATION
18-29-15ccc
DIGHTON
18-28-17ccc
WATER TABLE
NIOBRARA FORMATION
(SMOKY HILL CHALK MEMBER)
1 0 1 2 3 4 5 6
SCALE IN MILES

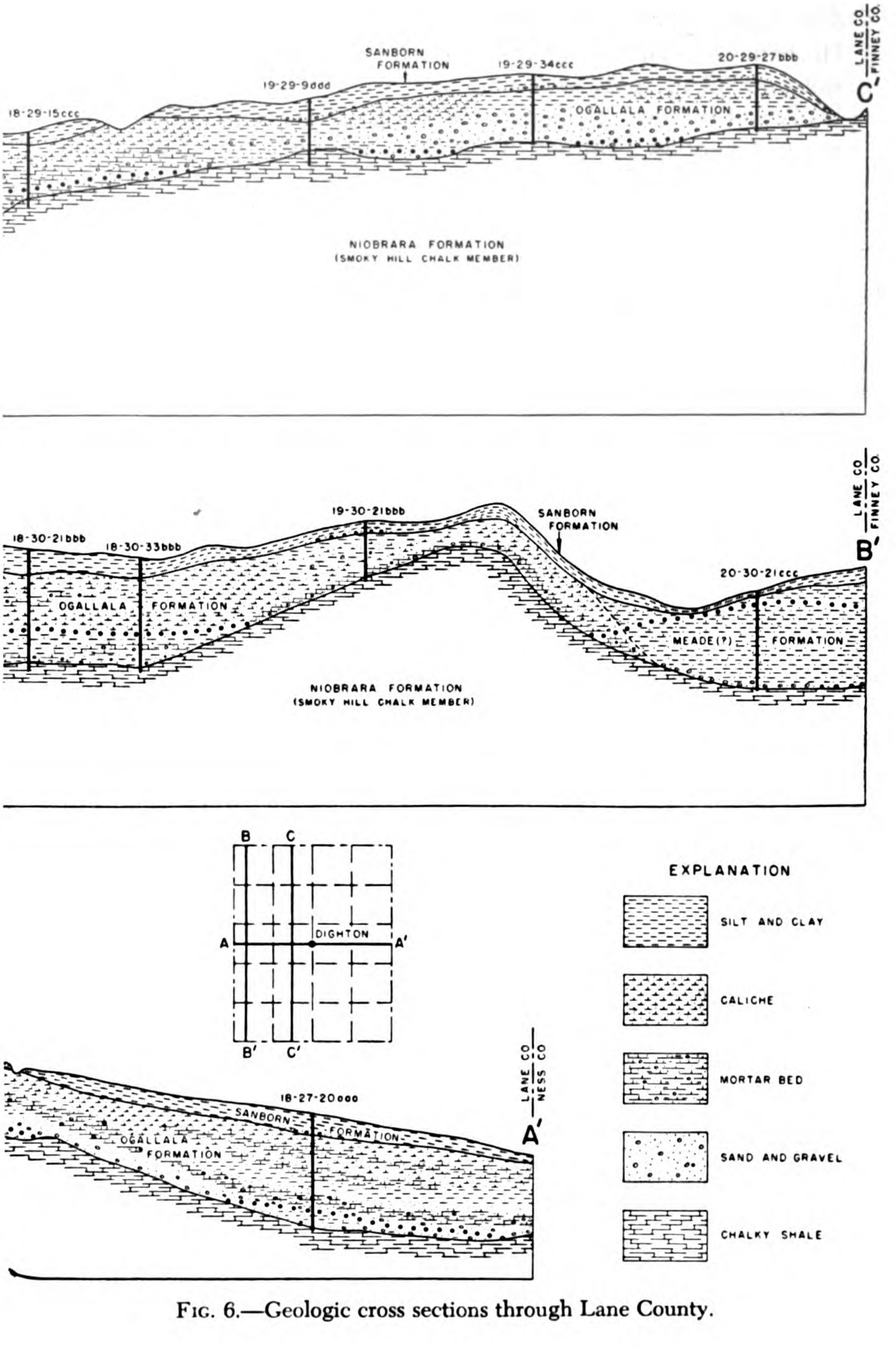


FIG. 6.—Geologic cross sections through Lane County.

referred to some of these High Plains depressions as "buffalo wallows" and explained their origin by the action of buffalos and wind. He believed that the depressions were started by buffalos at wet, salty, or alkali spots, and that they were excavated by tramping hoofs and by mud sticking to the shaggy coats of the animals during wet periods. During dry periods, the sod cover having been broken exposing the soil, wind scour became the dominant mode of erosion. Whereas this hypothesis might account for some of the small shallow depressions, it probably would be inadequate for the larger, more extensive depressions.

For the large basins in the area of Permian bedrock or where the Tertiary cover was thin, Johnson (1901, pp. 702-712) advocated an origin of solution of soluble beds of the Permian followed by collapse of the overlying beds and development of surface depressions. This theory explains satisfactorily the origin of large sinks such as the Salt Well in Meade County and the Big Basin and St. Jacob's Well in western Clark County, but would not adequately explain the origin of depressions—especially small, shallow, round, or oval depressions—in areas of thick Cretaceous bedrock as in Lane County.

Smith (1940, p. 171) stated that—

> . . . These depressions are probably a result of subsidence due to solution of salt or gypsum beds in Permian or early Mesozoic formations, or possibly in the case of the Scott-Finney depression, of calcareous beds in the Cretaceous.

Johnson (1901, p. 711) considered that—

> . . . the innumerable upland basins, especially where the floor is Cretaceous to great depths, are clearly ascribed to grain-by-grain processes of readjustment and compacting, at work within the Tertiary only.

Concerning the mechanics of the compaction process he stated (pp. 703, 704):

> Appearances indicate basining of the alluvial source as a consequence, first, of rain water accumulation in initial faint unevennesses of the plain; second, of percolation of this ponded surface water downward to the ground water in largely increased amount from these small areas of concentration, rather than from the surface uniformly, with the result that the alluvial mass is appreciably settled beneath the basins only. The inference is at once suggested that this settlement takes place as the combined effect of mechanical compacting of the ground particles and the chemical solution of the more soluble particles. Finally, these effects should be cumulative, resulting in the growth noted, since, with enlargement of the basins, concentration of rain water within them will be on an increased scale.

Johnson's hypothesis has not been widely accepted, but Latta (1944, p. 45) states that it accounts more plausibly than other theories for the origin of the small, shallow depressions in Finney

County. Likewise, Frye (1945, p. 31) accepts this theory of origin for surface depressions in Thomas County. Probably many of the depressions found in Lane County were formed in this manner, although it would be impossible to prove this with the evidence now available.

GROUND WATER

Principles of Occurrence

The following discussion of the occurrence of ground water has been adapted from Meinzer (1923, pp. 2-102) and the reader is referred to his report for a more detailed discussion. A general discussion of the principles of ground-water occurrence with special reference to Kansas has been made by Moore and others (1940).

All the water below the surface of the earth is termed subsurface water. The part of subsurface water that is in the zone of saturation is called ground water or phreatic water whereas subsurface water above the zone of saturation is called suspended subsurface water or vadose water. Ground water is the water that is obtained from wells and springs.

The rocks that form the outer crust of the earth are seldom solid throughout. They contain numerous open spaces called voids or interstices which may contain air, gas, oil, or water. The occurrence of water in the rocks of any region is determined by the character, distribution, and structure of the rocks—that is, by the geology of the region.

Interstices in rocks range in size from microscopic openings to large caverns. The open spaces are generally connected so that water may percolate from one to another, but in some rocks the interstices are largely isolated and the water has little opportunity to percolate.

In Lane County most of the ground water is obtained from poorly consolidated sands and gravels of the Ogallala formation. Generally Tertiary sands and gravels contain many interstices through which water may percolate, but locally the interstices are filled with calcium carbonate, silt, or clay, which makes the rock relatively impermeable. In many places the sands of the Ogallala are very poorly sorted and silt and fine sand fill the interstices, thereby decreasing the amount of space available for ground water. The lenticular sandstones in the Dakota formation yield water to a few wells in Lane County. These sandstones still have enough voids to contain water, although the individual sand grains are generally cemented with iron oxide, silicon dioxide, or calcium carbonate.

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The porosity of a rock is its property of containing interstices. The porosity is expressed quantitatively as the percentage of the total volume of the rock that is occupied by interstices. When all the interstices are full of water, a rock is said to be saturated and the porosity is practically the percentage of the total volume of rock that is occupied by water.

A rock may be very porous but may yield very little water to wells. A rock containing small interstices may be very porous, but water might pass through it with difficulty whereas a coarse-grained rock, although possibly less porous, might allow water to pass through it more freely. Several common types of open spaces or interstices and the relation of texture to porosity are shown in Figure 7. The specific yield of a water-bearing formation is defined as the ratio of (1) the volume of water which, after being saturated, the formation will yield by gravity to (2) its own volume. Specific yield is a measure of the yield of a water-bearing formation when it is drained by a lowering of the water table. The permeability of water-bearing material is defined as the material's capacity for transmitting water under hydraulic head; it is measured by the rate at which the material will transmit water through a given cross section under a given difference of head per unit of distance.

The upper surface of the zone of saturation is called the ground-water table or the water table. All the rocks above the water table are in the zone of aeration, which usually consists of three parts:

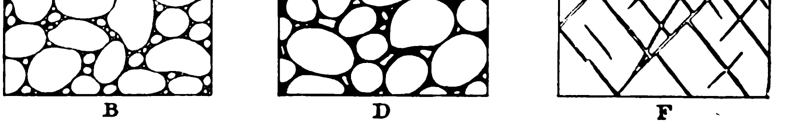

FIG. 7. Diagram showing several types of rock interstices and the relation of rock texture to porosity. A, Well-sorted sedimentary deposit having a high porosity; B, poorly sorted sedimentary deposit having low porosity; C, well-sorted sedimentary deposit consisting of pebbles that are themselves porous 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 O. E. Meinzer.)

the belt of soil water, the intermediate or vadose zone, and the capillary fringe.

The belt of soil water lies just below the land surface and contains water held by molecular attraction. The thickness of the zone is dependent upon the character and thickness of the soil and upon the precipitation and vegetation.

The intermediate zone lies between the belt of soil water and the capillary fringe. The interstices in this zone usually are filled with air but may at times contain appreciable amounts of water while it is moving downward to the water table. The intermediate zone may be absent in places where the water table is near the surface, or it may be more than 100 feet thick as in parts of Lane County.

The capillary fringe, which lies directly above the water table, comprises water rising from the zone of saturation by capillary action. The water in the capillary fringe is not available to wells, which must be deepened to the saturated zone before water will enter them. The capillary fringe is very thin in coarse-grained sediments where capillary action is negligible, but may be several feet thick in fine-grained sediments.

Rock Types and Their Water-Bearing Properties

WATER IN SAND AND GRAVEL

Lane County is underlain by deposits of unconsolidated and partially cemented materials that were laid down by streams in Tertiary and Quaternary time. The sorting action of streams on these sediments resulted in the deposition of distinct beds of gravel, sand, silt, and clay. Deposits of such uniform texture may have a relatively high porosity. Coarse, well-sorted gravel of this type has a high specific yield and permeability, whereas uniform deposits of silt or fine sand, although very porous, have a low specific yield and low permeability. Properly constructed wells in well-sorted uniform gravel yield large quantities of water. Much of the stream-laid material is poorly sorted, and fine material occupies much of the pore space between the larger grains, thus reducing the porosity and the specific yield.

The largest ground-water supplies in Lane County are obtained from beds of sand and gravel in the Ogallala formation. All the active irrigation wells and the majority of domestic and stock wells obtain their water from the Ogallala. In the southwest corner of the county, Pleistocene silts and fine sands of the Meade (?) formation yield water to wells, and Recent alluvial deposits yield small supplies of water along stream valleys.

WATER IN SANDSTONE

Sandstone ranks next to sand in its ability to store and transmit water. The factors determining the water-bearing properties of a sandstone are the grain size, sorting, and cementation. A coarse-grained, well-sorted sandstone generally yields water freely, whereas a well-sorted fine-grained sandstone may contain much water, but will surrender it slowly. Many sandstones are so tightly cemented that they will not yield water from the original openings between grains. A tightly cemented sandstone may, however, contain joints and fractures that bear water.

The Dakota formation contains the only water-bearing sandstones known to yield water to wells in Lane County. Information on the yield of these wells and on the character of the water-bearing beds is not available.

WATER IN LIMESTONE AND SHALE

Chalk, chalky limestone, and chalky shale are usually not important sources of water, but several wells in southern Lane County derive part of or all their water from the chalky limestone of the Fort Hays member of the Niobrara formation. Water occurs in limestone in fractures or in solution openings caused by water containing dissolved carbon dioxide. The occurrence of fractures and solution openings is very irregular, making it difficult to predict where water may be found in a limestone. Sometimes many test wells must be drilled to locate openings before a final well can be put down. In some areas it is impossible to recover enough water from limestone and chalk to supply even small domestic or stock wells.

Shale is a very unfavorable rock from which to obtain water. If not too tightly indurated, it may be highly porous and contain much water. However, the interstices are small and water held there by molecular attraction is not available to wells. Some water is found in shale along joints and bedding planes.

PERMEABILITY OF THE WATER-BEARING MATERIALS

The rate of movement of ground water is determined by the size, shape, quantity, and degree of connection of the interstices and by the hydraulic gradient. The capacity of a water-bearing material for transmitting water under hydraulic head is its permeability. The coefficient of permeability in Meinzer's units may be expressed as the rate of flow of water, in gallons a day, through a crosssectional area of 1 square foot under a hydraulic gradient of 100 percent at a temperature of 60° F. (Stearns, 1927, p. 148). The coefficient of transmissibility is a similar measure and is defined as the number of gallons of water a day transmitted through each 1 foot strip extending the height of the aquifer under a unit gradient (Theis, 1935, p. 520). It may also be expressed as the number of gallons of water a day transmitted through each section 1 mile wide extending the height of the aquifer, under a hydraulic gradient of 1 foot to the mile. The coefficient of transmissibility is equivalent to the coefficient of permeability multiplied by the thickness of the aquifer.

Concerning the relation of permeability of water-bearing materials, Wenzel (1942, p. 11) states:

> Although there are many water-bearing materials of low permeability, most formations that are sufficiently water-bearing to be utilized by wells have coefficients that are whole numbers of two or more figures when expressed in Meinzer's units—that is, above 10. The yields of wells depend, of course, not only on the permeability of the formations they tap but also on the thickness of the formations, the drawdown of the water level, and the diameter and construction of the wells. For many places in the United States the physical and economic conditions are such that wells with moderate to high yields—100 gallons a minute or more—generally penetrate materials with coefficients of permeability of 100 or more.

Pumping Tests

The coefficient of permeability of water-bearing materials can be determined in the laboratory (methods summarized by V. C. Fishel in Wenzel, 1942, pp. 56-58) or in the field using the recovery method involving the formula developed by Theis (1935, p. 522) and later described by Wenzel (1942, pp. 94-96). Three pumping tests were made in Lane County in September 1948 by Woodrow W. Wilson of the Federal Geological Survey.

From his final equation expressing the relation between the drawdown and the rate and duration of the discharge of a well, Theis developed the following formula:

$$T = \frac{264q}{s} \log_{10} \frac{t}{t_1}$$

in which T = coefficient of transmissibility

q = pumping rate, in gallons a minute

t = time since pumping started, in minutes

t_1 = time since pumping stopped, in minutes

s = residual drawdown at the pumped well, in feet, at time t_1

The residual drawdown (s) is computed by subtracting the static water-level measurement from depth to water-level measurements made after pumping ceases.

The proper ratio of $\log_{10} \frac{t}{t_1}$ to s is determined graphically by plotting $\log_{10} \frac{t}{t_1}$ against corresponding values of s. This procedure is simplified by plotting $\frac{t}{t_1}$ on the logarithmic coördinate and s on the arithmetic coördinate of semi-logarithmic paper. If $\log_{10} \frac{t}{t_1}$ is taken over one log cycle it will become unity and s will be the difference in drawdown over one log cycle.

Theoretically the curve is a straight line that passes through the origin. It does not do so for all pumping tests, however. W. F. Guyton, in a personal communication, stated that this condition need not be fulfilled; therefore, in these pumping tests no empirical correction was made in order that the straight line pass through the origin. Adjustment for temperature was unnecessary as the temperature was only slightly less than 60° F.

Well 17-28-22aaa, an irrigation well on the farm of Carl Filbert, was pumped for approximately 4 hours on Sept. 29, 1948. Drawdown measurements were made with a wetted tape during the period of pumping, and recovery measurements were made for nearly 2 hours after the pump was shut down. The well was pumped at an average rate of 1,040 gallons a minute (determined by a Collins flow meter); at the end of pumping the drawdown was 23.23 feet and the specific capacity was about 45 gallons per minute per foot of drawdown.

The computations for permeability and transmissibility are as follows:

$$T = \frac{264 \times 1{,}040 \times 1}{1.18} = 233{,}000 \text{ g. p. d./ft.}$$

$$P = \frac{233{,}000}{69} = 3{,}400 \text{ g. p. d./sq. ft.}$$

The transmissibility is computed to be 233,000 gallons per day per foot and the coefficient of permeability, determined by dividing the transmissibility by the thickness of the aquifer, which is 69 feet,

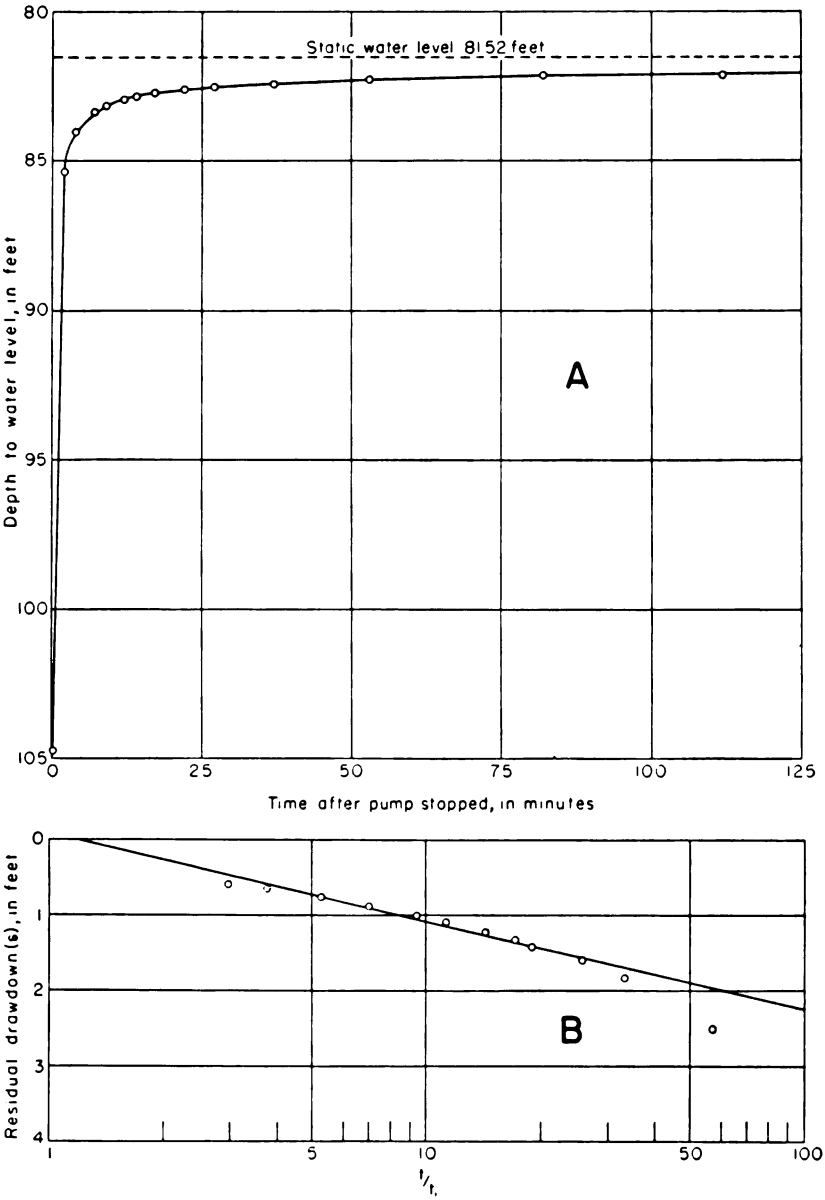

FIG. 8.—Curves for pumping test on well 17-28-22aaa on the Carl Filbert farm.

is 3,400 gallons per day per square foot. These values are higher than values obtained in other pumping tests made in Lane County.

Curves for the pumping test on well 17-28-22aaa are shown in Figure 8; data that were plotted to obtain these curves are given in Table 3. Results of this test and two other pumping tests are summarized in Table 4.

TABLE 3.—*Data on pumping test of well 17-28-22aaa in Lane County, Kansas, made on Sept. 29, 1948*

Time since pumping started, minutes	Time since pumping stopped, minutes	t/t_1	Yield, gallons per minute	Depth to water, feet	Draw-down, feet
....	....	....	....	81.52	....
9	....	....	1051	104.80	23.28
39	....	....	1037	104.75	23.23
69	....	....	1037	104.95	23.43
99	....	....	1034	105.10	23.58
129	....	....	1047	104.70	23.18
159	....	....	1039	104.80	23.28
189	....	....	1034	104.75	23.23
219	....	....	1041	104.75	23.23
229	2	114.5	....	85.35	3.83
231	4	57.8	....	84.04	2.52
234	7	33.4	....	83.38	1.86
236	9	26.0	....	83.14	1.62
239	12	19.9	....	82.95	1.43
241	14	17.2	....	82.85	1.33
244	17	14.4	....	82.74	1.22
249	22	11.3	....	82.62	1.10
254	27	9.4	....	82.54	1.02
264	37	7.1	....	82.42	.90
280	53	5.3	....	82.30	.78
309	82	3.8	....	82.19	.67
339	112	3.0	....	82.13	.61

Table 4.—*Results of pumping tests made on wells in Lane County, Kansas, using the Theis recovery method for determining permeability*

Well number	Discharge, gallons a minute	Drawdown, feet	Duration of pumping, minutes	Specific capacity	Coefficient of transmissibility	Approximate thickness of water-bearing material, feet	Coefficient of permeability
16–29–28dab........	550	36.37	252	15.1	23,000	73	320
17–28–22aaa........	1,040	23.23	227	44.8	233,000	69	3,400
17–28–15cb.........	790	11.52	242	68.6	174,000	60	2,900

Artesian Conditions

Artesian water is ground water under sufficient pressure to rise above the point at which it is encountered in wells. A well that flows at the land surface is a flowing artesian well. To be under artesian conditions a water-bearing bed must be overlain by an impermeable or relatively impermeable bed that dips from its outcrop area to its area of discharge. Water entering the bed at the outcrop percolates down gradient where it is held in the water-bearing bed by the overlying confining layer. Down dip from the outcrop the water exerts considerable pressure against the confining bed, causing the water to rise in a well drilled through the confining layer. If the water is under sufficient pressure and if the land surface of the well is at a lower altitude than that at the outcrop area, the water may rise high enough to flow at the surface. In places where there are lenses or beds of relatively impermeable clay or silt at the level of the water table, the water encountered beneath such lenses will rise to the level of the surrounding water table, but such water is under normal pressure and is not considered artesian.

Lane County has no flowing artesian wells, but it is reported that a seismograph drilling crew found an artesian flow in a shot hole drilled in the northeast corner of sec. 22, T. 18 S., R. 27 W. The depth of this hole is not known but the aquifer was probably a lenticular sandstone in the Dakota formation.

Artesian water has been found in several wells drilled to the Dakota formation in Lane County. Logs of these wells are not available, but Mr. Carlos Roberts informed me that in a 673-foot well drilled on his farm in the SE¼ SW¼ NW¼ sec. 4, T. 16 S., R. 28 W., an artesian aquifer was encountered at 642 feet and that the water rose to 285 feet. In 1948 at the time of this investigation the water level was 296 feet below the land surface.

The Water Table and Movement of Ground Water

SHAPE AND SLOPE

The water table is defined as the upper surface of the zone of saturation except where that surface is formed by an impermeable body (Meinzer, 1923a, p. 32). Where the upper surface is formed by impermeable material (as in several areas in Lane County) the water table is absent. The water table is not a plane surface in all parts of the county. Its shape is roughly comparable to that of the land surface although it is not so rugged. It fluctuates owing to variations in discharge and recharge.

The shape and slope of the water table are shown on Plate 1 by contour lines drawn on the water table. Water-table contour lines connecting points of equal altitude show the configuration of the water surface just as topographic contour lines show the shape of the land surface. The direction of movement of ground water is at right angles to the water-table contour lines.

It is not practical to draw water-table contours for several areas in Lane County because there is little or no water-bearing material in some areas (Fig. 9). Occasionally a well drilled in these areas obtains a little water from the Ogallala but generally a dry hole is the result. Some wells in areas where the Cretaceous bedrock is at or near the surface obtain water from limestone, shale, or alluvium in stream valleys. In some areas water cannot be obtained from limestone and chalk, and deep wells may be drilled to sandstone lenses in the Dakota.

Plate 1 shows that the ground water is moving through Lane County in a general easterly direction. Local differences in permeability and thickness of the water-bearing beds affect the slope of the water table, the average being about 10 feet to the mile. In general, the slope of the water table varies inversely with the permeability of the water-bearing material. In areas where the water-bearing beds are relatively impermeable, the slope of the water table steepens, but in areas of permeable water-bearing beds, the water-table contours are farther apart.

FLUCTUATIONS IN WATER LEVEL

The water table is not a static surface but a surface that fluctuates much like the surface of a lake. Over a long period of time, a condition of approximate equilibrium exists between the amount of water that is added annually to ground-water storage and the amount that is discharged annually by both artificial and natural means. In general, the water table rises when the amount of recharge exceeds the amount of discharge and declines when the discharge is greater than the recharge. Thus, changes in water levels in wells record the fluctuations of the water table and indicate to what extent the ground-water reservoir is being depleted or replenished.

The principal factors controlling the rise of the water table in Lane County are the amount of precipitation that penetrates the ground and reaches the zone of saturation, seepage from streams and depressions, and the amount that enters the county beneath the surface from the west. Factors controlling the decline of the water table are pumpage from wells, seeps and springs, evaporation and transpiration in shallow-water areas, and the eastward movement of ground water out of the county. The factors causing the water table to rise are discussed in the section on ground-water recharge and the factors causing the water table to decline are discussed in the section on ground-water discharge.

In the summer of 1948 a few wells in Lane County were selected as observation wells in order to obtain information concerning fluctuations in storage of the underground reservoir. No regular measurements of these wells were made until January 1950. Prior to this time, no record of water-table fluctuations had been kept in Lane County, although a close check on water levels has been kept for several years in adjacent Scott and Finney Counties.

Ground-Water Recharge

RECHARGE FROM LOCAL PRECIPITATION

Recharge, the addition of water to the underground reservoir, may be accomplished in several ways. All ground water available to wells in Lane County (except those wells to the Dakota formation) is derived from precipitation as rain or snow within the area or within near-by areas to the west. Part of the water that falls as some form of precipitation is carried away as surface runoff and is lost to streams; part may evaporate or be absorbed by vegetation and transpired directly to the atmosphere. The remaining water percolates slowly down through the soil and underlying strata until it joins the body of ground water in the zone of saturation.

The quantity of water that is carried away by surface runoff depends on the duration and intensity of rainfall, soil moisture, the slope of the land, the porosity of the soil, and the type and amount of vegetation. Conditions are much more favorable for rainfall penetration during a gentle rain of long duration than during a torrential downpour when runoff is high.

The slope of the land is an important factor in determining the amount of runoff and generally the steeper the slope, the greater the runoff. In much of Lane County the slope is gentle, but steep slopes occur along Walnut and along other small creeks, including several tributaries to Smoky Hill River. In the uplands, runoff is reduced considerably by drainage into many small depressions where water is held after rains until it sinks into the ground or is evaporated.

The type of soil also is important in determining the amount of runoff and recharge. In general, runoff is greater in places of tightly compacted fine-grained soil than in places of sandy loose soil. Furthermore, runoff is greater in the winter when the frozen ground is impervious, thereby preventing infiltration of precipitation.

The velocity of runoff is reduced by a suitable vegetative cover; thus water has a better opportunity to seep into the ground. Modern methods of land terracing and contour farming tend not only to retard the erosion of valuable soil but also to reduce runoff and therefore increase the recharge of water to the soil and to the water table.

Most of the water that reaches the surface as precipitation never reaches the water table because it is lost by evaporation and transpiration. Much of the precipitation falls from May through August when the climate is characterized by high temperatures, low humidity, good wind movement, and consequently a high rate of evaporation. Thirty-year records at the Garden City Experimental Farm show the following average rates of evaporation from a free water surface during the months of the growing season: April, 6.68 inches; May, 8.46 inches; June, 10.25 inches; July, 11.90 inches; August, 10.42 inches; and September, 8.10 inches (Smith, 1940, p. 28). It is obvious that the opportunity for evaporation exceeds the amount of precipitation; therefore much of the annual precipitation in this area is probably lost to evaporation.

The water that is not lost by evaporation and runoff percolates downward into the soil zone. When the amount of water absorbed by the soil is greater than can be held against gravity, movement from the soil zone to the zone of saturation will take place. During the growing season this downward movement will be largely prevented by evaporation, absorption, and transpiration by plants; at the end of the growing season the moisture in the soil may be depleted. During the fall and winter when transpiration and evaporation are at a minimum, the soil zone may again become saturated and recharge to the water table may take place if precipitation is sufficient.

Although the average annual rainfall in Lane County is from 18 to 19 inches, actually only a very small percentage ever reaches the water table. Frye (1942, p. 66) estimated that in the southern High Plains the average amount of precipitation that reaches the water table is about one-fourth inch. Theis, Burleigh, and Waite (1935, pp. 2-3) stated:

> . . . On the average over the High Plains only about half an inch of water a year escapes evaporation and absorption by the vegetation and percolates through the soil to the ground-water body.

This is a small percentage of the annual rainfall, but it should be mentioned that one-fourth inch of water entering the ground-water reservoir under a section of land (1 square mile) amounts to more than 4 million gallons or 13.3 acre-feet, and one-half inch of rainfall over a section of land amounts to more than 8 million gallons or nearly 26.7 acre-feet.

Recharge in sand-dune area.—Recharge from precipitation is probably fairly high in the sand-dune area that covers a few square miles in the southwestern corner of the county. Much of the rain that falls on the dune-covered area is absorbed by the sand; for that reason there is little runoff. However, only a small area in southwestern Lane County benefits from this high recharge, as most of the water that reaches the water table flows southward into Finney County.

Recharge in depressions.—Shallow depressions or basins are very common in Lane County, especially in the south-central part of the county. These depressions are shown on Plate 1 as intermittent ponds. After heavy rains water collects in the depressions to form temporary ponds. The water in some of these ponds disappears quickly, whereas in others it may remain for several weeks or months. Whether or not such intermittent ponds can furnish water to the underground reservoir depends upon the character of the underlying deposits. If the deposits beneath the floor of the depression are fine-textured and relatively impermeable, water will stand in the depression until evaporated. If the materials beneath the floor are relatively permeable, much of the accumulated water will sink into the ground. Studies of the character of deposits underlying similar depressions in the High Plains of Texas have been made by White, Broadhurst, and Lang (1940). Several hundred test holes showed that subsurface conditions beneath the depressions were quite variable. In some areas the sediments penetrated were relatively permeable from the surface to the bottom of the hole, but in others beds of caliche and cemented beds would have made downward infiltration of water very difficult. They (White, Broadhurst, and Lang, 1940, p. 7) noted also:

The bottom of most of the depressions is covered with deposits of silt and soil . . . After the ponds become dry, fractures and crevices several feet in depth frequently develop in their beds. In some of the depressions small sinks, apparently developed by solution channelling in the underlying caliche deposits, are present. These crevices and solution channels may provide a pathway for the downward movement of water for a time after the ponds are filled, although they may become sealed after water has stood over them for several days.

Latta (1944, pp. 73-74) presented evidence that rapid recharge from storm water took place in a Finney County well in one of these depressions. Even though the water level in the well is 112 feet below the surface, a rapid response to precipitation was noted and a temporary mound on the water table developed. This mound gradually smoothed out as the water moved out laterally to lower altitudes on the water table. Latta concluded that other depressions in the uplands probably act as catchment areas for recharge and the water table beneath them probably shows similar fluctuations.

In Lane County the floors of some depressions are traversed by mud cracks that develop during dry periods. Other depressions have a soil cover that seems to be an effective seal against recharge of ground water. Probably conditions similar to those found in the High Plains of Texas and in Finney County exist in Lane County.

Recharge from streams.—Lane County is crossed by no perennial streams; therefore ground-water recharge from streams occurs only after storms that produce surface runoff. The north fork of Walnut Creek drains a considerable area in the north-central part of the county. The stream valley contains some alluvium that is relatively permeable, and after periods of heavy rainfall limited amounts of water enter the alluvium to migrate downward to the water table. Near the eastern edge of the county, the stream has eroded through the mortar beds of the Ogallala formation into the Smoky Hill chalk member of the Niobrara formation. The stream has cut below the base of the main zone of saturation which is in the Ogallala formation; consequently, any precipitation that penetrates the alluvium cannot join the ground-water reservoir in the Ogallala formation but remains in the alluvium or travels eastward through the alluvium as underflow. The same condition prevails along the south fork of Walnut Creek, and from a point about three miles southeast of Dighton no water from the alluvium is added to the body of ground water in the Ogallala formation.

RECHARGE FROM OUTSIDE AREA

The movement of ground water in Lane County as indicated by the slope of the water table is eastward; therefore some recharge from precipitation that occurs in areas to the west eventually moves into the county and is added to the available supply of ground water.

The Dakota formation does not crop out in Lane County; the water available to wells in the Dakota in Lane County must have been derived from areas to the west and south.

RECHARGE FROM IRRIGATION WATER

In areas of extensive irrigation, ground-water recharge occurs by seepage from ditches and by downward percolation after the water has been spread on the fields. In the area of the pumped well the water table declines, but in the area where the water returns to the ground-water body, the water table rises temporarily. In 1948, five deep irrigation wells were completed in Lane County but only two of them were pumped appreciably and there was probably little or no recharge from irrigation water.

Discharge of Subsurface Water

Meinzer (1923a, p. 48) has divided the discharge of subsurface water into vadose-water discharge (discharge of soil water not derived from the zone of saturation) and ground-water discharge or discharge from the saturated zone.

DISCHARGE OF VADOSE WATER

The discharge of soil water not derived from the zone of saturation, called vadose-water discharge, includes the discharge of water directly from the soil by evaporation and discharge from growing plants in the process of transpiration. The large consumption of water by crops is vitally important to agriculture. This consumption of water reduces recharge because the deficiency of soil moisture must be replenished before recharge can take place.

DISCHARGE OF GROUND WATER

The discharge of water from the zone of saturation may be accomplished by transpiration and evaporation, by underflow from the area, and by discharge from springs and wells.

Discharge by transpiration and evaporation.—Water may be taken into the roots of plants directly from the zone of saturation or from the capillary fringe and may be discharged from the plants by the process known as transpiration. The depth from which plants will lift ground water varies greatly with different plant species and soils. The lift of ordinary grasses and field crops is limited to a few feet; alfalfa may obtain ground water where the water table is as much as 30 feet below the surface, and certain desert plants are known to send their roots to depths of 50 or 60 feet (Meinzer 1923, pp. 82, 83).

In most of Lane County the water table is considerably below the root tips of plants, and water that is used by plants must be obtained from the belt of soil moisture. In the small basin in southwest Lane County and in stream valleys where the water table is not far beneath the surface, plants may draw water directly from the zone of saturation. Direct evaporation to the atmosphere from the water table is also limited to such areas where the water table is but a few feet from the surface.

Discharge from springs.—In Lane County some water is discharged from springs in the northern part of the county at the heads of small valleys tributary to Smoky Hill River, at the eastern extremity of the north fork of Walnut Creek, at places along the south fork of the Walnut, and in other small valleys. Most of the springs are contact springs that occur at or near the contact between the water-bearing sands and gravels of the Ogallala formation and the impervious shales and limestones of the Niobrara.

In the fall of 1948 a spring near the cen. N½ sec. 20, T. 16 S., R. 30 W. had sufficient flow to give rise to a small stream that flowed northeastward for nearly 4 miles. A spring in the SE¼ sec. 11, T. 16 S., R. 27 W. furnished enough water for use at one farm home near by. Another spring that furnishes water to stock is in sec. 22, T. 17 S., R. 27 W. on the north side of a small draw where water in Ogallala deposits comes in contact with the underlying shale of the Niobrara formation and is forced to the surface. There are other contact springs in secs. 11 and 12, T. 18 S., R. 27 W. Yields of the springs were not measured but they probably do not exceed a gallon a minute.

Discharge from wells.—Another method of discharge of water from the ground-water reservoir is in the discharge of water from wells. Dighton is the only city in Lane County that has municipal wells. In 1948 two irrigation wells were in operation in the county and in 1949 there were five. Figures on the pumpage for irrigation are not available. All domestic supplies and most of the stock supplies in Lane County are obtained from wells, but the amount of water discharged for this purpose is comparatively small.

Discharge to areas outside the County.—Probably a considerable amount of ground water moves from Lane County to adjacent areas. As shown on Plate 1 Cretaceous rocks crop out in the eastern part of

Lane County, which indicates that very little ground water flows eastward from Lane County into Ness County. However, on the eastern and southern sides of Lane County, the area having a discontinuous water table contains a considerable amount of water derived mainly from local precipitation. It leaves the county mainly as underflow along Hackberry Creek, the forks of Walnut Creek, and other intermittent streams. Water discharged from springs may enter alluvial materials along creeks, again becoming ground water and leaving the county as underflow. Probably a small amount of ground water leaves the county to the north in alluvium along tributaries to Smoky Hill River. Much of the precipitation that falls on the sand-dune area in southwestern Lane County joins the ground-water body and flows southward into Finney County.

Recovery of Ground Water

PRINCIPLES OF RECOVERY

The discharge from a well is produced by a pump or some other lifting device or by artesian pressure. When water is standing in a well the pressure within the well is equal to the pressure outside the well. Whenever water is pumped from a well the pressure inside the well is reduced and water moves into the well.

When water is being discharged from a well the water table in the vicinity of the well declines, taking the form of an inverted cone (called the cone of depression). The distance that the water level is lowered is called the drawdown; the greater the pumping rate, the greater will be the drawdown, the diameter of the cone of depression, and the area of influence. When pumping stops, the cone of depression gradually fills with water from adjacent areas until equilibrium is reached.

The total capacity of a well is the rate at which it will yield water after the water stored in the well has been removed. The capacity depends upon the quantity of water available, the thickness and permeability of the water-bearing bed, and the construction and condition of the well.

The specific capacity of a well (its rate of yield per unit of drawdown) is determined by dividing its yield by the drawdown in feet. Well 17-28-15cb in Lane County has a yield of 790 gallons a minute with a drawdown of 11.52 feet. Therefore, the specific capacity of this well is 68.6 gallons a minute per foot of drawdown.

When a well is pumped the water level drops rapidly at first and then more slowly until conditions of approximate equilibrium are reached. The water table may continue to decline for several hours or days. In testing the specific capacity of a well, pumping should be continued until the drawdown of the water level is in approximate equilibrium with the rate of pumping. When pumping is stopped the water level rises rapidly at first but recovery becomes progressively slower and may continue for some time after pumping has ceased. A recovery curve of well 17-28-22aaa is shown in Figure 8.

DUG WELLS

Dug wells are excavated by hand, usually with pick and shovel and sometimes aided by dynamite. Dug wells visited in Lane County range from 2 to more than 4 feet in diameter. Some are uncased, but most are cased with concrete, rock, tile, brick, or metal for at least the top few feet. As a rule dug wells are poorly sealed and are more subject to surface contamination than drilled wells. Because of the labor involved in digging wells by hand, most dug wells penetrate only a few feet below the water table and are more likely to go dry during periods of drought than are the deeper drilled wells. Some of the water-bearing materials have a low permeability, and consequently the wells have a low specific capacity. Because a large dug well acts as a storage reservoir for collecting water during nonpumping periods it will furnish moderate quantities of water if pumped for short periods.

BORED WELLS

A few shallow wells in Lane County were bored in unconsolidated sediments with post-hole diggers or hand augers. Most of them are about 6 inches in diameter and commonly are not cased.

DRILLED WELLS

Most wells in Lane County have been drilled by either the percussion method or the hydraulic-rotary method. A portable cable-tool drill rig mounted on a truck or trailer is used in the percussion method. This method of drilling uses a heavy bit which is lifted and dropped regularly to produce a cutting action at the bottom of the hole. The crushed material at the bottom of the hole is mixed with water added during the drilling process and is removed by means of a bailer. In the hydraulic rotary method a hollow drill stem equipped with a cutting bit is rotated in the hole and cuttings are removed by circulating muddy water down through the drill stem and up through the annular space between the drill stem and the hole. The cuttings are brought to the surface by the drilling fluid. The mud also acts as plaster on the walls of the hole, thereby preventing caving until casing is installed.

Wells in consolidated deposits.—The majority of wells in Lane County obtain water from relatively unconsolidated deposits, but a few obtain water from consolidated Cretaceous sandstone, shale, and limestone of the Dakota and Niobrara formations. Ordinarily these are cased with steel casing through overlying unconsolidated materials and a few feet into bedrock but the lower part of the hole is not cased. When wells in consolidated formations must be cased perforated casing is placed opposite water-bearing beds.

Wells in unconsolidated deposits.—Most wells in unconsolidated deposits are cased to the bottom with galvanized-iron or steel casing to prevent caving of the walls. In some wells the water may enter only through the open end of the casing, but in most wells—particularly those used for irrigation—the casing is perforated below the water table or a well screen is used. The selection of proper size of perforations in casings may determine the capacity and life of a well. If the perforations are too large, fine material filtering through will fill the well; if the perforations are too small they will become clogged so that water cannot enter the well freely. It is good practice to select a slot size that will pass from 30 to 60 percent of the water-bearing material, depending upon the texture and degree of assortment. The coarser particles remaining around the screen form a natural gravel packing, increasing the effective diameter and therefore the capacity of the well.

Gravel-wall wells are often used to obtain large supplies of water from relatively fine-grained unconsolidated deposits, especially for municipal and irrigation wells. In constructing a well of this type, a hole of large diameter (about 30 inches) is cased with blank casing. A well screen or perforated casing of smaller diameter (18 inches in Lane County irrigation wells) is centered in the hole opposite the water-bearing beds, enough unperforated casing being added to reach to the surface. The space between the two casings is filled with well-sorted gravel of a grain size slightly larger than both the openings in the screen or perforated casing and the grain size of the water-bearing material. The outer casing is then withdrawn to allow the water to flow from the water-bearing material through the gravel packing. The selected gravel surrounding the screen increases considerably the effective diameter of the well, thereby decreasing the drawdown. A reduction in drawdown at a given yield increases the specific capacity of the well and reduces the cost of pumping. If the water-bearing formation consists of well-sorted coarse gravel, the capacity of the well may not be increased materially by addition of a gravel pack around the screen. If the best possible construction for a well is employed, the maximum amount of water that can be withdrawn from it is fixed by nature; nothing more can be done to make the well yield more than the water-bearing material will provide. McCall and Davison (1939, p. 29) have summarized some of the factors that influence the efficiency of a well.

> . . . First, the well should be put down through all valuable water-bearing material. Secondly, the casing used should be properly perforated so as to admit water to the well as rapidly as the surrounding gravel will yield the water. Third, the well should be completely developed so that the water will flow freely into the well. . . . Increasing the depth of the well will have a greater effect on reducing the drawdown than will increasing the diameter, so long as additional water-bearing formations are encountered.

For a description of different types of pumping plants, the conditions for which each is adapted, construction methods, and a discussion of construction costs, the reader is referred to a report by Davison (1939).

METHODS OF LIFT AND TYPES OF PUMPS

Most domestic and stock wells in Lane County are equipped with lift or force pumps which are generally operated by windmills. A few pumps employ small engines or electric motors. The cylinders or working barrels in lift pumps and force pumps are similar and for best results are placed at a level below the water table. A lift pump generally discharges water only at the pump head, whereas a force pump can force water above this level—to an elevated tank, for example. A few wells equipped with jet pumps employ a stream of water under pressure to raise water. In these a centrifugal pump impeller placed above the jet helps to increase the pressure, thus increasing the depth from which water may be pumped. Deep wells drilled to the Dakota formation are equipped with lift pumps with large cylinders, some of them using pump jacks similar to those on oil wells and powered by gasoline engines.

The irrigation wells in Lane County are equipped with deep-well turbine pumps. The pumps of four upland irrigation wells drilled in 1948 are operated by butane gas engines (Pl. 6A), and one is operated by a Diesel engine.

Other deep-well turbine pumps in the county are those used by the City of Dighton on their municipal wells. Electric motors are used to operate these pumps.

PLATE 6.—*A*, Deep-well pumping plant of B. U. Nichols in sec. 16, T. 17 S., R. 28 W. *B*, Mortar beds of Ogallala formation, SW¼ NW¼ sec. 1, T. 18 S., R. 28 W.; view looking east.

Utilization of Ground Water

Ground water in Lane County is used chiefly for domestic and stock purposes and for public supplies. Ground water used by the Santa Fe Railway has been obtained from the City of Dighton for approximately the last 20 years. A pumping station on the Missouri Pacific Railway in northeast Lane County was abandoned in 1948 as steam locomotives were replaced by Diesel. No water is used for industrial purposes as Lane County has no industrial plants. Records of 303 wells in the area are listed in Table 8; the principal uses of water are described below.

DOMESTIC AND STOCK SUPPLIES

Practically all the domestic and stock supplies in the rural areas and domestic supplies in small towns that have no public water supplies are obtained from wells. One spring is being used as a domestic supply and springs or ponds supplement well water for stock supplies. In Lane County the ground water generally is satisfactory for domestic purposes, although usually moderately hard. Some water with high fluoride content may be injurious to the teeth of children.

PUBLIC SUPPLIES

Dighton, the county seat and the only incorporated city in Lane County, has the only public water supply. Homes in smaller communities are supplied from private wells. Dighton (population 1,037 in 1946) is supplied by three drilled wells obtaining water from the Ogallala formation. One well, 18-28-18ccb, is at the power plant and the other two are on the west side of town (18-29-13ddc in the city park and 18-29-13ddb just north of the park). Well 18-29-13ddb is 73 feet deep with a static water level of 52 feet. Well 18-29-13ddc is 87 feet deep and the static water level is 51 feet; well 18-28-18ccb is reported to be about 100 feet deep with a water level of about 53 feet. The wells are cased with 18-inch steel casing and are equipped with electrically driven deep-well turbine pumps. The water from these wells is pumped directly into the city mains, the excess going into an elevated tank. The daily average consumption of water in Dighton is not known, and figures concerning the yields and drawdowns of the wells are not obtainable. An analysis of a sample of water from well 18-29-13ddc is given in Table 5. The water, although moderately hard, is not treated.

IRRIGATION SUPPLIES

A relatively small amount of water has been pumped for irrigation in Lane County. Prior to 1948 there were only three shallow irrigation wells, these having small yields and irrigating only small areas. In 1948 none of these was in use. Considerable test drilling was done in 1948 and five upland irrigation wells were drilled. However, only two of these, well 16-29-28dab and well 17-28-16dbb, were completed and had pumps installed during the growing season. The acreage irrigated in 1949 has been estimated by Silas Stone, Soil Conservationist, as less than 500 acres. The amount of water used cannot be estimated accurately. A few domestic wells equipped with windmills are sometimes used to irrigate small garden plots, but the amount of water used for this purpose is negligible.

The yields of three irrigation wells were determined by pumping tests made by the Federal Geological Survey. Yields determined by use of the Collins flow meter were 550, 1,040, and 790 gallons a minute. One new well not tested had an estimated yield of about 1,200 gallons a minute. Drawdowns measured by the wetted-tape method during the pumping tests ranged from 36 feet to 12 feet. Results of the pumping tests are given in Table 4. Analyses of two samples of water taken from irrigation wells show that it is of excellent quality for this use.

For data concerning cost of pumping water for irrigation and construction of irrigation plants, the reader is referred to reports prepared by the Kansas State Board of Agriculture (Davison, 1939; McCall and Davison, 1939). A report by Rohwer and Lewis (1940) published by the U. S. Department of Agriculture presents a good discussion of small irrigation pumping plants.

POSSIBILITIES OF FURTHER DEVELOPMENT OF IRRIGATION SUPPLIES

The future development of irrigation in Lane County will be limited by geologic and hydrologic factors. The amount of water available for irrigation depends upon the saturated thickness of water-bearing materials and their permeability. The saturated thickness of Pliocene and Pleistocene deposits in Lane County is shown in Figure 9. The contours showing saturated thickness were prepared by superimposing the water-table contour map (Pl. 1) on the map showing the configuration of the bedrock surface below the Ogallala formation (Fig. 5). Thickness of saturated materials is found by subtracting bedrock altitudes from water-table altitudes

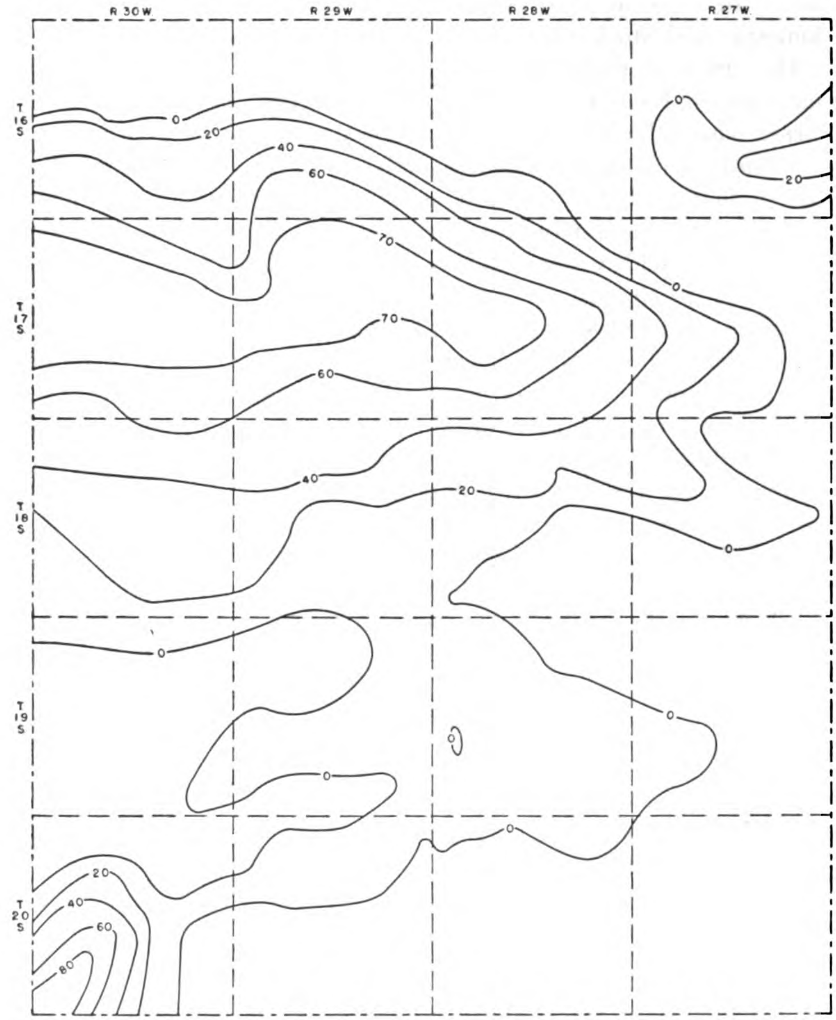

FIG. 9.—Map showing saturated thickness of the Tertiary and Quaternary deposits in Lane County.

at points of intersection. Contour lines are then drawn through points of equal thickness.

The contours indicate that the saturated water-bearing beds are thin throughout most of Lane County, particularly in the southern half. In many areas where the Cretaceous bedrock is at or near the surface, the Pliocene and Pleistocene deposits are above the water table. In these areas it is difficult to obtain sufficient water for domestic and stock use.

The greatest thickness of saturated Pliocene and Pleistocene materials in Lane County is in the basin area in the southwest corner where the Meade (?) formation contains more than 80 feet of saturated material. Unfortunately, however, the permeability (dependent upon the size and assortment of grains) is not high. Although the amount of water contained in the deposits is large, the material yields water so slowly that wells having large capacities cannot be developed.

An area situated largely in T. 17 S. extending from Scott County eastward for about 16 miles has a saturated thickness of 60 to 70 feet. The permeability of most water-bearing materials in the Ogallala of Lane County is rather low, but large amounts of water can be obtained where materials having high permeabilities are penetrated by wells. Test drilling by the State Geological Survey has shown that in many places the water-bearing beds are too tightly cemented or are composed of such fine materials that wells having large capacities cannot be obtained.

In some of the stream valleys the depths to water are not great and where the alluvium is underlain by the Ogallala formation, it may be possible to obtain supplies large enough for irrigation. However, the narrow creek valleys provide very little land suitable for irrigation.

Chemical Character of Ground Water

The chemical character of ground water in Lane County is shown by analyses of water from 31 wells representing the principal water-bearing formations (Table 5). An analysis of a sample from one of the wells of the City of Dighton is included. Figure 10 shows graphically the chemical character of typical water from the Ogallala, Dakota, and Meade (?) formations and from the alluvium. The samples were analyzed by Howard A. Stoltenberg, chemist, in the Water and Sewage Laboratory of the Kansas State Board of Health at Lawrence. The analyses show only the dissolved mineral content of the waters and do not indicate sanitary condition. General statements on the quality of the ground waters in the county are given below and the quality of waters in the different geologic formations is given in the section on geologic formations and their water-bearing properties.

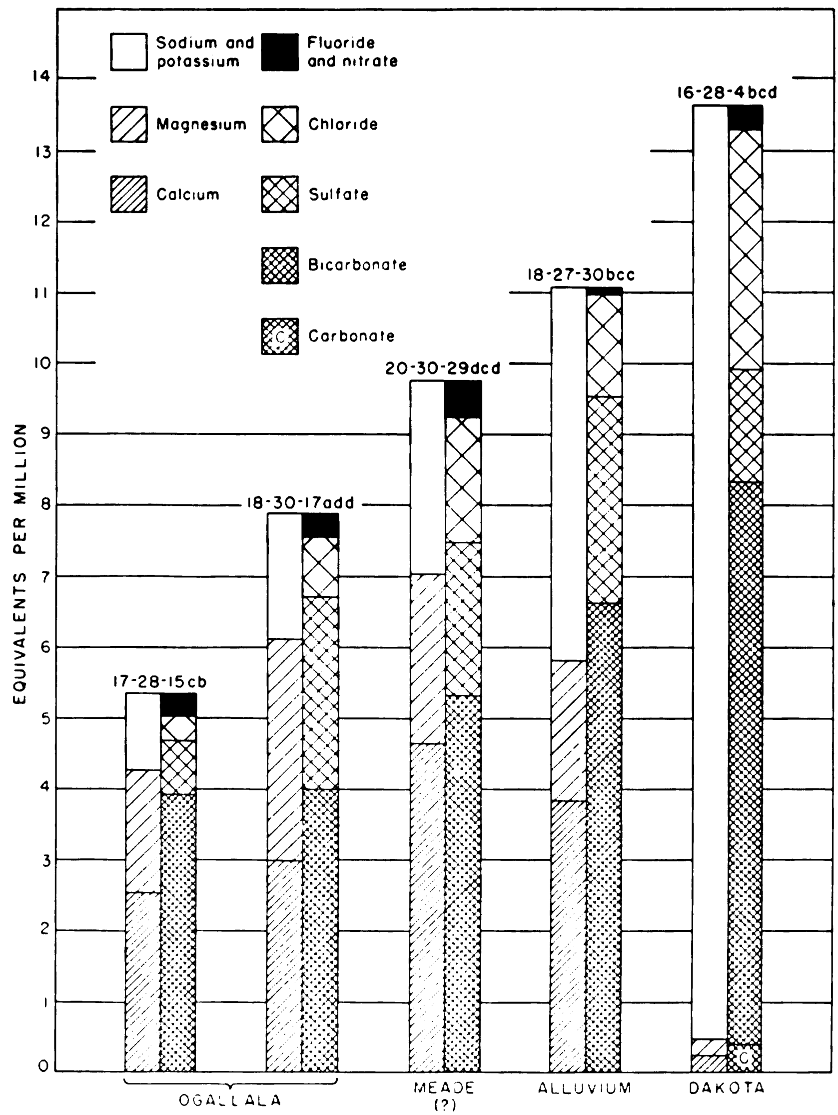

Fig. 10.—Analyses of water from the principal water-bearing formations in Lane County.

TABLE 5.—*Analyses of water from typical wells in Lane County*

Analyzed by H. A. Stoltenberg. Dissolved constituents given in parts per million[a], and in equivalents per million[b] (in italics)

Well Number	Depth (feet)	Geologic source	Date of collection, 1948	Temperature (°F)	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$		
																Total	Carbonate	Noncarbonate
T. 16 S., R. 27 W.																		
16-27-13ddd	80.0	Ogallala	Sept. 13	57	270	18	0.15	51 *2.54*	15 *1.23*	22 *.98*	204 *3.34*	22 *.46*	21 *.59*	0.7 *.04*	20 *.32*	188	167	21
T. 16 S., R. 28 W.																		
16-28-4bcd	673c	Dakota	Sept. 14	65	772	7.2	1.7	4.2 *.21*	2.8 *.23*	303 *13.17*	483d *7.92*	77 *1.60*	120 *3.38*	6 *.32*	1.1 *.02*	24	24	0
15-28 32caa	103.0	Ogallala	Sept. 15	....	496	57	2.0	76 *3.79*	33 *2.71*	31 *1.36*	221 *3.62*	107 *2.22*	47 *1.32*	3.2 *.17*	33 *.53*	325	181	144
T. 16 S., R. 29 W.																		
16-29-11ccc	749c	Dakota	Sept. 15	64	932	9.2	.98	5.2 *.26*	3 *.25*	378 *16.45*	734e *12.04*	39 *.81*	114 *3.21*	8 *.42*	0.7 *.01*	26	26	0
16-29-28dab	170.0	Ogallala	Sept. 15	58	332	43	.0	52 *2.59*	21 *1.73*	27 *1.17*	232 *3.80*	44 *.92*	16 *.45*	2.1 *.11*	13 *.21*	216	190	26
T. 16 S., R. 30 W.																		
16-30-13add	115.0	do	Sept. 15	59	333	44	1.2	55 *2.74*	20 *1.64*	24 *1.05*	227 *3.72*	45 *.94*	16 *.45*	1.5 *.08*	15 *.24*	219	186	33
16-30-21bcb	147.5	do	Sept. 15	60	311	44	.09	52 *2.59*	22 *1.81*	17 *.72*	214 *3.51*	39 *.81*	18 *.51*	2 *.10*	12 *.19*	220	276	44
16-30-22aba	36.5	do	Sept. 15	58	339	43	.08	57 *2.84*	20 *1.64*	25 *1.10*	234 *3.84*	45 *.94*	16 *.45*	1.7 *.09*	16 *.26*	224	192	32
T. 17 S., R. 27 W.																		
17-27-16ccc	30.0	do	Sept. 15	57	386	45	.06	84 *4.19*	21 *1.73*	15 *.65*	283 *4.64*	30 *.62*	34 *.96*	1.7 *.09*	16 *.26*	296	232	64
17-27-35bbb	110.0	do	Sept. 15	58	322	46	.21	55 *2.74*	21 *1.73*	20 *.87*	234 *3.84*	35 *.73*	16 *.45*	2.4 *.13*	12 *.19*	224	192	32
T. 17 S., R. 28 W.																		
17-28-15cb	147.0	do	Sept. 14	58	326	48	.13	51 *2.54*	21 *1.73*	25 *1.08*	239 *3.92*	37 *.77*	12 *.34*	2.6 *.14*	11 *.18*	214	196	18
T. 17 S., R. 29 W.																		
17-29-31aaa	44.0	do	Sept. 15	57	393	43	.08	60 *2.99*	26 *2.14*	32 *1.41*	257 *4.21*	51 *1.06*	24 *.68*	3 *.16*	27 *.43*	256	210	46

T. 18 S., R. 27 W.																		
18-27-30bcc	20.5	Alluvium	Sept. 15	57	654	38	.04	77 *3.84*	24 *1.97*	121 *5.26*	404 *6.62*	140 *2.91*	51 *1.44*	1.1 *.06*	2.7 *.04*	290	290	0
T. 18 S., R. 28 W.																		
18-28-16ccc	68.0	Ogallala	Sept. 14	58	438	70	.08	55 *2.74*	35 *2.88*	33 *1.45*	261 *4.28*	75 *1.56*	34 *.96*	3.8 *.20*	4.4 *.07*	281	214	67
T. 18 S., R. 29 W.																		
18-29-1dcc	65.5	do	Sept. 14	58	361	59	1.2	58 *2.89*	23 *1.89*	25 *1.10*	260 *4.26*	35 *.73*	18 *.51*	3.8 *.20*	11 *.18*	239	213	26
18-29-13ddc	88.5	do	Aug. 1 f	......	460	56	.13	58 *2.89*	33 *2.71*	27 *1.19*	278 *4.56*	45 *.94*	31 *.87*	3.4 *.18*	15 *.24*	280	228	52
18-29-20bbb	63.5	do	Sept. 15	58	333	67	.06	40 *2.00*	28 *2.30*	26 *1.13*	270 *4.43*	18 *.37*	10 *.28*	4.5 *.24*	6.6 *.11*	215	215	0
18-29-36aaa	47.0	do	Sept. 14	58	592	42	.03	106 *5.29*	34 *2.79*	31 *1.33*	277 *4.54*	67 *1.39*	51 *1.44*	.8 *.04*	124 *2.00*	404	227	177
T. 18 S., R. 30 W.																		
18-30-17add	96.5	do	Sept. 16	60	483	52	.14	60 *2.99*	38 *3.12*	41 *1.78*	244 *4.00*	130 *2.70*	30 *.85*	4 *.21*	8 *.13*	306	200	106
18-30-34aba	93.5	do	Sept. 16	58	362	57	.18	41 *2.05*	29 *2.38*	34 *1.50*	212 *3.97*	48 *1.00*	21 *.59*	4.5 *.24*	8 *.13*	222	198	24
T. 19 S., R. 27 W.																		
19-27-33dad	20.4	Alluvium	Sept. 16	61	789	28	.04	190 *9.48*	24 *1.97*	42 *1.83*	433 *7.10*	241 *5.01*	28 *.79*	.6 *.03*	22 *.35*	572	355	217
T. 19 S., R. 28 W.																		
19-28-35cbb	72.0	Ogallala	Sept. 16	59	412	29	.25	61 *3.04*	26 *2.14*	45 *1.94*	245 *4.02*	67 *1.39*	53 *1.49*	1.5 *.08*	8.8 *.14*	259	201	58
T. 19 S., R. 29 W.																		
19-29-22aad	73.7	do	Sept. 16	58	380	23	.92	51 *2.54*	21 *1.73*	54 *2.34*	254 *4.17*	67 *1.39*	30 *.85*	1.4 *.07*	8 *.13*	214	208	6
T. 19 S., R. 30 W.																		
19-30-30add	1,038c	Dakota	Sept. 16	69	669	8	4.2	11 *.55*	5.2 *.43*	238 *10.33*	331 *5.43*	154 *3.20*	67 *1.89*	5 *.26*	3.5 *.06*	49	49	0
19-30-35daa	74.0	Ogallala	Sept. 16	59	712	27	2.5	84 *4.19*	42 *3.45*	92 *4.02*	261 *4.28*	150 *3.12*	98 *2.76*	1.3 *.07*	89 *1.43*	382	214	168
T. 20 S., R. 27 W.																		
20-27-7aab	748c	Dakota	Sept. 16	67	1,174	8.6	3.4	4.8 *.24*	2.6 *.21*	447 *19.45*	470 h *7.71*	207 *4.31*	248 *6.99*	6 *.32*	2.6 *.04*	22	22	0
20-27-19bbc	31.7	Alluvium	Sept. 16	58	399	18	.08	90 *4.49*	14 *1.15*	28 *1.20*	293 *4.80*	45 *.94*	10 *.28*	.6 *.03*	49 *.79*	282	240	42
20-27-26bba	34.5	do	Sept. 16	59	449	20	.11	101 *5.04*	15 *1.23*	32 *1.38*	312 *5.12*	58 *1.21*	16 *.45*	.4 *.02*	53 *.85*	314	256	58
20-27-31cbb	23.8	do	Sept. 16	59	450	19	.06	114 *5.69*	11 *.90*	18 *.79*	249 *4.08*	55 *1.14*	30 *.85*	.4 *.02*	80 *1.29*	330	204	126

TABLE 5.—*Analyses of water from typical wells in Lane County—Concluded*

Analyzed by H. A. Stoltenberg. Dissolved constituents given in parts per million[a], and in equivalents per million[b] (in italics)

Well Number	Depth (feet)	Geologic source	Date of collection, 1948	Temperature (°F)	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$ Total	Carbonate	Noncarbonate
T. 20 S., R. 28 W. 20-28-19aaa.....	47.5	Ogallala........	Sept. 14....	57	571	32	.15	127 *6.34*	35 *2.88*	18 *.77*	454 *7.44*	16 *.33*	22 *.62*	.7 *.04*	97 *1.56*	461	372	89
T. 20 S., R. 30 W. 20-30-29dcd.....	30.0	Meade (?)......	Sept. 16....	56	562	20	3.00	93 *4.64*	29 *2.38*	63 *2.74*	324 *5.31*	104 *2.16*	63 *1.78*	.7 *.04*	29 *.47*	351	266	85

a. 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.
b. An equivalent per million is a unit chemical equivalent weight of solute per million unit weights of solution. Concentration in equivalents per million is calculated by dividing the concentration in parts per million by the chemical combining weight of the substance or ion.
c. Depth reported.
d. Sample also contains 12 p. p. m. carbonate (.40 equivalents per million).
e. Sample also contains 14 p. p. m. carbonate (.47 equivalents per million).
f. Sample collected in 1947 (Dighton municipal well).
g. Sample also contains 14 p. p. m. carbonate (.47 equivalents per million).
h. Sample also contains 16 p. p. m. carbonate (.53 equivalents per million).

CHEMICAL CONSTITUENTS IN RELATION TO USE

The following discussion of the chemical constituents of ground water has been adapted in part from publications of the Federal Geological Survey and the State Geological Survey of Kansas.

Dissolved solids.—Ground water dissolves some of the rock materials with which it comes in contact. After a natural water has been evaporated, the residue consists of mineral matter and some organic material and some water of crystallization. The kind and quantity of these materials in the water determine its suitability for various uses. Waters containing less than 500 parts per million of dissolved solids generally are satisfactory for domestic use, except for troubles resulting from their hardness and corrosiveness. Waters containing more than 1,000 parts per million dissolved solids generally are not satisfactory for most domestic and industrial uses for they are likely to contain enough of certain constituents to produce a noticeable taste or to make the water unsuitable in some other respect.

The water from only one of the wells sampled in Lane County contained more than 1,000 parts per million (1,174) dissolved solids. Nine samples contained from 500 to 1,000 and 21 contained less than 500, the smallest concentration being 270 parts per million. The amount of dissolved solids in the samples of ground water collected in Lane County is indicated for each important aquifer in Table 6.

Hardness.—The hardness of water is the property that receives the most attention and is commonly recognized by the increasing amount of soap needed to produce a lather and by the curdy precipitate that forms before a permanent lather can be obtained. Calcium and magnesium are the constituents that cause practically all hardness of ordinary waters and are the active agents in the formation of the greater part of the scale formed in steam boilers and in other vessels in which water is heated or evaporated.

In addition to the total hardness, the table of analyses (Table 5) shows carbonate and noncarbonate hardness. Carbonate hardness is that caused by calcium and magnesium bicarbonate and, because it can be almost entirely removed by boiling, it is sometimes called temporary hardness. Noncarbonate hardness, often called permanent hardness, is caused mainly by sulfates or chlorides of calcium and magnesium and cannot be removed by boiling. With reference to use with soap there is no difference between carbonate

TABLE 6.—*Summary of the chemical character of samples of water from typical wells in Lane County*

Range in parts per million	Number of samples			
	Ogallala formation	Alluvium	Meade (?) formation	Dakota formation
Dissolved solids				
0–200	0	0	0	0
201–300	1	0	0	0
301–400	13	1	0	0
401–500	4	2	0	0
501–600	2	0	1	0
More than 600	1	2	0	4
Total hardness				
0– 50	0	0	0	4
51–100	0	0	0	0
101–200	1	0	0	0
201–300	15	2	0	0
301–400	3	2	1	0
401–500	2	0	0	0
More than 500	0	1	0	0
Fluoride				
Less than 0.5	0	2	0	0
0.5–1.0	3	2	1	0
1.1–1.5	4	1	0	0
1.6–3.0	7	0	0	0
3.1–5.0	7	0	0	1
5.1–8.0	0	0	0	3
Iron				
Less than 0.10	8	4	0	0
0.10–0.20	6	1	0	0
0.21–0.50	2	0	0	0
0.51–1.0	1	0	0	1
1.1–2.0	3	0	0	1
2.1–3.0	1	0	1	0
3.1–5.0	0	0	0	2

and noncarbonate hardness. In general, waters with high permanent hardness tend to form harder scale in steam boilers.

Water having a hardness of less than 50 parts per million is generally rated as soft and treatment to remove hardness is unnecessary. Hardness between 50 and 150 parts per million does not seriously interfere with the use of water for most purposes, but it does increase the consumption of soap and its removal by a softening process may be profitable for laundries or other industries that use large quantities of soap. Treatment for the prevention of scale is necessary for the successful operation of steam boilers using water in the upper part of this range of hardness. Water having a hardness between 200 and 300 parts per million is sometimes treated to soften it to the point where it is suitable for household use. Sometimes cisterns to collect soft rain water are installed. Where municipal water supplies are softened the hardness is usually reduced to 60 to 80 parts per million.

Four analyses of water from the Dakota formation showed a hardness of less than 50 parts per million, and may be considered soft. Most of the waters derived from other formations, however, were quite hard, only 1 having a hardness of less than 200 parts per million; 9 samples had a hardness of more than 300 parts per million and 17 had a hardness of from 200 to 300.

Iron.—Next to hardness, iron content is the property of natural waters that usually receives the most attention. If a water contains more than 0.3 part per million of iron, the excess may separate out and settle as a reddish sediment when exposed to the air. Iron, which may be present in sufficient quantity to give a disagreeable taste or to stain cooking utensils, may be removed from most waters by aeration and filtration, but a few waters require additional treatment.

Maximum iron content in water samples collected in Lane County was 4.2 parts per million. One sample contained no iron; 11 others contained less than 0.1 part per million. All but three had less than 3 parts per million.

Fluoride.—Although fluoride is usually present only in small quantities in ground water, it is desirable to know the amount of fluoride in waters that are used by children. Fluoride in water has been shown to be associated with the dental defect known as mottled enamel, which may appear on the teeth of children who drink water containing fluoride during the period of formation of the permanent teeth. Dean (1936, pp. 1278-1279) has described the effects of fluoride in drinking water on the teeth of children as follows:

. . . from the continuous use of water containing about 1 part per million, it is probable that the very mildest forms of mottled enamel may develop in about 10 percent of the group. In water containing 1.7 or 1.8 parts per million, the incidence may be expected to rise 40 or 50 percent, although the percentage distribution of severity would be largely of the "very mild" and "mild" types. At 2.5 parts per million an incidence of about 75 to 80 percent might be expected, with possibly 20 to 25 percent of all cases falling into the "moderate" or severer type. A scattering few may show the "moderately severe" type.

At 4 parts per million the incidence is, in general, in the neighborhood of 90 percent, and as a rule, 35 percent or more of the children are classified as "moderate" or worse. In concentration of 6 parts per million or higher an incidence of 100 percent is not unusual. In other words, we are dealing with a low grade chronic fluorine poisoning of children.

A more recent report (Dean, Arnold, and Elvolve, 1942) has indicated that although more than one part per million of fluoride may be detrimental to the teeth of children, small amounts of fluoride are beneficial in helping to prevent tooth decay.

Of 31 samples from Lane County, only 8 contained less than 1 part per million of fluoride, 20 contained from 1 to 5 parts per million and 3 contained more than 5. Water from one well drilled to the Dakota formation had a fluoride content of 8.0 parts per million.

Nitrate.—The nitrate content of waters used for drinking has received a great deal of attention in the past few years. This concern is due to the discovery that high nitrate water is associated with cyanosis of infants when the water is used in the preparation of the baby's formula. The variation in nitrate content for different water samples is great and apparently is not related to any geologic formation. Although some nitrates may be derived from nitrate-bearing rocks and minerals in the water-bearing formation, high nitrate concentrations probably are due to direct flow of surface water into the well or to percolation of nitrate-bearing water into the well through the top few feet of the well. Nitrates are very soluble and may be dissolved readily from soils that have high concentrations of nitrate and from barnyard refuse. Dug wells, in most cases poorly sealed, generally allow more contamination by surface seepage than do drilled wells, which are ordinarily deeper and more tightly sealed at the surface.

Water having nitrate concentration greater than about 50 parts per million of nitrate as NO_3 should not be used for formula preparation. Although all the water samples collected contained some nitrate, only 5 samples contained more than 50 parts per million.

Nitrate content ranged from 0.7 in a deep well to the Dakota formation to 124 parts per million in one shallow dug well in the Ogallala formation.

WATER FOR IRRIGATION

The suitability of water for irrigation is dependent mainly on the total concentration of dissolved constituents and the percentage of sodium. A large quantity of chloride may make water unfit for irrigation and boron may be present in sufficient amounts to be harmful to plants. The total concentration of dissolved constituents may be expressed in terms of total equivalents per million of anions and cations, in terms of parts per million of dissolved solids, or in terms of electrical conductivity. Electrical conductivity is the measure of the ability of the organic salts in solution to conduct an electrical current, and it is related to the concentration of dissolved solids. Electrical conductivity measurements are not shown in analyses of water from Lane county, but an approximate value can be obtained by multiplying total equivalents per million of anions or cations by 100, or by dividing dissolved solids in parts per million by 0.7 (Wilcox, 1948, pp. 4-5). To find the percentage of sodium the results of the analysis must be reported in equivalents per million. The quantity of sodium in equivalents is divided by the sum of the quantities of calcium, magnesium, sodium, and potassium and the result is expressed as a percentage.

The classification of waters for irrigation use is shown in Table 7 (Wilcox, 1948a, p. 27).

TABLE 7.—*Permissible limits for electrical conductivity and percentage sodium of several classes of irrigation water* (Wilcox, 1948a, p. 27)

Classes of water		Electrical conductivity (micromhos at 25° C)	Percent sodium
Rating	Grade		
1	Excellent	less than 250	less than 20
2	Good	250–750	20–40
3	Permissible	750–2,000	40–60
4	Doubtful	2,000–3,000	60–80
5	Unsuitable	more than 3,000	more than 80

From Table 7 it can be said that in general, waters containing more than 60 percent sodium or waters having electrical conductances of more than 2,000 are unfit for irrigation. In Lane County water from four wells drilled to the Dakota formation was unfit for irrigation.

SANITARY CONDITIONS

The analyses of water given in the table show only the amounts of dissolved mineral matter in the water and do not indicate the sanitary quality of the water. The water in a well containing mineral matter that imparts an objectionable taste or odor may be free from harmful bacteria and safe for drinking. On the other hand, the water in a well although clear and palatable may contain harmful bacteria. An abnormal amount of certain mineral constituents, such as nitrate or chloride, however, may indicate pollution.

Great care should be taken to protect domestic and public water supplies from contamination by organic material. Much of the population of Lane County is dependent upon private water supplies from wells, and drillers and well owners must take precautions in constructing wells to insure safe and wholesome water supplies. The top of the casing should be sealed in such a manner as to prevent surface water from entering the well, and where pump pits are used the top of the casing should extend above the floor of the pit to prevent surface water from draining into the well. In constructing wells equipped with ordinary cylinder pumps it is a good plan to allow the casing to extend several inches above the platform so that the pump base will fit down over the top of the casing, thus effecting a tight seal. If the casing is left flush with the top of the platform opportunity for surface drainage into the well and for possible contamination is afforded. Wells should not be located where barnyards, privies, or cess pools are possible sources of contamination.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Cretaceous System

GULFIAN SERIES

Dakota Formation

Character.—The oldest formation known to yield water to wells in Lane County is the Dakota formation of the Gulfian Series of the Upper Cretaceous System. The Dakota is probably underlain by the Kiowa shale and the Cheyenne sandstone, but owing to lack of detail, little information concerning the character and thickness of these formations has been gained from the study of logs of deep oil and gas test wells drilled in the county. The formations below the Greenhorn limestone and above the Permian redbeds are similar in lithology and may be logged as one unit by oil-well drillers and described as a "group" by oil geologists. As no wells in Lane County are known to derive water from the Cheyenne sandstone or Kiowa shale, these formations will not be discussed further.

The Dakota formation is not exposed in Lane County and, because of its depth, was nowhere encountered in test holes drilled by the State Geological Survey. The closest outcrops of the Dakota are in southern and eastern Hodgeman County, where only the upper 50 or 60 feet of the formation is exposed (Moss, 1932, p. 32).

The Dakota is composed mainly of variegated clays and shales and lenticular sandstone beds. The sandstones generally are crossbedded. The sandstones of the Dakota formation are interbedded with and interfinger with clay and silty clay. McLaughlin (1943, p. 121) found that in Hamilton County about 40 to 45 percent of the formation consists of varicolored clay. The ratio of sandstone to shale and clay varies from place to place. Only about one-fourth of the formation is sandstone in Ness and Hodgeman Counties (Moss, 1932, p. 32). White to reddish sandstone and gray shale are the predominating beds in Lane County.

Distribution and thickness.—The Dakota formation underlies all of Lane County and has been encountered in several test wells for oil and gas and in water wells. The study of samples of a test well for oil in the NW¼ NE¼ sec. 16, T. 16 S., R. 28 W. indicates that the thickness of the Dakota formation, Kiowa shale, and Cheyenne sandstone is about 500 feet. Because of the similarity of the drill cuttings exact boundaries were not drawn, but the Dakota was approximately 300 feet in thickness. According to Landes and Keroher (1939, p. 24) the thickness (including Kiowa and Cheyenne) ranges from 450 to 550 feet in Logan, Gove, and Trego Counties. Because of the lenticular nature of the Dakota formation its thickness varies widely.

Water supply.—The Dakota formation is not an important aquifer in Lane County but it does yield water to several deep wells in areas where the Ogallala formation is thin or absent. Water in the Dakota is under artesian pressure but Lane County has no flowing wells. An analysis of the water from well 16-28-4bcd is shown graphically in Figure 10. The water from wells in the Dakota is soft sodium bicarbonate water, being very low in calcium and magnesium and very high in sodium. The analyses indicate that the water in the Dakota formation in this area has undergone a natural softening in which calcium bicarbonate water has exchanged its calcium and magnesium for sodium by a base-exchange process.

The base-exchange silicates active in the natural softening process are the clay-forming minerals in the Dakota formation. The degree of softening depends upon the amount and softening capacity of the clay-forming minerals and upon the length of time the hard water remains in contact with these minerals (Renick, 1924).

The water from the Dakota formation ranges in hardness from 22 to 49 parts per million and is considered soft. The fluoride content ranges from 5.0 to 8.0 parts per million and would be very undesirable for a drinking supply to be used by young children. The percentage of sodium is very high in water from the Dakota formation—in one sample sodium constituted 98 percent of the total bases. Water of this composition is unfit for irrigation.

Graneros Shale

Character.—Conformably overlying the Dakota formation is the Graneros shale, which consists of noncalcareous shale ranging from dark blue to black in fresh samples and from gray to brown in weathered exposures. It contains a few thin beds or lenses of sandstone and sandy shale. The contact between the Graneros shale and the Dakota is not everywhere distinct but may consist of a transitional zone in which sandstones and shales of the Dakota grade upward into sandstones and sandy shales of the Graneros. The top of the formation at most places is marked by a sharp lithologic break between the noncalcareous Graneros shale and the overlying calcareous beds of the Greenhorn limestone.

Distribution and thickness.—The Graneros shale is not exposed in Lane County and it was not encountered in any test holes. It probably underlies the entire county. The nearest exposures of the Graneros are in southern Hodgeman County and along Sawlog Creek in northern Ford County. The thickness of the Graneros in Lane County is about 50 feet.

Water supply.—No wells are known to obtain water from the Graneros shale in Lane County. Because of the low permeability of the sediments the quantity of water available in the shales and sandstone lenses is small.

Greenhorn Limestone

Character.—The Greenhorn limestone consists of thin chalky and crystalline limestones separated by thicker beds of chalky shale, which contain thin bentonite beds. Limestone concretions are common in the shales in the upper part of the formation. Fresh exposures of limestone and shales are dull gray, and the bentonites are light pearly gray. Upon weathering, the color of the limestones becomes tan, buff, or orange tan. The shales in the upper part weather to tan or light gray, and those in the lower part, to tan or orange tan. The bentonite weathers to rusty brown or orange. The Greenhorn limestone grades upward into chalky shale beds of the Fairport member of the Carlile, so there is no distinct lithologic break between the formations. The base of the Greenhorn is marked distinctly by a change from the noncalcareous beds of the Graneros to the chalky shales and the crystalline limestones at the base of the Greenhorn. The Greenhorn has been divided into four distinct members, but where the Greenhorn is known only from drill cuttings it is not possible to differentiate the members.

Distribution and thickness.—The Greenhorn limestone underlies all of Lane County but does not crop out in the county. The nearest exposures are in Ness and Hodgeman Counties. The thickness in Lane County is about 100 feet; it is approximately 125 feet in Hodgeman County (Moss, 1932, p. 26) and about 100 feet in Logan, Gove, and Trego Counties (Landes and Keroher, 1939, p. 24).

Water supply.—None of the wells visited in Lane County obtain water from the Greenhorn limestone. The water-yielding capacity of the formation is low, although water may occur in fractures and solution openings in the limestone. A few wells in southeastern Gray County (Latta, 1944, p. 153) and a few in Ford County (Waite, 1942, p. 154) probably obtain water from the Greenhorn.

Carlile Shale

Character.—The Carlile shale is the oldest Cretaceous formation exposed in Lane County. It is composed of two members, the Fairport chalky shale member and the Blue Hill shale member. The Fairport chalky shale member, which usually constitutes the lower one-third of the formation, consists of thick beds of chalky shale alternating with thin beds of chalk or chalky limestone. Many hard concretions occur in the lower part of the member and a few bentonite beds occur in the shale. The Fairport contains many poorly preserved fossils, the most common being *Inoceramus fragilis, Prionotropis woolgari, Ostrea congesta, Globigerina, Gumbelina,* and *Serpula plana.*

The Blue Hill shale member generally constitutes most of the upper two-thirds of the Carlile shale. It consists of dark-gray to bluish-black noncalcareous shale and contains seams and crystals of gypsum and, in the upper part, a zone of large septarian concretions.

The Codell sandstone is a sandy zone at the top of the Blue Hill shale member of the Carlile. Where exposed in the southeastern part of Lane County it consists of about 2 feet of tan fine-grained sandstone and sandy shale grading downward into the shale of the Blue Hill member.

Distribution and thickness.—The Carlile shale is present at the surface or beneath the surface everywhere in Lane County. The Blue Hill shale member which contains the Codell sandstone zone, crops out in the southeastern part of the county, but the Fairport chalky shale member is nowhere exposed. The thickness of the Carlile in Lane County is 200 feet, the Fairport being about 90 feet and the Blue Hill 110 feet thick (oil well test 16-28-16ab).

Water supply.—No wells in Lane County are known to obtain water from the Carlile shale. The Blue Hill and Fairport chalky shales generally do not yield water to wells but in Hamilton, Kearny (McLaughlin, 1943, p. 133), Finney, and Gray (Latta, 1944, p. 157) Counties the Codell is generally thicker than in Lane County and may yield small quantities of water to wells in some places. In Lane County, however, the Codell is thin, very fine-grained, and relatively impermeable.

Niobrara Formation

Character.—The Niobrara formation consists of beds of chalky limestone, chalky shale, and chalk, with chalky shale predominating. The Niobrara has been divided into two members—the Fort Hays limestone member below and the Smoky Hill chalk member above.

The Fort Hays limestone member is composed of thick massive beds of chalk or chalky limestone separated by thin beds of chalky shale. Some of the chalk beds are 6 feet thick, but the average is less than 3 feet. Shale partings are thin and are usually less than 4 inches. Fresh exposures of the Fort Hays are white or light gray, and weathered outcrops are white, tan, buff, or cream. The contact of the Fort Hays limestone with the underlying Carlile shale is marked distinctly by a sharp change from light-colored calcareous beds of the Fort Hays to the dark-colored noncalcareous beds (sandstone, sandy shale, or shale) of the Carlile. The Fort Hays contains the fossil pelecypods, *Inoceramus deformis* and *Ostrea con-*

gesta and many minute foraminifera which occur in the chalk beds.

The following measured section (shown on Pl. 4B) indicates the character of the Fort Hays limestone in southern Lane County.

Section of the Fort Hays limestone member of the Niobrara formation in the SW¼ sec 2, T. 19 S., R. 27 W.

		Thickness	
		Feet	Inches
Cretaceous—Gulfian			
Niobrara formation (Fort Hays limestone member)			
25	Limestone, broken, white	1	2
24	Shale, chalky, light-tan	..	2
23	Limestone, massive	1	4
22	Shale, light-tan	..	1
21	Limestone, massive, white	2	1
20	Shale, light-tan	..	1
19	Limestone, shaly, light-tan	..	3
18	Shale, light-tan	..	1
17	Limestone, massive	..	8
16	Shale, light-gray	..	3
15	Limestone, massive, white	2	11
14	Shale, light-tan	..	1
13	Limestone, massive, white	1	10
12	Shale, light-brown	..	1
11	Limestone, massive, white	1	5
10	Shale, light-gray	..	1
9	Limestone, massive, white	2	4
8	Limestone, shaly, light-tan	..	10
7	Limestone, white	..	9
6	Shale, chalky, light-tan	..	1
5	Limestone, white	..	10
4	Shale, chalky, light-tan	..	1
3	Limestone, massive, light-tan	1	3
2	Shale, chalky, light-tan	..	1
1	Limestone, fractured, light-tan	1	..
	Total	19	6

Conformably overlying the Fort Hays limestone member of the Niobrara formation is the Smoky Hill chalk member. It consists of soft beds of alternating chalky shale and chalk. Where unweathered, the beds are light to dark gray, but on weathering they become white, tan, buff, or yellowish pink. Thin bentonite beds and pyrite concretions are common in the Smoky Hill member. Bentonites are light colored when unweathered, but weather to a rusty brown. Pyrite concretions weather to limonite and exposures of chalk beds in many places are strewn with hard steel-gray concretions of pyrite or discoidal soft yellow-brown concretions of limonite many of which are a foot in diameter.

The Smoky Hill chalk member, especially in Logan and Gove Counties, has long been famous for the large number of fossils, both vertebrate and invertebrate, that it contains. Many of the large natural history museums of the world exhibit vertebrate fossils that came from the Smoky Hill chalk member of central and western Kansas. Vertebrates that have been found here include primitive birds, reptiles of many varieties, dinosaurs, and fish. The most abundant invertebrate fossils are *Inoceramus grandis,* a large pelecypod, and *Ostrea congesta,* a small oyster which often is attached to the larger *Inoceramus* shells. Foraminifera, chiefly *Globigerina* and *Gumbelina,* are very abundant in the chalk beds.

Fossil wood has been found in the formation. Williston (1897a, p. 243) reported a tree about 30 feet long discovered near Elkader in Logan County. I found a fossil tree trunk imbedded in the chalk in sec. 11, T. 16 S., R. 28 W. It was about 6 feet long and had been altered to lignite. The specimen could not be identified as no plant structures were recognizable.

Distribution and thickness.—The best exposures of the Smoky Hill chalk member in Lane County are in the northern part along small valleys tributary to Smoky Hill River and along the south fork of Walnut Creek east of Dighton. The Fort Hays limestone member crops out in the southeastern part of the county. The county is everywhere underlain by Fort Hays with the exception of areas where the Carlile shale crops out, but in parts of southeastern Lane County, the Smoky Hill has been removed by erosion. None of the test holes drilled by the State Geological Survey of Kansas penetrated the entire thickness of the Niobrara. Logs of oil-well tests drilled in Lane County indicate that the Niobrara may attain a thickness of about 400 feet, the Fort Hays member being about 50 feet thick and the Smoky Hill chalk being about 350 feet thick.

The contact between the Smoky Hill chalk member and the Fort Hays member is transitional from predominantly chalk beds in the Fort Hays to predominantly chalky shale beds in the Smoky Hill. A pair of bentonite seams is arbitrarily taken to be the top of the Fort Hays. Actually the top is several feet below the top of the uppermost thick chalk bed, but these bentonites are the only convenient and recognizable horizons at which to make a division. In Lane County the contact between the Fort Hays limestone and Smoky Hill chalk is exposed at only one place. In the SW¼ SE¼ sec. 31, T. 20 S., R. 27 W., both the Smoky Hill and the Fort Hays crop out. The contact is obscured by slope deposits, but seemingly the Smoky Hill is about 20 feet thick at this locality. Just across the county line in sec. 1, T. 21 S., R. 28 W., Finney County, the Smoky Hill chalk member is directly overlain by the "Algal limestone" of the Ogallala formation.

Water supply.—The Niobrara is not an important water-bearing formation in Lane County. The beds of chalk and chalky shale that make up the Fort Hays and Smoky Hill are relatively impervious and transmit water chiefly through fractures. The success of a well penetrating the Niobrara depends upon whether or not fractures are encountered. Several wells in areas in Lane County where Pleistocene and Pliocene deposits lie above the water table derive at least part of their water from the Niobrara. Amounts of water yielded by the Niobrara are small.

No samples of water were collected from wells obtaining water from the Niobrara formation. However, according to Latta (1944, p. 160) and Waite (1947, p. 118) the chemical character of water from the Niobrara formation is similar to that of water from Pliocene and Pleistocene deposits.

Tertiary System

PLIOCENE SERIES

Ogallala Formation

Character.—The Ogallala formation in Lane County consists chiefly of silt, clay, sand, and gravel, and some limestone. In other areas beds of volcanic ash, diatomaceous marl, bentonitic clay, and hard silicified beds resembling chert or quartzite are found. The character of the Ogallala is shown in logs of test holes included in this report. Despite the diversity of rock types found within the Ogallala, the outcrop pattern presents a uniformity of aspect that makes the formation easily identified.

With the exception of a limestone member at the top of the formation, the beds are characteristically lenticular and can be traced only short distances. In general the materials composing the formation are poorly sorted and gradations from one lithologic type to another may take place within short distances both laterally and vertically.

Sand, the principal constituent of the Ogallala formation, occurs at all horizons. It may be found in beds of silt or clay or in sandy limestones. It ranges in texture from fine- to coarse-grained. The sand is composed predominantly of quartz, but contains subordinate amounts of feldspar and other minerals. A few lenses of sand encountered in test drilling were relatively well sorted and free from other constituents, but most of them were poorly sorted, being mixed with silt, clay, or gravel. Deposits of well-sorted sand or sand and gravel are uncommon in the Ogallala.

The Ogallala contains many beds that are composed mainly of sandy silt and clay. The color of the silt is gray, brown, tan, or buff. Where it contains much lime it may be white. The sandy silt lenses may contain nodules or stringers of calcium carbonate as well as calcium carbonate cement.

Gravel in the Ogallala ranges in size from fine to coarse and may occur in almost any part of the formation. In several test holes drilled in Lane County the gravels at the base of the formation are coarser and thicker. Ordinarily the gravel is mixed with a considerable amount of sand and silt, thus rendering the formation less permeable to ground water.

Much of the material in the Ogallala is cemented, generally with calcium carbonate. Some of the beds of sand and gravel are firmly cemented with calcium carbonate to produce a series of hard ledges of sandstone, interbedded with only slightly cemented beds. The hard ledges are generally unevenly cemented and form rough weathered benches and cliffs called "mortar beds" (Pls. 6B, 7A). The first use of the term "mortar bed" applied to soft caliche rather than the sandstone. It was used as mortar in building early-day buildings.

Calcium carbonate is present as cementing material, nodules, concretions, lenses, and beds. The thickness of bedded caliche (calcium carbonate) in the Ogallala ranges from a few inches to about 12 feet (test hole log 18-29-15ccc). It is generally white and is fairly soft. Plate 7B is a photograph taken in a pit silo excavated in a bed of white caliche in the NW¼ sec. 26, T. 16 S., R. 30 W.

In some places the Ogallala formation is capped by a distinctive limestone layer, called "Algal limestone" (Elias, 1931, p. 136-141) because of its peculiar concentrically banded structure. The "Algal limestone" has a maximum thickness in Lane County of about 4 feet and in typical outcrops is reddish. It is hard and weathers to a knobby, irregular surface. Elias and Landes (Elias, 1931, p. 141) observed outcrops of "Algal limestone" 3 miles northwest of Alamota in Lane County, and along Highway K-96 on the eastern border of Lane County. I found 20 additional localities where limestone with prominent algal structure was exposed. I also found several other limestone beds lacking the concentric algal structures but otherwise similar to the Ogallala caprock.

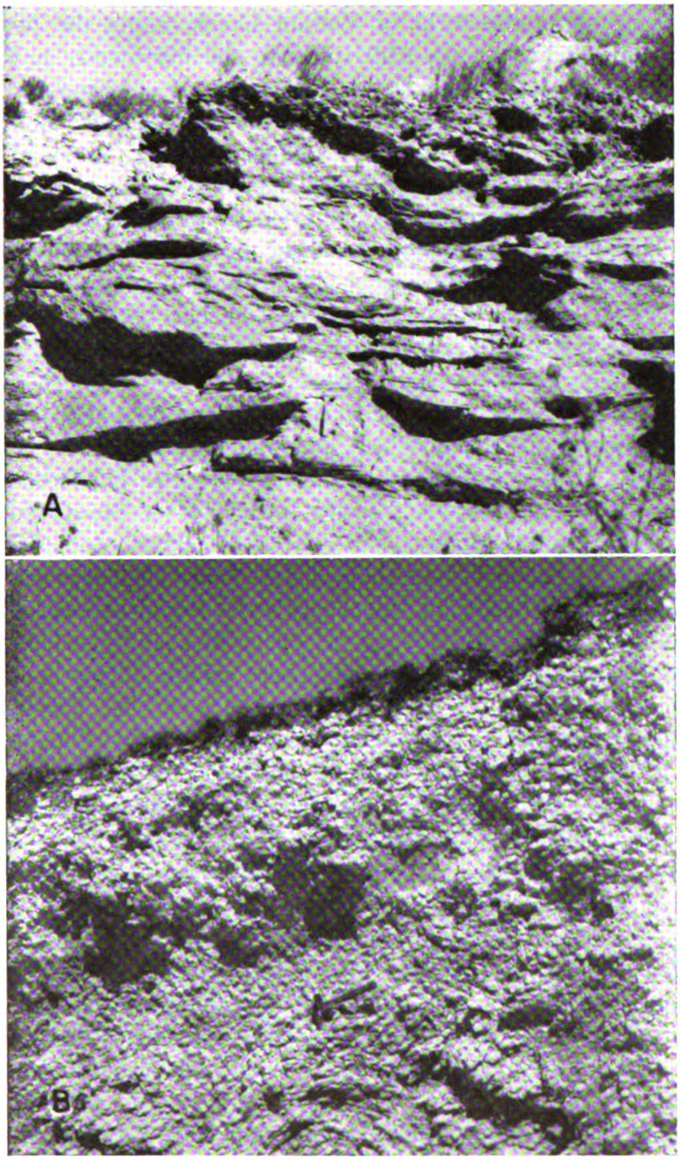

PLATE 7.—The Ogallala formation in Lane County. *A*, Cross-bedded partially cemented sand and gravel in the Ogallala formation; SW¼ NE¼ sec. 1, T. 18 S., R. 28 W. *B*, Caliche bed in Ogallala formation; photograph taken in a pit silo excavated in caliche, NW¼ sec. 26, T. 16 S., R. 30 W.

Distribution and thickness.—Exposures of the Ogallala formation occur along the forks of Walnut Creek, along the heads of draws tributary to Smoky Hill River to the northwest, and along other drainageways. In several of these areas ephemeral streams have cut through the Ogallala into the underlying Smoky Hill chalk member. Other isolated Ogallala outcrops, many of them "Algal limestone", occur throughout the county. Most of the upland surface in Lane County is mantled by deposits of Pleistocene age. The Ogallala formation, however, is found beneath younger deposits over most of the area. It is absent in some areas in the southeastern part of the county where it has been removed by erosion, thus exposing the underlying Cretaceous rocks. It has also been removed in some areas along the northern border of the county. In test holes 20-30-21ccc and 20-30-31ccc in southwestern Lane County the Ogallala formation was not encountered. It is probable that in this area the Ogallala formation was removed by erosion and sediments of Pleistocene age were deposited in its place.

The thickness of the Ogallala varies greatly because of the irregular Cretaceous surface upon which the sediments were deposited and in part because some of or all the sediments were removed by post-Ogallala erosion. The Ogallala formation ranges in thickness from a few feet to about 160 feet. The thickness of Ogallala sedimentary rocks encountered in test drilling ranged from 16 to 160 feet. The formation is thickest in the northwestern part of the county in the vicinity of Healy and in general becomes progressively thinner southward and southeastward.

Origin. — The Ogallala formation was deposited mainly by streams that flowed from the Rocky Mountain region. As time went by, stream channels became filled with deposits. This led to overflow of the streams and the building of broad flood plains. Erosion continued in the upland areas and deposition took place along the streams. Eventually the valleys became filled, divides were covered, and the depositional zones of individual streams overlapped.

Not all the Ogallala sediments were deposited by running water. At various times shallow lakes formed by the damming of stream channels were probably in existence. Beds of volcanic ash seem to have been deposited in still water (Frye and Leonard, 1949, p. 39) and the "Algal limestone" also formed in quiet water.

Most of the constituent materials of the Ogallala formation were derived from weathered rocks from the Rocky Mountains. Locally derived fragments of the Niobrara formation are also found near the base of the Ogallala. Some of the calcium carbonate that is very abundant in the Ogallala has probably been deposited by percolating subsurface water or ground water after the deposition of the rocks.

Age and correlation.—The Ogallala formation was named by Darton in 1899 (pp. 732, 734) from a locality in southwestern Nebraska, and its age was given as late Tertiary or Pliocene (?). In 1920 Darton (p. 6) designated the type locality as being near Ogallala station in western Nebraska. Elias (1931) made a detailed study of the Ogallala formation in Wallace County and in 1937 briefly described the Ogallala deposits in Rawlins and Decatur Counties. These deposits have recently been described in several southwestern Kansas Counties (Frye, 1942; Latta, 1941, 1944, 1948; McLaughlin, 1942, 1943; Waite, 1942, 1947) and in two counties in northern Kansas (Frye, 1945; Frye and Leonard, 1949).

The Ogallala formation is considered by the State Geological Survey of Kansas to range from early to late Pliocene in age. The Ogallala is subdivided into three members, which are in ascending order, the Valentine, Ash Hollow, and Kimball. The top of the Kimball is marked by the "Algal limestone". The Ogallala was not subdivided in Lane County.

Water supply.—The sand and gravel of the Ogallala formation is the most important source of ground water in Lane County. Most of the domestic and stock wells in the upland areas, all the public supply wells, and all the irrigation wells being pumped in 1948 derive water from the Ogallala formation. In addition the Ogallala supplies water to several springs in the county. The yields of wells tapping the Ogallala range from a few gallons a minute for small domestic and stock wells to about 1,200 gallons a minute for one irrigation well. The irrigation wells obtain their water from coarse materials that generally occur in the lower part of the Ogallala. The coarser materials, gravel and coarse sand, are good water bearers and generally yield abundant supplies of water where they occur beneath the water table. On the other hand, finer materials are generally rather porous and hold much water, but are not sufficiently permeable to yield water freely.

The permeability of a water-bearing material (its capacity for transmitting water under pressure) is described under permeability of water-bearing materials. Laboratory determinations of coefficients of permeability of samples from the Ogallala of Lane County were not made, but determinations on similar materials from Thomas County showed a range from 107 to 609 for uncemented sand and gravel (Frye, 1945, p. 65). Coefficients of permeability determined by pumping tests in Lane County ranged from 320 to 3,400, indicating that the permeability of sand and gravel beds in the Ogallala in places is sufficient to allow the development of wells of high capacities.

The thickness of saturated material in the Ogallala is shown in Figure 9 and in the cross sections in Figure 6. Logs of test holes indicate that much of the saturated zone of the Ogallala is composed of sand and gravel; therefore the amount of water in storage is large.

Water samples were collected from 20 wells that obtained water from the Ogallala formation. Analyses of the samples of water are given in Table 5 and graphic analyses of typical waters from the Ogallala are shown in Figure 10. Of the 21 samples of Ogallala waters analyzed, only one had a total hardness of less than 200 parts per million; 15 had a hardness of 200 to 300 parts; three had a hardness of 300 to 400; and two had a hardness of more than 400 parts per million. Hardness ranged from 188 to 461 parts per million. The iron content, generally low, had a maximum of 2.5 parts per million. The fluoride content of the 21 samples ranged from 0.7 to 4.5 parts per million. Three samples contained from 0.6 to 1.0 part per million, 4 contained from 1.1 to 1.5, 7 contained from 1.6 to 3.0, and 7 contained from 3.1 to 4.5 parts per million of fluoride. The fluoride content of most of the samples of Ogallala water is high and should be considered where the supply will be used for drinking purposes by children. Analyses indicate that water from the Ogallala formation is well within safe limits suggested for irrigation.

Quaternary System

PLEISTOCENE SERIES

Meade (?) Formation

Character.—The Meade (?) formation consists mainly of sandy silt and clay and very fine sand. At the base it contains fine sand and a little gravel. The gravel contains pebbles derived from the underlying Smoky Hill chalk member. The Meade in many places contains a volcanic ash bed, the Pearlette ash, but no ash was identified from well cuttings in Lane County. A terrace deposit along a tributary to Smoky Hill River on the northern border of the county is also tentatively classified as Meade formation and consists of sand, gravel, and silt.

Distribution and thickness.—In Lane County, the Meade (?) formation is limited to a few square miles in the southwestern part of the county and to a small terrace remnant along a tributary to Smoky Hill River in sec. 3, T. 16 S., R. 29 W. It ranges from a featheredge to about 120 feet in the southwest; it is thin in sec. 3, T. 16 S., R. 29 W.

Age and correlation.—Although the constituent materials in the Meade (?) deposits in southwestern Lane County are considerably different from the undifferentiated Pleistocene deposits of Scott County, I believe that they are of the same age. The basin in southwestern Lane County probably joins the Scott-Finney basin in northern Finney County. In order to prove this, more test holes must be drilled in Finney County.

The evidence of fossils indicates that at least part of the undifferentiated Pleistocene deposits in Scott County may be properly called Meade. A skull and horns of *Superbison latifrons,* a species commonly found in the lower part of the Meade, were unearthed in a gravel pit in Scott County (Waite, 1947, pp. 132-133; Colbert, 1948, p. 569). Teeth of *Parelephas columbi,* a mammoth found in Meade deposits, were also discovered in gravel deposits of Scott County. However, remains of this species have been found in younger Pleistocene deposits in Kansas (Frye, 1942, p. 110) and in Nebraska (Lugn, 1935, p. 142).

The Meade formation in Kansas is separated into two members, the lower or Grand Island member which generally consists of sand and gravel, and the upper or Sappa member which generally consists of stratified sand and silt and may contain the Pearlette volcanic ash (Frye, Swineford, and Leonard, 1948, pp. 518-523). In a road cut in the NW¼ NW¼ sec. 3, T. 16 S., R. 29 W. Peoria loess rests on a soil profile developed on the Loveland loess. The Loveland rests on terrace materials that consists of sands and silts of the Sappa member and sands and gravels of the Grand Island member. No volcanic ash was noted at this place, but in the SE¼ sec. 26, T. 15 S., R. 28 W. in Gove County, Pearlette ash was found in a terrace along a tributary to the Smoky Hill. Because the Meade (?) is exposed only in a very small area in sec. 3, T. 16 S., R. 29 W. (it is covered by dune sand and a thin loess mantle in southwestern Lane

County) it was included with the Sanborn formation in the geologic mapping.

Water supply.—The Meade (?) yields water to several wells in southwestern Lane County. It contains a large amount of water, but the water-bearing beds are composed of fine materials and no large yields can be obtained.

A water sample was collected from one well obtaining water from the Meade (?) formation. It was very similar in quality to Ogallala waters although it was slightly harder and contained more dissolved solids than most samples of Ogallala water. Its fluoride content was less than in most Ogallala waters.

Sanborn Formation

Character.—In 1931 Elias (pp. 163-181) described unconsolidated Pleistocene deposits consisting mostly of silt in northwestern Cheyenne County, Kansas, and named these deposits Sanborn formation from the town of Sanborn, Nebraska, just north of the type area.

Elias recognized three types of loess in Wallace County: loess of the divides, loess of the valley slopes, and valley-bottom loess. He considered that (1931, pp. 179-180)

> . . . only the loess that covers the divides can be considered of Pleistocene age (and, therefore, Sanborn formation), the loess of the valley slopes and bottoms being largely if not wholly redeposited from the divides, the redeposition having taken place probably for the most part in late Pleistocene and Recent times.

Most geologists consider that loess is eolian silt, having been transported and deposited by the wind. However, Elias applied the term loess to colluvial slope deposits that are composed of reworked loess from the divides, including some fragments of locally derived bedrock. Wind, surficial water, and slope processes have been the chief agents of transportation of these slope deposits. Elias also classed as loess certain deposits that he called valley-bottom loess. These deposits grade downward into alluvial sands and gravels and must be regarded as part of the alluvial deposits (Elias, 1931, p. 180).

Slope deposits of Recent age similar to those described in Wallace County (Elias, 1931) are extensive in Lane County and cover the slopes of most of the valleys. Where the parent material consists entirely of the Sanborn formation, slope deposits are indistinguishable from the Sanborn. In this report the term "loess" includes only loess that covers the divides. However, because of the similarity in character between colluvial slope deposits and loess of the divides, slope deposits are included with the Sanborn formation on the geologic map. In some areas, especially along the western end of the north fork of Walnut Creek, the Ogallala crops out at the side, whereas the stream channel is shown to cut into the Sanborn formation (Pl. 1). Presumably, the stream should also cut into the Ogallala because the stream is at a lower altitude than the Ogallala outcrops along the sides. The inclusion of slope deposits with Sanborn formation on the geologic map is the reason for this apparent discrepancy, the slopes between the Ogallala outcrops and the stream channel below in places being covered with colluvial slope deposits.

In Lane County two members of the Sanborn formation, the Peoria silt member and the Loveland silt member, have been recognized. The unconformity between the two is identified by a well-developed fossil soil zone at the top of the Loveland silt member. This soil zone is exposed in road cuts throughout the area and it has been encountered in some of the test holes (Pl. 8).

The Loveland silt member consists of massive reddish-brown silt. At the top is a leached zone that is dark reddish-brown in color owing to oxidation and probably some organic material. A concentration of lime leached from the upper zone has been redeposited below as nodules and stringers of caliche. Very few snail shells were found in the Loveland silt member.

The Peoria silt member which is above the Loveland consists predominantly of tan to light-brown unstratified silt. Many snail shells were recovered from drill cuttings and snails are abundant on outcrops of Peoria loess. The Brady soil zone found in many places at the top of the Peoria (Frye and Leonard, 1949, p. 46) has not been recognized in Lane County.

According to Elias (1931, p. 163) the basal part of the Sanborn loess is everywhere sandy and in many places coarse gravel is found at the base of the formation. Boulders as much as 2½ feet in diameter were noted in Wallace County. Test wells drilled in Lane County indicate that the basal part of the Sanborn may be sandy and may contain small amounts of gravel, but the coarse gravel described by Elias (1931, pp. 163-178) either is lacking or was not recovered from the test holes. However, in several localities throughout the county thin sheets of gravel composed of pebbles of basalt, quartz, quartzite, jasper, and flint (often as petrified wood), mantle the underlying rocks, generally the Smoky Hill chalk member of the Niobrara formation. This gravel is considered to be equivalent to the basal gravels of the Sanborn of Elias.

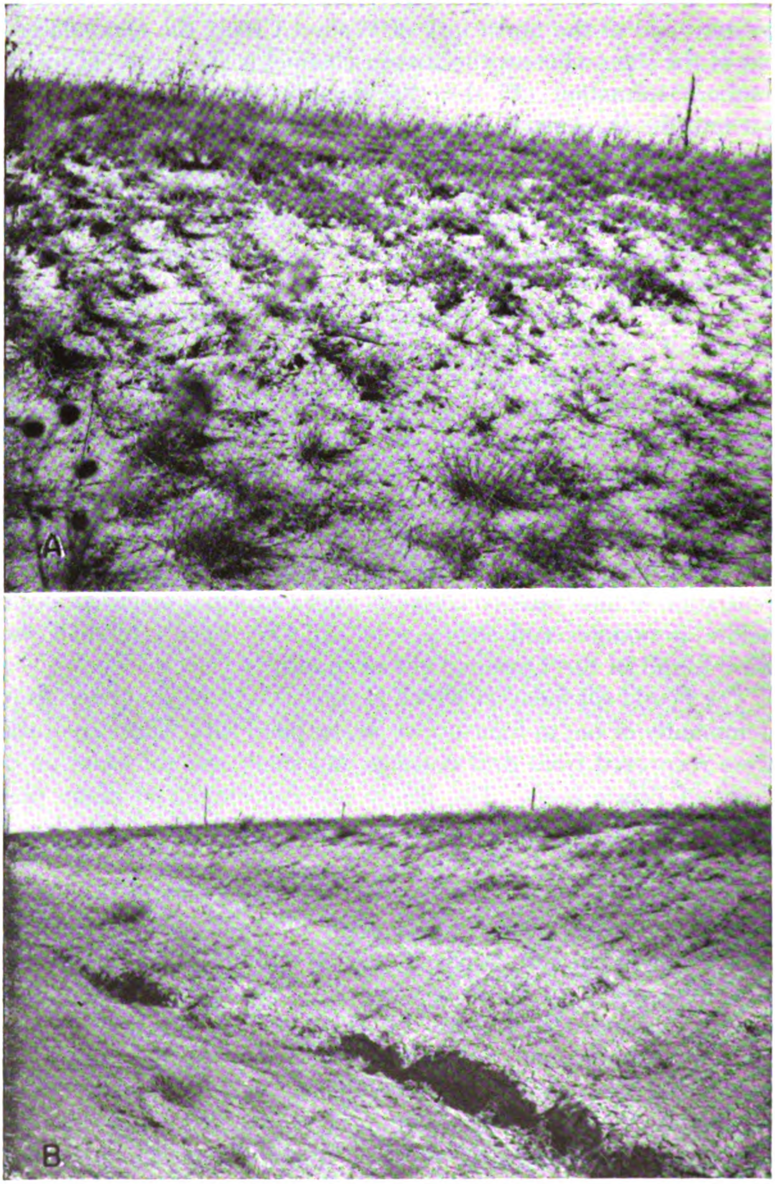

PLATE 8.—The Sanborn formation in Lane County. *A*, Peoria silt member of Sanborn formation, SE¼ NE¼ sec. 15, T. 16 S., R. 29 W. *B*, Peoria silt member of Sanborn formation lying on fossil soil zone developed on Loveland silt member; on east side of Highway 23, northern Lane County in the NW¼ SW¼ sec. 2, T. 16 S., R. 29 W. View looking northeast.

Distribution and thickness.—As indicated on the geologic map (Pl. 1), much of the surface of Lane County is underlain by the Sanborn formation. Most of the test holes drilled in the county encountered loess deposits. Because road cuts and other excavations are generally shallow and because natural exposures are few and small, the thickness of the Sanborn formation or of its members is not determinable. The greatest thickness of the Sanborn formation penetrated in test drilling was about 25 feet in test hole 18-30-21bbb.

Age and correlation.—The name Sanborn formation was first used in 1931 (p. 163) by Elias for the loess (with some sand and gravel at the base) that is widely distributed on the divides in western Kansas. The name replaced such terms as "Tertiary marl" and "Plains marl" used by Robert Hay (1895) and other early workers in the central Great Plains region. Elias considered that these deposits were Pleistocene. In the type section of the Sanborn formation south of Sanborn, Nebraska, stratigraphic units equivalent to the Peoria loess and the Loveland loess have been identified as well as a less well-developed fossil soil that may be equivalent to the Brady soil. Correlations of the various units exposed in the type section of the Sanborn have been made eastward across northern Kansas to the glaciated area. The loesses and buried soils have been traced by outcrops and auger holes southward from Jewell County across the uplands of Mitchell and Lincoln Counties to Rice and McPherson Counties (Frye and Fent, 1947, pp. 41, 42). Condra, Reed, and Gordon (1947) have traced the Loveland loess and the Peoria loess from western Iowa across Nebraska to eastern Colorado and into Kansas and Missouri. In Nebraska the Peoria silt member has been found beneath Iowa till and has been established as post-Iowan glaciation in age. The Loveland silt member underlies the Iowa till in places and is pre-Iowan glaciation in age.

Fossil snails collected from the Sanborn formation in Lane County by A. Byron Leonard and John C. Frye are listed below (Frye and Leonard, 1951, fig. 4).

Fossil snails from the Peoria silt member of the Sanborn formation in Lane County (identified by A. Byron Leonard).

Vallonia gracilicosta Reinhardt	*Helicodiscus parallelus* Say
Pupilla blandi Morse	*Discus shimeki* Pilsbry
Pupilla muscorum Linne	*Lymnea parva* Lea
Hawaiia miniscula Binney	*Vertigo milium* Gould
Succinea avara Say	*Discus cronkhitei* Newcomb

Water supply.—In most of Lane County the Sanborn formation lies above the water table and yields no water to wells. However, it is thought that in a few isolated areas where the water table is close to the surface the Sanborn may yield water to wells, probably from sand or gravel at the base of the formation. No analyses of water from the Sanborn formation were obtained. Because of the impermeability of its silts, the Sanborn exerts a strong retarding effect on ground-water recharge.

Dune Sand

Dune sand of Quaternary age covers an area of about 5 square miles in the southwestern corner of Lane County, and a small isolated dune occurs along the Lane-Finney County line 4 miles east of the border of Scott County (Pl. 1). The dune sand is composed predominantly of fine- to medium-grained quartz sand and contains smaller amounts of coarse sand, silt, and clay. The sand has been accumulated by the wind to form small hills and ridges. Most of the sand hills are covered by sparse vegetation, but in some spots there are areas of bare sand that are being subjected to renewed wind action. The thickness of the sand dunes in this area has not been determined but the maximum thickness of the sand probably is between 30 and 40 feet. The source of the dune sand is uncertain, but it probably was the near-by Pleistocene and Pliocene deposits or possibly the terrace deposits along Arkansas River. A detailed discussion on sand dunes is found in a report by Smith (1940, pp. 127-128; 153-168).

Of the wells inventoried in Lane County, none obtains water directly from dune sand. Because of its high permeability the dune sand serves as a valuable intake area for ground-water recharge from local precipitation.

Alluvium

Alluvial deposits of Recent age occur along the bottoms of parts of the valleys of Hackberry Creek, the forks of Walnut Creek and along some of the smaller streams and drainageways tributary to these creeks. A few of the valleys that drain northward to Smoky Hill River also are underlain by a thin band of alluvium. In most places the alluvium is fine textured and consists of materials derived from slope deposits. Coarser materials consisting of sand and gravel derived from the Ogallala formation or pebbles of limestone and chalk eroded from the Niobrara formation are also found in the alluvium. The alluvium is generally thin and forms a narrow band along the stream channel. The field mapping of the alluvium was somewhat arbitrary in some places, for the boundary between slope deposits and alluvium is not distinct. Probably in places slope deposits and valley-bottom loess (Elias, 1931, p. 180) have been mapped as alluvium.

Many wells obtain their water from alluvial deposits in Lane County. Two wells that supply most of the water used in the village of Alamota derive water from the alluvium of the south fork of Walnut Creek. These wells are about 35 feet deep. An unused (in 1948) irrigation well in sec. 25, T. 18 S., R. 28 W. obtained water from the alluvium. A test hole drilled near by indicates a thickness of 55 feet of alluvial (and possibly some slope) deposits.

Five analyses of water samples derived from wells tapping alluvial deposits have been made. Results of these analyses are given in Table 5 and one analysis is shown graphically in Figure 10. In general the composition of water in the alluvium was similar to that obtained from the Ogallala formation. However, the fluoride content was less than that of Ogallala water, only one sample containing more than one part per million of fluoride. Fluoride ranged from 0.4 to 1.1 parts per million and would be satisfactory for a drinking supply. Total hardness ranged from 282 to 572 parts per million, and dissolved solids ranged from 399 to 789 parts per million. The ratio of calcium to magnesium is greater in waters obtained from alluvium than in waters obtained from the Ogallala. This may indicate that these wells, which are in areas of Cretaceous bedrock, may penetrate chalky beds that may be the source of the high calcium content.

RECORDS OF TYPICAL WELLS

Descriptions of wells visited in Lane County are given in Table 8. All information classed as reported was obtained from the owner or tenant. Depths of wells not classed as reported were measured and are given to the nearest tenth of a foot below the measuring point described in the table. Depths to water level not classed as reported were measured and are given to the nearest hundredth of a foot. An explanation of the well-numbering system is on page 13.

TABLE 8.—*Records of Wells in Lane County, Kansas*

WELL NUMBER	Owner or tenant	Type of well (1)	Depth of well (feet) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above or below (—) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet) (6)	Date of measurement, 1948	REMARKS (Yield given in gallons a minute; drawdown in feet)
T. 16 S., R. 27 W.															
16-27-3cdc	Dale Mendenhall	Dr	711	8	S	Sandstone	Dakota	Cy,W	D,S	....	....	....	300	Sept. 14	
16-27-12ddd	B. Evel	Dr	13.9	6	GI	Sand, gravel	Ogallala	Cy,W	S	Top of casing	0.5	2,589.8	8.04	July 28	
16-27-13ddd	E.P. and M.S.Horchem	Du	80.0	36	C	(?)	do	Cy,H,W	D,S	Top of concrete curb	.8	2,664.9	77.66	Sept. 6	Chemical analysis
16-27-17dcc	Clarence Nevins	Du	78.5	36	......	(?)	do	Cy,W	N	Top of board curb	.9	2,717.4	68.18	July 28	Abandoned domestic and stock well
16-27-19dad	H. B. Cates et al	Dr	81.7	6	GI	(?)	do	Cy,H,W	D,S	Top of concrete curb	1.6	2,735.3	77.87	Sept. 3	Not used very much
16-27-24dcd	Missouri Pacific R. R.	Dr	113	18	S	(?)	do	T, E	RR	....	....	....	100	Sept. 6	Abandoned in 1948
16-27-25abb	J. C. Peters et al	Dr	105.6	6	GI	(?)	do	Cy,H,W	D,S	Top of casing	1.0	2,684.1	93.67	Sept. 7	Not being used
16-27-26baa	C. Anderson	Dr	94.5	6	GI	(?)	do	Cy,H,W	S	do	.8	2,698.0	82.20	Sept. 6	
16-27-28baa	Cynthia Leighton	Dr	73.7	6	GI	(?)	do	N,N	N	do	.3	2,701.2	55.11	Nov. 10	Abandoned stock well
16-27-29ddc	G. L. Wheatcroft	Dr	65.5	6	GI	(?)	do	Cy,H	N	Top of casing north side	.2	2,711.2	52.88	July 28	Abandoned domestic well
16-27-36bbc	F. Hymes	Du	24.0	42	C	(?)	do	Cy,W	S	Top of board cover, west side	1.7	2,629.3	22.24	July 28	
16-27-36ddd	do	Dr	29.1	6	GI	(?)	do	Cy,W	S	Top of casing	.7	2,618.5	23.69	Sept. 6	
T. 16 S., R. 28 W.															
16-28-3abb	G. R. Davidson	Du	10.3	36	C	Silt	Sanborn	Cy,H,W	S	Top of board cover	1.1	2,559.0	5.85	Sept. 3	
16-28-4bcd	Carlos Roberts	Dr	673	8	S	Sandstone	Dakota	Cy,W,G	D,S	Top of casing	1.9	2,603.2	346.10	Sept. 7	Chemical analysis. Reported to have hit water at 642 ft.
16-28-6aba	W. M. James	Du	8.3	22	OB	Silt	Alluvium	Cy,W	S	Top of board cover	.8	2,555.0	5.43	Sept. 3	
16-28-16bbc	Inez Dickson	Dr	300	6	GI	Chalk, shale	Smoky Hill	N,N	N	Top of tin sheet, north side	.7	2,698.0	102.18	July 27	Abandoned
16-28-28cdc	W. Schmied	Dr	75.0	6	GI	(?)	Ogallala	Cy,H	S	Top of concrete curb	.0	2,772.2	57.52	Sept. 3	
16-28-29cdc	J. W. Bradley, Jr.	Dr	96.8	6	GI	(?)	do	Cy,W	S	Top of casing	.7	2,781.0	82.85	Aug. 14	
16-28-30aca	W. J. Tillotson	Dr	92.2	6	N	(?)	do	Cy,W	S	Top of concrete curb	1.0	2,783.5	79.50	Aug. 14	
16-28-32caa	do	Dr	103.0	6	GI	(?)	do	Cy,W	D	do	.5	2,781.6	84.68	Aug. 14	Chemical analysis
16-28-33ccc	E. R. Terwilliger	Dr	101.7	6	GI	(?)	do	Cy,W	D,S	do	.5	2,779.0	85.74	Sept. 7	
16-28-34cbb	Mabel M. Terwilliger	Dr	82.5	6	GI	(?)	do	Cy,H,W	D,S	Top of casing	.9	2,762.6	69.18	Sept. 7	
16-28-36bcc	R. Terwilliger	Dr	28.5	6	GI	(?)	do	Cy,H,W	D,S	do	.6	2,686.7	17.43	Aug. 23	

T. 16 S., R. 29 W.														
16-29-3bcb	M. Macie et al.	Dr	25.1	6	GI	Silt, sand	Alluvium	Cy,W	D,S	do.	.0	2,599.3	24.23	Sept. 2	
16-29-11ccc	D. P. Dowell	Dr	749	8	S	Sandstone	Dakota	Cy,W	D,S			2,730.2	400	Sept. 2	Chemical analysis. Reported to have hit water at 726 ft.
16-29-13ca	J. S. Eaton	Dr	717	8	S	do.	do.	Cy,G	D,S				300	Sept. 9	Water level is very rough estimate
16-29-17dda	C. Gano Munns	Dr	26.2	6	GI	Silt	Alluvium	Cy,H,W	D	Top of casing	1.8	2,718.1	21.44	Sept. 1	
16-29-18cbc	E. Z. Gano	Dr	50.5	6	GI	(?)	Ogallala	Cy,W	S	do.	.4	2,777.8	43.15	July 26	
16-29-21dad	C. Gano Munns	Dr	94.5	6	GI	(?)	do.	Cy,W	S	do.	.6	2,803.6	86.35	Sept. 2	
16-29-25ddd	W. M. James	Dr	90.5	6	GI	(?)	do.	Cy,W,H	D,S	Top of curb	.5	2,789.8	85.26	Aug. 14	
16-29-26bbc	C. J. Van Pelt	Dr	97.4	6	GI	(?)	do.	Cy,W,H	S	Top of casing	1.0	2,801.3	86.94	Sept. 1	
16-29-27cdd	Ross Jasper	Dr	103.5	6	GI	(?)	do.	Cy,G	S	do.	.0	2,804.9	88.23	Sept. 1	
16-29-28dab	do.	Dr	170.0	18	S	Sand, gravel	do.	T,B	I	Hole, base of pump	.3	2,812.3	93.53	Sept. 1	Chemical analysis
16-29-30aba	H. S. Jennison	Dr	46.4	6	GI	(?)	do.	Cy,H,W	S	Top of casing	.6	2,773.0	38.85	Sept. 2	
16-29-31bdb	B. I. Dickey	Dr	77.1	6	GI	(?)	do.	N,N	N	do.	1.7	2,782.3	53.74	Sept. 1	Well not completed
16-29-33bcc	C. Gano Munns	Dr	98.0	6	GI	(?)	do.	Cy,H,W	D,S	do.	.5	2,812.8	89.82	Sept. 1	
T. 16 S., R. 30 W.															
16-30-8cb	Clifford E. Cooley	Dr	18.5	6	GI	(?)	Alluvium	Cy,H,G	D,S	do.	1.2	2,659.3	9.20	Aug. 27	
16-30-11ccc	J. E. Lewis	Du	9.8	96	C	(?)	do.	Cy,W	N	Top of curb	.0	2,678.4	7.00	July 24	Not used
16-30-13add	Nellie J. Harper	Dr	115.0	6	GI	(?)	Ogallala	Cy,H,W	S	Top of casing	.9	2,833.5	102	July 21	Chemical analysis. Measurement only approximate
16-30-17dad	Carl Mathes	Du	19.1	23	OB	Sand, gravel	do.	Cy,W	D	Top of casing, west side	3.0	2,760.3	12.79	Aug. 27	Also used to irrigate small garden
16-30-21bcb	R. F. Hagans	Dr	147.5	6	GI	(?)	do.	Cy,W	S	Top of casing	−4.5	2,866.4	107.51	Aug. 31	Chemical analysis
16-30-22aba	Clayton Bentley	Dr	36.5	6	GI	Sand, gravel	do.	Cy,W	S	do.	1.0	2,747.1	28.45	Sept. 2	Chemical analysis. Also used to irrigate small garden
16-30-25ccc	B. I. Dickey	Dr	119	6	GI	(?)	do.	Cy,H,W	D,S			2,837.9	113	Sept. 1	Not used frequently
16-30-27add	Leah Bentley	Dr	119.1	6	GI	(?)	do.	Cy,H,W	D,S	Top of casing	.7	2,844.7	108.18	Sept. 1	Not used
16-30-30dda	C. E. Simonsen	Dr	156.0	6	GI	(?)	do.	Cy,H,W	S	do.	.6	2,879.2	116.75	Aug. 27	
16-30-31ddc	D. D. Hageman	Dr	116.2	6	GI	(?)	do.	Cy,W	D,S	Top of curb	.2	2,888.6	113.30	Aug. 26	Not in use
16-30-32ddc	Loella M. Hagans	Dr	134.7	6	GI	(?)	do.	Cy,H,W	D	Top of casing	.4	2,879.4	111.98	Sept. 9	Not used frequently
16-30-35ccb	E. Z. Gano	Dr	129.0	6	GI	(?)	do.	Cy,H,W	D	do.	.3	2,844.8	108.30	Sept. 2	Not in use at present
16-30-36ccc	D. L. and L. M. Snider	Dr	114.0	6	GI	(?)	do.	Cy,H,W	N	do.	.6	2,838.5	109.02	July 26	Abandoned domestic well
T. 17 S., R. 27 W.															
17-27-4dbc	C. C. Leighton	Dr	25.2	6	GI	(?)	do.	Cy,W	S	do.	.5	2,614.0	17.20	Sept. 6	
17-27-5bcb	Nancy E. Miller	B	35.0	6	GI	(?)	Ogallala and Smoky Hill	Cy,W	D,S	do.	2.0	2,637.1	18.00	Aug. 24	
17-27-12ddd	R. F. Hagans	Dr	31.1	6	GI	(?)	Alluvium and Smoky Hill	Cy,H,W	S	do.	.9	2,568.0	19.15	Sept. 6	
17-27-15ddb	Mrs. Wm. F. Major	Dr	100.0	6	GI	(?)	Ogallala	Cy,H,W	D,S	do.	.7	2,682.5	87.05	Aug. 24	
17-27-16ccc	Ed. C. Wheatcroft	Du	30.0	6	GI	(?)	do.	Cy,H,W	D,S	do.	−2.8	2,655.7	22.65	Sept. 6	Chemical analysis
17-27-18bcb	Vernon Waterson	Dr	85.5	6	GI	(?)	do.	Cy,W	D,S	Top of concrete curb	.8	2,741.7	83.49	July 22	Abandoned
17-27-20cdd	Edith Neeley	Dr	103.0	6	GI	(?)	do.	Cy,H	N	Base of board platform	.4	2,711.2	80.86	July 22	Abandoned domestic well
17-27-21aad	J. E. Russell	Du	10.1	36	B	(?)	Alluvium	Cy,W	S	Top of casing	1.9	2,636.0	9.12	Sept. 4	
17-27-27bdd	do.	Dr	36.3	6	GI	Sand	Ogallala	N,N	N	do.	.9	2,647.0	35.28	Sept. 4	Unfinished stock well
17-27-28abb	A. Ross Hanks	Dr	99.8	4	N	Sand, gravel	do.	N,N	N	Surface of ground	.0	2,706.1	82.98	Sept. 4	Irrigation test hole
17-27-35bbb	Elgin Repshire	Dr	110.0	6	GI	(?)	do.	Cy,W	D,S	Top of casing	.4	2,[illegible]91.7	96.37	Sept. 4	Chemical analysis
17-27-36ccd	G. M. Brown	Dr	28.7	6	GI	(?)	do.	Cy,H,W	S	do.	1.1	2,618.3	24.77	Aug. 24	

TABLE 8.—*Records of Wells in Lane County, Kansas—Continued*

Well Number	Owner or tenant	Type of well (1)	Depth of well (feet) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed		Method of lift (4)	Use of water (5)	Measuring point			Depth to water level below measuring point (feet) (6)	Date of measurement, 1948	REMARKS (Yield given in gallons a minute; drawdown in feet)
						Character of material	Geologic source			Description	Distance above or below (—) land surface (feet)	Height above mean sea level (feet)			
T. 17 S., R. 28 W.															
17-28-1ccc	F. Schneider	Dr	96.5	6	GI	(?)	Ogallala	Cy,H,G	S	Top of concrete curb	.7	2,738.1	77.58	Aug. 23	
17-28-4cbb	R. Terwilliger	Dr	92.8	6	GI	(?)	do	Cy,H,W	S	Top of casing	.8	2,777.6	87.73	Sept. 3	
17-28-5cbb	Albert Petrzelka	Dr	96.6	6	GI	(?)	do	Cy,H,W	D	Top of concrete curb	1.1	2,779.6	87.14	July 27	Used infrequently
17-28-9aba	H. Grusing	Dr	85.0	6	GI	(?)	do	Cy, H	S	do	.7	2,768.2	82.62	July 22	Not used often
17-28-10aaa	D. Mumma	Dr	90.0	6	GI	(?)	do	Cy,H,W	S	Top of casing	.2	2,751.5	77.60	Aug. 23	
17-28-14bab	Ed Borell	Dr	106.0	6	GI	(?)	do	Cy,H,W	D, S	do	—4.0	2,758.3	87.84	Aug. 23	
17-28-15cb	Lawrence Richards	Dr	147.0	18	S	Sand, gravel	do	T, B	I	Hole, base of pump	1.6	2,756.5	86.33	July 19	Chemical analysis. Yield measured 790
17-28-16dbb	B. U. Nichols	Dr	155.0	18	S	do	do	T, B	I	do	.9	2,761.7	82.46	July 17	Estimated yield 600
17-28-18aaa	R. C. Wheatcroft	Dr	102.5	6	GI	(?)	do	Cy,H,W	D, S	Top of curb	.0	2,777.5	82.72	Aug. 14	
17-28-19bcc	John Niedens	Dr	78.0	6	GI	(?)	do	Cy, W	S	Top of concrete curb	.2	2,768.6	67.14	July 26	
17-28-20ccc	M. Garten	Du	25.8	18	GI	(?)	do	Cy,H,W	S	Top of board cover	.8	2,706.0	13.69	Aug. 23	
17-28-22aaa	Carl Filbert	Dr	150.5	18	S	Sand, gravel	do	T, B	I	Hole, base of pump	1.3	2,747.5	81.37	July 19	Measured yield 1040
17-28-22bbb	Paul Lonner	Dr	155.0	18	S	do	do	T, D	I	do	.7	2,753.9	81.32	July 19	Estimated yield 1,200
17-28-24bbb	L. A. Davis	Dr	95.0	6	GI	(?)	do	Cy,W,G	D, S	Top of concrete curb	.4	2,736.0	80.49	Aug. 23	Not used frequently
17-28-26cbc	B. Hartman	Dr	23.5	6	GI	(?)	do	N, N	N	Top of casing	.8	2,676.3	22.86	July 22	Abandoned domestic and stock well
17-28-28acd	F. Boone	Dr	25.7	6	GI	(?)	do	Cy, W	D, S	do	.7	2,684.0	13.73	Sept. 4	Abandoned
17-28-31bbb	M. G. Bryant	Dr	91.5	6	GI	(?)	do	Cy, W	S	do	.5	2,778.9	74.39	Aug. 14	
17-28-31ccb	Pete Maser	Dr	62.0	6	GI	(?)	do	Cy,H,W	D, S	do	.5	2,764.1	59.61	Aug. 5	
17-28-33ccc	L. M. Bretz	Dr	80.5	6	GI	(?)	do	Cy, W	S	do	.7	2,745.8	61.69	Sept. 4	
17-28-35daa	Edna Van Wey	Dr	18.3	6	GI	(?)	do	N, N	N	do	.0	2,654.6	17.71	July 22	Abandoned school well
T. 17 S., R. 29 W.															
17-29-1dda	J. Newman	Dr	90.5	6	GI	(?)	do	Cy, W	S	do	.2	2,787.9	84.73	Aug. 14	
17-29-2cbb	Myrtle E. Walton	Dr	113.0	6	GI	Gravel	do	Cy, W	S	do	.4	2,798.8	85.03	Aug. 21	
17-29-4ccc	Fred Schmieg	Dr	115.0	6	GI	(?)	do	Cy,H,W	D, S	do	.5	2,828.3	105.00	Aug. 21	
17-29-5dda	do	Dr	117.7	6	GI	(?)	do	Cy,H,W	S	do	.5	2,819.3	94.59	Sept. 1	
17-29-5bcb	Ray Dodge	Dr	114.0	6	GI	(?)	do	Cy,H,W	D, S	do	.2	2,822.5	92.36	Sept. 1	Not used frequently
17-29-8ccc	G. R. Harper	Dr	96.5	6	GI	(?)	do	Cy,W,H	D, S	do	—4.3	2,822.0	86.40	Aug. 27	

T. 17 S., R. 29 W.															
17-29-9ddd	D. L. Snider	Dr	115.5	6	GI	Sand, gravel	do.	N, N	D	do.	2.8	2,807.5	87.36	Aug. 21	Uncompleted domestic well
17-29-13acc	H. G. Rusing	Dr	44.7	6	GI	(?)	do.	Cy,H,W	S	do.	.4	2,743.2	37.15	Aug. 23	
17-29-15aaa	S. Lyman	Dr	85.8	6	GI	(?)	do.	Cy,H,W	D, S	Top of concrete curb	.6	2,791.1	77.14	July 27	
17-29-19bab	Mrs. S. I. Zink	Dr	87.8	6	GI	(?)	do.	Cy,H,W	D, S	Top of casing	.8	2,831.0	77.58	Aug. 27	
17-29-20bad	E. L. Shay	Dr	110.5	6	GI	Sand, gravel	do.	Cy, W	S	Top of casing, north side	.8	2,810.5	64.66	Aug. 27	
17-29-20ddd	do.	Dr	110	6	GI	do.	do.	Cy,H,W	D				88	Aug. 27	
17-29-21ddd	Clara M. Snider	Dr	90.0	6	GI	(?)	do.	Cy,H,W	D, S	Top of concrete curb	.2	2,816.9	76.72	July 21	
17-29-22bab	Mary E. Schneider	Dr	87.5	6	GI	(?)	do.	Cy,H,W	S	Top of casing	1.0	2,803.8	82.58	July 21	
17-29-24cdd	G. H. Borell	Dr	82.0	6	GI	(?)	do.	Cy,H,W	S	do.	.3	2,781.8	73.53	Sept. 2	Not used frequently
17-29-25ccc	J. W. Pelton	Dr	102.0	6	GI	(?)	do.	Cy,H,W	D, S	do.	.3	2,797.3	79.77	Aug. 23	
17-29-26cdc	J. Armantrout	Dr	83.5	6	GI	(?)	do.	Cy, W	N	Top of concrete curb	.2	2,801.5	75.69	July 21	Abandoned domestic and stock well
17-29-31aaa	H. S. Johnson	Dr	44.0	6	GI	(?)	do.	Cy,H,W	D	Top of casing	.3	2,794.3	28.95	Aug. 25	Chemical analysis
17-29-31aaa2	do.	Dr	41.5	6	GI	(?)	do.	Cy,W,G	S	do.	.9	2,791.7	26.18	Aug. 25	
17-29-32ca	H. E. Hahn	Dr	49.2	18	S	(?)	do.	T, T	I	Hole in south side of pump	.9	2,711.0	11.93	July 30	Not pumped in 1948
17-29-34aaa	A. H. Rockwell	Dr	81.4	6	GI	(?)	do.	N, N	N	Top of casing	.0	2,801.8	72.62	July 21	Abandoned school well
17-29-35cdc	C. Riley	Dr	71.3	6	GI	(?)	do.	Cy, H	D	Top of hole in casing, east side	.0	2,797.2	70.36	Aug. 23	Used infrequently
T. 17 S., R. 30 W.															
17-30-2ccc	W. H. Anderson	Dr	115.0	6	GI	Sand	do.	Cy,H,W	D	Top of casing	.1	2,853.4	101.48	Sept. 2	
17-30-3baa	Healy Cemetery	Dr	113.0	6	GI	do.	do.	Cy,H,W	D	do.	.1	2,848.6	106.52	Aug. 27	
17-30-5ddd	Clara M. Mikesall	Dr	111.0	6	GI	(?)	do.	Cy, W	S	Top of casing, south side	.0	2,882.3	107.98	July 26	Not frequently used
17-30-8bcb	Ethel L. Graves	Dr	138	6	GI	Sand	do.	Cy, W	D			2,890.2	100	Aug. 26	
17-30-12abb	J. M. Cooling	Dr	115.0	6	GI	(?)	do.	Cy,W,H	D, S	Top of casing	—4.1	2,837.5	97.28	Aug. 27	
17-30-13cbb	F. L. Burmeister	Dr	94.0	6	GI	(?)	do.	Cy, N	O	Top of casing, west side	.1	2,859.4	86.64	July 24	Abandoned domestic and stock well
17-30-14bcb	Thelma Wilkens	Dr	112.7	6	GI	(?)	do.	Cy, W	S	Top of casing	.6	2,859.2	86.96	Aug. 26	
17-30-16aaa	Roy F. Hagans	Dr	105.0	6	GI	(?)	do.	Cy, W	S	Top of concrete curb	.7	2,867.3	89.26	Aug. 26	
17-30-21cdc	C. H. Merriweather	Dr	82.5	6	GI	(?)	do.	Cy, W	N	Top of casing	.6	2,871.4	76.55	Aug. 25	Abandoned domestic well
17-30-23ccd	C. W. Monroe	Dr	95.0	6	GI	(?)	do.	Cy,W,G	D, S	Top of concrete curb, west side	1.2	2,858.9	77.33	July 24	Not used
17-30-25cbb	Charles Strobel	Dr	94.5	6	GI	Sand, gravel	do.	Cy, W	S	Top of casing	.4	2,857.0	65.37	Aug. 25	
17-30-25daa	H. S. Johnson	Dr	51.0	6	GI	(?)	do.	Cy,W,H	S	do.	.7	2,823.8	50.32	Aug. 25	
17-30-30aaa	Nancy Jane Austin	Dr	85.0	6	GI	(?)	do.	Cy,H,W	D, S				80	Aug. 26	
17-30-33bcb	W. Krug	Dr	87.0	6	GI	(?)	do.	Cy,H,W	D, S	do.	2.3	2,876.8	74.80	Aug. 25	Not used frequently
17-30-35bbb	J. M. Edmundson	Du	70.0	36	(?)	Sand	do.	Cy, W	D, S	Top of curb	1.3	2,854.2	67.59	Aug. 11	
17-30-36ccc	H. M. Yates	Dr	77.0	6	GI	(?)	do.	Cy,H,W	D, S	Top of casing	1.2	2,853.0	72.87	Aug. 11	

TABLE 8.—*Records of Wells in Lane County, Kansas*—*Continued*

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T. 18 S., R. 27 W.															
18-27-3bbb	W. A. Doerschlag	Dr	54.1	6	GI	(?)	Ogallala	Cy,W,H	D, S	Top of casing	—4.2	2,648.7	44.09	Sept. 4	
18-27-4cbb	do	Dr	27.0	6	GI	(?)	do	Cy, H	D	do	.6	2,625.3	17.28	Aug. 24	
18-27-5bbb	Isadore Stacklin	Dr	40.0	18	S	(?)	Alluvium and Ogallala	T, G	I	do	.2	2,624.6	11.10	Aug. 7	Not used in 1948
18-27-5bbb2	do	Dr	38.9	5	GI	(?)	Ogallala	Cy, E	D	do	—4.7	2,638.0	21.90	Aug. 7	
18-27-10bab	Emil Dutoit	Dr	30.4	6	GI	(?)	Alluvium	N, N	N	Top of casing, east side	.4	2,606.2	23.68	Aug. 24	Abandoned stock well
18-27-13ccc	C. H. Merriweather	Dr	95.4	6	GI	(?)	Ogallala	Cy, H	O, D	Top of casing, south side	.6	2,674.1	88.56	July 28	Used very infrequently
18-27-14ddd	S. F. Dickinson	Du	88.0	36	R	(?)	do	Cy,W,H	N	Top of platform	1.7	2,674.7	87.96	July 28	Abandoned domestic and stock well
18-27-16aaa	Delmar Durr	Dr	88.5	6	GI	(?)	do	Cy,W,H	S	Top of casing	.0	2,702.3	84.93	July 22	
18-27-17add	do	Dr	101.5	6	GI	(?)	do	Cy, W	S	do	1.0	2,701.3	86.99	Aug. 24	
18-27-17ddd	do	Dr	96.0	6	GI	(?)	do	Cy, W	D, S	do	.5	2,703.3	91.52	Aug. 5	
18-27-19ddd	C. Hulme	Dr	62.0	6	GI	(?)	Ogallala and Smoky Hill	N, N	N	do	.8	2,652.6	41.32	Oct. 18	Abandoned stock well
18-27-22abb	Fritz Kuehn	Du	86.0	36	(?)	(?)	Ogallala	Cy, W	D	Top of curb	.5	2,679.7	80.23	Aug. 5	
18-27-22baa	do	Dr	85.5	6	GI	(?)	do	Cy, W	D, S	Top of casing	—3.0	2,676.6	75.62	Aug. 5	
18-27-25ccd	L. A. Hauschild	Dr	28.5	6	GI	(?)	Alluvium	Cy,H,G	D	do	.5	2,558.2	20.05	Aug. 7	
18-27-27ccb	R. G. Ely	Dr	30.0	6	GI	(?)	do	Cy,H,W	D, S	do	—3.8	2,589.1	20.83	Aug. 7	
18-27-28bbb	F. J. Vyvital	Dr	94.5	6	GI	(?)	Ogallala	Cy,H,W	S	Top of curb	.6	2,670.7	61.91	Aug. 7	
18-27-28dbb	do	Du	36.8	36	B	(?)	Alluvium	Cy, W	D	Top of concrete curb	.2	2,609.2	32.14	Sept. 4	Supplies much of water used in Alamota
18-27-28dbb2	do	Du	33.5	48	C	(?)	do	Cy, W	D	do	.0	2,609.3	32.83	Sept. 4	do
18-27-29caa	C. Hulme	Dr	41.0	6	GI	(?)	do	Cy, W	S	Top of casing	.0	2,626.6	30.03	Aug. 7	
18-27-30bcc	E. F. Alexander	Du	20.5	36	T, N	(?)	do	N, N	D	Top of curb	.3	2,634.2	12.78	Aug. 3	Chemical analysis; connected to near-by drilled well
18-27-35bbb	L. Greenwald	Dr	31.0	6	GI	(?)	do	Cy,H,W	D	Top of casing	.7	2,570.4	23.86	Aug. 7	

T. 18 S., R. 28 W.														
18-28-1bdd	A. J. and V. Selfridge	Dr	27.6	6	GI	(?)	Ogallala	Cy,H,W	S	do.	.2	2,638.1	10.43	Sept. 11	
18-28-3cac	B. U. Nichols	Dr	71.0	6	GI	(?)	do.	J, E	D, S	do.	−5.7	2,687.5	21.40	Aug. 16	
18-28-4ada	W. D. Holmes	Dr	46.0	6	GI	(?)	do.	N, N	N	do.	1.0	2,715.6	44.47	July 22	Abandoned
18-28-7caa	H. Ehmke	Dr	81.0	6	GI	(?)	do.	Cy, W	S	Top of concrete curb	.7	2,766.0	61.30	Aug. 23	
18-28-13cbc	Lena Ruth Durr	Dr	82.8	6	GI	(?)	do.	Cy, W	S	Top of casing, south side	.5	2,726.6	77.96	Aug. 7	
18-28-15abb	Herman Grusing	Dr	85.0	6	GI	(?)	do.	N, N	S	Top of casing, north side	.3	....	58.27	July 22	Unused stock well
18-28-15ccc	C. S. and F. E. Boone	Dr	61.0	6	GI	(?)	do.	N, N	O	Top of casing, south-west side	.5	2,740.0	56.88	Aug. 5	Not being used
18-28-16ccc	Dighton Cemetery	Dr	63.0	6	GI	(?)	do.	Cy, W	D	Top of casing	.0	2,752.8	53.52	July 20	Chemical analysis
18-28-18ccb	City of Dighton	Dr	100	18	S	(?)	do.	T, E	PS	....	....	....	53	....	Reported yield 200
18-28-22daa	H. A. Richards	(?)	55.4	(?)	(?)	(?)	do.	Cy, H	D	Top of curb	.6	2,695.1	40.49	Aug. 5	Used very seldom
18-28-25bca	Paul Hershberger	Dr	55.0	18	S	Silt, fine sand	Alluvium	T, G	I	Top of casing, south side	.1	....	16.69	Aug. 16	Not used in 1948
18-28-26aad	Henry Reifschneider	Dr	35.0	6	GI	(?)	do.	N, N	N	Top of casing, south-west side	.4	2,667.0	20.96	Aug. 16	Abandoned domestic well
18-28-30aab	Frances Ware	Dr	35.2	6	GI	(?)	Ogallala	Cy,H,W	D, S	Top of curb, south side	.3	2,737.7	24.06	Aug. 7	
18-28-34abb	Fred Belgard	Du	65.0	36	(?)	(?)	do.	Cy,H,W	D	Top of concrete curb	.8	2,738.0	58.20	Aug. 4	
18-28-34bbb	George E. Hineman	Dr	42.8	6	GI	(?)	do.	Cy, W	S	Top of casing	.1	2,710.6	25.79	Aug. 4	
18-28-35bc	Fred Belgard	Dr	19.6	6	GI	(?)	Alluvium and Ogallala	Cy, G	S	Top of casing, south-east side	.6	2,666.7	10.16	Aug. 4	
T. 18 S., R. 29 W.															
18-29-1dcc	I. L. Peck	Dr	65.5	6	GI	(?)	Ogallala	Cy,H,W	D, S	Top of concrete curb	.3	2,769.7	60.70	Aug. 23	Chemical analysis
18-29-3bdc	J. A. Fosdick	B	16.2	6	GI	(?)	Alluvium and Ogallala	N, N	N	Top of casing	1.2	2,748.6	11.08	Aug. 25	Abandoned stock well
18-29-5bdd	H. E. Hahn	Dr	39.0	6	GI	(?)	Ogallala	CyHWG	S	do.	.6	2,792.0	33.57	Aug. 19	
18-29-6acd	do.	Dr	126.0	18	S	Sand, gravel	do.	N, N	N	do.	.0	2,832.0	66.38	Aug. 19	Drilled as an irrigation well, not completed
18-29-10cbb	Wilbur E. McKenna	Dr	71.5	6	GI	(?)	do.	Cy,H,W	D, S	do.	.4	2,798.7	52.10	Aug. 25	
18-29-10daa	Emily A. Schiereck	Dr	69.0	6	GI	(?)	do.	N, N	N	Top of casing, south side	.3	2,790.3	57.78	July 21	Abandoned school well
18-29-11add	Isaac S. Armantrout	Dr	75.0	6	GI	(?)	do.	Cy,H,W	S	Top of casing, east side	.8	2,788.0	66.03	Aug. 23	Not in use
18-29-13acc	J. G. McClelland	Dr	55.0	6	GI	(?)	do.	Cy,H,W	D	Top of casing	.4	2,772.1	53.08	Aug. 23	
18-29-13bcb	Lane Co. Airport Assn.	Dr	65.3	6	GI	(?)	do.	N, N	O	Top of tin cover, north side	.8	2,787.2	58.36	July 29	Abandoned stock well
18-29-13ddb	City of Dighton	Dr	74.8	18	S	(?)	do.	T, E	PS	Ledge inside opening in base of pump	1.7	2,667.0	53.29	July 26	Yield unknown
18-29-13ddc	do.	Dr	88.5	18	S	Sand, gravel	do.	T, E	PS	Top of concrete curb	1.2	2,766.7	52.29	Aug. 29	Chemical analysis. Yield unknown
18-29-14bcc	O. L. Bryant	Dr	76.8	6	GI	(?)	do.	Cy, W	S	Top of casing	.4	2,792.7	51.57	Aug. 19	
18-29-16ddd	William McKenna	Dr	73.6	6	GI	(?)	do.	Cy, W	S	Top of casing, north-east side	.2	2,805.6	55.68	July 29	Not in use

TABLE 8.—*Records of Wells in Lane County, Kansas—Continued*

Well Number	Owner or tenant	Type of well (1)	Depth of well (feet) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above or below (—) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet) (6)	Date of measurement, 1948	REMARKS (Yield given in gallons a minute; drawdown in feet)
T. 18 S., R. 29 W.															
18-29-20bbb	George Ehmke	Dr	63.5	6	GI	(?)	Ogallala	Cy, W	S	Top of casing, southwest side	.1	2,832.4	55.95	Aug. 11	Chemical analysis
18-29-22ccc	Anna Hoffman	Dr	71.8	6	GI	(?)	do	Cy,H,W	S	Top of casing, west side	.4	2,813.4	55.22	July 29	
18-29-23baa	W. B. Marlin	Dr	60.5	6	T, GI	(?)	do	Cy, H	D	Top of tile casing	.4	2,788.6	50.75	Aug. 19	
18-29-21add	John Armantrout	Dr	57.5	6	GI	(?)	do	Cy,H,W	S	Top of curb	.3	2,767.2	42.23	Aug. 4	
18-29-32bbb	R. J. Ramsey	Dr	67.0	4	S	(?)	do	Cy,W,H	N	Top of casing	.5	2,838.3	58.87	July 24	Abandoned stock well
18-29-34cbb	Elgin McWhirter	Dr	71.5	6	GI	(?)	do	Cy, W	D, S	do	.1	2,825.1	59.20	Aug. 2	
18-29-34dda	W. H. Crow	Dr	63.0	6	GI	(?)	do	Cy,H,W	S	Top of concrete curb	1.0	2,809.8	48.84	Aug. 20	
18-29-35bbb	L. B. Splitter	Dr	76.5	6	GI	(?)	do	Cy, W	S	Top of casing	.6	2,805.0	47.65	July 29	
18-29-36aaa	Freeman Hall	Du	47.0	36	C	(?)	do	Cy,H,G	D, S	Top of platform	.6	2,769.0	33.19	Aug. 3	Chemical analysis
T. 18 S., R. 30 W.															
18-30-1bcb	S. G. Sharp	Dr	80.0	6	GI	(?)	do	Cy,H,W	S	Top of casing	.3	2,850.2	69.98	July 21	
18-30-2cdd	do	Dr	81.0	6	GI	(?)	do	Cy, W	N	do	.3	2,861.0	77.02	Aug. 26	Abandoned
18-30-4ddc	Dwight Shull	Dr	79.5	6	GI	(?)	do	Cy,H,W	D	do	.7	2,874.7	75.82	Aug. 25	
18-30-6ccb	George Ehmke	Dr	92.0	6	GI	(?)	do	Cy,H,W	S				78	Aug. 26	
18-30-7aaa	Loren O. Stormont	Dr	104.0	6	GI	(?)	do	Cy, W	S	do	.0	2,896.9	78.61	Aug. 26	
18-30-12ccc	C. R. Neeley	Dr	78.5	6	GI	(?)	do	Cy,G,H	S	do	.2	2,842.2	62.38	Aug. 11	
18-30-13ccb	L. West	Dr	70.8	6	GI	(?)	do	Cy,H,W	D, S	do	—4.0	2,840.3	59.96	Aug. 19	
18-30-14bbc	Mary A. Bruner	Dr	74.8	6	GI	(?)	do	Cy,H,W	D	Top of curb	.4	2,866.1	72.74	Aug. 13	
18-30-17add	Thomas J. Shull	Dr	96.5	6	GI	(?)	do	Cy,H,W	D, S	Top of concrete curb	1.4	2,887.0	80.50	Aug. 13	Chemical analysis
18-30-20add	Catherine L. and Mary J. Cramer	Dr	87.5	6	GI	(?)	do	Cy, W	S	do	.4	2,889.2	81.19	Aug. 11	
18-30-22dbb	Mary and B. M. Bickers	Dr	80.3	6	GI	(?)	do	Cy, W	S	Top of board cover	.0	2,866.8	68.82	Aug. 27	
18-30-23abb	School district	Dr	85.5	6	GI	(?)	do	Cy,H,W	D	Top of curb	.8	2,861.5	68.80	Aug. 26	
18-30-24aad	W. P. Owen	Dr	83.3	6	GI	(?)	do	N, N	D, S	Top of casing, north side	1.1	2,835.4	55.53	July 30	Pump not installed
18-30-25bbc	do	Dr	92.5	6	GI	(?)	do	Cy, W	S	Top of concrete curb	.2	2,861.5	67.77	Aug. 13	

18-30-29dad	School district	Dr	97.0	6	GI	(?)	do	Cy,H,W	D	Top of casing	.3	2,874.6	71.50	Aug. 11	
18-30-30baa	C. L. Shull	Dr	92.0	6	GI	(?)	do	Cy, W	D, S			2,907.2	80	Aug. 13	
18-30-31ccc	C. N. Owen	Dr	98.0	6	GI	(?)	do	Cy, W	D	Top of concrete curb	.5	2,902.8	79.71	Aug. 11	
18-30-34aba	Paul Conner	Dr	93.5	6	GI	(?)	do	Cy,H,W	D, S	Top of curb	1.1	2,878.2	80.62	July 30	Chemical analysis
18-30-35abb	A. W. Ehmke	Dr	90.0	6	GI	(?)	do	Cy,H,W	D, S	Top of concrete curb	1.2	2,873.9	77.81	Aug. 19	
18-30-36aba	D. J. Hutchins	Dr	70.8	6	GI	(?)	do	Cy,H,W	D, S	Top of casing	.7	2,855.3	65.24	Aug. 19	
T. 19 S., R. 27 W.															
19-27-1baa	P. Shramek	Dr	726	8	S	Sandstone	Dakota	Cy, W	S					Aug. 4	Encountered Dakota at 706
19-27-8cdc	John Kehr	Dr	65.0	6	GI	(?)	Ogallala	Cy, W	D, S				62	Aug. 4	
19-27-13abc	F. C. Moore	B	10.6	6	GI	(?)	Alluvium	Cy, W	S	do	1.9	2,624.9	4.99	Aug. 7	
19-27-14cbc	Henry C. Beahm	Du	6.5	36	C	(?)	do	Cy, H	D	Base of board cover	.6	2,631.9	4.40	Aug. 17	
19-27-16ada	C. N. Owen	Du	20.2	36	C	(?)	Ogallala	Cy,H,W	D, S	Top of concrete curb	1.2	2,649.2	11.84	Aug. 7	
19-27-18ccc	John Bohr	Du	68.0	24	(?)	(?)	do	Cy, H	D	do	1.0	2,730.8	53.54	July 23	
19-27-21baa	John W. Beahm	Dr	62.0	6	GI	(?)	do	Cy,H,W	S	Top of casting, west side	.5	2,705.9	59.13	Aug. 4	
19-27-22baa	do	Du	30.5	24	R	(?)	do	Cy,H,W	D	Top of rock casing inside well	—3.5	2,670.2	26.65	Aug. 4	
19-27-29abb	J. W. Wagner	Dr	68.0	6	GI	(?)	do	Cy, W	D, S	Top of casing	.5	2,722.9	66.42	July 20	Not in use
19-27-30bbb	School district	Du	71.5	36	(?)	(?)	do	Cy, H	D	Top of concrete curb	.5	2,743.7	68.53	July 23	
19-27-31cdc	John West	Du	49.0	36	(?)	(?)	do	N, N	N	Top of curb	.5	2,698.8	36.95	Aug. 16	Abandoned
19-27-32bbc	Robert West	Dr	36.5	6	GI	(?)	Ogallala and Smoky Hill	N, N	N	Top of casing	2.0	2,688.3	32.17	Aug. 16	do
19-27-33dad	Marvin Mudd	Du	20.4	6	GI	(?)	Alluvium	Cy, W	S	do	2.0	2,614.4	11.99	Aug. 4	Chemical analysis. Originally dug, later recased
19-27-36bab	F. E. Blakely	Du	35.5	36	GI	(?)	Ogallala	Cy,W,H	D, S	Top of concrete curb	2.5	2,672.2	26.28	Aug. 17	
T. 19 S., R. 28 W.															
19-28-2cdc	S. Van Wey	Dr	55.0	6	GI	(?)	do	Cy, W	S	Top of casing	.8	2,744.3	52.46	July 23	Not in use
19-28-6baa	George Hineman	Dr	13.7	6	GI	(?)	do	Cy, W	S	do	1.7	2,737.7	5.25	Sept. 8	
19-28-6daa	do	Dr	72.0	6	GI	Sand	do	Cy, W	D				52	Aug. 4	
19-28-9add	S. R. Stormont	Du	65.0	6	GI	(?)	do	Cy, W	D, S				59	Aug. 4	Originally dug, later recased
19-28-14aba	J. H. Fair	Dr	70.0	6	GI	(?)	do	Cy,H,G	S	Top of casing	.7	2,743.6	59.50	Aug. 4	
19-28-15bcb	Orlena Randle	Du	64.4	36	(?)	(?)	do	Cy,H,W	S	Top of curb	1.5	2,765.0	54.20	Aug. 4	Unused
19-28-19ada	J. A. Hineman	Dr	70.0	6	GI	Sand	do	Cy,H,W	S	Top of curb, west side	.3	2,785.4	67.24	Aug. 3	
19-28-22abb	W. Stormont	Du	71.6	18	C, N	(?)	do	N, N	N	Top of platform	1.2	2,765.0	63.09	Aug. 3	
19-28-25cad	A. Swartz, Jr.	Dr	27.0	6	GI	(?)	do	Cy,H,W	S	Top of casing	.2	2,698.7	23.33	Aug. 16	
19-28-26cbb	L. Stremel	Dr	69.6	6	GI	(?)	do	Cy, W	D	Top of concrete block	2.0	2,753.7	66.18	Aug. 3	
19-28-29bbb	John Hineman	Dr	87.5	6	GI	Sand	do	Cy, W	S	Opening at ground level	.0	2,797.9	78.93	Sept. 13	
19-28-32dda	A. S. Speer	Du	66.0	36	(?)	(?)	do	Cy,H,W	D	Top of concrete curb	.8	2,770.0	55.46	July 23	do
19-28-34bbb	J. S. Jasper	Dr	92.4	6	GI	Sand	do	Cy, W	S	Top of hole in pump, west side	.4	2,774.3	81.63	Sept. 8	Not used frequently
19-28-35acc	William Shaffer	Dr	62.0	6	GI	(?)	do	Cy, W	S	Top of curb	.4	2,740.1	54.70	Aug. 16	
19-28-35cbb	do	Du	72.0	36	C, N	(?)	do	Cy,H,W	D	do	.6	2,754.0	66.68	Aug. 16	Chemical analysis

TABLE 8.—*Records of Wells in Lane County, Kansas—Continued*

Well Number	Owner or tenant	Type of well (1)	Depth of well (feet) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above or below (−) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet) (6)	Date of measurement, 1948	REMARKS (Yield given in gallons a minute, drawdown in feet)
T. 19 S., R. 29 W.															
19-29-3bcc	David McWhirter	Dr	75.7	6	GI	(?)	Ogallala	Cy, W	S	Top of casing	.8	2,827.9	61.11	Aug. 20	
19-29-5cbb	Raymond Ehmke	Dr	66.5	6	GI	(?)	do	Cy, W	S	Top of curb	.0	2,841.5	61.23	Aug. 12	
19-28-8cbc	D. J. Hutchins	Dr	91.0	6	GI	(?)	do	Cy,H,W	S	Top of casing	.4	2,849.9	73.25	Aug. 12	
19-29-10bbb	Alex McWilliams	Dr	67.0	6	GI	(?)	do	Cy,W,G	S				62	Aug. 2	
19-29-12aaa	Glen A. Paris	Du	65.5	36	C, N	(?)	do	Cy, W	D	Top of board curb	.3	2,797.6	59.93	Aug. 3	
19-29-16ccc	V. D. Vincent and B. Holmes	Dr	69.0	6	GI	(?)	do	Cy,H,W	D, S	Top of casing, southeast side	.3	2,845.2	59.17	Aug. 2	Abandoned
19-29-19add	A. V. Erickson	Dr	75.0	6	GI	Chalky shale	Smoky Hill	Cy,W,H	D, S	Top of casing	.5	2,858.6	53.86	Aug. 2	Reported water encountered in Niobrara and rose up in well
19-29-22aad	George W. Sparrow	Du	73.7	48	N	(?)	Ogallala	Cy, W	D, S	Top of concrete curb	1.0	2,833.9	67.43	Aug. 12	Chemical analysis
19-29-24daa	Eula Mock	Dr	61.5	6	GI	(?)	do	Cy, W	N	Top of casing, east side	.4	2,800.3	52.15	July 20	Abandoned
19-29-32ada	D. J. Hutchins	Dr	76.5	6	GI	(?)	do	Cy, W	S	Top of casing, west side	1.8	2,856.9	65.32	Aug. 20	
19-29-36dad	Roy Ware	Dr	65.7	6	GI	(?)	do	Cy, W	S	Top of casing	.2	2,811.3	62.02	Aug. 2	
T. 19 S., R. 30 W.															
19-30-2dad	Mrs. Stella Lewis	Dr	104.0	6	GI	(?)	do	Cy,H,W	D	Top of curb	0.4	2,867.9	76.79	Aug. 19	
19-30-3daa	John Kees	Du	73.2	48	(?)	(?)	do	Cy, W	O	Top of concrete curb	.7	2,870.6	70.40	July 25	Abandoned
19-30-5aad	Mary Uppendahl	Dr	95.0	6	GI	(?)	do	Cy,H,W	S	Base of pump	1.7	2,885.4	79.64	Aug. 13	
19-30-6daa	I. Whiting	Dr	88.0	6	GI	(?)	do	Cy,H,W	S	Top of concrete curb	.1	2,890.4	74.67	Aug. 13	
19-30-10abb	H. S. Conner	Dr	90.5	6	GI	(?)	do	Cy, W	S	Top of casing	.2	2,879.4	77.20	Aug. 20	
19-30-10add	School district	Dr	86.7	6	GI	(?)	do	Cy,H,W	D	do	1.0	2,869.1	73.87	July 30	
19-30-24bab	M. G. Clark	Du	74.3	30	C	(?)	do	N, N	N	Top of concrete curb, north side	.0	2,870.8	57.34	Aug. 2	
19-30-27aaa	Maurice Freeman	Dr	112	6	GI	(?)	Ogallala and Smoky Hill	Cy, G	D, S				100	July 30	
19-30-30add	Orville Krehbiel	Dr	1,038	8	S	Sandstone	Dakota	Cy, G	D, S				500	Aug. 20	Chemical analysis. Reported to pump about 3

19-30-33cbd	E. S. Freeman	Du	46.0	36	(?)	(?)	Ogallala and Smoky Hill	Cy,H,W	D	Top of board platform	.7	2,921.1	44.14	July 25	
19-30-35daa	Earl Bosley	Dr	74.0	6	GI	(?)	Ogallala	Cy,H,W	D, S	Top of curb, west side	.4	2,903.4	64.98	July 30	Chemical analysis
T. 20 S., R. 27 W.															
20-27-2dcc	J. W. Thomas	Du	49.0	48	N	(?)	Alluvium and Fort Hays	Cy,H,W	D	Top of curb	.5	2,579.8	29.26	Aug. 17	
20-27-3aab	Etta F. Mudd	Du	18.5	48	C	(?)	Alluvium	Cy, W	S	Top of concrete cover, southwest side	1.5	2,594.6	16.86	Aug. 17	
20-27-7aab	Karl Litzenberger	Dr	742	8	S	Sandstone	Dakota	Cy, W	D, S			2,710.7	400	Sept. 16	do
20-27-7aab2	do	Dr	225.0	6	GI	Chalk, shale	Niobrara	Cy,G,H	D, S	Top of concrete curb	.0	2,710.2	68.90	Aug. 16	Not used frequently
20-27-12bbc	F. W. Prose	Dr	36.5	6	GI	Chalky limestone	Fort Hays	Cy,H,G	S	Top of casing	.0	2,563.1	27.54	Aug. 17	
20-27-19bbc	F. R. Miller	B	31.7	6	GI	(?)	Alluvium	Cy,H,W	D, S	Top of board cover	.8	2,611.2	22.27	Sept. 8	Chemical analysis
20-27-20cdd	Lizzie Wernet	Dr	27.0	6	GI	(?)	do	Cy,H,W	D, S	Top of concrete curb	.8	2,584.7	21.50	Sept. 8	Not used frequently
20-27-21add	Leslie Thomas	Du	71.5	36	R	Limestone	Fort Hays	Cy,H,W	D, S	Top of casing	.3	2,586.1	16.89	Aug. 4	
20-27-23ddd	Chas. Offerle	Dr	36.0	6	GI	(?)	Sanborn and Fort Hays	Cy, W	S	do	.6	2,520.8	32.26	Aug. 17	
20-27-25aac	A. C. Stevens	Dr	16.0	6	GI	(?)	Alluvium	N, N	N	Top of casing, west side	.6	2,489.4	14.60	Aug. 17	Abandoned stock well
20-27-26bba	Fred Prose	Dr	34.5	6	GI	(?)	do	Cy,H,W	D, S	Top of curb	.4	2,533.0	32.20	Aug. 17	Chemical analysis
20-27-27acb	Leroy Burnett	B	25.0	6	GI	(?)	do	Cy, H	D	Top of casing	.2	2,533.6	22.10	Aug. 18	
20-27-28bcb	T. V. Wancura	Dr	47.0	6	GI	(?)	Alluvium and Fort Hays	Cy,H,G	S	Top of concrete curb	.6	2,566.2	30.78	Aug. 18	
20-27-28daa	Owen Rowe	Du	51.0	24	N	Limestone and shale	Fort Hays and Carlile (?)	Cy, H	N	Top of concrete curb, south side	1.0	2,564.8	42.23	July 29	Abandoned
20-27-31cbb	Roy Hampson	B	23.8	6	GI	(?)	Alluvium	Cy,H,W	D, S	Top of casing	—4.4	2,628.1	15.03	Aug. 18	Chemical analysis
20-27-32bcb	Lyman S. Miller	Du	30.0	24	(?)	(?)	do	Cy,H,G	S	Top of concrete curb	.8	2,608.1	24.47	Aug. 18	
20-27-32dcd	C. A. Rowe	Dr	134	6	GI	Limestone and shale	Fort Hays and Carlile (?)	Cy,H,W	D, S				124	Aug. 18	
T. 20 S., R. 28 W.															
20-28-1bbc	Cliff Ware	Du	76.0	30	C, N	(?)	Ogallala	N, N	N	Top of concrete curb, south side	.2	2,749.0	63.70	July 23	Abandoned
20-28-5daa	J. C. Johnston	Du	71.5	36	C, N	(?)	do	Cy,H,E	D	Base of well cover	.3	2,779.9	65.43	Aug. 2	
20-28-8bcc	J. C. Murphy	Du	20.0	12	GI	(?)	Alluvium and Ogallala	Cy, W	S	Top of board curb	.2	2,720.5	13.14	Aug. 18	
20-28-9bcc	Roy Atterbury	Dr	68.5	6	GI	(?)	Ogallala and Smoky Hill	Cy,W,G	D, S	Top of casing	—4.1	2,726.1	44.23	Aug. 18	
20-28-11bcb	W. F. Smeltzer	Du	52.0	12	GI	(?)	Ogallala	Cy, W	D, S	do	1.5	2,682.4	39.06	Aug. 3	
20-28-13bcb	Frank Warner	Dr	16.0	6	GI	(?)	Alluvium	Cy, W	S	do	1.3	2,631.9	15.55	Aug. 3	
20-28-19aaa	Lee Cantrell	Dr	47.5	6	GI	(?)	Ogallala	Cy,H,W	D, S	do	.7	2,780.5	38.73	Sept. 8	Chemical analysis
20-28-22ddd	W. E. Meage	Du	19.3	48	N	(?)	Sandborn and Smoky Hill	Cy, W	S	Top of piece of GI casing, west side	2.2	2,724.4	10.30	July 23	
20-28-25cdc	C. J. Block	Dr	28.2	6	GI	(?)	Sanborn and Fort Hays (?)	Cy, H	D	Top of curb, southwest side	.6	2,653.6	24.89	Aug. 3	Unused
20-28-32abc	J. C. Johnston	Dr	14.0	6	GI	(?)	Alluvium	Cy, W	S	Top of curb	.0	2,749.3	9.34	Aug. 18	do.
20-28-34bab	J. F. Smid	Dr	40.0	8	GI	Sand	Sanborn	N, N	N	Top of concrete curb	.7	2,728.1	37.64	July 23	Abandoned domestic well
20-28-35bcb	John Bryant	Du	30.0	(?)	(?)	(?)	Alluvium	Cy,H,W	D, S	Top of casing	.4	2,695.9	23.98	Aug. 3	

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TABLE 8.—*Records of Wells in Lane County, Kansas—Concluded*

Well Number	Owner or tenant	Type of well (1)	Depth of well (feet) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above or below (—) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet) (6)	Date of measurement, 1943	REMARKS (Yield given in gallons a minute; drawdown in feet)
T. 20 S., R. 29 W.															
20-29-7ddd	Harold E. Mulville	Dr	88.0	6	S	(?)	Ogallala	Cy, W	D, S	Top of casing	—2.5	2,881.4	74.73	Aug. 2	
20-29-8acd	George Boofing	Dr	75.0	6	GI	(?)	do	Cy, W	S	Top of casing, west side	.2	2,874.6	74.26	Aug. 12	Abandoned
20-29-9dbb	F. Jewett	Du	75.6	48	N	(?)	do	Cy, W	D, S	Base of concrete curb	.6	2,863.9	69.13	Aug. 2	
20-29-13abc	Dale McMillen	Du	19.7	36	R	(?)	do	Cy,W,E	D, S	Top of concrete curb	1.0	2,757.7	7.19	Aug. 18	
20-29-14bad	G. and J. H. McCoy	Du	49.6	48	N	(?)	do	Cy, W	S	Top of board cover	.6	2,804.4	36.12	Aug. 18	
20-29-30ccb	D. J. Hutchins	Dr	252.0	6	GI	Limestone and shale	Fort Hays and Carlile	Cy,H,W	N	Top of board platform	.2	2,878.9	62.71	Aug. 20	Unused domestic and stock well
T. 20 S., R. 30 W.															
20-30-1aad	Phil Atterbury	Du	66.0	36	C, N	(?)	Ogallala	Cy,H,W	D, S	Top of board at top of casing	.6	2,890.8	62.75	Aug. 2	
20-30-8ddd	Mrs. Nelle T. Graves	Dr	31.7	6	GI	Fine sand and silt	Meade (?)	Cy,H,E	D	Top of curb	.0	2,838.5	24.78	Aug. 12	
20-30-13add	M. A. Campbell	Du	83.0	36	(?)	do	Ogallala	Cy, W	D, S	Top of concrete curb	.0	2,891.7	79.03	Aug. 12	
20-30-14abb	G. L. Mumma	Du	22.8	36	R	(?)	Ogallala and Smoky Hill	Cy, W	S	Top of board, north side	.8	2,868.0	20.04	Aug. 20	
20-30-16ccc	Federal Land Bank	Dr	78.7	6	GI	Fine sand and silt	Meade (?)	N, N	N	Top of casing, west side	.4	2,823.4	5.04	Aug. 12	Abandoned stock well
20-30-19db	Julia Freeman	Du	55.7	(?)	(?)	do	do	Cy, W	S	Top of curb	1.5	2,840.1	15.96	Oct. 30	
20-30-20ddc	Federal Land Bank	Dr	19.6	6	GI	do	do	Cy, W	S	Top of board curb, west side	.6	2,838.2	8.67	July 30	
20-30-21bcc	G. E. Hineman	Dr	66.0	14	C	do	do	Cy, W	S	Top of concrete curb	.3	2,833.5	9.88	July 20	Drilled as an irrigation well, yield was not large enough
20-30-21ccc	B. F. Wallace	Dr	24.2	6	GI	do	do	Cy, W	S	Top of curb	.6	2,844.6	11.63	July 30	Not used
20-30-23bbb	W. A. Thomas	Dr	32.0	6	GI	do	do	Cy, G	S	Top of casing, east side	.3	2,841.3	16.13	July 20	
20-30-23ccc	Fred Miller	Dr	61.0	6	GI	(?)	Ogallala	Cy, W	N	Top of 2 x 4 board	7	2,870.1	54.50	July 20	Abandoned stock well

20-30-25ccd	J. A. Ellis	Du	62.5	48	N	(?)	Ogallala and Smoky Hill (?)	N, N	N	Top of board cover	.8	2,866.9	47.80	Aug. 20	Unused domestic and stock well
20-30-27bbb	Irene Miller	Dr	56.0	6	GI	(?)	Ogallala	Cy,H,W	D, S	Top of casing	.8	2,863.9	42.52	Aug. 20	
20-30-29dca	Plumb D. Carl	B	35.0	6	N	Fine sand and silt	Meade (?)	N, N	N	do	.7	2,859.7	29.09	July 30	Abandoned
20-30-29dcd	do	B	30.0	6	N	do	do	Cy, W	S	do	.4	2,855.6	24.91	July 30	Chemical analysis
20-30-31dcc	R. F Plummer	Dr	48.2	5½	GI	do	do	N, N	N	Top of round pump base, south side	1.0	2,889.5	44.49	Oct. 8	Measured in 1940 by H. A. Waite
20-30-33add	J. D. Stevenson	Dr	32.5	12	S	(?)	do	Cy, W	S	Top of tin cover	.6	2,838.5	17.55	Aug. 20	
T. 21 S., R. 30 W.															
21-30-2aaa	O. A. Clark	Dr	51.5	6	GI	(?)	Sanborn and Fort Hays	N, N	N	Top of casing	1.1	2,830.8	17.80	Oct. 29	New well; no pump as yet. Situated in Finney Co.
21-30-3bcd	do	Dr	126.5	6	GI		Ogallala	Cy,H,W	D, S	do	.5		98.42	Oct. 4	Measured in 1949. Situated in Finney Co.

(1) B, bored; Dr, drilled; Du, dug.
(2) Reported depths below land surface given in feet; measured depths given in feet and tenths below measuring point.
(3) B, brick; C, concrete; GI, galvanized iron; N, natural; OB, oil barrels; R, rock; S, steel; T, tile.
(4) Type of pump: Cy, cylinder; J, jet; N, none; T, turbine. Type of power: B, butane; D, diesel; E, electricity; G, gasoline engine; H, hand; N, none; T, tractor; W, wind.
(5) D, domestic; I, irrigation; N, not in use; O, observation; PS, public supply; RR, railroad; S, stock.
(6) Measured depths to water level given in feet, tenths and hundredths; reported depths to water level given in feet.

LOGS OF TEST HOLES AND WELLS

Listed on the following pages are logs of 33 test holes drilled by the State Geological Survey and logs of eight irrigation test holes or wells drilled by George L. Weishaar and Son of Scott City. Location of test holes drilled by the State Geological Survey in 1948 and 1949 is shown in Figure 5. Samples from test holes were studied in the field by Kenneth L. Walters, who supervised the drilling and prepared logs of the holes. The samples were subsequently studied microscopically by me.

Logs entitled sample logs were those drilled by the State Geological Survey and for which samples were collected.

Sample log of test hole 16-27-17cdd in the SE cor. SW¼ sec. 17, T. 16 S., R. 27 W., drilled September, 1948. Surface altitude, 2,719.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt and clay, light-tan; contains gastropod shells	10	10
Clay, silty, tan to brown	4.5	14.5
TERTIARY—Pliocene		
Ogallala formation		
Clay, calcareous, pink-gray, with some sand	4	18.5
Clay, dense, tan	6.5	25
Clay, calcareous, with some gravel and caliche pebbles	3	28
Gravel, medium to coarse, rounded; contains some coarse sand	15	43
Mortar bed, tan	5.5	48.5
Clay, tan-brown	9.5	58

Sample log of test hole 16-27-20add in the SE cor. NE¼ sec. 20, T. 16 S., R. 27 W., drilled September, 1948. Surface altitude, 2,711.1 feet.

	Thickness, feet	Depth, feet
Silt, dark-brown (road-fill)	2	2
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, brown; contains gastropods	10	12
Silt, hard, dark-brown	2	14
TERTIARY—Pliocene		
Ogallala formation		
Silt, calcareous, light-tan, and some sand	4	18
Gravel, coarse to fine	16	34
Gravel, fine to coarse, and fine to coarse sand	9	43
Mortar bed	3	46

Sample log of test hole 16-28-30ddd in the SE cor. sec. 30, T. 16 S., R. 28 W., drilled September, 1948. Surface altitude, 2,779.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt and clay, sandy, dark-gray	2	2
Clay, silty, sandy, tan	10	12
TERTIARY—Pliocene		
Ogallala formation		
Clay, calcareous, light-tan to white, with a trace of caliche	11	23
Caliche, pinkish-gray	2	25
Mortar beds, light-brown, and caliche	6	31
Caliche, white	3	34
Mortar beds, light-brown	6	40
Mortar beds, pinkish-brown	8	48
Gravel, fine to medium, with sand and mortar bed	7	55
Clay and fine sand, pinkish-brown	8	63
Sand, coarse, and fine gravel, with thin mortar beds	9	72
Sand, coarse, and fine gravel	3	75
Mortar bed, gray	8	83
Sand, gravel, and yellow chalky clay	4	87
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, chalky, yellow	5	92

Driller's log of irrigation well of Ross Jasper, in the NW¼ NE¼ SE¼ sec. 28, T. 16 S., R. 29 W. George Weishaar, driller.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Clay	16	16
TERTIARY—Pliocene		
Ogallala formation		
Gyp	18	34
Sand and gyp streaks	41	75
Clay	8	83
Sand	14	97
Sand, dirty	3	100
Sand	17	117
Sand, fine, and clay	11	128
Sand	4	132
Sand, fine	7	139
Gravel	4	143
Sand, dirty	7	150
Sand, fine, and clay streaks	15	165
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Soapstone	5	170
Shale	..	..

Sample log of test hole 16-30-29aaa in the NE cor. sec. 29, T. 16 S., R. 30 W., drilled September, 1948. Surface altitude, 2,872.7 feet; depth to water level, 116.5 feet, September 18, 1948.

	Thickness, feet	Depth, feet
Silt, sandy, light-brown (road fill)	2	2
TERTIARY—Pliocene		
Ogallala formation		
Sand and clay	8	10
Clay and silt, calcareous, light-tan to gray	7	17
Caliche	10	27
Caliche and medium sand, thin alternating layers	7	34
Mortar bed, with sand and caliche	10	44
Sand, fine, and silt, calcareous, brown	4	48
Mortar bed, with sand and gravel	10	58
Silt and fine sand, brown	2	60
Silt, with sand and gravel	3	63
Mortar bed, with sand and gravel	27	90
Sand, coarse to fine, with some gravel	10	100
Silt and very fine sand, light-brown	16	116
Sand, fine to coarse	4	120
Sand, very fine, and brown clay	10	130
Clay, light-gray, and fine sand	10	140
Sand, fine to medium	10	150
Gravel, igneous and quartz, fine to coarse, subangular,	6	156
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, yellow to tan	4	160

Sample log of test hole 17-27-2aaa in the NE cor. sec. 2, T. 17 S., R. 27 W., drilled September, 1948. Surface altitude, 2,641.6 feet.

	Thickness, feet	Depth, feet
Road fill	4 5	4 5
TERTIARY—Pliocene		
Ogallala formation		
Clay and coarse sand and gravel	2 5	7
Sand, coarse, with clay	3	10
Clay, chalky, white to tan	4 5	14 5
Sand, fine to medium, and clay	1 5	16
Clay and silt, tan	6	22
Clay, very sandy, light-gray	6 5	28 5
Gravel, fine to medium, and coarse sand	1	29 5
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, yellow	10 5	40

Sample log of test hole 17-27-21cbb in the NW cor. SW¼ sec. 21, T. 17 S., R. 27 W., drilled September, 1948. Surface altitude, 2,706.7 feet; depth to water level, 78.7 feet, September 25, 1948.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt and very fine sand, black	1.5	1.5
Silt and clay, with some fine quartz gravel	7.5	9
TERTIARY—Pliocene		
Ogallala formation		
Clay, silty, calcareous, pink-tan	9.5	18.5
Clay, silty, calcareous; contains some caliche pebbles,	2.5	21
Caliche, white to tan	4	25
Clay, sandy, and caliche	5	30
Mortar bed, soft, brown-tan	14.5	44.5
Sand, quartz, fine to medium	9.5	54
Clay, calcareous, and fine sand	4	58
Mortar bed and medium sand	10.5	68.5
Sand, medium, and fine gravel	4.5	73
Clay, calcareous, sandy, pink-tan	6	79
Sand, quartz, medium, angular, and fine gravel	11	90
Gravel, medium, rounded, and coarse sand	4	94
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, yellow to gray	10	104

Driller's log of test hole of Dwight Terwilliger in the NW¼ SW¼ sec. 4, T. 17 S., R. 28 W. George Weishaar, driller.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Clay	32	32
TERTIARY—Pliocene		
Ogallala formation		
Gyp	11	43
Clay	6	49
Gyp	17	66
Clay	6	72
Sand and clay	13	85
Sand, fair	17	102
Gyp and sand	13	115
Sand	17	132
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Soapstone	4	136
Shale	4	140

Driller's log of irrigation well of Paul Lonner in the NW cor. sec. 22, T. 17 S., R. 28 W.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Clay	25	25
TERTIARY—Pliocene		
Ogallala formation		
Gyp	20	45
Sand, hard	30	75
Sand and gyp	20	95
Sand	30	125
Sand and gyp streaks	10	135
Sand	21	156
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Soapstone	4	160

Sample log of test hole 17-28-32bbb in the NW cor. sec. 32, T. 17 S., R. 28 W., drilled September, 1948. Surface altitude, 2,768.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt and clay, sandy, tan to brown	8	8
TERTIARY—Pliocene		
Ogallala formation		
Clay and caliche	10	18
Caliche	9	27
Caliche; contains some clay and sand	9	36
Sand, quartz, medium	7	43
Mortar bed and sand	3.5	46.5
Sand and some thin mortar beds	9	55.5
Mortar bed and some gravel	3	58.5
Sand and medium gravel	4	62.5
Sand, gravel, and thin mortar bed	7.5	70
Sand, quartz, medium	6	76
Caliche and some medium sand	9	85
Mortar beds and caliche	8	93
Sand, quartz, medium to coarse	17	110
Sand, quartz, medium	23	133
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, yellow	7	140

Sample log of test hole 17-29-9aaa in the NE cor. sec. 9, T. 17 S., R. 29 W., drilled September, 1948. Surface altitude, 2,810.6 feet; depth to water level, 92.2 feet, October 2, 1948.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, light-brown	1	1
Silt and clay, tan; contains gastropod shells	11	12
TERTIARY—Pliocene		
Ogallala formation		
Clay, calcareous, sandy, pink-tan	6	18
Caliche, tan	10	28
Mortar bed, brown	16	44
Mortar bed and medium sand, brown	9	53
Sand, medium to coarse	11	64
Clay, very sandy, pink-tan	6	70
Sand, fine to coarse	9 5	79 5
Clay, sandy, pink-tan; contains sand and gravel and some thin mortar beds	8	87 5
Sand, fine to medium	12 5	100
Sand, fine to medium, and yellow clay	10	110
Sand, fine to medium, and pink-gray clay	20	130
Sand, fine to coarse; contains green-gray clay and thin mortar beds	10	140
Sand, fine	10	150
Sand, fine to coarse; contains some gravel and clay	14	164
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, yellow-gray	6	170

Sample log of test hole 17-29-22bbb in the NW cor. sec. 22, T. 17 S., R. 29 W., drilled September, 1948. Surface altitude, 2,806.5 feet; depth to water level, 84.1 feet, September 20, 1948.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, light-brown to dark-gray	2 5	2 5
Silt and clay, brown to dark-gray; contains some sand and gravel; calcareous in lower half	9 5	12
TERTIARY—Pliocene		
Ogallala formation		
Clay, calcareous, light-gray; contains some gravel and caliche pebbles	8	20
Caliche	6	26
Mortar bed, buff to brown, noncalcareous, with some gravel	13	39
Sand, quartz, medium to coarse	4	43
Gravel, fine to medium, cemented with caliche	2	45
Mortar bed, calcareous, light-tan	5	50

	Thickness, feet	Depth, feet
Sand and gravel, with thin mortar beds throughout; 2-inch chertlike mortar bed at 55 feet	10	60
Mortar bed, light-gray; contains some thin clay beds,	5	65
Sand, quartz, medium to coarse, semirounded	8.5	73.5
Clay, calcareous, sandy, pinkish-tan	6.5	80
Sand, medium to coarse; contains some clay	6.5	86.5
Gravel, medium, with clay and mortar beds	3.5	90
Clay, calcareous, light-gray; contains some gravel	7	97
Sand, medium to coarse; contains some mortar beds,	3	100
Sand, medium, with some clay and thin mortar beds,	9	109
Sand, quartz, very fine	9	118
Sand, quartz, fine to medium	7	125
Sand, medium	15	140
Sand, fine to medium	4.5	144.5
Sand, medium to coarse; contains some clay	6.5	151
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, tan to yellow	4	155
Shale, calcareous, dark-gray to black	5	160

Sample log of test hole 17-29-33aaa in the NE cor. sec. 33, T. 17 S., R. 29 W., drilled September, 1948. Surface altitude, 2,812.1 feet; depth to water level, 72.2 feet, October 2, 1948.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, light-brown	1.5	1.5
Silt and clay, soft, brown	11.5	13
TERTIARY—Pliocene		
Ogallala formation		
Clay, silt, and fine sand; contains some fine caliche	9	22
Mortar bed, tan to gray	8	30
Mortar bed, hard, light-tan; contains some opal-like material	4.5	34.5
Mortar bed, pale-green, and sand	11.5	46
Sand, fine	7	53
Mortar bed, light-brown, and some gravel	8	61
Sand, medium, some fine gravel and thin mortar beds,	14	75
Mortar bed, very chalky, white	5	80
Mortar bed, light-brown, and pink-gray clay	5	85
Mortar bed, light-brown, and fine sand	10	95
Sand, fine to coarse, with some fine gravel and mortar bed	8	103
Sand, fine	11	114
Gravel, fine to medium	3.5	117.5
Mortar bed, calcareous, gray; contains some sand	7.5	125
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, yellow and gray	5	130

Driller's log of test hole of D. Graves in the NW¼ sec. 9, T. 17 S., R. 30 W.

	Thickness, feet	Depth, feet
QUATERNARY AND TERTIARY—Pleistocene and Pliocene		
Sanborn and Ogallala formations		
Clay	45	45
TERTIARY—Pliocene		
Ogallala formation		
Gyp	22	67
Sand, hard	9	76
Gyp	32	108
Gyp, sand, and clay	24	132
Sand, fine	23	155
Sand and clay	20	175
Sand	5	180
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Soapstone	5	185
Shale	5	190

Sample log of test hole 17-30-4bbb in the NW cor. sec. 4, T. 17 S., R. 30 W., drilled September, 1948. Surface altitude, 2,873.2 feet; depth to water level, 105.9 feet, September 20, 1948.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, light-brown	2	2
Silt and clay, calcareous, tan; contains numerous gastropod shells	13	15
TERTIARY—Pliocene		
Ogallala formation		
Clay and silt, sandy, white	7	22
Clay, sandy, calcareous, light grayish-green, and white caliche	8	30
Caliche, dense, light-gray; contains some sand	5	35
Mortar bed, red to brown, and fine sand	11.5	46.5
Sand, very fine, and clay; contains some caliche and medium sand	3.5	50
Sand, quartz, medium, and thin mortar beds	8	58
Clay, very sandy, pale-green	3	61
Sand, mortar beds, and gravel	9	70
Mortar beds, white	8	78
Mortar beds, pale-tan, and fine sand	3	81
Clay, very sandy, pink-tan, and some thin hard mortar beds	4	85
Mortar bed, fine to medium, pink-tan	12	97
Sand, fine, with pink-tan clay	4	101
Clay, buff-tan, with some calcareous sand	9	110
Clay, buff-tan, with some sand and silt	10	120
Sand, quartz and feldspar, very fine to coarse, angular	9	129
Clay, calcareous, sandy, light-tan	15	144

	Thickness, feet	Depth, feet
Sand, fine to medium	10	154
Gravel, fine, rounded	6	160
Gravel, fine to medium, rounded	10	170
Sand, quartz, fine to medium	5	175
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, yellow-tan	5	180
Shale, calcareous, greenish-brown	2	182

Sample log of test hole 17-30-17ddd in the SE cor. sec. 17, T. 17 S., R. 30 W., drilled September, 1948. Surface altitude, 2,874.0 feet; depth to water level, 82.9 feet, September 21, 1948.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, black to brown	4 5	4 5
Silt and clay, light-tan; contains numerous gastropod shells	11 5	16
Clay and silt, calcareous, light-tan; contains some sand	4	20
TERTIARY—Pliocene		
Ogallala formation		
Clay, calcareous, light-tan; contains some sand and caliche	6	26
Sand, very fine, cemented with clay; contains some caliche	4	30
Sand, very fine, with clay, some mortar bed and caliche,	3	33
Caliche, white, and some gravel	4	37
Sand and clay, calcareous, with some fine gravel	3	40
Sand, quartz, medium	6	46
Mortar bed and light-tan fine sand	2	48
Sand, very fine, with pale greenish-gray clay	3	51
Sand, medium to coarse	9	60
Sand, medium to fine; contains some medium gravel and thin mortar beds	12	72
Clay, reddish-tan, caliche, and some gravel	3	75
Mortar bed, light-tan to gray	4	79
Mortar bed, light-gray	9	88
Mortar bed, reddish-brown	3	91
Clay, light-tan; contains some gravel and caliche	9	100
Sand, medium, rounded, brown	54	154
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, yellow to tan	5	159
Shale, calcareous, greenish-black	1	160

Sample log of test hole 17-30-32aaa in the NE cor. sec. 32, T. 17 S., R. 30 W., drilled September, 1948. Surface altitude, 2,875.2 feet; depth to water level, 80.8 feet, September 22, 1948.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, light-brown	2.5	2.5
Silt and clay, calcareous, light-tan	7.5	10
Silt and clay, calcareous, light-tan; contains some gravel and caliche	7	17
TERTIARY—Pliocene		
Ogallala formation		
Clay, silty, calcareous, light-tan to light-gray	5	22
Clay, calcareous, sandy, light-gray to tan	8	30
Caliche, white	2	32
Clay, reddish-brown, calcareous; contains some very fine sand	5.5	37.5
Sand, feldspar and quartz, medium	21.5	59
Sand and thin light-gray mortar beds	6	65
Sand, medium to coarse	17	82
Mortar bed, light-gray, and clay	16	98
Clay, sandy, pinkish-tan	2	100
Mortar bed, light-gray, and sand	9	109
Sand, medium to coarse	13	122
Clay, sandy, light-gray, and mortar bed	14	136
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, yellow-tan	4	140

Driller's log of test hole of Joe Edmondson in NW¼ sec. 35, T. 17 S., R. 30 W.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Clay	12	12
TERTIARY—Pliocene		
Ogallala formation		
Gyp	20	32
Sand and gyp	13	45
Sand	42	87
Clay	8	95
Clay, sandy	12	107
Sand	5	112
Clay and sand streaks	13	125
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Soapstone	3	128
Shale	2	130

Sample log of test hole 18-27-20aaa in the NE cor. sec. 20, T. 18 S., R. 27 W., drilled September, 1948. Surface altitude, 2,701.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt and clay, sandy, tan	8.5	8.5
Clay, sandy, light-tan	8	16.5
Clay, light-tan; contains caliche pebbles	4.5	21
TERTIARY—Pliocene		
Ogallala formation		
Caliche; contains some light-tan sand	7	28
Mortar bed and fine sand, light-brown	11	39
Caliche, very massive, white to gray	4.5	43.5
Mortar bed and fine sand, tan	9	52.5
Clay, noncalcareous, sandy, tan	7.5	60
Clay, sandy, tan	7	67
Clay, tan, and mortar bed	11	78
Sand, fine to medium	2	80
Mortar bed, tan	7	87
Sand, medium to coarse, and fine gravel	4	91
Clay, sandy, green	5	96
Sand, medium, and fine gravel	7	103
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, yellow	3	106
Shale, gray-brown	3	109

Sample log of test hole 18-27-31ccc in the SW cor. sec. 31, T. 18 S., R. 27 W., drilled September, 1948. Surface altitude, 2,724.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, sandy, light-brown	1.5	1.5
Silt and clay, tan	8.5	10
Clay, silty, calcareous, light-tan; contains some caliche pebbles	10	20
TERTIARY—Pliocene		
Ogallala formation		
Caliche, tan-gray; contains some gravel	16	36
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, chalky, alternating hard and soft, yellow and white	10	46
Shale, very chalky, yellow	14	60

Sample log of test hole 18-28-17ccc in the SW cor. sec. 17, T. 18 S., R. 28 W., drilled September, 1948. Surface altitude, 2,755.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Clay, dark-gray to tan	6	6
Silt and silty clay, tan; contains numerous gastropod shells and some caliche	7	13
TERTIARY—Pliocene		
Ogallala formation		
Caliche	4	17
Clay, pinkish-brown, grading into pale-tan	8	25
Sand and silt, very fine, noncalcareous, yellow	8	33
Mortar bed, and light-gray sand	4	37
Sand, quartz, medium, rounded	4	41
Caliche, light-gray	2	43
Mortar bed, brown, and fine sand and gravel	8	51
Clay and sand, tan, and some gravel	1	52
Clay, calcareous, very sandy, light pinkish-gray	3 5	55 5
Sand, quartz, fine to medium	2	57 5
Caliche and medium gravel	2 5	60
Caliche, medium gravel, and some sand and mortar bed	4	64
Caliche	1	65
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, chalky, gray to yellow	7	72
Shale, calcareous, tannish-brown	2	74

Sample log of test hole 18-29-9aaa in the NE cor. sec. 9, T. 18 S., R. 29 W., drilled September, 1948. Surface altitude, 2,802.2 feet; depth to water level 61.2 feet, October 2, 1948.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Clay and silt, sandy, tan; contains some caliche pebbles	10	10
TERTIARY—Pliocene		
Ogallala formation		
Clay and caliche	7	17
Caliche, blocky, light-gray	5	22
Mortar bed, soft, light-tan	5	27
Mortar bed, hard, brown	4 5	31 5
Sand, medium to coarse, partially cemented	13 5	45
Sand, fine to medium	3 5	48 5
Mortar bed, light-gray	4 5	53
Sand, fine to medium	3	56
Clay, light-gray, with mortar bed and sand	2 5	58 5
Sand, fine, partially cemented	8	66 5
Mortar bed, gray, and gray clay	3 5	70
Mortar bed, gray, and sand	6 5	76 5

	Thickness, feet	Depth, feet
Clay and sand	4 5	81
Clay, red-brown	3	84
Sand, medium, and clay	5	89
Clay, sandy, red-brown	6	95
Sand, clay, and chalk fragments	6	101
Clay, sandy, pink-gray	3	104
Gravel, fine to medium	4	108
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, yellow	2	110

Sample log of test hole 18-29-15ccc in the SW cor. sec. 15, T. 18 S., R. 29 W., drilled September, 1948. Surface altitude, 2,803.2 feet; depth to water level 51.8 feet, September 16, 1948.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt and clay, sandy, dark-brown	2	2
Clay, silty and sandy, tan	6	8
Sand, fine, brown	5	13
TERTIARY—Pliocene		
Ogallala formation		
Clay and fine caliche, grayish-brown	4	17
Caliche	12	29
Mortar bed and caliche	10	39
Mortar bed, brown, and fine sand	8	47
Mortar bed and caliche	2	49
Mortar bed; contains pale-green sand	5	54
Sand, quartz, medium to coarse	3	57
Mortar bed	3	60
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, yellow to tan	8	68

Sample log of test hole 18-30-8aaa in the NE cor. sec. 8, T. 18 S., R. 30 W., drilled September, 1948. Surface altitude, 2,882.8 feet; depth to water level 75.0 feet, September 22, 1948.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt and clay, dense, black	7	7
Clay, sandy, light-tan; contains gastropod shells	9	16
Clay, calcareous, pinkish-brown to gray; contains some caliche gravel	7	23
TERTIARY—Pliocene		
Ogallala formation		
Caliche, soft, with some caliche gravel, white	7	30
Caliche, predominantly hard, white	7	37

	Thickness, feet	Depth, feet
Clay, very sandy, noncalcareous, reddish-brown	10	47
Sand, medium; contains some gray mortar bed	7	54
Sand, medium to coarse; contains some gravel	5	59
Mortar bed, fine, tan	9	68
Clay, very sandy, light-gray; contains some thin mortar beds	7	75
Sand, fine to medium	8	83
Mortar bed	8	91
Mortar bed, fine, brown	9	100
Clay, sandy, pinkish-gray	5	105
Mortar bed, white, mottled with black	4	109
Sand, medium to coarse, with some clay	9	118
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, yellow-gray	2	120

Sample log of test hole 18-30-21bbb in the NW cor. sec. 21, T. 18 S., R. 30 W., drilled September, 1948. Surface altitude, 2,882.1 feet; depth to water level 73.5 feet, September 23, 1948.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, dense, black-brown	2 5	2 5
Clay and silt, calcareous, tan, with some sand	8 5	11
Clay, silty, calcareous, brown-tan; contains caliche gravel and some gastropod shells	9	20
Clay, silty, light-tan, with some gravel	5 5	25 5
TERTIARY—Pliocene		
Ogallala formation		
Caliche, light-gray, and clay	6	31 5
Caliche, massive, hard, light-gray	7 5	39
Mortar bed and caliche, hard, calcareous; contains some unconsolidated sand	11	50
Mortar bed, reddish-brown, and fine sand	18	68
Caliche, light-gray, with thin chalky clay bed at 68 feet and some mortar bed	10	78
Clay, chalky, white to gray; contains some medium sand	6	84
Clay, sandy, pinkish-tan	7	91
Mortar bed, hard, tan; contains some weathered Niobrara (chalk) formation	1 5	92 5
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, yellow-tan	7 5	100

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Sample log of test hole 18-30-33bbb in the NW cor. sec. 33, T. 18 S., R. 30 W., drilled September, 1948. Surface altitude, 2,874.1 feet; depth to water level 70.2 feet, September 23, 1948.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, black	4.5	4.5
Silt and clay, tan; contains gastropod shells	13.5	18
TERTIARY—Pliocene		
Ogallala formation		
Clay and fine quartz sand, calcareous	4.5	22.5
Clay, chalky, sandy, calcareous, gray to tan; contains some caliche and gravel	6.5	29
Clay, calcareous, white to pink-tan; contains some caliche and gravel	5	34
Mortar bed, calcareous, light-gray	10	44
Mortar bed, light-gray and tan	6	50
Mortar bed, brown-tan	5	55
Mortar bed, calcareous, light-gray	9	64
Clay, chalky, sandy, white to pinkish-gray	6	70
Mortar bed, calcareous, hard	7.5	77.5
Mortar bed, hard, brown-tan	2.5	80
Clay, red-tan, and sand and gravel	19	99
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, yellow-tan	6	105

Sample log of test hole 19-27-28bbb in the NW cor. sec. 28, T. 19 S., R. 27 W., drilled September, 1948. Surface altitude, 2,714.0 feet; depth to water level 60.0 feet, September 24, 1948.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, light-brown	1.5	1.5
Silt, sandy, tan	10.5	12
TERTIARY—Pliocene		
Ogallala formation		
Caliche, soft, white, and pink-tan clay	11	23
Sand, fine to medium, rounded	5.5	28.5
Sand, medium, and some gravel	8	36.3
Gravel, medium, and tan mortar bed; contains yellow clay	4.5	41
Sand, fine to medium, with tan clay	6	47
Sand, quartz, medium, rounded	3	50
Sand, coarse, and fine gravel	17	67
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, yellow	3	70

Sample log of test hole 19-28-18ddd in the SE cor. sec. 18, T. 19 S., R. 28 W., drilled September, 1948. Surface altitude, 2,790.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, sandy, light-brown	1.5	1.5
Clay, sandy, tan	8.5	10
TERTIARY—Pliocene		
Ogallala formation		
Clay, sandy, light-tan	6	16
Clay, very calcareous, light-gray	5	21
Clay, noncalcareous, very sandy, reddish-brown; contains some gravel	5	26
Clay, plastic, calcareous, white	5	31
Clay, calcareous, plastic, sandy, white	6	37
Clay, very light-tan, and coarse sand and gravel	10	47
Sand, medium to coarse and fine to medium rounded quartz gravel	5	52
Gravel, fine to coarse, rounded	8	60
Gravel, fine to coarse, mostly quartz, with some fragments of chalk	4	64
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, sandy, calcareous, tan to gray	6	70

Driller's log of test hole of John Hineman in NE¼ sec. 19, T. 19 S., R. 28 W.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Clay	18	18
TERTIARY—Pliocene		
Ogallala formation		
Clay and gyp	7	25
Gyp	7	32
Sand	5	37
Clay	5	42
Clay and fine sand	11	53
Sand	16	69
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Soapstone	8	77
Shale	3	80

Driller's log of test hole of Jim Jasper in the NW cor. sec. 34, T. 19 S., R. 28 W.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Clay	25	25
TERTIARY—Pliocene		
Ogallala formation		
Gyp	5	30
Clay	5	35
Sand	12	47
Rock	2	49
Sand and gyp streaks	9	58
Clay, yellow	7	65
Sand, fine	12	77
Sand, good	5	82
Gyp and sand	3	85
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Soapstone	7	92
Shale	3	95

Sample log of test hole 19-29-9ddd in the SE cor. sec. 9, T. 19 S., R. 29 W., drilled September, 1948. Surface altitude, 2,831.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt and clay, sandy, light-tan, calcareous; contains some gravel	10	10
Clay, silty, sandy, light-tan; contains some gravel	8	18
Clay, sandy, light-tan	4	22
TERTIARY—Pliocene		
Ogallala formation		
Clay, calcareous, white to light-gray; contains some caliche	6	28
Clay, pinkish-gray, calcareous, and very fine sand; contains some gravel	13	41
Gravel, fine to medium, and coarse sand	1 5	42 5
Clay, sandy, calcareous, light pinkish-gray	4 5	47
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk	4	51
Shale, sandy, calcareous, light-yellow	9	60

Sample log of test hole 19-29-34ccc in the SW cor. sec. 34, T. 19 S., R. 29 W., drilled September, 1948. Surface altitude, 2,854.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, brown, and some sand	4	4
Silt and clay, light-gray; contains some sand and gravel	10.5	14.5
TERTIARY—Pliocene		
Ogallala formation		
Clay, slightly sandy, calcareous, pinkish-tan	12	26.5
Clay, sandy, pinkish-brown and white; contains some gravel	9.5	36
Sand and gravel, quartz and feldspar; contains some clay	8	44
Sand, medium to coarse; contains some fine gravel and lenses of mortar bed	3.5	47.5
Sand and fine gravel	13.5	61
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, yellow	2	63

Sample log of test hole 19-30-21bbb in the NW cor. sec. 21, T. 19 S., R. 30 W., drilled September, 1948. Surface altitude, 2,900.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt and clay, sandy, tan; contains caliche pebbles	10	10
TERTIARY—Pliocene		
Ogallala formation		
Clay, silty, sandy; contains some caliche	10	20
Clay, silty, sandy, greenish-tan; contains a small amount of gravel	7	27
Caliche and clay, chalky, white	15	42
Mortar bed, pinkish-tan	7	49
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, yellow	4	53

Sample log of test hole 20-28-20ccc in the SW cor. sec. 20, T. 20 S., R. 28 W., drilled September, 1948. Surface altitude, 2,817.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, sandy, gray to brown	2	2
Clay and silt, granular texture, calcareous; contains sand and some gravel and gastropod shells	8	10
Silt and clay, reddish-brown, calcareous; contains some fine sand	7	17
Clay, calcareous, light-tan	6	23

	Thickness, feet	Depth, feet
TERTIARY—Pliocene		
Ogallala formation		
Caliche, with some quartz and granite gravel	9	32
Mortar bed	5	37
Gravel, fine, and calcareous clay	2	39
Gravel, fine to medium, rounded quartz; contains some caliche and mortar bed	5	44
Mortar bed, very tightly cemented	1.5	45.5

Sample log of test hole 20-28-24dad in the SE¼ NE¼ SE¼ sec. 24, T. 20 S., R. 28 W., drilled September, 1948. Surface altitude, 2,622.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, sandy, tan	5	5
Silt and clay, sandy, tan	4	9
Clay and silt, yellow	8	17
Clay, silty, tan-brown	4	21
CRETACEOUS—Gulfian		
Niobrara formation—Fort Hays limestone member		
Limestone, soft, white	9	30

Sample log of test hole 20-28-27dcc in the SW cor. SW¼ SE¼ sec. 27, T. 20 S., R. 28 W., drilled October, 1949. Surface altitude, 2,731.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, dark-brown	4	4
Silt, tan	6	10
Silt, dark red-brown	8	18
Silt, red-brown	2	20
Silt and clay, red-brown to gray; contains a very small amount of sand and gravel at the base	19	39
Sand, medium to coarse; contains yellow clay	5	44
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk, yellow	3	47
Shale, blue	3	50

Sample log of test hole 20-28-30ccc in the SW cor. sec. 30, T. 20 S., R. 28 W., drilled September, 1948. Surface altitude, 2,824.6 feet; depth to water level, 34.3 feet, September 25, 1948.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, sandy, black	1.5	1.5
Clay, silty and sandy, tan	11.5	13
TERTIARY—Pliocene		
Ogallala formation		
Clay, calcareous, white to light-tan; contains some caliche pebbles	5	18
Caliche, massive, pink-tan	6	24
Clay, sandy, pink-gray	2.5	26.5

	Thickness, feet	Depth, feet
Sand and gravel, and mortar beds, thin, soft, light-tan	9.5	36
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, yellow to tan	14	50

Sample log of test hole 20-29-27bbb in the NW cor. sec. 27, T. 20 S., R. 29 W., drilled September, 1948. Surface altitude, 2,861.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, sandy, dark-brown	3	3
Silt and clay, sandy, calcareous	10	13
TERTIARY—Pliocene		
Ogallala formation		
Clay, slightly sandy, buff to tan	3	16
Clay, calcareous, light-tan, with some caliche and gravel	7	23
Clay, light-tan, with caliche	5	28
Caliche and clay, light-gray	3	31
Clay, quite sandy, calcareous, pinkish-tan grading into pinkish-brown	3	34
Clay, calcareous, pinkish-gray, with gravel	4.5	38.5
Gravel, fine to medium, rounded and semirounded quartz and feldspar	10	48.5
Gravel, fine to coarse; contains some medium quartz sand	7.5	56
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, calcareous, yellow	4	60

Sample log of test hole 20-30-21ccc in the SW cor. sec. 21, T. 20 S., R. 30 W., drilled September, 1948. Surface altitude, 2,842.8 feet; depth to water level, 14.7 feet, September 25, 1948.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, sandy, black	4.5	4.5
Meade (?) formation		
Clay, sandy, green-gray	15.5	20
Clay, very sandy, green-gray	6	26
Sand, with some clay	4	30
Clay, silty, tan	6	36
Sand, very fine, silty	2	38
Clay, sandy, greenish-tan; contains iron-stained streaks	18	56
Clay, sandy, greenish-tan; contains some fine gravel	4	60
Clay, sandy, tan	10	70

	Thickness, feet	Depth, feet
Clay, sandy, gray	8	78
Sand, fine, predominantly quartz	2	80
Gravel, fine to medium; contains some clay and fragments of chalk	9	89
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Shale, green-black	1	90

Sample log of test hole 20-30-31ccc in the SW cor. sec. 31, T. 20 S., R. 30 W., drilled October, 1949. Surface altitude, 2,893.1 feet; depth to water level, 35.3 feet, October 12, 1949.

QUATERNARY—Pleistocene	Thickness, feet	Depth, feet
Dune sand		
Sand, medium to coarse	4	4
Meade (?) formation		
Clay and silt, cream-colored	6	10
Clay, silt, and fine to very fine sand, compact, light-brown	10	20
Sand, very fine to fine, compact, light-brown; contains limy zones	32	52
Sand, very fine to fine, compact, light-brown; contains calcium carbonate decreasing with depth,	18	70
Sand, very fine to fine, compact, light-brown; contains a small amount of medium to coarse sand,	23	93
Sand, very fine to fine, compact, light-brown	11	104
Clay, brown	6	110
Sand, fine to coarse; contains a little gravel	4	114
Silt, and fine to very fine sand, sticky	6	120
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Chalk, yellow	5	125
Shale, gray	5	130

Driller's log of test hole of R. F. Plummer in NW¼ sec. 33, T. 20 S., R. 30 W.

QUATERNARY—Pleistocene	Thickness, feet	Depth, feet
Sanborn and Meade (?) formations		
Clay	45	45
Clay, sandy	10	55
Clay	15	70
CRETACEOUS—Gulfian		
Niobrara formation—Smoky Hill chalk member		
Soapstone	10	80

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INDEX

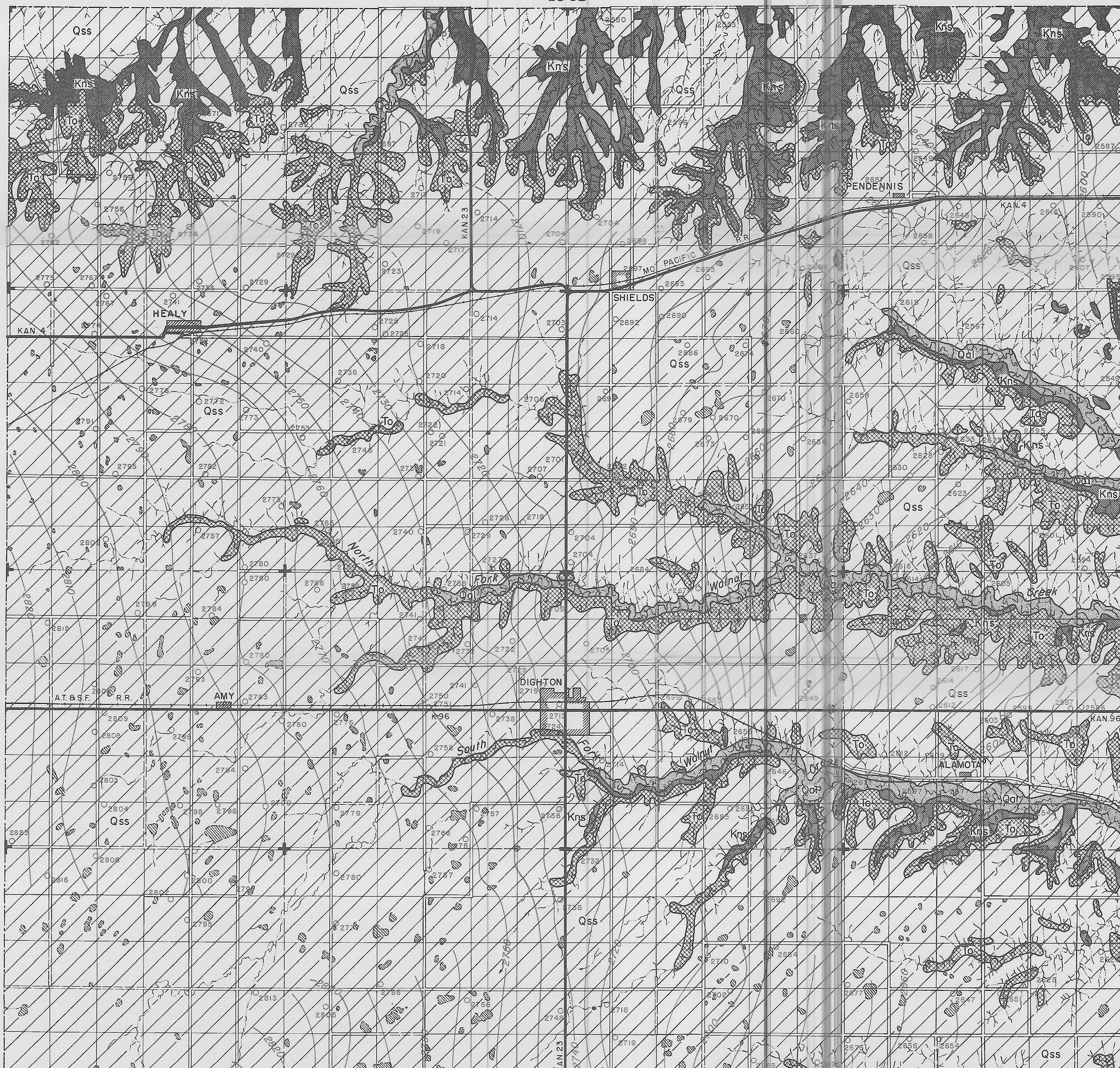
AREAL GEOLOGY OF LANE COUNTY, KANSAS

With Water-Table Contours

State Geological Survey of Kansas

Bulletin 93
Plate 1

by Glenn C. Prescott, Jr.
1948



Base modified from map prepared by State Highway Commission of Kansas

Drainage from map prepared by U. S. Dept. of Agriculture

EXPLANATION

QUATERNARY — PLEISTOCENE

Qal — **Alluvium**
Sand, gravel, and silt comprising stream deposits along some of the valleys. Yields small supplies of water to wells in some areas.

Qds — **Dune sand**
Fine- to medium-grained wind-blown sand. The sand dunes are above the water table and do not furnish water directly to wells, but serve as intake areas for ground-water recharge.

Qss — **Sanborn formation (including slope deposits)**
Tan to brownish massive silt. Locally contains sand and gravel at base. Generally lies above the water table but yields a small amount of water to a few wells.

TERTIARY — PLIOCENE

To — **Ogallala formation**
Gravel, sand, silt, clay and caliche; sand and gravel beds sometimes cemented by calcium carbonate to form "mortar beds." The most important water-bearing formation in Lane County. Yields large to moderate supplies of water.

CRETACEOUS — GULFIAN

Kns — **Niobrara formation**
Smoky Hill chalk member
Chalk and chalky shale. Yields small amounts of water to wells in a few areas.

Knf — **Niobrara formation**
Fort Hays limestone member
Massive chalk beds separated by chalky shale layers. Yields water to very few wells in southeastern Lane County.

Kc — **Carlile shale**
Blue Hill shale member
Consists of sandy shale (Codell sandstone zone) and bluish-gray noncalcareous shale containing gypsum seams and septarian concretions. Not known to yield water to wells in Lane County.

o 2740 — Well location. Number refers to altitude of water level

2770 — Water-table contours based on instrumental levels (dashed where position is inferred; absent where water table is discontinuous)

Intermittent lake or pond

Contour interval 10 feet

- Federal or State Highway
- Graded road
- Railroad
- Ungraded road
- County line (no road)
- Township line (no road)
- Section line (no road)
- Intermittent stream

MAP OF LANE COUNTY, KANSAS

Showing the depths to Water Level and the Location of Wells for which Records are given

by Glenn C. Prescott, Jr.

1948

State Geological Survey of Kansas

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Plate 2