Geology and Ground-Water Resources of Decatur County, Kansas

By Warren G. Hodson

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ABSTRACT

Decatur County is a 900-square-mile area in the High Plains section of northwestern Kansas. The altitude of land surface ranges from about 2,330 to 2,970 feet above mean sea level. The climate is subhumid to semi-arid, with a mean annual precipitation of 18.42 inches.

The oldest rocks exposed consist of chalk and shale beds of Late Cretaceous age. The Cretaceous rocks crop out in only two small exposures but form the relatively impervious bedrock above which ground water occurs in nearly all the county. The Ogallala Formation of Tertiary (Pliocene) age overlies the Cretaceous rocks in the upland areas and is the most widespread aquifer in the county. Stream erosion has removed the Ogallala Formation along the principal valleys, but streams, through several cycles of alluviation, have subsequently deposited the more permeable sediments in the valleys. Eolian silts of late Pleistocene age mantle much of the upland areas and obscure the stream terraces along the principal valleys.

There are two principal aquifers in the county—the Ogallala Formation that underlies the upland areas and the relatively narrow alluvial deposits in the four major stream valleys. The upland areas have more areal extent than the alluvial valleys, but the highest yielding wells are in the major valleys where most of the irrigation is practiced. Based on population figures and livestock statistics, an estimated 750 to 1,000 acre-feet of ground water is used annually in rural areas for household and livestock purposes. Three cities use a total of about 400 acre-feet of ground water per year. About 17,000 acre-feet of ground water is appropriated for the irrigation of 10,500 acres. Ground water in the county is moderately hard, but its quality is adequate for most purposes.

INTRODUCTION

Scope of Investigation

This report of a study of the ground-water resources of Decatur County, Kans., was made as part of the ground-water program of the State Geological Survey of Kansas and the United States Geological Survey, in cooperation with the Division of Water Resources of the Kansas State Board of Agriculture and the Environmental Health Services of the Kansas State Department of Health. The status of the program and the location of Decatur County are shown on figure 1.

A test-drilling program was started in northwestern Kansas in 1952. Data obtained from this program are included in this report. About 3 months during the summer and fall of 1962 were spent in the field by the author gathering additional data on which this report is based. The areal geology was mapped from field observations and from stereoscopic study of aerial photographs obtained from the U.S. Department of Agriculture. Data on the 355 water wells inventoried as a part of this project are given in table 6. Logs of 35 wells and test holes are given at the end of the report. Aquifer tests made in the alluvial deposits in the principal valleys were used to compute the coefficients of transmissibility. Samples of water collected from representative wells were analyzed under the supervision of Howard A. Stoltenberg, Chemist, in the Sanitary Engineering Laboratory of the Kansas State Department of Health.

Previous Investigations

Studies related to the geology or to the ground-water resources of Decatur County and adjacent areas have been made by several people. Adams (1898) has given a historical summary of the early studies of the Cretaceous rocks in Kansas. Williston (1897) discussed the Pleistocene deposits of Kansas. Haworth contributed reports on the physiography (1897a), Tertiary deposits (1897b), and ground water (1897c) in western Kansas. Studies of the High Plains and their ground-water resources were made by Johnson (1901, 1902) and Darton (1905). In a special report on well waters in Kansas, Haworth (1913) discussed the water-bearing characteristics of deposits in western Kansas. Elias (1937) reported on the geology of Decatur and Rawlins Counties with special reference to water resources. A report by Byrne and others (1950) describes the occurrence of construction materials in Decatur County. Frye and Leonard (1952) discussed the Pleistocene

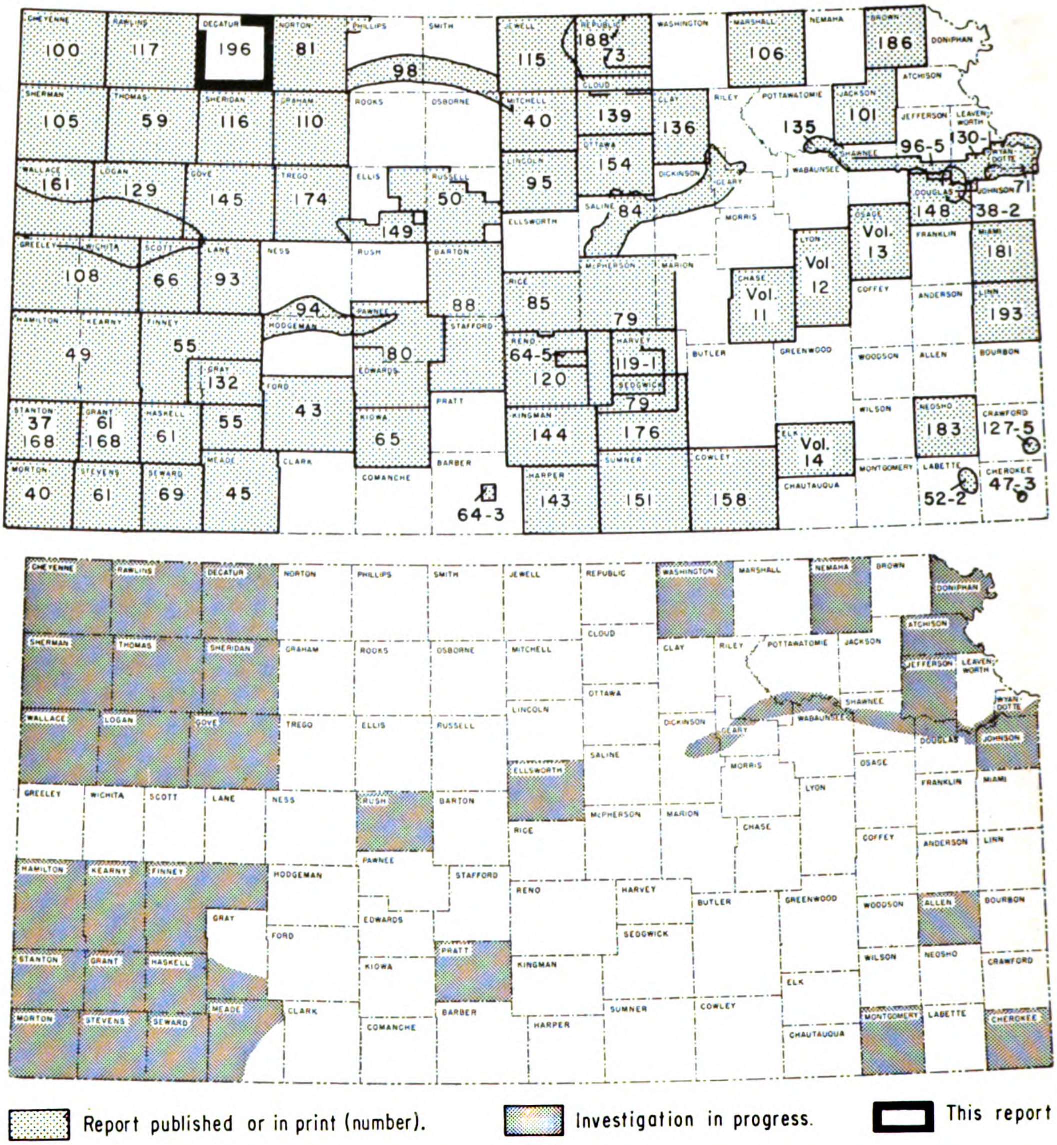


FIGURE 1.—Index maps of Kansas showing area discussed in this report and other areas for which ground-water reports have been published by the State Geological Survey or are in preparation.

geology of Kansas; and Frye, Leonard, and Swineford (1956) discussed the Ogallala Formation of northern Kansas. Ground-water studies in counties that border Decatur County were made by Frye (1945), Frye and Leonard (1949), Prescott (1955), Bayne (1956), and Walters (1956).

Well-Numbering System

The locations of wells and test holes in this report are designated according to General Land Office surveys in the following order: township, range, section, quarter section, quarter-quarter section, and quarter-quarter-quarter section (10-acre tract). The quarter sections, quarter-quarter sections, and 10-acre tracts are designated *a, b, c,* and *d* in a counterclockwise direction beginning in the northeast quadrant. For example, well 1-30W-35cdd is in the SE¼ SE¼ SW¼ sec. 35, T. 1 S., R. 30 W. (fig. 2). If more than one well or test hole is located in the same 10-acre tract, the location numbers are

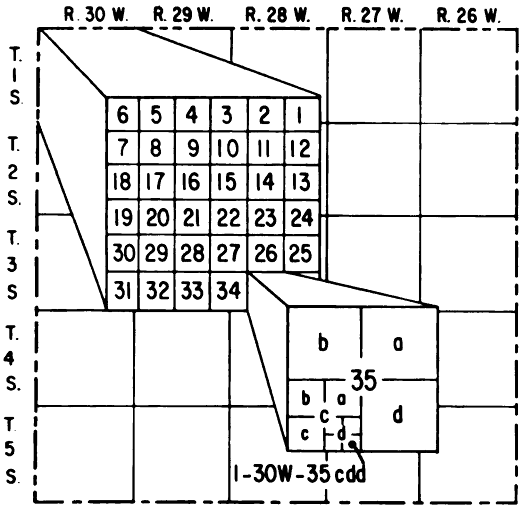


FIGURE 2.—Well-numbering system used in this report.

followed by serial numbers in the order in which they were inventoried.

Topography and Drainage

Decatur County, an area of about 900 square miles, is in the High Plains section of the Great Plains physiographic province (Frye and Schoewe, 1953). Gently rolling uplands moderately dissected by small drainageways comprise much of the county. Four principal streams (Beaver Creek, Sappa Creek, Prairie Dog Creek, and North Fork Solomon River) cross the county in a northeasterly direction. The slopes into the valleys of the principal streams tend to be gentle, but they are steeper and more rugged in most places along the south side of Beaver Creek valley in the northwestern part of the county. The general slope of the land surface of Decatur County is eastward. The total topographic relief is about 640 feet. The lowest altitude of land surface, about 2,330 feet above mean sea level, is in the channel of Sappa Creek at the Decatur County-Norton County line; the highest altitude, about 2,970 feet above mean sea level, is in the uplands in the southwestern part of the county between Sappa Creek and Prairie Dog Creek.

Climate

Decatur County has a subhumid to semiarid climate characterized by slight to moderate precipitation, moderately high average wind velocity, and rapid evaporation. The mean annual precipitation at Oberlin is 18.42 inches, and the mean annual temperature is 53.2°F

TABLE 1.—Monthly and annual precipitation and temperature at Oberlin, 1931-60 (from records of U.S. Weather Bureau).

Month	Mean precipitation, in inches	Mean temperature, °F
January	0.40	28.2
February	.49	32.4
March	1.09	39.7
April	1.75	52.0
May	2.91	62.1
June	3.20	72.7
July	2.72	78.8
August	2.35	77.3
September	1.57	68.0
October	.95	55.6
November	.60	39.5
December	.39	31.5
Mean annual, 1931-60	18.42	53.2

(table 1). The average length of the growing season is 160 days. The average date of the last killing frost is May 2, and the average date of the first killing frost is October 9. About 70 percent of the precipitation occurs during the growing season. Rainfall is erratic, however, sometimes coming as storms of 3 inches or more; at other times, several weeks may pass without an appreciable amount of precipitation.

According to the U.S. Census in 1960, Decatur County had a population of 5,778, an average of 6.4 persons per square mile as compared to a State average of 26.6 persons. Oberlin, the county seat, had a population of 2,337. Other cities and their 1960 populations are: Norcatur, 302; Jennings, 292; and Dresden, 134.

GEOLOGIC SETTING

Summary of Stratigraphy[1]

SUBSURFACE ROCKS

The subsurface rocks in Decatur County do not yield potable water to wells. However, a brief summary of their occurrence is presented because of their significance to the occurrence of oil in northwestern Kansas.

Structural setting.—Decatur County is located on the northwestern flank of the Cambridge arch, the principal structural element in northwestern Kansas. This uplift of granitic, gneissic, and schistose basement rocks, which are about 3,800 feet below land surface, is reflected nearly to the surface through that thickness of sedimentary rocks of Paleozoic and Mesozoic ages (Merriam and Hambleton, 1956;

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

Merriam, 1963; Scott and McElroy, 1964). The Precambrian arched surface plunges southeastward and slopes both northeastward and southwestward. The Jennings anticline on the west side of the arch in Decatur County is a subsidiary structure that plunges southward (Merriam, 1963).

Paleozoic rocks.—Rocks of Pennsylvanian and Permian age, which overlie Precambrian rocks in much of Decatur County, are known from oil-well borings. Rocks of Mississippian age thin on the flanks of the Cambridge arch and are absent over the crest. Older Paleozoic rocks are upturned, truncated, and overstepped on the flanks. The Paleozoic rocks are about 1,700 feet thick and yield some oil to wells in Decatur County.

Mesozoic rocks.—In addition to the thick rocks of Late Cretaceous age that crop out sparsely in Decatur County (discussed below), other Mesozoic rocks of Jurassic and Early Cretaceous age underlie the county. The thickness of all the Mesozoic rocks ranges from about 1,600 to about 2,200 feet (Merriam, 1963).

Oil production from subsurface rocks.—Through 1965 about 5,500,000 barrels of oil had been produced from 14 small oil fields having from 1 to 18 wells each. Oil production has been from Pennsylvanian rocks from 109 wells ranging in depth from 3,156 to 3,863 feet. No oil has yet been produced from rocks of other ages, but exploration continues in the county (Beene and Oros, 1967).

OUTCROPPING ROCKS

The areal distribution of rocks exposed in Decatur County is shown on plate 1. The rocks are sedimentary in origin and range in age from Cretaceous to Recent. A generalized section of the rock units and their water-bearing properties is given in table 2. The stratigraphic relation of the rock units is illustrated by geologic sections on plate 2.

The oldest rocks that crop out in Decatur County are chalk and shale beds of Late Cretaceous age. Two small outcrops of Cretaceous rocks were noted in Decatur County by the author; elsewhere, Cretaceous rocks are overlain by younger deposits. The Cretaceous rocks are relatively impervious and retard or prevent the downward percolation of water, thereby serving as an impervious floor below the overlying permeable fluviatile deposits. The rocks underlying the Cretaceous chalk and shale beds are not known to contain potable water in northwestern Kansas.

The Ogallala Formation of Tertiary age (Pliocene Series) unconformably overlies the Cretaceous rocks in the upland areas of Decatur County. Erosion during the Pleistocene Epoch has removed it along the valleys of the larger streams, but elsewhere in the county, the Ogallala Formation is present. Owing to its widespread occurrence and generally porous texture, the Ogallala is an important source of ground water.

Unconsolidated deposits of both fluviatile and eolian origin represent the Pleistocene Series in Decatur County. Fluviatile deposits occur along the principal streams and are shown on plate 1 as alluvium (Wisconsinan and Recent age) and as the Crete Formation (Illinoisan age). The Crete Formation underlies the terraces along the larger stream valleys. Eolian deposits (Loveland Formation of Illinoisan age and the Peoria Formation of Wisconsinan age) mantle the uplands and valley slopes and in places overlie the terrace deposits along the stream valleys.

Geologic Formations

CRETACEOUS SYSTEM—UPPER CRETACEOUS SERIES

Niobrara Chalk

The Niobrara Chalk of Late Cretaceous age is the oldest rock formation that crops out in Decatur County. Only one small outcrop of the Niobrara was noted in Decatur County—along the road and ditches about 0.4 mile east of the SW1/4 cor. sec. 12, T. 1 S., R. 26 W., on the north side of Sappa Creek valley near the northeastern corner of the county. The total thickness of the Niobrara Chalk in Decatur County is about 600 feet, but only a small part of the formation is exposed. The outcropping rock consists chiefly of brown and orange-brown silicified chalk beds separated by thin chalky shale partings. The Niobrara is relatively impervious and is not known to yield water to wells in Decatur County.

Pierre Shale

The Pierre Shale of Late Cretaceous age conformably overlies the Niobrara Chalk. A small outcrop of the Pierre Shale occurs in the southwestern part of the county along the north side of South Fork Sappa Creek valley in secs. 2 and 3, T. 4 S., R. 30 W. Because it is relatively soft and easily eroded, the Pierre Shale does not crop out as good exposures. However, it is locally near the surface under the slopes

TABLE 2.—Generalized section of outcropping rocks and their water-bearing properties.

System	Series	Stage	Formation	Maximum thickness, feet	Physical character	Water supply
Quaternary	Pleistocene	Recent and Wisconsinan	Alluvium	90	Stream-deposited silt, sand, and gravel. Thick, coarse deposits in major valleys, and finer deposits in smaller valleys.	Yields moderate to large quantities of water to wells along major valleys, and lesser amounts along smaller valleys.
		Wisconsinan and Illinoisan	Peoria and Loveland Formations	52	Silt, mostly eolian, sandy in lower part. Mantles most of the uplands and masks much of the valley walls.	Yields no water to wells.
		Illinoisan	Crete Formation	62	Stream-deposited silt, sand, and gravel in a terrace position (older alluvium) along the major valleys.	Yields small to large quantities of water to wells where deposits occur along major valleys.
Tertiary	Pliocene		Ogallala Formation	240	Fluviatile deposits of sand, gravel, silt, and clay. Mostly unconsolidated, but cemented locally to various degrees.	Yields small to moderate quantities of water to wells in most of the county.
Cretaceous	Upper Cretaceous		Pierre Shale	600	Fissile dark-gray clayey shale. Limonite stains common along fractures. Selenite crystals characteristic of outcrops.	Yields no water to wells.
			Niobrara Chalk	600	Chalk and chalky shale, thin-bedded and platy. Light gray to dark gray where fresh; weathers to orange, brown, or yellow.	Yields no water to wells.

of the larger valleys, particularly along Beaver Creek valley and along North Fork Sappa Creek valley in the western part of the county. The Pierre Shale consists of dark-gray thin-bedded clayey shale, commonly with limonite stains along fractures. Selenite crystals characterize weathered exposures. It ranges in thickness from a thin edge in the central part of the county to about 600 feet in the northwestern part. It is relatively impervious and is not known to yield water to wells in Decatur County.

TERTIARY SYSTEM—PLIOCENE SERIES

Ogallala Formation

The Ogallala Formation of Pliocene age is divided into three members in Kansas which are, in ascending order, the Valentine, Ash Hollow, and Kimball. No attempt was made to divide the Ogallala Formation in Decatur County, and it is treated as a single unit in this report.

Character.—The Ogallala Formation was deposited on an erosional surface of Upper Cretaceous rocks by eastward-trending streams whose source of sediment was igneous rocks of the Rocky Mountains and sedimentary rocks of eastern Colorado. During early stages of deposition of the Ogallala, through-flowing streams which headed in the Rockies occupied broad, shallow valleys across what now constitutes the High Plains. As deposition continued, valleys became filled, divides were covered, topographic relief was reduced, and the depositional zones of individual streams overlapped and coalesced. Thus, the Ogallala Formation consists of a heterogeneous complex of predominantly clastic deposits, ranging in texture from clay to very coarse gravels and pebbles. The lithology changes abruptly both vertically and laterally, and only rarely can an individual bed be traced for any appreciable distance. Although the sediments are largely unconsolidated, cementation of beds occurs to some extent. Calcium carbonate is a common constituent, both as interstitial material and as stringers and nodules of caliche. Silica also is present as a cementing material in beds of opaline sandstone or as chert.

Sand is the principal material within the Ogallala and is present at all horizons. Although beds of uniform grain size occur, the sand in most beds ranges from fine to coarse and commonly is mixed with gravel, silt, or clay. Beds of silt, sandy silt, and clayey silt are present throughout the Ogallala and are mostly pink, tan, gray, and greenish gray. Where the fine sediments contain a large amount of calcium carbonate, they are light gray or white.

The topographic expression of the formation includes flat uplands, gentle erosional slopes, and nearly vertical cliffs. Typical outcrops are cemented to various degrees and are ash gray in color. Because the cemented beds are more resistant to erosion, hard ledges and knobby, irregular benches are characteristic.

Distribution and thickness.—The Ogallala Formation occurs extensively in Decatur County, overlying the Cretaceous rocks in most of the county. Erosion during the Pleistocene Epoch has removed the Ogallala along the principal valleys, but elsewhere in the county, although generally mantled with eolian silts, the Ogallala underlies the uplands and valley slopes and serves as the principal aquifer from which domestic and stock supplies are obtained.

The Ogallala Formation rests on a subaerially eroded surface developed on chalk and shale beds of Late Cretaceous age. This surface has a relief of several hundred feet in Decatur County and slopes generally eastward at about 10 to 15 feet per mile. Logs of test holes show that the thickness of the Ogallala in Decatur County ranges from a thin edge along the outer margins of the stream valleys to more than 200 feet in the interstream areas.

QUATERNARY SYSTEM—PLEISTOCENE SERIES

Deposits of Pleistocene age, although relatively thin, are the surficial deposits in much of Decatur County. They include the Crete Formation of Illinoisan age (terrace deposits), the Loveland Formation of Illinoisan age and the Peoria Formation of Wisconsinan age (loess deposits), and alluvium of late Wisconsinan and Recent age.

The classification of Pleistocene deposits by the State Geological Survey of Kansas is based on the classification of glacial deposits in the midcontinent region (Frye and Leonard, 1952; Bayne and O'Connor, 1968). Correlations between the glaciated and nonglaciated areas have been made on the basis of continuous loesses, molluscan fauna, buried soils, and petrologically distinctive volcanic ash (Condra and others, 1947; Frye and others, 1948).

Crete Formation

Character.—Deposits classified as the Crete Formation in this report occur along the major valleys as older alluvial deposits in a position topographically higher than the modern flood plain. The deposits consist chiefly of sand, gravel, and silt that were deposited by streams during earlier aggradational cycles. Only the upper part of the deposits is exposed in the county, and the deposits have not been dated on the basis of fossils. That the deposits are largely the Crete Formation of Illinoisan age is indicated by their topographic position above the modern flood plain, the relative youthfulness of the terrace, and the lithologic and stratigraphic similarity to deposits that are classified as Illinoisan in age in adjacent and nearby areas. It is possible that fluviatile deposits of Kansan age occur in places in the basal part of the deposits as they do locally in central and north-central Kansas, but the terrace is believed to be Illinoisan in age. Loess deposits blanket and obscure the terrace locally. Where loess is present, the terrace deposits appear to grade into the Loveland Formation, further indicating an Illinoisan age for the terrace deposits.

The upper part of the terrace deposits is composed of tan or gray silt that is similar in many respects to the upland loess. The soil profile generally is well developed, and at places there are one or more buried soil zones. Columnar structure is common, and shells of fossil gastropods are found locally. In general, the deposits are coarser at depth, and sandy silt, sand, and gravel are found in the basal part.

Distribution and thickness.—The Crete Formation occurs as terrace deposits along the major valleys in the county. The deposits are much more common along the north sides of the valleys than along the south sides. Along the north side of Beaver Creek valley in the northwestern part of the county and along the north side of the North Fork Solomon River valley in the southeastern corner, the Crete is exposed nearly continuously. The Crete occurs along much of Sappa Creek valley northeastward from the city of Oberlin. However, much of the Crete Formation has been removed by stream erosion, and in places only remnants remain. The width of the terrace is generally from a quarter to half a mile. Loess and slope wash have obscured the deposits to the extent that it is difficult to delineate the outer edge of the terrace.

The Crete Formation ranges in thickness from a thin edge along the margins of the deposits to more than 60 feet in test hole 1-26W-8ddd. Along the principal valleys it is generally from 50 to 60 feet thick. In general, the thickness increases eastward across the county.

Loveland and Peoria Formations

Character.—The Loveland Formation is a reddish-tan silt, mostly eolian, which commonly grades into sandy silt or sand in the lower part. The buried Sangamon Soil marks the top of the Loveland and separates it from the overlying Peoria Formation. The Peoria is a tan to gray massive eolian silt that blankets much of the upland areas. The deposits classified as Loveland and Peoria in this report are above the water table and yield no water to wells.

Distribution and thickness.—Loess of late Pleistocene age covers a considerable part of Decatur County with a relatively thin mantle ranging in thickness from a thin edge to as much as 52 feet in test hole 1-31W-1aaa. In general, the thickness of the loess is greater in the northwestern part of the county. The loess caps the rolling hills and flat uplands and tends to mask the valley slopes and subdue the topography. Although the Sangamon Soil occurs between the Loveland Formation of Illinoisan age and the Peoria Formation of Wisconsinan age, the formations could not be readily separated, and are mapped as one unit on plate 1.

Alluvium

Character.—Alluvium of late Wisconsinan and Recent age occurs as relatively narrow deposits beneath the flood plains of the principal streams in the county. The alluvium consists of the deposits beneath the narrow stream channels and the adjacent low terraces commonly inundated by flood waters. The deposits, largely silt and sand, become coarser with depth. Beds of very coarse sand and gravel are common in the middle and lower parts of the alluvium. The upper part consists predominantly of silt and sandy silt deposited during floods.

Distribution and thickness.—The width and thickness of the alluvium are greatest in the principal valleys. Along Beaver Creek and Sappa Creek valleys, the alluvium ranges from about half a mile to a mile in width; along Prairie Dog Creek and South Fork Solomon River valleys, the alluvium ranges from about half to three-quarters of a mile in width. It ranges in thickness from a thin edge along the margins of the deposits to as much as 90 feet in irrigation well 1-27W-34bab. In the principal valleys the alluvium is generally about 50 to 70 feet thick in the deepest parts of the valley fill.

GROUND WATER

Source and Occurrence

Ground water in Decatur County is derived almost entirely from precipitation within the county or nearby. Part of the precipitation returns to the air by evaporation, part moves away as surface runoff into streams, and part infiltrates into the ground. A very small part percolates downward through the soil and underlying strata until it reaches the water table and becomes ground-water recharge. The ground water moves slowly to points of discharge in directions determined largely by the shape and slope of the water table. Ground water is discharged by springs or wells, by seeps into streams, or by evaporation or transpiration near the land surface, commonly along stream valleys. The movement of ground water in Decatur County is generally eastward, and some ground water leaves the county by subsurface outflow.

Water Table and Movement of Ground Water

The configuration of the water table in Decatur County is shown on plate 1 by water-table contours that connect points of equal altitude of the water level. The water-table contours were compiled from measurements of depth to water in wells and test holes, the surface altitudes of which were determined by plane table and alidade. Water-level measurements and altitudes of land surface for the wells are given in table 6 and for the test holes are given at the end of this report. Ground water moves downgradient at right angles to the contours.

The water table has a generally eastward gradient of 10 to 15 feet per mile. Along the four principal valleys, however, the contours swing sharply upstream, indicating that ground water is moving from the Ogallala Formation toward the stream valleys and into the alluvial deposits. In some localities near the principal valleys, the water table has a gradient of about 50 feet per mile toward the stream valleys. Considerable discharge occurs by evaporation and transpiration along the valley sides where the contact of the Ogallala Formation and the underlying Cretaceous bedrock is near the land surface.

Recharge

LOCAL PRECIPITATION

The mean annual precipitation in Decatur County is about 18 inches, but only a small fraction of the precipitation reaches the water table and becomes ground water. The slope of the land surface and the type of material through which the water must percolate are important factors that affect the amount and frequency of recharge. The broad, flat alluvial surfaces of the principal valleys offer excellent conditions for recharge. The alluvial deposits contain sand, silt, and sandy silt, and the water table is near the land surface; consequently, the infiltration of water generally is relatively rapid. Conversely, in the maturely dissected uplands, the land surface is characterized by waterways and moderately steep slopes underlain by massive beds of silt and buried soils, and the water table lies at a considerable depth. These areas receive relatively little recharge, probably less than half an inch per year.

STREAMS AND PONDS

The four principal streams that flow across Decatur County are entrenched below the water table and receive water from the ground-water reservoir. Thus, they do not constitute sources of recharge, except in local areas where heavy pumping from wells near major streams may have lowered the water table temporarily below the level of the stream channel. The smaller tributary streams are above the water table, and during periods of stream runoff following rain or melting snow, some water seeps into the underlying deposits to supplement the ground water. Surface ponds also constitute a source of recharge where the ponds are above the water table and are underlain by permeable materials.

INFILTRATION OF IRRIGATION WATER

Recharge from water applied for irrigation can amount to 25 or 30 percent of the applied water where good recharge conditions exist. In Decatur County, most of the irrigated land is in the principal valleys where the alluvial deposits consist chiefly of silt, sand, and sandy silt, and where the soil is relatively permeable. Thus, conditions in the valleys are conducive to the return of irrigation water to the ground-water reservoir. Although there were 83 irrigation wells in the county at the time of this investigation in 1962, only a small part of the land was under irrigation. Because irrigation is not extensive and because the areal extent of the alluvial valleys is relatively small, the amount of recharge to the aquifer from the return of irrigation water is not considered significant. However, the return of irrigation water to the ground-water reservoir represents a source of recharge, and as irrigation becomes more extensive, an increasing amount of recharge will occur. Only a few irrigation wells have been drilled in the uplands of Decatur County; thus, the recharge from irrigation water applied in the uplands is negligible.

Discharge

NATURAL

Before any wells were drilled in Decatur County, the ground-water reservoir was in approximate equilibrium—that is, the average annual recharge plus subsurface inflow of ground water to the county was equal to the average annual discharge plus the outflow of ground water from the county. The factors producing discharge by ground-water movement into the principal stream channels and by evaporation and transpiration by plants in low-lying areas of shallow water table have changed little, and loss by these means still accounts for the major part of the ground-water discharge from the county.

WELLS

Municipal water departments reported a use of about 400 acre-feet of ground water in 1961. According to records of the Division of Water Resources of the Kansas State Board of Agriculture, 17,000 acre-feet of ground water per year was appropriated for irrigation as of October 1963. About 3,900 acre-feet of ground water was reported used for irrigation in 1962 by 60 irrigation wells, with more than 20 irrigators not reporting. An estimated annual use of 6,000 to 8,000 acre-feet of ground water is used for irrigation in Decatur County.

Most rural residents obtain water for domestic and livestock purposes from small-diameter drilled wells equipped with cylinder pumps, many of which are powered by windmills. The yields of these wells are small and probably average about 1 gpm (gallon per minute). Because of their considerable number and long pumping periods, however, such wells represent an important withdrawal of ground water, which is estimated to be 750 to 1,000 acre-feet per year for household and livestock purposes.

Inflow and Outflow

As indicated by the water-table contours on plate 1, the movement of ground water in the interstream areas is in an easterly direction. Hence, a small amount of recharge from precipitation that occurs in eastern Rawlins County moves into western Decatur County. Computations using the saturated thickness of water-bearing deposits along geologic section A-A′ (pl. 2) near the western edge of the county, the water-table gradient (pl. 1), and an assumed average coefficient of permeability of 300 gpd (gallons per day) per square foot indicate a subsurface inflow of about 5,000 acre-feet per year. The saturated thickness along section B-B′ in the eastern part of the county is about equal to the saturated thickness along section A-A′. Assuming equal permeability, the subsurface outflow from Decatur County probably is equal to the subsurface inflow.

Water in Storage

To determine the quantity of ground water in storage in the Pliocene and Pleistocene deposits, a map showing the saturated thickness of the deposits (fig. 3) was prepared by superimposing a contour map of the water table upon a contour map of the bedrock surface (fig. 4) and connecting points of equal saturated thickness. The area between contours was measured with a planimeter and was multiplied by the average saturated thickness to give the volume of saturated materials. Assuming a specific yield (ratio of the volume of water the saturated part of the aquifer will yield, by gravity, to its own volume) of 20 percent from the saturated materials, about 5 million acre-feet of ground water would be available for pumping from the Pliocene and Pleistocene deposits if the deposits were completely drained. From a practical standpoint, much less water than this would be available for pumping.

Hydrologic Properties of Water-Bearing Materials

COEFFICIENTS OF STORAGE AND TRANSMISSIBILITY

The quantity of ground water that an aquifer will yield to wells depends upon the hydrologic properties of the material forming the aquifer. The hydrologic properties of greatest significance are the ability of the aquifer to store and transmit water, which are measured by the coefficients of storage and transmissibility, respectively. Aquifer tests provide the data to compute these coefficients.

The coefficient of storage (S) may be expressed as the change in the stored volume of water per unit surface area of the aquifer per unit change in the component of head normal to that surface.

The coefficient of transmissibility (T) may be expressed as the rate of flow of water, in gallons per day, through a vertical strip 1 foot wide and extending the full height of the saturated thickness of the aquifer, under a hydraulic gradient of 1 foot per foot, at the prevailing ground-water temperature.

The field coefficient of permeability (P) can be computed by dividing the coefficient of transmissibility by the aquifer thickness (m), and may be expressed as the rate of flow of water, in gallons per day, through a cross-sectional area of 1 square foot, under a hydraulic gradient of 1 foot per foot, at the prevailing ground-water temperature.

Aquifer tests were made in three of the principal valleys. An existing irrigation well and two observation wells constructed at ap-

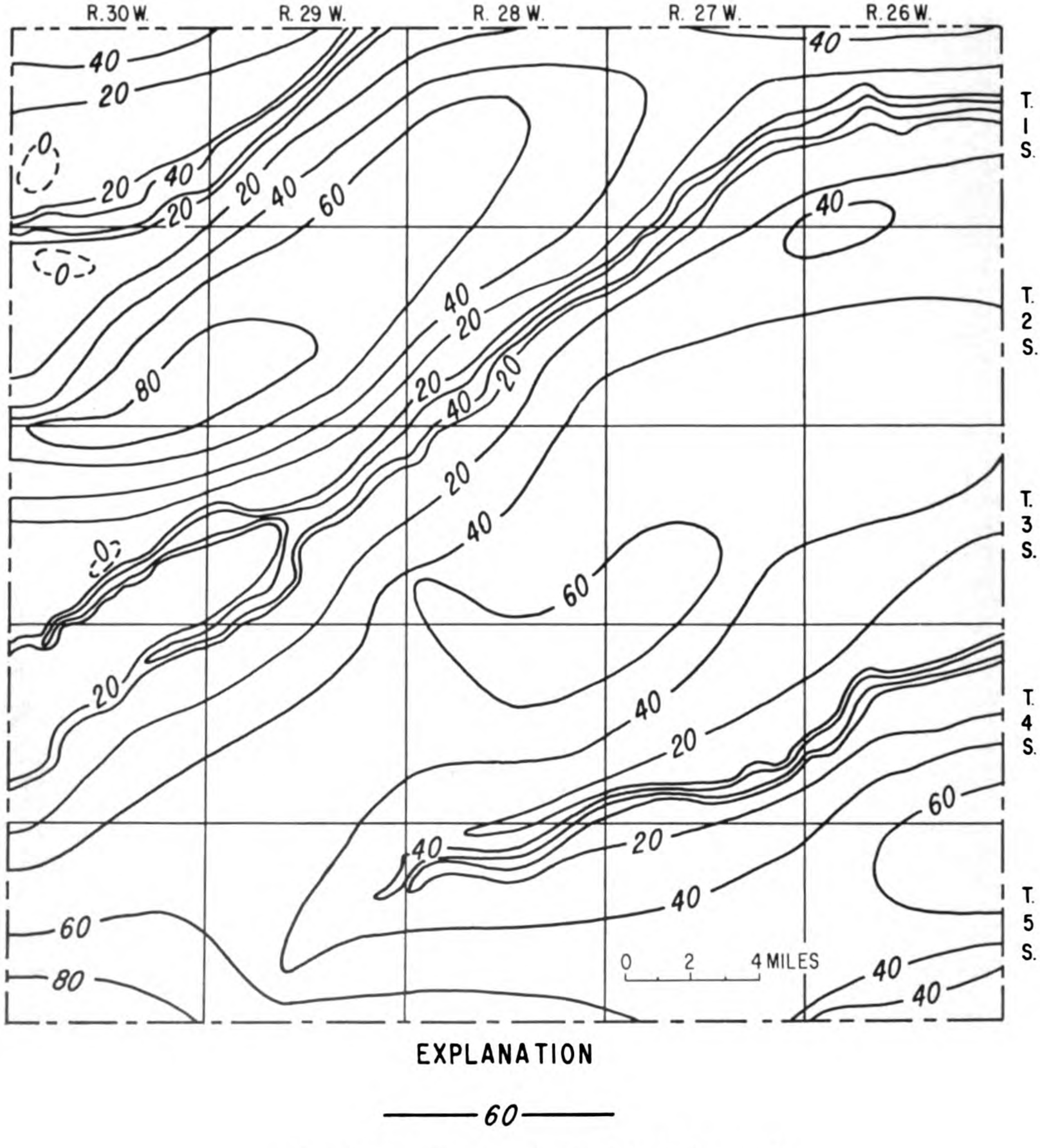
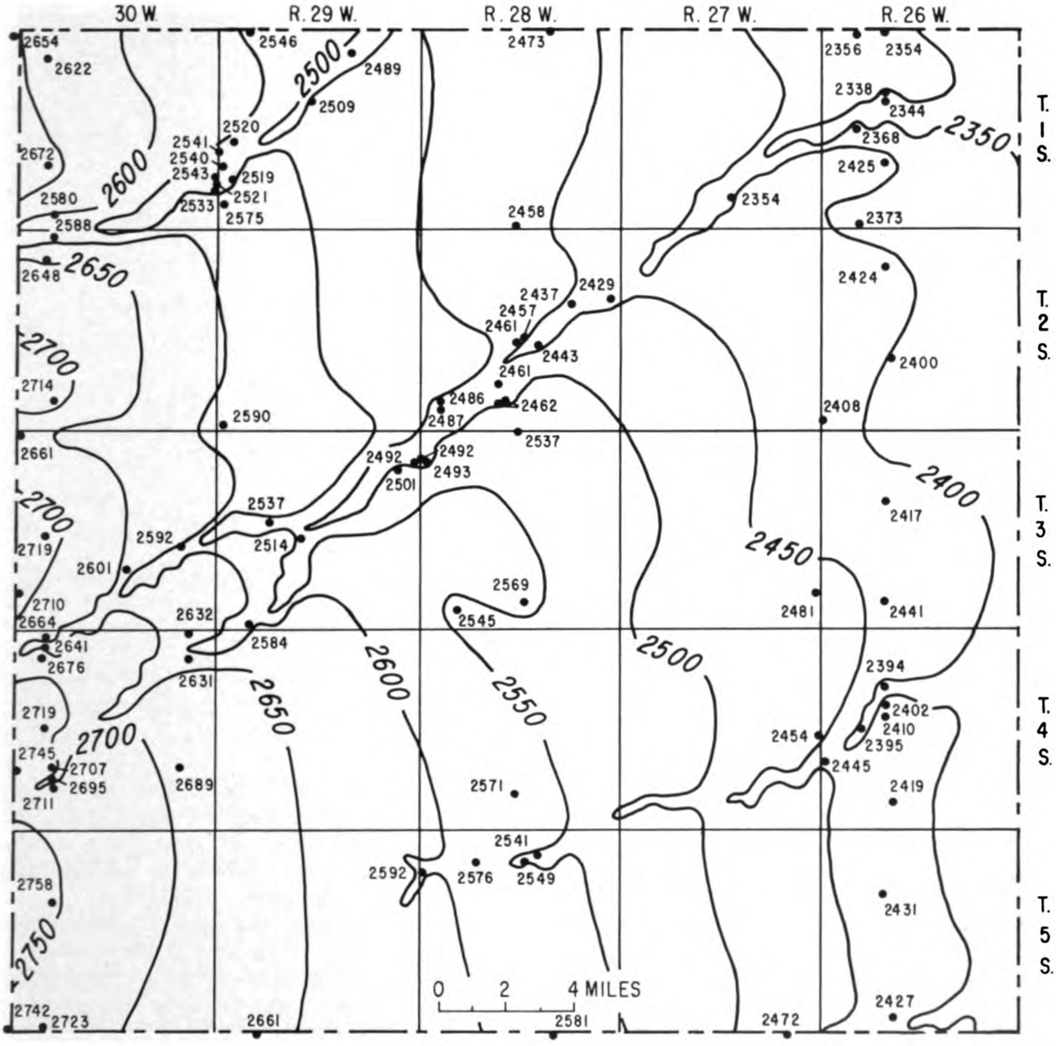


FIGURE 3.—Saturated thickness of Tertiary and Quaternary deposits.

propriate distances from the pumped well were used for each aquifer test.

Figure 5 shows the results of the tests using drawdown measurements in the observation wells and analysis by the Thiem method. The coefficients of transmissibility also were computed by the Theis nonequilibrium method and by the Jacob modified nonequilibrium method. The results obtained by these methods were similar to those obtained by the Thiem method shown on figure 5. The theory of these methods and its application are discussed by Ferris and others (1962). The results of the aquifer-test analyses indicated coefficients of transmissibility of 70,000 gpd per foot near well 5-28W-5dcd1 in Prairie Dog Creek valley, 120,000 gpd per



EXPLANATION

—— 2500 ——

Bedrock contour

Shows altitude of top of Cretaceous bedrock
Contour interval 50 feet. Datum is mean sea level

• 2545

Test hole or well with log

Number is altitude of bedrock surface, in feet

FIGURE 4.—Configuration of Cretaceous bedrock surface beneath Tertiary and Quaternary deposits.

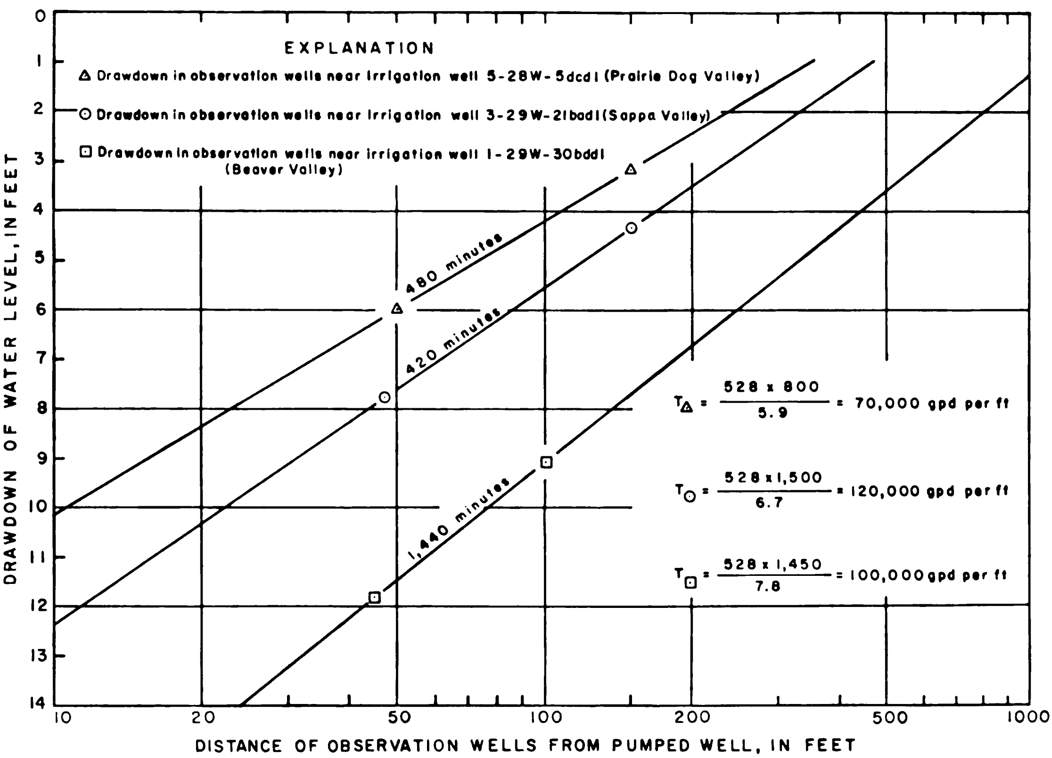


FIGURE 5.—Drawdown of water level in observation wells during aquifer tests.

foot near well 3-29W-21bad1 in Sappa Creek valley, and 100,000 gpd per foot near well 1-29W-30bdd1 in Beaver Creek valley.

The aquifer tests indicate the hydrologic properties only in the vicinity of the test, but they are believed to be indicative of the hydrologic properties that can be expected for much of the alluvial deposits along the principal valleys in the county.

DRAWDOWN, DISTANCE, AND TIME RELATIONSHIPS

To compute possible future drawdowns in the vicinity of any particular well, assumptions were made that all water pumped would be from storage within the aquifer, that pumping would be continuous at a rate of 1,000 gpm, and that the water-bearing material has a T of 100,000 gpd per foot and an S of 0.2. The computations of drawdown are in error to the extent that these assumptions are in error, but the computations are probably of the right order of magnitude.

Figure 6 shows, under the assumed conditions specified, the drawdown of water level at any distance from the pumped well after 1, 10, 100, and 1,000 days. After 10 days of pumping at a rate of 1,000 gpm, the drawdown 10 feet from the well would be 11 feet, the drawdown 100 feet from the well would be 5.8 feet, and the drawdown 1,000 feet from the well would be nearly 1 foot. After 100 days of pumping, the drawdown 100 feet from the well would be 8.4 feet.

Figure 7 shows the rate of decline caused by pumping under the assumed conditions. The decline of water level 100 feet from a well pumped at 1,000 gpm would be 5.8 feet after 10 days, and 8.4 feet after 100 days.

The cone of depression caused by a pumping well will increase in area and depth in response to pumping. Large-yielding wells can interfere with one another unless the wells are spaced at considerable distances. When wells mutually interfere, the drawdown at any one point will be the sum of the drawdowns produced by each well at that point. When wells interfere, the pumping lift in each well is increased and the discharge is decreased. To maintain a constant discharge would further increase the drawdown and extend the cone of depression. In areas where many wells are pumping from the same aquifer, the large cone of depression resulting

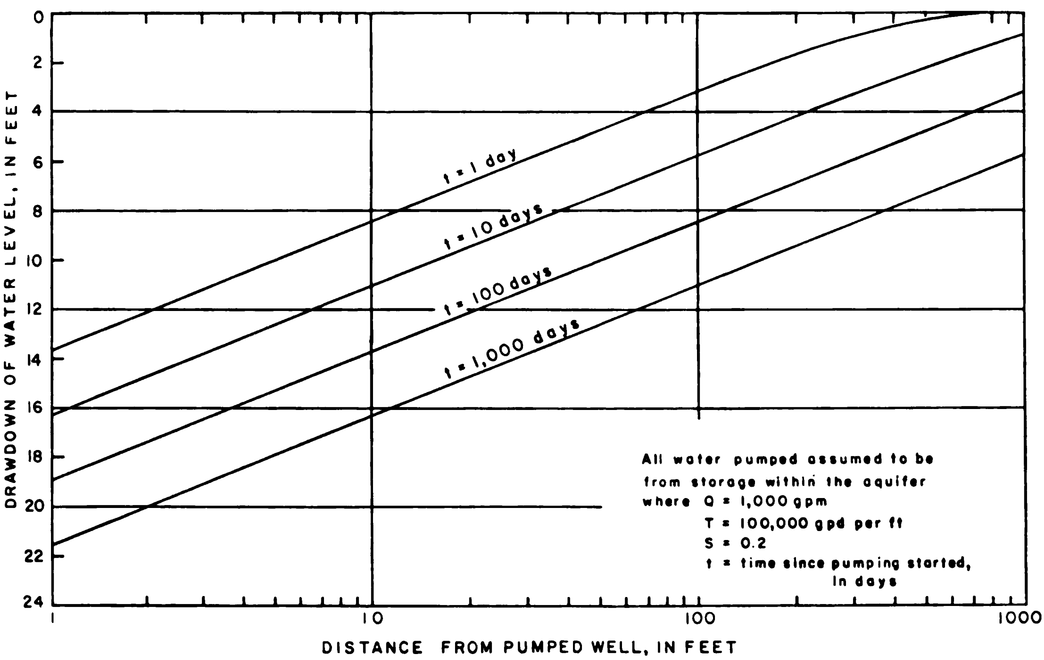


FIGURE 6.—Drawdown of water level at any distance from the pumped well after pumping has begun.

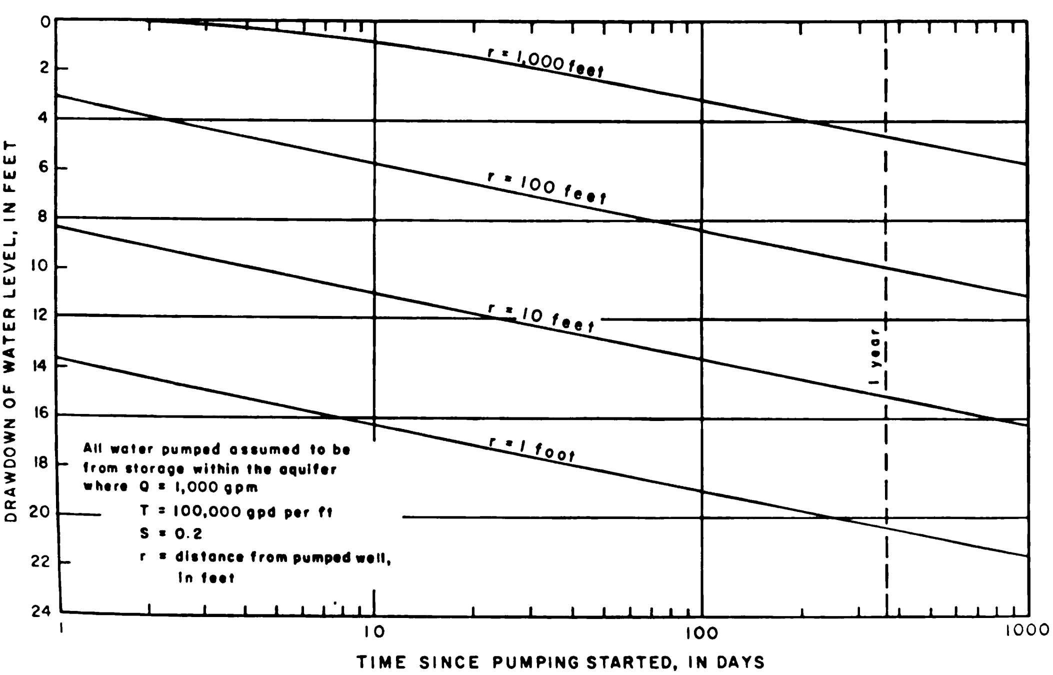


FIGURE 7.—Drawdown of water level at any time after pumping has begun.

from mutual interference may not have sufficient time to recover between pumping periods, and the water level may decline persistently.

As shown by the water-table contours on plate 1, ground water in the Ogallala Formation along the edges of the upland areas is moving toward the stream valleys. Because the water table is near the land surface along the valley edges and because of the slow movement of the water, a large part of this water either is evaporated or is transpired by plants. However, if sufficient ground water were pumped from the valley aquifers to appreciably increase the gradient of the water table along the edges of the valleys, it is possible that part of the ground water now lost to evaporation and transpiration in the shallow-water areas along the edges of the valleys could be induced into the deeper part of the valley aquifers, and thus eventually become available for pumping by wells. In addition, increased pumping from a valley aquifer could lower the water level sufficiently to intercept some water that now discharges into streams.

Most of the land irrigated with ground water in Decatur County is in the alluvial valleys, and about half of the land irrigated is in Sappa Creek valley, which extends northeastward across the central and northern parts of the county. If it is assumed that the alluvial deposits within Sappa Valley have an average width of half a mile, a length of 30 miles, an average saturated thickness of 30 feet, and a specific yield of 20 percent, then about 60,000 acre-feet of water is in storage in the alluvial deposits of Sappa Creek valley. Obviously, it would be impossible to pump all this water from the aquifer. However, the amount of water in storage in Sappa Valley, as computed above, is nearly 4 times the amount of ground water appropriated (17,000 acre-feet) in all Decatur County in 1962, and is more than 15 times as much as the ground water pumped for irrigation (3,900 acre-feet) in Decatur County in 1962, as reported by the Division of Water Resources of the Kansas State Board of Agriculture.

Availability

The people of Decatur County are fortunate that potable ground water is available at most places in the county. In some areas, the quantity is sufficient only for domestic and stock supplies. In other areas, yields of several hundred to more than 1,000 gpm are available from wells and, therefore, are sufficient for irrigation or industrial use.

There are two principal aquifers in Decatur County—the alluvial deposits in the stream valleys and the Ogallala Formation that underlies the upland areas. The quantity of water that is available from the aquifers is dependent upon the saturated thickness and the permeability of the deposits. Although the upland areas have considerably more areal extent than the alluvial valleys, the highest-yielding wells are in the major valleys, and it is here that most of the irrigation is practiced. The higher yields are due to the higher permeabilities of the valley deposits.

Depth to water level in the valleys generally ranges from about 10 to 40 feet below land surface. Depth to water level in the uplands exceeds 100 feet below land surface in most places and is 200 feet or more below land surface in some of the topographically higher parts of the county.

ALLUVIAL VALLEYS

The relatively narrow alluvial deposits along the principal stream valleys are an important source of ground water. The alluvial deposits are shown on the geologic map (pl. 1) as alluvium and the Crete Formation. The alluvium underlies the modern flood plain. The Crete Formation underlies the terrace along the outer margins of the valleys, the terrace ranging in most places from 10 to 25 feet higher than the flood plain. The alluvium of Wisconsinan and Recent age and the fluvial deposits of the Crete Formation are lithologically similar and are in contact with each other. The water table in the alluvial valleys is continuous in both the alluvium and the Crete Formation.

Many domestic and stock wells obtain water from the valley deposits, and most irrigation wells in the county are in the stream valleys. Small to large quantities of ground water are available from the valley deposits at most localities in the principal valleys. In areas of greater saturated thickness, ground water in quantities adequate for irrigation can be obtained. Yields of irrigation wells along Beaver Creek and Sappa Creek valleys range from about 500 gpm to a reported 1,450 gpm, and yields from irrigation wells along Prairie Dog Creek and the North Fork Solomon River valleys range from about 300 to 700 gpm.

OGALLALA FORMATION

The uplands of Decatur County are mantled by deposits of silt, sand, and gravel of the Ogallala Formation, which are as much as 240 feet thick and average about 200 feet thick in most of the upland areas. The saturated thickness of the deposits exceeds 80 feet in places and averages about 45 feet (fig. 3). The Ogallala Formation is the most widespread water-bearing formation in the county. It supplies water for most domestic and stock purposes and for several irrigation wells. Yields of wells in the Ogallala range from a few gallons per minute from domestic and stock wells to a reported 825 gpm from irrigation well 5-30W-35bcb.

Only a few irrigation wells had been drilled in the uplands of Decatur County at the time of this field investigation, although wells in areas of greater saturated thickness may be expected to yield as much as 500 gpm.

Utilization

Data on 355 wells are given in table 6. Only part of the domestic and stock wells were visited, but records were made of all municipal and irrigation wells in the county at the time of this investigation. The principal uses of ground water in the county are given below.

DOMESTIC AND STOCK SUPPLIES

One of the chief uses of ground water in Decatur County is for domestic and stock purposes. Quantities of ground water adequate for domestic and stock needs are available at nearly all places in the county. Most domestic and stock wells are drilled wells equipped with displacement-type pumps. Most pumps are operated by windmills; others are operated by electric or gasoline motors, or by hand.

MUNICIPAL SUPPLIES

Data regarding city wells and details of well construction are given in table 6. Data collected at the time of this field investigation regarding municipal water supplies are given below. Dresden (1960 population of 134) had no municipal water supply.

Oberlin

Oberlin obtains its water supply from six drilled wells in the alluvial deposits of Sappa Creek valley near the southern and southeastern edges of the city. Each well yields about 300 gpm and is equipped with an electrically driven turbine pump. The elevated storage tank has a capacity of 500,000 gallons. Water used in 1961 was about 112 million gallons, as reported by the city water department.

Norcatur

Norcatur obtains its water supply from three drilled wells in the Ogallala Formation near the northwestern edge of the city. Two of the wells are equipped with electrically driven turbine pumps; the other well is equipped with a diesel-driven centrifugal pump. Storage is provided by an elevated storage tank with a capacity of 50,000 gallons. Water used in 1961 was about 10 million gallons, as reported by the city water department.

Jennings

Jennings obtains its water supply from one drilled well in the alluvial deposits of Prairie Dog Creek valley near the northwestern edge of the city. The well is equipped with an electrically driven turbine pump with a capacity of 200 gpm. Storage is provided by an elevated storage tank with a capacity of 45,000 gallons. Water used in 1961 was about 7 million gallons, as reported by the city water department.

IRRIGATION SUPPLIES

There were 83 irrigation wells in Decatur County in the fall of 1962, all but 10 of which were in the alluvial valleys. Beaver Creek valley, which extends across the northwestern corner of the county, had the greatest concentration of irrigation wells and also the highest-yielding wells in general. In this valley, a number of irrigation wells have yields exceeding 1,000 gpm, and nearly all have yields exceeding 500 gpm.

Sappa Creek valley had the greatest number of irrigation wells (nearly half) because of its greater length in transversing the county. Yields of several hundred gallons per minute may be obtained from wells in Sappa Creek valley and a few irrigation wells have yields of about 1,000 gpm.

Several irrigation wells were in Prairie Dog Valley. Although most yields were less than those in Beaver Valley or Sappa Valley, the irrigation wells in Prairie Dog Valley yield about 300 to 500 gpm.

The North Fork Solomon Valley extends across the southeastern corner of Decatur County. The length of the valley in the county is about 6 miles, and several irrigation wells were in this part of the valley. The yield of most of these wells ranged from about 300 to 700 gpm.

At the time of this investigation, only 10 irrigation wells were in the uplands deriving water from the Ogallala Formation. Reported yields of irrigation wells in the uplands ranged from 55 to 825 gpm.

According to records of the Division of Water Resources of the Kansas State Board of Agriculture, 17,000 acre-feet of ground water was appropriated for the irrigation of 10,500 acres as of October 1963. Irrigators reported that about 3,900 acre-feet of ground water from 60 irrigation wells was applied in 1962 to about 3,000 acres, with more than 20 irrigators not reporting.

Chemical Quality

The chemical character of ground water in Decatur County is indicated by analyses of samples from wells deriving water from the principal aquifers (table 3). The results of the analyses are given in parts per million. The analyses show only the dissolved mineral constituents and do not indicate the sanitary condition of the water.

CHEMICAL CONSTITUENTS IN RELATION TO USE

Ground water in Decatur County is predominantly a calcium bicarbonate type. The water is moderately hard, with most of the hardness resulting from the presence of calcium and magnesium (carbonate hardness). The characteristics and concentrations of the principal chemical constituents are given in table 4. Most samples of water contained less than 500 ppm (parts per milllion) dissolved solids, and only one sample contained more than 1,000 ppm. The samples were low in nitrate and chloride content. Only one sample exceeded 250 ppm sulfate. The iron content was fairly high in many samples.

Ground water in the alluvial valleys is somewhat more mineralized than ground water in the Ogallala Formation. The sulfate content was appreciably higher in the alluvial valleys, particularly along Sappa Creek and Beaver Creek valleys.

SANITARY CONSIDERATIONS

The analyses of water in table 3 give only the dissolved-solids content and do not indicate the sanitary quality of the water. Water containing mineral matter that imparts an objectionable taste or odor may be free from harmful bacteria and safe for drinking. Conversely, water clear and pleasant to the taste may contain harmful bacteria. Great care should be taken to protect domestic and public water supplies from pollution. To guard against contamination, a well must be properly sealed to keep out dust, insects, vermin, debris, and surface water. Wells should not be placed where barnyards, privies, or cesspools are possible sources of pollution.

SUITABILITY OF WATER FOR IRRIGATION

Sodium is required in very limited amounts for most plant growth. However, sodium in high concentrations is not only toxic to plants but also detrimental to the soil, particularly where leaching is not adequate. It has been widely recommended that the percentage of sodium (equivalents per million of sodium divided by total equivalents per million of sodium, potassium, calcium, and magnesium) should not exceed 50 or 60 percent. In 1954, the staff of the U.S. Salinity Laboratory proposed that the sodium hazard of irrigation water could best be expressed in terms of the sodium-adsorption ratio, or SAR. This ratio expresses the relative activity of sodium ions in exchange reactions with soil. The effect of sodium in irrigation water is discussed in detail in U.S. Department of Agriculture Handbook 60 (U.S. Salinity Laboratory Staff, 1954), which was used as a guide for the following discussion of the relation of sodium to irrigation water.

Deterioration of soil that was originally nonsaline and nonalkaline may result if an excess of soluble salts or exchangeable sodium is allowed to accumulate as a result of inadequate leaching and drainage of the soil. If the amount of water applied to the soil is not more than is needed by plants, water will not percolate downward below the root zone, and mineral matter will accumulate. Likewise, impermeable soil zones near the surface can retard the downward movement of water and cause waterlogging of the soil and deposition of salts.

Analyses of water samples from 10 irrigation wells deriving water from the principal aquifers in Decatur County were used to illustrate the suitability of ground water for irrigation (table 5).

Sodium-adsorption ratios and electrical conductivities are plotted on figure 8 to provide a classification of waters for irrigation use. Low-sodium water (S1) can be used for irrigation on most soils with little danger of development of harmful levels of exchangeable sodium. Medium-sodium water (S2) may be used safely on coarse-textured or organic soils having good permeability, but S2 water will present an ap-

TABLE 3.—Chemical analyses of water from selected wells.[1]
[Dissolved constituents and hardness in parts per million.]

Well number	Depth, in feet	Geologic source	Date of collection	Temperature (°F)	Dissolved solids (evaporated at 180°C)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate[2] (NO_3)	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)
1-26W-14bcc	32	Alluvium	5-13-63	57	626	21	0.07	......	130	30	44	390	188	18	0.6	2.2	448	128	....
1-27W-33dba	34	do	5-14-53	56	428	19	.78	......	101	21	28	393	44	20	.4	1.8	338	16	....
1-28W-27bba	165	Ogallala Formation	5-14-53	56	280	24	1.2	......	43	19	29	239	21	12	.9	13	186	0	....
1-29W- 1bbc	28	Alluvium	5-12-53	56	1,147	33	.09	......	172	48	169	617	282	133	.6	5.8	626	120	....
10cdb	22	do	5-12-63	55	440	28	.89	......	100	14	35	332	50	31	.3	19	307	35	....
19ccd	40	do	8-15-62	....	648	35	.51	0.62	109	33	80	551	97	21	.9	.8	408	0	1,080
30bdd1	75	do	9-14-62	55	571	43	.03	.00	107	27	60	415	82	29	.6	18	378	35	890
1-30W-20ddd	112	Ogallala Formation	5-13-53	56	293	34	.71	......	53	17	25	268	13	12	.8	5.8	202	0	....
31dad	43	Crete Formation	8-15-62	58	557	31	.21	.35	85	25	83	446	89	23	1.1	.4	315	0	930
2-26W-11cda	125	Ogallala Formation	5-13-63	55	307	28	.06	......	84	10	10	295	7.4	9.0	.1	13	250	8	....
2-27W- 4cbb	92	do	5-14-63	56	283	22	.11	......	57	18	20	268	18	10	.5	5.8	216	0	....
2-28W-12cdd	53	Alluvium	5-14-63	55	392	30	.66	......	71	21	44	378	21	18	.5	.9	264	0	....
28bcd	61	do	8-15-62	....	547	37	.45	.44	101	25	59	407	96	24	.6	4.0	355	21	900
2-30W-13ddd	169	Ogallala Formation	5-13-63	58	306	32	.49	......	48	19	31	254	25	14	.7	11	198	0	....
3-26W-30bcc	142	do	5-13-53	55	269	25	.16	......	64	11	16	254	10	10	.3	7.5	204	0	....
3-28W-32bcb	205	do	8-16-62	....	283	49	.03	.00	43	17	29	239	12	10	.9	4.3	178	0	460
3-29W-18cbd	57	Alluvium	8-15-62	58	626	37	.01	.41	110	35	63	427	113	47	.8	10	418	68	1,040
21bad1	62	do	9-18-62	55	712	33	.02	.51	131	34	73	432	178	42	.6	7.5	466	112	1,090
31dda	49	do	9- 2-64	56	612	33	.00	.00	118	21	74	449	95	37	.7	12	381	13	970
3-30W- 3cba	129	Ogallala Formation	8-15-62	59	296	50	.16	.04	45	17	29	246	17	10	.8	6.2	182	0	480
27bdc	50	Alluvium	5-12-53	56	520	22	.57	......	103	28	44	378	99	36	.8	1.2	372	62	....
4-26W-11abd	50	do	5-14-53	56	391	28	2.2	......	84	19	32	366	28	19	.4	1.0	288	0	....
17ccd	70	do	8-13-62	....	398	37	.70	.18	90	19	27	354	33	17	.5	.4	302	12	670

TABLE 3.—Chemical analyses of water from selected wells (*Concluded*).

Well number	Depth, in feet	Geologic source	Date of collection	Temperature (°F)	Dissolved solids (evaporated at 180°C)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate[2] (NO_3)	Hardness as $CaCO_3$ Total	Hardness as $CaCO_3$ Noncarbonate	Specific conductance (micromhos at 25°C)
21ccc	155	Ogallala Formation	5-13-53	59	274	28	.49	......	62	13	17	268	5.3	10	.3	6.6	208	0	....
4-27W-17dac	165	do	8-13-62	....	282	47	.01	.00	54	15	22	251	6.6	9.0	.6	4.9	196	0	470
4-29W- 3dbb	132	do	5-15-53	58	250	35	.60	......	40	16	23	229	8.2	10	.9	3.6	166	0	....
5-26W-20ddd	110	do	5-15-53	58	250	27	.26	......	54	14	14	239	8.2	10	.5	4.2	192	0	....
32dbc	......	Alluvium	8-14-62	....	356	44	.35	.00	69	20	27	300	23	12	.7	13	254	8	590
34cad	55	do	5-15-53	57	441	19	1.9	......	101	25	25	381	57	25	.5	.8	355	43	....
5-28W- 3dbb	56	do	8-16-62	....	457	43	.01	.14	90	24	40	386	52	16	.6	1.8	323	7	750
5dcd1	58	do	9-11-62	56	393	42	.04	.00	90	17	27	334	25	22	.3	5.8	294	20	640
5-29W-10bab	36	Ogallala Formation	9-19-62	56	385	36	.15	.00	94	16	24	356	23	9.0	.6	7.1	300	8	620
16bca	80	do	9-18-62	56	299	41	.21	.00	59	16	18	249	14	9.0	.3	19	213	9	470
20cdc	110	do	9-19-62	56	277	49	.37	.00	50	16	18	232	10	10	.8	9.3	191	1	430
28bdd	48	Alluvium	8-14-62	....	403	45	.01	.06	74	21	37	337	38	13	.9	8.4	271	0	670
5-30W-34abb	62	Ogallala Formation	5-12-53	57	278	29	.27	......	55	18	16	249	16	12	1.0	8.0	211	7	....
35bcc	200	do	8-14-62	....	281	43	.01	.06	58	15	15	251	7.4	10	.5	8.0	206	0	480

[1] Samples analyzed by H. A. Stoltenberg, Kansas State Department of Health.
[2] In areas where the nitrate content of water is known to exceed 45 ppm, the public should be warned of the potential dangers of using the water for infant feeding (U.S. Public Health Service, 1962, p. 7).

TABLE 4.—Quality of water in relation to use.

Principal constituents	Characteristics	Acceptable maximum concentration, in parts per million[1]	Range in concentration, in parts per million
Dissolved solids	Water high in dissolved solids may have a disagreeable taste or a laxative effect. When water is evaporated, the residue consists mainly of the minerals listed in table 3.	500	250-1,147
Hardness	Hardness is caused by calcium and magnesium. Forms scale in vessels used in heating or evaporative processes. Hardness is commonly noticed by its effect when soap is used with the water. Carbonate hardness can be removed by boiling, noncarbonate hardness cannot.	......	166-626
Iron (Fe)	Stains cooking utensils, plumbing fixtures, and laundry. Water may have a disagreeable taste.	0.3	0-2.2
Fluoride (F)	Fluoride concentration of about 1 ppm in drinking water used by children during the period of calcification of teeth prevents or lessens the incidence of tooth decay; 1.5 ppm may cause mottling of the tooth enamel (Dean, 1936). Bone changes may occur with concentrations of 8-20 ppm.	1.2	0.1-1.1
Nitrate (NO_3)	Nitrate concentration of 90 ppm may cause cyanosis in infants (Metzler and Stoltenberg, 1950). Comly (1945) states that concentrations of 45 ppm may be harmful to infants. Adverse effects from drinking high-nitrate water are also possible in older children and adults.	45	0.4-19
Sulfate (SO_4)	Derived from solution of gypsum and oxidation of iron sulfides (pyrite, etc.). Concentrations of magnesium sulfate (Epsom salt) and sodium sulfate (Glauber's salt) may have a laxative effect on some persons.	250	5.3-282
Chloride (Cl)	Chloride in ground water may be derived from connate marine water in sediments, surface contamination, or solution of minerals containing chlorides.	250	9-133

[1] Concentrations as recommended by the U.S. Public Health Service (1962).

TABLE 5.—Suitability for irrigation of ground water from selected wells.

Well number	Sample number on figure 8	Na (equivalents per million)	Ca + Mg (equivalents per million)	SAR	Conductivity (micromhos per centimeter at 25°C)
1-29W-19ccd	1	2.91	8.15	1.45	1,080
1-30W-31dad	2	2.96	6.30	1.65	930
2-28W-28bcd	3	1.83	7.10	1.00	900
3-28W-32bcb	4	.87	3.55	.65	460
3-29W-21bad1	5	2.39	9.33	1.15	1,090
3-29W-31dda	6	2.44	7.62	1.30	970
4-26W-17ccd	7	.74	6.05	.43	670
5-28W-3dbb	8	1.30	6.46	.70	750
5-29W-28bdd	9	1.17	5.42	.65	670
5-30W-35bcc	10	.39	4.12	.27	480

preciable sodium hazard in certain fine-textured soils, especially under poor-leaching conditions. With increasing sodium hazard, harmful levels of exchangeable sodium will result in most soils unless special soil management is practiced, such as good drainage, leaching, and additions of organic matter.

Low-salinity water (C1) can be used for irrigation on most soils with little likelihood that soil salinity will develop. Medium-salinity water (C2) can be used if a moderate amount of leaching occurs. With increasing salinity, less exchangeable sodium can be tolerated and more leaching will be required to prevent salinity damage. On figure 8, all the waters were classified as low-sodium water (S1) and either medium-salinity water (C2) or high-salinity water (C3).

RECORDS OF WELLS AND TEST HOLES

Information pertaining to wells and test holes is given in table 6. The wells and test holes are listed in order by townships from north to south, and by ranges from east to west. Within a township, they are listed in order of the section numbers. The well-numbering system is illustrated on figure 2. Measured depths of wells and depths to water level are given in feet and tenths. Reported depths of wells and depths to water level are given to the nearest foot.

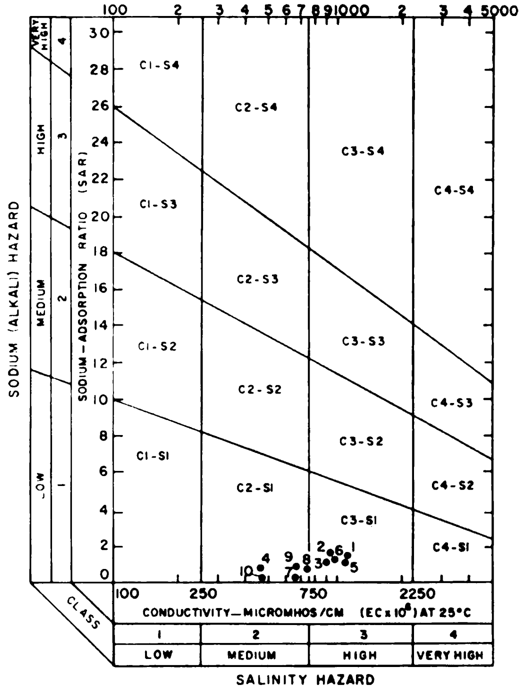


FIGURE 8.—Classification of water used for irrigation (method of the U.S. Salinity Laboratory Staff, 1954). Number by circle refers to table 5.

TABLE 6.—Records of wells and test holes.

Well number[1]	Owner or user	Depth of well, in feet[2]	Diameter of well, in inches	Type of casing[3]	Principal water-bearing geologic unit	Method of lift,[4] type of power[5]	Use[6]	Depth to water level below land surface, in feet[2]	Date of measurement	Altitude of land surface above mean sea level, in feet	Yield, in gallons per minute[2]
1-26W- 1ddd	Elton Ohare	95	5	G	Ogallala Formation	Cy, W	D, S	62.5	8-62	2,423	
2bbb	J. E. Helm		4	I	do	Cy, W	S	139	1-53	2,525	
5aaa	State Geol. Survey	220	4	N	do	N	T		10-62	2,559	
5dcc	Gerald Brown	93	6	G	do	Cy, H	N	89.2	8-62	2,489	
10ddd	Edward Lockhart	35	4	I	Alluvium	Cy, W	S	27.9	8-62	2,384	
12bab	Virgil Price	135	6	G	Ogallala Formation	Cy, E	D, S	116	8-62	2,478	
14bcc*	E. E. Lawson	32	5	G	Alluvium	Cy, E	D, S	27.4	5-53	2,372	
14ccc	A. L. Chambers		5	G	Crete Formation	Cy, G	S	48.2	1-53	2,404	
14dad	C. C. Huff	50	6	G	Alluvium	Cy, W	S	25.8	8-62	2,366	
17aaa	State Geol. Survey	47	4	N	do	N	T	10.0	10-62	2,381	
17caa	Lewis Bless	50	18	S	do	T, LPG	I	32.8	8-62	2,406	200 R
17dbb	Lewis Bless	50 R	18	S	do	T, T	I	18 R	8-62		150 R
18ddb	Wyatt Wiggins	59	5	G	do	Cy, W	S, O	29.0	10-62	2,413	
26ddc	Glen Alexander	140	4	S	Ogallala Formation	Cy, W	D, S	131	8-62	2,534	
29aaa	State Geol. Survey	91	4	N	do	N	T		10-62	2,514	
29bbb	L. L. Chambers	120	6	G	do	Cy, W	N	118	7-62	2,538	
1-27W- 3bab	P. H. Kilzer	217	5	S	do	Cy, W	S	184	7-62	2,630	
4ddc	E. Weatherwax	134	4	G	do	Cy, W	S	127	7-62	2,579	
6abd	Fred Osburn	155	5	G	do	N	N	147	9-62	2,614	
9bbb	W. E. Van Vleet	140	6	G	do	Cy, W	S	129	9-62	2,589	
13ccc	L. L. Huff	40	5	G	Alluvium	J, E	D	33.1	8-62	2,439	
14abb	J. McQuillan		5	G	Ogallala Formation	Cy, W	S	24.7	8-62	2,445	
17ddd	V. C. Cathcart		5	G	do	Cy, W	S	69.7	1-53	2,531	
19dad	Melvin M. Miller	108	5	G	do	Cy, W	D, S	96.0	7-62	2,571	
22dcd	Tom Townsend	62.5	18	S	Alluvium	T, LPG	I	24.6	8-62	2,437	340 R
23add	J. McQuillan	47	4	G	do	N	N	35.6	7-62	2,438	
24cbb	School District	48	5	G	Crete Formation	Cy, W	D	40.9	7-62	2,443	
25ccc	Sarah Wooley	125	4	G	Ogallala Formation	N	N	120	8-62	2,551	
26bad	Ella MacFee	64	16	S	Alluvium	T, LPG	I	21.8	8-62	2,429	1,200
29ccc	J. A. Coulter	115	5	G	Ogallala Formation	Cy, W	S	104	7-62	2,576	
33dba*	Elmer Metcalf	34	5	G	Alluvium	Cy, W	D	25.0	7-62	2,454	
33dcb	Elmer Metcalf	52	18	S	do	T, LPG	I	18.7	8-62	2,450	
34bab	Dorothy M. Corcoran	86	18	S	do	T, LPG	I	24.8	8-62	2,444	1,200
34cbb	Elmer Metcalf	36.0	5	G	do	Cy, W	S	28.7	8-62	2,458	
1-28W- 1bbc	L. C. Heston	148	6	G	Ogallala Formation	Cy, W	S	139	9-62	2,615	
4bca	C. Wishon	38	6	G	do	Cy, W	S	32.5	9-62	2,539	
11ddc	M. C. Johnson	175	5	G	do	Cy, W	S	169	9-62	2,678	
16ddc	Matt Wurm	155	6	G	do	Cy, W	S	145	9-62	2,686	
17aaa	W. S. Lafferty	77	5	G	do	Cy, W	S	69.6	7-63	2,608	
24cbc	M. C. Johnson	60	6	G	do	Cy, W	S	54.1	8-62	2,557	
27bba*	Ross Van Pelt	165 R	5	G	do	Cy, W	D	142	5-53	2,674	

TABLE 6.—Records of wells and test holes *(Continued)*.

Well number[1]	Owner or user	Depth of well, in feet[2]	Diameter of well, in inches	Type of casing[3]	Principal water-bearing geologic unit	Method of lift,[4] type of power[5]	Use[6]	Depth to water level below land surface, in feet[2]	Date of measurement	Altitude of land surface above mean sea level, in feet	Yield, in gallons per minute[2]
27ddd	J. W. Farr	145	6	G	do	Cy, W	S	128	8-62	2,638	
29bbb	W. R. Ridgway	157	5	G	do	Cy, W	S	143	7-62	2,704	
31dad	Edward Watkins	138	6	G	do	Cy, E, W	D, S	133	8-62	2,692	
34bcc	Myrtle Cochran	117	6	G	do	Cy, W	S	108	9-62	2,632	
1-29W- 1bbc*	D. Moore	28	5	G	Alluvium	Cy, W	D	16.0	5-53	2,519	
1bbd	D. Moore	58	16	S	Crete Formation	T, D	I	26.0	8-62	2,528	750 R
2dbb	W. R. Redhern	37.4	6	G	Alluvium	Cy, W	S	30.9	12-52	2,540	
3add	Cecil Vernon	60 R	18	S	Crete Formation	T, NG	I	36.6	9-62	2,554	500
3dad	Marion Mockry	54	18	S	Alluvium	T, NG	I	25.0	9-62	2,541	700
3ddd	Marion Mockry	44	18	S	do	T, NG	I	13.4	9-62	2,530	500 R
6ddd	Milton Witt	120	5	G	Ogallala Formation	Cy, W	D, S	114	7-62	2,690	
10bdd	Charles Larue		18	G	Alluvium	T, NG	I			2,544	
10cca	D. Tilton	19	5	G	do	N	N	11.9	12-52	2,542	
10cdb*	G. M. Tuttle	22.0	5	G	do	Cy, W	S	13.9	8-62	2,545	
13cdd	E. R. Pollnow	136	5	G	Ogallala Formation	Cy, W	S	125	8-62	2,692	
15aba	O. M. Relph	133	5	G	do	Cy, W	N	127	12-52	2,671	
16aac	Hal Demay	42 R	18	G	Alluvium	T, E	I	4.5	8-62	2,544	400 R
19bcc	B. E. McCartney	80 R	18	G	Crete Formation	N	I			2,615	225
19bdd	Byron McCartney	54 R	18	G	Alluvium	T, NG	I, O	8.9	8-62	2,573	500 R
19cac	Carl Schreiber	54 R	18	S	do	T, NG	I	6.8	8-62	2,571	1,200 R
19ccd*	George Leitner	40	18	S	do	T, NG	I	6.3	8-62	2,571	800 R
19dbc	Eugene Lohoefener	57 R	18	G	do	T, G	I	9.0	8-62	2,570	1,000
20cba	C. J. G. Fritz	21	5	G	Crete Formation	Cy, W	S	13.8	11-52	2,572	
26cdd	C. H. Diederich	170	5	G	Ogallala Formation	Cy, W	S	156	5-56	2,745	
30bbb	State Geol. Survey	38	4	N	Alluvium	N	T		10-52	2,575	
30bdd1*	Lawrence Wolf	75 R	20	S	do	T, LPG	I	26.0	9-62	2,594	1,235
1-30W- 1bcc	A. R. Rothmeyer	175 R	5	G	Ogallala Formation	Cy, W	D, S	166	5-56	2,774	
5cdd	G. O. Lippelman	230 R	5	G	do	Cy, W	S	195	8-62	2,870	
6ddd	State Geol. Survey	245	4	N	do	N	T		10-62	2,860	
9ddd	T. Wammack	50 R	5	G	do	Cy, W	S	43.3	5-56	2,682	
11aaa	D. Hodson	225	4	G	do	N	N	203	5-56	2,802	
12baa	Mike Crocker	163	5	G	do	Cy, W	D, S	152	8-62	2,744	
16ddd	Carl Schreiber	135 R	6	G	do	Cy, W	S	110	5-56	2,737	
17acb	L. Steiner	175	5	G	do	Cy, W	S	156	5-56	2,815	
20ddd*	J. M. Wurm	112 R	5	G	do	Cy, W	D, S	104	5-53	2,739	
24add	C. E. Hendrix	62	5	G	Crete Formation	Cy, W	S	41.0	8-62	2,614	
24ccc	G. Leitner	24.6	5	G	do	Cy, W	S	23.1	11-52	2,604	
24dad	State Geol. Survey	39	4	N	do	N	T		10-62	2,578	
25ada	State Geol. Survey	39	4	N	Alluvium	N	T	12.0	10-62	2,580	
25dad	State Geol. Survey	64	4	N	do	N	T		10-62	2,583	
25dda	State Geol. Survey	53	4	N	do	N	T	11.0	10-62	2,583	

26cdc	Ed Helmkamp	50 R	18	G	do	T, LPG	I	3.9	8-62	2,592	
30aaa	State Geol. Survey	80	4	N	Ogallala Formation	N	T		10-62	2,747	
31aaa	G. Lippelman	65	4	G	do	Cy, W	S	55.4	9-62	2,685	
31dad*	Harold Demmer	43 R	18	G	Crete Formation	T, LPG	I	6.8	8-62	2,623	650 R
32cbb	State Geol. Survey	52	4	N	do	N	T		10-62	2,630	
34ddd	Russell Anderson	60	18	S	Alluvium	T, NG	I	20.6	8-62	2,610	
35bbc	R. Anderson	25 R	6	G	do	Cy, W	D	10.2	8-62	2,598	
35cdd	Russell Anderson	70.5	18	S	do	T, NG	I	26.2	8-62	2,617	
36abb	M. Anderson	105	6	G	Ogallala Formation	Cy, W	S	30.3	8-62	2,610	
2-26W- 1dad	Don Alexander	60	5	G	do	Cy, E	S	50.6	8-62	2,458	
3add	Joe Eckhart		5	G	do	Cy, W	S	127	8-62	2,549	
4dcc	W. O. Shirley	105	6	G	do	Cy, W	S	90.6	8-62	2,524	
6add	Verl Crabill	177	5	G	do	Cy, W	D, S	160	7-62	2,606	
8aaa	State Geol. Survey	180	4	N	do	N	T		10-62	2,594	
11cda*	B. H. Rist	125 R	5	G	do	Cy, W	D	81.4	7-62	2,507	
17bcc	Charles Hessenflow	175	5	G	do	Cy, W	S	173	8-62	2,627	
19ddd	Charles Hessenflow	182	6	G	do	Cy, W	D, S	177	8-62	2,636	
22add	C. F. Gallentine	79	5	G	do	Cy, W	S	74.9	8-62	2,512	
24ccc	Otto Smolinski	190 R	6	G	do	Cy, W	D, S	157	8-62	2,590	
31cbc	State Geol. Survey	228	4	N	do	N	T		10-52	2,630	
31ddd	C. E. Brunk	188	4	G	do	Cy, W	S	178	8-62	2,639	
36bac1	City of Norcatur	297 R			do	T, E	PS	210 R	10-62		
36bac2	City of Norcatur	240 R			do	Ce, D	PS	210 R	10-62		
36bac3	City of Norcatur	240 R			do	T, E	PS	210 R	10-62		
2-27W- 4cbb*	E. Bogart	92 R	5	G	do	Cy, W	D	68.0	7-62	2,513	
5bdc	Doug Macfee	63	16	S	Alluvium	T, E	I	30.2	8-62	2,472	350 R
7dab	A. Uehlin	40	5	G	do	Cy, W	D, S	32.0	7-62	2,489	
8bcc	Carroll Miller		4	G	do	Cy, W	D, S	29.2	7-62	2,487	
11aaa	L. E. Snyder	178 R	4	G	Ogallala Formation	Cy, W	D, S	168	8-62	2,627	
14add	W. E. Long	195	5	G	do	Cy, W	D, S	187	8-62	2,660	
16aaa	L. Chambers	50	6	G	do	Cy, W	S	42.0	8-62	2,517	
24ccc	Leonard Woods	225 R	4	G	do	N	N	223	1-53	2,697	
28add	R. A. Mermis	150	5	G	do	N	N	143	8-62	2,644	
30dda	F. N. Harmon	119	4	G	do	Cy, W	S	109	12-52	2,642	
36ddd	Lydia Johnson	187	3	S	do	Cy, W	S	182	8-62	2,648	
2-28W- 6dda	V. I. Steiner	88	5	G	do	N	N	60.1	12-52	2,613	
7ccc	W. Torluemke	115	5	G	do	N	N	103	7-62	2,670	
9ccd	W. W. Sauvage	85	4	G	do	N	N	80.7	8-62	2,600	
12ccc	A. L. Miller	63	18	I	Alluvium	T, T	I	27.6	8-62	2,490	600 R
12cdd*	A. L. Miller	53 R	5	G	do	Cy, W	D	32.5	8-62	2,491	
13aba	Stuart Euhus	60 R	18	S	do	T, LPG	I	27.7	8-62	2,487	700 R
14abc	Robert Barratt	64 R	18	G	do	T, LPG	I	21 R	8-62	2,497	600 R
15ddc	H. A. Barratt		4	G	do	Cy, H	D	27.8	12-52	2,505	
21add	State Geol. Survey	40	4	N	do	N	T	10.8	10-52	2,499	
21dac	Carl Frickey	56 R	18	S	do	T, LPG	I			2,504	800 R
22acc	Allen Richards	70 R	18	S	do	T, LPG	I	25.4	8-62	2,511	1,000 R

TABLE 6.—Records of wells and test holes (*Continued*).

Well number[1]	Owner or user	Depth of well, in feet[2]	Diameter of well, in inches	Type of casing[3]	Principal water-bearing geologic unit	Method of lift,[4] type of power[5]	Use[6]	Depth to water level below land surface, in feet[2]	Date of measurement	Altitude of land surface above mean sea level, in feet	Yield, in gallons per minute[2]
22bcb	E. L. Richards	57 R	18	S	do	T, LPG	I	24.5	8-62	2,512	650 R
24ccc	W. W. Sauvage	120	5	G	Ogallala Formation	Cy, W	S	97.1	7-62	2,620	
28bbd	H. F. Euhus	57 R	18	S	Alluvium	T, LPG	I	13 R	8-62	2,511	1,000 R
28bcd•	H. F. Euhus	61 R	18	S	do	T, LPG	I	27 R	8-62	2,525	550 R
28cac	Chris G. Jorn	70	18	S	do	T, LPG	I	29.1	8-62	2,528	1,000 R
29ccd	Carl Frickey	69	18	S	do	T, LPG	I	18.0	8-62	2,544	1,000 R
30ccc	H. O. Lohoefener	34.7	4	G	do	Cy, W	S	19.2	8-62	2,566	
31abc	Harold Lohoefener	67 R	18	G	do	T, NG	I	19.9	8-62	2,551	1,000
31acb	Harold Lohoefener	68 R	18	G	do	T, NG	I			2,553	650 R
31dbb	E. Norton	72 R	24	I	do	T, G	I		10-52	2,552	1,100 R
32aab	Paul Harman				do	N	I			2,532	
32ddc	Oberlin Country Club	59.0	5	G	Crete Formation	Cy, W	D	52.4	7-62	2,576	
33abb	R. A. Deines	58	24	G	Alluvium	T, LPG	I	16.1	8-62	2,514	1,300
33bac	Fred Rehm	65 R	18	S	do	T, LPG	I	27.7	8-62	2,527	1,500
36ccc	June Owen	141	6	G	Ogallala Formation	Cy, W	D, S	138	7-62	2,690	
2-29W- 3bba	D. G. Campbell	205	5	G	do	Cy, W	S	195	8-62	2,800	
4caa	H. Votopka	138	4	G	do	Cy, W	S	137	12-52	2,757	
5cdd	H. Pollnow	163	5	G	do	Cy, W	S	151	8-62	2,790	
11aaa	A. E. Burg	162	6	G	do	Cy, W	D, S	153	7-62	2,741	
13ccc	E. M. Cochran	127	6	G	do	N	N	126	12-52	2,712	
16bba	Paul Scott	54	5	G	do	Cy, W	S	42.0	8-62	2,684	
17cdd	School District	85	6	G	do	Cy, H	N	69.8	9-62	2,731	
22cbc	J. B. Scott	48	4	G	do	Cy, W	N	40.3	12-52	2,670	
24bcc	Everett Smith	124	5	G	do	Cy, W	D, O	97.4	7-62	2,682	
25ccc	Guy Votopka	95	5	G	do	Cy, W	S	86.8	8-62	2,661	
29daa	P. A. Nitsch	113	5	G	do	Cy, W	S	108	8-62	2,759	
34ddd	John Nitsch	82	5	G	do	Cy, W	N	68.7	7-62	2,668	
2-30W- 1dad	Ward Waldo	153	5	G	do	Cy, W	S	138	9-62	2,770	
2bbd	A. M. Weber	79 R	18	S	Alluvium	T, NG	I	25 R	8-62	2,625	1,450
2bcb	A. M. Weber	45 R	6	G	do	Cy, W	S	21.8	8-62	2,623	
2dbb	A. H. Kiger	30	6	G	Ogallala Formation	N	N	27.3	7-62	2,644	
4daa	F. R. Humes	91	30	G	do	T, NG	I	41.4	8-62	2,652	700 R
5bab	Harold Demmer	45 R	18	G	Alluvium	T, G	I	4.9	8-62	2,620	660 R
5bbc	State Geol. Survey	40	4	N	do	N	T		10-62	2,625	
5bcc	Floyd Harshman	25	4	G	Crete Formation	Cy, W	D, S	18.7	12-52	2,640	
6cbb	Matt Demmer	23	5	G	do	Cy, H	N	21.8	12-52	2,652	
6ddd	State Geol. Survey	70	4	N	Ogallala Formation	N	T		10-62	2,713	
10ddc	Paul Hofbauer	178	5	G	do	Cy, W	D, S	149	7-62	2,824	
13ddd•	Elwood Mines	169	5	G	do	Cy, W	S	126	8-62	2,808	
17bcb	W. E. Wurm	158	5	G	do	Cy, W	S	153	11-52	2,832	
18acc	Ralph Wolfram	50 R	18	S	do	T, LPG	I	28.3	9-62	2,714	240 R

20bcc	J. Wolfram	40	5	G	do	Cy, W	S	33.5	9-62	2,748	
20cba	A. Leitner	36	6	G	do	N	N	32.6	9-62	2,751	
22acb	Ward Waldo	156	5	G	do	Cy, W	S	133	9-62	2,841	
24add	Clara Friedemann	110	5	G	do	Cy, W	S	97.2	5-56	2,781	
27ccb	G. Wondelin	170	6	G	do	Cy, W	S	155	9-62	2,878	
27dda	Albert Hoffman	138	6	G	do	Cy, W	N	127	11-52	2,839	
32cba	Henry May	155	5	G	do	Cy, W	D, S	151	11-52	2,890	
35bcc	Henry May	127	4	G	do	Cy, W	D	112	11-52	2,820	
36aaa	N. Rogers	105	6	G	do	Cy, W	S	93.4	7-62	2,776	
2-31W-13daa	P. Wolfram	58	4	G	do	Cy, W	S	45.4	9-62	2,737	
3-26W- 1bab	Roscoe McCallister	175	6	G	do	Cy, W	D, S	166	8-62	2,600	
4aab	Frank Brunk	165	5	S	do	Cy, W	D, S	160	8-62	2,609	
5ccb	John Hicks	147	5	G	do	N	O	142	8-62	2,604	
9ddd	Jesse Gallentine	105	5	S	do	Cy, W	S	97.0	7-62	2,549	
13aab	Norman Gallentine	103	6	G	do	Cy, E	S	83.9	8-62	2,514	
18aab	Dewey Pelkey	168	6	G	do	Cy, W	S	157	8-62	2,624	
21ddc	George C. Warrick	140	6	G	do	Cy, W	D	129	8-62	2,587	
25bcc	John Gallentine	60	5	G	Alluvium	Cy, E	S	25.6	8-62	2,433	
30bcc*	A. W. Heilman	142	5	G	Ogallala Formation	Cy, W	D	121	8-62	2,611	
32aaa	State Geol. Survey	155	4	N	do	N	T		10-62	2,583	
33bba	C. F. Miller	109	6	G	do	Cy, W	N	104	11-52	2,565	
3-27W- 4aba	Howard Mockry	197	6	G	do	Cy, W	D, S	182	8-62	2,700	
5ccc	Walter Panter	148	5	G	do	Cy, W	S	135	7-62	2,683	
12ddc	F. Wentz	197	4	G	do	Cy, W	S	194	11-52	2,670	
14abb	E. L. Bailey	170	5	G	do	Cy, W	S	166	8-62	2,654	
20bbb	F. M. Schroeder	135	5	G	do	N	N	128	8-62	2,688	
25cbb	H. J. Rohan	93	6	G	do	N	N	75.4	9-62	2,578	
26ccc	F. R. Cilek	65	5	G	do	Cy, W	S	55.8	9-62	2,573	
32aba	Otto Johnson	93	5	G	do	Cy, W	S	76.1	8-62	2,637	
3-28W- 2ccd	H. M. Greenslit	153	5	G	do	Cy, W	S	133	8-62	2,701	
4aaa	State Geol. Survey	56	4	N	do	N	T	38.8	10-52	2,582	
6bdd	G. J. Kolsky	75	18	S	Alluvium	T, NG	I	27.5	8-62	2,545	1,100 R
6ccc1	Sam Steinmetz	55	18	S	do	T, NG	I	15.6	8-62	2,546	1,100 R
6ccc2	State Geol. Survey	55	4	N	do	N	T	15.8	9-62	2,546	
6cdc	M. J. Gardner	58 R	18	S	do	T, G	I			2,551	200 R
6dca	J. D. Paddock	55 R	18	S	Crete Formation	T, NG	I	34.6	8-62	2,571	850 R
10bbb	G. H. Scott	145	6	S	Ogallala Formation	Cy, G	S	135	8-62	2,708	
13ccc	Edward Fiala	148	6	G	do	Cy, W	S	140	8-62	2,720	
15ddd	W. C. Roa	148	6	G	do	Cy, W	S	145	11-52	2,732	
17dba	J. Ruzicka	62	4	G	do	Cy, W	S	52.2	8-62	2,644	
28ccb	C. R. Vavroch	138	5	G	do	Cy, W	S	135	8-62	2,743	
32bcb*	C. A. Vernon	205 R	18	S	do	T, LPG	I, O	133	8-62	2,749	550 R
36cdb	W. Jennings	102	5	G	do	Cy, W	S	89.9	8-62	2,676	
3-29W- 1cbd	City of Oberlin	68 R	18	S	Alluvium	T, E	PS	32 R	10-62		
1dab	L. L. Williams	65 R			do	T, NG	I	38.8	8-62	2,557	

TABLE 6.—Records of wells and test holes (*Continued*).

Well number[1]	Owner or user	Depth of well, in feet[2]	Diameter of well, in inches	Type of casing[3]	Principal water-bearing geologic unit	Method of lift,[4] type of power[5]	Use[6]	Depth to water level below land surface, in feet[2]	Date of measurement	Altitude of land surface above mean sea level, in feet	Yield, in gallons per minute[2]
1dba1	City of Oberlin	70 R	18	S	do	T, E	PS	35 R	10-62		
1dba2	City of Oberlin	72 R	18	S	do	T, E	PS	35 R	10-62		
1dbb1	City of Oberlin	70 R	18	S	do	T, E	PS	35 R	10-62		
1dbb2	City of Oberlin	68 R	18	S	do	T, E	PS	35 R	10-62		
1dbd	City of Oberlin	74 R	18	S	do	T, E	PS	35 R	10-62		
1ddc	Shirley Cochran	71	18	G	do	T, NG	I	27.5	8-62	2,557	700
4bba	Myron Pollnow	95.0	6	G	Ogallala Formation	Cy, W	S, O	79.8	7-62	2,718	
8daa	R. Simpson	57.0	6	G	do	Cy, W	S	40.5	7-62	2,630	
11aaa	W. W. Sauvage		5	G	Alluvium	Cy, W	S	35.6	8-62	2,561	
11ada	W. W. Sauvage	64 R	18	S	do	T, G	I			2,566	850
11bba	E. Barker	55	5	G	Ogallala Formation	Cy, W	S	49.7	8-62	2,598	
12bab	Warren White	60 R	18	S	Alluvium	T, NG	I, O	26.1	8-62	2,556	1,100
14cbb	L. W. Morford	15.0	5	G	do	Cy, W	S	9.5	7-62	2,557	
17dcb	Gaylord Bryan	51 R	36	G	do	T, LPG	I, O	19.9	8-62	2,587	500 R
18cbc	Wayne Larson	58 R	18	G	do	T, LPG	I	20 R	8-62	2,618	450 R
18cbd*	Wayne Larson	57	18	G	do	T, LPG	I	20.0	8-62	2,613	400 R
21bad1*	J. W. Barratt	62	18	S	do	T, LPG	I	21.8	8-62	2,578	1,260
22bcb	H. D. Counter	42	5	G	do	Cy, W	S	33.0	7-62	2,593	
25ddd	Elmer H. Wilcox	145	5	G	Ogallala Formation	Cy, W	S	130	8-62	2,751	
28cbb	V. E. Larrick	23.5	5	G	Alluvium	N	N	21.8	12-52	2,608	
31dcc	Aard Erickson	40 R	18	S	do	T, LPG	I	20.2	8-62	2,633	460
31dda*	Aard Erickson	49	18	S	do	T, E	I	22.3	8-62	2,630	160
32cbb	C. V. Carlson	30.3	5	G	do	N	N	28.2	8-62	2,631	
34bba	D. Muller	134	5	G	Ogallala Formation	Cy, W	S	121	12-52	2,733	
3-30W- 1ccc	H. A. Olson	59	5	G	do	Cy, W	S	56.1	11-52	2,726	
3cba*	Henry Euhus	129 R	42	N	do	T, T	I	100 R	8-62	2,807	300 R
6bbb	State Geol. Survey	280	4	N	do	N	T		6-52	2,933	
6cca	R. May	152	5	G	do	Cy, W	D, S	149	8-62	2,901	
8daa	Rudolph Paschke	120	5	G	do	Cy, W	D, S	106	5-56	2,830	
10aaa	Henry Euhus	53	5	G	do	Cy, W	S	45.5	8-62	2,740	
14dac	Oscar Walinder	41	5	G	do	Cy, W	D	37.1	8-62	2,672	
16bab	A. Unger	100	5	G	do	Cy, W	D	95.7	12-52	2,808	
20bca	S. M. Marvin	50 R	5	G	do	Cy, G	S	21.5	8-62	2,735	
23add	State Geol. Survey	40	4	N	Alluvium	N	T		10-52	2,625	
23dba	Simon Johnson	30	6	G	do	Cy, W	D	19.5	8-62	2,633	
25bbc	R. D. Tongish	72	6	G	Ogallala Formation	Cy, W	S	61.1	8-62	2,677	
26bbb	Arlo Wurm	51 R	24	G	Alluvium	T, LPG	I, O	7.0	8-62	2,629	450 R
27bac	G. L. Shields	42 R	24	G	do	T, LPG	I	9.2	8-62	2,641	400 R
27bdc*	Leonard Brown	50	12	S	do	N	N	23.0	8-62	2,657	
30ccc	State Geol. Survey	138	4	N	Ogallala Formation	N	T		6-52	2,840	
32bbb	E. J. Brown	97	5	G	do	Cy, W	S, O	88.0	5-56	2,770	

4-26W- 5aad	O. E. Ohl	86	6	G	do	Cy, W	S	81.4	11-52	2,541	
8dad	State Geol. Survey	62	4	N	Alluvium	N	T		10-62	2,454	
8ddd	Vernon Jones	70	18	S	do	T, LPG	I, O	27.2	8-62	2,456	650 R
10dba	W. W. Frank	39	5	G	do	Cy, W	S	32.3	8-62	2,433	
11abd*	R. P. Paul	50 R	5	G	do	Cy, W	D	37.4	5-53	2,423	
17ccd*	Emil Petracek	70 R	18	S	do	T, LPG	I	26.9	8-62	2,465	350 R
17daa	State Geol. Survey	53	4	N	do	N	T		10-62	2,461	
19aaa	Julius Tacha	28 R	48	S	do	N	N	11.9	8-62	2,453	
19ccc	State Geol. Survey	46	4	N	do	N	T		10-52	2,479	
19dca	Joe Doherty	37 R	18	S	do	T, T	I, O	13.3	8-62	2,464	700 R
21ccc*	L. A. McManus	155	5	G	Ogallala Formation	Cy, W	S	146	5-62	2,595	
22ddd	C. L. Stephens	180 R	5	G	do	Cy, W	D, S	161	8-62	2,594	
24dad	L. L. Stephens	118	6	G	do	Cy, W	S	109	8-62	2,516	
29dda	G. R. Robbins	142	5	G	do	Cy, W	S	104	8-62	2,567	
31bbb	W. E. Vansickel	111	4	G	do	Cy, W	D, S	103	8-62	2,581	
33bbb	State Geol. Survey	200	4	N	do	N	T		10-62	2,611	
36bbb	E. Schmidt	138	6	G	do	Cy, W	S, O	134	1-53	2,572	
4-27W- 8dca	John Petracek	137 R	6	S	do	Sub, E	I, D	100 R	8-62	2,661	55 R
12cdd	Everett Carper	72	5	G	do	Cy, W	S	61.7	7-62	2,564	
16aaa	L. A. Shimmick	102	5	G	do	N	N	89.3	7-62	2,622	
17dac*	James Vacura	165 R	18	S	do	T, LPG	I, O	106	9-62	2,648	585
22dca	C. W. Comfort	52	5	G	do	Cy, W	S	34.8	9-62	2,536	
24ddd	City of Jennings	66 R	18	S	Alluvium	T, E	PS	34 R	10-62		200 R
29bbc	Emil Mazanek	85	6	G	Ogallala Formation	Cy, W	S	71.3	9-62	2,602	
33bbb	Keith Muirhead	55	18	S	Alluvium	T, LPG	I, O	16.2	9-62	2,528	
35aaa	V. L. Skubal	80	6	G	Ogallala Formation	Cy, W	D, S	69.4	9-62	2,553	
4-28W- 3baa	James Vavroch	102	5	G	do	Cy, E	D, S	84.4	8-62	2,690	
6aaa	G. Martin	135	5	G	do	Cy, W	S	123	8-62	2,747	
11cdd	Frank Vacura	102	5	G	do	N	N	86.7	7-62	2,686	
15aaa	E. Petracek	106	5	G	do	Cy, W	S, O	95.1	9-64	2,700	
16dcc	Walter Gaumer	105	6	G	do	Cy, W	S	92.4	8-62	2,710	
17bab	O. W. Cullison	148	6	G	do	Cy, W	D, S	141	8-62	2,769	
24bac	J. Mazanek	115	5	G	do	Cy, W	S	101	8-62	2,670	
26ccc	G. D. Bremer	95 R	5	G	do	Cy, E	D, S	81.3	8-62	2,662	
30ddd	Bryan Ehlers	110	5	G	do	Cy, W	D, S, O	93.0	7-62	2,726	
4-29W- 1bba	R. Adamson	148	4	G	do	Cy, W	S	127	12-52	2,761	
3dbb*	E. Wymore	132	5	G	do	Cy, W	D	132	9-62	2,780	
13aad	J. H. Smith	163	6	G	do	N	N	154	9-62	2,796	
14cad	J. I. Robertson	138	5	G	do	Cy, W	S	117	9-62	2,779	
15baa	G. T. Anderson	142	5	G	do	Cy, W	S	133	9-62	2,803	
16cdd	E. R. Anderson	181	5	G	do	N	O	130	9-62	2,817	
17bac	Russel Raulston	110	5	G	do	Cy, W	S	106	12-52	2,789	
22bcc	L. Foster	146	4	G	do	Cy, G	S	141	7-62	2,822	
23ddd	J. R. Sage	116	5	G	do	Cy, W	S	101	7-62	2,759	
25aad	Mrs. B. Starlin	120	5	G	do	Cy, W	D, S	115	9-62	2,761	
29abb	E. W. Anderson	120	7	G	do	Cy, W	S	96.5	9-62	2,797	

TABLE 6.—Records of wells and test holes (*Continued*).

Well number[1]	Owner or user	Depth of well, in feet[2]	Diameter of well, in inches	Type of casing[3]	Principal water-bearing geologic unit	Method of lift,[4] type of power[5]	Use[6]	Depth to water level below land surface, in feet[2]	Date of measurement	Altitude of land surface above mean sea level, in feet	Yield, in gallons per minute[2]
30bba	E. W. Marcuson	141	5	G	do	N	N	137	9-62	2,852	
33cbb	T. A. Marcuson	104	5	G	do	N	S	85.5	8-62	2,790	
35abb	Fred Anderson	120	5	G	do	Cy, W	S	102	8-62	2,765	
36ddd	Fred W. Bremer	90 R	18	S	do	T, LPG	I	52.0	8-62	2,690	240 R
4-30W- 1bbb	State Geol. Survey	105	4	N	do	N	T		10-52	2,732	
1ccb	State Geol. Survey	26	4	N	Alluvium	N	T	6.5	10-52	2,652	
4bbb	W. L. Barr	16.0	5	G	do	Cy, H	S	11.7	1-53	2,681	
6aad	State Geol. Survey	42	4	N	Crete Formation	N	T		10-62	2,702	
6ccc	C. B. Rummel	45	5	G	Alluvium	J, E	D, S	22.1	5-56	2,712	
6dda	State Geol. Survey	29	4	N	do	N	T	12.8	10-62	2,701	
9ddd	G. H. Lippelman	91	6	G	Ogallala Formation	Cy, W	D, S, O	83.7	9-64	2,760	
11aaa	J. P. Screen	28.0	6	G	Alluvium	Cy, W	S	17.9	9-62	2,671	
14ddc	H. Klawonn	162	6	G	Ogallala Formation	Cy, W	S	152	8-62	2,867	
17ada	R. W. Johnson	42.8	5	G	Crete Formation	N	N	35.0	8-62	2,731	
18bdc	L. E. Morton	114	5	G	Ogallala Formation	Cy, W	D	104	1-53	2,846	
18ddd	State Geol. Survey	45	4	N	do	N	T	36.5	10-62	2,759	
19add	J. T. Young	35.0	5	G	do	N	N	28.9	9-62	2,749	
21bbd	B. C. Feaster	24.0	4	G	Alluvium	Cy, H	D	16.2	8-62	2,718	
29bbc	State Geol. Survey	28	4	N	do	N	T		10-62	2,733	
29cbb	State Geol. Survey	34	4	N	do	N	T	16.4	10-62	2,743	
30bbb	State Geol. Survey	110	4	N	Ogallala Formation	N	T		6-52	2,847	
30dca	Carl Brown	21	5	G	Alluvium	J, E	D	13.6	1-53	2,744	
34bcb	Keith Sauvage	118	6	G	Ogallala Formation	Cy, W	S	111	8-62	2,870	
35aad	Albert Koehler	115	6	G	do	Cy, W	D, S	98.8	8-62	2,835	
4-31W-25ddd	C. C. Brown	320	5	G	Alluvium	Cy, W	S	20.3	8-62	2,755	
5-26W- 5add	A. M. Brock	138	6	G	Ogallala Formation	Cy, H	O	129	8-62	2,607	
12bbb	L. A. Mindrup	185	5	G	do	Cy, W	D, S	155	8-62	2,606	
12dad	Leo Mindrup	171	5	G	do	Cy, W	D, S	150	8-47	2,591	
14bbb	H. Grove	170	6	G	do	Cy, W	D, S	162	1-53	2,623	
15ddd	Olive Gnagy	115	5	G	do	Cy, W	S	104	8-62	2,565	
18daa	A. Dumler	169	5	G	do	Cy, W	S	165	8-62	2,661	
20ddd*	F. E. Bader	110	5	G	do	Cy, W	D	103	8-62	2,583	
26dda	Rodney Scott	74.5	18	S	Crete Formation	T, LPG	I, O	27.8	8-62	2,437	
31cdc	W. P. Noone	72	18	S	Alluvium	T, G	I	28.6	8-62	2,524	500 R
32dbc*	K. L. Zimmerman		24	G	do	T, E	I			2,497	400 R
33bcd	O. B. Steele	51.4	5	G	Crete Formation	Cy, H	N	38.5	1-53	2,501	
33dcc	Louis Randolph	60	30	G	Alluvium	T, LPG	O	20.4	8-62	2,475	800 R
34cad*	J. Mangold	55	5	G	do	Cy, H	D	20.4	8-62	2,462	
35acd	Rodney Scott				do	N	N	17.2	8-62	2,433	
36bdc	Gerald Shipley	69 R	18	S	do	T, LPG	I	25.0	8-62	2,435	1,000 R

5-27W- 7ccc	H. Vaughn	143	5	G	Ogallala Formation	Cy, W	N	132	8-62	2,701	
10dda	C. E. Feely	179	6	G	do	Cy, W	S	160	1-53	2,681	
12aad	J. Carter	110	6	G	do	Cy, W	S	100	9-62	2,598	
16aad	B. L. Woodward	162	5	G	do	Cy, W	S	133	8-62	2,669	
22ddd	C. E. Feely	135	6	G	do	Cy, W	N	124	9-62	2,666	
29abd	A. J. Backwith	105	5	G	do	Cy, W	S	99.4	8-62	2,681	
33ddd	H. R. Walker	115	6	G	do	Cy, W	S	106	9-62	2,670	
36ddd	A. M. Boutz				Alluvium	T, E	I			2,521	
5-28W- 2aad	R. M. Jacobs	36	5	G	Ogallala Formation	Cy, W	S	33.2	9-62	2,595	
3ccc	State Geol. Survey	50	4	N	Alluvium	N	T		10-52	2,594	
3dbb*	Marion Bremer	56.0	18	S	do	T, LPG	I	14.6	8-62	2,596	750 R
5dcd1*	Melvin Moore	58 R	18	S	do	T, LPG	I	22.2	8-62	2,628	
6bdd	F. Mazanek	72	6	G	Ogallala Formation	Cy, W	N	54.4	8-62	2,682	
7bbc	John Meitl	55 R	18	S	Alluvium	T, LPG	I, O	16.0	8-62	2,644	500 R
14add	M. J. Brewer	142	5	G	Ogallala Formation	Cy, W	N	135	7-62	2,723	
17dac	F. J. Ympa	124	7	G	do	Cy, W	S, O	103	8-62	2,734	
28dda	A. Zogrow	120	5	G	do	N	N	115	7-62	2,759	
30ddd	Tony Trommeter	135	5	G	do	Cy, W	S	125	7-62	2,791	
35bbb	J. A. Karls	130	6	G	do	Cy, W	S	122	8-62	2,753	
36abb	F. L. Marcoux	150	6	G	do	Cy, W	D, S	141	9-62	2,752	
5-29W- 7aad	H. R. Anderson	122	5	G	do	Cy, W	S	115	8-62	2,836	
10bab*	F. H. Neff	36	6	G	do	Cy, W	S	23.7	9-62	2,704	
12bbd	S. Meitl	65	5	G	Crete Formation	Cy, W	D, S	53.4	7-62	2,695	
13bbd	J. H. McKay	52.5	18	S	Alluvium	T, LPG	I	10.0	8-62	2,657	100 R
14adb	J. H. McKay	38 R	18	S	do	T, LPG	I	16.0	8-62	2,667	400 R
14bcd	D. C. Emigh	84	5	G	Ogallala Formation	N	N	73.5	8-62	2,733	
16bca*	Walter Breantley	80	6	G	do	Cy, W	S	67.0	8-62	2,769	
20cdc*	C. L. Shuler	110	6	G	do	Cy, W	S	95.5	9-62	2,818	
22cbb	Elmer Corder	46	18	S	Alluvium	T, LPG	I	8.3	8-62	2,686	400 R
24cdc	F. C. Chance	112	4	G	Ogallala Formation	Cy, W	S	96.6	8-62	2,761	
27bba	Cleo Anderson				do	Ce, LPG	I	9.3	8-62	2,691	
28bdd*	Alton Carman	48 R	18	S	Alluvium	T, LPG	I	15.1	8-62	2,709	500 R
34ccb	J. Peter	105	6	G	Ogallala Formation	Cy, W	S	99.3	8-62	2,810	
35ddc	J. Peter	114	5	G	do	Cy, W	S	102	8-62	2,798	
5-30W- 1ccc	Edward Shields	95	6	G	do	Cy, W	S	82.0	9-62	2,829	
6add	E. L. Walker	131	5	G	do	Cy, W	S	110	9-62	2,891	
7dcd	L. O. Colson	130	5	G	do	Cy, W	D	116	9-62	2,918	
8aad	E. L. Walker	132	6	G	do	Cy, W	S	112	9-62	2,898	
10bbb	May Rapp	137	4	G	do	Cy, W	D, S	130	12-52	2,900	
13bbb	T. Nauer	125	4	G	do	Cy, W	S	110	8-62	2,861	
15bba	L. M. Wessel	110	5	G	do	Cy, W	D, S, O	95.4	8-62	2,870	
23ddd	W. J. Nauer	35	5	G	do	Cy, W	S	32.6	9-62	2,794	
28abc	D. G. Addleman	90	7	G	do	Cy, W	S	80.5	9-62	2,878	
29dcc	C. A. Hays	125	5	G	do	Cy, W	S	105	12-52	2,920	
30abb	Bill Cheney	135	5	G	do	Cy, W	D, S	111	8-62	2,931	
34abb*	George Knopp	62	5	G	do	Cy, W	D	57.0	8-62	2,842	

TABLE 6.—Records of wells and test holes (*Concluded*).

Well number[1]	Owner or user	Depth of well, in feet[2]	Diameter of well, in inches	Type of casing[3]	Principal water-bearing geologic unit	Method of lift,[4] type of power[5]	Use[6]	Depth to water level below land surface, in feet[2]	Date of measurement	Altitude of land surface above mean sea level, in feet	Yield, in gallons per minute[2]
35bcb	Fred Mumm	201 R	18	S	do	T, LPG	I	114	9-62	2,891	825 R
35bcc*	Fred Mumm	200 R	18	S	do	T, LPG	I	112	9-62	2,889	415 R
36ddc	Joe A. Trembley	31.5	6	G	Alluvium	Cy, W	S	23.2	8-62	2,783	
5-31W-36ddd	State Geol. Survey	170	4	N	Ogallala Formation	N	T		6-52	2,905	
6-27W- 3aaa	State Geol. Survey	74	4	N	Alluvium	N	T	22.8	8-52	2,543	
6-28W- 6aaa	A. Trommeter	148	6	G	Ogallala Formation	Cy, W	S	124	9-62	2,793	
6-29W- 6bbb	State Geol. Survey	150	4	N	do	N	T	52.8	6-52	2,789	

[1] Asterisk following well number indicates analysis of water is given in table 3.
[2] *R*, reported.
[3] *G*, galvanized; *I*, black iron; *N*, none; *S*, steel.
[4] *Ce*, centrifugal; *Cy*, cylinder; *J*, jet; *N*, none; *T*, turbine; *Sub*, submersible.
[5] *D*, diesel; *E*, electric; *G*, gasoline; *H*, hand; *LPG*, liquefied petroleum gas; *NG*, natural gas; *T*, tractor; *W*, wind.
[6] *D*, domestic; *I*, irrigation; *N*, none; *O*, observation; *PS*, public supply; *S*, stock; *T*, test.

LOGS OF WELLS AND TEST HOLES

Listed on the following pages are logs of 35 selected wells and test holes. Logs of an additional 56 wells and test holes used in the preparation of this report are retained in the files of the U.S. and State Geological Surveys, Lawrence, Kans., and may be consulted there.

The logs are numbered according to the well-numbering system illustrated on figure 2. Location of wells and test holes are shown on plate 1. The character of the material drilled is illustrated on plate 2. Logs designated "sample log" describe test holes which were drilled by the State Geological Survey of Kansas and from which samples were collected. Water-level measurements are given in feet below land surface.

1-26W-5bbb.—Sample log of test hole in the NW¼ NW¼ NW¼ sec. 5, T. 1 S., R. 26 W., 14 feet east and 12 feet south of center of crossroads; drilled October 1952. Altitude of land surface, 2,531 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Peoria and Loveland Formations		
Silt, brown	11	11
Silt, gray	15	26
Silt, compact, dark-brown	2	28
TERTIARY SYSTEM		
PLIOCENE SERIES		
Ogallala Formation		
Silt, sandy, tan and brown; contains limy layers	19	47
Silt, sandy; contains thin layers of coarse sand and fine gravel	8	55
Silt, very sandy, light-tan	5	60
Sand, fine to coarse; contains cemented layers of limy silt	18	78
Silt, limy, light-tan; contains layers of sand and gravel	15	93
Sand, fine to very coarse, and fine gravel, silty, cemented	20	113
Silt, very sandy, light-tan	11	124
Silt, sandy, limy, tan and gray	8	132
Sand, fine to coarse, and fine gravel, silty, limy, cemented	27	159
Sand, fine to coarse, and fine gravel; contains chalk fragments	16	175
CRETACEOUS SYSTEM		
UPPER CRETACEOUS SERIES		
Niobrara Chalk		
Shale, silicified, very hard, yellowish-brown	1	176

1-26W-8ddd.—Sample log of test hole in the SE¼ SE¼ SE¼ sec. 8, T. 1 S., R. 26 W., at edge of road, 0.1 mile north of SE corner; augered October 1962. Altitude of land surface, 2,400 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Crete Formation		
Silt, sandy, brown	10	10
Sand, fine, silty	5	15
Silt, sandy, light-brown	10	25

	Thickness, feet	Depth, feet
Silt, very sandy, brown	10	35
Silt, sandy, brown	10	45
Sand, medium to coarse, and fine to medium gravel	17	62
CRETACEOUS SYSTEM		
UPPER CRETACEOUS SERIES		
Niobrara Chalk		
Shale, dark-gray	1	63

1-26W-17ccc.—Sample log of test hole in the SW¼ SW¼ SW¼ sec. 17, T. 1 S., R. 26 W., 50 feet south of bridge and 40 feet east of road center; drilled October 1952. Altitude of land surface, 2,406 feet; depth to water, 21.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Alluvium		
Silt, tannish-brown	5	5
Silt, compact, dark-brown	6	11
Silt, sandy, tan and gray	19	30
Sand, fine to coarse, and fine to medium gravel	8	38
CRETACEOUS SYSTEM		
UPPER CRETACEOUS SERIES		
Niobrara Chalk		
Shale, weathered, yellow and tan	2	40
Shale, dark-gray	4	44

1-26W-32ccc.—Sample log of test hole in the SW¼ SW¼ SW¼ sec. 32, T. 1 S., R. 26 W., 0.1 mile north of crossroads and 12 feet east of road center; drilled October 1952. Altitude of land surface, 2,594 feet; depth to water, 153 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Peoria and Loveland Formations		
Silt, dark-brown	5	5
Silt, gray and tan	15	20
Silt, clayey, tan and brown	6	26
TERTIARY SYSTEM		
PLIOCENE SERIES		
Ogallala Formation		
Silt, limy, tan and brown	20	46
Silt, sandy, limy	6	52
Sand, fine to coarse, limy, cemented	13	65
Silt, sandy, reddish-brown	4	69
Sand, silty, limy; contains cemented layers	40	109
Silt and fine sand, cemented; contains shale fragments	23	132
Sand, fine, silty; contains cemented streaks	5	137
Silt, blocky, olive and light-tan	3	140
Sand, fine to coarse, silty	5	145
Silt, sandy, olive and yellowish-tan	3	148
Sand, fine to coarse, and fine gravel, silty	20	168
Sand, fine to medium, silty	28	196
Sand, fine to medium	18	214
Sand, fine to coarse, and fine gravel	7	221
CRETACEOUS SYSTEM		
UPPER CRETACEOUS SERIES		
Niobrara Chalk		
Shale, silicified, very hard, yellow and brown	1	222

1-27W-34bab.—Driller's log of irrigation well in the NW¼ NE¼ NW¼ sec. 34, T. 1 S., R. 27 W.; drilled by Elmer Corder. Altitude of land surface, 2,444 feet; depth to water, 24.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Alluvium		
Top	33	33
Sand, silty	10	43
Sand	2	45
Silt, hard	1	46
Sand, loose	14	60
Sand	3	63
Sand, fine	27	90
CRETACEOUS SYSTEM		
UPPER CRETACEOUS SERIES		
Niobrara Chalk		
Clay, limy	3	93
Shale	2	95

1-28W-3aaa.—Sample log of test hole in the NE¼ NE¼ NE¼ sec. 3, T. 1 S., R. 28 W., 80 feet south and 12 feet west of NE corner; drilled October 1952. Altitude of land surface, 2,662 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Peoria and Loveland Formations		
Silt, dark-brown	3	3
Silt, gray and tan	28	31
TERTIARY SYSTEM		
PLIOCENE SERIES		
Ogallala Formation		
Silt, sandy, light-tan	10	41
Sand, fine to coarse; contains layers of brown silt	10	51
Sand, fine to coarse, clean	17	68
Silt, very sandy; contains cemented layers	30	98
Sand, fine to coarse, and fine gravel, cemented	59	157
Sand, fine to coarse; contains limy silt	32	189
CRETACEOUS SYSTEM		
UPPER CRETACEOUS SERIES		
Niobrara Chalk		
Clay, yellow and tan	6	195
Shale, yellowish-tan and light-gray	11	206
Shale, dark-gray	2	208

1-28W-33ddd.—Sample log of test hole in the SE¼ SE¼ SE¼ sec. 33, T. 1 S., R. 28 W., 80 feet north and 10 feet west of center of crossroads; drilled October 1952. Altitude of land surface, 2,621 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Peoria and Loveland Formations		
Silt, dark-brown	2	2
Silt, gray	8	10
Silt, tan and gray	10	20
Silt, sandy, tan	6	26
TERTIARY SYSTEM		
PLIOCENE SERIES		
Ogallala Formation		
Silt, clayey, dark-brown	2	28
Silt, tan	11	39
Sand, fine to coarse, silty	4	43

	Thickness, feet	Depth, feet
Sand, fine to coarse, and fine gravel, silty	10	53
Sand, fine to coarse; contains thin layers of silt	11	64
Sand, fine, silty, very limy, grayish-white	10	74
Sand, fine to coarse, very limy, cemented	17	91
Sand, fine to medium, silty	13	104
Silt, clayey, brown and yellow	19	123
Sand, fine to medium, silty, cemented	24	147
Silt, very sandy, tan and yellow	16	163
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Niobrara Chalk		
Shale, yellow	7	170

1-29W-6aaa.—Sample log of test hole in the NE¼ NE¼ NE¼ sec. 6, T. 1 S., R. 29 W., 300 feet south and 30 feet west of NE corner; drilled October 1952. Altitude of land surface, 2,691 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Peoria and Loveland Formations		
Silt, tan	10	10
Silt, gray	10	20
Silt, sandy, tannish-brown	9	29
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Silt, limy, light-tan	6	35
Silt, very sandy, limy, light-gray	5	40
Sand, fine to medium; contains cemented limy silt	10	50
Sand, fine to coarse, cemented	4	54
Sand, fine to medium, very limy, cemented	14	68
Silt, very sandy	4	72
Sand, fine to very coarse, silty	15	87
Sand, fine to coarse, very silty	22	109
Silt, sandy, yellowish-tan	13	122
Sand, fine to coarse, and fine to medium gravel	11	133
Silt, tough, tan and gray	4	137
Sand, fine to coarse, and fine gravel, silty	5	142
Silt, sandy, tan and gray	3	145
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Pierre Shale		
Shale, yellowish-gray and light-gray	12	157

1-29W-30bdd2.—Sample log of test hole in the SE¼ SE¼ NW¼ sec. 30, T. 1 S., R. 29 W.; augered September 1962. Altitude of land surface, 2,593 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Alluvium		
Silt, dark-brown	3	3
Silt, light-brown	7	10
Silt, sandy, light-brown	5	15
Silt, sandy, tannish-brown	5	20
Silt, sandy, tough, light-brown	10	30
Silt, sandy, light-brown	10	40
Silt, sandy, tough, light-brown	10	50
Sand, medium to very coarse, and fine gravel	24	74
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Pierre Shale		
Shale, bluish-gray	1	75

1-29W-31bbc.—Sample log of test hole in the SW¼ NW¼ NW¼ sec. 31, T. 1 S., R. 29 W., 600 feet south of crossroads and 30 feet east of road center; drilled October 1952. Altitude of land surface, 2,623 feet.

	Thickness, feet	Depth, feet
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Silt, very sandy; contains cemented streaks	7	7
Silt, sandy, tannish-brown	8	15
Sand, fine to coarse; contains streaks of limy silt	13	28
Sand, fine to coarse, and fine gravel, cemented	11	39
Silt, compact, tan, sandy	9	48
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Pierre Shale		
Shale, yellow and light-gray	12	60

1-31W-1aaa.—Sample log of test hole in the NE¼ NE¼ NE¼ sec. 1, T. 1 S., R. 31 W., 180 feet south of fence line and 40 feet west of road center; drilled June 1952. Altitude of land surface, 2,892 feet; depth to water, 190.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Peoria and Loveland Formations		
Silt, dark-brown to black	3	3
Silt, fossiliferous, gray	14	17
Silt and fine sand, tan	21	38
Silt, sandy, tan	14	52
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Silt, sandy, limy, light-tan	35	87
Silt, very limy, white	5	92
Silt, sandy, limy, tan and gray	5	97
Sand, silty, limy	25	122
Sand, fine to coarse, and fine gravel	6	128
Sand, fine, cemented, tan	21	149
Sand, fine to coarse, and fine gravel, silty	11	160
Silt, very sandy, tan	12	172
Silt, sandy, limy; contains cemented streaks	5	177
Sand, fine, silty, cemented	8	185
Silt, sandy, limy, tan and white	7	192
Sand, fine to coarse, and fine gravel, silty	7	199
Silt, very limy, white	20	219
Silt, very sandy, limy, tan and light-gray	19	238
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Pierre Shale		
Clay, yellow and gray	16	254
Shale, gray	6	260

2-26W-21ccc.—Sample log of test hole in the SW¼ SW¼ SW¼ sec. 21, T. 2 S., R. 26 W., 135 feet east and 15 feet north of center of crossroads; drilled October 1962. Altitude of land surface, 2,622 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Peoria and Loveland Formations		
Silt, dark-brown	8	8
Silt, sandy, light-brown	4	12
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Silt, very sandy, limy, light-tan	18	30
Silt, sandy, limy, cemented, light-tan	20	50
Silt, very sandy, limy, cemented, light-tan	20	70
Sand, fine, silty, very limy, cemented, hard	15	85
Silt, very sandy, limy, cemented	15	100
Sand, fine, very limy, cemented	10	110
Sand, fine to medium, limy, cemented	10	120
Silt, very sandy, limy, cemented	16	136
Sand, fine to very coarse	6	142
Bentonite, grayish-green	5	147
Sand, fine to very coarse, cemented	13	160
Gravel, fine to medium, and very coarse sand	25	185
Silt, sandy, brown	7	192
Sand, medium to very coarse, cemented	18	210
Gravel, fine, and very coarse sand, clean	12	222
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Niobrara Chalk		
Shale, dark-gray	13	235

2-28W-22acc.—Driller's log of irrigation well in the SW¼ SW¼ NE¼ sec. 22, T. 2 S., R. 28 W.; drilled by Elmer Corder. Altitude of land surface, 2,511 feet; depth to water, 25.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Alluvium		
Top	19	19
Sand and clay	9	28
Clay	17	45
Sand, dark	6	51
Silt, blue	1	52
Sand, loose	6	58
Clay	2	60
Sand	1	61
Clay	1	62
Sand, loose	6	68
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Niobrara Chalk		
Shale	2	70

2-28W-31abc.—Driller's log of irrigation well in the SW¼ NW¼ NE¼ sec. 31, T. 2 S., R. 28 W.; drilled by Elmer Corder. Altitude of land surface, 2,551 feet; depth to water, 19.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Alluvium		
Top	45	45
Sand	9	54
Sand, fine	3	57
Sand, coarse	4	61
Sand, fine	2	63
Sand, coarse	2	65
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Niobrara Chalk		
Shale	2	67

2-29W-31ccc.—Sample log of test hole in the SW¼ SW¼ SW¼ sec. 31, T. 2 S., R. 29 W., 150 feet north and 20 feet east of SW corner; drilled October 1952. Altitude of land surface, 2,763 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Peoria and Loveland Formations		
Silt, sandy, tannish-brown	4	4
Silt, tan and gray	18	22
Silt, sandy, tan	6	28
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Silt, limy, light-tan and light-gray	3	31
Sand, fine to coarse, cemented	15	46
Sand, fine to medium, silty, limy	18	64
Sand, fine to coarse, and fine gravel, cemented	18	82
Silt, sandy, tan	3	85
Sand, fine to coarse, and fine gravel, limy, cemented	5	90
Silt, sandy, tan	4	94
Sand, fine to coarse, and fine to medium gravel	11	105
Sand, fine to medium, silty	20	125
Silt and fine sand, tan	29	154
Sand, fine to coarse, and fine gravel, silty	19	173
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Pierre Shale		
Shale, yellowish-tan and light-gray	17	190

2-30W-32bbb.—Sample log of test hole in the NW¼ NW¼ NW¼ sec. 32, T. 2 S., R. 30 W., 35 feet south and 15 feet east of center of crossroads; drilled October 1962. Altitude of land surface, 2,899 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Peoria and Loveland Formations		
Silt, brown	12	12
Silt, sandy, tan	18	30
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Silt, sandy, very limy, light-tan	10	40
Sand, fine, very silty	10	50
Silt, sandy, limy	26	76
Sand, medium to very coarse, and fine to medium gravel, clean	14	90

	Thickness, feet	*Depth, feet*
Gravel, fine to medium, and very coarse sand	15	105
Silt, very sandy, limy; contains cemented layers	15	120
Sand, fine to medium; contains layers of limy silt	45	165
Sand, medium to very coarse, and fine gravel	10	175
Sand, fine to medium, cemented	10	185
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Pierre Shale		
Shale, brown	15	200

3-26W-17aaa.—Sample log of test hole in the NE¼ NE¼ NE¼ sec. 17, T. 3 S., R. 26 W., 75 feet west and 10 feet south of center of crossroads; drilled October 1962. Altitude of land surface, 2,547 feet.

	Thickness, feet	*Depth, feet*
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Silt, sandy, limy, tan	18	18
Sand, fine to medium, very limy, cemented	12	30
Sand, fine to very coarse, limy, cemented	14	44
Silt, sandy, limy, reddish-tan	8	52
Sand, fine to medium	13	65
Clay, bentonitic, grayish-green	3	68
Sand, fine to coarse; contains cemented streaks	12	80
Sand, fine to very coarse; contains layers of limy silt	20	100
Sand, fine to very coarse; contains streaks of limy silt	20	120
Sand, fine to coarse, very limy, cemented	10	130
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Niobrara Chalk		
Shale, brown and gray	10	140

3-27W-25ddd.—Sample log of test hole in the SE¼ SE¼ SE¼ sec. 25, T. 3 S., R. 27 W., 40 feet north and 28 feet west of center of crossroads; drilled October 1962. Altitude of land surface, 2,572 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series		
Peoria and Loveland Formations		
Silt, dark-brown	3	3
Silt, gray	9	12
Silt, sandy, tan	8	20
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Silt, limy, brown	7	27
Silt, very limy, light-tan	10	37
Sand, fine to coarse, and fine gravel, silty, limy	12	49
Sand, fine to coarse, and fine gravel, clean, loose	6	55
Sand, fine to medium; contains thin layers of green silt	11	66
Sand, fine to coarse, silty, limy	9	75
Sand, fine to coarse, and fine gravel, cemented	16	91
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Niobrara Chalk		
Clay, yellow and brown	2	93
Shale, bentonitic, grayish-white and tan	7	100

3-28W-34bbb.—Sample log of test hole in the NW¼ NW¼ NW¼ sec. 34, T. 3 S., R. 28 W., 40 feet east and 15 feet south of center of crossroads; drilled October 1952. Altitude of land surface, 2,737 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series		
Peoria and Loveland Formations		
Silt, dark-brown	2	2
Silt, tan and gray	13	15
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Silt, very limy, light-tan	11	26
Sand, fine to coarse, silty, limy	6	32
Sand, fine to coarse; contains layers of reddish-brown silt	35	67
Sand, fine to medium, limy	20	87
Sand, fine to medium, silty, limy	49	136
Sand, fine to coarse, silty	32	168
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Niobrara Chalk		
Shale, yellow and tan	12	180

3-29W-12bab.—Driller's log of irrigation well in the NW¼ NE¼ NW¼ sec. 12, T. 3 S., R. 29 W.; drilled by Klein's Motor Electric Co. Altitude of land surface, 2,556 feet; depth to water, 26.1 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series		
Alluvium		
Silt	11	11
Silt and fine sand	4	15
Sand and fine gravel	11	26
Silt, blue	2	28
Gravel, medium	12	40
Gravel and pebbles	2	42
Gravel, medium	4	46
Gravel, coarse	4	50
Gravel and pebbles	5	55
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Niobrara Chalk		
Shale	5	60

3-29W-21bad2.—Sample log of test hole in the SE¼ NE¼ NW¼ sec. 21, T. 3 S., R. 29 W.; augered September 1962. Altitude of land surface, 2,578 feet; depth to water, 22.1 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series		
Alluvium		
Silt, light-brown	5	5
Silt, sandy	5	10
Silt, tannish-brown	5	15
Silt, sandy, light-brown	10	25
Silt, sandy, brown	9	34
Sand, medium to very coarse, and fine gravel	30	64

	Thickness, feet	Depth, feet
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Pierre Shale		
Shale, gray	2	66

3-29W-31dda.—Driller's log of irrigation well in the NE¼ SE¼ SE¼ sec. 31, T. 3 S., R. 29 W.; drilled by Elmer Corder. Altitude of land surface, 2,630 feet; depth to water, 22.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Alluvium		
Silt, dark	5	5
Clay	25	30
Sand	16	46
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Pierre Shale		
Shale	3	49

3-30W-19aaa.—Sample log of test hole in the NE¼ NE¼ NE¼ sec. 19, T. 3 S., R. 30 W., 50 feet south and 15 feet west of center of crossroads; drilled October 1962. Altitude of land surface, 2,744 feet.

	Thickness, feet	Depth, feet
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Silt, very sandy, limy, light-brown	10	10
Silt, sandy, limy, tan	5	15
Sand, fine to coarse, silty, limy; contains cemented layers	10	25
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Pierre Shale		
Shale, brown and gray	5	30

4-26W-17aad.—Sample log of test hole in the SE¼ NE¼ NE¼ sec. 17, T. 4 S., R. 26 W., at edge of road, 0.24 mile south of NE corner; augered October 1962. Altitude of land surface, 2,437 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Alluvium		
Sand, fine to medium	5	5
Sand, medium	5	10
Sand, medium to very coarse	10	20
Sand, medium to very coarse, and fine gravel	15	35
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Niobrara Chalk		
Shale, bluish-gray	1	36

4-27W-24aaa.—Sample log of test hole in the NE¼ NE¼ NE¼ sec. 24, T. 4 S., R. 27 W., 50 feet west and 12 feet south of center of crossroads; drilled October 1952. Altitude of land surface, 2,531 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Peoria and Loveland Formations		
Silt, gray	12	12
Silt, brown	16	28
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Sand, fine to coarse	10	38
Sand, fine to coarse, silty, limy	7	45
Silt, sandy, yellow	11	56
Sand, fine to medium	8	64
Sand, fine to coarse, silty, very limy	13	77
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Niobrara Chalk		
Shale, yellow and light-gray	6	83

4-28W-28ddd.—Sample log of test hole in the SE¼ SE¼ SE¼ sec. 28, T. 4 S., R. 28 W., 35 feet west and 8 feet north of center of crossroads; drilled October 1952. Altitude of land surface, 2,688 feet; depth to water, 86.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Peoria and Loveland Formations		
Silt, brown and gray	10	10
Silt, tannish-gray, limy in lower part	15	25
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Sand, fine to coarse, silty, very limy	4	29
Sand, fine to coarse, and fine gravel, silty	13	42
Sand, fine to medium, silty, very limy	20	62
Sand, fine to coarse	30	92
Silt, very sandy, limy, tannish-white	5	97
Sand, fine to coarse; contains chalk fragments	20	117
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Niobrara Chalk		
Shale, yellow and gray	6	123

4-30W-6add.—Sample log of test hole in the SE¼ SE¼ NE¼ sec. 6, T. 4 S., R. 30 W., at edge of road near half-mile line; augered October 1962. Altitude of land surface, 2,694 feet; depth to water, 13.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Alluvium		
Silt, sandy, light-brown	5	5
Silt, brown	5	10
Silt, sandy, brown	2	12
Sand, medium to coarse	18	30
Sand, medium to very coarse	23	53
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Pierre Shale		
Shale, hard	2	55

4-30W-26aaa.—Sample log of test hole in the NE¼ NE¼ NE¼ sec. 26, T. 4 S., R. 30 W., 12 feet south and 10 feet west of center of crossroads; drilled October 1952. Altitude of land surface, 2,852 feet; depth to water, 126.2 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series		
Peoria and Loveland Formations		
Silt, tan and gray	10	10
Silt, tan	11	21
Silt, sandy, limy in lower part	9	30
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Silt, sandy, very limy, tan and white	3	33
Sand, fine to coarse, and fine gravel	6	39
Sand, fine to coarse, silty, cemented	20	59
Silt, sandy, cemented, tan	7	66
Silt, light-green	3	69
Silt, very sandy, cemented	9	78
Sand, fine to coarse, limy, cemented	20	98
Sand, fine to very coarse, very limy, cemented	32	130
Sand, fine to coarse, cemented	8	138
Sand, fine to coarse, silty, limy, cemented	16	154
Silt, sandy, tan	4	158
Sand, fine to coarse, and fine to medium gravel	5	163
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Pierre Shale		
Shale, yellow and light-gray	11	174
Shale, dark-gray	4	178

4-30W-29bcc.—Sample log of test hole in the SW¼ SW¼ NW¼ sec. 29, T. 4 S., R. 30 W., at edge of road, 100 feet south of bridge; augered October 1962. Altitude of land surface, 2,740 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series		
Alluvium		
Silt, brown	5	5
Silt, dark-brown	4	9
Silt, sandy, light-tan	6	15
Sand, medium to coarse	15	30
Silt, clayey, tough	2	32
Sand, medium to very coarse, and fine to medium gravel	13	45
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Pierre Shale		
Shale, bluish-gray	2	47

5-26W-8ddd.—Sample log of test hole in the SE¼ SE¼ SE¼ sec. 8, T. 5 S., R. 26 W., 50 feet west and 15 feet north of SE corner; drilled October 1962. Altitude of land surface, 2,616 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series		
Peoria and Loveland Formations		
Silt, dark-brown	5	5
Silt, sandy, light-brown	9	14
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Silt, very sandy, limy, light-tan	6	20
Sand, fine to very coarse, limy	10	30
Sand, fine to very coarse, limy, cemented	15	45
Silt, very sandy, very limy, light-gray	7	52
Clay, bentonitic, grayish-green	6	58
Silt, very sandy, very limy, cemented	14	72
Sand, medium to coarse, well-sorted, clean	12	84
Silt, sandy, very limy, cemented	4	88
Sand, fine to very coarse, clean	7	95
Sand, medium to very coarse, and fine gravel	15	110
Gravel, fine to medium, and fine to coarse sand	10	120
Gravel, fine to medium, sandy	18	138
Silt, sandy, limy, cemented	12	150
Sand, fine to very coarse, silty, limy	8	158
Silt, very limy, cemented	10	168
Sand, fine to very coarse, and fine gravel	17	185
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Niobrara Chalk		
Shale, brown and gray	15	200

5-26W-33cbb.—Sample log of test hole in the NW¼ NW¼ SW¼ sec. 33, T. 5 S., R. 26 W., at edge of road, 0.1 mile south of highway; augered October 1962. Altitude of land surface, 2,477 feet; depth to water, 12.5 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series		
Alluvium		
Silt, dark-brown	5	5
Silt, sandy, brown	5	10
Silt, very sandy	3	13
Sand, medium to coarse	7	20
Sand, medium to very coarse, clean	15	35
Silt, clayey, tough, dark-brown	2	37
Sand, medium to very coarse, and fine to medium gravel, clean	13	50
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Niobrara Chalk		
Shale, brown and gray	3	53

5-28W-5dcd2.—Sample log of test hole in the SE¼ SW¼ SE¼ sec. 5, T. 5 S., R. 28 W.; augered September 1962. Altitude of land surface, 2,627 feet; depth to water, 21.2 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series		
Alluvium		
Silt, dark-brown	5	5
Silt, sandy	7	12
Silt, light-brown	3	15
Silt, sandy, tough, brown	13	28
Sand, fine, silty	2	30
Sand, medium to coarse, clean	21	51
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Niobrara Chalk		
Shale, brown and gray	2	53

5-30W-17bbb.—Sample log of test hole in the NW¼ NW¼ NW¼ sec. 17, T. 5 S., R. 30 W., 150 feet south and 100 feet east of center of crossroads; drilled October 1962. Altitude of land surface, 2,927 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Peoria and Loveland Formations		
Silt, sandy, light-brown	15	15
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Silt, sandy, limy, light-tan	12	27
Silt, sandy, very limy, cemented	15	42
Sand, fine to coarse, silty, limy	18	60
Gravel, fine to medium, and coarse sand; contains layers of limy silt	15	75
Sand, medium to very coarse; contains layers of limy silt	15	90
Silt, sandy, very limy, cemented	10	100
Sand, fine to very coarse, silty, limy	30	130
Silt, very limy, cemented	15	145
Silt, sandy; contains cemented layers	23	168
Sand, fine, cemented, hard, green	1	169
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Pierre Shale		
Shale, dark-gray	1	170

5-30W-31ddd.—Sample log of test hole in the SE¼ SE¼ SE¼ sec. 31, T. 5 S., R. 30 W., at edge of road near driveway to farm home; drilled October 1962. Altitude of land surface, 2,863 feet.

	Thickness, feet	Depth, feet
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Silt, sandy, dark-brown	8	8
Sand, medium to very coarse, limy	14	22
Silt, sandy, limy, light-brown	6	28
Sand, medium to coarse, and fine gravel	12	40
Sand, fine to very coarse, limy	10	50
Sand, fine to medium, limy, cemented	10	60
Sand, fine to coarse, silty, limy	10	70
Silt, sandy, very limy, cemented, hard, gray and green	20	90
Sand, medium to very coarse, and fine gravel, cemented	20	110
Sand, medium to very coarse, clean, loose	20	130
Sand, fine to coarse, silty, limy	10	140
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Pierre Shale		
Shale, brown and light-gray	10	150

6-28W-4aaa.—Sample log of test hole in the NE¼ NE¼ NE¼ sec. 4, T. 6 S., R. 28 W., 35 feet west of road center and 15 feet south of county line; drilled August 1952. Altitude of land surface, 2,769 feet; depth to water, 123.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Peoria and Loveland Formations		
Silt, tannish-gray	11	11
Silt, tannish-green; contains snail shells	9	20
TERTIARY SYSTEM		
Pliocene Series		
Ogallala Formation		
Sand, fine to coarse, limy	5	25
Sand, fine to coarse, silty, cemented	10	35
Sand, fine to coarse, silty	4	39
Sand, fine to coarse, and fine gravel	23	62
Sand, fine to medium, cemented	8	70
Silt, limy, light-gray and tan	7	77
Sand, fine to coarse, silty, cemented	14	91
Sand, fine to coarse, and fine gravel	7	98
Silt, sandy, tan and brown; contains shale fragments	14	112
Sand, fine to coarse	4	116
Sand, fine to coarse, silty	12	128
Gravel, fine to medium, limy	4	132
Silt, sandy, very limy, grayish-white	6	138
Sand, fine to medium, silty, light-gray	7	145
Sand, fine to coarse, and fine gravel; contains thin layers of green silt	6	151
Sand, fine to coarse, limy	7	158
Sand, fine to coarse, and fine gravel; contains thin layers of yellow silt	20	178
Sand, fine to coarse, and fine gravel	10	188
CRETACEOUS SYSTEM		
Upper Cretaceous Series		
Niobrara Chalk		
Shale, clayey, yellow and gray	20	208
Shale, clayey, dark-gray	2	210

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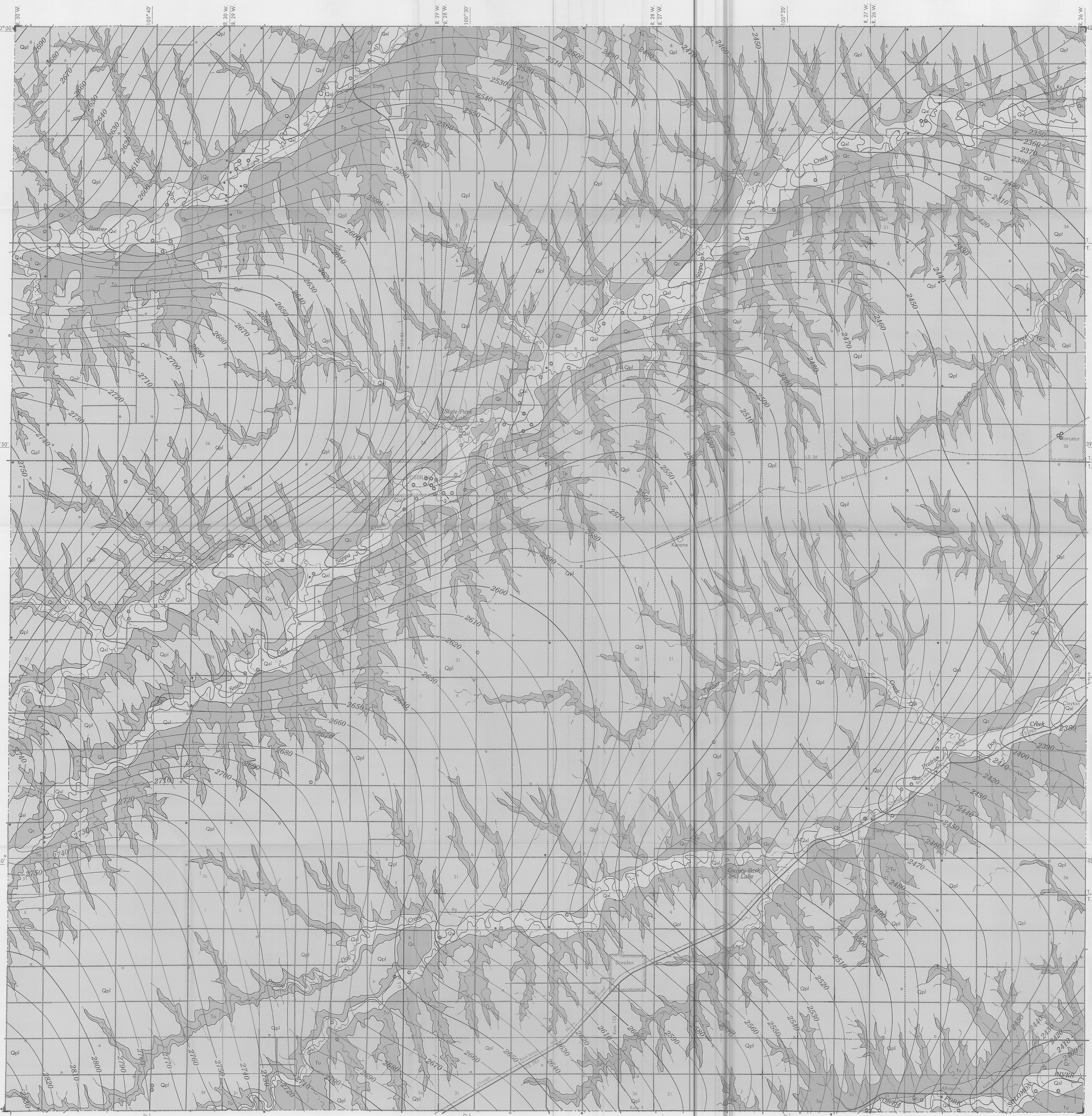
GEOHYDROLOGIC MAP OF DECATUR COUNTY, KANSAS



EXPLANATION

QUATERNARY — Pleistocene

Qal — Alluvium

Stream deposits of silt, sand, and gravel along the principal valleys. Yields moderate to large quantities of water to wells along larger valleys; lesser amounts along smaller valleys.

Qpl — Peoria and Loveland Formations

Silt, mostly eolian, sandy in lower part. Mantles most of uplands and masks much of the valley walls. Locally includes slope wash derived from the Ogallala Formation. Yields no water to wells.

Qc — Crete Formation

Stream deposits of silt, sand, and gravel in a terrace position along the major valleys. Continuous in places; locally consists of remnants. Yields small to large quantities of water to wells.

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Fluviatile deposits of sand, gravel, silt, and clay; generally very calcareous. Mostly unconsolidated, but cemented locally to various degrees. Occurs in the interstream upland areas. Yields small to moderate quantities of water to wells.

CRETACEOUS — Upper Cretaceous

Kp — Pierre Shale

Fissile, dark-gray shale; contains selenite crystals and limonite stains at outcrops. Yields no water to wells.

Kn — Niobrara Chalk

Chalk and chalky shale, thin-bedded and platy. Light gray to dark gray where fresh; weathers to brown and orange at outcrops. Yields no water to wells.

—— 2450 ——

Water-table contour

Shows altitude of water table, based on instrumental levels. Contour interval 10 feet. Datum is mean sea level

Approximate geologic contact

Domestic or stock well

Irrigation well

Municipal well

Test hole

True North
Magnetic North

APPROXIMATE MEAN DECLINATION, 1965

1 0 1 2 3 MILES

Base and drainage adapted from maps of the State Highway Commission of Kansas

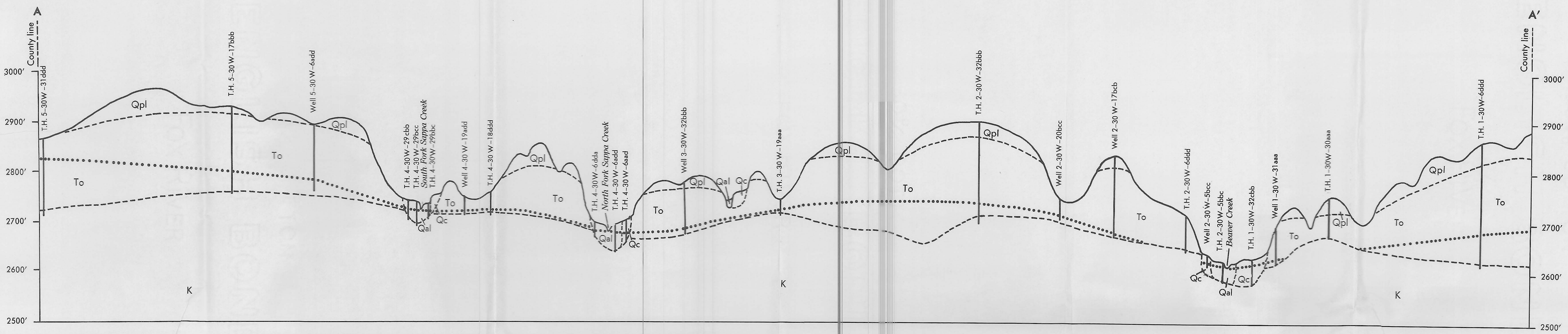
Prepared by the United States Geological Survey and the State Geological Survey of Kansas, with the cooperation of the Division of Water Resources of the Kansas State Board of Agriculture and the Environmental Health Services of the Kansas State Department of Health

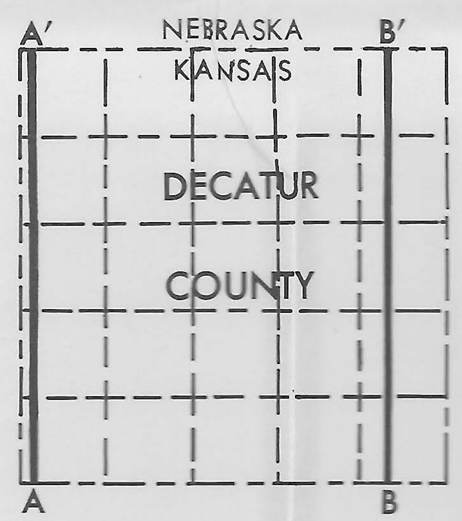
Geology and hydrology by Warren G. Hodson, 1962

State Geological Survey
of Kansas

GEOLOGIC SECTIONS IN DECATUR COUNTY, KANSAS

Bulletin 196
Plate 2





Index map showing locations of sections

0 1 2 3 4 5 MILES

Datum is mean sea level

Vertical exaggeration X 52

EXPLANATION

QUATERNARY — Pleistocene

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Qpl — Peoria and Loveland Formations

Qc — Crete Formation

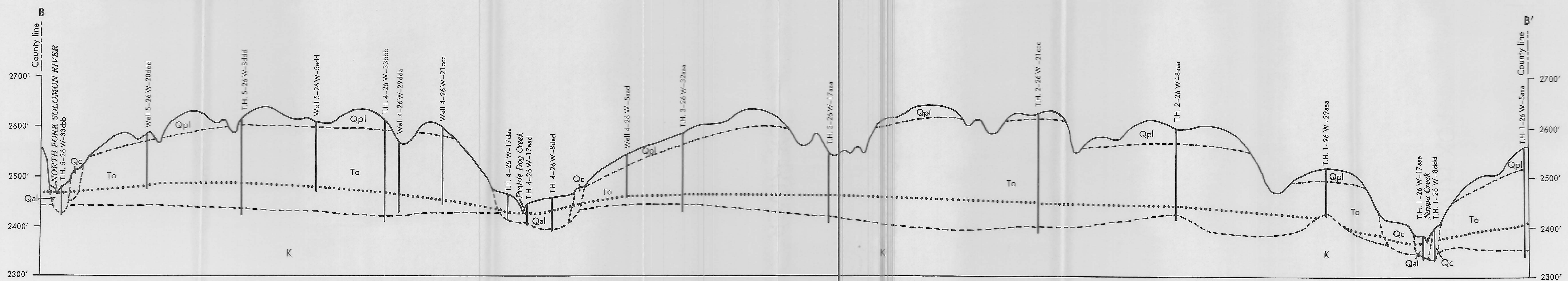
TERTIARY — Pliocene

To — Ogallala Formation

K — Cretaceous rocks

- - - - Approximate geologic contact

. . . . . . Water table



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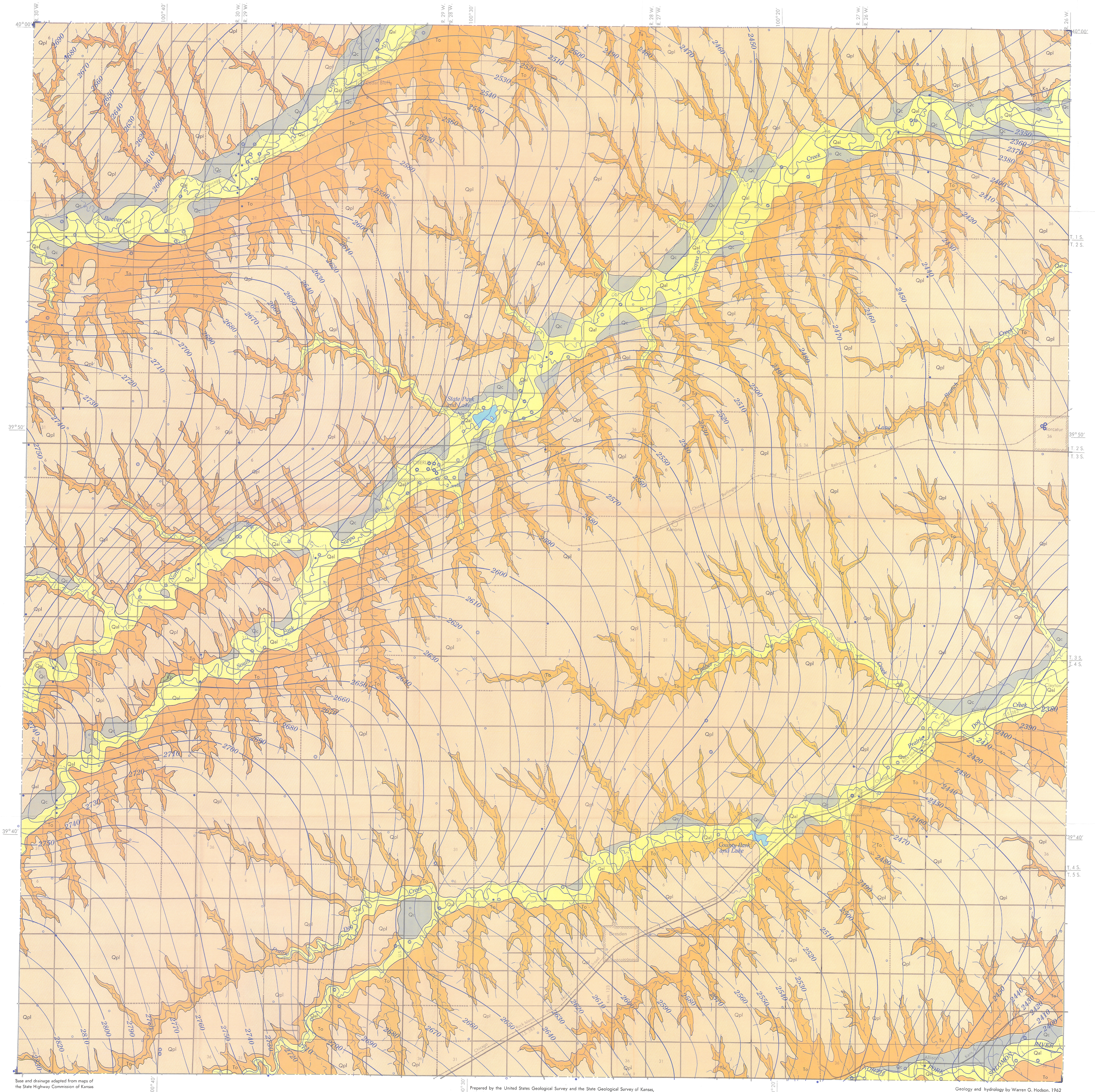

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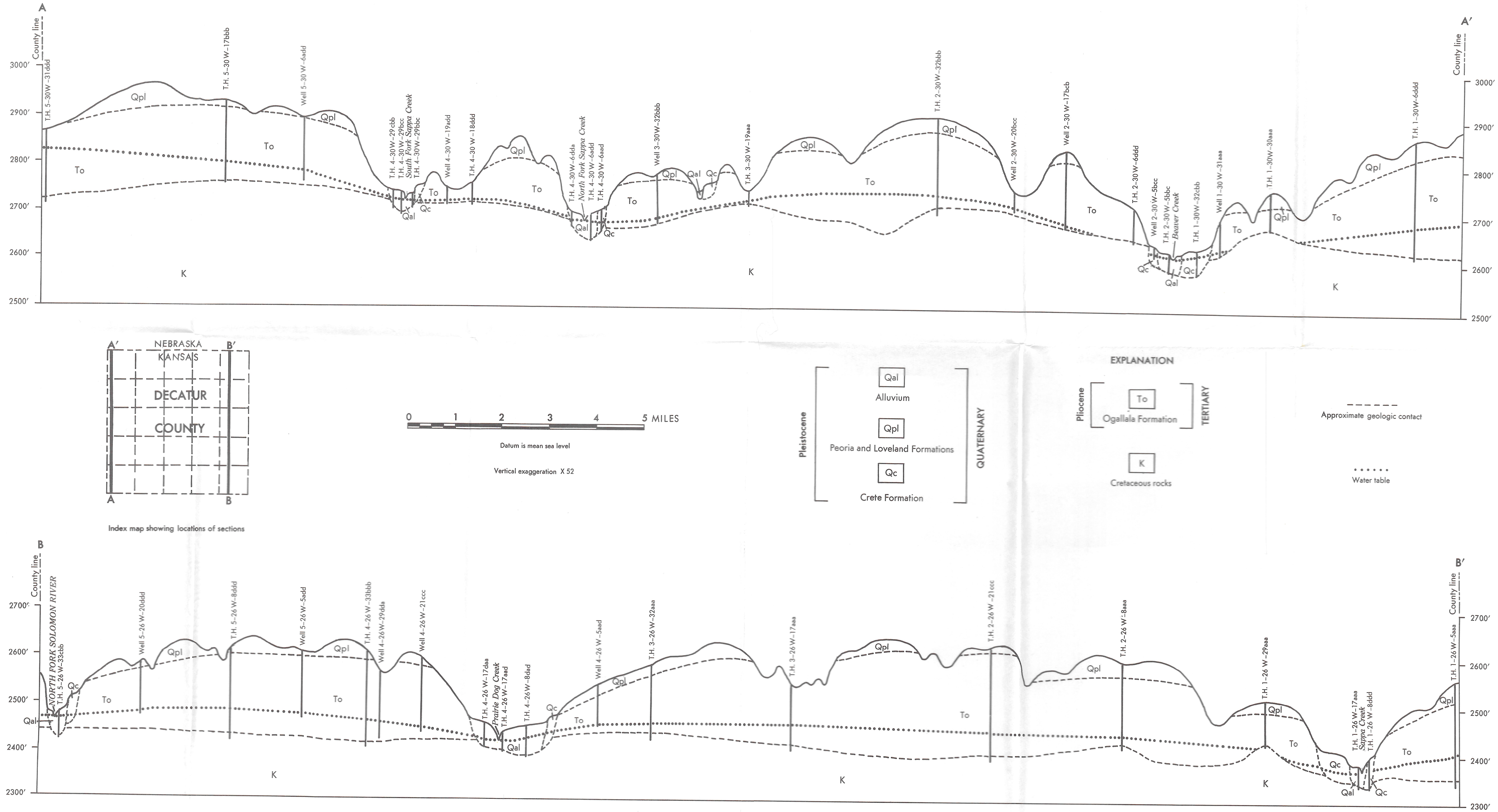

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