Geology and Ground-Water Resources of Mitchell County, Kansas

By

WARREN G. HODSON

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By WARREN G. HODSON
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By Warren G. Hodson

ABSTRACT

This report describes the geography, geology, and ground-water resources of Mitchell County, north-central Kansas. The county has an area of about 720 square miles and a population of about 10,000. Mitchell County lies within the Smoky Hills physiographic province of Kansas.

The rocks that crop out in Mitchell County are sedimentary and range in age from Cretaceous to Recent. The oldest rocks exposed are sandstone, clay, and shale beds of the Dakota Formation. They are overlain by a conformable sequence of Cretaceous marine rocks classified, in ascending order, as the Graneros Shale, Greenhorn Limestone, Carlile Shale, and Fort Hays Limestone member of the Niobrara Formation. Unconsolidated continental deposits of fluviatile and eolian origin represent three stages of the Pleistocene Epoch. Pleistocene deposits include the Crete Formation and Loveland Formation of Illinoian age, Peoria Formation of Wisconsinan age, and alluvial deposits of Wisconsinan and Recent ages. The surface geology is shown by a map, and cross sections illustrate the stratigraphic relations of the geologic formations.

Ground water in Mitchell County is recharged mainly by local precipitation; ground water is discharged mainly by effluent seepage to streams and by transpiration. Most municipal, industrial, domestic, and stock water supplies are obtained from wells. Moderate supplies of ground water are available from the alluvium and terrace deposits of Solomon Valley, but ground-water supplies in the upland areas are small. A map shows the direction of movement of ground water in Solomon Valley and the location of test holes and wells inventoried in Mitchell County.

In general, ground water in Mitchell County is hard but otherwise suitable for most uses. Waters from some wells, however, contained excessive amounts of certain constituents. The Dakota Formation provides potable ground water only in the eastern part of the county; ground water from the Dakota in the western part is too mineralized for most uses.

The field data upon which this report is based are given in tables. They include records of 310 wells, logs of 60 test holes, and chemical analyses of waters from 53 representative wells.

INTRODUCTION

Purpose and Scope of Investigation

This report gives the results of a study of the geology and ground-water resources of Mitchell County, Kansas. The study was designed to determine the quantity and quality of ground water in the county and as a guide to future ground-water development. The only source of moderate supplies of ground water in Mitchell County is the alluvium of Solomon Valley and the adjacent alluvial terrace deposits. The Cretaceous bedrock formations in Mitchell County are not good aquifers, but because they are the only sources of ground water in the upland, consideration is given to these formations and their water-bearing properties.

This study was made as a part of the co-operative ground-water program begun in 1937 by the State Geological Survey of Kansas and the United States Geological Survey, in co-operation with the Division of Sanitation of the Kansas State Board of Health and the Division of Water Resources of the Kansas State Board of Agriculture. The purpose of this program is to survey county areas and major stream valleys or irrigation districts to determine the availability of ground water.

Location and Extent of Area

Mitchell County lies in the second tier of counties from the northern border of Kansas and midway between the east and west borders of the state (Fig. 1). The county extends 24 miles north and south and 30 miles east and west and has an area of about 720 square miles.

Previous Investigations

In 1897 Haworth discussed the physiography of western Kansas, and Williston (1897) described the stratigraphy of the Niobrara

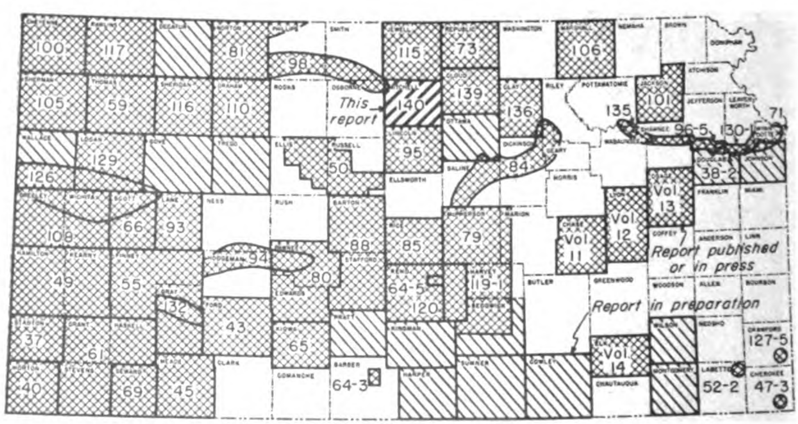


FIG. 1.—Index map of Kansas showing area discussed in this report and areas for which co-operative ground-water reports have been published or are in preparation.

Formation of western Kansas. Darton (1905) included in his report a discussion of water wells in western Kansas. In 1913, Haworth briefly discussed the availability of ground water along the Solomon Valley. Landes (1930) described the geology of Mitchell and Osborne Counties and included a brief discussion of ground-water resources. Moore and others (1940) discussed the general occurrence of ground water in Kansas; the general availability of ground water along the Solomon Valley was mentioned by Lohman and others (1942). Byrne, Johnson, and Bergman (1951) discussed construction-material resources in Mitchell County. Leonard (1952) described the geology and ground-water resources of North Fork Solomon Valley, which traverses the extreme northwestern part of Mitchell County.

Methods of Investigation

The writer spent 3½ months during the summer and fall of 1954 and 2 months during the summer of 1955 in the field gathering the data upon which this report is based. The areal geology was mapped from field observations and stereoscopic study of aerial photographs obtained from the U. S. Department of Agriculture. County maps prepared by the State Highway Commission of Kansas at a scale of 1 inch to the mile were used to record field data.

Wells inventoried in the county total 310 (Table 17). Most wells were measured by means of a steel tape graduated to hundredths of a foot to determine the depth of the well and the depth to the water level. Measurements in a few wells could not be made, or were unreliable, and data on depth and water level for these wells were obtained from the owner or driller. Surface altitudes of most of the wells that were used as control for the water-table contours shown in the Solomon Valley on Plate 3 were interpolated from topographic quadrangle maps of the U. S. Geological Survey. Surface altitudes of wells for which topographic quadrangle maps were not available were determined by plane table and alidade.

Water samples were collected from 48 typical wells in the county, and the chemical analyses of these samples are given in Table 5. In addition, analyses of municipal water supplies within the county were obtained from the State Board of Health. Water samples were collected from Solomon River at 3-mile intervals for partial analysis to determine points of contribution of chloride (Table 14).

All samples were analyzed by Howard A. Stoltenberg, Chemist, in the Water and Sewage Laboratory of the Kansas State Board of Health.

Test holes in a line across the Solomon Valley were drilled by Leo Reavis and William Gellinger, using a hydraulic-rotary drilling machine of the State Geological Survey. Samples of drill cuttings were collected and examined in the field and were studied later in the laboratory. Logs of test holes drilled in a line across the Solomon Valley along the Mitchell-Cloud county line during the fall of 1953 (Bayne and Walters, 1959) and logs of test holes drilled in a line across North Fork Solomon Valley in western Mitchell County in the spring of 1946 (Leonard, 1952) are included in this report. In addition, logs of test holes drilled for the proposed Glen Elder dam project in the vicinity of Glen Elder by the Bureau of Reclamation in the fall of 1949, the winter of 1952, and the spring of 1954 are included. Cross sections were prepared from test-hole data; logs of the test holes are given at the end of the report.

Location and Well-Numbering System

The location of wells, test holes, and local features in this report are designated according to General Land Office surveys in the following order: township, range, section, 160-acre tract within that section, 40-acre tract within that quarter section, and 10-acre tract within that quarter-quarter section. The 160-acre, 40-acre, and 10-acre tracts are designated a, b, c, or d in a counterclockwise direction beginning in the northeast quarter. For example, well 7-9-12bca is in the NE¼ SW¼ NW¼ sec. 12, T. 7 S., R. 9 W. (Fig. 2).

Acknowledgments

Appreciation is expressed to the residents and municipal officials of Mitchell County who so kindly supplied information and gave assistance during the course of the field work. The manuscript of this report has been reviewed critically by several members of the Federal and State Geological Surveys; by Robert V. Smrha, Chief Engineer, and George S. Knapp, Engineer, Division of Water Resources, Kansas State Board of Agriculture; and by Dwight F. Metzler, Chief Engineer, and Willard O. Hilton, Geologist, Division of Sanitation, Kansas State Board of Health.

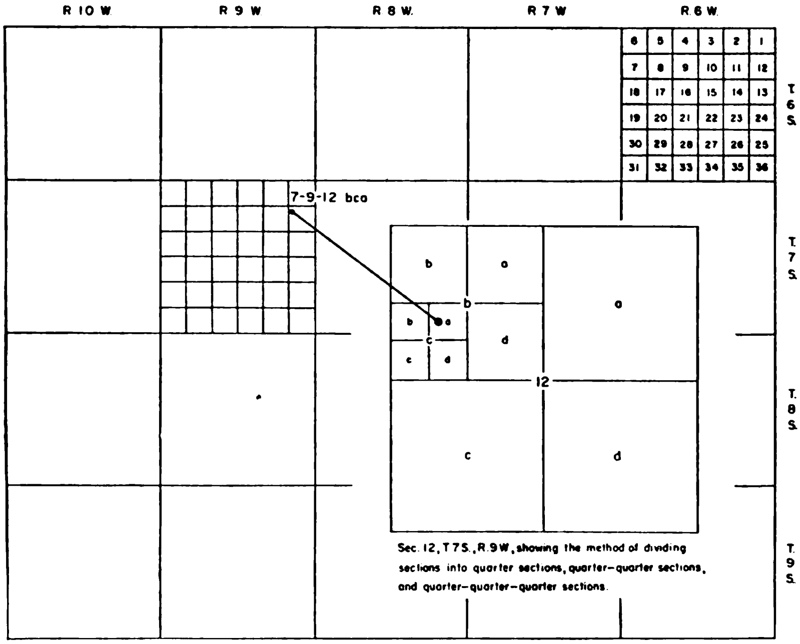


Fig. 2.—Diagram of Mitchell County illustrating location and well-numbering system used in this report.

GEOGRAPHY

Topography and Drainage

Mitchell County lies within the Plains Border section of the Great Plains physiographic province as defined by Fenneman (1931). In Adams' physiographic divisions of Kansas (1903), Mitchell County lies within the Smoky Hills Upland division. Later Schoewe (1949) placed the area within the Dissected High Plains physiographic division of Kansas. More recently Frye and Schoewe (1953) have proposed that the area be placed within the Smoky Hills physiographic division of Kansas (Fig. 3).

Surface drainage in Mitchell County is controlled chiefly by Solomon River and its tributaries. Salt Creek is the largest stream in the southern part of the county, and flows eastward to a confluence with Solomon River in Ottawa County. The southwestern corner of Mitchell County is drained by tributaries of Saline River, which flows eastward across Lincoln County. The valley of Solomon River is asymmetrical, the south walls being markedly steeper than the north walls. Asymmetrical valleys are characteristic of eastward- (and westward-) flowing streams in Kansas. Such valleys are believed to result from a combination of climatic factors that cause more rapid weathering and erosion of southward-facing slopes, which in turn results in deposition of more material on the north slope, thus forcing the river southward (Bass, 1929, p. 17-23).

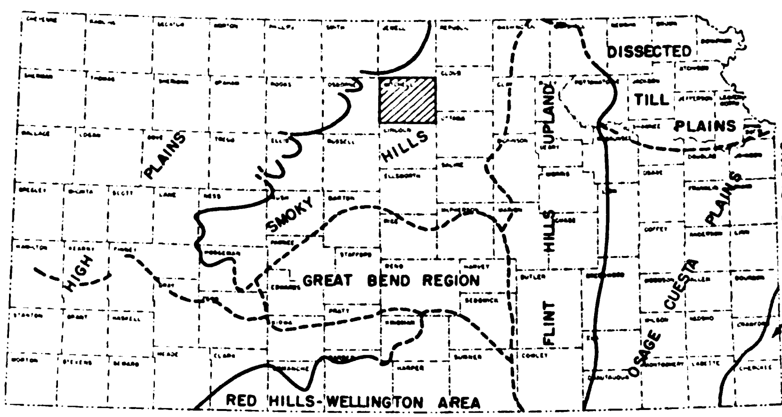


FIG. 3.—Physiographic regions of Kansas, showing areas of topographic homogeneity (after Frye and Schoewe, 1953).

Topographically Mitchell County can be divided into three areas: the alluvial valleys, the dissected upland, and the Blue Hills. The alluvial valleys are those of Solomon River and its major tributaries. The Solomon River valley consists of a narrow flood plain and broad terraces designated the Kirwin Terrace by Leonard (1952). The surface of the Kirwin Terrace is consistent with the terrace surfaces in the major tributary valleys. North and South Forks of Solomon River join about 2 miles south of Cawker City to form the main stream. Salt Creek drains much of the southern part of the county. The valley of Salt Creek is broad and flat, and is entrenched by the narrow channel of the creek. Most of Mitchell County is a rolling upland plain moderately dissected by the tributaries of Solomon River in the central and northern parts of the county and by those of Salt Creek in the southern part. The upland consists of rounded to moderately steep sided hills of Cretaceous bedrock covered by a relatively thin layer of loess. The walls of the valleys through which the smaller streams flow are gently sloping for the most part. The Blue Hills in the southwestern part of Mitchell County stand almost 300 feet above the general upland level. The hills are buttes and small mesas; the steep slopes are developed on the Blue Hill Shale member of the Carlile Shale, which is capped by the Fort Hays Limestone member of the Niobrara Formation. Soil on the butte tops is very thin and stony.

The average altitude of Mitchell County is about 1,600 feet. The lowest altitude, about 1,300 feet, is along Solomon River at the east boundary of the county. The altitude of the Blue Hills in the southwestern part of the county is nearly 1,900 feet. In the western part of Mitchell County, Solomon River flows about 150 feet below the general summit level of the upland. In the eastern part, Solomon River flows about 250 feet below the upland. From the Kirwin Terrace level the relief of the upland ranges from about 100 feet in the western part of the county to slightly more than 200 feet in the eastern part. Scattered small remnants of Pleistocene alluvial deposits form high terraces along the valley walls.

Climate

The climate of Mitchell County is subhumid (U. S. Department of Agriculture, 1941) and is characterized by relatively cold winters and warm summers. Annual precipitation (Fig. 5) exceeds mean annual water loss (precipitation minus runoff, Fig. 11) by only a small margin. Precipitation normally is concentrated in the late spring and early summer when it is most effective for the growing of crops. The principal source of moisture is tropical air from the Gulf of Mexico. Winter weather is variable as a result of the procession of cyclones and anticyclones and their assorted tropical and polar air masses that cross the region.

According to records of the U. S. Weather Bureau and to Flora (1948), the mean annual temperature of Mitchell County is about 54° F. The longest growing season and the shortest growing season on record are 194 days and 128 days, respectively. Figure 4 shows graphically the normal monthly precipitation at Beloit. The normal annual precipitation in Mitchell County is 24.17 inches, about 75 percent of which falls during the 6 months of the growing season. Records show that the precipitation at Beloit has ranged from a minimum of 12.46 inches during 1934 to a maximum of 41.95 inches during 1951. The annual precipitation and cumulative departure from normal precipitation are shown in Figure 5.

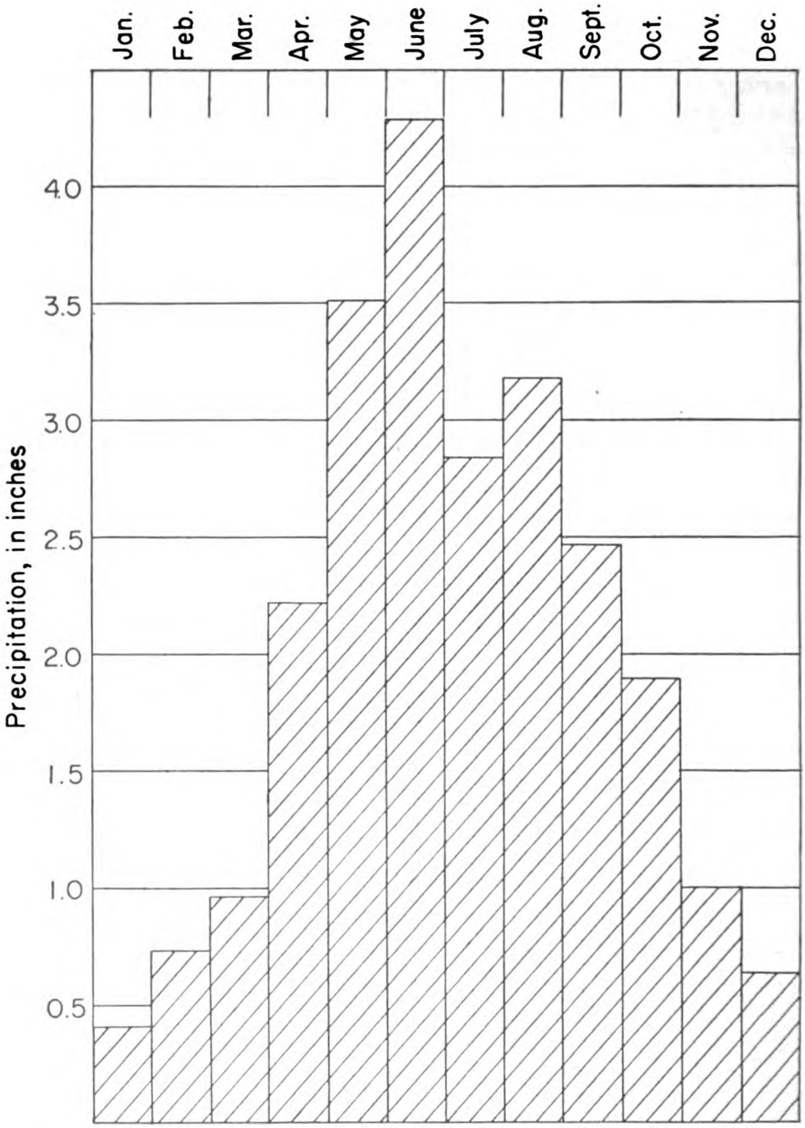


FIG. 4.—Normal monthly precipitation at Beloit for the period 1898-1942.

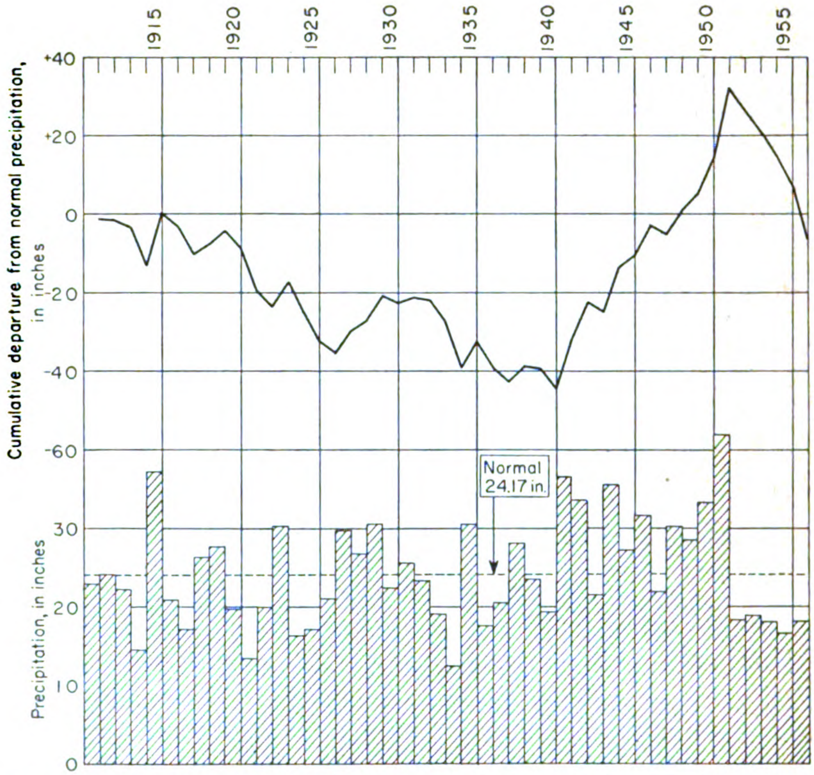


FIG. 5.—Annual precipitation and cumulative departure from normal precipitation at Beloit.

POPULATION

According to the 1950 census, Mitchell County had a population of 10,320, of which 6,235 were rural and 4,085 were urban. The population density in the more thickly settled Solomon Valley area is considerably greater than the average for the county. The 1950 population of Beloit, the county seat and largest city, was 4,085. Cawker City, Glen Elder, and Simpson, three other communities within Solomon Valley, had populations of 547, 305, and 298, respectively. Tipton and Hunter, in southwestern Mitchell County, had populations of 246 and 236, respectively; Scottsville, in the northwestern corner of the county, had a population of 108.

Transportation

Three railroads serve the county. A line of the Missouri Pacific Railroad Co. extends east-west along the north side of the Solomon Valley and northeastward from Beloit through Scottsville. A branch line of the Union Pacific Railway Co. extends southeastward from Beloit. A line of the Atchison, Topeka & Santa Fe Railway Co. crosses the southwest corner of the county through Tipton and Hunter. U. S. Highway 24 extends east-west along the Solomon Valley, and Kansas Highway 9 from the east joins U. S. Highway 24 near Beloit. Kansas Highway 14 runs north-south through Beloit, and Kansas Highway 128 extends north from a point near Glen Elder. Kansas Highway 181 crosses the southwest corner of the county through Tipton and Hunter. The rest of the county is served by improved county and township roads.

Agriculture

Agriculture is the chief industry in Mitchell County, wheat being the principal crop. Other major crops are sorghum, oats, barley, and alfalfa. Cattle and sheep are the predominant livestock. The distribution of cultivated and grazing land is influenced by topography and stratigraphy. Nearly all the cultivated land lies in the alluvial valleys or on the loess-mantled uplands. The grazing land is generally the rolling upland having a thin soil cover underlain by limestone or shale.

GEOLOGY

Summary of Stratigraphy*

The areal distribution of rocks exposed in Mitchell County is shown on Plate 1. The rocks are sedimentary in origin and range in age from Cretaceous to Recent (Moore and others, 1951). A generalized section of the geologic rock units is given in Table 1. The Dakota Formation of Cretaceous age is the oldest stratigraphic unit exposed in Mitchell County. It underlies the entire county and crops out in the eastern part. Overlying the Dakota Formation is a conformable sequence of Cretaceous marine rocks classified in ascending order as the Graneros Shale, Greenhorn Limestone, Carlile Shale, and Niobrara Formation. The Sanborn Group, of late Pleistocene age, is represented by wind-deposited loess mantling the uplands, by colluvial deposits of unsorted Cretaceous rock frag-

* The stratigraphic classification used in this report is that of the State Geological Survey of Kansas and differs somewhat from that of the United States Geological Survey.

ments and eolian silt lapping against the valley walls, and by high terrace deposits, of which only a few isolated remnants remain. Adjacent to the river channel and its tributaries is a narrow belt of alluvium. The alluvium is of Recent age, and this material is still being deposited by the streams. Adjacent to the alluvium of Solomon River and its main tributaries are terrace deposits of late Wisconsinan age laid down by these streams during an earlier aggradational cycle. These terrace deposits are classified as a part of the Sanborn Group, but owing to differences in lithology and water-bearing characteristics, they have been mapped and discussed separately in this study.

Geologic History and Geomorphology

The oldest rocks exposed in Mitchell County are the sandstones and clay shales of the Dakota Formation of Cretaceous age. The history of geologic events that preceded the deposition of the Dakota Formation is deduced partly from logs of oil and gas test wells in Mitchell County and surrounding areas and partly from surface exposures of rocks that, although deeply buried in Mitchell County, crop out farther east.

Precambrian Rocks

The oldest rocks beneath Mitchell County are the Precambrian crystalline rocks. These rocks have not been reached in any known test wells drilled in Mitchell County but have been penetrated in adjacent areas and are the basement rocks upon which later rocks were deposited. Landes (1927), in a study of the Precambrian rocks in Kansas from samples of deep-well cuttings, determined that the Precambrian rocks consist mainly of granite or granite gneiss and schist. The Precambrian rocks were subjected to long exposure and erosion, which reduced the land surface to a relatively level plain.

Paleozoic Era

Upper Cambrian sandstone and dolomite are the oldest rocks of Paleozoic age in this area of Kansas (Lee and others, 1948). Throughout the Paleozoic, this area was repeatedly inundated by epicontinental seas and subjected to subaerial erosion, resulting in deposition of sandstone, limestone, dolomite, and shale separated by many hiatuses.

A period of folding that began in Mississippian time and continued with diminishing movement through Pennsylvanian into

TABLE 1.—*Outcropping geologic formations of Mitchell County and their water-bearing properties*

SYSTEM	Series	Group	Formation	Thickness, feet	Physical character	Water supply
Quaternary	Pleistocene		Recent alluvium	0–30	Unconsolidated sand, gravel, silt, and clay. Crossbedded and lenticular, stratified in upper part. Underlies recent flood plain and occurs in stream channels.	Yields moderate quantities of water to wells along Solomon Valley; smaller supplies along tributary valleys.
		Sanborn	Terrace deposits	0–60	Unconsolidated sand and gravel grading upward into stratified clay and silt. Lower part lenticular and crossbedded. Humic layers common in upper part. Underlie flat terraces in valleys of larger streams.	Yield moderate quantities of water to wells along Solomon Valley; smaller supplies along tributary valleys.
			Peoria Formation	0–35	Massive eolian silt and sandy silt, calcareous, tan and gray. Blankets much of upland.	Yields no water to wells.
			Loveland Formation	0–10	Reddish-tan silt. Part eolian and part slopewash consisting of eroded Cretaceous bedrock.	Yields little or no water to wells.
			Crete Formation	0–20	Remnants of alluvial deposits consisting of sand, gravel, and silt, forming high terraces along Solomon Valley and its major tributaries.	Yields no water to wells.
Cretaceous	Gulfian	Colorado	Niobrara Formation (Fort Hays Limestone member)	0–45	Massive beds of cream-colored chalky limestone separated by thin partings of chalky shale. Forms prominent buttes.	Yields no water to wells.
			Carlile Shale	0–300	Gray to black clayey shale containing large septarian concretions near top and thin silty sandstone (Codell Sandstone zone) at top. Lower part consists of alternating beds of chalky shale and thin chalky limestone; limestone beds contain discoidal calcareous concretions.	Yields no water to wells.

		Greenhorn Limestone	0–85	Alternating beds of calcareous shale and chalky limestone. Thin beds of hard crystalline limestone at base. Contains thin bentonite beds.	Yields meager to small supplies of water of variable quality from place to place.
		Graneros Shale	0–25	Shale, noncalcareous, fissile, blue gray. Locally contains red-brown sandstone lenses.	Yields little or no water to wells.
		Dakota Formation (includes Kiowa Shale)	350	Clay, shale, siltstone, and sandstone; interbedded and varicolored. Contains lignite and "ironstone". Sandstone is lenticular, crossbedded, soft, and brown to orange.	Yields small to moderate supplies of water of variable quality from place to place in eastern part of county, becoming too mineralized for use in the central and western parts.

Permian time (Lee and others, 1948) produced the Nemaha Anticline, which trends slightly east of north and extends through Kansas along a line running through Sumner County and Nemaha County. Upward folding along the Nemaha Anticline was accompanied by a downwarping along its flanks. This downwarping created a large syncline, known as the Salina Basin, on the west flank of the anticline and paralleling the northern flank of the Central Kansas Uplift, which was still active at that time (Lee and others, 1948). Pre-Pennsylvanian erosion removed nearly all the Paleozoic rocks from the anticline and beveled part of the rocks on its flanks. In Mitchell County, within the Salina Basin, an estimated total of 1,200 feet of Cambrian, Ordovician, Silurian, Devonian, and Mississippian rocks remained at the beginning of Pennsylvanian time.

During most of Pennsylvanian and early Permiam times, the floor of the Salina Basin stood close to sea level, and cyclical deposits of alternating beds of limestone and shale were laid down in shallow and fluctuating seas (Moore, 1936). A middle and late Permiam interval during which a widespread emergence produced shallow basins and low plains is recorded by "redbed" deposits of sandstone, shale, siltstone, and evaporites. Chemical precipitates of salt and gypsum were deposited as products of evaporation in shallow bodies of water resulting from an arid climate during middle and late Permian time. These salt deposits thin to the east and north and are not present in the subsurface in the eastern and northern parts of Mitchell County (Bass, 1926a, p. 90). A continental environment predominated during the latter part of the Permian, and by the close of the period the shallow seas had withdrawn completely.

Mesozoic Era

Triassic and Jurassic rocks are not present in Mitchell County. If deposits of Triassic and Jurassic age, as well as late Permian, were deposited, they were later removed. During the Triassic and Jurassic periods and into early Cretaceous time, this area of Kansas was subjected to subaerial erosion.

The Cheyenne Sandstone, of continental and littoral origin, is the oldest Cretaceous deposit in Kansas and was laid down across the beveled edges of Permian rocks as the Cretaceous sea advanced northward. The Cheyenne Sandstone, however, does not reach as far north as Mitchell County (Frye and Brazil, 1943). The oldest Cretaceous rocks in Mitchell County are believed to be the marine shales of the Kiowa Shale. Overlying the Kiowa Shale are clay shales and sandstones of the Dakota Formation, which represent a return of continental and littoral deposition. The Cretaceous sea again advanced northward, and marine conditions prevailed during deposition of the thick sequence of Cretaceous shale, limestone, and chalk of the Graneros Shale, Greenhorn Limestone, Carlile Shale, and Niobrara Formation, that forms much of the bedrock in Mitchell County. At the close of Cretaceous time the sea had withdrawn from the area, and the environment has been continental since that time.

Cenozoic Era

Tertiary Period.—In early Tertiary time the Rocky Mountain province to the west was uplifted extensively. Eastward-flowing streams that crossed the Great Plains during most of Tertiary time removed considerable quantities of Cretaceous rocks in western and central Kansas. During the Pliocene Epoch a reversal from stream erosion to stream deposition occurred. Streams from the Rocky Mountains that crossed western and central Kansas began to aggrade their channels and deposited large quantities of alluvial material in their valleys. As the stream valleys became filled, the streams spread across the bedrock divides, shifted laterally, and developed an extensive alluvial plain of sand, gravel, clay, and silt (Ogallala Formation) that merged westward with the erosional surface in the Rocky Mountain region (Frye, 1945). Low stream gradients and choking of the channels and lateral shifting of streams near the end of deposition of the Ogallala may have resulted in the formation of many small water-table lakes and abandoned channel segments. The "Algal limestone", a distinctive hard bed of limestone, marks the top of the Ogallala Formation. The origin of the "Algal limestone" is controversial. Elias (1931) postulated a lacustrine origin for the capping limestone. Later workers advanced the hypothesis of subaerial origin as a caliche zone. Smith (1940) discussed the two hypothesis regarding the origin of the "Algal limestone", and more recently Frye, Leonard, and Swineford (1956) critically discussed the origin of the bed, postulating a mode of origin by development of a mature to senile lime-accumulating soil, which was later modified by solution.

As much as 350 feet of the Ogallala Formation was deposited in parts of western Kansas, but these deposits thin rapidly toward the east. In Mitchell County, the only known exposure of the Ogallala is a small outcrop of "Algal limestone" about 1 foot thick on an upland stream divide in the SE¼ NE¼ sec. 1, T. 9 S., R. 6 W., on the Mitchell-Ottawa County line. Other thin "Algal limestone" deposits in Mitchell County similar to this one may be concealed between the Carlile Shale and the overlying loess cover.

Quaternary Period.—The events that formed the present topographic features in Mitchell County began with the close of "Algal limestone" deposition and the beginning of the Pleistocene Epoch. Climatic changes that resulted in the formation of the great ice sheets characterize the Pleistocene Epoch. Although none of the continental ice sheets that advanced toward the central United States reached Mitchell County, the development of the present landscape of the county was influenced greatly by Pleistocene glaciation and the associated climatic fluctations that prevailed during Pleistocene time.

The Pleistocene in Kansas is divided into four glacial stages, each one followed by an interglacial stage. The Nebraskan Stage (glacial) was followed by the Aftonian Stage (interglacial), the Kansan Stage (glacial) was followed by the Yarmouthian Stage (interglacial), the Illinoian Stage (glacial) was followed by the Sangamonian Stage (interglacial), and the Wisconsinan Stage (glacial) was followed by the Recent Stage, which may be regarded as an interglacial stage.

No deposits of Nebraskan or Kansan age have been identified in Mitchell County. Thus, the sequence of events that took place during Nebraskan and Aftonian time and Kansan and Yarmouthian time is deduced from early Pleistocene deposits in other areas. Shortly before the beginning of the Pleistocene Epoch there was either uplift of the land or a climatic change that caused streams to entrench their channels through former deposits and, in those areas where the Ogallala Formation was thin, to cut into the underlying bedrock. The major streams of this area during early Pleistocene time were probably flowing at about the same locations as are the present streams. These streams were probably not trunk streams, however, but headed not far west of Mitchell County. Thus, they would not have cut into the thick Tertiary deposits of sand and silt farther west until later in the Pleistocene. During the Nebraskan Stage the principal activity of these streams probably consisted of cutting down their channels, and only a minor amount of alluvial material seemingly was deposited, later to be removed by erosion.

Deposits of late Kansan age at Kirwin in Phillips County (Frye and Leonard, 1954) attest that by Kansan time Solomon River had become a trunk stream and the approximate pattern of modern drainage was established. During early Kansan time, stream activity in Mitchell County was probably much the same as during early Nebraskan time, the principal activity being downcutting of the drainage system. During late Kansan time the streams became overloaded and began to aggrade their channels. Deposits of sand and gravel forming high terraces along North Fork Solomon River near Cedar in Smith County and near Portis in Osborne County have been classified as late Kansan in age (Leonard, 1952, p. 38). No deposits of Kansan age have been recognized along North Fork or Solomon River downstream from Portis, near the Osborne-Smith county line.

During the early part of the Illinoian stage, stream activity was renewed and streams again degraded and widened their valleys. A depositional phase of stream activity during Illinoian time consisted of aggrading the earlier channels with coarse chalk fragments, sand, gravel, and silt. In Mitchell County these poorly sorted materials form early Illinoian channel deposits classified as the Crete Formation. Almost all these deposits subsequently have been eroded away, and most of those remaining are being quarried for road-construction material. Much of the Crete Formation is of local origin, but arkosic sand and gravels that are present in the deposits indicate that Solomon River during Illinoian time was a trunk stream carrying eroded Tertiary deposits from the west.

Following Illinoian fluviatile deposition and probably in part contemporary with it, eolian silt classed as the Loveland Formation was deposited over much of the upland of Mitchell County. Aggraded valleys and their resultant flood plains were probably the source of the wind-deposited silt making up the Loveland loess. Late Sangamonian time represented a period of stability at which time a well-developed soil (Sangamon) formed on the Loveland loess. The topography of the area at this time was more subdued than the present topography, as Solomon River had not made its maximum incision.

During Wisconsinan time streams again deepened their valleys and most of the earlier Illinoian channel deposits were removed. Solomon River cut its channel in Mitchell County an estimated 100 feet below the base of the Crete Formation of Illinoian age. This period of cutting was followed by rapid alluviation during late Wisconsinan time, and alluviation probably extended into early Recent time. During this time Solomon River filled its channel with deposits of sand, gravel, and silt (late Wisconsinan terrace deposits). In the deeper parts of the valley fill, these alluvial deposits range from 40 to 60 feet in thickness and constitute the most important ground-water reservoir in Mitchell County.

The blanket of Peoria loess that mantles the upland and overlies the Loveland loess has been dated as early Wisconsinan in age (Frye and Leonard, 1952). The Peoria probably was picked up by the wind from the flood plains of Platte and Republican Rivers to the north and spread in a broad sheet across northwestern and north-central Kansas. The Peoria loess overlies the Loveland of late Illinoian age in the upland but is not present on the late Wisconsinan terrace deposits of the Solomon Valley. That the deposits of the Peoria are mostly eolian in origin is attested by their fine texture, lack of bedding, molluscan fauna, and stratigraphic position above an extensive well-developed soil, and by the fact that they blanket the upland, valley slopes, and high terraces alike.

In some areas of Kansas, cut-and-fill cycles of both early and late Wisconsinan age are present and in places, very distinct (Frye and Leonard, 1952). In north-central Kansas early Wisconsinan alluvial deposits are rarely exposed, if at all, however, and if present they generally constitute the lower part of the alluvial valley fill below the Kirwin Terrace surface. Inferred early Wisconsinan deposits in the lower part of valley fills have been penetrated by test drilling in parts of northern Kansas (Frye and Leonard, 1952, p. 125; Leonard, 1952, p. 50). Cross section E-E′ (Pl. 2) illustrates what seems to be a separate and older cut-and-fill cycle within the Wisconsinan stage and may be early Wisconsinan alluvial deposits. From the topography of the area it seems that the north wall of Solomon Valley runs along a line about half a mile north of Solomon Rapids. Data from test holes, however, show that at this point the valley wall stands more than a mile farther north. Against the north side of the valley wall, as shown in cross section E-E′, is an old meander loop that has been cut off and abandoned. The depth of the incision is well below the late Illinoian terrace deposits, but is about 30 feet above the deeper incision in the main part of the Solomon Valley cut. Logs of test holes (6-8-35bbb, 6-8-35bcc, and 6-8-35ccc) show that the fill contains sand and gravel in the lower part and silt in the upper part. A buried soil horizon in the upper part of the silt was recognized in the test holes. Surface expression of the old channel is masked by eolian silt that covers the older alluvial deposits (Pl. 1). The old meander, which seemingly swings back into Solomon Valley about 3 miles west of Beloit, may be responsible, in part, for the high yield of the irrigation well (7-8-1adc1) on the Gerald Smith farm.

In early Recent time, Solomon River was again rejuvenated and began to cut into the late Wisconsinan alluvial fill. Since this cutting cycle began, Solomon River has entrenched its channel well into the older alluvial deposits, cutting both vertically and laterally. Segments of intermediate minor terrace scarps on the flood plain record former flood-plain levels as the meander belt of the stream shifted laterally back and forth across the flood plain. Slip-off slope terraces facing the undercut amphitheaters in expanded meander curves are common along the edges of the narrow flood plain.

Solomon River continues to broaden its flood plain, removing the older terrace deposits. As the meander belt swings back and forth across the valley, terrace deposits are eroded away on the outer bank of meander curves by means of bank caving; beds of lateral accretion are deposited on the inner side of meander curves, building and extending the alluvial flood plain. Deposition during flood stages continues to spread a thin veneer of fine sediments (vertical accretion) over the modern flood plain. This process of erosion and deposition still goes on as Solomon River continues to deepen its channel and widen its flood plain. That the meander belt of the river is active is exemplified by old meander scars, ox-bow lakes, and cutoffs on the modern Solomon River flood plain.

GROUND WATER

Principles of Occurrence

The discussion of the occurrence of ground water in Mitchell County is based on the treatment of the occurrence of ground water by Meinzer (1923). Moore and others (1940) discussed the principles of ground-water occurrence with special reference to Kansas.

All the water below the surface of the earth is called subsurface water to distinguish it from surface water and from atmospheric water. The rocks that form the crust of the earth are rarely, if ever, solid throughout but contain many open spaces called interstices. These open spaces range in size from minute spaces between particles of silt, clay, or shale, through larger openings between grains or pebbles in sandstone, sand, and gravel to open channels formed by fractures or solution. The percentage of the total volume of material that consists of open spaces is termed the porosity. A formation in which the openings are interconnected and large enough to allow water to move to a well is called an aquifer. Although the amount of water that can be stored in an aquifer depends on the porosity, it is the permeability of an aquifer that determines the rate at which ground water can move. The permeability of an aquifer depends upon the number and size of its open spaces, or interstices, and the extent to which these interstices are interconnected. The permeability of an aquifer is measured by the quantity of water that will flow per unit time through a unit area of the aquifer under a hydraulic gradient of unity.

Water percolating from the surface into the rocks of the earth is drawn downward by gravity. Some of the water will reach a zone where all the open spaces are filled with water under hydrostatic pressure. This zone is called the zone of saturation. A part of the water percolating downward will not reach the zone of saturation but will be held by molecular attraction, or surface tension, to the walls of the open spaces through which the water passes in its descent. This zone of suspended water above the water table is termed the zone of aeration. The zone of aeration consists of three parts: the belt of soil water, the intermediate belt, and the capillary fringe. The belt of soil water, lying just below the land surface, consists of soil and loose materials from which water discharges into the atmosphere by plant transpiration or by direct evaporation. The open spaces of the intermediate belt below the belt of soil water are usually filled with air and water and may at times contain appreciable amounts of water in transit to the water table. The intermediate belt may be absent, however, where the water table is near the surface. The capillary fringe lies directly above the water table and contains water drawn up by capillary action from the zone of saturation. In general, the thickness of the capillary fringe varies inversely with the size of the interstices. In clean gravel, the capillary fringe almost disappears; in silt or clay, the fringe may be several feet thick. Figure 6 is a diagram showing, in general, the divisions of subsurface water.

Under water-table conditions, the term water table designates the surface between the zone of saturation and the zone of aeration. Where a water-bearing formation is confined between relatively impermeable beds and water is supplied to it from an adjacent area of higher altitude, the water table is absent and the water is said to be confined or under artesian pressure. Under artesian condi-

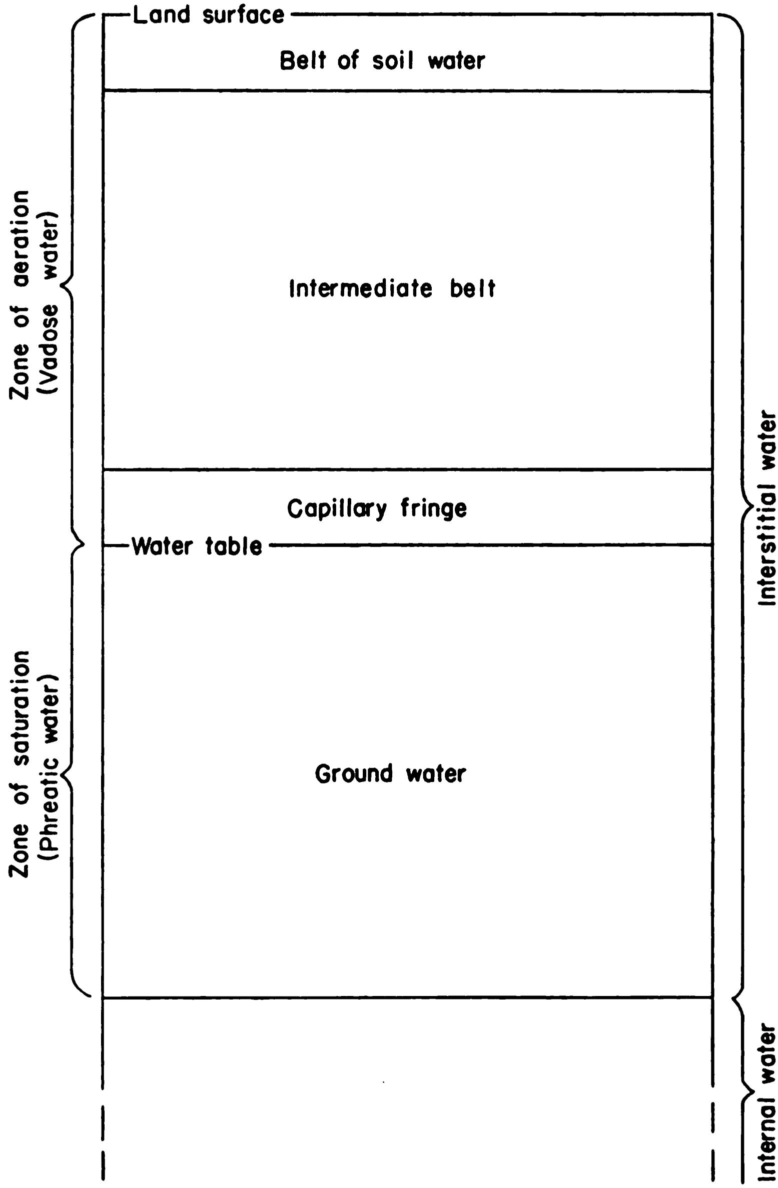


Fig. 6.—Diagram showing generalized divisions of subsurface water, after Meinzer (1923a, Fig. 2).

tions, water enters the water-bearing formation at the intake area, percolates downdip, and exerts considerable pressure on the upper confining layer. Under these conditions, water is confined under hydraulic pressure similar to water in a pipe connected to a reservoir at a higher elevation. When an aquifer under artesian pressure is penetrated by a well, water will rise in the well to a height equal to the hydraulic head. The imaginary surface connecting this level in wells is called the piezometric surface. Whether the well flows at the surface depends on the altitude of the piezometric surface. For an artesian well to flow, the piezometric surface must be at a higher altitude than the land surface.

Ground water in Mitchell County is under both water-table and artesian conditions. Water-table conditions are present in shallow aquifers such as terrace deposits and alluvium. Much of the ground water in the Dakota Formation is under artesian pressure. To determine whether water is artesian or under water-table conditions may necessitate an aquifer test to determine the hydraulic characteristics of the aquifer.

Source of Ground Water

In north-central Kansas, as in other parts of the Great Plains, ground water is derived almost entirely from local precipitation in the form of rain or snow. Part of the precipitation that falls in Mitchell County becomes surface runoff and is carried away by streams; part of it is absorbed by vegetation and is transpired into the atmosphere; part of it is returned directly to the atmosphere by evaporation. The rest percolates downward to the water table, later to be discharged by effluent seepage to bodies of surface water, or to be evaporated and transpired.

The movement of ground water in Solomon Valley, as shown on Plate 3 by the slope of the water table, is in a downstream direction toward the east and southeast. Therefore, a small amount of water from the drainage basins of North and South Forks of Solomon River to the west and north eventually enters Mitchell County by subsurface inflow and contributes to the supply of ground water in the area.

Ground water available to wells in the Dakota Formation in the Dakota outcrop area in the eastern part of Mitchell County is for the most part derived locally, but wells that penetrate the Dakota Formation west of its outcrop area tap artesian water, and the piezometric surface at some places is more than 80 feet above the level at which the water is confined. This indicates that the water in the Dakota is derived from some adjacent area where the formation either crops out or is overlain by permeable beds. Bayne and Walters (1959) have constructed a water-table map for the Dakota Formation in Cloud County that indicates that ground water in the Dakota in the western part of Cloud County is moving westward into Mitchell County.

Water Table

The water table is not a level surface but is a sloping surface marked by many mounds, depressions, and ridges. In general, the water table is a subdued reflection of the land surface. The shape of the water table is affected by differences in permeability of the water-bearing material and by unequal additions or withdrawals of ground water. In places where recharge to an aquifer is exceptionally high owing to the presence of overlying permeable material, such as sandy silt, the water table may build up a low mound from which the water slowly spreads out. Depressions in the water table indicate places where ground water is discharging, generally where water is withdrawn by wells or along streams that are below the level of the water table. Streams that gain water from the flow of ground water are said to be gaining or effluent streams. Conversely, streams that are above the water table and contribute water to the water table are said to be losing or influent streams (Fig. 7).

The streams in Mitchell County are the principal features affecting the water table. Solomon River and its North and South Forks are perennial. The larger tributaries of Solomon River flow except during prolonged dry seasons. Most tributaries in the area are intermittent streams that are sometimes influent streams and sometimes effluent, depending upon the relation of the water table to the stream bed. Other streams in the area are ephemeral streams and flow only in response to precipitation.

Fluctuations of the Water Table

The water table does not remain stationary but fluctuates up and down in response to recharge and discharge of ground water. A rise of the water level indicates that recharge exceeds discharge; a decline of the water level indicates that discharge exceeds recharge. Thus, changes in water levels indicate to what extent the reservoir is being replenished or depleted. If the water-bearing materials have a specific yield of 20 percent, the addition of 1 foot of water

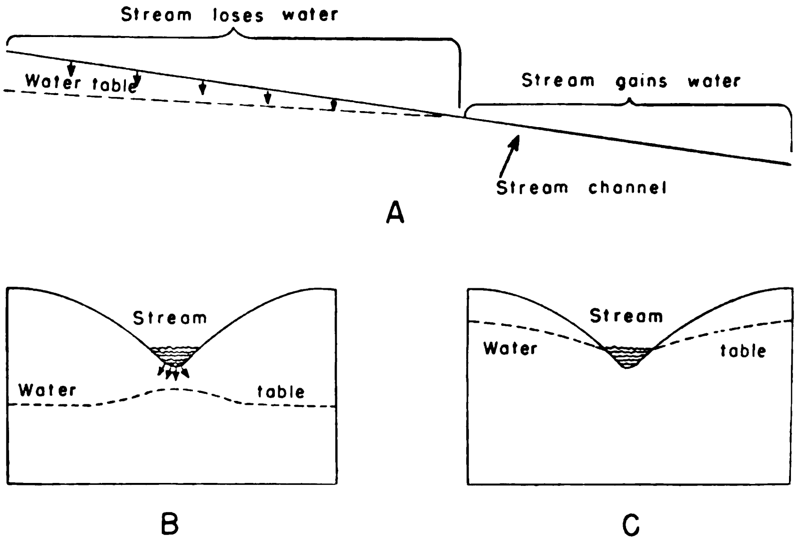


FIG. 7.—Diagrammatic sections showing influent and effluent streams. A, Longitudinal section showing (right) how river gains water and (left) how it loses water. B, Transverse section across influent part of river. C, Transverse section across effluent part of river. (After Latta, 1944, fig. 14.)

to the ground-water reservoir will cause a rise of the water table of 5 feet.

Hydrographs showing the fluctuations of the water level in 12 observation wells and graphs showing monthly precipitation are given in Figures 8 and 9. The graphs show the normal precipitation in the area of the wells, the monthly precipitation, and the cumulative departure from the normal annual precipitation. Figure 10 is a hydrograph of a well near Glen Elder having a 22-year record. The graphs indicate that, for a large part of the record, precipitation and fluctuations of the water levels correlate closely. Records of these water levels are published annually by the U. S. Geological Survey (1935-56). Water-level measurements in well 6-9-27abc from 1934 to 1956 are given in Table 16.

Movement of Ground Water

The rate of movement of ground water is determined by the size, shape, number, and degree of connection of the open spaces in the aquifer and by the hydraulic gradient. The configuration of the water table in Solomon Valley is shown by water-table contours on Plate 3. The direction of ground-water movement is at right angles to the contour lines in the downslope direction. The movement of ground water is toward Solomon River and down the valley from the west toward the east. This conforms to the general rule that ground water under water-table conditions moves toward and with the major drainage.

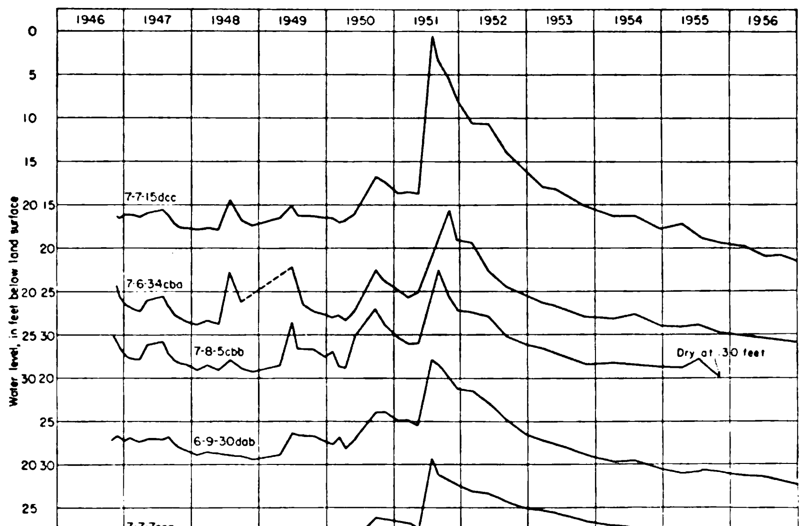


FIG. 8.—Hydrographs showing fluctuations of water levels in six wells, and graphs showing monthly precipitation and annual cumulative departure from normal precipitation at Beloit.

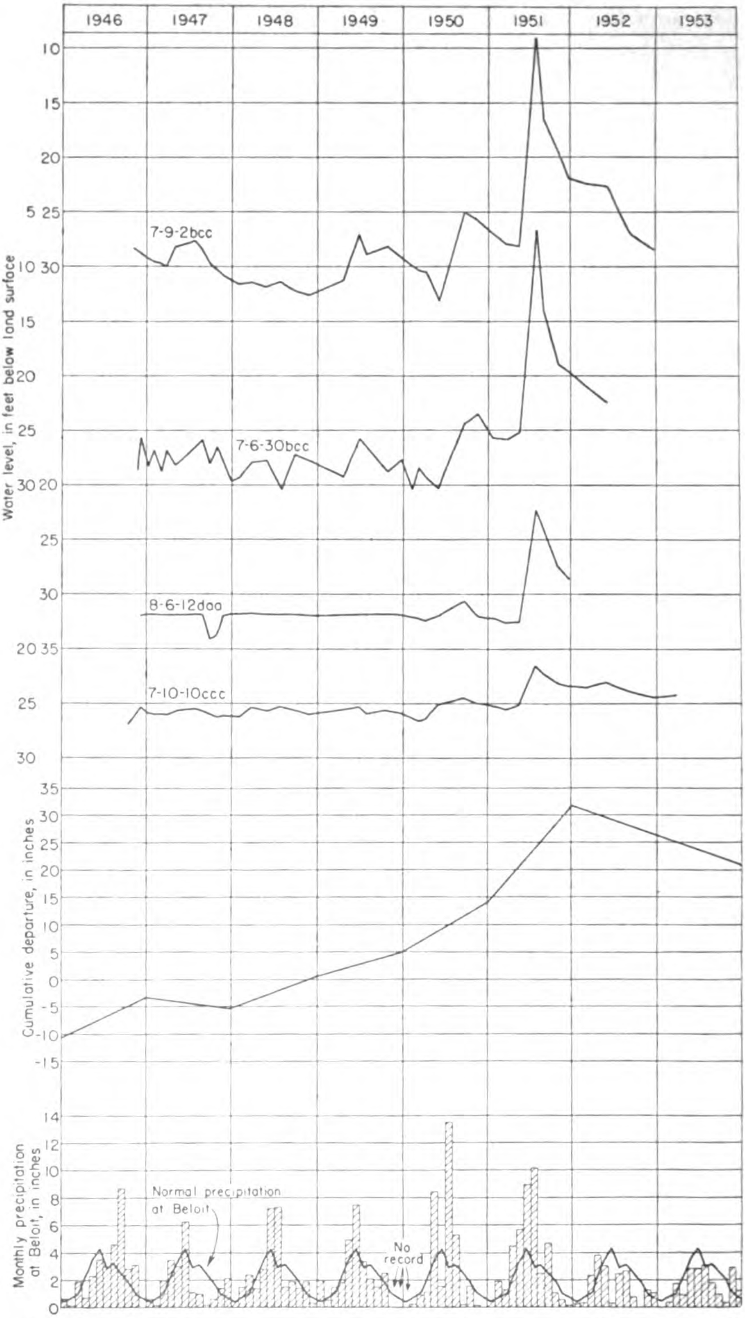


Fig. 9.—Hydrographs showing fluctuations of water levels in four wells, and graphs showing monthly precipitation and annual cumulative departure from normal precipitation at Beloit.

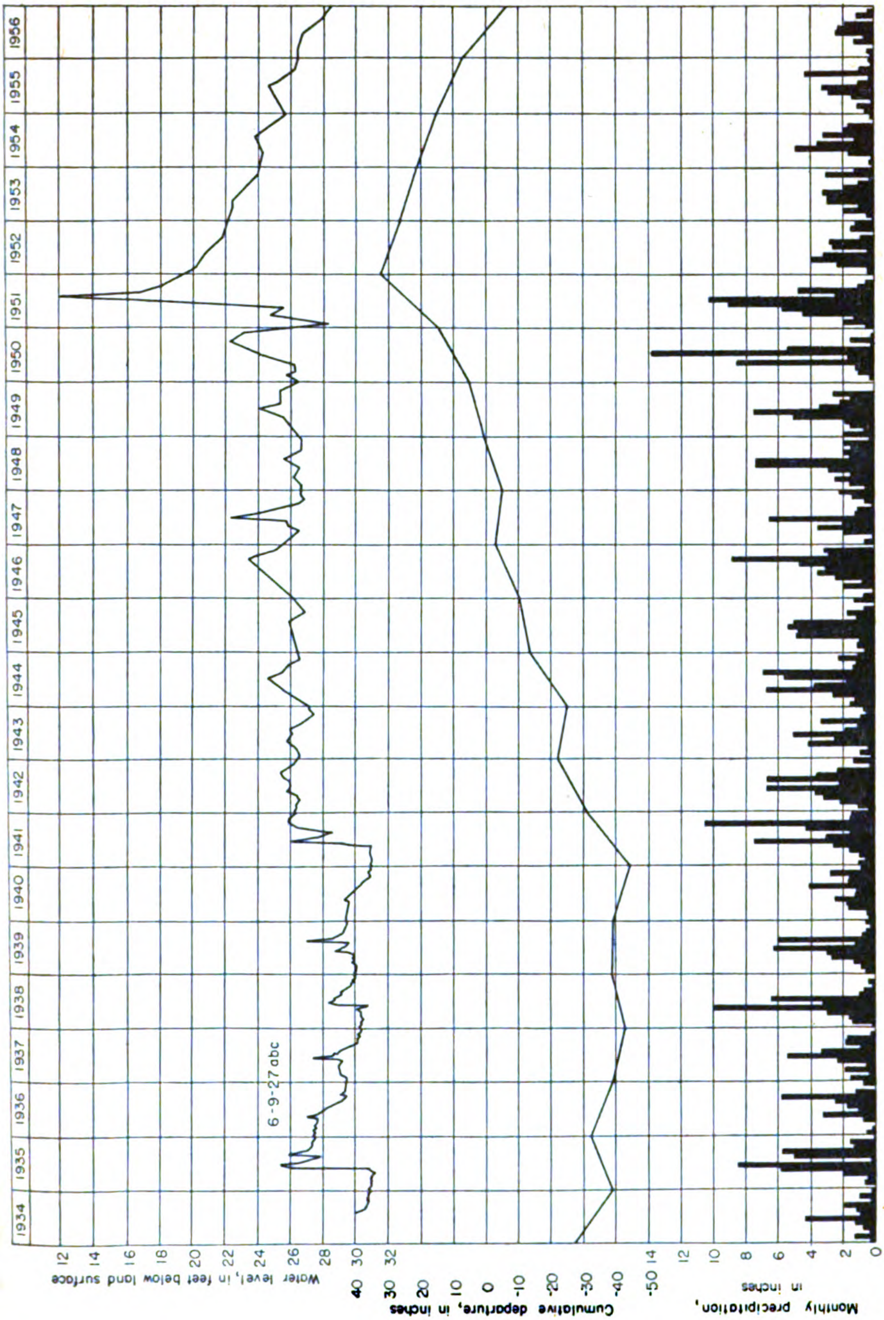


FIG. 10.—Hydrograph showing fluctuation of water level of a well, and graphs showing monthly precipitation and annual cumulative departure from normal precipitation at Beloit.

In general, the slope of the water table varies inversely with the permeability of the aquifer. In areas where the water-bearing beds are less permeable, the slope of the water table steepens and the water-table contours are closely spaced; in areas of permeable water-bearing beds, the water-table contours are spaced farther apart. The downstream slope of the water table in Solomon Valley averages about 5 feet per mile across Mitchell County.

Ground-Water Recharge

Recharge is the addition of water to the ground-water reservoir. Ground water in Mitchell County is derived primarily from local precipitation. One inch of water falling on 1 square mile amounts to more than 17 million gallons. Thus, the normal annual precipitation of 24.17 inches amounts to approximately 420 million gallons of water per square mile. Only a small part of the normal annual precipitation, however, reaches the ground-water reservoir. Part of the water that falls as precipitation is carried away as surface runoff by streams; part is evaporated into the atmosphere; part is absorbed by vegetation and later transpired to the atmosphere. Water that is not discharged by these processes percolates downward to the zone of saturation. After the water reaches the water table, it moves slowly down the gradient of the water table toward points of discharge such as springs, wells, or effluent streams.

The type of soil as well as the type of material above the water table are important in determining the amount of recharge in an area. A loose, permeable soil will allow penetration of water that would otherwise be discharged by surface runoff. A good vegetative cover will retard the velocity of runoff and will allow water to seep into the soil. Conditions are always much more favorable for rainfall infiltration during a gentle rain of considerable duration than during a sudden downpour. Conservation practices such as land terracing and contour farming tend not only to retard soil erosion but also to reduce runoff. Conservation practices such as these provide additional moisture for growing plants and where the precipitation is sufficient may increase the amount of recharge to the ground-water reservoir. In the upland of Mitchell County many ponds have been constructed to provide water for livestock. Most ponds are in small tributaries, and some of the water they impound eventually becomes ground-water recharge.

About 77 percent of the normal annual precipitation in Mitchell County falls during the months of April through September, when the climate is characterized by strong wind movement, high temperatures, and relatively low humidity. Consequently, a high rate of evaporation results, and much of the annual precipitation returns to the atmosphere. Because much of the precipitation falls during the growing season, a considerable part is returned to the atmosphere through absorption and transpiration by plants. In Mitchell County, the amount of annual precipitation that is discharged through evaporation and transpiration is estimated to be about 22 or 23 inches, as shown in Figure 11. The mean annual precipitation for Mitchell County is about 24 inches; thus, the amount of runoff, including both surface and ground-water runoff, averages only about 1 or 2 inches a year. The amount of recharge over Mitchell County is far from uniform, because of variations in soil conditions and topography and because of variations in the amount of precipitation from one place to another.

Ground-Water Discharge

Ground-water discharge is the release of water from the zone of saturation. In Mitchell County, ground water is discharged into streams through effluent seepage, by discharge of springs, by transpiration of plants whose roots tap the zone of saturation or the capillary fringe, by evaporation, and by pumping of wells. Ground water leaves the valleys also by subsurface movement to the east and southeast.

Effluent seepage and springs.—A stream whose bed is lower than the water table receives water from the zone of saturation. Water-table contour lines on Plate 3 indicate that ground water is moving toward Solomon River and its North and South Forks. Ground water also contributes to the flow of the larger tributaries of Solomon River, except during extended dry periods. A few small springs issue from the Greenhorn Limestone in Mitchell County. The springs generally are in stream beds or along stream banks where erosion has exposed the formation. Many of these springs are of the "wet weather" type and flow only during times of normal or excessive precipitation.

Evapotranspiration.—Direct evaporation to the atmosphere from the zone of saturation is limited to areas where the water table is sufficiently near the land surface, such as along stream banks and in stream beds. As these conditions are restricted to a small part of Mitchell County, discharge by evaporation probably is not large. After floods or after long periods of exceptionally heavy rainfall when the water table is near the surface in local areas, appreciable

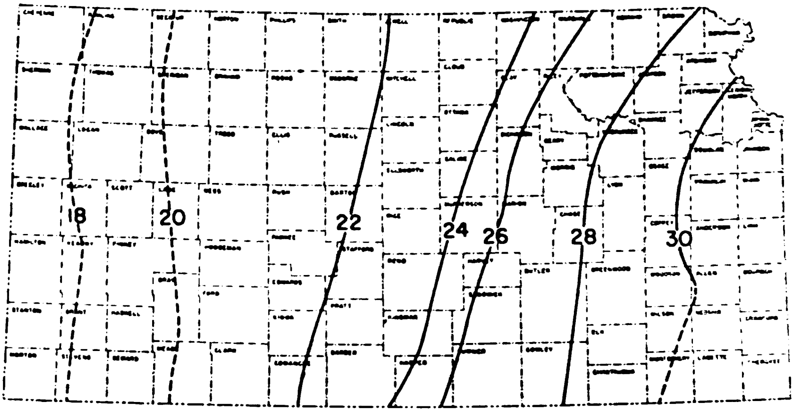


FIG. 11.—Map of Kansas showing lines of mean annual water loss, in inches (precipitation minus runoff), adapted from Williams and others (1940, pl. 2).

amounts of ground water from lowland areas may be evaporated into the atmosphere.

Water may be taken into the roots of plants directly from the capillary fringe or from the zone of saturation, as well as from the soil zone, and discharged from the plants by evaporation from the leaves (transpiration). The depth from which plants will lift ground water varies with different plant species and with the type of material the roots penetrate. The lift of common field crops and grasses is only a few feet, but many water-loving plants, called phreatophytes, are capable of sending their roots deep in search of water. Certain desert plants are known to send their roots to depths of 50 or 60 feet (Meinzer 1923, p. 82). In Mitchell County, phreatophytes capable of obtaining ground water at considerable depths include alfalfa, cottonwood and willow trees, and certain weeds. Alfalfa may obtain ground water where the water table is as much as 30 feet below the surface. The discharge of ground water by transpiration is not significant in the upland of Mitchell County. In the Solomon Valley and some of the larger tributary valleys, however, alfalfa is one of the principal farm crops, and probably in some places considerable water is drawn directly from the zone of saturation through transpiration by this plant. In addition, many trees line the banks of Solomon River and its major tributaries and draw water from the zone of saturation.

Ground-water pumping.—The pumping of ground water by wells is one of the principal means of ground-water discharge. The effect of pumping of wells upon ground water within an aquifer depends upon the size, extent, and permeability of the aquifer and the quantity of water pumped from the aquifer by all wells in the area. Discharge from domestic and stock wells obtaining water from sand and gravel in the alluvial deposits of the larger streams of Mitchell County produces little effect upon the water table. Discharge from wells in bedrock aquifers in the upland areas may deplete the water supply, especially during prolonged periods of deficient precipitation. The effect of pumping high-yielding wells from the alluvial deposits of the Solomon Valley is discussed on page 40.

Subsurface movement.—Some ground water leaves the area by subsurface movement, principally toward the east and southeast. This movement of water takes place in the alluvium and terrace deposits of stream valleys, the most important of which are those of Solomon River and Salt Creek. Some water may move westward out of the county in the Dakota Formation and deeper rocks.

Waconda Springs

Waconda Springs, about 2½ miles east of Cawker City, obtain water under artesian pressure from the Dakota Formation. As early as 1885, Hay recognized this probability (Hay, 1885). The largest spring, known as Great Spirit Spring, is the only one usually visited. Great Spirit Spring is at the northern edge of the flood plain of Solomon River. Another spring is on the flood plain about half a mile southeast of Great Spirit Spring. A third spring is in the bed of Solomon River, a short distance south of the second spring.

A mound of travertine has accumulated around the orifice of Great Spirit Spring. The travertine cone is about 300 feet wide at the base and rises about 30 feet above the flood plain. The top of the cone is approximately at the same level as the surface of the nearby Kirwin Terrace. The travertine of the cone consists of irregular thin sheets that tend to parallel the surface of the cone. The cone was circular in original development, but one side has been truncated by a chute across the flood plain caused by Recent stream action (Pl. 4A). The spring orifice, or vent at the top, is about 54 feet in diameter. The water of the spring rises nearly to the top of the mound, most of the water escaping through openings on the flanks of the mound (Pl. 4B).

Many opinions are expressed locally concerning the origin of Great Spirit Spring. Some people are of the opinion that the spring is of volcanic origin; others believe that it is connected with the ocean and is affected by the tides. The chemical analysis

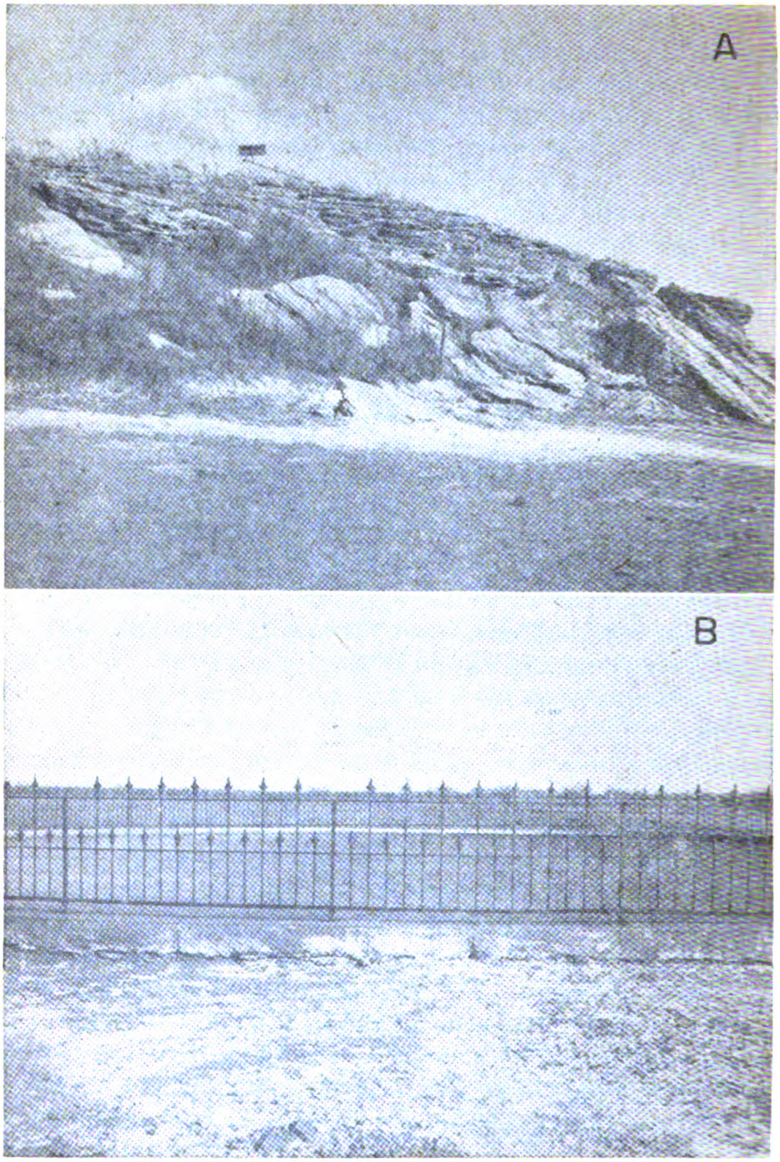


PLATE 4.—**A,** Travertine cone of Great Spirit Spring. A chute, in foreground, has truncated one side of cone. **B,** Orifice of Great Spirit Spring.

of the water shows that water from Great Spirit Spring and water from the Dakota Formation in Mitchell County are very much alike, both having a very high content of sodium, sulfate, and chloride.

Thus, Waconda Springs seem to be artesian springs in which water from the Dakota Formation rises in cracks or fissures to the surface under hydrostatic pressure. That water from the Dakota Formation will rise to the level of the Kirwin Terrace was demonstrated at a test hole in the SW cor. sec. 32, T. 6 S., R. 8 W., about 7 miles east of Waconda Springs. This test hole was drilled through the terrace deposits and into sandstone of the Dakota Formation. Until the hole was plugged, water that was salty to the taste flowed at the surface.

Swineford and Frye (1955) postulated a mechanism to account for Great Spirit Spring and its mound of travertine. They assumed a fault zone in the underlying Cretaceous bedrock through which artesian water from the Dakota Formation is transmitted upward via a tubelike vent through the fresh-water zone in the overlying alluvial deposits. The walls of the vent were made impermeable by precipitation, in the interstices of the alluvial material, of calcium carbonate from the mineralized artesian water.

Swineford and Frye (1955) dated the age of Great Spirit Spring as relatively recent by the association of its travertine cone with the terrace deposits and flood plain of the Solomon River valley. They concluded that the building of the travertine cone started less than 8,000 years ago and that the deposition of travertine may have terminated as much as 1,000 years ago. The chemical composition of water from Great Spirit Spring is given in Table 2.

TABLE 2.—*Chemical composition of water from Great Spirit Spring, November 1954* (Analysis by Howard Stoltenberg, Chemist, Division of Sanitation, Kansas State Board of Health).

Constituents	ppm	Constituents	ppm
Calcium (Ca^{++})	213	Carbonate (CO_3^{--})	0.0
Magnesium (Mg^{++})	413	Bicarbonate (HCO_3^-)	1,720
Sodium (Na^+)	6,230	Sulfate (SO_4^{--})	3,370
Silica (SiO_2)	6.0	Chloride (Cl^-)	7,700
Iron (total Fe)	.52	Nitrate (NO_3^-)	2.0
Manganese (Mn)	.15	Fluoride (F^-)	1.6
Total solids	18,800		
Total hardness*	2,230		
*as $CaCO_3$			

Recovery of Ground Water

Discharge from a well (other than a flowing artesian well) is effected by the operation of a pump or some other lifting device. When a well is at rest, the head of water inside the well is in equilibrium with that of water outside the well. When water is discharged from a well, a difference in head is established between the water inside the well and water in the surrounding aquifer. As a result of this differential head, water moves from the aquifer toward the well.

When water is withdrawn from a well, the water level in the vicinity of the well is lowered to form what is called the cone of depression (Fig. 12). The lateral extent of the cone of depression is called the area of influence, and the vertical distance that the water level is lowered is called the drawdown. When pumping stops, the cone of depression gradually fills with water from the surrounding area until equilibrium is again reached between the water level in the well and the surrounding aquifer. A higher pumping rate in a well produces a greater drawdown; thus, water moves toward the well under a steeper gradient and at a greater rate. When large quantities of water are withdrawn from a high-yielding well, such as an irrigation well, the water level drops rapidly at first, but gradually drops more slowly until it becomes almost stationary. When pumping stops, the water level rises rap-

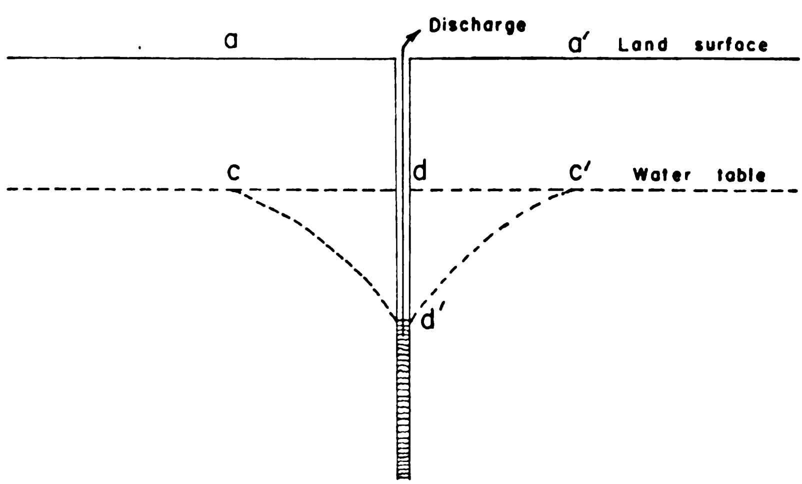


Fig. 12.—Diagrammatic section of a well that is being pumped, showing drawdown (dd′), cone of depression (cc′d′), and area of influence (aa′), after Meinzer (1923a, fig. 30).

idly at first, gradually rising more slowly until it finally reaches approximately its original position. A recovery curve of irrigation well 7-6-20bdd is shown in Figure 13.

The character, thickness, and extent of the water-bearing materials as well as the construction and condition of the well determine the yield and resultant drawdown of a well. If the water-bearing material is coarse, well rounded, and uniform in size, it will readily yield large quantities of water and have relatively little drawdown. If the water-bearing material is fine or poorly sorted, it will offer more resistance to the flow of water toward the well and decrease the yield and increase the drawdown.

Hydrologic Properties of Water-Bearing Materials

Porosity and specific yield.—The amount of water that can be stored in an aquifer depends upon the porosity of the aquifer. Porosity is expressed quantitatively as the percentage of the total volume of material that consists of open spaces. An aquifer is said to be saturated when all its open spaces are filled with water.

Not all the water will drain from the aquifer, some being held by molecular attraction. The part that drains from the aquifer is called the specific yield and the part that is retained is called the specific retention. The specific yield of a water-bearing formation is defined by Meinzer (1923a, p. 28) as the ratio of the volume of water that a saturated sample of the formation will yield by gravity, divided by the volume of the sample. The specific yield is a measure of the quantity of water that a formation will yield when it is drained by a lowering of the water table and is usually stated as a percentage.

Permeability and transmissibility.—The coefficient of permeability of an aquifer is defined as the rate of flow of water, in gallons per day, through a square foot of its cross section, under a hydraulic gradient of 1 foot per foot, at a temperature of 60°F. The field coefficient of permeability is the same, except that it is measured at the prevailing temperature rather than at 60°F. The coefficient of permeability of water-bearing materials may be stated as discharge per unit of area per unit of hydraulic gradient.

The coefficient of transmissibility is a function similar to the coefficient of permeability. The coefficient of transmissibility may be expressed as the rate of flow of water, in gallons per day, through a vertical strip of the aquifer 1 foot wide, under a hydraulic gradient of 1 foot per foot, at the prevailing temperature. The coefficient of transmissibility is equal to the field coefficient of permeability multiplied by the saturated thickness of the aquifer. Both permeability and transmissibility can be conveniently expressed for field use as the flow in gallons per day, across a section 1 mile wide under a hydraulic gradient of 1 foot per mile, rather than a section 1 foot wide under a gradient of 1 foot per foot.

Aquifer tests.—The permeability and transmissibility of the alluvial materials in Solomon Valley were calculated from an aquifer test by use of the recovery method developed by Theis (1935, p. 522) and described also by Wenzel (1942, p. 94). According to the recovery formula:

$$T = \frac{264Q \log_{10} t/t'}{s'}$$

in which T is the coefficient of transmissibility, in gallons per day per foot

Q is the pumping rate, in gallons per minute
t is the time since pumping began, in minutes
t′ is the time since pumping stopped, in minutes
s′ is the residual drawdown at the pumped well at time t′, in feet.

The residual drawdown (s′) at any time after pumping ceases (t′) is computed by subtracting the static water-level measurement before pumping began from the water-level measurement made at time t′. The ratio of $\log_{10} t/t'$ to s′ may be determined graphically by plotting $\log_{10} t/t'$ against corresponding values of s′. This procedure is simplified by plotting t/t′ on the logarithmic co-ordinate and s′ on the arithmetic co-ordinate of semilogarithmic paper (Fig. 13). If $\log_{10} t/t'$ is taken over one log cycle, it will become unity, and s′ will be the difference in drawdown over one log cycle. The above formula then reduces to: $T = \frac{264\,Q}{\Delta s'}$ in which $\Delta s'$ is the change in residual drawdown for one log cycle.

An aquifer test using irrigation well 7-6-20bdd, owned by Henry Remus, was made on September 30, 1954. The well was pumped 4½ hours at a rate of 256 gallons per minute and the depth to water was measured frequently. Depth-to-water measurements were made frequently during the recovery period for 6½ hours after pumping ceased. The data used in the calculation of the coefficients of transmissibility and permeability are given in Table 3. The time-versus-drawdown curve is shown in Figure 13.

TABLE 3.—*Data on aquifer test using well 7-6-20bdd, made on September 30, 1954.*

Time since pumping began, minutes (t)	Time since pumping ended, minutes (t′)	t/t′	Depth to water level, feet	Drawdown or residual drawdown, feet
0	....	....	9.49	0
35	....	....	35.40	25.91
65	....	....	31.97	22.48
90	....	....	33.54	24.05
120	....	....	32.77	23.28
150	....	....	33.80	24.31
180	....	....	35.53	26.04
210	....	....	33.10	23.61
240	....	....	34.97	25.48
268	....	....	35.99	26.50
270	0	....	....	....
272	2	136.0	15.65	6.16
275	5	55.0	13.65	4.16
277	7	39.6	13.33	3.84
278	8	34.7	13.00	3.51
280	10	28.0	12.33	2.84
282	12	23.5	12.11	2.62
284	14	20.3	11.91	2.42
286	16	17.9	11.74	2.25
288	18	16.0	11.60	2.11
290	20	14.5	11.49	2.00
292	22	13.3	11.40	1.91
294	24	12.2	11.28	1.79
296	26	11.4	11.21	1.72
298	28	10.6	11.14	1.62
300	30	10.0	11.07	1.58
303	33	9.2	10.98	1.49
306	36	8.5	10.90	1.41
309	39	7.9	10.85	1.36
312	42	7.4	10.74	1.25
315	45	7.0	10.72	1.23
318	48	6.6	10.69	1.20
321	51	6.3	10.62	1.13
324	54	6.0	10.57	1.08
327	57	5.7	10.56	1.07
330	60	5.5	10.53	1.04
335	65	5.1	10.47	.98
340	70	4.9	10.42	.93
345	75	4.6	10.39	.90
350	80	4.4	10.34	.85
355	85	4.2	10.31	.82
360	90	4.0	10.28	.79
375	105	3.6	10.18	.69
390	120	3.2	10.13	.64
405	135	3.0	10.07	.58

TABLE 3.—*Data on aquifer test using well 7-6-20bdd, made on September 30, 1954—Concluded.*

Time since pumping began, minutes (t)	Time since pumping ended, minutes (t′)	t/t′	Depth to water level, feet	Drawdown or residual drawdown, feet
420	150	2.8	10.02	.53
435	165	2.6	10.00	.51
480	210	2.3	9.90	.41
540	270	2.0	9.81	.32
600	330	1.8	9.77	.28
660	390	1.7	9.75	.26

TABLE 4.—*Data on aquifer test using well 7-8-1adc, made on June 9, 1955.*

Time since pumping began, minutes (t)	Time since pumping ended, minutes (t′)	t/t′	Depth to water level, feet	Drawdown or residual drawdown, feet
0	....	....	35.27	0
5	....	....	46.55	11.28
8	....	....	42.40	7.13
12	....	....	42.30	7.03
20	....	....	42.29	7.02
25	....	....	42.31	7.04
35	....	....	42.30	7.03
50	....	....	42.32	7.05
60	....	....	42.13	6.86
73	....	....	42.25	6.98
85	....	....	42.36	7.09
130	....	....	42.45	7.18
135	....	....	42.42	7.15
155	....	....	42.43	7.16
158	0	....	....	....
159	1	159.0	35.79	0.52
161	3	53.7	35.70	0.43
162	4	40.5	35.66	0.39
164	6	27.3	35.62	0.35
167	9	18.6	35.60	0.33
170	12	14.2	35.58	0.31
175	17	10.3	35.54	0.27
180	22	8.2	35.53	0.26
186	28	6.6	35.52	0.25
192	34	5.6	35.50	0.23
196	38	5.2	35.49	0.22
230	72	3.2	35.44	0.17
365	207	1.7	35.38	0.11

The computations are as follows:

$$T = \frac{(264)(256)}{1.60} = 42{,}000 \text{ gpd/ft.}$$

$$P_f = \frac{42{,}000}{31.5} = 1{,}300 \text{ gpd/ft.}^2$$

The coefficient of transmissibility is computed to be about 42,000 gallons per day per foot. The coefficient of permeability, which is obtained by dividing the transmissibility by the thickness of the water-bearing material, 31.5 feet, is about 1,300 gallons per day per square foot.

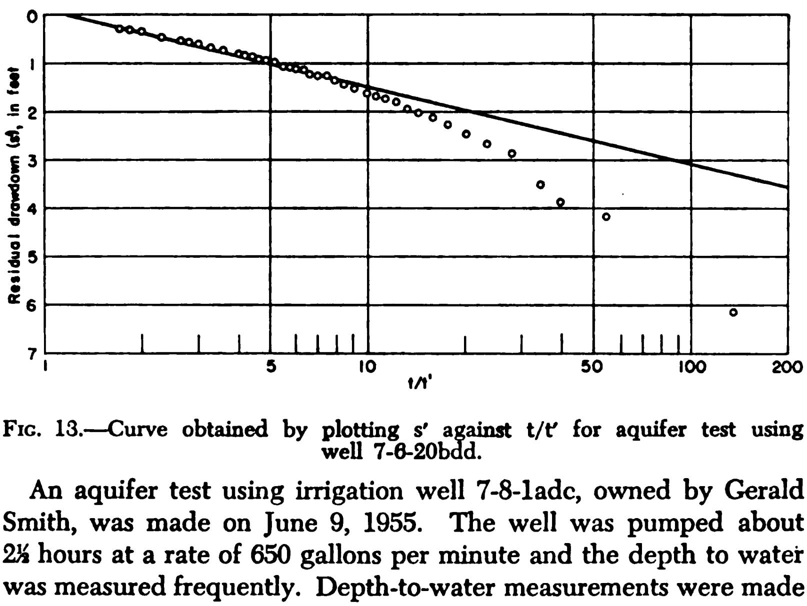


FIG. 13.—Curve obtained by plotting s' against t/t' for aquifer test using well 7-6-20bdd.

An aquifer test using irrigation well 7-8-1adc, owned by Gerald Smith, was made on June 9, 1955. The well was pumped about 2½ hours at a rate of 650 gallons per minute and the depth to water was measured frequently. Depth-to-water measurements were made frequently during the recovery period for about 6 hours after pumping ceased. The transmissibility computed from these data was much too high and has been omitted from this report, but the data are given to show that the local permeability of the water-bearing material is high (Table 4).

The approximate rate of movement of water through the alluvium of the Solomon Valley can be obtained by application of the following formula: $v = \frac{PI}{395p}$, where v is the average velocity of the ground water in feet per day, P is the coefficient of permeability, defined in Meinzer's units (gallons per day per square foot under a hydraulic gradient of 100 percent and a temperature of 60° F), I is the hydraulic gradient in feet per mile, and p is the porosity in percentage. By substitution of the coefficient of permeability of the water-bearing material at well 7-6-20bdd of 1,300 gallons a day per square foot, a hydraulic gradient of 5 feet per mile, and an assumed porosity of 30 percent, the average velocity of the ground water can be computed by the above formula as follows:

$$v = \frac{1{,}300 \times 5}{395 \times 30} = 0.5 \text{ foot per day.}$$

Utilization

During this investigation 310 domestic, stock, municipal, industrial, and irrigation wells were inventoried. Information regarding type, construction, depth, use of wells, and the depth to water is given in Table 17. Principal uses of ground water and types of wells are described below.

Domestic and Stock Supplies

One of the chief uses of ground water in Mitchell County is for domestic and stock supplies. Most domestic and stock wells that were inventoried were dug wells, the walls of which were lined with native stone, but drilled wells in which standard size galvanized casing has been set are common in the Solomon Valley and the valleys of the larger tributaries where ground water is plentiful. In the eastern part of the upland, where potable ground water from the Dakota Formation is available, most wells are drilled and tap this deeper artesian water.

Most domestic and stock wells are equipped with displacement-type pumps in which the cylinder is below the water level, and most pumps are operated by windmills; others are operated by electric motors, by gasoline engines, or by hand. A few wells are equipped with electrically driven jet pumps, which use a stream of water under pressure to raise the water. Most water for rural domestic use is ground water, but many residents rely on cisterns, particularly in much of the upland of Mitchell County where only meager supplies of ground water can be obtained from the underlying Cretaceous bedrock. In parts of the upland where ground-water supplies are difficult to obtain, ponds made by the construction of dams across hillside watercourses help solve the problem of stock supplies.

Municipal Supplies

Brief descriptions of cities in Mitchell County and their water supplies are given below; details of well construction are given in the table of wells and logs at the end of the report. Analyses of water from municipal wells are given in Table 5.

Beloit.—Beloit (population in 1950 was 4,085), the county seat of Mitchell County, obtains its water supply from Solomon River. The flood of July, 1951, destroyed two wells just west of the city limits that had been used as auxiliary wells during times of low river flow. During the summer of 1955, test drilling was done in the terrace deposits west of Beloit in anticipation of establishing two new wells to supplement surface water from Solomon River. The average amount of water used by Beloit is reported to be about 325,000 gallons per day. Table 14 gives partial chemical analyses of water taken from Solomon River at 3-mile intervals.

Cawker City.—Cawker City (population in 1950 was 691) obtains its water supply from a dug well (6-10-27cdd) deriving water from terrace deposits of the Solomon Valley south of the city. The well is 60 feet deep and is walled with brick. The well is equipped with two electrically driven turbine pumps having capacities of 250 and 300 gallons per minute. Water is pumped directly into the mains, the excess going into an elevated 75,000-gallon tank. The average amount of water used by Cawker City is reported to be about 80,000 gallons per day.

Glen Elder.—Glen Elder (population in 1950 was 582) obtains its water supply from two dug wells deriving water from terrace deposits of the Solomon Valley east of the city. The wells are 48 feet deep and are walled with native stone. One well having a 350-gpm turbine pump driven by a 30-horsepower electric motor pumps water directly into the mains, the excess going into an elevated 75,000-gallon tank. The other well has a 150-gpm turbine pump and is used as an auxiliary well in case of emergency. The average amount of water used by Glen Elder is reported to be about 50,000 gallons per day.

Tipton.—Tipton (population in 1950 was 246) obtains its water supply from two dug wells and a drilled well deriving water from alluvial deposits along Carr Creek at the south edge of the city. The wells are about 42 feet deep and are equipped with electrically driven turbine pumps. Water is pumped directly into the mains, the excess going into an elevated 15,000-gallon tank. The average amount of water used by Tipton is reported to be about 25,000 gallons per day.

Hunter.—Hunter (population in 1950 was 236) obtains its water supply from a dug well deriving water from alluvial deposits along a small creek one-fourth mile west of the city. The well is 34 feet deep and is equipped with an electrically driven jet pump. Water is pumped directly into the mains, the excess going into an elevated 33,000-gallon tank. The average amount of water used by Hunter is reported to be about 20,000 gallons per day.

Simpson.—Simpson (population in 1950 was 231) obtains its water supply from a drilled well deriving water from terrace deposits of the Solomon Valley. The well is 47 feet deep and is equipped with an electrically driven turbine pump having a capacity of 70 gpm. Water is pumped directly into the mains, the excess going into an elevated 75,000-gallon tank. The average amount of water used by Simpson is reported to be about 15,000 gallons per day.

Scottsville.—Scottsville (population in 1950 was 108) has no municipal water supply, and residents rely on wells or cisterns. Only small supplies of ground water are available in the Scottsville area, and during extended dry periods many users are forced to haul water from nearby cities.

Asherville.—Asherville (unincorporated) has no municipal water supply. Residents reported that ground water in the Asherville area was unsatisfactory for domestic purposes because it had a bad taste. Although salty water in small areas of Wisconsinan terrace deposits in the Beloit area is attributed to the underlying Dakota Formation, an analysis of water from a stock well in Asherville indicates that ground water in the Asherville area has been locally contaminated from the barnyards, feeding pens, privies, and cesspools that are evident throughout Asherville. The analysis (7-6-27cdd, Table 5) of ground water in the Asherville area shows the water to be hard and relatively low in chloride, sulfate, and sodium ions, which is typical of ground water in the terrace deposits in Mitchell County. In addition, the water has an exceptionally high concentration of nitrate (456 ppm), indicating surface pollution. In contrast, analysis of water (7-7-15cbc, Table 5) from terrace deposits south of Beloit shows the water to be high in chloride (2,000 ppm), sulfate (1,090 ppm), and sodium (1,710 ppm), which is characteristic of ground water from the Dakota Formation in

Mitchell County. Although there are stock wells in the Asherville area, residents depend upon cisterns for household water. During periods of deficient rainfall, water is hauled from Simpson or Beloit and stored in the cisterns.

Industrial Supplies

Mitchell County is primarily an agricultural area having very few industries and, therefore, very little water is used for industrial purposes. Most industries in Mitchell County are in Beloit, and many obtain their water supplies from the municipal water system in Beloit.

The Hund Ice Co., the Nehi Bottling Co., and the Beloit Dairy Products each have private wells in the 100 block of West Second Street in Beloit. These wells are drilled to a depth of about 50 feet and are cased with 8- to 12-inch casing; the wells derive water from terrace deposits of the Solomon Valley (Table 17). Although no pumpage data are available, the wells are reported to supply sufficient quantities of water.

Several business houses in Beloit maintain wells to provide water for air conditioning. These wells commonly are bored or driven from basement floors and derive water from the underlying terrace deposits. No data on pumpage are available.

The Union Pacific Railway Co. and Missouri Pacific Railroad Co. at one time maintained wells at Beloit, Simpson, and Asherville and used them to fill the boilers of steam locomotives. In recent years the railroads have converted to diesel engines, and the wells have been destroyed or abandoned.

Irrigation Supplies

At the time of the field investigation there were three irrigation wells in Mitchell County. All obtain water from Wisconsinan terrace deposits in the Solomon Valley. An irrigation well (7-6-20bdd) owned by Henry Remus was drilled during the early part of 1954. The well has a reported yield of 325 gpm and a drawdown of about 30 feet and hence a specific capacity of about 11 gpm per foot of drawdown. The well is used to irrigate 60 acres. A well owned by Alfred Emmot (7-7-15dcc2), drilled in the spring of 1955, has a reported yield of 250 gpm and a drawdown of about 27 feet and a specific capacity of about 9 gpm per foot of drawdown. An irrigation well (7-8-1adc1, about 2 miles west of Beloit) owned by Gerald Smith has the greatest yield reported. The reported yield at the time of installation was 900 gpm, the drawdown about 25 feet, and specific capacity about 36 gpm per foot of drawdown. Aquifer tests were made on the Smith well and the Remus well. Additional data regarding these irrigation wells and their construction are given in Table 17.

Several pumping plants along Solomon River draw water from the river for irrigation. Water generally is pumped up to the flood plain surface or to the Kirwin Terrace surface by means of a centrifugal pump powered by a stationary engine or tractor. As a rule, sprinkler systems are used for distributing the water.

Possibilities for Additional Ground-Water Irrigation

Logs of test holes show that fine to coarse alluvial material of moderate thickness underlies the valley of Solomon River. Although considerable sand and gravel generally is present in the lower part of the alluvial fill, this material is not well sorted in many places, and transmissibility is not great. Data from logs of test holes indicate that the saturated material, in general, is neither thick enough nor permeable enough for the development of wells having large yields. Wells of moderate yield, however, capable of irrigating small tracts, can be obtained in alluvial materials of the Solomon Valley.

Quality of Ground Water

The chemical character of ground water in Mitchell County is indicated by analyses of water from wells distributed over the county deriving water from the principal aquifers (Table 5). Also included in the table are analyses from five municipal supplies. Partial analyses of water collected from Solomon River at 3-mile intervals are given in Table 14. An analysis of water from Great Spirit Spring is given in Table 2. The analyses were made by H.

Table 6.—*Factors for converting parts per million to equivalents per million.*

Mineral constituent	Chemical symbol	Factor
Calcium	Ca^{++}	0.0499
Magnesium	Mg^{++}	.0822
Sodium	Na^{+}	.0435
Potassium	K^{+}	.0256
Carbonate	CO_3^{--}	.0333
Bicarbonate	HCO_3^{-}	.0164
Sulfate	SO_4^{--}	.0208
Chloride	Cl^{-}	.0282
Fluoride	F^{-}	.0526
Nitrate	NO_3^{-}	.0161

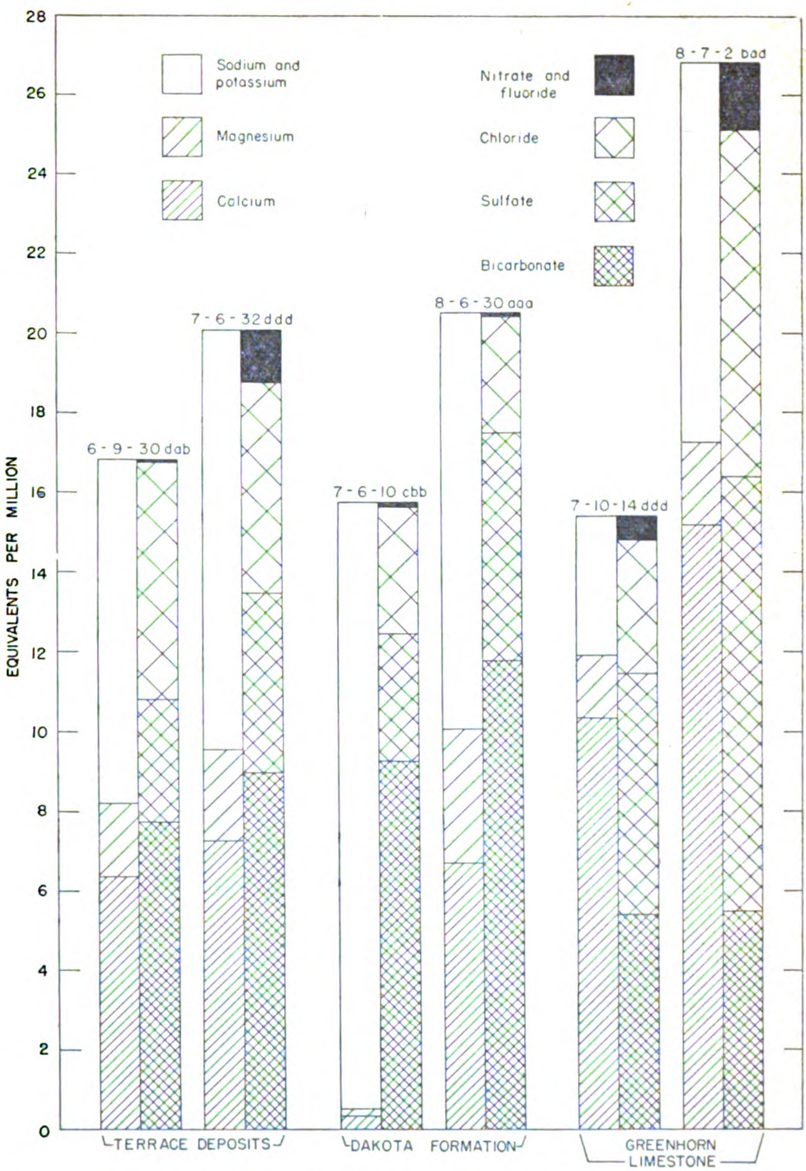


FIG. 14.—Graphic representation of chemical analyses of samples of water from wells in principal water-bearing formations.

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

Analyzed by H. A. Stoltenberg. Dissolved constituents given in parts per million.[a]

Well no.	Depth, feet	Geologic source	Date of collection	Temperature (°F)	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$		
																Total	Carbonate	Noncarbonate
6-6-17ddd	39.0	Greenhorn Limestone	8-10-55	59	1,230	24	0.41	202	20	187	357	286	222	0.3	111	586	292	294
6-7-13cdd	140	Dakota Formation	7-22-55	56	3,000	7.5	1.1	17	16	1,140	964	258	1,080	3.4	2.1	108	108	0
6-7-14dcc	93	do	7-22-55	57	805	22	1.1	81	13	212	473	43	199	0.3	1.9	256	256	0
6-8-24cdc	28.0	Greenhorn Limestone	8-12-55	59	2,000	14	0.33	323	59	236	412	365	325	0.8	478	1,050	340	710
6-8-32ccd	44.7	Terrace deposits	10-21-54	58	1,600	45	0.18	316	37	162	546	142	312	0.1	319	940	448	492
6-8-34ddc	53.5	do	10-21-54	58	402	24	0.48	96	7.4	39	315	19	43	0.2	18	270	258	12
6-9-15bbb	33.0	do	8-10-55	59	765	34	0.58	165	10	93	444	111	111	0.1	23	452	364	88
6-9-20dcd	55.0	Greenhorn Limestone	11-18-54	58	497	22	0.70	145	8.3	20	395	53	28	0.2	26	396	324	72
6-9-26cad1	48	Terrace deposits	8-9-55	58	729	37	0.05	164	12	74	449	130	75	0.0	12	458	368	90
6-9-30dab	37.0	do	11-18-54	58	975	32	4.2	128	22	199	473	147	212	0.1	1.9	410	388	22
6-9-33acc	48.7	do	10-21-54	57	696	41	1.8	130	16	98	433	86	111	0.2	1.2	390	355	35
6-10-16ddc	35.5	Greenhorn Limestone	10-21-54	59	434	42	0.13	103	9.5	32	310	28	48	0.3	18	296	254	42
6-10-27cdd	60	Terrace deposits	5-23-55	57	462	35	0.04	110	9.1	36	361	48	29	0.1	3.3	312	296	16
7-6-10cbb	130	Dakota Formation	7-22-55	56	921	10	0.69	7.1	2.3	351	568	154	114	0.6	2.2	27	27	0
7-6-20bdd	41.0	Terrace deposits	10-21-54	58	1,110	24	1.2	172	18	206	429	192	283	0.2	1.5	503	352	151
7-6-21cdd	40	Dakota Formation	11-19-54	59	1,300	12	5.9	256	52	90	376	668	30	0.8	1.2	852	308	544
7-6-27cdd	42	Terrace deposits	10-21-54	58	1,860	34	0.32	403	38	132	476	271	290	0.1	456	1,160	390	770
7-6-32ddd	40	do	11-18-54	58	1,200	28	1.1	146	28	242	549	217	188	0.3	80	479	450	29
7-6-36aab	45.0	do	11-19-54	58	658	22	0.19	167	9.1	52	403	158	48	0.3	3.8	454	330	124
7-7-11cbb	145	Dakota Formation	11-10-54	56	1,910	10	6.0	127	23	562	654	320	540	0.6	2.8	412	412	0
7-7-12bac	38.5	Terrace deposits	10-21-54	57	1,030	18	0.05	240	19	89	479	302	107	0.1	15	677	393	284
7-7-15cbc	37.5	do	8-12-55	58	5,580	38	16	211	100	1,710	859	1,090	2,000	0.4	2.7	938	704	234
7-7-21bbb	40	do	11-10-54	57	4,350	26	5.5	371	85	1,110	637	735	1,700	0.2	5.3	1,280	520	760
7-7-29ab	32.0	Terrace deposits	11-12-54	58	952	32	0.17	195	10	115	468	217	73	0.2	80	528	384	144
7-8-1adc2	45.0	do	11-19-54	57	1,180	23	0.12	186	19	201	410	152	271	0.1	128	542	336	206
7-8-27aaa	35.0	Greenhorn Limestone	10-21-54	58	1,670	23	0.06	384	32	107	422	824	72	0.6	19	1,090	346	744
7-9-9cc	40	do	10-21-54	58	3,650	18	3.4	693	96	376	671	1,700	440	0.9	2.2	2,120	550	1,570
7-10-3dda	40	Terrace deposits	11-12-54	57	583	31	0.25	153	11	30	344	109	52	0.1	28	426	282	144
7-10-8bbb	62.5	Greenhorn Limestone	11-12-54	57	1,000	16	0.44	198	18	115	298	371	125	0.8	11	568	244	324
7-10-14ddd	14.5	do	11-10-54	58	939	25	0.74	208	19	80	332	291	120	0.3	32	597	272	325
7-10-19add	45.0	Terrace deposits	10-21-54	57	732	24	2.2	149	15	86	339	99	139	0.2	53	434	278	156
7-10-22cca	15.5	do	7-29-55	58	370	45	0.10	86	11	26	315	19	22	0.3	5.8	260	258	2
7-10-25bcb	27.4	Greenhorn Limestone	7-28-55	59	2,140	45	0.22	433	45	183	351	901	249	0.3	106	1,270	290	980

7-10-32baa	26.7	Terrace deposits	8-11-55	58	473	24	0.10	128	10	23	327	81	34	0.1	12	360	268	92
8-6-1add	47	do.	3-17-55	59	568	34	0.08	140	9.4	52	454	84	22	0.1	13	388	372	16
8-6-9bcc	50	Dakota Formation	10-21-54	58	1,120	23	0.23	256	17	102	356	251	234	0.1	58	708	292	416
8-6-20cdc	165	do.	7-22-55	56	615	7.0	2.1	4.0	3.2	242	532	62	32	1.4	1.1	23	23	0
8-6-30aaa	165	do.	7-22-55	57	1,160	7.0	0.45	135	41	241	722	275	105	0.5	1.9	506	506	0
8-7-2bad	41.0	Greenhorn Limestone	10-21-54	58	1,680	24	0.06	305	25	220	337	523	311	0.4	102	864	276	588
8-8-22aaa	34.0	do.	8-11-55	59	2,770	16	5.3	614	85	119	351	1,650	79	0.8	28	1,880	290	1,590
8-8-31dcc	26.0	do.	8-11-55	59	1,558	15	0.11	311	33	150	417	423	191	0.4	230	912	342	570
8-9-17aab	42.0	Terrace deposits	8-10-55	57	730	35	1.6	181	17	43	442	214	20	0.2	1.5	522	362	160
8-10-30aac	42	do.	3-29-55	59	959	39	0.10	211	18	74	407	347	37	0.2	17	600	334	266
9-6-10bcb	180	Dakota Formation	8- 3-55	56	987	15	0.44	110	15	216	439	368	42	0.6	4.1	336	336	0
9-6-29aaa	190	do.	8-12-55	57	479	13	3.6	52	12	112	366	83	21	0.6	5.3	179	179	0
9-7-19da	22.0	Terrace deposits	8- 4-55	59	1,460	33	0.08	299	23	172	398	203	415	0.2	115	840	326	514
9-7-22ddd	26.5	Dakota Formation	8- 4-55	58	1,600	19	0.30	296	19	200	415	218	270	0.2	376	816	340	476
9-8-15bad	27.0	Terrace deposits	8- 5-55	59	2,460	23	2.7	324	46	460	409	843	555	0.5	2.2	998	336	662
9-8-34bcc	185.0	Dakota Formation	7-19-55	57	2,270	8.5	3.8	22	17	835	637	261	810	1.2	2.8	125	125	0
9-9-7dcb	23.0	Colluvium	7-27-55	59	888	22	0.12	180	15	110	520	167	63	0.4	75	510	426	84
9-9-26aaa	24.5	Greenhorn Limestone	8-11-55	59	803	19	0.18	198	20	44	371	169	90	0.4	80	576	304	272
9-10-21ab	28.0	Colluvium	8- 1-55	59	5,380	34	0.14	625	354	541	471	2,920	364	0.8	310	3,010	380	2,630
9-10-26ddc	34	Terrace deposits	2-18-54	58	1,610	40	0.13	348	27	105	456	686	78	0.4	11	979	374	605

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

A. Stoltenberg, Chemist, in the Water and Sewage Laboratory of the Kansas State Board of Health. The results of the analyses are given in parts per million. Factors for converting parts per million of mineral constituents to equivalents per million are given in Table 6. The analyses show only the dissolved mineral contents and do not indicate the sanitary condition of the water. Representative analyses of ground water from the principal aquifers are shown graphically in Figure 14.

Chemical Constituents in Relation to Use

The following discussion of the chemical constituents of ground water in relation to use has been adapted in part from publications of the U. S. Geological Survey and the State Geological Survey of Kansas.

Dissolved solids.—The residue left after a natural water has evaporated consists mainly of the mineral constituents but may also include some organic material and water of crystallization. Water containing less than 500 ppm of dissolved solids generally is satisfactory for domestic and many industrial purposes. Water containing more than 1,000 ppm of dissolved solids generally contains enough of certain constituents to produce a disagreeable taste or to make the water unsuitable in other respects.

The dissolved solids in samples of water from wells in Mitchell County ranged from 370 to 5,580 ppm. Seven samples contained less than 500 ppm of dissolved solids and about half the samples (25) contained less than 1,000 ppm (Table 7).

Hardness.—Hardness of water is recognized most commonly by the amount of soap needed to produce a lather or suds and by an

TABLE 7.—*Dissolved solids in samples of water from wells in Mitchell County.*

Dissolved solids, parts per million	Number of samples
Less than 400	1
400— 600	8
601— 800	7
801—1,000	9
1,001—1,500	10
1,501—2,000	8
More than 2,000	10
Total	53

insoluble scum that forms during washing processes. Calcium and magnesium cause almost all the hardness of water and are the constituents that form most of the scale in steam boilers and other containers in which water is heated or evaporated. The table of analyses (Table 5) gives carbonate hardness and noncarbonate hardness in addition to total hardness. Calcium and magnesium bicarbonates cause carbonate hardness, which is sometimes called temporary hardness because the hardness can be virtually removed by boiling the water. Noncarbonate hardness, which is sometimes called permanent hardness because it cannot be removed by boiling, is caused by calcium and magnesium salts of the strong acid constituents—sulfate, chloride, nitrate, and fluoride. Both types of hardness react similarly with soap.

Water that has a hardness of 50 ppm or less is considered soft. Water that has a hardness of 50 to 150 ppm is satisfactory for most purposes, but the hardness does increase the amount of soap needed, and treatment of such water by a softening process generally is profitable for laundries. Water having a hardness in the upper part of this range will cause considerable scale in steam boilers. Hardness of more than 150 ppm is very obvious, and water that has a hardness of 200 or 300 ppm generally is undesirable for household purposes until it is treated by a softening process. Where municipal water supplies are softened, the hardness generally is reduced to about 100 ppm.

Water samples from wells in Mitchell County ranged in total hardness from 23 to 3,010 ppm. Four samples had a hardness of less than 150 ppm. Only 9 samples had hardnesses of less than 300 ppm, and 8 had hardnesses of more than 1,000 ppm (Table 8).

TABLE 8.—*Hardness of samples of water from wells in Mitchell County.*

Hardness, parts per million	Number of samples
Less than 100	2
100— 200	3
201— 300	4
301— 400	6
401— 500	8
501— 600	10
601—1,000	12
More than 1,000	8
Total	53

Iron.—Iron and manganese in quantities that exceed a few tenths of a part per million are undesirable, as they stain fabrics and plumbing fixtures and produce an objectionable coloration in the water. The limit generally specified is 0.3 ppm. Water in the ground may contain considerable iron, but upon exposure to air most of the iron is oxidized and precipitated as a reddish sediment, only a few tenths of a part per million of the iron remaining in solution. Iron may be removed from most water by aeration and filtration, but some water requires additional treatment.

The iron content of water samples from wells in Mitchell County ranged from 0.04 to 16 ppm. Ten samples contained 0.1 ppm of iron or less, and 24 samples contained 0.3 ppm or less (Table 9).

TABLE 9.—*Iron content of samples of water from wells in Mitchell County.*

Iron, parts per million	Number of samples
0—0.10	10
0.11—0.30	14
0.31—0.50	7
0.51—1.00	4
More than 1.00	18
Total	53

Fluoride.—Fluoride generally is present only in small concentrations in ground water, but to know the amount of fluoride in water used by children is important. Too much fluoride in water has been shown to be associated with the dental defect known as mottled enamel, which may appear on the teeth of children who drink water containing too much fluoride during the period when permanent teeth are forming (Dean, 1936, p. 1270).

Recent studies have shown that concentrations of fluoride too small to cause objectionable mottling of tooth enamel—from 1.0 to 1.5 ppm—may help to prevent tooth decay. The United States Public Health Service (1946) has published standards that set or recommend the concentrations of mineral constituents permissible in drinking water that is used on interstate carriers. The maximum amount of fluoride permissible is 1.5 ppm.

The fluoride content of water samples from wells in Mitchell County ranged from 0 to 3.4 ppm. Only 3 samples contained more than 1.0 ppm (Table 10).

TABLE 10.—*Fluoride content of samples of water from wells in Mitchell County.*

Fluoride, parts per million	Number of samples
0.0	1
0.1	11
0.2	11
0.3—0.5	16
0.6—1.0	11
More than 1.0	3
Total	53

Nitrate.—The variation in nitrate content for different waters is great and in many waters seemingly is not related to any geologic formation. Although some nitrate may be derived from nitrate-bearing rocks and minerals in the water-bearing formation, high nitrate concentrations may be due to direct flow of surface water into the well or to percolation of water into the well from the overlying soil zone. Nitrates are dissolved readily from soils that contain concentrations of nitrate derived from plants, animal waste, or nitrifying action. Because privies, cesspools, and barnyards are sources of organic nitrogen, a large amount of nitrate in well water may indicate the presence of harmful bacteria or prior pollution.

Nitrate in concentrations greater than about 45 ppm is undesirable because of the possible toxic effect that it may have on infants (Metzler and Stoltenberg, 1950). This effect, which is known as cyanosis, may result when water that contains excessive nitrate is used in the preparation of the baby's formula. In cyanosis, the baby becomes listless and drowsy, and the skin takes on a blue color. The Kansas State Board of Health regards 45 ppm as the safe limit of nitrate (as NO_3). This is equivalent to 10 ppm of nitrate nitrogen. Water containing as much as 90 ppm of nitrate generally is considered very dangerous to infants, and water containing as much as 150 ppm may cause severe cyanosis. Nitrate in drinking water does not cause cyanosis in adults or older children but may be responsible for certain digestive disorders. Nitrate cannot be removed from water by boiling.

The nitrate content of water from wells sampled in Mitchell County ranged from 1.1 to 478 ppm; 21 samples contained less than 10 ppm of nitrate, but 17 samples contained more than the 45 ppm limit set by the Kansas State Board of Health (Table 11).

Table 11.—*Nitrate content of samples of water from wells in Mitchell County.*

Nitrate, parts per million	Number of samples
0— 10	21
11— 50	15
51—100	6
More than 100	11
Total	53

Sulfate.—Sulfate (SO_4) in ground water is derived principally from gypsum or anhydrite (calcium sulfate) and from the oxidation of pyrite (iron disulfide). Magnesium sulfate (Epsom salt) and sodium sulfate (Glauber's salt), if present in sufficient quantities, will impart a bitter taste to the water and the water may act as a laxative for people not accustomed to drinking it. More than 250 ppm of sulfate in drinking water generally is undesirable (U. S. Public Health Service, 1946).

The sulfate content of water samples from wells in Mitchell County ranged from 19 to 2,920 ppm. Nearly half (25) of the samples contained more than 250 ppm of sulfate (Table 12).

Table 12.—*Sulfate content of samples of water from wells in Mitchell County.*

Sulfate, parts per million	Number of samples
Less than 100	12
100—250	16
251—500	14
More than 500	11
Total	53

Chloride.—Water that contains less than 150 ppm of chloride is satisfactory for most purposes. Water containing more than 250 ppm of chloride generally is objectionable for municipal supplies, and water containing more than 350 ppm is objectionable for most irrigation or industrial use. Water containing as much as 500 ppm of chloride has a disagreeable taste. H. A. Stoltenberg (personal communication) believes the upper limit of chloride in water permissible for cattle to be about 4,000 or 5,000 ppm.

The chloride content of water samples from wells in Mitchell County ranged from 20 to 2,000 ppm. Thirty samples contained less than 150 ppm of chloride (Table 13).

TABLE 13.—*Chloride content of samples of water from wells in Mitchell County.*

Chloride, parts per million	Number of samples
Less than 50	14
50—150	16
151—500	17
More than 500	6
Total	53

Bicarbonate.—Bicarbonate, the predominant anion in ground water in Mitchell County, and carbonate cause alkalinity of ground water. The concentration of bicarbonate in samples from wells in Mitchell County ranged from 298 to 964 ppm.

Silica.—Silica is a mineral constituent in most ground water and may be deposited with other scale-forming constituents in steam boilers, but it has little effect on the use of water for other purposes. The concentration of silica in samples from wells in Mitchell County ranged from 7.0 to 45 ppm.

Sodium.—The amount of sodium in water to be used for irrigation is important because a large percentage of sodium (equivalents per million of sodium divided by equivalents per million of sodium, potassium, calcium, and magnesium, expressed as a percentage) is undesirable in water to be used for irrigation. The effect of sodium content in irrigation water is discussed on page 61.

Quality of Water from Solomon River

Twelve samples of water from Solomon River were collected at 3-mile intervals across Mitchell County for partial analysis (Table 14). The samples were collected at a time of relatively low flow in the river, when ground water was contributing largely to the river flow. The analyses indicate a general decrease in chloride content upstream across the county toward the west. An increase of chloride in the sample collected in the NW¼ sec. 31, T. 6 S., R. 9 W., probably can be attributed to Waconda Springs, about half a mile northwest. The analyses show that west of Waconda Springs the chloride content is small.

TABLE 14.—*Partial analyses of water collected October 1, 1954, from Solomon River. Analyses given in ppm*

Location	Total hardness as $CaCO_3$	Alkalinity as $CaCO_3$	Chloride	Sulfate
SE¼ sec. 12, T. 8 S., R. 6 W.	336	267	251	161
SE¼ sec. 33, T. 7 S., R. 6 W.	318	236	240	170
NW¼ sec. 31, T. 7 S., R. 6 W.	332	254	180	149
NE¼ sec. 21, T. 7 S., R. 7 W.	330	244	179	158
NE¼ sec. 12, T. 7 S., R. 8 W.	320	234	134	152
SE¼ sec. 4, T. 7 S., R. 8 W.	296	214	123	152
SE¼ sec. 1, T. 7 S., R. 9 W.	298	223	108	146
NW¼ sec. 34, T. 6 S., R. 9 W.	276	186	90	151
NW¼ sec. 31, T. 6 S., R. 9 W.	292	196	120	163
NW¼ sec. 3, T. 7 S., R. 10 W.	286	216	33	113
SW¼ sec. 31, T. 6 S., R. 10 W.	270	220	24	95
NW¼ sec. 19, T. 7 S., R. 10 W.	266	169	32	149

Natural Softening Process in the Dakota Formation

The soft sodium bicarbonate water characteristic of the Dakota Formation is believed to result from a natural softening process in which calcium bicarbonate water has exchanged part of its calcium and magnesium for sodium by reaction with base-exchange silicates within the Dakota Formation (Latta, 1944). The completeness of the base-exchange reaction in the bicarbonate water is indicated by the ratio between the calcium and sodium ions, a small ratio of calcium to sodium indicating a soft water. The principal base-exchange silicates in the Dakota Formation are believed to be the clay-forming minerals of the montmorillonite, kaolinite, and illite groups. However, Plummer (personal communication) believes that the abundant mica and feldspar in the sandstones of the Dakota could be partly responsible for the base exchange.

Analysis of water from well 7-6-10cbb (Fig. 14) illustrates natural softening of water in the Dakota Formation by base exchange. Water samples collected from wells 8-6-20cdc and 8-6-30aaa (Table 5), about a quarter mile apart, further illustrate natural softening of water in the Dakota Formation. Analysis of water from well 8-6-20cdc shows a very low calcium and magnesium content and a total hardness of 23 ppm. Conversely, water from well 8-6-30aaa shows fairly high concentrations of calcium and magnesium and a total hardness of 506 ppm.

Sanitary Considerations

The analyses of water in Table 5 give only the amount of dissolved mineral matter in the water and do not indicate the sanitary quality of the water, although a large amount of certain mineral constituents such as nitrate or chloride may indicate pollution. 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 of a ground-water supply, a well must be properly sealed in order 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

This discussion of the suitability of water for irrigation is based on methods outlined in Agriculture Handbook Number 60, U. S. Department of Agriculture (U. S. Salinity Laboratory Staff, 1954).

In areas of sufficient rainfall and ideal soil conditions, soluble salts originally present in the soil or added to the soil with water are carried downward by percolation and ultimately reach the water table. Soil that was originally nonsaline and nonalkali may become unproductive if excessive soluble salts or exchangeable sodium are allowed to accumulate owing to improper irrigation and soil management or inadequate drainage. If the amount of water applied to the soil is not in excess of the amount needed by plants, water will not percolate downward below the root zone, and an accumulation of mineral matter will form at that point. Likewise impermeable soil zones near the surface can retard the downward movement of water, resulting in waterlogging of the soil and deposition of salts.

The characteristics of an irrigation water that seem to be most important in determining its suitability are the total concentration of soluble salts and the relative activity of sodium ions in exchange reactions. For diagnosis and classification the total concentration of soluble salts in irrigation water can be expressed in terms of electrical conductivity, which is a measure of the ability of the inorganic salts in solution to conduct an electrical current. The electrical conductivity can be determined accurately in the laboratory, or an approximation of the electrical conductivity can be obtained by multiplying the total equivalents per million of cations (calcium, magnesium, sodium, and potassium) by 100 or by dividing the total dissolved solids in parts per million by 0.64.

Salt-sensitive crops such as strawberries, green beans, and red clover may be affected adversely by irrigation water having an electrical conductivity exceeding 250 micromhos per centimeter, but waters having electrical-conductivity values below 750 micromhos per centimeter are generally satisfactory for irrigation insofar as salt content is concerned. Waters in the range of 750 to 2,250 micromhos per centimeter are widely used, and satisfactory crop growth is obtained under good management and favorable drainage conditions, but saline conditions will develop if leaching and drainage are inadequate. Use of waters having conductivities of more than 2,250 micromhos per centimeter is the exception, and few instances can be cited where such waters have been used successfully.

The sodium-adsorption ratio may be determined by the formula

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

where the ionic concentrations are expressed in equivalents per million. The sodium-adsorption ratio may also be determined by use of the nomogram shown in Figure 15. In using the nomogram to determine the sodium-adsorption ratio of a water, the concentration of sodium expressed in equivalents per million is plotted on the left scale (A), and the concentration of calcium plus magnesium expressed in equivalents per million is plotted on the right scale (B). (In this report the concentrations of sodium and potassium are given together, as sodium, but the amount of potassium is negligible.) The point at which a line connecting these two points intersects the sodium-adsorption-ratio scale (C) determines the sodium-adsorption ratio of the water. Table 15 gives the well numbers for the analyses plotted on Figures 15 and 16, sodium-adsorption ratios, and approximate electrical conductivities.

When the sodium-adsorption ratio and the electrical conductivity of a water are known, the suitability of the water for irrigation can be determined graphically by plotting these values on the diagram shown in Figure 16. Low-sodium water (S1) can be used for irrigation on almost all soils with little danger of the 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 appreciable sodium hazard in certain fine-textured soils, especially under low-leaching conditions. High-sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management such as good drainage, high leaching, and organic matter additions. Very high sodium water (S4) generally is unsatisfactory for irrigation unless special action is taken, such as addition of gypsum to the soil.

Low-salinity water (C1) can be used for irrigation of most crops on most soils with little likelihood that soil salinity will develop. Medium-salinity water (C2) can be used if a moderate amount of leaching occurs. Crops that tolerate moderate amounts of salt, such

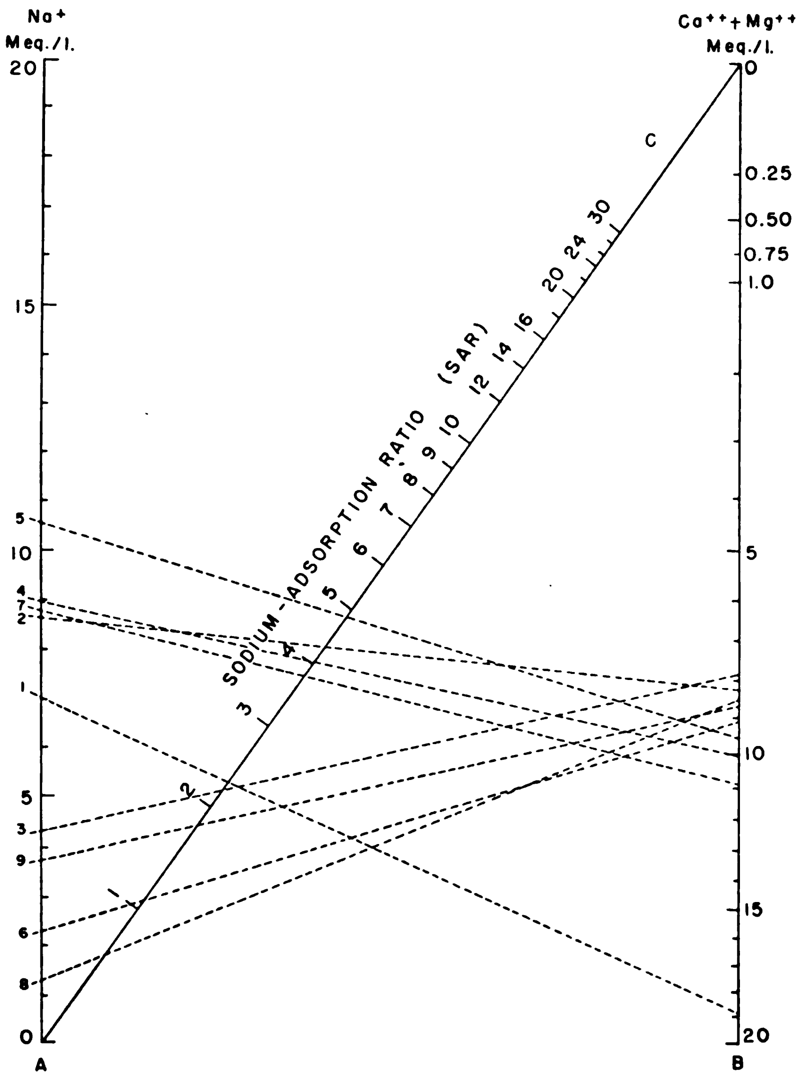


Fig. 15.—Nomogram for determining the sodium-adsorption ratio of a water.

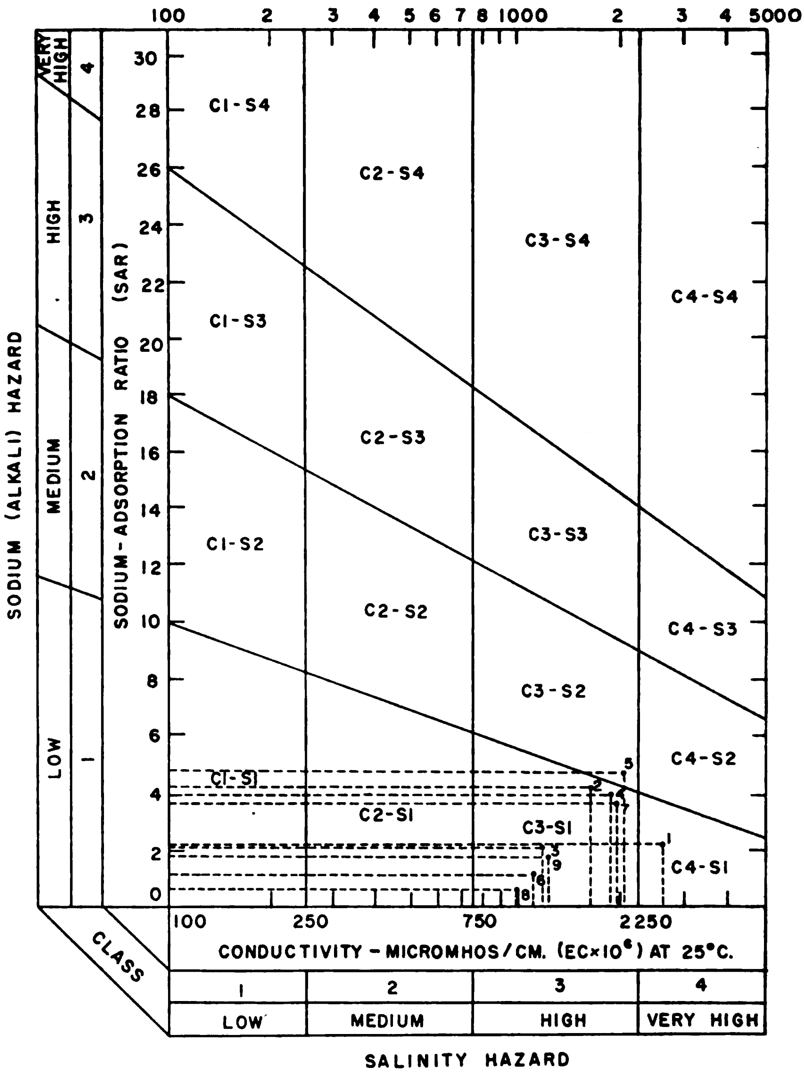


FIG. 16.—Classification of selected irrigation waters in Mitchell County.

as potatoes, corn, wheat, oats, and alfalfa, can be irrigated with C2 water without special practices. High-salinity water (C3) cannot be used on soils having restricted drainage. Very high salinity water (C4) can be used only on certain crops and then only if special practices are followed.

TABLE 15.—*Analyses used in determining suitability of water for irrigation.*

Well number	Number used in Figures 16 and 17	Sodium-adsorption ratio, SAR	Approximate conductivity
6-8-32ccd	1	2.25	2,550
6-9-30dab	2	4.30	1,600
6-9-33acc	3	2.15	1,150
7-6-20bdd	4	4.00	1,825
7-6-32ddd	5	4.85	1,950
7-6-36aab	6	1.10	1,075
7-8-1adc2	7	3.75	1,875
7-10-3dda	8	0.55	950
7-10-19add	9	1.80	1,200

GEOLOGIC FORMATIONS IN RELATION TO GROUND WATER

CRETACEOUS SYSTEM

Gulfian Series

Dakota Formation

The term Dakota Group (Meek and Hayden, 1862) was first applied to the varicolored clay, sandstone, and lignite beds beneath the Benton Group in exposures near Dakota City, Dakota County, Nebraska. The use of this grouping has been discontinued (Plummer and Romary, 1942), and the Dakota Formation now includes strata between the Kiowa Shale below and the Graneros Shale above.

Character and subdivisions.—The Dakota Formation consists of variously colored clays, dark-gray shale, sandy shale, and lenticular beds of siltstone and sandstone. Yellow-brown to brown ironstone and quartzitic sandstone characterize outcrops of the Dakota. Owing to the resistance of sandstone beds, the Dakota Formation in outcrop may appear to be mostly sandstone, but much of the formation is clay and shale. In Kansas the Dakota Formation has been divided into two members, the lower called the Terra Cotta Clay member and the upper called the Janssen Clay member (Plummer and Romary, 1942). In Mitchell County only the upper part of the Dakota Formation is exposed.

Distribution and thickness.—The Dakota Formation crops out along the Solomon Valley in the eastern part of Mitchell County and along the Salt Creek valley in the southeastern part (Pl. 1). In the rest of the county the Dakota Formation is concealed by younger overlying formations. Leonard (1952) determined the top of the Dakota Formation to lie at a depth of about 100 feet near Downs, just west of the Mitchell-Osborne County line. At a test hole drilled in the SW cor. sec. 8, T. 7 S., R. 5 W., in western Cloud County near the Mitchell County line, the thickness of the Dakota was about 350 feet (C. K. Bayne, personal communication). The Kiowa Shale, if present, could not be differentiated; no Cheyenne Sandstone was present, and Permian red beds were penetrated below 350 feet.

Water supply.—The Dakota Formation contains lenticular sand bodies that are sources of moderate supplies of water. In eastern and southeastern Mitchell County this supply is adequate for domestic and stock use (Fig. 17). In the rest of the county, to the west, water from the Dakota Formation is too mineralized for use. Water from the Dakota Formation in most of Mitchell County is under artesian pressure but rarely flows at the surface. Figure 17 illustrates the areas in Mitchell County where potable water is available from the Dakota Formation. The chemical character of water obtained from the Dakota is shown by analyses in Table 5 and graphically in Figure 14.

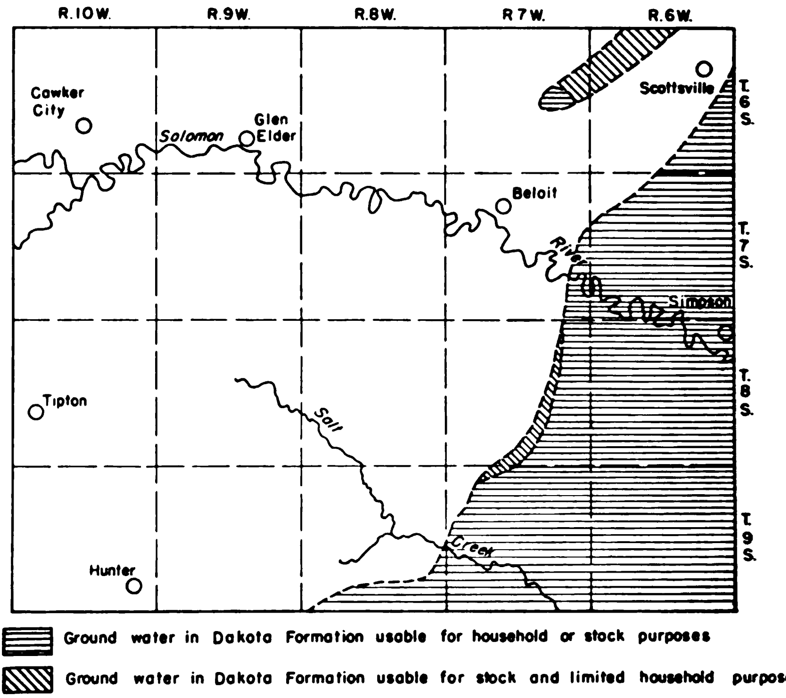


FIG. 17.—Map of Mitchell County showing generalized areas where water in Dakota Formation is fresh. Ground water in Dakota Formation in unshaded areas is too mineralized for ordinary uses.

Along the Solomon Valley in the eastern and central parts of Mitchell County, sand and gravel of the alluvial terrace deposits are underlain by the Dakota Formation. Water within the Dakota Formation is under artesian pressure, and under certain hydraulic conditions it contaminates the overlying fresh water. Water from terrace deposits is known to be salty at several localities in the Beloit area. Chemical analysis 7-7-15cbc (Table 5) of water from a well penetrating terrace deposits about a mile southeast of Beloit in the SW¼ sec. 15 shows 2,000 ppm of chloride, 1,710 ppm of sodium, and 1,090 ppm of sulfate. Analysis 7-7-21bbb from a well obtaining water from terrace deposits about a mile south of Beloit in the NW¼ sec. 21 also shows the water to be salty. Water too salty for domestic or stock use is present in the alluvial deposits south and southwest of Beloit in sec. 16, 17, and 18. An irrigation well drilled in March 1956 about 2 miles east of Beloit in the NE¼ sec. 14 was reported to be too salty for use.

Graneros Shale

Character.—The Graneros Shale was named by Gilbert (1896) from exposures of marine shale along Graneros Creek, south of Pueblo, Colorado. The Graneros Shale is a noncalcareous dark-blue-gray clayey shale that weathers gray and tan. Included locally in the formation are interbedded thin layers of bentonite and thin lenses of ferruginous sandstone. Selenite crystals are common. The formation is soft and forms a gentle slope between the Dakota Formation and the Greenhorn Limestone.

Distribution and thickness.—The Graneros Shale crops out in the eastern and southeastern parts of Mitchell County, but because the formation is soft, good exposures are rare. The only outcrop in Mitchell County where an entire section of the Graneros Shale is exposed is in the SE¼ sec. 24, T. 8 S., R. 6 W., where the shale is about 25 feet thick.

Water supply.—No wells in Mitchell County are known to obtain water from the Graneros Shale. A sandstone lens in the shale could yield water if penetrated below the water table by a well, but because of the low permeability of the sediments, the yield would be small.

Greenhorn Limestone

Character and subdivisions.—Gilbert (1896, p. 564) named the Greenhorn Limestone from outcrops of interbedded limestone and shale near Greenhorn Station, south of Pueblo, Colorado. Central Kansas rocks referred to as "Benton" were correlated with the

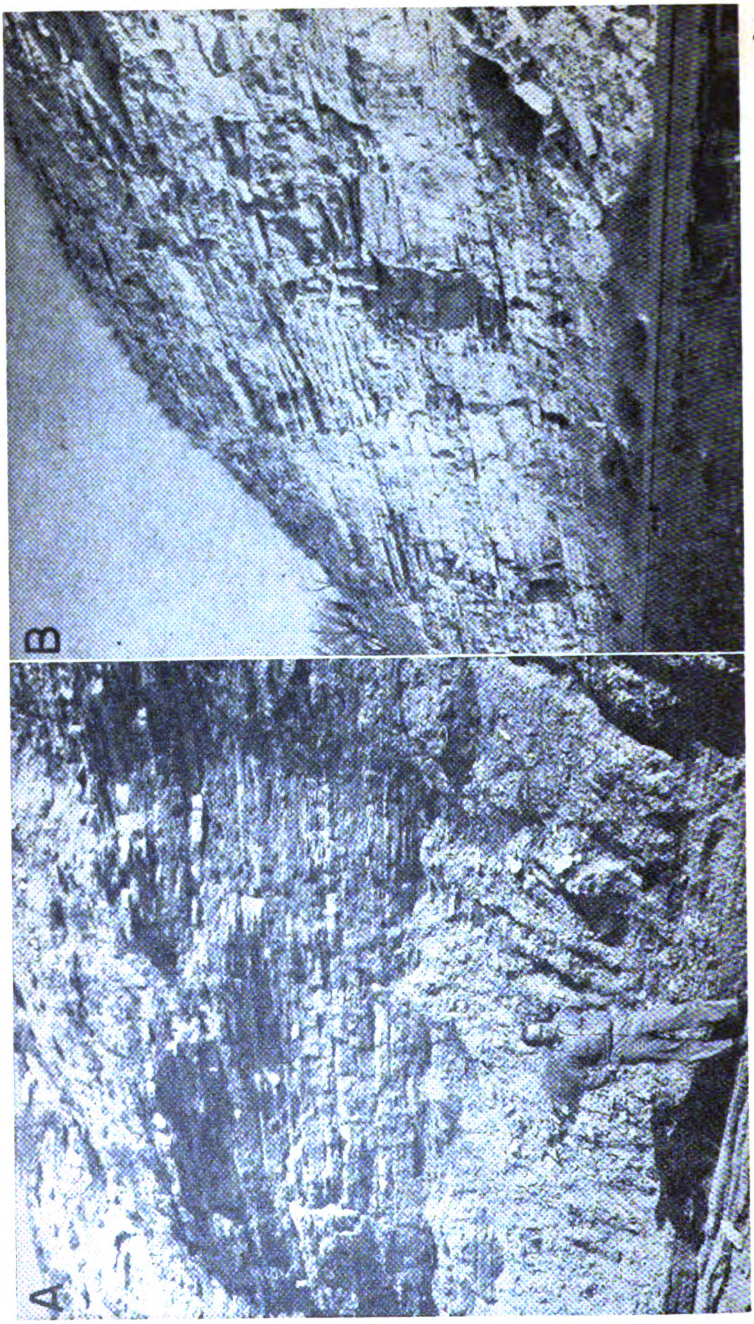


Plate 5.—A, Upper part of Greenhorn Limestone exposed in SW¼ sec. 18, T. 7 S., R. 7 W. B, Greenhorn Limestone exposed in railroad cut in SW¼ sec. 27, T. 6 S., R. 9 W.

Colorado section of the Greenhorn by Logan (1897, p. 232). In Kansas, the Greenhorn Limestone is divided into four members (Rubey and Bass, 1925; Bass, 1926), which in ascending order are the Lincoln Limestone, Hartland Shale, Jetmore Chalk, and Pfeifer Shale members. The Greenhorn Limestone consists of interbedded chalky limestone and chalky shale, including some thin bentonite seams, and lies conformably between the Carlile Shale above and the noncalcareous Graneros Shale below. Plate 5 shows typical sections of the upper part of the Greenhorn Limestone. The top of the Greenhorn Limestone is marked by the Fencepost Limestone bed, which is a hard, dense limestone about 1 foot thick having an iron-stained layer near the center. The measured section below illustrates the lithology of the Greenhorn Limestone.

Section of Greenhorn Limestone and Graneros Shale measured in quarry and road cut in SE¼ sec. 24, T. 8 S., R. 6 W., by A. R. Leonard, C. K. Bayne, and K. L. Walters, August 13, 1953.

	Thickness, feet
Greenhorn Limestone	
Pfeifer Shale member	
69. Fencepost Limestone bed, iron-stained in center, split ave.	0.7
68. Shale, calcareous; has concretionary limestone at 1.4 ft. above base and bentonite seam 2.2 ft. above base	2.7
67. Limestone, brown, concretionary	0.3
66. Shale, calcareous; has ½-in. bentonite 0.3 ft. above base	2.1
65. Limestone, concretionary, split in center ave.	0.2
64. Shale, calcareous; contains concretionary limestones at 0.7, 1.4, 2.2, 3.0, 3.9, and 4.5 ft. above base and 0.1-ft. bentonite 0.1 ft. below top	5.5
63. Limestone, chalky, persistent	0.2
62. Shale, calcareous. Concretionary zones at 1.0 and 2.0 ft. above base, sandy limestone at top, and bentonite streak below limestone	3.1
61. Limestone, blocky, persistent, laminated	0.2
60. Shale, calcareous	3.9
(Total Pfeifer)	18.9
Jetmore Chalk member	
59. Limestone, chalky, very fossiliferous—"Shell rock"	1.0
58. Shale, calcareous	2.9
57. Limestone	0.4
56. Shale, chalky	0.8
55. Limestone, gray streak at top	0.5
54. Shale, calcareous, fossilferous; contains bentonite layer at base	0.8
53. Limestone, stained brown in center	0.6

		Thickness, feet
52.	Shale, calcareous	0.6
51.	Limestone	0.4
50.	Shale, calcareous	0.8
49.	Limestone, chalky	0.2
48.	Shale, calcareous	0.7
47.	Limestone, chalky, limonitic stained	0.3
46.	Shale, calcareous	0.8
45.	Limestone, chalky, white, solid	0.4
44.	Shale, calcareous	4.7
43.	Limestone, shaly, irregular ave.	0.25
42.	Shale, limy	0.75
41.	Limestone, similar to 39	0.2
40.	Shale, limy; brown limonitic zone 0.6 ft. above base	0.9
39.	Limestone, chalky, white	0.3
38.	Shale, limy, fossilferous, light gray	0.6
37.	Limestone, massive, blocky; brown zone in center	0.4
	(Total Jetmore)	19.4
Hartland Shale member		
36.	Shale, calcareous, limy zones 1.4 and 2.3 ft. above base	6.4
35.	Bentonite, gray and orange	0.5
34.	Limestone, chalky white	0.2
33.	Shale, chalky, basal part brownish	2.3
32.	Limestone, blocky, persistent, fossilferous	0.2
31.	Shale, calcareous, has 0.4-ft. limy zone 1.0 ft. above base and 0.2-ft. bentonite 1.8 ft. above base	2.5
30.	Bentonite	0.1
29.	Shale, calcareous	0.4
28.	Bentonite	0.2
27.	Shale; contains bentonite seams at 0.5, 0.8, 1.5, 1.7, and 2.0 ft. above base and 0.2-ft. laminated limestone 2.2 ft. above base	4.4
26.	Bentonite, orange brown	0.1
25.	Shale, calcareous; contains bentonite layer 0.2 ft. below top	2.9
24.	Bentonite, lenticular	0.25
23.	Shale, slabby, limy	0.4
22.	Bentonite, uniform and persistent	0.25
21.	Shale, calcareous	0.9
20.	Bentonite, orange brown	0.25
19.	Shale, calcareous, creamy; contains 0.6-ft. slabby limestone at 1.4 ft. above base and bentonite layer at 0.6 ft. above base	2.7
18.	Bentonite	0.25
17.	Shale, limy, slabby	1.3
	(Total Hartland)	26.0

	Thickness, feet
Lincoln Limestone member	
16. Limestone, slabby	2.0
15. Shale, calcareous, dark gray	0.5
14. Bentonitic clay, granular, gray	0.15
13. Limestone, granular, soft; upper part shaly	0.4
12. Shale, calcareous, gray	0.3
11. Bentonite, brown and gray	0.3
10. Shale, calcareous, tabular, weathers fissile, black to blue gray, top very limy	4.5
9. Bentonite	0.2
8. Shale, gray, some brown; generally noncalcareous, but contains calcareous zone 2 ft. below top (bedding planes covered with powdery gypsum coating)	8.8
7. Shale, brown, generally calcareous, gypsum coating	1.4
6. Limestone, petroliferous, very fossiliferous, thin bedded to slabby. Some beds are hard, dark, and crystalline. Contains 0.2-ft. noncalcareous shale 0.2 ft. above base and 0.1-ft. shale 0.5 ft. above base	3.3
(Total Lincoln)	21.75
(Total Greenhorn Limestone)	86.55
Graneros Shale	
5. Shale, noncalcareous; contains sand and gypsum crystals	0.4
4. Bentonite, orange and white	1.0
3. Shale, noncalcareous, blue gray	10.0
2. Shale, noncalcareous; contains ochre and sandy zones in upper part	6.5
1. Shale, noncalcareous (partly covered slope)	3.5
(Total Graneros Shale exposed)	21.4
Covered	

The Lincoln Limestone, basal member of the Greenhorn Limestone, is about 22 feet thick in Mitchell County and consists principally of gray calcareous shale. Thin gray and orange bentonite seams and thin limestone beds occur irregularly within the member. The limestone beds are shaly and slabby except in the basal part, where they are hard, dark, and crystalline. Limestone beds in the lower part are generally petroliferous, giving off a petroleum odor when freshly broken.

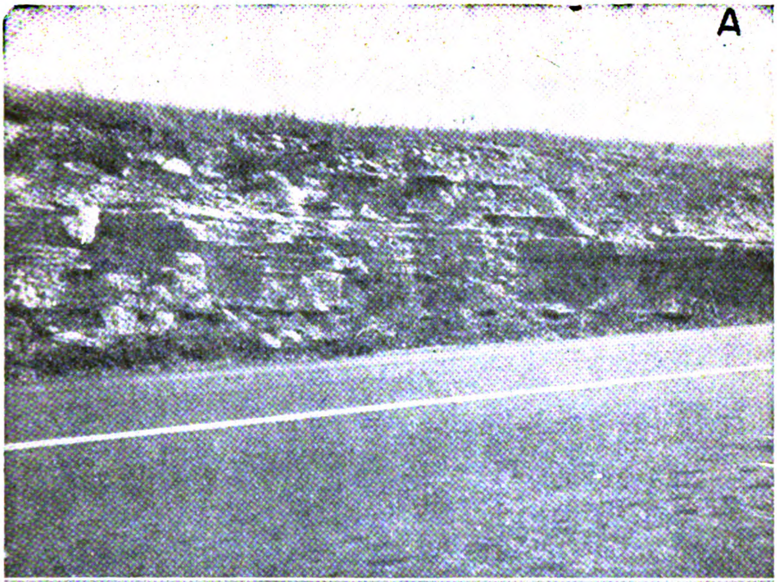
The Hartland Shale member of the Greenhorn Limestone is composed of about 26 feet of gray calcareous shale containing interbedded brown to orange bentonite seams and chalky limestone beds. The Hartland Shale member has a relatively obscure outcrop.

The Jetmore Chalk member consists of alternating thin beds of chalky limestone and calcareous shale. The "Shell-rock limestone" bed marks the top of the Jetmore and forms a rocky hillside bench. The "Shell-rock limestone" bed is shaly, contains many *Inoceramus* shells, and is about 1 foot thick. The Jetmore Chalk member in Mitchell County is about 19 feet thick.

The Pfeifer Shale, uppermost member of the Greenhorn Limestone, is about 19 feet thick in Mitchell County and consists principally of alternating beds of thin chalky limestone and calcareous shale. The limestone is concretionary and contains abundant *Inoceramus* shells. The shale is calcareous, fissile, and light gray. A few thin bentonite layers occur in this member at some localities. The top of the member is marked by the Fencepost Limestone bed, a hard chalky limestone about 1 foot thick having an iron-stained layer near its center. This bed, the thickest persistent limestone bed in the Pfeifer Shale member, is easily recognized by its creamy color, its uniform thickness, the iron-stained band, and the hillside bench it forms (Pl. 6A). The Fencepost Limestone bed has been quarried extensively in north-central Kansas for fence posts and building stone. Plate 6B shows building stone being quarried and cut from the Fencepost Limestone bed about 3½ miles south of Simpson on the Mitchell-Cloud County line.

Distribution and thickness.—The Greenhorn Limestone is the most prominent bedrock formation in Mitchell County, but in many places it is concealed by the overlying Carlile Shale or by the mantle of eolian silt characteristic of the upland. The Fencepost Limestone bed and "Shell-rock limestone" bed form prominent rocky shoulders along hillsides where they are not masked by loess. The thickness of the Greenhorn Limestone in the SE¼ sec. 24, T. 8 S., R. 6 W., measured 86.5 feet and is representative of the formation in Mitchell County. The areal distribution of the Greenhorn Limestone is shown on Plate 1.

Water Supply.—The water-yielding capacity of the Greenhorn Limestone is low, but wells that intercept cracks and fissures or solution openings may yield small amounts of water. Nearly all wells obtaining water from the Greenhorn Limestone in Mitchell County are dug wells. In the upland area many rural domestic and stock wells obtain water from the Greenhorn Limestone, and during times of normal rainfall these wells are generally adequate. Because water in the Greenhorn Limestone is replenished by local rainfall, many wells obtaining water from this formation are dry



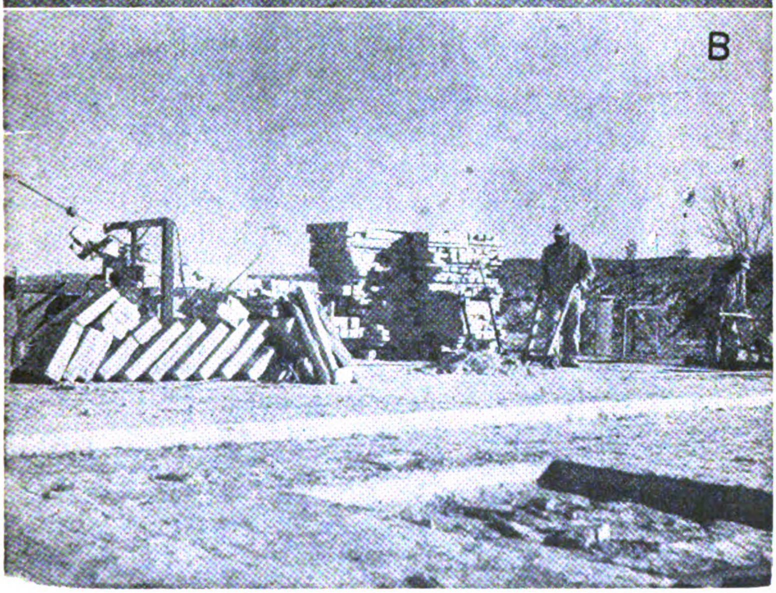


PLATE 6.—**A,** Contact of Greenhorn Limestone and Carlile Shale 1.5 miles south of Beloit on Kansas Highway 14. Thick bed containing iron-stained band near middle of section is Fencepost Limestone bed, marking top of Greenhorn Limestone. **B,** Building-stone quarry in Fencepost Limestone bed in SE¼ sec. 24, T. 8 S., R. 6 W., south of Simpson.

during prolonged dry periods when the water level drops below the bottom of the well. Most of these wells probably would withstand dry periods longer before failing if they were deepened. Many farm wells in Mitchell County are dependent upon water from the Greenhorn Limestone, although where possible other sources of water such as the underlying Dakota Formation or the alluvial terrace deposits are used. The chemical character of water from the Greenhorn Limestone is shown by analyses in Table 5 and graphically in Figure 14.

Carlile Shale

Character and subdivisions.—The Carlile Shale was named by Gilbert (1896) from exposures of gray argillaceous shale along Carlile Creek, 21 miles south of Pueblo, Colorado. Logan (1897) correlated Gilbert's section with Cretaceous beds along Solomon River from Beloit in Mitchell County westward into Norton County. Rubey and Bass (1925) divided the Carlile Shale into two members, the Fairport (chalky shale) Member below and the Blue Hill Shale above. Bass (1926) named the Codell Sandstone zone in the upper part of the Blue Hill Shale member from exposures along Saline River in Ellis County, Kansas.

The Fairport Member consists of alternating beds of calcareous shale and thin nodular chalky limestone. *Ostrea* shells are abundant. The limestones are soft and chalky; they are cream color to gray in fresh exposures and tan to brown in weathered exposures. The shale is chalky and contains thin bentonite seams near the base. The lower part of the member contains abundant chalky limestone beds and resembles the underlying Pfeifer Shale member of the Greenhorn Limestone.

The Blue Hill Shale member is a noncalcerous gray to blue-black clayey shale containing abundant ordinary and septarian concretions and selenite crystals. Septarian concretions 3 to 4 feet in diameter containing crosscutting veins of brown calcite are common in the upper part of the member (Pl. 7A). The Codell Sandstone zone marks the top of the Blue Hill Shale member and crops out in the Blue Hills area. In Mitchell County the sandstone is about 2 to 3.5 feet thick. It is fine grained to silty and contains considerable clay; the color is characteristically yellow brown.

Distribution and thickness.—In Mitchell County the Carlile Shale is almost everywhere concealed beneath eolian silts of the Sanborn Group or, as in the Blue Hills southeast of Tipton, beneath the Fort Hays Limestone member of the Niobrara Formation. In the eastern

PLATE 7.—A, Septarian concretions 3 to 4 feet in diameter common in the upper part of Carlile Shale, NW¼ sec. 19, T. 9 S., R. 9 W. B, Contact of Carlile Shale and overlying Fort Hays Limestone member of Niobrara Formation, SW¼ sec. 12, T. 9 S., R. 10 W.

part of the county the Carlile Shale is exposed in only a few places, where it caps some of the uplands in the interstream areas. In the western part of the county, particularly the southwestern part, exposures of the Carlile Shale are more extensive.

The total thickness of the Carlile Shale is about 300 feet. The Fairport Member is about 100 feet thick and the Blue Hill Shale member, including the Codell Sandstone zone, is about 200 feet thick.

Water supply.—The Carlile Shale is impervious and does not yield water to wells in Mitchell County. The Codell Sandstone zone is well above the water table and yields no water to wells. A few wells in the Blue Hills area, where ground-water supplies are meager, obtain water from slope-wash deposits resting on slopes of the Carlile Shale.

Niobrara Formation

Character and subdivisions.—The Niobrara Formation was named by Meek and Hayden (1862) from exposures of calcareous marl and chalky limestone near the mouth of Niobrara River in northeastern Nebraska. In 1897 Logan (p. 219) described the Niobrara in north-central Kansas and subdivided it into the Fort Hays Limestone member below and the Smoky Hill Chalk member above. He described a section of Cretaceous rocks in Mitchell County from Beloit to Tipton (Pl. 31, fig. 1). Williston (1897, p. 235) discussed the paleontology and stratigraphy of the Niobrara in western Kansas. Landes (1930, p. 16) described the appearance and occurrence of the lower part of the Niobrara Formation in Mitchell and Osborne Counties.

In Mitchell County only the Fort Hays Limestone, lower member of the Niobrara Formation, is present. The Fort Hays Limestone member consists of thick to massive layers of soft chalky limestone separated by thin layers of chalky shale. The color ranges from creamy white to light brown. The beds of chalky limestone typically become platy when weathered. The contact of the Fort Hays Limestone member with the underlying Carlile Shale is marked by a distinct change from light-colored calcareous beds of the Fort Hays to the dark noncalcareous sand and shale of the Carlile Shale (Pl. 7B).

Distribution and thickness.—The Fort Hays Limestone member crops out in the Blue Hills area in the southwestern part of Mitchell

County, where it caps the butte-like hills. The maximum thickness of the Fort Hays in Mitchell County is about 45 feet.

Water supply.—The Fort Hays Limestone member is well above the water table in Mitchell County and does not yield water to wells.

Quaternary System

Pleistocene Series

Quaternary deposits in Mitchell County are of continental origin and are assigned to the Pleistocene Series. The deposits are both fluviatile and eolian and are composed of clay, silt, sand, and gravel. Fluviatile deposits are associated with the present drainage system or with ancient drainage systems. Eolian deposits generally mantle the upland but locally extend into the valleys and rest on older fluviatile deposits. The Pleistocene Epoch as defined by the State Geological Survey of Kansas is the last of the major divisions of geologic time and has been called the "Ice Age", owing to the presence of continental glaciers in North America and other parts of the world. The Pleistocene Epoch has been divided into four main glacial stages, the Nebraskan, Kansan, Illinoian, and Wisconsinan, and three interglacial stages, the Aftonian, Yarmouthian, and Sangamonian.

Deposits of Quaternary age, although relatively thin in Mitchell county, are near-surface materials in much of the county, as shown by the geologic map (Pl. 1). Deposits of Nebraskan or Kansan age were not recognized in Mitchell County. Quaternary deposits are classed in this report as the Sanborn Group and Recent alluvium. The Sanborn Group includes deposits of Illinoian and Wisconsinan ages and is composed of the Crete Formation, silts of the Loveland and Peoria Formations, and terrace deposits. Because it is impracticable to differentiate between the Loveland Formation and the Peoria Formation in ordinary field mapping, these formations were mapped as a unit. The Crete Formation and the Wisconsinan terrace deposits were mapped separately.

In 1931, Elias (p. 163) described unconsolidated late Pleistocene deposits consisting mostly of silt in northwestern Cheyenne County, Kansas, and named these deposits the Sanborn Formation. In 1944, Hibbard, Frye, and Leonard made a reconnaissance of Pleistocene deposits of north-central Kansas and concluded that the Sanborn in most of north-central Kansas consisted of wind-deposited silt. In 1947, Frye and Fent divided the Sanborn into three members, in ascending order the Loveland, Peoria, and Bignell Silts. This classification was modified by Frye and Leonard (1949) when they applied the name Crete to the sand and gravel underlying the Loveland Silt. In 1952, Frye and Leonard recognized the Crete (sand and gravel) Member, Loveland (silt) Member, early Wisconsinan alluvial deposits, Peoria (silt) Member, late Wisconsinan alluvial deposits, and Bignell (silt) Member within the Sanborn Formation.

A Pleistocene conference was held in Lawrence, Kansas, on June 28-29, 1956, for the purpose of developing a correlative stratigraphic nomenclature for Pleistocene deposits of Kansas. Names of some formations and members were dropped and some other names were changed in rank. New names were selected to replace some that were dropped. The Sanborn was elevated to group rank and the Loveland, Peoria, and Bignell within the Sanborn were elevated to formational rank. In November, 1956, this classification of the Sanborn Group was modified by the State Geological Survey of Kansas, and the Crete was elevated to formational rank. In Kansas the Sanborn Group now includes, in ascending order, the Crete Formation, Loveland Formation commonly containing the Sangamon buried soil at the top, early Wisconsinan terrace deposits, Peoria Formation commonly containing the Brady buried soil at the top, late Wisconsinan terrace deposits, and Bignell Formation.

Crete Formation

Stream-deposited sand, gravel, and silt overlying Cretaceous bedrock and forming high terraces along the Solomon Valley and its larger tributaries represent the Crete Formation, of Illinoian age. The terrace is dissected, discontinuous, and in a position higher than the younger Wisconsinan terrace deposits that constitute the major part of the valley fill. Scattered remnants of the Crete Formation, most of which are being excavated for sand and gravel, are all that remain of these alluvial deposits. They are more numerous along the north side of the Solomon Valley and its tributaries from the north than they are along the south side. There are also several deposits along the Salt Creek Valley in the southeastern corner of the county, mostly along the north side of the valley. The Crete Formation consists of poorly sorted silt, lenses of sand and quartz gravel, and angular to partly rounded fragments of indigenous chalky limestone (Pl. 8A). The deposits are as much as 20 feet thick and grade upward into sandy silt, classed as the Loveland Formation. Unexposed sand and gravel deposits of the Crete Formation possibly underlie the Loveland and Peoria Formations at other places in Mitchell County. The Crete Formation is above the water table in Mitchell County and does not yield water to wells.

Loveland and Peoria Formations

In the upland of Mitchell County, eolian silts form the most extensive outcrop, blanketing much of the county with a cover of loess ranging from a featheredge to more than 40 feet in thickness. Eolian silts in Mitchell County represent the Loveland Formation of Illinoian age and the Peoria Formation of Wisconsinan age. The Bignell Formation was not recognized in Mitchell County and if present is incorporated within the modern soil profile. Loess in Mitchell County occurs as an upland phase, in which it caps the rolling topography of the uplands, as well as a valley phase, in which it masks the valley walls of the larger streams. Colluvium, material deposited by slope wash and consisting of reworked loess and Cretaceous bedrock fragments, has been mapped with the Loveland and Peoria Formations where it is sufficiently thick to conceal the underlying bedrock.

The Loveland Formation is a reddish-tan silt, in part eolian, at the top of which is the Sangamon buried soil. In much of Mitchell County the Loveland Formation is almost entirely within the Sangamon soil profile and consists of 2 or 3 feet of silt forming a fossil soil resting on the eroded surface of Cretaceous rocks. In places the pre-soil material seems to represent local slope-wash deposits consisting mostly of eroded Cretaceous rocks. The bulk of the upland silt mantle in Mitchell County consists of the Peoria Formation, which overlies the Loveland Formation. The Peoria Formation is a massive tan to gray-buff calcareous eolian silt that extends in an almost unbroken blanket over much of the upland (Pl. 8B). The deposits mapped as Peoria and Loveland Formations in this report consist mostly of relatively thin wind-deposited silts overlying Cretaceous rocks and are generally well above the water table. In the southwestern part of Mitchell County and in parts of the upland of the county where ground-water supplies are meager, however, shallow wells obtain some water from colluvial and slope deposits classed as Sanborn Group in this report.

Terrace Deposits

Character and extent.—The extent of the terrace deposits is shown on the geologic map (Pl. 1). Their thickness and character are shown on cross sections in Plate 2 and are described in logs of test holes at the end of this report. Broad smooth terrace surfaces interrupted by a relatively narrow flood-plain belt characterize the Solomon Valley (Pl. 9A). The terrace deposits along the Solomon Valley are continuous with the terrace deposits along the valley of

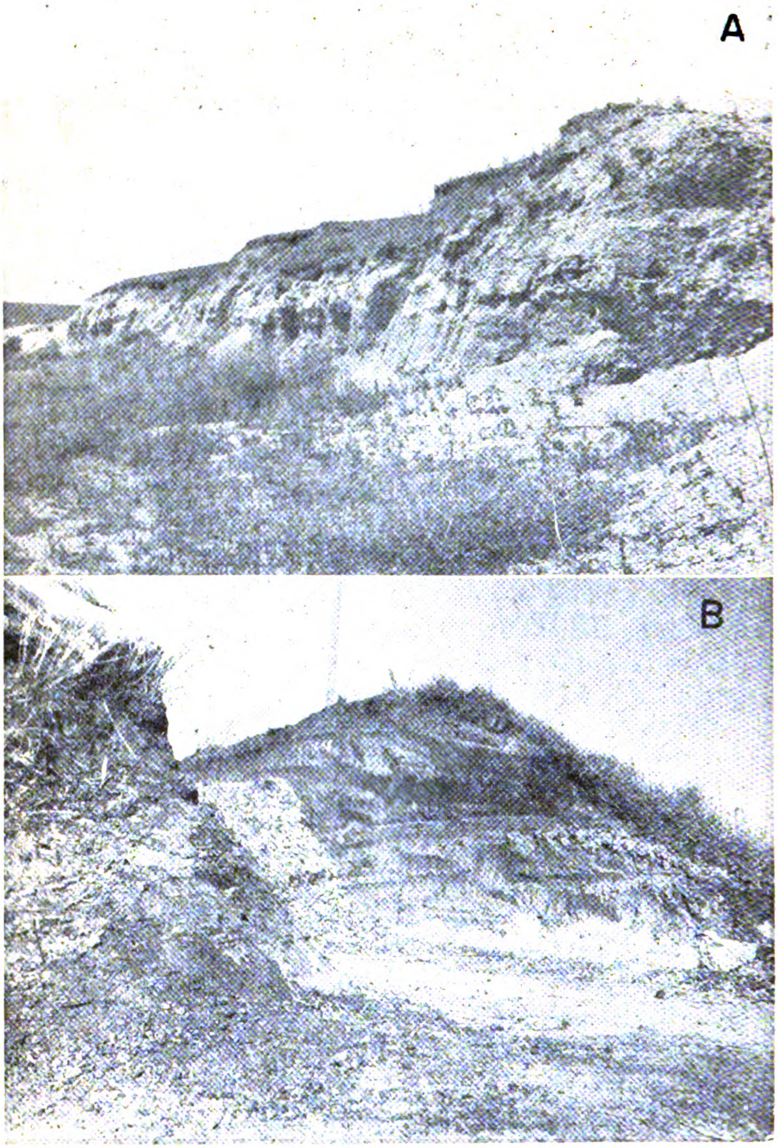


Plate 8.—A, Crete Formation, SW¼ sec. 33, T. 8 S., R. 8 W. B, Pit silo showing eolian silts classed as Peoria Formation overlying Carlile Shale, SW¼ sec. 11, T. 7 S., R. 8 W.

North Fork, where the level upper surface has been called the Kirwin Terrace (Leonard, 1952). The Kirwin Terrace is the most prominent physiographic feature in the Solomon Valley, and the underlying deposits constitute the most important aquifer in Mitchell County. The width of the Kirwin Terrace ranges from about 1½ miles in the western part of the county to slightly more than 3 miles in the eastern part. The height of the terrace above the alluvial flood plain is about 15 or 20 feet. Narrow prongs of the Kirwin Terrace extend into the valleys of the larger tributaries. The Salt Creek valley is characterized by broad smooth Wisconsinan terraces consistent with the Kirwin Terrace and entrenched by a narrow channel of Recent age incised very little into the older alluvial deposits.

The deposits underlying the Kirwin Terrace represent a single cycle of valley cutting and filling during late Wisconsinan time, but minor terrace scarps on the terrace surface suggest a complex of several partly developed episodes in the closing stages of the terrace cycle. The more recognizable breaks (Pl. 9B) in the terrace surface—where a flat terrace surface drops to a slightly lower level —are shown by dashed lines on the geologic map. The presence of distinctive humic bands in the upper part of the terrace deposits further indicates short periods of surface stability.

Test-hole data show that, in general, the terrace surface in the Solomon Valley is underlain by about 45 to 60 feet of unconsolidated deposits in the main part of the valley fill. The Cretaceous bedrock beneath the terrace fill is overlain by moderately well sorted gravel grading upward into sand and gravel, which in turn grades upward into fine sand and silt. Clay lenses are common within the terrace fill, and the upper part of the terrace deposits consists of clay, silt, and sandy silt. Gravel within the terrace deposits is predominantly from the Rocky Mountains, derived secondarily from the Ogallala Formation to the west. Also present is a small amount of chalky limestone gravel derived from eroded Cretaceous rocks. The terrace deposits fill a well-developed valley, which is cut considerably below the older stream deposits of the Crete Formation of early Illinoian age along the valley margins. The Peoria Formation of the Sanborn Group, which mantles the upland and its slopes, is seemingly truncated along the valley walls.

That the terrace deposits of the Solomon Valley are relatively youthful is exemplified by the relation of the terrace deposits to the channel of Solomon River. Meanders are incised into the

PLATE 9.—**A,** Kirwin Terrace in Solomon Valley, northeast from NW¼ sec. 27, T. 7 S., R. 7 W. **B,** Kirwin Terrace scarp, NE¼ sec. 33, T. 6 S., R. 9 W.

terrace surface from a meander belt that is not fully developed. At many places along Solomon River, peninsulas and islands of terrace deposits extend into meander loops of the stream (Pl. 1). As the meanders move downstream, they will cut off the peninsulas to form islands, which eventually will be removed completely. In a short span of geologic time, a meander belt of uniform width without projections of terrace deposits will be established.

Water supply.—Wisconsinan terrace deposits constitute the principal source of ground water in Mitchell County. The relatively coarse sand and gravel in the lower part of the fill of the Solomon River valley is fairly permeable and lies below the water table. The broad flat terrace surface also constitutes a large recharge area. In addition, many small streams that drain adjacent uplands and that flow only after periods of rainfall do not have channels across the terrace but fan out and disappear on the terrace surface, contributing water to the ground-water reservoir. Some ground water also moves from the upland into the terrace deposits, contributing to the replenishment of water in the alluvial material. Ground water moves laterally through the terrace deposits and into the alluvium or into the channel of Solomon River. The chemical character of water obtained from the terrace deposits is shown by analyses in Table 5 and graphically in Figure 14.

Alluvium

Character and extent.—Alluvium of Recent age underlies the flood plain of the Solomon Valley and narrow extensions in the tributary valleys. Recent alluvium is the stream-deposited material that has accumulated since the close of the alluvial cycle during which the broad Kirwin Terrace was formed. The alluvium occupies channels cut into Wisconsinan terrace deposits. As most of the alluvium was derived from the terrace deposits it is similar in composition to the terrace deposits and consists predominantly of coarse sand and gravel. Because of the similarity of the unconsolidated deposits in the tributary valleys, the separation of alluvium and terrace deposits is difficult, and alluvium along the smaller streams could not be shown at the mapping scale used. In places the alluvium and terrace deposits of the small tributary streams grade headward into colluvium, slope wash, and eolian silts of the Sanborn Group. Thus, the alluvial contact in the tributary valleys is arbitrary, and in the upland areas the contact between the area mapped as terrace deposits and the area mapped as silt deposits of the Sanborn Group also is arbitrary. The areal extent of the alluvium is shown on the geologic map (Pl. 1). The precise thickness of the alluvium is not generally determinable, but the inferred thickness at several places is shown on cross sections in Plate 2.

The Recent alluvial flood plain along Solomon River is about one-fourth mile to nearly a mile in width. The surface of the flood plain is about 10 to 25 feet below the level of the Kirwin Terrace and about 15 to 20 feet above the normal water surface of the river. The Recent alluvium fills a narrow valley cut into the terrace deposits and represents a single cycle of cutting and filling. It consists of gravel and coarse sand grading upward into fine sand and silt and represents a reworking of the older alluvial material. The alluvium in the valleys of tributary streams is representative of the bedrock making up their drainage basins and consists predominantly of fragments of bedrock material mixed with stratified deposits of clay and sandy silt. For the most part, however, the larger tributaries contain in their lower parts fairly coarse alluvial material, mostly below the water table. Such deposits constitute sources of moderate supplies of ground water. Cross section C-C' on Plate 2 shows the character of deposits across Limestone Creek.

Water supply.—Along the Solomon Valley there are only a few wells in the area mapped as alluvium, as it is subject to frequent floods. The alluvial deposits are an important potential source of ground water, however, and wells penetrating the alluvium can be expected to yield adequate amounts of water.

The alluvium of the smaller streams contains less sand and gravel and more silt and clay than that of the main valley, and has a lower transmissibility. In the upland, the thin alluvial material of the minor tributaries constitutes a poor aquifer, but in places it is the only source of ground water. Chemical analyses of water from wells in Recent alluvium are given in Table 5 and are shown graphically in Figure 14.

RECORD OF WATER LEVEL IN OBSERVATION WELL 6-9-27abc

A 22-year record of water-level measurements in observation well 6-9-27abc is given in Table 16. This table includes measurements from the beginning of record in July 1934 through December 1956.

TABLE 16.—*Water levels, in feet below land surface, in observation well 6-9-27abc (1934-1956)*

Date	Water level	Date	Water level
July 11, 1934	29.53	Aug. 2, 1935	27.30
25	29.87	9	27.52
Aug. 3	30.05	15	27.69
10	30.17	22	27.82
17	30.24	29	27.63
24	30.37	Sept. 5	26.03
31	30.43	12	26.17
Sept. 6	30.49	19	26.66
14	30.52	26	26.95
21	30.57	Oct. 3	26.98
27	30.60	10	27.10
Oct. 4	30.68	17	27.25
13	30.74	24	27.23
23	30.74	31	27.25
27	30.82	Nov. 7	27.26
Nov. 3	30.73	14	27.30
10	30.83	21	27.35
17	30.76	29	27.36
24	30.76	Dec. 5	27.36
Dec. 1	30.75	12	27.34
8	30.79	19	27.47
15	30.77	26	27.47
22	30.79	Jan. 2, 1936	27.37
29	30.82	9	27.42
Jan. 5, 1935	30.80	16	27.43
12	30.80	23	27.48
19	30.85	30	27.48
26	30.85	Feb. 6	27.48
Feb. 2	30.87	13	27.38
9	30.86	20	27.47
16	30.90	27	27.48
23	30.85	Mar. 5	27.54
Mar. 2	30.84	12	27.51
9	30.82	19	27.55
16	30.90	26	27.52
23	30.91	April 2	27.61
30	30.91	9	27.55
April 6	30.88	16	27.65
13	30.92	23	27.57
20	30.92	30	27.61
27	30.96	May 7	27.63
May 4	30.99	14	26.89
11	31.10	21	27.29
18	30.89	28	27.42
24	29.88	June 4	27.63
31	28.38	11	27.74
June 7	26.05	18	27.85
14	26.40	25	28.00
21	25.24	July 2	28.08
28	26.04	9	28.22
July 5	26.03	16	28.38
12	26.57	23	28.50
19	26.86	30	28.67
26	27.07		

TABLE 16.—*Water levels, in feet below land surface, in observation well 6-9-27abc (1934-1956)—Continued*

Date	Water level	Date	Water level
Aug. 6, 1936	28.77	Sept. 1, 1937	29.60
13	28.85	8	29.69
20	28.98	15	29.71
27	29.09	22	30.04
Sept. 3	29.22	29	30.11
10	29.20	Oct. 6	29.99
17	29.29	13	30.06
24	29.36	20	30.08
Oct. 1	29.08	27	30.11
8	29.12	Nov. 3	30.23
15	29.18	10	30.19
22	29.27	17	30.17
29	29.25	24	30.19
Nov. 5	29.26	Dec. 1	30.25
12	29.28	8	30.28
19	29.31	15	30.30
25	29.31	22	30.32
Dec. 3	29.30	29	30.33
10	29.35	Jan. 5, 1938	30.28
17	29.32	12	30.30
24	29.34	19	30.32
31	29.35	26	30.38
Jan. 7, 1937	29.38	Feb. 2	30.33
14	29.39	9	30.39
23	29.40	17	30.37
28	29.43	23	30.48
Feb. 4	29.41	Mar. 2	30.35
11	29.42	10	30.39
18	29.16	16	30.30
25	29.13	23	30.25
Mar. 4	29.10	30	30.26
11	28.99	April 6	30.26
18	28.99	13	30.31
25	29.05	20	30.29
April 1	29.00	27	30.13
8	29.04	May 4	30.12
14	29.01	11	30.04
22	29.00	19	29.95
28	29.04	25	29.78
May 5	29.12	June 2	28.82
12	29.13	8	28.55
19	29.14	15	28.36
26	29.23	22	28.25
June 3	29.20	29	28.51
10	28.45	July 6	28.51
16	27.37	13	28.64
23	28.28	20	28.61
30	28.54	27	28.71
July 7	28.69	Aug. 3	28.80
14	28.83	10	28.93
21	28.98	17	28.99
28	29.01	24	29.07
Aug. 4	29.17	31	29.17
12	29.30	Sept. 7	29.14
18	29.37	14	29.26
25	29.55	21	29.36

TABLE 16.—*Water levels, in feet below land surface, in observation well 6-9-27abc (1934-1956)—Continued*

Date	Water level	Date	Water level
Sept. 26, 1938	29.43	May 15, 1940	29.25
Oct. 5	29.54	June 10	29.43
12	29.61	Aug. 20	30.35
19	29.72	Sept. 20	30.46
Nov. 2	29.72	Oct. 23	30.85
9	29.77	Dec. 2	30.72
16	29.79	21	30.89
23	29.86	Jan. 20, 1941	30.91
Dec. 1	29.82	Feb. 21	30.96
7	29.85	Mar. 19	30.84
14	29.90	April 21	30.81
21	29.90	May 23	30.94
28	29.88	June 25	25.99
Jan. 4, 1939	29.84	July 23	27.61
10	29.91	Aug. 26	28.28
18	29.93	Sept. 22	26.31
24	29.95	Oct. 27	25.89
Feb. 1	29.89	Nov. 26	25.99
7	29.91	Dec. 29	26.29
14	29.96	Jan. 26, 1942	26.25
21	30.01	Feb. 19	26.38
Mar. 7	29.97	Mar. 21	26.51
16	29.99	April 22	26.41
29	29.78	May 26	25.67
April 5	29.78	June 22	25.90
12	29.84	July 28	25.99
18	29.84	Aug. 28	25.51
26	29.76	Sept. 25	25.42
May 3	29.79	Oct. 28	25.85
10	29.83	Nov. 23	26.09
17	29.89	Jan. 6, 1943	26.41
24	29.65	29	26.47
31	29.59	Mar. 4	26.30
June 7	29.35	April 26	25.74
14	28.78	June 30	26.01
21	29.07	July 30	25.99
28	28.99	Aug. 27	26.66
July 5	29.17	Oct. 21	27.43
19	29.55	Nov. 27	27.20
Aug. 2	29.59	Dec. 30	27.14
17	27.07	June 27, 1944	24.51
30	28.30	Aug. 2	25.55
Sept. 13	28.69	Sept. 29	25.74
27	28.91	Oct. 31	26.26
Oct. 11	29.12	July 16, 1945	25.88
25	29.21	Sept. 24	26.87
Nov. 8	29.27	Sept. 17, 1946	23.32
22	29.32	Oct. 15	24.17
Dec. 6	29.32	Nov. 15	25.00
20	29.38	Dec. 21	25.45
Jan. 3, 1940	29.37	Jan. 25, 1947	25.83
Feb. 7	29.36	Feb. 25	26.14
Mar. 14	29.39	Mar. 25	26.27
April 3	29.42	April 25	25.89
18	29.49	May 26	25.63
May 2	29.50	June 24	22.36

TABLE 16.—*Water levels, in feet below land surface, in observation well 6-9-27abc (1934-1956)*—*Concluded*

Date	Water level	Date	Water level
July 25, 1947	24.56	Mar. 19, 1951	24.63
Aug. 26	25.63	May 11	25.47
Sept. 29	26.52	July 25	12.00
Oct. 27	26.78	Aug. 28	16.78
Nov. 26	26.60	Oct. 24	18.25
Dec. 29	26.58	Dec. 12	19.14
Feb. 2, 1948	26.61	Feb. 27, 1952	20.15
Mar. 30	26.18	May 25	19.75
May 27	26.48	Sept. 5	21.76
July 29	25.55	Mar. 17, 1953	22.40
Sept. 28	26.63	May 20	22.45
Nov. 29	26.57	Nov. 2	23.93
April 21, 1949	25.68	April 5, 1954	24.20
June 29	24.00	July 23	23.82
July 30	25.28	Dec. 13	25.57
Oct. 26	25.25	April 4, 1955	25.04
Dec. 28	26.39	July 10	24.55
Feb. 7, 1950	25.73	22	24.98
Mar. 8	26.21	Oct. 28	26.58
April 12	26.19	Mar. 5, 1956	26.42
June 3	24.50	June 25	26.80
Sept. 20	22.15	Sept. 18	27.86
Nov. 15	23.04	Dec. 19	28.44
Jan. 22, 1951	28.10		

RECORDS OF WELLS AND TEST HOLES

Information pertaining to 310 wells inventoried and 60 test holes in Mitchell County is given in Table 17. The well-numbering system in this table is illustrated in Figure 2 and described on page 10.

TABLE 17.—*Records of wells and test holes in Mitchell County.*

Well number (1)	Location	Owner or tenant	Type of well (2)	Depth of well below land surface, feet (3)	Diameter of well, inches	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift and type of power (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above land surface, feet	Measuring point: Height of L. S. above mean sea level, feet (7)	Depth to water level below land surface, feet (8)	Date of measurement	REMARKS
	T. 6 S., R. 6 W.															
6-6-3ddd	SE SE SE sec. 3	Lloyd Lesley	Du	20.0	36	R	Chalky limestone	Greenhorn Limestone	Cy, W	N	Top of board platform	0.3	....	13.42	7- 1-55	
6-6-8bbd	SE NW NW sec. 8	Charles B. Hartman	Dr	160	6	GI	Sandstone	Dakota Formation	Cy, W	D, S	Top of concrete cover	0.0	....	140	7- 1-55	"Soda" taste reported.
6-6-9ccc	SW SW SW sec. 9	Howard R. Abernethy	Du	17.5	36	R	Chalky limestone	Greenhorn Limestone	N	N	Top of rock curb	0.1	....	6.03	6-25-55	Abandoned stock well.
6-6-12dda	NE SE SE sec. 12	B. C. Culp	Dr	220	8	GI	Sandstone	Dakota Formation	Cy, W	S	Land surface	0.0	....	100	7- 1-55	Reported salty but used for stock.
•6-6-17ddd	SE SE SE sec. 17	Jim Snyder	Du	39.0	42	R	Chalky limestone	Greenhorn Limestone	Cy, W	D, S	Top of board platform	0.1	....	33.25	6-21-55	
6-6-18da	NE SE sec. 18	Charles B. Hartman	Dr	200	8	GI	Sandstone	Dakota Formation	N	N	Top of casing	0.5	....	106.50	7- 1-55	Reported salty; unused.
6-6-19bbc	SW NW NW sec. 19	Mary S. Wessling	Du	20.0	36	R	Chalky limestone	Greenhorn Limestone	Cy, W	S	Top of rock curb	0.1	....	8.30	6-21-55	
6-6-22aba	NE NW NE sec. 22	Inez I. Cox	Du	25.0	36	R	do	do	Cy, H	S	Top of board platform	0.2	....	10.10	6-22-55	
6-6-23ddc	SW SE SE sec. 23	Elva Ross	Du	19.0	36	R	do	do	Cy, W	S	do	2.0	....	7.35	6-23-55	
6-6-25dcc	SW SW SE sec. 25	H. File	Du	15.0	36	R	do	do	Cy, H	S	do	2.0	....	7.90	6-22-55	
6-6-27ddd	SE SE SE sec. 27	N. H. Shadowen	Dr	118.0	8	GI	Sandstone	Dakota Formation	Cy, W	S	Top of concrete base	0.3	....	97.94	8- 6-55	
6-6-31ccc	SW SW SW sec. 31	Philip Doyle	Du	22.0	60	R	Sand and gravel	Terrace deposits	T, E	D, S	Top of pump base	0.5	....	12.87	8- 6-55	
6-6-33bb	NW NW sec. 33	Anna File	Du	19.0	36	R	Chalky limestone	Greenhorn Limestone	Cy, H	N	Top of board platform	1.0	....	9.53	6-22-55	Abandoned farm well.
	T. 6 S., R. 7 W.															
6-7-3bd	SE NW sec. 3	Joe Shaffer	Du	28.0	42	R	Sand, gravel	Terrace deposits	Cy, W	S	Top of rock base	2.0	....	18.35	7- 1-55	
6-7-7aad	SE NE NE sec. 7	Clara Pauly	Du	25.0	30	R	Chalky limestone	Greenhorn Limestone	Cy, H	N	Top of board platform	0.5	....	15.48	6-14-55	Abandoned farm well.

*6-7-13cdd	SE SE SW sec. 13	Glen Helmbrecht	Dr	140	6	GI	Sandstone	Dakota Formation	Cy, E	S	Land surface	0.0	....	100	7- 1-55	
6-7-14ba	NE NW sec. 14	Joseph Eilert	Dr	71.5	6	GI	Sand, gravel	Terrace deposits	Cy, H	N	Top of casing	0.5	....	35.10	8-10-55	
6-7-14bdc	SW SE NW sec. 14	Felix Gengler	Dr	62.0	7	GI	do	do	Cy, E	S	Top of concrete base	1.0	....	27.20	8-10-55	
*6-7-14dcc	SW SW SE sec. 14	J. S. Gholdson	Dr	93	8	GI	Sandstone	Dakota Formation	Cy, W	D, S	Top of board platform	0.0	....	40	7- 1-55	
6-7-18cdc	SW SE SW sec. 18	Joseph Eilert	Du	20.0	30	R	Chalky limestone	Greenhorn Limestone	N	N	do	0.2	....	14.73	6-20-55	
6-7-21bcc	SW SW NW sec. 21	Ben Schwerman	Du	35.0	42	R	do	do	Cy, W	S	do	0.1	....	28.30	6-21-55	
6-7-22aaa	NE NE NE sec. 22	Idonia Davis	Du	96.0	36	R	Sandstone	Dakota Formation	Cy, W	N	do	0.3	....	45.82	6-21-55	
6-7-26bab	NW NE NW sec. 26	H. C. Nelson	Du	32.5	42	R	Sand and gravel	Terrace deposits	Cy, E	D, S	Top of concrete curb	0.2	....	31.50	8-10-55	
6-7-28cdc	SW SE SW sec. 28	Will J. Budke	Du	34.0	36	R	Chalky limestone	Greenhorn Limestone	Cy, W	S	Top of board platform	0.2	....	19.60	7-16-55	
6-7-31aaa	NE NE NE sec. 31	John L. Wilson	Du	50.0	36	R	Sand, gravel	Terrace deposits	J, E	D, S	do	0.6	....	29.71	8-26-54	
6-7-33aad	SE NE NE sec. 33	Frank Eck	Dr	56.0	6	GI	Chalky limestone	Greenhorn Limestone	Cy, H	S	Top of concrete base	0.6	....	9.80	9- 1-54	
6-7-35aaa	NE NE NE sec. 35	John Wessling	Du	27.5	30	R	Sand, gravel	Terrace deposits	Cy, W	S	Top of rock curb	0.2	....	16.65	6-22-55	
	T. 6 S., R. 8 W.															
6-8-3ddd	SE SE SE sec. 3	Clyde Bean	Dr	30	6	N	Chalky limestone	Greenhorn Limestone	N	N	Top of board platform	0.1	....	17.33	8-10-55	Uncased hole.
6-8-6bba	NE NW NW sec. 6	J. Kittel	Du	33.0	36	R	do	do	Cy, W	S	Top of rock curb	0.6	....	18.97	6-20-55	
6-8-8ddc	SW SE SE sec. 8	Hazel Sutton	Du	30.0	42	R	do	do	Cy, H	N	do	0.2	....	24.74	6- 9-55	
6-8-9ddc	SW SE SE sec. 9	Grace Gaylord	Du	25.0	30	R	do	do	Cy, W	S	Top of board platform	0.6	....	18.80	6-20-55	
6-8-14aab	NW NE NE sec. 14	W. C. Flinn	Du	20.0	48	R	do	do	Cy, W	N	do	0.1	....	7.82	6-20-55	Abandoned farm well.
6-8-14dcd	SE SW SE sec. 14	John Schmitz	Du	24.0	36	R	do	do	Cy, W	S	do	0.5	....	15.34	6-14-55	
6-8-20bcc	SW SW NW sec. 20	E. A. Troughton	Du	38.5	42	R	do	do	N	N	Top of rock curb	0.2	....	15.08	11-17-54	Abandoned farm well.
*6-8-24cdc	SW SE SW sec. 24	Clarence Kelly	Du	28.0	30	R	do	do	Cy, H	S	do	1.0	....	20.90	8-12-55	
6-8-25cbb	NW NW SW sec. 25	Alfred Koch	Du	24.5	90	R	Sand and gravel	Terrace deposits	Cy, W	S	Top of concrete base	1.5	....	13.08	8-26-54	
6-8-27ccc	SW SW SW sec. 27	Robert Wagner	Du	34.2	48	R	Chalky limestone	Greenhorn Limestone	Cy, W	D, S	Top of board platform	0.1	....	30.03	8-20-54	
6-8-30ada	NE SE NE sec. 30	Frank Kirgis	Du	30.0	40	R	do	do	Cy, W	D	do	0.2	....	20.54	8-19-54	
6-8-31bbb	NW NW NW sec. 31	Arch McKechnie	Du	32.0	40	R	Sand, gravel	Terrace deposits	Cy, W	D, S	do	0.2	1,422	19.34	11-12-54	
6-8-32bcc	SW SW NW sec. 32	....	Dr	50.0	4	N	do	do	N	O	Land surface	0.0	1,423	27.70	7-22-54	Test hole.
6-8-32cbb	NW NW SW sec. 32	....	Dr	44.0	4	N	do	do	N	O	do	0.0	1,411	18.10	7-22-54	do
6-8-32ccc	SW SW SW sec. 32	....	Dr	90.0	4	N	do	do	N	O	do	0.0	1,407	....	....	do
*6-8-32ccd	SE SW SW sec. 32	R. W. McKinnie	Dr	44.7	6	GI	do	do	Cy, W	S	Top of casing	3.1	1,405	19.60	8-19-54	
6-8-34bbc	SW NW NW sec. 34	Earnest Metcalf	Du	43.6	36	R	Chalky limestone	Greenhorn Limestone	J, E	D, S	Board floor of pump house	-4.6	....	37.07	8-20-54	Reported good well.
6-8-34cc	SW SW sec. 34	R. L. Metcalf	Du	32.0	48	R	Sand, gravel	Terrace deposits	Cy, W	O	do	0.2	1,399	17.63	8-20-54	Observation well.

Table 17.—*Records of wells and test holes in Mitchell County*—Continued.

Well number (1)	Location	Owner or tenant	Type of well (2)	Depth of well below land surface, feet (3)	Diameter of well, inches	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift and type of power (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above land surface, feet	Measuring point: Height of L. S. above mean sea level, feet (7)	Depth to water level below land surface, feet (8)	Date of measurement	REMARKS
	T. 6 S. R. 8 W.															
*6-8-34cdc	SW SE SW sec. 34	R. L. Metcalf	Du	53.5	36	R	Sand, gravel	Terrace deposits	Cy, E	D, S	Board floor of pumphouse	0.2		49.20	8-20-54	
6-8-34ddd	SE SE SE sec. 34	Cities Service Co.	Dr	44	6	GI	do	do	J, E	D,Ind	Land surface	0.0	1,419	40	9-15-54	
6-8-35bbb	NW NW NW sec. 35		Dr	70.0		N	do	do	N	O	do	0.0	1,439.0			Test hole.
6-8-35bcc	SW SW NW sec. 35		Dr	38.0		N	do	do	N	O	do	0.0	1,424.8			do
6-8-35ccc	SW SW SW sec. 35		Dr	37.0		N	do	do	N	O	do	0.0	1,409.8			do
	T. 6 S., R. 9 W.															
6-9-2ccb	NW SW SW sec. 2	Earl White	Du	17.0	30	R	Chalky limestone	Greenhorn Limestone	Cy, W	N	Top of rock curb	0.2		4.02	6- 8-55	
6-9-5aba	NE NW NE sec. 5	G. M. Nusbaum	Du	27.0	36	R	do	do	Cy, W	S	Top of board platform	0.2		22.10	6- 7-55	
*6-9-15bbb	NW NW NW sec. 15	Leo Hayden	Du	33.0	36	R	Sand, gravel	Terrace deposits	Cy, W	D, S	do	0.1		24.09	6- 8-55	
6-9-15ccc	SW SW SW sec. 15	M. E. Gentleman	Du	37.0	36	R	do	do	Cy, W	N	do	0.2		31.52	9- 8-54	Abandoned farm well.
*6-9-20dcd	SE SW SE sec. 20	O. E. Dean	Du	55.0	36	R	Chalky limestone	Greenhorn Limestone	Cy, W	D, S	do	0.1		49.56	11-15-54	
6-9-22aaa	NE NE NE sec. 22	M. E. Gentleman	Du	37.0	36	R	do	do	N	N	do	0.1		34.54	9- 8-54	
6-9-22aab	NW NE NE sec. 22	do	Du	28.0	48	R	Sand, gravel	Terrace deposits	Cy, W	N	do	0.5	1,431.7	23.14	9- 8-54	
6-9-23ccc1	SW SW SW sec. 23		Dr	40.0		N	do	do	N	O	Land surface	0.0	1,418.8	16.20	6- 4-54	Test hole.
6-9-23ccc2	SW SW SW sec. 23		Dr	35.5		N	do	do	N	O	do	0.0	1,418.6	17.00	5-17-54	do
6-9-23ccd1	SE SW SW sec. 23		Dr	44.0		N	do	do	N	O	do	0.0	1,421.9			do
6-9-23ccd2	SE SW SW sec. 23		Dr	44.5		N	do	do	N	O	do	0.0	1,425.3			do
6-9-23cdc	SW SE SW sec. 23		Dr	20.5		N			N	O	do	0.0	1,432.7			do
6-9-23cdd	SE SE SW sec. 23		Dr	12.0		N					do	0.0	1,479.3			do
6-9-23dcc	SW SW SE sec. 23		Dr	27.0		N					do	0.0	1,462.5			do
*6-9-26cad1	SE NE SW sec. 26	City of Glen Elder	Du	48	168	R	do	do	T, E	P	do	0.0	1,419	21	9-17-55	
6-9-26cad2	SE NE SW sec. 26	do	Du	48	168	R	do	do	T, E	P	do	0.0	1,419	21	9-17-55	Emergency city well.

6-9-26dcd	SE SW SE sec. 26	Frank Nash	Du	39.0	48	R	do	do	Cy, W	D, S	Top of board platform	0.3	1,419.2	23.18	9-9-54	
6-9-27aba1	NE NW NE sec. 27		Dr	37.0		N	do	do	N	O	Land surface	0.0	1,421.2	23.00	5-27-54	Test hole
6-9-27aba2	NE NW NE sec. 27		Dr	32.0		N	do	do	N	O	do	0.0	1,415.2	17.70	5-27-54	do.
6-9-27abb1	NW NW NE sec. 27		Dr	24.0		N	do	do	N	O	do	0.0	1,411.3	14.30	6-3-54	do
6-9-27abb2	NW NW NE sec. 27		Dr	41.5		N	do	do	N	O	do	0.0	1,422.0	24.60	5-19-54	do
6-9-27abb3	NW NW NE sec. 27		Dr	28.0		N					do	0.0	1,435.5			do
6-9-27abc	SW NW NE sec. 27	L. Lowdermilk	Du	36.0	48	R	Sand, gravel	Terrace deposits	N	N	Top of rock base	0.4	1,422	23.82	7-23-54	Observation well.
6-9-27bbb	NW NW NW sec. 27		Dr	25.0		N					Land surface	0.0	1,491.2			Test hole.
6-9-27cad	SE NE SW sec. 27		Dr	62.0		N					do	0.0	1,494.2			do
*6-9-30dab	NW NE SE sec. 30	John Reinhardt	Dr	37.0	6	GI	Sand, gravel	Terrace deposits	Cy, W	O	Top of casing	0.2	1,432.0	29.94	9-13-54	Observation well.
*6-9-33acc	SW SW NE sec. 33	C. I. Stuart	Dr	48.7	7	GI	do	do	Cy, W	D, S	Top of board platform	0.2	1,427	31.59	9-10-54	
6-9-34baa1	NE NE NW sec. 34		Dr	36.0		N	do	Alluvium and terrace deposits	N	O	Land surface	0.0	1,404.6	13.80	10-5-49	Test hole.
6-9-34baa2	NE NE NW sec. 34		Dr	61.0		N	do	Terrace deposits	N	O	do	0.0	1,424.1	31.8	10-6-49	do
6-9-34bda	NE SE NW sec. 34		Dr	59.0		N	do	do	N	O	do	0.0	1,422.8	30.2	10-7-49	do
6-9-34bdd	SE SE NW sec. 34		Dr	60.0		N	do	do	N	O	do	0.0	1,426.1			do
6-9-34cad	SE NE SW sec. 34		Dr	76.0		N	do	do	N	O	do	0.0	1,423.0	28.5	10-14-49	do
6-9-36ddc	SW SE SE sec. 36	Carl Thiesen	Du	38.5	42	R	do	do	Cy, W	N	Top of board platform	1.5	1,410	25.39	11-17-54	
	T. 6 S., R. 10 W.															
6-10-1bbb	NW NW NW sec. 1	E. G. Brown	Du	18.0	48	R	Chalky limestone	Greenhorn Limestone	N	N	do	0.1		9.05	6-7-55	Abandoned farm well.
6-10-1dd	SE SE sec. 1	M. M. Davey	Du	18.0	48	R	do	do	Cy, W	S	do	0.5		13.58	6-8-55	
6-10-3ccc	SW SW SW sec. 3	Warren Inskeep	Du	21.5	36	R	do	do	Cy, W	D, S	Top of concrete base	0.5		18.20	6-7-55	
6-10-5cdc	SW SE SW sec. 5		Dr	60.0	4	N	Sand, gravel	Terrace deposits	N	O	Land surface	0.0	1,541.1	34.10	5-6-46	Test hole.
6-10-6ddc	SW SE SE sec. 6	Bob Bowman	Du	23.5	36	R	do	do	Cy, W	D, S	Top of board platform	0.2		19.95	6-6-55	
6-10-7ddd	SE SE SE sec. 7	Carl Lutzen	Du	27.5	36	R	do	do	Cy, W	D, S	do	0.3	1,483.2	23.27	9-15-54	
6-10-8ccb	NW SW SW sec. 8		Dr	40.0	4	N	do	do	N	O	Land surface	0.0	1,508.1	30.40	5-6-46	Test hole.
6-10-12ccd	SE SW SW sec. 12	G. V. Countryman	Du	25.0	42	R	do	do	Cy, W	S	Top of rock curb	0.2		17.53	6-8-55	
6-10-15ddd	SE SE SE sec. 15	A. P. Myers	Du	20.0	36	R	Chalky limestone	Greenhorn Limestone	N	N	Top of board platform	0.1		14.90	6-7-55	
*6-10-16ddc	SW SE SE sec. 16	John Reimann	Du	35.5	40	R	do	do	Cy, W	D, S	Top of concrete base	0.4		32.57	9-15-54	
6-10-17bcc	SW SW NW sec. 17		Dr	40.0	4	N	Sand, gravel	Terrace deposits	N	O	Land surface	0.0	1,473.9	15.70	5-6-46	Test hole.
6-10-18bbb	NW NW NW sec. 18	John Schoen	Dr	40	12	T	do	do	Cy, W	D, S	Top of board platform	0.7	1,482.8	24.80	9-14-54	
6-10-20bbc	SW NW NW sec. 20		Dr	40.0	4	N	do	do	N	O	Land surface	0.0	1,469.9	22.00	5-4-46	Test hole.
6-10-20bcc	SW SW NW sec. 20	Charles Klechner	Dr	41.5	12	T	do	do	Cy, W	S	Top of board platform	0.1	1,471.1	27.58	9-14-54	do
6-10-20ccb	NW SW SW sec. 20		Dr	40.0	4	N	do	do	N	O	Land surface	0.0	1,464.7	30.90	5-4-46	do
6-10-23bcc	SW SW NW sec. 23	Ernest Moxter	Du	19.0	48	R	do	do	J, E	D, S	Top of rock curb	3.0		15.82	11-12-54	

TABLE 17.—*Records of wells and test holes in Mitchell County—Continued.*

Well number (1)	Location	Owner or tenant	Type of well (2)	Depth of well below land surface, feet (3)	Diameter of well, inches	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift and type of power (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above land surface, feet	Measuring point: Height of L. S. above mean sea level, feet (7)	Depth to water level below land surface, feet (8)	Date of measurement	REMARKS
	T. 6 S., R. 10 W.															
6-10-24ba	NE NW sec. 24	H. C. Pargett	Du	25.5	42	R	Chalky limestone	Greenhorn Limestone	Cy, E	D, S	Top of pump shelter	2.5	.....	23.62	9-13-54	Reported good well.
6-10-24cbb	NW NW SW sec. 24	Eugene Thull	Dr	32.0	6	GI	Sand and gravel	Terrace deposits	J, E	D	Top of board platform	0.5	1,455.9	25.63	9-13-54	
6-10-25daa	NE NE SE sec. 25	Carlos Bingesser	Dr	54	8	GI	do	do	T, E	D, S	Land surface	0.0	1,438.9	36	9-15-54	Reported use of 5,000 gpd.
6-10-26bcc	SW SW NW sec. 26	G. Weeks	Du	42.0	42	R	do	do	Cy, H	N	Top of board platform	1.5	1,445.8	31.10	11-12-54	Abandoned farm well.
*6-10-27cdd	SE SE SW sec. 27	City of Cawker City	Du	60	144	B	do	do	T, E	P	Land surface	0.0	1,451	33	9-17-54	
6-10-29baa	NE NE NW sec. 29		Dr	58.0	4	N	do	do	N	O	do	0.0	1,464.2	30.00	5-2-46	Test hole.
6-10-29caa	NE NE SW sec. 29		Dr	40.0	4	N	do	do	N	O	do	0.0	1,462.8	29.70	5-2-46	do
6-10-29cad	SE NE SW sec. 29	Louie Schlaelli	Dr	45.0	8	GI	do	do	Cy, W	N	Top of board platform	0.3	1,462	31.47	9-14-54	
6-10-29ccd	SE SW SW sec. 29		Dr	55.0	4	N	do	do	N	O	Land surface	0.0	1,467.1	37.60	5-2-46	Test hole.
6-10-30bbb	NW NW NW sec. 30	F. S. Klechner	Du	50	36	R	do	do	Cy, W	N	Top of concrete curb	0.5	1,490.9	46.85	9-14-54	
6-10-31ada	NE SE NE sec. 31		Dr	40.0	4	N	do	Alluvium and terrace deposits	N	O	Land surface	0.0	1,450.4	20.00	5-3-46	Test hole.
6-10-31dda	NE SE SE sec. 31		Dr	10.0	4	N					do	0.0	1,485.1			do
6-10-32aad	SE NE NE sec. 32	Earl Haryman	Du	35.0	42	R	Sand and gravel	Alluvium	Cy, W	N	Top of board platform	0.1	1,453	31.57	9-14-54	
6-10-33bb	NW NW sec. 33	J. K. Margreiter	Du	43.5	40	R	do	Terrace deposits	Cy, W	S	do	0.1	1,459.9	34.45	9-14-54	Reported water is very hard.
6-10-36bbb	NW NW NW sec. 36	E. H. Boyd	Dr	54.0	6	GI	do	do	Cy, W	N	do	0.3	1,443	35.25	9-13-54	
	T. 7 S., R. 5 W.															
7-5-31cbc	SW NW SW sec. 31		Dr	35.0	4	N	Sand, gravel	do	N	O	Land surface	0.0	1,311.0	9.20	10-29-53	Test hole.

	T. 7 S., R. 6 W.														
7-6-8bcb	NW SW NW sec. 8	John File	Dr	60.0	7	GI	Chalky limestone	Greenhorn Limestone	Cy, W	S	Top of casing	1.0	....	39 48	6-23-55	
*7-6-10cbb	NW NW SW sec. 10	G. Hull	Dr	130	7	GI	Sandstone	Dakota Formation	Cy, W	S	Land surface	0.0	....	110	6-23-55	
7-6-11cd	SE SW sec. 11	Buck Melton	Du	20.0	36	R	Chalky limestone	Greenhorn Limestone	N	N	Top of rock curb	0.5	....	14.80	6-23-55	
7-6-15bcc	SW SW NW sec. 15	C. Grittman est.	Dr	120	6	GI	Sandstone	Dakota Formation	N	N	do	0.2	....	50.20	6-23-55	Abandoned farm well.
7-6-16ddb	NW SE SE sec. 16	Fred Jorgensen	Du	38.5	60	R	do	do	Cy, W	S	Top of concrete base	0.5	....	32.25	9- 2-54	
7-6-18aad	SE NE NE sec. 18	Ora File	Du	18.2	48	R	Chalky limestone	Greenhorn Limestone	Cy, W	S	Top of board platform	0.1	....	13.69	9- 3-54	
7-6-19bbc	SW NW NW sec. 19	Nelli Sherrard	Du	20.8	36	R	Sand and gravel	Terrace deposits	N	N	Top of concrete base	2.0	1,360	13.94	9- 3-54	
*7-6-20bdd	SE SE NW sec. 20	Henry Remus	Dr	41.0	12	S	do	do	T, G	I	Top of pump base	0.6	1,355	8.89	11-17-54	Reported yield 325 gpm.
7-6-22cc	SW SW sec. 22	Rose Grittman	Du	33.0	36	R	do	do	Cy, E	S	Top of rock base	2.5	1,371	25.86	11-15-54	
7-6-23dd	SE SE sec. 23	Loren Reiter	Dr	62.5	6	GI	Sandstone	Dakota Formation	Cy, W	S	Top of board platform	0.6	....	43.73	9- 3-54	
*7-6-24cdd	SE SE SW sec. 24	Clara Dickie	Dr	40	6	GI	do	do	Cy, W	S	Land surface	0.0	....	38	11-19-54	
7-6-25ddd	SE SE SE sec. 25	....	Dr	30.0	4	N	....	....	....	....	do	0.0	1,378.0	....	....	Test hole.
*7-6-27cdd	SE SE SW sec. 27	Gene Grau	Du	42	36	R	Sand, gravel	Terrace deposits	Cy, W	S	do	0.0	1,347	20	10-21-54	
7-6-30aab	NW NE NE sec. 30	Ross Strawn	Dr	35	6	GI	do	do	Cy, W	D	Top of casing	1.0	1,357	19.46	9- 2-54	
7-6-30dbb	NW NW SE sec. 30	Francis Eresch	Dr	34.0	6	GI	do	do	Cy, E	D, S	do	-5.0	1,356	23.00	9- 2-54	Reported good well.
7-6-31cab	NW NE SW sec. 31	George Eresch	Du	31.5	60	R	do	do	Cy, W	N	Top of board platform	0.1	1,356	24.57	9- 8-54	
*7-6-32ddd	SE SE SE sec. 32	C. V. Strawn	Du	40	36	R	do	do	Cy, W	S	Land surface	0.0	1,340	19	11-18-54	
7-6-34cba	NE NW SW sec. 34	Thelma Spicher	Dr	32.0	6	GI	do	do	Cy, W	O	Top of casing	0.3	1,346	28.04	9- 2-54	Observation well.
*7-6-36aab	NW NE NE sec. 36	Joe McClure	Du	45.0	40	R	do	do	Cy, E	S	Top of board platform	1.0	1,360	14.26	9- 3-54	
7-6-36ada	NE SE NE sec. 36	....	Dr	38.0	4	N	do	do	N	O	Land surface	0.0	1,351.0	13.10	10-28-53	Test hole.
7-6-36bab	NW NE NW sec. 36	May Vernon	Dr	31.2	8	GI	do	do	Cy, H	N	Top of board platform	0.1	1,354	20.42	9- 3-54	
	T. 7 S., R. 7 W.														
7-7-4dad	SE NE SE sec. 4	Sibilla Gengler	Du	13.0	60	R	Chalky limestone	Greenhorn Limestone	N	N	Top of rock curb	0.1	....	8.65	8-30-54	Abandoned farm well.
7-7-5aab	NW NE NE sec. 5	Harold Shamburg	Dr	50	6	GI	Sand and gravel	Terrace deposits	Cy, E	Ind	Land surface	0.0	....	30	11-18-54	Supplies water for Waconda Motel.
7-7-5aba	NE NW NE sec. 5	do	Dr	50	6	GI	do	do	Cy, E	Ind	do	0.0	....	30	11-18-54	Supplies water for 24-66 Cafe and Shamburg Oil Co.
7-7-5bcc	SW SW NW sec. 5	Alfred Engelbert	Du	42.8	30	R	do	do	Cy, E	D, S	Top of board platform	0.3	1,405	37.67	8-26-54	Reported dug to bedrock

TABLE 17.—*Records of wells and test holes in Mitchell County*—*Continued.*

Well number (1)	Location	Owner or tenant	Type of well (2)	Depth of well below land surface, feet (3)	Diameter of well, inches	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift and type of power (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above land surface, feet	Measuring point: Height of L. S. above mean sea level, feet (7)	Depth to water level below land surface, feet (8)	Date of measurement	REMARKS
	T. 7 S., R. 7 W.															
7-7-7aaa....	NE NE NE sec. 7...	Albert McDysan	Dr	42.5	8	GI	Sand, gravel..	Terrace deposits	J, E	D,S,O	Top of casing...	1.4	1,391	27.07	8-26-54	Observation well.
7-7-8cbc....	SW NW SW sec. 8...	Sara B. Lukens..	B	37	6	GI	do..........	do............	Cy, H	S	Top of concrete base	0.2	1,380	19.92	8-26-54	
7-7-9bdc1...	SW SE NW sec. 9...	Beloit Dairy Products	Dr	50	8	GI	do..........	do............	Cy, E	Ind	Land surface....	0.0	1,395	30	11-18-54	Gravel packed.
7-7-9bdc2...	SW SE NW sec. 9...	Nehi Bottling Company	Dr	50	8	GI	do..........	do............	J,E	Ind	do............	0.0	....	30	11-18-54	do
7-7-9bdc3...	SW SE NW sec. 9...	Hund Ice Co....	Dr	45	12	GI	do..........	do............	T, E	Ind	do............	0.0	....	30	11-18-54	do
*7-7-11cbb...	NW NW SW sec. 11	Walter Way....	Dr	145	6	GI	Sandstone....	Dakota Formation	Cy, E	N	do............	0.0	....	60	11-10-54	
7-7-11cbc....	SW NW SW sec. 11	do............	Dr	45.0	6	GI	Sand and gravel	Terrace deposits	Cy, W	N	Top of board platform	0.1	1,400	35.57	11-16-54	Abandoned farm well.
*7-7-12bac...	SW NE NW sec. 12	Fred Sahlfeld...	Du	38.5	72	R	do..........	do............	J, E	D, S	Top of concrete base	0.5	....	24.74	8-30-54	
*7-7-15cbc....	SW NW SW sec. 15	V. R. Schmidt...	Dr	37.5	6	S	do..........	do............	Cy, W	S	Top of rock base	1.2	1,367	15.42	8-30-54	
7-7-15dcc1...	SW SW SE sec. 15...	Alfred Emmot...	Du	28.5	48	R	do..........	do............	N	O	Top of rock curb	0.3	1,371	21.28	8-30-54	Observation well.
7-7-15dcc2...	SW SW SE sec. 15...	do............	Dr	52	18	S	do..........	do............	T, G	I	Top of concrete base	0.5	1,370	21.70	8-12-55	Reported yield 250 gpm.
7-7-16cbc....	SW NW SW sec. 16	W. E. Porter....	Du	35.0	42	R	do..........	do............	N	N	Top of rock base	0.2	1,375	22.40	11-16-54	Reported salty.
7-7-18dbd...	SE NW SE sec. 18...	Joe Mispagel....	Du	31.0	36	R	do..........	do............	Cy, W	N	Top of board platform	3.0	1,382	25.73	8-27-54	
*7-7-21bbb...	NW NW NW sec. 21	J. H. Matheis...	Du	40	36	R	do..........	do............	Cy, W	S	Land surface....	0.0	1,375	20	11-10-54	
7-7-23aaa...	NE NE NE sec. 23..	F. Wood.......	Dr	43.2	8	GI	do..........	do............	Cy, W	N	Top of board platform	2.5	1,362	13.90	9- 1-54	
7-7-28dad...	SE NE SE sec. 28...	Ed Wrench.....	Du	19.5	36	R	Chalky limestone	Greenhorn Limestone	Cy, H	S	do............	0.1	....	12.84	8-30-54	Used very little.
*7-7-29ab....	NW NE sec. 29.....	Pete Deneke....	Du	32.0	36	R	Sand and gravel	Terrace deposits	T, E	D, S	Top of concrete base	2.3	1,388	28.27	11-12-54	
7-7-29ccd....	SE SW SW sec. 29...	Andrew Long...	Du	29.3	42	R	do..........	do............	Cy, W	D, S	do............	0.3	1,400	19.94	8-27-54	Used considerably.

7-7-30cc	SW SW sec. 30	A. G. Hackett	Du	33.0	36	R	Chalky limestone	Greenhorn Limestone	Cy, W	N	Top of board platform	0.1	....	18.53	11-12-54	
7-7-33ccc	SW SW SW sec. 33	Susan Miller	Du	25.0	36	R	do	do	Cy, W	S	do	0.2	....	11.72	11-12-54	
7-7-36ba	NE NW sec. 36	Jim Kennedy	Du	21.1	30	R	do	do	Cy, H	N	do	0.6	....	19.25	8-30-54	
	T. 7 S., R. 8 W.															
7-8-1adc1	SW SE NE sec. 1	Gerald Smith	Dr	62.5	12	S	Sand and gravel	Terrace deposits	T, G	I	Top of concrete base	0.4	1,398	34.87	6- 9-55	Reported yield 1,100 gpm.
*7-8-1adc2	SW SE NE sec. 1	do	Du	45.0	42	R	do	do	Cy, W	S	Top of board platform	2.0	1,399	36.47	6- 9-55	
7-8-2cbc	SW NW SW sec. 2	Will Thiessen	Du	42.0	72	R	do	do	Cy, W	N	do	0.1	1,394	24.76	8-24-54	
7-8-3ad1	SE NE sec. 3	....	Dr	42.0	......	N	do	do	N	O	Land surface	0.0	1,388.5	....	....	Test hole.
7-8-3ad2	SE NE sec. 3	....	Dr	40.0	......	N	do	do	N	O	do	0.0	1,388.8	....	....	do
7-8-3dca	NE SW SE sec. 3	....	Dr	43.4	......	N	do	Alluvium and terrace deposits	N	O	do	0.0	1,384.6	15.30	1-10-52	do
7-8-3dcd	SE SW SE sec. 3	....	Dr	33.8	......	N	do	do	N	O	do	0.0	1,383.9	....	....	do
7-8-5cbb	NW NW SW sec. 5	Eva Mears	Dr	47.5	6	GI	do	Terrace deposits	Cy, W	O	Top of casing	1.5	1,405	26.95	8-24-54	Observation well.
7-8-5cbc	SW NW SW sec. 5	....	Dr	45.0	4	N	do	Alluvium and terrace deposits	N	O	Land surface	0.0	1,397	18.10	7-22-54	Test hole.
7-8-6daa	NE NE SE sec. 6	....	Dr	60.0	4	N	do	Terrace deposits	N	O	do	0.0	1,407	29.00	7-21-54	do
7-8-7aaa	NE NE NE sec. 7	....	Dr	60.0	4	N	do	do	N	O	do	0.0	1,410	31.00	7-22-54	do
7-8-7add	SE SE NE sec. 7	....	Dr	58.0	4	N	do	do	N	O	do	0.0	1,420	32.20	7-22-54	do
7-8-8ccc	SW SW SW sec. 8	Bill Weidenhaft	Du	28.5	36	R	Chalky limestone	Greenhorn Limestone	Cy, W	S	Top of board platform	0.2	....	21.74	8-19-54	Reported poor well.
7-8-10ab	NW NE sec. 10	Roy Fobes	Du	42.0	30	R	Sand and gravel	Terrace deposits	Cy, W	S	do	0.2	1,397	26.45	8-24-54	Reported good well.
7-8-10aba	NE NW NE sec. 10	....	Dr	28.5	......	N	do	Alluvium and terrace deposits	N	O	Land surface	0.0	1,380.6	12.20	1-10-52	Test hole.
7-8-10ccc	SW SW SW sec. 10	Ella Reist	Du	30.0	36	R	Chalky limestone	Greenhorn Limestone	Cy, H	S	Top of rock base	0.3	....	26.19	8-24-54	
7-8-11aac	SW NE NE sec. 11	Paul Mears	Dr	36.2	6	GI	Sand, gravel	Terrace deposits	N	N	Top of casing	-5.8	1,391	29.56	8-26-54	
7-8-13ccd	SE SW SW sec. 13	Joe J. Zimmer	Du	24.0	54	R	do	do	Cy, W	S	Top of board platform	0.2	....	18.19	8-24-54	
7-8-17bc	SW NW sec. 17	Earl Treaster	Du	30.0	36	R	Chalky limestone	Greenhorn Limestone	Cy, H	S	do	0.1	....	7.18	8-19-54	
7-8-21ccd	SE SW SW sec. 21	Leroy Moss	Du	21.5	30	R	Sand, gravel	Terrace deposits	Cy,E	D, S	Top of rock base	0.5	....	13.39	11-16-54	
7-8-26aab	NW NE NE sec. 26	Minnie Thiessen	Du	22.0	48	R	do	do	Cy, H	S	Top of board platform	0.5	....	13.03	8-24-54	
*7-8-27aaa	NE NE NE sec. 27	Frank Engelbert	Du	35.0	48	R	Chalky limestone	Greenhorn Limestone	Cy, W	S	do	0.5	....	19.28	8-24-54	
7-8-29aa	NE NE sec. 29	Don Moss	Du	27.0	36	R	do	do	Cy, W	N	do	0.2	....	18.05	11-16-54	
7-8-31ddd	SE SE SE sec. 31	Kendall Studer	Du	30.0	42	R	do	do	Cy, E	S	do	0.7	....	16.95	7-19-55	
7-8-34cdd	SE SE SW sec. 34	R. X. Belknap	Du	37.0	30	R	do	do	Cy, W	S	do	0.5	....	18.12	7-19-55	
7-8-35ccd	SE SW SW sec. 35	D. M. Ramsay	Du	36.0	36	R	do	do	Cy, W	S	do	0.1	....	22.02	7-12-55	
	T. 7 S., R. 9 W.															
7-9-1cba	NE NW SW sec. 1	Albert Morris	Du	44.0	48	R	do	do	Cy, W	D, S	do	0.2	1,418	33.39	9- 9-54	
7-9-3bad	SE NE NW sec. 3	....	Dr	75.0	......	N	Sand, gravel	Terrace deposits	N	O	Land surface	0.0	1,415.2	18.20	10-10-49	Test hole.

TABLE 17.—*Records of wells and test holes in Mitchell County*—*Continued.*

Well number (1)	Location	Owner or tenant	Type of well (2)	Depth of well below land surface, feet (3)	Diameter of well, inches	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift and type of power (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above land surface, feet	Measuring point: Height of L. S. above mean sea level, feet (7)	Depth to water level below land surface, feet (8)	Date of measurement	REMARKS
	T. 7 S., R. 9 W.															
7-9-3bbb	NW NW NW sec. 3	K. A. Helm	Du	28.0	36	R	Sand and gravel	Terrace deposits	Cy, W	N	Top of board platform	0.2	1,421	23.60	9-10-54	
7-9-3bda	NE SE NW sec. 3	....	Dr	59.0	......	N	....	....	....	......	Land surface	0.0	1,434.2	....	....	Test hole.
7-9-3cda	NE SE SW sec. 3	....	Dr	75.0	......	N	....	....	....	......	do	0.0	1,480.0	....	....	do
7-9-3cdd	SE SE SW sec. 3	....	Dr	70.0	......	N	....	....	....	......	do	0.0	1,492.5	....	....	do
7-9-4cdd	SE SE SW sec. 4	Delmar German	Du	34.5	36	R	Sand and gravel	Terrace deposits	Cy, W	S	Top of board platform	0.5	....	21.30	9-10-54	
7-9-6ddd	SE SE SE sec. 6	S. P. Trueblood	Du	38.0	28	R	Chalky limestone	Greenhorn Limestone	Cy, W	S	do	0.5	....	27.60	9-10-54	
7-9-7ddd	SE SE SE sec. 7	F. H. Randall	Du	38.0	36	R	do	do	Cy, W	N	do	0.2	....	35.13	9-10-54	
*7-9-9cc	SW SW sec. 9	C. H. Albertetal	Du	40	36	R	do	do	Cy, W	N	Land surface	0.0	....	38	10-21-54	
7-9-10ddd	SE SE SE sec. 10	Clift Brunnemer	Du	24.5	36	R	Sand and gravel	Terrace deposits	Cy, E	S	Top of board platform	0.1	....	15.19	11-18-54	
7-9-13cd	SE SW sec. 13	Walter Golladay	Du	24.5	60	R	Chalky limestone	Greenhorn Limestone	Cy, W	N	do	2.0	....	11.56	9- 9-54	
7-9-17dcd	SE SW SE sec. 17	C. H. Albert	B	22.5	6	GI	do	do	J, E	D, S	Top of concrete curb	2.5	....	17.20	9-10-54	
7-9-19bbb	NW NW NW sec. 19	J. Megaffin	Du	34.0	48	R	do	do	N	N	Top of board platform	1.4	....	7.71	9-13-54	Abandoned farm well.
7-9-19ddd	SE SE SE sec. 19	Howard McCune	Du	31.3	42	R	do	do	Cy, W	S	do	0.6	....	15.46	7-27-55	
7-9-23bbb	NW NW NW sec. 23	G. E. Remus	Du	23.0	36	R	Sand and gravel	Terrace deposits	Cy, H	N	do	2.0	....	11.15	11-17-54	Abandoned stock well.
7-9-24ddd	SE SE SE sec. 24	Arch Odle	Du	16.0	42	R	Chalky limestone	Greenhorn Limestone	Cy, W	S	Top of rock curb	0.2	....	12.30	7-18-55	
7-9-27bab	NW NE NW sec. 27	Leo F. Ahlvers	Du	18.8	42	R	do	do	Cy, W	S	Top of board platform	0.1	....	15.85	7-26-55	
7-9-35aaa	NE NE NE sec. 35	G. E. Remus	Du	32.0	42	R	do	do	Cy, W	S	do	0.6	....	20.82	7-20-55	
	T. 7 S., R. 10 W.															
7-10-2abb	NW NW NE sec. 2	H. C. Pargett	Du	36	36	R	Sand, gravel	Terrace deposits	Cy, H	N	do	1.0	1,449	35.54	9-13-54	
*7-10-3dda	NE SE SE sec. 3	Mathias Koster	Du	40	36	R	do	do	Cy, W	S	Land surface	0.0	1,455	30	11-12-54	

7-10-5ada	NE SE NE sec. 5	Leo Walter	Du	21.0	42	R	do	do	Cy, W	D, S	Top of board platform	0.9	1,465.0	15.39	11-12-54	
7-10-6aad	SE NE NE sec. 6		Dr	10.0	4	N					Land surface	0.0	1,499.5			Test hole.
7-10-6dad	SE NE SE sec. 6		Dr	10.0	4	N					do	0.0	1,493.2			do
*7-10-8bbb	NW NW NW sec. 8	C. W. Remus	Du	62.5	40	R	Chalky limestone	Greenhorn Limestone	Cy, W	D, S	Top of board platform	0.5		56.60	9-15-54	
7-10-9da	NE SE sec. 9	Mat Hake	Dr	48	6	GI	Sand, gravel	Terrace deposits	Cy, W	S	do	0.1	1,462	35.11	9-14-54	
7-10-10ccc	SW SW SW sec. 10	John Koster	Dr	41.0	12	T	do	do	Cy, E	S	do	1.0		25.98	9-14-54	
7-10-13aa	NE NE sec. 13	Hazel Hohe	Du	43.5	36	R	Chalky limestone	Greenhorn Limestone	Cy, W	N	do	2.0		13.90	9-13-54	Abandoned farm well.
*7-10-14ddd	SE SE SE sec. 14	Henry Bock	Du	14.5	90	R	do	do	Cy, W	S	do	0.5		9.92	9-13-54	
7-10-15ccd	SE SW SW sec. 15	M. A. Jasper	Du	26.5	36	R	do	do	Cy, W	S	do	1.0		15.05	9-14-54	
7-10-18add	SE SE NE sec. 18	Ella Lavery	Du	50	48	R	Sand, gravel	Terrace deposits	J, E	D	do	0.5	1,476	40.47	11-12-54	
*7-10-19add	SE SE NE sec. 19	E. C. Mosier	Du	45.0	40	R	do	do	Cy, W	D, S	do	0.3	1,499	36.32	9-14-54	
7-10-21ccc	SW SW SW sec. 21	J. E. Reel	Du	34.0	60	R	do	do	N	N	do	0.1		27.70	9-14-54	
*7-10-22cca	NE SW SW sec. 22	W. W. and J. W. Haseltine	Du	15.5	120	R	do	do	J, E	D, S	Top edge of manhole	2.0		10.38	7-28-55	
*7-10-25bcb	NW SW NW sec. 25	Earl Boehner	Du	27.4	42	R	Chalky limestone	Greenhorn Limestone	Cy, W	S	Top of board platform	0.5		14.23	7-28-55	
*7-10-32baa	NE NE NW sec. 32	Vince Thummel	Dr	26.7	18	T	Sand and gravel	Terrace deposits	Cy, E	D, S	Top of concrete base	0.1		18.07	8- 1-55	
7-10-33daa	NE NE SE sec. 33	Katie Moore	Du	27.8	36	R	Chalky limestone	Greenhorn Limestone	Cy, W	S	Top of board platform	0.2		21.87	7-29-55	
7-10-35dda	NE SE SE sec. 35	Jim Pahls	Du	25.2	72	R	Sand, gravel	Terrace deposits	Cy, E	D, S	do	1.0		11.45	7-28-55	
	T. 8 S., R. 5 W.															
8-5-6cbb	NW NW SW sec. 6		Dr	60.0	4	N	do	do	N	O	Land surface	0.0	1,332.2	17.00	10-29-53	Test hole.
8-5-6ccc	SW SW SW sec. 6		Dr	58.0	4	N	do	do	N	O	do	0.0	1,330.0	19.50	10-28-53	do
8-5-7cbb	NW NW SW sec. 7		Dr	52.0	4	N	do	do	N	O	do	0.0	1,333.0	26.80	10-28-53	do
8-5-18bcb	NW SW NW sec. 18		Dr	50.0	4	N	do	do	N	O	do	0.0	1,344.0	32.40	10-28-53	do
8-5-19bbc	SW NW NW sec. 19		Dr	32.0	4	N			N	O	do	0.0	1,376.0			do
8-5-19bcb	NW SW NW sec. 19		Dr	30.0	4	N	Sand, gravel	Terrace deposits	N	O	do	0.0	1,374.0	22.30	10-27-53	do
	T. 8 S., R. 6 W.															
*8-6-1add	SE SE NE sec. 1	City of Simpson	Dr	47	24	S	do	do	T, E	P	do	0.0	1,334	18	9-17-55	
8-6-5baa	NE NE NW sec. 5	Tom Hyde	Dr	58.0	8	GI	Sandstone	Dakota Formation	Cy, W	S	Top of board platform	0.3	1,371	48.09	9- 2-54	Reported good well.
*8-6-9bcc	SW SW NW sec. 9	F. K. Schwerman	Dr	50	6	GI	do	do	Cy, W	S	Land surface	0.0		42	10-21-54	
8-6-9dcb	NW SW SE sec. 9	Retta Melton	Du	22.0	36	R	Sand and gravel	Terrace deposits	N	N	Top of board platform	0.2		13.70	9- 2-54	Abandoned farm well.
8-6-11bc	SW NW sec. 11	Clyde Gentry	Du	22.0	36	R	do	do	Cy, E	S	do	1.0		15.47	11-15-54	
8-6-12ddd	SE SE SE sec. 12		Dr	45.0	4	N	do	do	N	O	Land surface	0.0	1,338.0	31.50	10-28-53	Test hole.
8-6-13da	NE SE sec. 13	Joe Louthan	Du	23.0	48	R	Sandstone	Dakota Formation	Cy, W	S	Top of concrete base	1.0		17.61	9- 8-54	
8-6-14aac	SW NE NE sec. 14	Jens Asmussen	Dr	56.0	5	GI	do	do	Cy, W	N	Top of rock base	0.3		20.65	11-15-54	Abandoned farm well.
8-6-16bdd	SE SE NW sec. 16	Frank Creitz	Du	28.5	36	R	Sand, gravel	Terrace deposits	N	N	Top of rock curb	0.2		23.62	9- 2-54	

TABLE 17.—*Records of wells and test holes in Mitchell County*—Continued.

Well number (1)	Location	Owner or tenant	Type of well (2)	Depth of well below land surface, feet (3)	Diameter of well, inches	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift and type of power (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above land surface, feet	Measuring point: Height of L. S. above mean sea level, feet (7)	Depth to water level below land surface, feet (8)	Date of measurement	REMARKS
8-6-17abb	NW NW NE sec. 17	W. G. Huffman	Dr	112.0	6	GI	Sandstone	Dakota Formation	Cy, W	S	Top of board platform	0.2	....	26.95	8-31-54	Reported good well.
8-6-17bbb	NW NW NW sec. 17	Jess Peterson	Dr	109	6	GI	do	do	Cy, E	S	Land surface	0.0	....	70	9- 1-54	
8-6-17cc	SW SW sec. 17	Perry Zachary	Dr	140	6	GI	do	do	Cy, W	D, S	Top of rock curb	1.0	....	93.20	9- 8-54	
8-6-18ccc	SW SW SW sec. 18	J. Watson	Dr	110.0	7	GI	do	do	Cy, W	N	Top of board platform	0.3	....	108.20	7- 8-55	Abandoned farm well.
*8-6-20cdc	SW SE SW sec. 20	Theodore Torr	Dr	165	6	GI	do	do	Cy, W	S	Top of casing	0.2	....	128.00	8-12-55	
8-6-21bbd	SE NW NW sec. 21	Elmer Watson	Dr	165	3	S	do	do	Cy, W	N	do	0.3	....	119.76	9- 8-54	
8-6-23cc	SW SW sec. 23	H. C. Duvall	Dr	160.0	6	GI	do	do	Cy, W	S	Top of concrete base	0.3	....	147.70	9- 8-54	
8-6-24adb	NW SE NE sec. 24	Mose Louthan	Dr	114.5	6	GI	do	do	N	N	Top of rock base	1.0	....	80.75	9- 8-54	Reported salty but used as stock well.
8-6-25ddd	SE SE SE sec. 25	A. V. Krizek	Dr	73.0	6	GI	do	do	Cy, W	S	do	0.3	....	64.70	8- 2-55	
8-6-29aaa	NE NE NE sec. 29	C. L. McKee	Dr	172	6	S	do	do	Cy, W	D, S	Top of board platform	0.0	....	125	8- 2-55	
8-6-29aab	NW NE NE sec. 29	Frank Kerns	Dr	178	6	GI	do	do	Cy, W	D, S	Top of concrete base	0.0	....	100	6-29-55	
8-6-30aaa	NE NE NE sec. 30	Theodore Torr	Dr	165	6	GI	do	do	Cy, W	D, S	Land surface	0.0	....	125	8-12-55	
8-6-32aa	NE NE sec. 32	Cleo Hiller	Du	38.0	36	R	Chalky limestone	Greenhorn Limestone	Cy, H	N	Top of concrete base	0.2	....	12.40	6-29-55	
8-6-33daa	NE NE SE sec. 33	Caroline Pearson	Dr	180	8	GI	Sandstone	Dakota Formation	Cy, W	S	Land surface	0.0	....	100	6-28-55	
8-6-34ddd	SE SE SE sec. 34	Lewis Murray	Dr	188	4	GI	do	do	Cy, E	D, S	do	0.0	....	146	8- 2-55	
	T. 8 S., R. 7 W.															
8-7-1cdc	SW SE SW sec. 1	George Budke	Dr	100.0	8	GI	do	do	Cy, W	S	Top of rock base	0.1	....	61.03	9-10-54	
*8-7-2bad	SE NE NW sec. 2	Clifford Whorton	Du	41.0	48	R	Chalky limestone	Greenhorn Limestone	J, E	S	Top of board platform	0.5	....	37.32	8-30-54	

8-7-2dbd	SE NW SE sec. 2	Walter Way	Du	27.0	36	R	do	do	Cy, H	N	Top of concrete base	0.3	....	21.93	9- 1-54	Spring in creek 150 feet southeast.
8-7-4ddd	SE SE SE sec. 4	Bert W. Belden	Du	38.5	36	R	do	do	Cy, W	S	Top of board platform	0.3	....	26.63	9- 1-54	
8-7-9bbb	NW NW NW sec. 9	do	Du	25.0	36	R	do	do	Cy, G	S	do	2.0	....	11.44	7- 6-55	
8-7-10cbb	NW NW SW sec. 10	F. E. Hoy est.	Du	53.0	36	R	do	do	Cy, H	N	do	0.2	....	34.30	6-29-55	
8-7-11dc	SW SE sec. 11	C. E. Belles	Dr	127.0	6	GI	Sandstone	Dakota Formation	Cy, W	S	Top of casing	1.0	....	88.52	7- 8-55	
8-7-12ccd	SE SW SW sec. 12	A. G. Plymire	Dr	210	8	GI	do	do	Cy, W	D, S	Land surface	0.0	....	100	9- 1-54	
8-7-12dcd	SE SW SE sec. 12	W. N. Holway	Dr	178	6	GI	do	do	Cy, W	D, S	do	0.0	....	39	8-31-54	
8-7-18da	NE SE sec. 18	Gerald Briney	Du	16.0	96	R	Sand, gravel	Terrace deposits	Cy, W	S	Top of board platform	0.1	....	7.40	7-12-55	
8-7-19ada	NE SE NE sec. 19	Neil Hewitt	Dr	77.0	6	GI	Chalky limestone	Greenhorn Limestone	N	N	Top of casing	0.7	....	24.65	8- 5-55	
8-7-20da	NE SE sec. 20	E. M. Burkhead	Du	48.0	42	R	do	do	Cy, H	N	Top of rock base	3.5	....	30.08	7- 6-55	
8-7-22ccd	SE SW SW sec. 22	Aimee M. Fuller	Du	29.5	36	R	do	do	Cy, W	N	Top of board platform	1.0	....	24.80	7- 8-55	
8-7-23aaa	NE NE NE sec. 23	Joan F. Heinen	Dr	132.0	8	GI	Sandstone	Dakota Formation	N	N	Top of casing	0.3	....	107.60	6-28-55	
8-7-25bcc	SW SW NW sec. 25	E. E. Booker	Dr	131.0	6	GI	do	do	Cy, W	S	do	0.3	....	116.70	8- 3-55	
8-7-32add	SE SE NE sec. 32	E. F. and Agnes Broadbent	Dr	120.0	8	N	do	do	N	N	do	0.2	....	65.80	7- 1-55	Reported salty.
8-7-32bbb	NW NW NW sec. 32	Carldon Broadbent	Du	34.0	36	R	Chalky limestone	Greenhorn Limestone	Cy, E	S	Top of rock curb	0.2	....	32.38	8- 5-55	
8-7-34cbd1	SE NW SW sec. 34	Philip Elder	Dr	85.0	6	GI	Sandstone	Dakota Formation	Cy, W	S	Top of concrete base	3.0	....	30.00	8- 4-55	
8-7-34cbd2	SE NW SW sec. 34	do	Du	14.0	36	R	Chalky limestone	Greenhorn Limestone	N	N	do	3.0	....	7.20	8- 4-55	
8-7-36dcc	SW SW SE sec. 36	P. E. Bassford Jr.	Dr	126.0	6	GI	Sandstone	Dakota Formation	Cy, W	S	Top of board platform	0.2	....	29.90	8- 4-55	
	T. 8 S., R. 8 W.															
8-8-1da	NE SE sec. 1	Mary Amos	Du	30.0	42	R	Chalky limestone	Greenhorn Limestone	Cy, H	N	do	0.2	....	26.15	7- 7-55	
8-8-10ccc	SW SW SW sec. 10	Leroy Wagner	Du	23.0	30	R	do	do	Cy, H	N	do	1.0	....	15.85	7-19-55	
8-8-11ddd	SE SE SE sec. 11	Bertha B. Hutton	Du	31.5	36	R	do	do	Cy, H	N	do	1.0	....	17.08	7-12-55	Abandoned farm well.
8-8-17ccc	SW SW SW sec. 17	F. W. Lukens	Du	33.5	90	R	do	do	Cy, E	D, S	Top of concrete curb	2.0	....	15.35	7-19-55	Community well dug by W.P.A. in 1935.
8-8-21ccc	SW SW SW sec. 21	Ivan Tolbert	Du	19.0	36	R	do	do	Cy, W	S	Top of board platform	0.2	....	18.25	7-19-55	
*8-8-22aaa	NE NE NE sec. 22	J. H. Walter	Du	34.0	36	R	do	do	Cy, W	S	do	1.0	....	24.48	8- 5-55	
8-8-24ada	NE SE NE sec. 24	Henrietta Hahenkratt	Du	27.5	36	R	do	do	Cy, W	N	do	2.0	....	11.55	7- 7-55	Abandoned farm well.
8-8-26ddd	SE SE SE sec. 26	Bertha and H. N. Tice	Du	24.0	42	R	do	do	Cy, W	N	do	0.1	....	16.60	7- 7-55	do

TABLE 17.—*Records of wells and test holes in Mitchell County—Continued.*

WELL NUMBER (1)	Location	Owner or tenant	Type of well (2)	Depth of well below land surface, feet (3)	Diameter of well, inches	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift and type of power (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above land surface, feet	Measuring point: Height of L. S. above mean sea level, feet (7)	Depth to water level below land surface, feet (8)	Date of measurement	REMARKS
	T. 8 S., R. 8 W.															
•8-8-31dcc	SW SW SE sec. 31	Clarence A. Mehl	Du	26.0	48	R	Chalky limestone	Greenhorn Limestone	Cy, E	D, S	Top of concrete curb	0.2	....	17.65	7-19-55	
	T. 8 S., R. 9 W.															
8-9-3bda	NE SE NW sec. 3	R. Weir and F. Brown	Du	28.7	36	R	do	do	Cy, H	S	Top of board platform	0.1	....	22.68	7-26-55	
8-9-6aaa	NE NE NE sec. 6	Doyle Albert	Du	27.2	30	R	do	do	Cy, W	S	do	0.2	....	16.24	7-27-55	
8-9-8cdc	SW SE SW sec. 8	J. Krier	Du	49.5	36	R	do	do	Cy, W	N	do	0.4	....	36.03	7-27-55	
8-9-11daa	NE NE SE sec. 11	J. J. Brokaw	Du	32.5	36	R	do	do	Cy, H	N	do	0.2	....	10.63	7-20-55	
8-9-14ddd	SE SE SE sec. 14	John Albert	Du	34.0	52	R	do	do	Cy, E	S	do	0.5	....	12.25	7-20-55	
8-9-15abb	NW NW NE sec. 15	Gladys Riedel	Du	19.5	42	R	do	do	Cy, H	N	do	0.1	....	8.18	7-26-55	
•8-9-17aab	NW NE NE sec. 17	V. P. Palen	Du	42.0	96	R	Sand and gravel	Terrace deposits	Cy, W	D, S	Top of concrete base	1.0	....	15.29	8-11-55	
8-9-19adb	NW SE NE sec. 19	Carl Witt	Dr	31	16	T	do	do	Cy, E	D, S	Land surface	0.0	....	18	7-27-55	
8-9-21bcc	SW SW NW sec. 21	H. Koch	Du	25.8	42	R	do	do	Cy, W	S	Top of board platform	0.3	....	12.87	7-26-55	
8-9-22adb	NW SE NE sec. 22	A. E. Kresin	Du	19.0	36	R	Slope wash	Colluvium	Cy, W	S	do	0.1	....	4.65	7-26-55	
8-9-35bac	SW NE NW sec. 35	Perry Griffith	Du	34.5	120	R	Sand and gravel	Terrace deposits	Cy, G	S	Top of concrete base	0.2	....	16.54	7-20-55	
8-9-36bcc1	SW SW NW sec. 36	Frank May	Du	27.5	60	R	Chalky limestone	Greenhorn Limestone	Cy, H	D, S	Top of board platform	0.1	....	27.25	7-28-55	
8-9-36bcc2	SW SW NW sec. 36	Frank May	Du	26.5	60	R	do	do	Cy, W	S	do	0.2	....	25.04	7-28-55	
	T. 8 S., R. 10 W.															
8-10-2cdd	SE SE SW sec. 2	H. Brummer	Du	22.0	36	R	Slope wash	Colluvium	Cy, W	S	do	0.7	....	16.87	7-29-55	
8-10-7adb	NW SE NE sec. 7	Henry Schmitt	Dr	38.8	7	GI	do	do	Cy, W	S	do	0.1	....	20.25	8-1-55	Drilled to bedrock.
8-10-16aab	NW NE NE sec. 16	Lawrence Grief	Du	24.6	30	R	do	do	Cy, W	S	do	0.5	....	15.00	7-29-55	
8-10-19ada	NE SE NE sec. 19	Mike May	Du	15.5	51	R	do	do	J, E	D, S	do	0.2	....	14.15	8-1-55	
8-10-21ada	NE SE NE sec. 21	S. A. Arnoldy	Dr	27.0	7	GI	do	do	Cy, W	S	do	1.5	....	11.20	7-29-55	

8-10-22cba	NE NW SW sec. 22	Edmund Arnoldy	Du	25.0	42	R	do	do	Cy, W	S	Top of concrete curb	0.4	....	21.38	7-29-55	
8-10-26aaa	NE NE NE sec. 26	Bernard Eck	Du	23.5	60	R	do	do	J, E	D, S	do	0.3	....	19.43	7-27-55	
8-10-29bb	NW NW sec. 29	City of Tipton	Du	42	120	B	Sand, gravel	Terrace deposits	T, E	P	Land surface	0.0	....	26	8- 1-55	
8-10-29bc	SW NW sec. 29	do	Dr	42	18	S	do	do	T, E	P	do	0.0	....	26	8- 1-55	
*8-10-30aac	SW NE NE sec. 30	do	Du	42	144	B	do	do	T, E	P	do	0.0	....	26	8- 1-55	
8-10-32bbb	NW NW NW sec. 32	Mary H. Schmitt	Du	19.5	52	R	Slope wash	Colluvium	Cy, W	S	Top of board platform	0.2	....	13.90	7-29-55	
8-10-34cab	NW NE SW sec. 34	Ed Wagner	Du	28.0	48	R	Sand, gravel	Terrace deposits	Cy, G	D, S	do	0.1	....	25.20	7-29-55	
	T. 9 S., R. 6 W.															
9-6-7ccc	SW SW SW sec. 7	H. S. Pruitt	Dr	118.0	7	GI	Sandstone	Dakota Formation	Cy, W	S	Top of casing	1.0	....	56.20	7- 6-55	
9-6-8aaa	NE NE NE sec. 8	T. I. Myers	Dr	152.0	7	GI	do	do	Cy, W	N	do	0.2	....	122.63	6-28-55	Abandoned farm well.
*9-6-10bcb	NW SW NW sec. 10	Willard McClintock	Dr	180	6	GI	do	do	Cy, E	D, S	Land surface	0.0	....	150	8- 3-55	
9-6-12ccc	SW SW SW sec. 12	Wilbur Pearson	Dr	160	5	S	do	do	Cy, W	D, S	do	0.0	....	154	8- 2-55	
9-6-16daa	NE NE SE sec. 16	Walter L. Adams	Dr	280	6	GI	do	do	Cy, E	D, S	Top of board platform	0.2	....	144.60	8- 3-55	
9-6-17cdd	SE SE SW sec. 17	Laverne Freeman	Dr	160	6	GI	do	do	Cy, E	D, S	Land surface	0.0	....	120	8- 3-55	
9-6-17ddc	SW SE SE sec. 17	Ethel Pruitt	Dr	180	6	GI	do	do	Cy, W	D, S	Top of concrete base	0.0	....	100	8- 3-55	
9-6-22ddc	SW SE SE sec. 22	O. H. Kimsey	Dr	150	6	GI	do	do	Cy, W	D, S	Land surface	0.0	....	112	8- 3-55	
9-6-24add	SE SE NE sec. 24	John A. Prochaska	Dr	95	6	GI	do	do	Cy, W	D, S	do	0.0	....	60	8- 2-55	
9-6-26aad	SE NE NE sec. 26	Corwin Freeman	Dr	176.0	7	GI	do	do	Cy, E	D, S	Top of board platform	0.3	....	144.20	8- 2-55	
*9-6-29aaa	NE NE NE sec. 29	Herman Adams	Dr	190	8	GI	do	do	Cy, W	D, S	Land surface	0.0	....	135	6-28-55	
9-6-31ba	NE NW sec. 31	Dale Adams	Dr	180	8	S	do	do	Cy, W	S	Top of board platform	1.3	....	54.20	6-28-55	
9-6-31bad	SE NE NW sec. 31	do	Du	17.0	36	R	Chalky limestone	Greenhorn Limestone	Cy, H	D	do	0.2	....	14.90	6-28-55	
	T. 9 S., R. 7 W.															
9-7-5ad	SE NE sec. 5	Raymond Walters	Dr	125	8	S	Sandstone	Dakota Formation	Cy, G	S	Land surface	0.0	....	60	7-12-55	
9-7-6aba	NE NW NE sec. 6	Carleton Hewitt	Du	48.5	48	R	Chalky limestone	Greenhorn Limestone	Cy, W	S	Top of rock curb	2.0	....	39.90	8- 5-55	
9-7-9adc	SW SE NE sec. 9	Bernice Simmons	Dr	40.0	8	GI	Sandstone	Dakota Formation	Cy, W	S	Top of casing	2.0	....	19.74	6-30-55	
9-7-9cbc	SW NW SW sec. 9	Joe Weber	Du	16.5	84	R	Chalky limestone	Greenhorn Limestone	Cy, H	S	Top of concrete base	0.5	....	12.15	7- 7-55	
9-7-11ddd	SE SE SE sec. 11	P. E. Bassford	Dr	108	6	GI	Sandstone	Dakota Formation	Cy, W	S	Top of board platform	0.2	....	27.30	8- 4-55	
9-7-19cc	SW SW sec. 19	Otis Pruitt	Du	23.0	48	R	Sand, gravel	Terrace deposits	Cy, W	S	do	0.2	....	14.30	8- 4-55	
*9-7-19da	NE SE sec. 19	do	Du	22.0	48	R	do	do	Cy, W	S	do	0.1	....	12.05	8- 4-55	

TABLE 17.—*Records of wells and test holes in Mitchell County—Concluded.*

Well number (1)	Location	Owner or tenant	Type of well (2)	Depth of well below land surface, feet (3)	Diameter of well, inches	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift and type of power (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above land surface, feet	Measuring point: Height of L. S. above mean sea level, feet (7)	Depth to water level below land surface, feet (8)	Date of measurement	REMARKS
	T. 9 S., R. 7 W.															
9-7-21daa...	NE NE SE sec. 21..	Cecil E. Pruitt..	Du	27.0	54	R	Sand and gravel	Terrace deposits	Cy, W	N	Top of board platform	0.3	....	15.12	8- 3-55	
9-7-22dcc...	SW SW SE sec. 22...	G. A. Wrench...	Du	32.0	36	R	Sandstone....	Dakota Formation	Cy, W	N	do............	0.2	....	21.07	7- 6-55	Abandoned farm well.
*9-7-22ddd...	SE SE SE sec. 22....	Hershel Broadbent	Du	26.5	36	R	do..........	do............	J, E	D, S	Top of concrete curb	2.0	....	21.90	7- 6-55	
9-7-23ccc....	SW SW SW sec. 23..	do............	Dr	92.0	6	GI	do..........	do............	Cy, W	S	Top of casing...	1.0	....	45.85	7- 6-55	
9-7-29add...	SE SE NE sec. 29...	Bob Blanding...	Dr	26.0	4	GI	do..........	do............	J, E	D, S	Top of concrete base	0.3	....	12.20	6-30-55	
9-7-30cb....	NW SW sec. 30.....	H. Heiman.....	Dr	120.0	6	GI	do..........	do............	Cy, W	S	Top of casing...	0.5	....	64.97	7- 7-55	
9-7-34baa...	NE NE NW sec. 34	O. M. Tatum...	Dr	60	6	GI	do..........	do............	Cy, E	D, S	Top of concrete base	0.0	....	30	8- 3-55	
9-7-35aab...	NW NE NE sec. 35	J. Kaul.......	B	16.0	6	GI	Sand and gravel	Terrace deposits	Cy, H	N	Top of board platform	0.2	....	9.63	8- 3-55	
	T. 9 S., R. 8 W.															
9-8-2abb....	NW NW NE sec. 2..	Harold Maxwell	Du	25	48	R	Chalky limestone	Greenhorn Limestone	Cy, W	S	Land surface....	0.0	....	20	8- 5-55	
9-8-4aba....	NE NW NE sec. 4..	W. Thiessen....	Du	26.0	42	R	Sand and gravel	Terrace deposits	Cy, H	N	Top of board platform	0.1	....	19.57	7-19-55	
9-8-12abb...	NW NW NE sec. 12	K. E. Jordan ...	Du	23.0	84	R	Chalky limestone	Greenhorn Limestone	Cy, G	D, S	Top of concrete base	0.5	....	17.13	7- 7-55	
*9-8-15bad...	SE NE NW sec. 15..	J. J. Vanier.....	Dr	27.0	6	GI	Sand, gravel..	Terrace deposits	Cy, W	S	Top of rock base	2.0	....	15.30	8- 5-55	
9-8-17ab....	NW NE sec. 17.....	Denny Helvey..	Du	22.5	96	R	do..........	do............	Cy, W	S	Top of board platform	0.1	....	20.25	7-19-55	
9-8-20cbc ...	SW NW SW sec. 20	Lee Bruce......	Du	25.0	48	R	do..........	do............	Cy, W	S	do............	0.2	....	17.72	7-19-55	
9-8-26add...	SE SE NE sec. 26...	E. A. Peavey...	Dr	150	6	GI	Sandstone....	Dakota Formation	Cy, W	N	Land surface....	0.0	....	100	7-12-55	Abandoned farm well.
9-8-28ccc....	SW SW SW sec. 28..	Rainus Stewart .	Dr	163	6	GI	do..........	do............	Cy, E	S	do............	0.0	....	57	7-19-55	
9-8-29ccc....	SW SW SW sec. 29..	C. Munch......	Du	30.5	36	R	Chalky limestone	Greenhorn Limestone	Cy, H	S	Top of board platform	0.1	....	14.05	7-19-55	

*9-8-34bcc	SW SW NW sec. 34	E. L. Tolbert	Dr	185.0	6	GI	Sandstone	Dakota Formation	Cy, W	S	Top of rock curb	0.5	....	110.50	7-19-55	
	T. 9 S., R. 9 W.															
9-9-3bba	NE NW NW sec. 3	L. N. Halfhide	Du	29.0	36	R	Slope wash	Colluvium	Cy, W	S	Top of board platform	0.2	....	15.57	7-20-55	
9-9-5aba	NE NW NE sec. 5	Clarence Parks	Du	25.5	36	R	do	do	Cy, W	S	do	1.2	....	18.05	7-26-55	
9-9-6aa	NE NE sec. 6	Herman Zemke	Du	42.5	72	R	Sand, gravel	Terrace deposits	Cy, E	D, S	do	0.1	....	22.95	7-26-55	Dug to bedrock.
9-9-7aca	NE SW NE sec. 7	Albert Gillen	Du	17.5	48	R	Slope wash	Colluvium	Cy, W	S	do	0.6	....	14.75	7-27-55	
*9-9-7dcb	NW SW SE sec. 7	Maurice Wiles	Du	23.0	48	R	do	do	Cy, E	D, S	do	2.0	....	12.85	7-27-55	
9-9-14ad	SE NE sec. 14	Ogden Kadel	Du	24.0	30	R	do	do	J, E	N	do	1.0	....	11.22	7-20-55	
9-9-14baa	NE NE NW sec. 14	E. A. Peavey	Du	20.0	36	R	do	do	Cy, W	S	Top of rock curb	0.1	....	10.25	7-20-55	
9-9-22bbc	SW NW NW sec. 22	A. J. Diers	Du	18.5	36	R	do	do	N	N	Top of rock base	0.2	....	11.54	7-20-55	
*9-9-26aaa	NE NE NE sec. 26	Beatrice Creamery Co.	Du	24.5	42	R	do	do	Cy, H	D, S	Top of board platform	0.3	....	14.25	7-20-55	
9-9-30acd	SE SW NE sec. 30	Harold Heller	Du	30	36	R	Sand, gravel	Terrace deposits	Cy, W	D, S	Land surface	0.0	....	25	7-27-55	
9-9-34abb	NW NW NE sec. 34	Victor Travis	Du	33.5	120	R	Slope wash	Colluvium	Cy, G	S	Top of concrete base	0.2	....	18.24	7-20-55	
9-9-35baa	NE NE NW sec. 35	Josephine Scofield	Du	28.5	36	R	do	do	Cy, W	N	Top of board platform	0.1	....	23.40	7-20-55	
9-9-36daa	NE NE SE sec. 36	Pearl Van Pelt	Du	22.5	42	R	do	do	Cy, W	S	Top of concrete curb	1.0	....	16.35	7-20-55	
	T. 9 S., R. 10 W															
9-10-7add	SE SE NE sec. 7	P. Arnoldy	Du	25.7	40	R	Sand and gravel	Terrace deposits	Cy, G	D, S	Top of concrete cover	0.2	....	19.30	7-29-55	
9-10-8baa	NE NE NW sec. 8	Jim Houghton	Du	25.0	40	R	do	do	Cy, W	S	Top of board platform	0.3	....	17.50	7-29-55	
9-10-14dcc	SW SW SE sec. 14	N. Greiner	Du	35.6	60	R	do	do	Cy, W	D, S	Top of rock base	0.1	....	18.26	7-28-55	
9-10-17cbc	SW NW SW sec. 17	Everal Pickett	Du	21.0	48	R	Slope wash	Colluvium	Cy, W	S	Top of board platform	0.3	....	10.64	8- 1-55	
*9-10-21ab	NW NE sec. 21	Ben Schulz, Jr.	Du	28.0	60	R	do	do	Cy, W	S	do	0.4	....	18.43	7-27-55	
9-10-25dcc	SW SW SE sec. 25	A. V. Haymond	Du	32.8	36	R	do	do	N	N	Top of concrete curb	1.0	....	13.67	7-28-55	
*9-10-26ddc	SW SE SE sec. 26	City of Hunter	Du	34	96	R	Sand, gravel	Terrace deposits	J, E	P	Land surface	0.0	....	16	7-28-55	
9-10-28ddd	SE SE SE sec. 28	Harry Smith	Du	24.7	60	R	do	do	Cy, W	S	Top of board platform	2.0	....	17.30	7-29-55	
9-10-30ddd	SE SE SE sec. 30	N. Reinert	Du	20.5	48	R	Slope wash	Colluvium	Cy, H	N	do	0.2	....	11.77	8- 1-55	
9-10-31aad	SE NE NE sec. 31	Frank and Otto Koenigsman	Du	20.5	36	R	Sand and gravel	Terrace deposits	Cy, W	N	do	0.7	....	10.05	8- 1-55	

* Chemical analysis included in Table 5.
1. Well number indicates, in the following order, township, range, section, quarter section, quarter-quarter section, and quarter-quarter-quarter section.
2. B, bored well; Dr, drilled well or test hole; Du, dug well.
3. Reported depths below the land surface are given in feet; measured depths are given in feet and tenths below land surface.
4. B, brick; GI, galvanized iron; N, none; R, rock; S, steel; T, tile.
5. Method of lift: Cy, cylinder; J, jet; N, none; T, turbine.
   Type of power: E, electric; G, gas engine; H, hand operated; W, windmill.
6. D, domestic; I, irrigation; Ind, industrial; N, none; O, observation; P, public supply; S, stock.
7. Elevations determined by instruments are given in feet and tenths; elevations interpolated from U. S. Geological Survey topographic maps are given in feet.
8. Measured depths to water are given in feet, tenths, and hundredths; reported depths are given in feet.

LOGS OF TEST HOLES

The logs of 60 test holes in Mitchell County are given on the following pages. Of these, 29 are sample logs of test holes drilled by the State Geological Survey of Kansas, and 31 were drilled by the Bureau of Reclamation in conjunction with a study of the proposed Glen Elder dam. The logs of 12 test holes in a line across North Fork Solomon Valley are given by Leonard (1952) and the logs of 10 test holes near the Mitchell-Cloud County line are given by Bayne and Walters (1959). The test holes are numbered according to the system illustrated in Figure 2. Locations of test holes are shown on Plate 3. Plate 2 shows the character of material penetrated by test holes. Water-level measurements are stated in feet below land surface.

6-8-32bcc.—*Sample log of test hole in SW¼ SW¼ NW¼ sec. 32, T. 6 S., R. 8 W., 0.2 mile north of U. S. Highway 24, 150 feet north of farmstead drive, on east shoulder of road. Drilled by State Geological Survey, July 22, 1954. Surface altitude, 1,423 feet. Depth to water, 27.70 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, dark brown (soil)	2	2
Silt, light brown	4	6
Silt, clayey, light brown	8	14
Silt, clayey, and very fine to fine sand	10	24
Silt, clayey; contains caliche	14	38
Sand, fine to medium, and fine limestone gravel	3	41
CRETACEOUS—Gulfian		
Graneros Shale		
Shale, blue black; contains very thin hard limestone layers	9	50

6-8-32cbb.—*Sample log of test hole in NW¼ NW¼ SW¼ sec. 32, T. 6 S., R. 8 W., 35 feet north of center of U. S. Highway 24, 60 feet east of center of section-line road. Drilled by State Geological Survey, July 22, 1954. Surface altitude, 1,411 feet. Depth to water, 18.10 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, sandy, light brown (soil)	3	3
Silt, clayey, tan brown	4	7
Silt, clayey, light brown	3	10
Silt, clayey, light brown, and very fine sand	10	20
Silt, light brown, and fine sand	16	36
Sand, medium to coarse, and fine gravel	2	38
CRETACEOUS—Gulfian		
Graneros Shale		
Shale, dark blue gray, hard	6	44

6-8-32ccc.—*Sample log of test hole in SW¼ SW¼ SW¼ sec. 32, T. 6 S., R. 8 W., 60 feet northeast of section corner. Drilled by State Geological Survey, July 21, 1954. Surface altitude, 1,407 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, black (soil)	2	2
Silt, light brown	4	6
Silt, clayey, light brown	12	18
Silt, clayey, and very fine sand	16	34
Clay, dark blue gray	2	36
Sand, medium to coarse, and fine to medium gravel	6	42
Gravel, fine to coarse	10	52
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, clayey, dark blue gray	30	82
Sandstone, fine grained, light gray, hard	8	90

6-8-35bbb.—*Log of core hole DH-30, in NW¼ NW¼ NW¼ sec. 35, T. 6 S., R. 8 W. Drilled by Bureau of Reclamation, February 6-7, 1952. Surface altitude, 1,439.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria Formation and terrace deposits		
Silt, soft, dark brown; contains some clay	1.0	1.0
Silt, clayey, soft, light brown; contains white and dark-brown layers	7.2	8.2
Loess and silty clay, soft, light brown; contains 1-ft. dark-brown layer at 8.2 feet, which resembles old soil horizon	9.5	17.7
Loess and silty clay, soft, yellow brown; contains white spots	3.3	21.0
Loess and silty clay, soft, brown; contains limy nodules as much as 1½ inches in diameter	6.5	27.5
Silt, soft, gray; contains some clay and a trace of fine sand	5.5	33.0
Sand, fine to coarse; contains some gravel and chalk fragments	14.0	47.0
Sand; contains some silt and clay binder, hard and soft chalk or limestone fragments, and rust stains	2.0	49.0
Clay, silty, light brown	1.5	50.5
Sand, fine to coarse, contains some fine and medium gravel and many hard and soft chalk or limestone fragments	13.0	63.5
Clay, firm, rusty brown	1.0	64.5
CRETACEOUS—Gulfian		
Graneros Shale		
Shale, very firm, dark blue	5.5	70.0

6-8-35bcc.—*Log of core hole DH-31, in SW¼ SW¼ NW¼ sec. 35, T. 6 S., R. 8 W. Drilled by Bureau of Reclamation, February 8-11, 1952. Surface altitude, 1,424.8 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria Formation and terrace deposits		
Silt, clayey, soft, black	0.8	0.8
Loess and silty clay, soft, brown; contains white layers,	8.1	8.9
Loess and silty clay, brown; contains limy stringers and nodules as much as 1 inch in diameter. A 15-inch layer of black silty clay at 8.9 ft. may indicate old soil horizon	20.0	28.9
Sand, fine to coarse, and fine to medium gravel, rusty gray; contains limy nodules	1.8	30.7
Sand, fine to coarse, and fine gravel, rusty gray; contains chalk or limestone fragments and a 10-inch layer of gray sandy silt at 30.7 ft.	2.8	33.5
CRETACEOUS—Gulfian		
Graneros Shale		
Shale, hard, blackish; contains layers of sandstone near top	4.5	38.0

6-8-35ccc.—*Log of core hole DH-32, in SW¼ SW¼ SW¼ sec. 35, T. 6 S., R. 8 W. Drilled by Bureau of Reclamation, February 11-12, 1952. Surface altitude, 1,409.8 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria Formation and terrace deposits		
Silt, soft, dark brown	0.6	0.6
Loess and silty clay, soft, light brown	3.4	4.0
Loess and silty clay, soft, dark brown (may be old soil horizon)	1.9	5.9
Loess and silty clay, soft, light reddish brown	2.6	8.5
Loess and silty clay, soft, dark brown; contains light-gray layers	2.5	11.0
Loess and silty clay, yellow brown; contains limy stringers	1.7	12.7
Silt, clayey, soft, light brown; contains a trace of fine sand	5.6	18.3
Silt and silty clay, soft, light brown	3.7	22.0
Silt, clayey, soft, light brown; contains some fine sand,	4.0	26.0
Sand, fine to coarse, and fine gravel; contains limestone or chalk fragments	5.0	31.0
CRETACEOUS—Gulfian		
Graneros Shale		
Shale, hard, black to dark blue; contains 4-inch layer of sandstone at top	6.0	37.0

6-9-23ccc1.—*Log of core hole DH-4, in SW¼ SW¼ SW¼ sec. 23, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, June 4, 1954. Surface altitude, 1,418.8 feet. Depth to water, 16.20 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, slightly compacted, brown	3	3
Clay, silty, compact, brown	4	7
Clay, compact, damp, brown	7	14
Clay, silty, compact, moist to wet, brown	1	15
Silt, soft, wet, brown	3	18
Clay, slightly compacted, wet, brown	2	20
Clay, slightly compacted, wet, dark brown	6	26
Clay, slightly compacted, wet, brown	1	27
Silt, soft, saturated, light brown	3	30
Gravel, limestone fragments, and medium sand, saturated, loose, brown	7	37
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, slightly sandy, firm, blue	3	40

6-9-23ccc2.—*Log of core hole DH-5, in SW¼ SW¼ SW¼ sec. 23, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, May 17, 1954. Surface altitude, 1,418.6 feet. Depth to water, 17.00 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, compact, dark brown	1.5	1.5
Clay, compact, dark brown	2	3.5
Clay, silty, compact, brown	6.5	10
Silt, slightly compacted, brown	9	19
Clay, silty, slightly compacted, brown	1	20
Clay, compact, brown	1.5	21.5
Clay, compact, dark brown; contains chalk fragments,	1	22.5
Clay, silty, brown; contains chalk fragments	1	23.5
Silt, slightly compacted, brown	1.5	25
Chalk fragments and medium sand; contains some 1-inch layers of gray silt	6.5	31.5
Sand, fine to medium, loose, brown; contains chalk fragments	2	33.5
CRETACEOUS—Gulfian		
Graneros Shale		
Shale, slightly sandy, firm, blue	2	35.5

6-9-23ccd1.—*Log of core hole DH-3, in SE¼ SW¼ SW¼ sec. 23, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, May 14, 1954. Surface altitude, 1,421.9 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, compact, dark brown	1.5	1.5
Clay, compact, dark brown	6	7.5
Clay, compact, brown	6.5	14
Silt, slightly compacted, brown	7	21
Clay, compact, damp, brown	6	27
Clay, compact, moist, dark brown	5.5	32.5
Clay, compact, wet, blue	3	35.5
Clay, compact, wet, blue; contains chalk fragments	2.5	38
Sand, medium, loose, saturated, brown to gray; contains many chalk fragments	2.5	40.5
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, firm, blue	3.5	44

6-9-23ccd2.—*Log of core hole DH-17, in SE¼ SW¼ SW¼ sec. 23, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, June 8, 1954. Surface altitude, 1,425.3 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, compact, brown	8.5	8.5
Silt, slightly compacted, brown	13.5	22
Silt, soft, wet, brown	5	27
Clay, silty, slightly compacted, wet, dark brown	7	34
Clay, slightly compacted, dark brown; contains many limestone fragments	2.5	36.5
Clay, slightly compacted, wet, blue	1.5	38
Clay and fragments of limestone, soft, saturated, gray,	3	41
Gravel, limestone fragments, and sand, loose, saturated, brown	0.5	41.5
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, firm, blue	3	44.5

6-9-23cdc.—*Log of core hole DH-2, in SW¼ SE¼ SW¼ sec. 23, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, June 7, 1954. Surface altitude, 1,432.7 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, compact, brown; contains some fine sand	4.5	4.5
Limestone fragments, weathered; contains some medium sand	4	8.5

CRETACEOUS—Gulfian	Thickness, feet	Depth, feet
Greenhorn Limestone		
Limestone, chalky, deeply weathered, brown	4	12.5
Limestone, chalky, weathered, brown	2.5	15
Shale, weathered, brown and blue	2	17
Graneros Shale		
Shale, firm, blue	3.5	20.5

6-9-23cdd.—*Log of core hole DH-16, in SE¼ SE¼ SW¼ sec. 23, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, June 7, 1954. Surface altitude, 1,479.3 feet.*

QUATERNARY—Pleistocene	Thickness, feet	Depth, feet
Peoria and Loveland Formations		
Silt, compact, dark brown	1	1
Clay, silty, brown; contains considerable medium sand and limestone fragments	3.5	4.5
Limestone fragments, chalky, weathered, brown; contains some medium sand	2	6.5
CRETACEOUS—Gulfian		
Greenhorn Limestone		
Limestone, chalky, weathered, brownish gray	4.5	11
Limestone, hard, gray	1	12

6-9-23dcc.—*Log of core hole DH-1, in SW¼ SW¼ SE¼ sec. 23, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, May 18, 1954. Surface altitude, 1,462.5 feet.*

QUATERNARY—Pleistocene	Thickness, feet	Depth, feet
Peoria and Loveland Formations		
Clay, silty, compact, brown	3	3
Clay, compact, dark brown	5	8
Clay, compact, brown; contains chalk and limestone fragments	6	14
Limestone fragments, chalky, weathered; contains some brown clay	2	16
CRETACEOUS—Gulfian		
Greenhorn Limestone		
Limestone, chalky, weathered, yellow and gray	9	25
Shale, firm, blue	2	27

6-9-27aba1.—*Log of core hole DH-13, in NE¼ NW¼ NE¼ sec. 27, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, May 27, 1954. Surface altitude, 1,421.2 feet. Depth to water, 23.00 feet.*

QUATERNARY—Pleistocene	Thickness, feet	Depth, feet
Terrace deposits		
Clay, silty, compact, dark brown	1.5	1.5
Clay, compact, brown	3.5	5
Clay, compact, dark brown	10.5	15.5
Clay, compact, brown	2	17.5
Clay, compact, moist, brown	3.5	21
Clay, silty, wet, brown; contains small amount of very fine sand and a few limestone fragments	7	28

	Thickness, feet	Depth, feet
Clay, silty; contains considerable medium sand and limestone fragments	1.5	29.5
Clay, silty, slightly compacted, brown	1.5	31
Gravel, limestone fragments, loose, saturated; contains some medium sand and a few thin layers of gravel having clay binder	2.5	33.5
CRETACEOUS—Gulfian		
Graneros Shale		
Shale, slightly sandy, blue	1	34.5
Shale, slightly sandy, firm, blue	2.5	37

6-9-27aba2.—*Log of core hole DH-14, in NE¼ NW¼ NE¼ sec. 27, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, May 27, 1954. Surface altitude, 1,415.2 feet. Depth to water, 17.70 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, compact, brown	3	3
Silt, compact, light brown; contains small amount of very fine sand	4.5	7.5
Silt, compact, brown; contains small amount of fine sand	3	10.5
Silt, soft, wet to saturated, brown; contains small amount of fine sand	6	16.5
Sand, medium, loose, saturated, brown; contains abundant limestone fragments and some silt	2	18.5
Sand, medium to coarse, saturated, brown; contains considerable limestone gravel and layers of blue-gray silt	5	23.5
Sand, fine to medium, loose, clean, saturated, brown	1.5	25
Silt, soft, saturated, blue	1	26
CRETACEOUS—Gulfian		
Graneros Shale		
Shale, weathered, brown	3	29
Shale, slightly sandy, firm, blue	3	32

6-9-27abb1.—*Log of core hole DH-15, in NW¼ NW¼ NE¼ sec. 27, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, June 3, 1954. Surface altitude, 1,411.3 feet. Depth to water, 14.30 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, compact, brown	3	3
Silt, compact, brown	4.5	7.5
Silt, slightly compacted, moist to wet, brown	3	10.5
Silt, slightly compacted, saturated, brown	4.5	15
Clay, silty, blue and brown, saturated; contains some limestone fragments and a few thin layers of medium sand	5	20
Shale, sandy, reworked, blue; contains some limestone fragments	1	21
CRETACEOUS—Gulfian		
Graneros Shale		
Shale, sandy, firm, blue	3	24

6-9-27abb2.—*Log of core hole DH-7, in NW¼ NW¼ NE¼ sec. 27, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, May 19, 1954. Surface altitude, 1,422.0 feet. Depth to water, 24.60 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Clay, silty, compact, dark brown	1	1
Clay, compact, dark brown	3	4
Silt, compact, brown	1.5	5.5
Clay, compact, brown; contains some limestone fragments	1	6.5
Clay, compact, dark brown	2.5	9
Clay, compact, dark brown; contains limestone fragments	0.5	9.5
Clay, silty, compact, brown	2.5	12
Clay, compact, dark brown	2.5	14.5
Clay, silty, compact, greenish gray	4.5	19
Clay, compact, greenish gray	5.5	24.5
Clay, compact, and very fine sand, greenish gray; contains small limestone fragments	3.5	28
CRETACEOUS—Gulfian		
Graneros Shale		
Shale, weathered, brown and blue, and limestone fragments	10	38
Dakota Formation		
Shale, firm, blue	3.5	41.5

6-9-27abb3.—*Log of core hole DH-8, in NW¼ NW¼ NE¼ sec. 27, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, May 19, 1954. Surface altitude, 1,435.5 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, slightly compacted, dark brown	3	3
Silt, compact, brown; contains fine limestone fragments	3.5	6.5
Clay, compact, brown	4.5	11
Clay, brown; contains limestone fragments	1	12
CRETACEOUS—Gulfian		
Greenhorn Limestone		
Shale, weathered, brown	10	22
Graneros Shale		
Shale, firm, blue	4	26
Concretion, hard, gray	0.5	26.5
Shale, firm, blue	1.5	28

6-9-27bbb.—*Log of core hole DH-10, in NW¼ NW¼ NW¼ sec. 27, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, May 25, 1954. Surface altitude, 1,491.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, brown; contains considerable sand and gravel	1	1

Cretaceous—Gulfian	Thickness, feet	Depth, feet
Greenhorn Limestone		
Limestone, chalky, and calcareous shale	21	22
Shale, slightly sandy, firm, blue	3	25

6-9-27cad.—*Log of core hole DH-12, in SE¼ NE¼ SW¼ sec. 27, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, December 2, 1949. Surface altitude, 1,494.2 feet.*

Quaternary—Pleistocene	Thickness, feet	Depth, feet
Peoria and Loveland Formations		
Silt, compact, brown; contains chalk fragments	4	4
Sand, fine to medium; contains fine to medium chalk fragments	5	9
Cretaceous—Gulfian		
Greenhorn Limestone		
Limestone, chalky, weathered, gray	7	16
Limestone and shale, chalky, weathered, gray	7	23
Shale, bluish, and hard broken limestone, weathered,	6	29
Shale, firm, blue; contains layers of selenite crystals	4	33
Shale, firm, blue, and interbedded hard gray limestone; contains 4-inch bentonite seam at 41 ft.	12	45
Shale, firm, blue; contains a few thin limestone layers,	17	62

6-9-34baa1.—*Log of core hole DH-1, in NE¼ NE¼ NW¼ sec. 34, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, October 5, 1949. Surface altitude, 1,404.6 feet. Depth to water, 13.80 feet.*

Quaternary—Pleistocene	Thickness, feet	Depth, feet
Alluvium (Recent) and terrace deposits		
Silt, compact, brown	2	2
Silt, sandy, compact, gray	6	8
Silt and fine sand, compact, brown	4	12
Sand, very fine, clean	4	16
Sand, medium, clean, gray	2	18
Sand, coarse, saturated, gray	6	24
Sand, coarse, gray; contains 5 percent fine gravel	5	29
Cretaceous—Gulfian		
Dakota Formation		
Shale, firm, blue	7	36

6-9-34baa2.—*Log of core hole DH-2, in NE¼ NE¼ NW¼ sec. 34, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, October 6, 1949. Surface altitude, 1,424.1 feet. Depth to water, 31.80 feet.*

Quaternary—Pleistocene	Thickness, feet	Depth, feet
Terrace deposits		
Silt, compact, brown	25	25
Sand, fine, compact, clean	4	29
Sand, fine, and silt, compact, saturated, brown to gray,	6	35
Sand, medium, clean, saturated, gray	5	40
Sand, coarse, clean, saturated, gray	6	46
Sand, medium, clean, saturated, gray	8	54
Sand, coarse, and some fine gravel	1	55
Cretaceous—Gulfian		
Dakota Formation		
Shale, firm, blue	6	61

6-9-34bda.—*Log of core hole DH-3, in NE¼ SE¼ NW¼ sec. 34, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, October 7, 1949. Surface altitude, 1,422.8 feet. Depth to water, 30.20 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, compact, brown	2	2
Sand, fine, silty, gray	6	8
Silt, compact, brown	4	12
Sand, fine, and silt, gray	15	27
Sand, fine to medium, gray	6	33
Sand, medium to coarse, clean, gray	13	46
Sand, coarse; contains some silt	4	50
Sand, coarse; contains considerable silt and 10 percent fine to medium gravel	5	55
Sand, coarse, and fine gravel	3	58
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, firm, blue	1	59

6-9-34bdd.—*Log of core hole DH-4, in SE¼ SE¼ NW¼ sec. 34, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, October 7, 1949. Surface altitude, 1,426.1 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, compact, gray	4	4
Silt, firm, brown	40	44
Sand, medium, clean, saturated, gray	4	48
Sand, coarse, saturated, gray; contains some silt	7	55
Sand, medium to coarse; contains 10 percent fine gravel and some chalk fragments	4	59
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, firm, blue	1	60

6-9-34cad.—*Log of core hole DH-5, in SE¼ NE¼ SW¼ sec. 34, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, October 14, 1949. Surface altitude, 1,423.0 feet. Depth to water, 28.50 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, firm, brown	34	34
Silt, brown; contains considerable clay	5	39
Silt, firm, saturated, brown	6	45
Sand, medium to coarse, clean, saturated, gray	10	55
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, firm, blue	3	58
Shale, hard, gray	1	59
Shale, firm, blue	8	67
Shale, firm, blue gray	9	76

CRETACEOUS—Gulfian	Thickness, feet	Depth, feet
Greenhorn Limestone		
Limestone, chalky, and calcareous shale	21	22
Shale, slightly sandy, firm, blue	3	25

6-9-27cad.—*Log of core hole DH-12, in SE¼ NE¼ SW¼ sec. 27, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, December 2, 1949. Surface altitude, 1,494.2 feet.*

QUATERNARY—Pleistocene	Thickness, feet	Depth, feet
Peoria and Loveland Formations		
Silt, compact, brown; contains chalk fragments	4	4
Sand, fine to medium; contains fine to medium chalk fragments	5	9
CRETACEOUS—Gulfian		
Greenhorn Limestone		
Limestone, chalky, weathered, gray	7	16
Limestone and shale, chalky, weathered, gray	7	23
Shale, bluish, and hard broken limestone, weathered,	6	29
Shale, firm, blue; contains layers of selenite crystals	4	33
Shale, firm, blue, and interbedded hard gray limestone; contains 4-inch bentonite seam at 41 ft.	12	45
Shale, firm, blue; contains a few thin limestone layers,	17	62

6-9-34baa1.—*Log of core hole DH-1, in NE¼ NE¼ NW¼ sec. 34, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, October 5, 1949. Surface altitude, 1,404.6 feet. Depth to water, 13.80 feet.*

QUATERNARY—Pleistocene	Thickness, feet	Depth, feet
Alluvium (Recent) and terrace deposits		
Silt, compact, brown	2	2
Silt, sandy, compact, gray	6	8
Silt and fine sand, compact, brown	4	12
Sand, very fine, clean	4	16
Sand, medium, clean, gray	2	18
Sand, coarse, saturated, gray	6	24
Sand, coarse, gray; contains 5 percent fine gravel	5	29
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, firm, blue	7	36

6-9-34baa2.—*Log of core hole DH-2, in NE¼ NE¼ NW¼ sec. 34, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, October 6, 1949. Surface altitude, 1,424.1 feet. Depth to water, 31.80 feet.*

QUATERNARY—Pleistocene	Thickness, feet	Depth, feet
Terrace deposits		
Silt, compact, brown	25	25
Sand, fine, compact, clean	4	29
Sand, fine, and silt, compact, saturated, brown to gray,	6	35
Sand, medium, clean, saturated, gray	5	40
Sand, coarse, clean, saturated, gray	6	46
Sand, medium, clean, saturated, gray	8	54
Sand, coarse, and some fine gravel	1	55
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, firm, blue	6	61

6-9-34bda.—*Log of core hole DH-3, in NE¼ SE¼ NW¼ sec. 34, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, October 7, 1949. Surface altitude, 1,422.8 feet. Depth to water, 30.20 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, compact, brown	2	2
Sand, fine, silty, gray	6	8
Silt, compact, brown	4	12
Sand, fine, and silt, gray	15	27
Sand, fine to medium, gray	6	33
Sand, medium to coarse, clean, gray	13	46
Sand, coarse; contains some silt	4	50
Sand, coarse; contains considerable silt and 10 percent fine to medium gravel	5	55
Sand, coarse, and fine gravel	3	58
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, firm, blue	1	59

6-9-34bdd.—*Log of core hole DH-4, in SE¼ SE¼ NW¼ sec. 34, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, October 7, 1949. Surface altitude, 1,426.1 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, compact, gray	4	4
Silt, firm, brown	40	44
Sand, medium, clean, saturated, gray	4	48
Sand, coarse, saturated, gray; contains some silt	7	55
Sand, medium to coarse; contains 10 percent fine gravel and some chalk fragments	4	59
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, firm, blue	1	60

6-9-34cad.—*Log of core hole DH-5, in SE¼ NE¼ SW¼ sec. 34, T. 6 S., R. 9 W. Drilled by Bureau of Reclamation, October 14, 1949. Surface altitude, 1,423.0 feet. Depth to water, 28.50 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, firm, brown	34	34
Silt, brown; contains considerable clay	5	39
Silt, firm, saturated, brown	6	45
Sand, medium to coarse, clean, saturated, gray	10	55
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, firm, blue	3	58
Shale, hard, gray	1	59
Shale, firm, blue	8	67
Shale, firm, blue gray	9	76

6-10-5cdc.—*Sample log of test hole in SW¼ SE¼ SW¼ sec. 5, T. 6 S., R. 10 W., 6 feet north of center of road, 0.3 mile east of road intersection. Drilled by State Geological Survey, May 6, 1946. Surface altitude, 1,541.1 feet. Depth to water, 34.10 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria Formation and terrace deposits		
Silt, dark gray, loose (soil)	3	3
Silt, medium compact, brown	9	12
Silt, compact, sandy, light gray tan	25	37
Sand and gravel, very fine to coarse	12	49
Silt, medium compact, sandy, gray	7	56
Sand and limestone gravel, very fine to coarse	3	59
CRETACEOUS—Gulfian		
Carlile Shale		
Shale, medium hard, silty, black	1	60

6-10-8ccb.—*Sample log of test hole in NW¼ SW¼ SW¼ sec. 8, T. 6 S., R. 10 W., 10 feet east of center of road and 0.21 mile north of road intersection. Drilled by State Geological Survey, May 6, 1946. Surface altitude, 1,508.1 feet. Depth to water, 30.40 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria Formation and terrace deposits		
Silt, loose, dark brown (soil)	2	2
Silt, medium compact, light gray	2	4
Silt, fairly compact, brown	13	17
Silt, compact, yellow tan to gray	4	21
Silt, soft, sandy, light tan	6	27
Silt, light tan, and very fine to fine quartz sand	3	30
Sand, very fine to medium; contains small amount of coarse sand, fine to coarse gravel, and some gray silt	7.5	37.5
CRETACEOUS—Gulfian		
Greenhorn Limestone		
Shale, medium hard, calcareous, black	2.5	40

6-10-17bcc.—*Sample log of test hole in SW¼ SW¼ NW¼ sec. 17, T. 6 S., R. 10 W., 7 feet east of center of road and 36 feet north of half-mile line fence. Drilled by State Geological Survey, May 6, 1946. Surface altitude, 1,473.9 feet. Depth to water, 15.70 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, medium loose, black and gray (soil)	5	5
Silt, medium compact, gray to tan	13	18
Silt, soft, sandy, light green gray and dark gray	12	30
Sand, very fine to medium, quartz, and fine to coarse limestone gravel; contains small amount of gray-green silt and shale fragments	6.5	36.5
CRETACEOUS—Gulfian		
Greenhorn Limestone		
Shale, fairly hard, calcareous, black and gray	3.5	40

6-10-20bbc.—*Sample log of test hole in SW¼ NW¼ NW¼ sec. 20, T. 6 S., R. 10 W., 10 feet east of center of road and 0.15 mile south of road intersection. Drilled by State Geological Survey, May 4, 1946. Surface altitude, 1,469.9 feet. Depth to water, 22.00 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, dark gray black	2	2
Silt, medium soft, friable, tan and light gray	3	5
Silt, compact, plastic, dark gray	4	9
Silt, soft, light gray tan	9	18
Silt, gray, and sand, very fine to fine; contains small amount of fine to coarse limestone gravel	11	29
Silt, soft, sandy, gravelly, dark gray blue	7.5	36.5
Sand, fine to coarse, and fine to coarse limestone and quartz gravel	2.5	39
CRETACEOUS—Gulfian		
Greenhorn Limestone		
Shale, medium hard, calcareous, black	1	40

6-10-20ccb.—*Sample log of test hole in NW¼ SW¼ SW¼ sec. 20, T. 6 S., R. 10 W., 10 feet east of center of road and 0.21 mile north of intersection of road with U. S. Highway 24. Drilled by State Geological Survey, May 4, 1946. Surface altitude, 1,464.7 feet. Depth to water, 30.90 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, dark gray to black	3	3
Silt, medium compact, brown and gray	16	19
Silt, soft, tan, and very fine to fine quartz sand	8	27
Sand, very fine to medium, quartz; contains small amount of coarse sand and fine limestone gravel	6	33
Sand, fine to coarse, quartz; contains a small amount of fine to medium limestone gravel	6	39
CRETACEOUS—Gulfian		
Greenhorn Limestone		
Limestone, very hard, light gray	0.3	39.3
Shale, hard, fissile, calcareous, black	0.7	40

6-10-29baa.—*Sample log of test hole in NE¼ NE¼ NW¼ sec. 29, T. 6 S., R. 10 W., 12 feet west of center of half-mile road and 0.09 mile south of intersection of road with U. S. Highway 24. Drilled by State Geological Survey, May 2, 1946. Surface altitude, 1,464.2 feet. Depth to water, 30.00 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, plastic, medium compact, gray	6	6
Silt, sandy, light gray to tan	9	15
Silt, dark tan to tan; contains fine quartz sand	3	18
Sand, very fine to medium, and tan silt; contains chalk gravel	5	23

	Thickness, feet	Depth, feet
Sand, very fine to medium, and fine to medium limestone gravel	9	32
Sand, very fine to coarse; contains much fine to very coarse limestone gravel and granitic gravel and small amount of white to yellow clay	22	54
CRETACEOUS—Gulfian		
Greenhorn Limestone		
Shale, fissile, medium hard, silty, gray, and soft, silty, gray-blue shale; contains soft light-blue bentonite	4	58

6-10-29caa.—*Sample log of test hole in NE¼ NE¼ SW¼ sec. 29, T. 6 S., R. 10 W., 11 feet west of center of half-mile road and just south of half-mile fence. Drilled by State Geological Survey, May 2, 1946. Surface altitude, 1,462.8 feet. Depth to water, 29.70 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, compact, sandy, black and dark gray (soil)	3	3
Silt, medium compact, coarse, sandy, gray to brown	8	11
Silt, sandy, tan	7	18
Silt, blocky, sandy, dark brown	7	25
Silt, slightly ironstained, light gray; contains very fine to medium sand and a few small snail shells	2	27
Sand, very fine to fine, quartz and feldspar; contains a small amount of medium to coarse sand and fine to medium limestone gravel	3	30
Sand and gravel, fragments of very fine to coarse chalk, quartz, granite, and black igneous rock	6	36
CRETACEOUS—Gulfian		
Greenhorn Limestone		
Shale, fissile, hard, dark gray black, and soft calcareous shale	4	40

6-10-29ccd.—*Sample log of test hole in SE¼ SW¼ SW¼ sec. 29, T. 6 S., R. 10 W., 12 feet north of center of road and 0.2 mile east of road intersection. Drilled by State Geological Survey, May 2, 1946. Surface altitude, 1,467.1 feet. Depth to water, 37.60 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, soft, brown and tan; contains a few small snail shells	10	10
Silt, soft, sandy, gray to brown	21	31
Silt, sandy, gray	9	40
Silt, soft, light gray; contains small amount of very fine to fine sand and a few small snail shells	3	43
Sand, very fine to coarse, quartz and chalk; contains gray silt	7	50
Sand, very fine to coarse; contains a small amount of fine to medium limestone gravel and shale fragments	2.5	52.5
CRETACEOUS—Gulfian		
Greenhorn Limestone		
Shale, hard, fissile, gray black	2.5	55

6-10-31ada.—*Sample log of test hole in NE¼ SE¼ NE¼ sec. 31, T. 6 S., R. 10 W., 10 feet west of center of road, 200 feet south of approach to Solomon River bridge. Drilled by State Geological Survey, May 3, 1946. Surface altitude, 1,450.4 feet. Depth to water, 20.00 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium (Recent) and terrace deposits		
Silt, soft, sandy, dark brown	5	5
Silt, soft, slightly sandy, gray and brown; contains small snail shells	11	16
Sand, very fine to fine; contains small amount of medium to coarse sand, fine gravel, and gray silt	5	21
Sand and gravel, fine to coarse, poorly sorted; contains limestone and shale pebbles and a small amount of gray clay	8	29
Silt, soft, sandy, gray blue; contains fine gravel and many small snail and clam shells	3	32
Sand, fine to coarse, and fine to coarse quartz and limestone gravel	7	39
CRETACEOUS—Gulfian		
Greenhorn Limestone		
Shale, hard, silty, dark gray black	1	40

6-10-31dda.—*Sample log of test hole in NE¼ SE¼ SE¼ sec. 31, T. 6 S., R. 10 W., 11 feet west of center of road and 0.2 mile north of road intersection. Drilled by State Geological Survey, May 3, 1946. Surface altitude, 1,485.1 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, sandy, dark brown	2	2
Silt, medium compact, slightly sandy, tan and brown,	3	5
CRETACEOUS—Gulfian		
Carlile Shale		
Clay shale, weathered, calcareous, gray yellow; contains fragments of *Ostrea* shells	2	7
Clay shale, calcareous, light gray to tan; contains thin medium-soft gray limestone	1	8
Clay shale, calcareous, light gray; contains shell and chalk fragments	2	10

7-5-31cbc.—*Sample log of test hole in SW¼ NW¼ SW¼ sec. 31, T. 7 S., R. 5 W., Cloud County, on east side of road, 25 feet north of concrete culvert. Drilled by State Geological Survey, October 29, 1953. Surface altitude, 1,341.0 feet. Depth to water, 9.20 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, black	4	4
Clay, dark gray	2	6
Clay, light gray	2	8
Clay, brown	3	11
Clay, dark brown	2	13
Clay, silty, tan	4	17

	Thickness, feet	Depth, feet
Clay, yellow to gray	5	22
Sand, fine to medium, quartz	6	28
CRETACEOUS—Gulfian		
Dakota Formation		
Clay, red and yellow	3	31
Clay, gray	3	34
Clay, red and gray	1	35

7-6-25ddd.—*Sample log of test hole in SE¼ SE¼ SE¼ sec. 25, T. 7 S., R. 6 W. Drilled by State Geological Survey, October 28, 1953. Surface altitude, 1,378.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, dark gray	2	2
Silt, brown	3	5
Silt, tan	8	13
Sand, coarse, and fine gravel	9	22
Clay, calcareous, light gray	2	24
CRETACEOUS—Gulfian		
Dakota Formation		
Clay, red	1	25
Clay, yellow	3	28
Clay, blue gray	2	30

7-6-36ada.—*Sample log of test hole in NE¼ SE¼ NE¼ sec. 36, T. 7 S., R. 6 W. Drilled by State Geological Survey, October 28, 1953. Surface altitude, 1,351.0 feet. Depth to water, 13.10 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, black	3	3
Clay, brown	3	6
Silt, sandy	3	9
Clay, brown	2	11
Clay, calcareous, light tan	11	22
Sand, fine to medium, quartz	8	30
Sand, fine to medium; contains some fine limestone gravel	2	32
CRETACEOUS—Gulfian		
Dakota Formation		
Clay, blue gray	6	38

7-8-3ad1.—*Log of core hole DH-36, in SE¼ NE¼ sec. 3, T. 7 S., R. 8 W. Drilled by Bureau of Reclamation, February 18, 1952. Surface altitude, 1,388.5 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, clayey, dark brown to brown; contains a few light-brown stringers	23.0	23.0
Silt and silty clay, light gray; contains many rusty and black stringers and a few stringers of fine to medium sand	9.2	32.2

	Thickness, feet	Depth, feet
Sand, fine to coarse, soft, rusty gray; contains some fine to medium gravel	0.7	32.9
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, very firm; contains stringers of fine to medium blue sand	0.8	33.7
Shale, hard, dark blue	2.6	36.3
Sandstone, very hard, light gray	5.7	42.0

7-8-3ad2.—*Log of core hole DH-41, in SE¼ NE¼ sec. 3, T. 7 S., R. 8 W. Drilled by Bureau of Reclamation, March 18-19, 1952. Surface altitude, 1,388.8 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, clayey, soft, brown; contains a few thin lenses of fine sand	15	15
Silt, clayey, brown, containing dark-brown streaks; contains a few thin lenses of fine sand	4.5	19.5
Clay, silty, limy, dark brown; contains chalk fragments	4.5	24
Clay, silty, very soft, dark gray; contains layers of fine to coarse sand	15	39
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, firm; contains thin layers of fine sand	1	40

7-8-3dca.—*Log of test hole CH-5, in NE¼ SW¼ SE¼ sec. 3, T. 7 S., R. 8 W. Drilled by Bureau of Reclamation, January 10, 1952. Surface altitude, 1,384.6 feet. Depth to water, 15.30 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium (Recent) and terrace deposits		
Clay, brown	5.5	5.5
Sand, fine, silty, light brown	13.0	18.5
Sand, fine, clean, brown, containing rusty seams	2.3	20.8
Sand, fine, brown; contains small amount of silt	4.2	25.0
Sand, fine to coarse, clean, blue gray	16.8	41.8
Sand, coarse, and fine gravel	1.0	42.8
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, firm, gray blue	0.6	43.4

7-8-3dcd.—*Log of core hole DH-37, in SE¼ SW¼ SE¼ sec. 3, T. 7 S., R. 8 W. Drilled by Bureau of Reclamation, March 20, 1952. Surface altitude, 1,383.9 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium (Recent) and terrace deposits		
Silt and silty clay, soft, dark brown	1.3	1.3
Silt, sandy, light brown	15.7	17.0
Sand, fine to coarse, and fine to medium gravel	15.2	32.2
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, firm, dark blue	1.6	33.8

7-8-5cbc.—*Sample log of test hole in SW¼ NW¼ SW¼ sec. 5, T. 7 S., R. 8 W., 100 feet south of Solomon River bridge, 20 feet east of road center. Drilled by State Geological Survey, July 22, 1954. Surface altitude, 1,397 feet. Depth to water, 18.10 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium (Recent) and terrace deposits		
Silt, sandy, light brown (soil)	3	3
Silt, light brown	9	12
Sand, very fine to fine, tan	8	20
Sand, medium to coarse, tan	7	27
Sand, coarse to very coarse, and fine gravel	13	40
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, clayey, noncalcareous, dark gray	5	45

7-8-6daa.—*Sample log of test hole in NE¼ NE¼ SE¼ sec. 6, T. 7 S., R. 8 W., 25 feet west of road center, 250 feet north of Solomon River bridge. Drilled by State Geological Survey, July 21, 1954. Surface altitude, 1,407 feet. Depth to water, 29.00 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, dark brown (soil)	2	2
Silt, light brown	5	7
Silt, clayey, light brown	7	14
Silt, light brown, and fine sand	13	27
Sand, fine to medium	5	32
Sand, medium; contains fine to medium limestone gravel	4	36
Sand, medium to coarse, and fine to medium limestone gravel	6	42
Sand, very coarse, and fine quartz and limestone gravel	3	45
Gravel, medium to coarse, pebbles of limestone and quartz	3	48
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, clayey, noncalcareous, dark gray	12	60

7-8-7aaa.—*Sample log of test hole in NE¼ NE¼ NE¼ sec. 7, T. 7 S., R. 8 W., 60 feet west and 6 feet south of section corner. Drilled by State Geological Survey, July 22, 1954. Surface altitude, 1,410 feet. Depth to water, 31.00 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, light brown (soil)	3	3
Silt, clayey, light brown, and very fine sand	12	15
Silt, light brown, and very fine sand	10	25
Sand, very fine to fine, tan brown	9	34
Sand, medium to coarse, and medium limestone gravel	6	40
Gravel, fine to coarse	5	45
Sand, medium to very coarse, and fine gravel	9	54
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, clayey, hard, noncalcareous, dark gray	6	60

7-8-7add.—*Sample log of test hole in SE¼ SE¼ NE¼ sec. 7, T. 7 S., R. 8 W., 0.4 mile south of section corner, on west shouder of road. Drilled by State Geological Survey, July 22, 1954. Surface altitude, 1,420 feet. Depth to water, 32.20 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, light brown (soil)	3	3
Silt, tan brown	7	10
Silt, clayey, light brown, and fine sand	10	20
Silt and very fine sand	12	32
Sand, medium to very coarse, clean	13	45
Sand, very coarse, and fine to medium gravel	8	53
CRETACEOUS—Gulfian		
Graneros Shale		
Shale, hard, blue gray	5	58

7-8-10aba.—*Log of test hole CH-6, in NE¼ NW¼ NE¼ sec. 10, T. 7 S., R. 8 W. Drilled by Bureau of Reclamation, January 10, 1952. Surface altitude, 1,380.6 feet. Depth to water, 12.20 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium (Recent) and terrace deposits		
Silt, light brown	1.0	1.0
Clay, brown	6.0	7.0
Sand, fine, silty, brown	6.7	13.7
Sand, fine to coarse, clean, light brown	10.3	24.0
Sand, fine to medium; contains small amount of silt	2.9	26.9
Sand, fine to coarse, gray	0.7	27.6
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, hard, greenish gray	0.9	28.5

7-9-3bad.—*Log of core hole DH-6, in SE¼ NE¼ NW¼ sec. 3, T. 7 S., R. 9 W. Drilled by Bureau of Reclamation, October 10, 1949. Surface altitude, 1,415.2 feet. Depth to water, 18.20 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, firm, brown	34	34
Clay, firm, blue brown; contains some silt	4	38
Sand, medium to coarse; contains a 6-inch layer of clay at 40 ft.	4	42
Sand, fine to coarse, saturated; contains silt and some clay balls	5	47
CRETACEOUS—Gulfian		
Dakota Formation		
Shale; contains thin layers of hard cemented zones	10	57
Shale, hard, gray	0.5	57.5
Shale, firm, blue	4	61.5
Shale, hard, gray	0.5	62
Shale, firm, blue; contains thin cemented layer at 67.5 feet	13	75

7-8-5cbc.—*Sample log of test hole in SW¼ NW¼ SW¼ sec. 5, T. 7 S., R. 8 W., 100 feet south of Solomon River bridge, 20 feet east of road center. Drilled by State Geological Survey, July 22, 1954. Surface altitude, 1,397 feet. Depth to water, 18.10 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium (Recent) and terrace deposits		
Silt, sandy, light brown (soil)	3	3
Silt, light brown	9	12
Sand, very fine to fine, tan	8	20
Sand, medium to coarse, tan	7	27
Sand, coarse to very coarse, and fine gravel	13	40
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, clayey, noncalcareous, dark gray	5	45

7-8-6daa.—*Sample log of test hole in NE¼ NE¼ SE¼ sec. 6, T. 7 S., R. 8 W., 25 feet west of road center, 250 feet north of Solomon River bridge. Drilled by State Geological Survey, July 21, 1954. Surface altitude, 1,407 feet. Depth to water, 29.00 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, dark brown (soil)	2	2
Silt, light brown	5	7
Silt, clayey, light brown	7	14
Silt, light brown, and fine sand	13	27
Sand, fine to medium	5	32
Sand, medium; contains fine to medium limestone gravel	4	36
Sand, medium to coarse, and fine to medium limestone gravel	6	42
Sand, very coarse, and fine quartz and limestone gravel	3	45
Gravel, medium to coarse, pebbles of limestone and quartz	3	48
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, clayey, noncalcareous, dark gray	12	60

7-8-7aaa.—*Sample log of test hole in NE¼ NE¼ NE¼ sec. 7, T. 7 S., R. 8 W., 60 feet west and 6 feet south of section corner. Drilled by State Geological Survey, July 22, 1954. Surface altitude, 1,410 feet. Depth to water, 31.00 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, light brown (soil)	3	3
Silt, clayey, light brown, and very fine sand	12	15
Silt, light brown, and very fine sand	10	25
Sand, very fine to fine, tan brown	9	34
Sand, medium to coarse, and medium limestone gravel	6	40
Gravel, fine to coarse	5	45
Sand, medium to very coarse, and fine gravel	9	54
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, clayey, hard, noncalcareous, dark gray	6	60

7-8-7add.—*Sample log of test hole in SE¼ SE¼ NE¼ sec. 7, T. 7 S., R. 8 W., 0.4 mile south of section corner, on west shouder of road. Drilled by State Geological Survey, July 22, 1954. Surface altitude, 1,420 feet. Depth to water, 32.20 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, light brown (soil)	3	3
Silt, tan brown	7	10
Silt, clayey, light brown, and fine sand	10	20
Silt and very fine sand	12	32
Sand, medium to very coarse, clean	13	45
Sand, very coarse, and fine to medium gravel	8	53
CRETACEOUS—Gulfian		
Graneros Shale		
Shale, hard, blue gray	5	58

7-8-10aba.—*Log of test hole CH-6, in NE¼ NW¼ NE¼ sec. 10, T. 7 S., R. 8 W. Drilled by Bureau of Reclamation, January 10, 1952. Surface altitude, 1,380.6 feet. Depth to water, 12.20 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium (Recent) and terrace deposits		
Silt, light brown	1.0	1.0
Clay, brown	6.0	7.0
Sand, fine, silty, brown	6.7	13.7
Sand, fine to coarse, clean, light brown	10.3	24.0
Sand, fine to medium; contains small amount of silt	2.9	26.9
Sand, fine to coarse, gray	0.7	27.6
CRETACEOUS—Gulfian		
Dakota Formation		
Shale, hard, greenish gray	0.9	28.5

7-9-3bad.—*Log of core hole DH-6, in SE¼ NE¼ NW¼ sec. 3, T. 7 S., R. 9 W. Drilled by Bureau of Reclamation, October 10, 1949. Surface altitude, 1,415.2 feet. Depth to water, 18.20 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, firm, brown	34	34
Clay, firm, blue brown; contains some silt	4	38
Sand, medium to coarse; contains a 6-inch layer of clay at 40 ft.	4	42
Sand, fine to coarse, saturated; contains silt and some clay balls	5	47
CRETACEOUS—Gulfian		
Dakota Formation		
Shale; contains thin layers of hard cemented zones	10	57
Shale, hard, gray	0.5	57.5
Shale, firm, blue	4	61.5
Shale, hard, gray	0.5	62
Shale, firm, blue; contains thin cemented layer at 67.5 feet	13	75

7-9-3bda.—*Log of core hole DH-7, in NE¼ SE¼ NW¼ sec. 3, T. 7 S., R. 9 W. Drilled by Bureau of Reclamation, November 30, 1949. Surface altitude, 1,434.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, compact, brown	4	4
Clay, compact, brown	23	27
Sand, fine, brown; contains small amount of silt	6	33
CRETACEOUS—Gulfian		
Graneros Shale		
Shale, weathered, gray	2	35
Shale, slightly weathered; contains thin layers of bentonite	5	40
Shale, hard, gray	7	47
Shale, massive, firm, blue	12	59

7-9-3cda.—*Log of core hole DH-8, in NE¼ SE¼ SW¼ sec. 3, T. 7 S., R. 9 W. Drilled by Bureau of Reclamation, November 29, 1949. Surface altitude, 1,480.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, firm, brown; contains chalk fragments at base	12	12
CRETACEOUS—Gulfian		
Greenhorn Limestone		
Limestone, chalky, weathered; contains layers of shale	8	20
Limestone, chalky, hard; contains thin layers of shale and thin bentonite seams	15	35
Shale, chalky, soft, gray	2	37
Limestone, hard, gray, and interbedded firm blue shale	19.5	56.5
Bentonite, soft, gray	1.5	58
Shale, firm, blue; contains 7-inch bentonite bed at 62.5 feet	12	70
Limestone, hard, and interbedded firm blue shale; contains bentonite seams	5	75

7-9-3cdd.—*Log of core hole DH-9, in SE¼ SE¼ SW¼ sec. 3, T. 7 S., R. 9 W. Drilled by Bureau of Reclamation, October 17, 1949. Surface altitude, 1,492.5 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, compact, brown	14	14
CRETACEOUS—Gulfian		
Greenhorn Limestone		
Limestone, firm, weathered, yellow gray	12	26
Shale, firm, weathered; contains layers of hard chalky limestone	10	36
Shale, weathered, blue	3	39
Limestone, hard, gray	2	41
Shale, weathered, blue	3	44
Shale, blue, and interbedded hard gray limestone	20	64
Limestone, hard, gray	6	70

7-10-6aad.—*Sample log of test hole in SE¼ NE¼ NE¼ sec. 6, T. 7 S., R. 10 W., 10 feet west of center of road and 0.15 mile south of road intersection. Drilled by State Geological Survey, May 3, 1946. Surface altitude, 1,499.5 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, soft, dark brown to black	3	3
Silt, plastic, medium compact, gray and tan	2	5
CRETACEOUS—Gulfian		
Carlile Shale		
Shale, soft, plastic, light gray, tan, and reddish; contains a few fragments of *Ostrea* shells	5	10

7-10-6dad.—*Sample log of test hole in SE¼ NE¼ SE¼ sec. 6, T. 7 S., R. 10 W., 13 feet west of center of road and 0.35 mile north of road intersection. Drilled by State Geological Survey, May 3, 1946. Surface altitude, 1,493.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria and Loveland Formations		
Silt, soft, sandy, dark brown	1	1
Silt, medium compact, sandy, tan and gray	4	5
CRETACEOUS—Gulfian		
Carlile Shale		
Clay shale, soft, silty, tan; contains shell fragments	1	6
Clay shale, tan and light gray; contains shell fragments	1	7
Clay shale, soft, chalky, light gray	3	10

8-5-6cbb.—*Sample log of test hole in NW¼ NW¼ SW¼ sec. 6, T. 8 S., R. 5 W., Cloud County. In town of Simpson, in NW corner of triangle formed by railroad and old highway. Drilled by State Geological Survey, October 29, 1953. Surface altitude, 1,332.2 feet. Depth to water, 17.00 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt and clay, brown	12	12
Clay, silty, brown	13	25
Clay, gray green	6	31
Sand, coarse, and fine to medium gravel of limestone and quartz	7	38
Sand, coarse, ironstained, quartz and limestone granules	5	43
Gravel, fine; contains some limestone pebbles	3	46
Sand, fine, quartzose, yellow	6	52
CRETACEOUS—Gulfian		
Dakota Formation		
Sandstone, hard, light gray	8	60

8-5-6ccc.—*Sample log of test hole in SW¼ SW¼ SW¼ sec. 6, T. 8 S., R. 5 W., Cloud County. On north side of road, about 45 feet east of road intersection. Drilled by State Geological Survey, October 28, 1953. Surface altitude, 1,330.0 feet. Depth to water, 19.50 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, black	3	3
Silt and clay, brown	2	5
Silt and clay, gray and brown	22	27
Clay, black	9	36
Sand, fine to medium	6	42
Gravel, medium, quartz and limestone pebbles	3	45
Sand, fine, quartz	9.5	54.5
CRETACEOUS—Gulfian		
Dakota Formation		
Clay, blue gray	3.5	58

8-5-7cbb.—*Sample log of test hole in NW¼ NW¼ SW¼ sec. 7, T. 8 S., R. 5 W., Cloud County. On east side of road, 40 feet south of half-mile line. Drilled by State Geological Survey, October 28, 1953. Surface altitude, 1,333.0 feet. Depth to water, 26.80 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, gray	6	6
Clay, dark gray	9	15
Clay, sandy, light gray	12	27
Silt, light brown; contains some fine limestone gravel,	5	32
Sand, fine to medium, quartz	6	38
Gravel, fine to coarse, quartz and limestone pebbles	10	48
CRETACEOUS—Gulfian		
Dakota Formation		
Clay, pink and gray	4	52

8-5-18bcb.—*Sample log of test hole in NW¼ SW¼ NW¼ sec. 18, T. 8 S., R. 5 W., Cloud County. On east side of road about 20 feet south of culvert into field. Drilled by State Geological Survey, October 28, 1953. Surface altitude, 1,344.0 feet. Depth to water, 32.40 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, clayey, black	7	7
Clay, silty, dark gray	4	11
Clay, gray	5	16
Clay, light gray	11	27
Clay, tan to gray	10	37
Sand, fine	5	42
Gravel, fine to coarse, limestone pebbles	3	45
CRETACEOUS—Gulfian		
Dakota Formation		
Clay, red	5	50

8-5-19bbc.—*Sample log of test hole in SW¼ NW¼ NW¼ sec. 19, T. 8 S., R. 5 W., Cloud County. On east side of road, 70 feet west of red barn. Drilled by State Geological Survey, October 27, 1953. Surface altitude, 1,376.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, black	5	5
Clay, silty, gray	3	8
Clay, silty, dark brown	8	16
Clay, silty, light brown	5	21
Gravel, fine to medium, limestone pebbles	7	28
CRETACEOUS—Gulfian		
Dakota Formation		
Clay, gray	4	32

8-5-19bcb.—*Sample log of test hole in NW¼ SW¼ NW¼ sec. 19, T. 8 S., R. 5 W., Cloud County. On east side of road, 54 feet south of culvert across drive to house east of road. Drilled by State Geological Survey, October 27, 1953. Surface altitude, 1,374.0 feet. Depth to water, 22.30 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt, black	4	4
Clay, silty, brown	9	13
Clay, brown	5	18
Gravel, fine to coarse, angular limestone pebbles	7	25
CRETACEOUS—Gulfian		
Dakota Formation		
Clay, dark gray	5	30

8-6-12ddd.—*Sample log of test hole in SE¼ SE¼ SE¼ sec. 12, T. 8 S., R. 6 W. Drilled by State Geological Survey, October 28, 1953. Surface altitude, 1,338.0 feet. Depth to water, 31.50 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Terrace deposits		
Silt and clay, black	4	4
Silt and clay, dark brown	2	6
Clay, silty, brown	2	8
Silt and clay, dark brown	3	11
Clay, sandy, brown	10	21
Sand and gray clay	17	38
Gravel, fine to medium, limestone and quartz pebbles,	2	40
CRETACEOUS—Gulfian		
Dakota Formation		
Clay, sandy, red and gray	2	42
Clay, blue gray	3	45

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27-6424

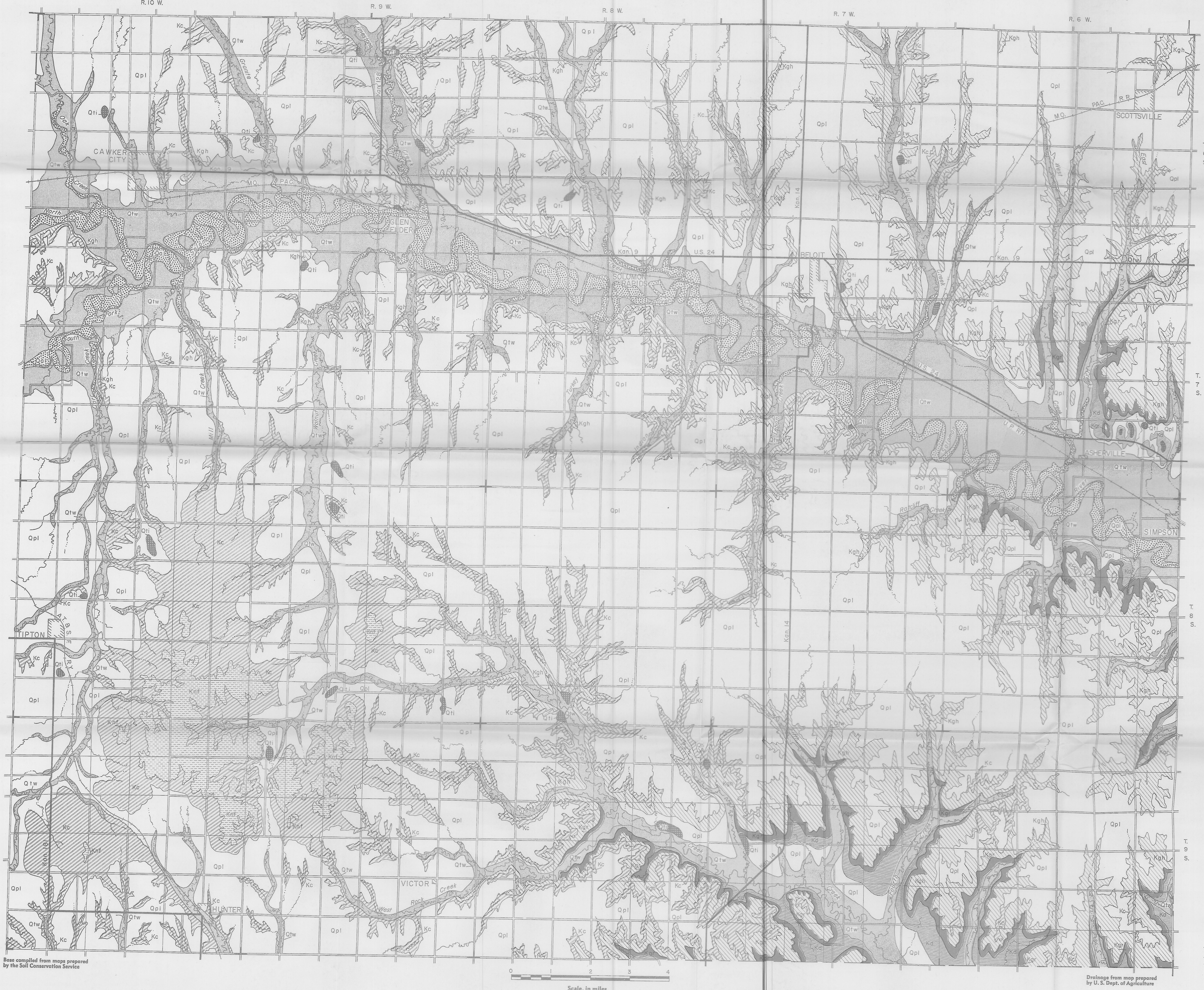
AREAL GEOLOGY OF MITCHELL COUNTY, KANSAS

State Geological Survey
of Kansas

By Warren G. Hodson
1957

Bulletin 140

Plate 1



EXPLANATION

QUATERNARY

PLEISTOCENE

Qal

Alluvium

Unconsolidated sand, gravel, silt, and clay of Recent age. Underlies Recent flood plain in stream channels. Dashed lines indicate minor terrace scarps. Yields moderate quantities of water to wells along Solomon Valley and smaller quantities along tributary valleys.

Qtw

Terrace deposits

Unconsolidated sand and gravel grading upward into clay and silt of late Wisconsinan age. Underlie terraces in valleys of larger streams. Yield moderate quantities of water to wells along Solomon Valley and smaller quantities along tributary valleys.

Qpl

Peoria and Loveland Formations of Sanborn Group

Silt and sandy silt, mostly eolian, of Wisconsinan and Illinoian age. Blanket much of the upland. Include colluvium in upland draws. Yield little or no water to wells.

Qti

Crete Formation

Remnants of alluvial deposits consisting of sand, gravel, and silt of Illinoian age in a high terrace position along Solomon Valley and its major tributaries. Yields no water to wells.

CRETACEOUS

GULFIAN

Knf

Fort Hays Limestone member of Niobrara Formation

Massive beds of cream-colored chalky limestone separated by thin partings of chalky shale. Forms prominent buttes. Yields no water to wells.

Kc

Carlile Shale

Gray to black shale containing large septarian concretions near top and thin silty sandstone (Codell Sandstone zone) at top. Lower part consists of alternating beds of chalky shale and thin chalky limestone. Yields no water to wells.

Kgh

Greenhorn Limestone

Alternating beds of calcareous shale and chalky limestone. Contains thin bentonite beds; thin bed of hard crystalline limestone at base. Yields meager to small quantities of water of variable quality from place to place.

Kgr

Graneros Shale

Dark-blue-gray shale that weathers gray and tan. Locally contains thin layers of bentonite and thin lenses of silty red-brown sandstone. Yields little or no water to wells.

Kd

Dakota Formation

Clay, shale, siltstone, and sandstone. Contains lignite and "ironstones". Yields small to moderate quantities of water, potable in eastern part of county, too mineralized for use in central and western parts.

Federal or state highway
Township or county road
Section line (no road)
Railroad
Perennial stream
Intermittent stream

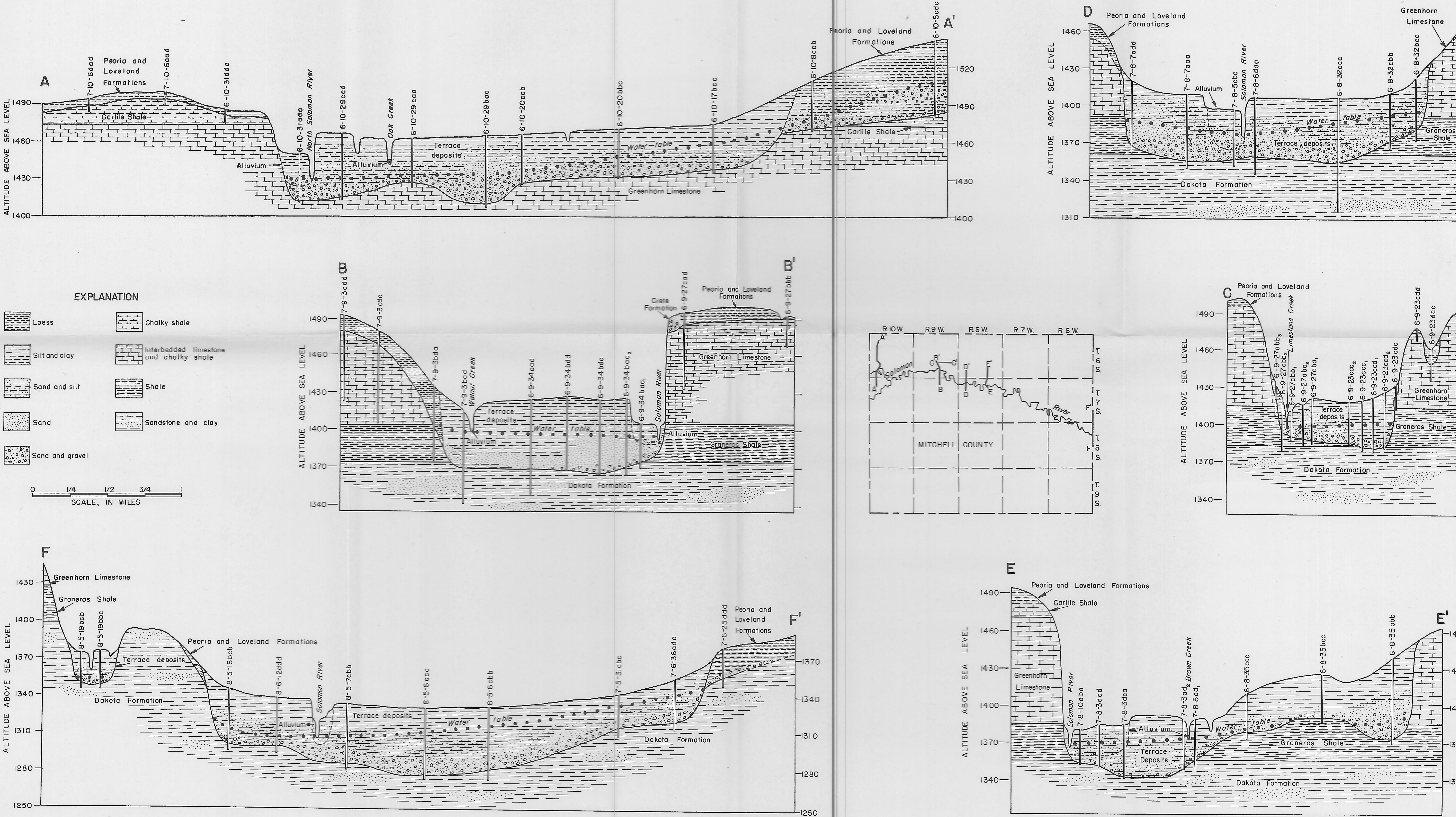
State Geological Survey of Kansas

GEOLOGIC CROSS SECTIONS

of Solomon Valley, Mitchell County

By Warren G. Hodson

Bulletin 140
Plate 2



MAP OF MITCHELL COUNTY, KANSAS

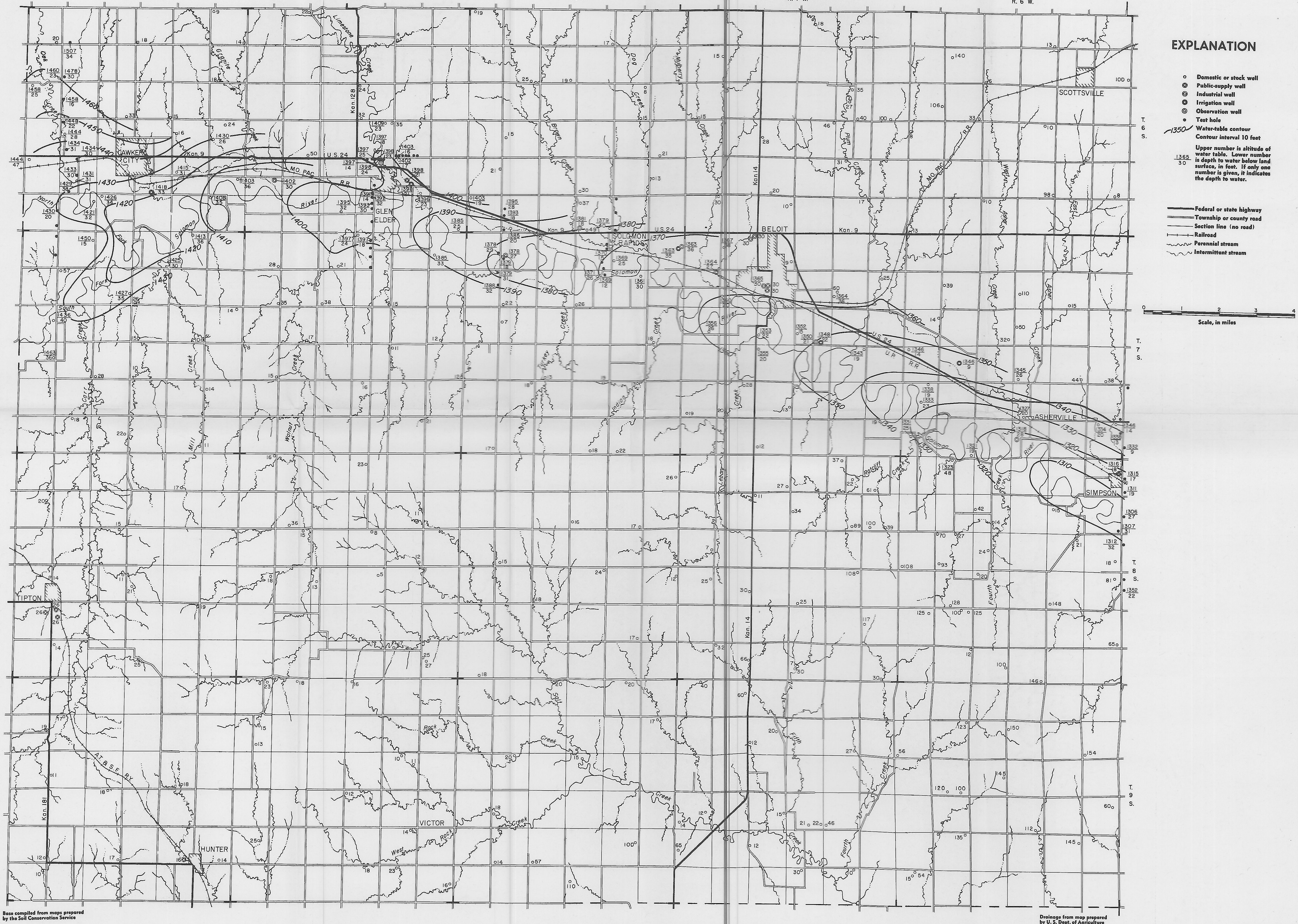
showing locations of wells and test holes, depth to water, and water-table contours in Solomon River Valley

By Warren G. Hodson

1955

State Geological Survey of Kansas

Bulletin 140
Plate 3



Base compiled from maps prepared by the Soil Conservation Service

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