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BULLETIN 45

GEOLOGY AND GROUND-WATER RESOURCES OF MEADE COUNTY, KANSAS

By JOHN C. FRYE

with analyses by

ROBERT H. HESS *and* ELZA O. HOLMES

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GEOLOGY AND GROUND-WATER RESOURCES OF MEADE COUNTY, KANSAS

By John C. Frye

ABSTRACT

This report describes the geography, geology, and ground-water resources of Meade county, southwestern Kansas. Many previously published geologic reports, particularly those by Cragin, Haworth, Johnson, Hibbard, and Smith, were freely used in the preparation of this report. The hydrologic information was obtained in the field in 1939 and 1940, chiefly by interviewing well drillers and owners of private and public-supply wells; measuring water levels, discharges, or both in 354 wells; and the drilling of 24 test holes by a portable hydraulic-rotary drilling machine owned by the State and Federal Geological Surveys. Considerable time in the field was devoted to a study of the water-bearing formations, particularly the Pliocene and Pleistocene deposits, which are the most productive sources of ground water in the county.

The county lies in the High Plains and Plains Border sections of the Great Plains physiographic province. The total relief in Meade county is about 700 feet. The county is drained by the Cimarron river and two tributaries—Crooked and Sand creeks.

The rocks underlying the county consist of Permian redbeds; Cretaceous sandstone and shale, which do not crop out in the county; the Laverne formation, lower Pliocene and possibly upper Miocene, consisting of shale, sandstone and limestone; the Ogallala formation, middle and upper Pliocene, consisting of sand, gravel, silt and caliche; and two Quaternary formations, which immediately underlie the surface of much of the county, the Pleistocene Meade formation, consisting of sand, gravel, silt, clay, volcanic ash and caliche, and the Kingsdown silt of Pleistocene and Recent age. Locally, sand dunes cover the surface of the uplands, and the major valleys contain shallow fills of alluvium.

Unconfined ground water of good quality occurs under nearly all of Meade county. The depth below the surface to the water table ranges from less than one foot to slightly more than 220 feet.

Of particular interest is the confined, or artesian water, that has been obtained within a considerable area both north and south of the city of Meade. Most of the artesian water is obtained from the Pliocene deposits, but some of it comes from the Pleistocene beds. Development of the artesian water in this area was started in 1886, and in 1938 approximately 3,860 acre-feet of water was produced from wells by pumping and natural flow from the artesian aquifers of the area. In addition, about 3,240 acre-feet of water was discharged by large springs in 1938. The head of the artesian water in wells has declined only a few feet since the first well was drilled, and the increased discharge from flowing wells has been about equal to the decrease in spring discharge. The shallow nonartesian water is derived partly from upward leakage of

artesian water. The water table has been depressed considerably during the last fifty years. The perennial yield obtainable from the artesian water-bearing beds without decreasing the head is about equal to the total annual discharge at the present time, that is, about 7,100 acre-feet annually, of which 3,860 acre-feet is derived from wells and 3,240 acre-feet from springs. A considerable quantity of artesian water is lost by leakage into the overlying body of shallow ground water. It is estimated that under conditions of general pumping throughout the basin sufficient to lower the head enough to stop all surface flow and underground leakage, an annual yield of about 10,000 acre-feet could be obtained from wells. Under such conditions, however, the main source of recharge to the shallow water reservoir would be destroyed and serious consequences to naturally subirrigated crops might result.

The analyses of 48 samples of ground water are given, together with a discussion of the principal chemical constituents in relation to the use and geologic occurrence of the water. Most of the ground waters in the county are satisfactory for ordinary purposes, but some are sufficiently hard as to require softening for some purposes.

Tabulated records of 354 typical water wells in all parts of the county, and logs of the 24 test holes drilled in the county by the State and Federal Geological Surveys are given.

INTRODUCTION

Purpose and scope of the investigation.—An extensive program of ground-water investigations in the western part of Kansas was initiated in 1937 by the State Geological Survey of Kansas and the Geological Survey, United States Department of the Interior, in cooperation with the Division of Sanitation of the Kansas State Board of Health, and the Division of Water Resources of the Kansas State Board of Agriculture. The first studies were made in the "Equus Beds" area of McPherson, Harvey and Sedgwick counties (Lohman and Frye, 1940) and in Ford county (Lohman, 1938). In 1939 investigations were made in several western counties that contain either extensive existing or potential ground-water developments for irrigation or some other special hydrologic features. Meade county, and especially the Meade artesian basin, was selected for early investigation because of the many flowing artesian wells that for years have attracted attention to this county. This report presents the results of a study made during a part of the summers of 1939 and 1940 to determine the availability, quantity, and quality of ground water in Meade county.

The investigation was made under the general supervision of R. C. Moore and K. K. Landes, state geologists, and O. E. Meinzer, geologist in charge of the Division of Ground Water of the Federal Geological Survey, and under the immediate supervision of S. W. Lohman, federal geologist in charge of ground-water investigations in Kansas.

Ground water is one of the principal natural resources of Meade county, hence there is a definite need for an adequate understanding of the quantity and quality of the available supply and what measures are necessary to safeguard its continuance. All public, railroad, and domestic supplies, and most of the stock supplies of the county are obtained from wells. In addition, ground water is being used to some extent for irrigation and it is quite possible that this use will increase in the future. Although at the present rate of with-

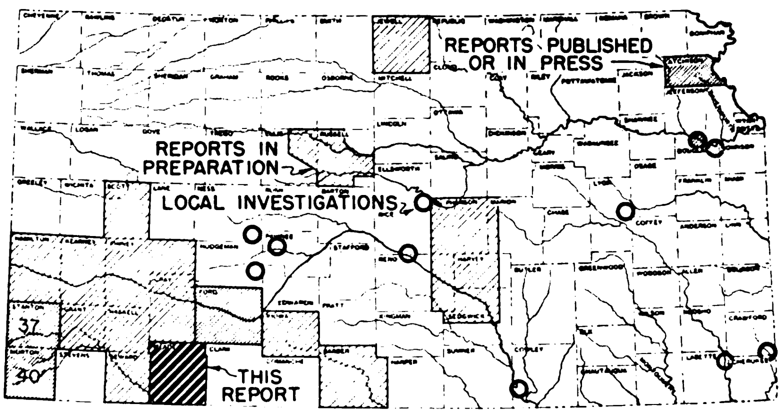

FIG. 1. Index map of Kansas. Area covered by this report and other areas for which coöperative ground-water reports have been published or are in preparation are shown.

drawal there appears to be little danger of seriously depleting the ground-water supply, the problem may become more acute as the number of large pumping plants increases.

Location and size of the area.—Meade county, in southwestern Kansas, is in the fourth tier of counties east from the Colorado state line and lies immediately north of Oklahoma, as shown in figure 1. It lies between meridians 100°4′ and 100°36′ west longitude and parallels 37°0′ and 37°29′ north latitude. It has an area of about 974 square miles, is nearly square, and extends 30 miles east and west and about 32.5 miles north and south.

Previous geologic and hydrologic work.—The geology and hydrology of Meade county, and particularly the Meade artesian basin, attracted considerable attention during the closing years of the last century. Cragin (1891, 1896, 1897), Haworth (1896, 1897, 1897a, 1897b), and Johnson (1901, 1902) carried on field studies in this area, described and named some of the Tertiary and Quaternary deposits, and discussed the physiography, structure and ground water of the county. Following the early work of these men a period of years elapsed during which little work was done on the geology or hydrology of this part of the state. Two publications touching briefly on the hydrology of the area belong to this period, however—a water-supply paper by Parker (1911), and a report on well waters in Kansas by Haworth (1913).

During the last few years interest has been revived in the geology, vertebrate fossils, and ground water of the area. Hibbard (1938, 1939, 1939a, 1940, 1941, 1941a) spent the seasons of 1937 to 1941 collecting and studying vertebrate fossils of Meade county. Smith (1940) made a reconnaissance of the Cenozoic geology of southwestern Kansas, in which he placed considerable emphasis on this area. A preliminary report on the ground-water resources of the Meade artesian basin has been published (Frye, 1940), and Frye and Hibbard (1941) have summarized the stratigraphy and paleontology of the area.

Methods of investigation.—The months of July, August and September, 1939, and the same months in 1940 were spent by me in Meade county collecting data for this report. During this time 354 wells were visited and the depth to water level or head and flow were measured. All measurements of the depth to water level were made with a steel tape from a fixed measuring point at the top of the well. The methods used in determining artesian pressures, or heads and flows, are described in a later section. Information regarding the nature and thickness of the water-bearing material, yield of the wells, and the use and general character of the water was obtained from many residents of the county. Samples of water were collected from 45 wells and chemical analyses of them were made by Robert H. Hess and Elza O. Holmes, chemists, in the Water and Sewage Laboratory of the Kansas State Board of Health.

Four test holes in 1939 and 20 test holes in 1940 were drilled by Ellis D. Gordon, Perry McNally, Fred T. Holden (1939 only), and Laurence P. Buck (1940 only), using a portable hydraulic-rotary drilling machine owned by the State and Federal Geological Surveys. The altitude of the land surface at the sites of the test holes and the altitude of the measuring points of about half of the wells visited were determined by Pierson Lyon, F. S. Bradshaw and assistants, through a coöperative arrangement with the Topographic Branch of the Federal Geological Survey.

The geology of the county was studied by me in conjunction with C. W. Hibbard, S. L. Schoff, Frank Byrne and H. T. U. Smith, and a geologic map of the county (Pl. 1) was prepared. Logs and samples obtained from the test holes supplemented surface studies and supplied invaluable data as to the subsurface character, thickness and extent of the deposits.

A map of the county compiled by the State Highway Department was used as a base map in preparing plates 1 and 2. The drainage was corrected from aerial photographs obtained from the United States Department of Agriculture, Agricultural Adjustment Administration.

Acknowledgments.—Thanks and appreciation are expressed to the many residents of Meade county who supplied information and aided in the collection of field data. Special thanks are due to William Sourbeer, who drilled many of the early wells in the artesian basin and who supplied much of the historical data for this report, and to J. E. McCohn, formerly county agent, and R. S. Kirk, formerly county engineer, for their helpful advice. George S. Knapp, chief engineer of the Division of Water Resources, Kansas State Board of Agriculture, supplied measurements of artesian pressure made under his supervision in this area in 1923. These data have proven to be of much value. Thanks are also extended to Claude W. Hibbard and H. T. U. Smith, of the University of Kansas, and the several members of the Federal and State Geological Surveys who have offered valuable suggestions and criticisms.

The manuscript for this report has been critically reviewed by S. W. Lohman, O. E. Meinzer, and W. D. Collins of the Federal Geological Survey; R. C. Moore, state geologist, and Thomas Payne, editor, State Geological Survey of Kansas; George S. Knapp, chief engineer of the Division of Water Resources of the Kansas State Board of Agriculture; and Lewis Young, acting director of the Division of Sanitation of the Kansas State Board of Health. The illustrations were drawn by G. W. Reimer.

GEOGRAPHY

Relief

Meade county lies partly within the High Plains section and partly within the Plains Border section of the Great Plains physiographic province, the boundary line, as designated by Fenneman (1931), passing across the county from north to south, west of Crooked creek valley. The topography of the western and northwestern parts of the county, which are in the High Plains section, is quite flat and featureless. Low sand dunes occur on the surface along the Seward county line north of the Cimarron valley. The eastern and southeastern parts of the county, which are in the Plains Border section, are relatively rough and locally present steep slopes. Isolated areas of flat upland and areas of upland sand dunes also occur in this part of the county, however. The lowest point in the county occurs where the valley of Crooked creek crosses the Kansas-Oklahoma state line. The valley floor at this point is at an altitude of about 2,100 feet. The High Plains in the northwestern part of the county rise to an altitude of nearly 2,800 feet and include the highest point in the county. The total relief of the area, therefore, is about 700 feet. The greatest local relief, 250 feet, occurs along the south side of the Cimarron valley in the southwestern corner of the county, and also along Crooked creek valley in the southeastern part of the county.

The topography is to a certain extent a reflection of the underlying deposits. The flat High Plains are underlain chiefly by the Kingsdown silt, and the steep sided canyons are cut in the relatively resistant beds of the Ogallala formation and in Permian rocks.

Drainage

All of Meade county is drained by the Cimarron river and its tributaries. Most of this area is drained by Crooked creek, which enters the north-central part of the county, flows eastward along the north side, and in a wide swing leaves and reënters the county in the northeastern corner. From that point it flows south-southwest across the central part of the county, but about 6 miles from the state line it swings sharply to the southeast and joins the Cimarron in Beaver county, Oklahoma, south of the southeastern corner of Meade county. Sand creek, which with its tributaries drains east-central Meade county, joins the Cimarron in southern Clark county.

The gradient of the Cimarron river, for the distance it flows across this area, is approximately 10 feet to the mile. For reasons given under Geologic history, the gradient of Crooked creek differs in three segments of its course through the county as follows: upstream from Fowler it is 5 feet to the mile, from Fowler to Meade it is 3 feet to the mile, and downstream from Meade it is 8 feet to the mile. The gradient of Crooked creek across northern and central Meade county is shown in figure 2.

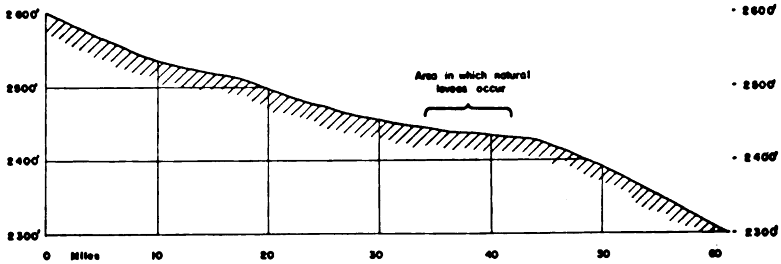

FIG. 2. Gradient of Crooked creek across northern and central Meade county. Altitudes based on topographic map of the Meade quadrangle.

CLIMATE

This county lies in a region only moderately well supplied with rainfall, but well supplied with sunshine. About 75 percent of the annual precipitation falls in the six-month period from April through September, when the moisture is most needed. The average precipitation for this six-month period in this part of Kansas is approximately the same as that in the Dakotas and three-fourths of the average for Illinois, Indiana and Ohio. The normal annual precipitation at Plains, the one Weather Bureau station maintained in the county, is 20.36 inches, but the average annual precipitation for the 31-year period of record is 18.43 inches. The wettest year of record, as shown in figure 3, was 1915, when 31.62 inches fell at Plains. The driest year of record was 1910, when only 9.35 inches fell. January is the driest month and June the wettest month of the year.

The average annual snowfall is about 17 inches. As a rule the ground is not covered with snow for more than a few days at a time, even in midwinter, on account of the melting effects of sunshine and drying winds.

The annual precipitation at Plains since the beginning of the period of record, cumulative departure from normal precipitation, and cumulative departure from average precipitation, are shown in figure 3.

It is to be noted that the graphs showing the cumulative departures from normal and average precipitation show a roughly rythmic, or cyclic, repetition of periods of excess and deficient precipitation. Although graphs B and C in general are similar in shape, graph B shows an extreme cumulative departure below normal at the end of 1940, whereas graph C shows that there is no cumulative departure from the average precipitation by the end of 1940. This apparent discrepancy results from the fact that the normal selected by the

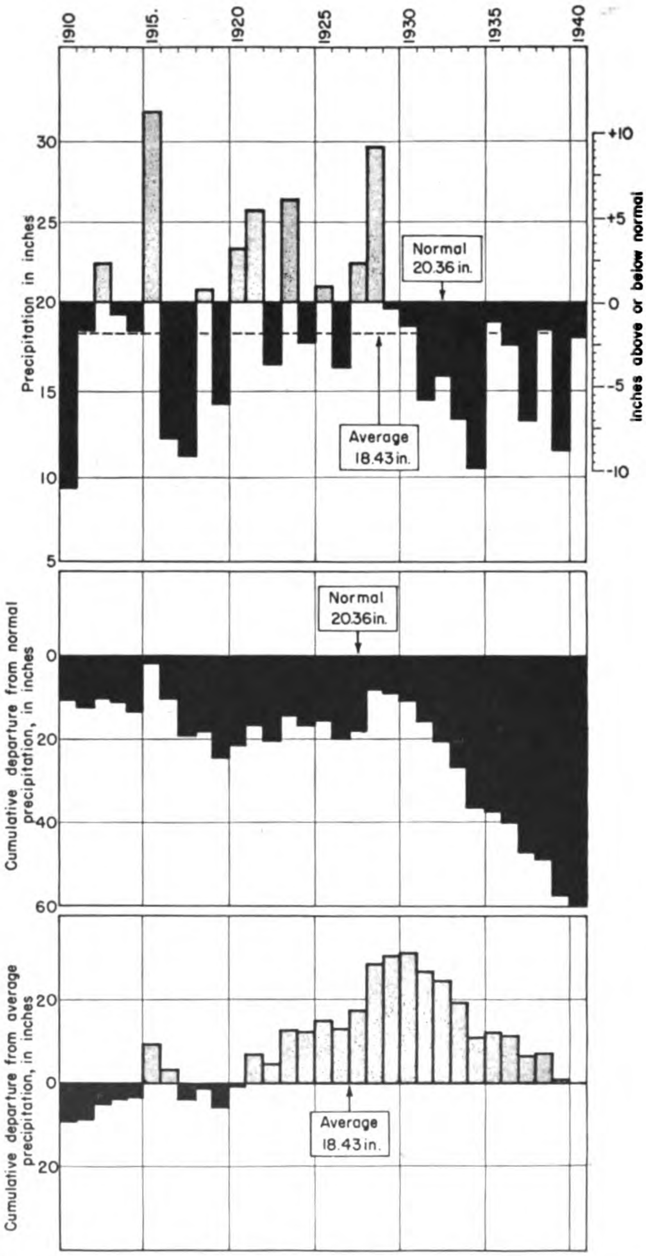

FIG. 3. Precipitation at Plains, Meade county. A, Annual departure from normal precipitation at Plains; B, Cumulative departure from normal precipitation at Plains; C, Cumulative departure from the average precipitation during the 31 years of record at Plains.

Weather Bureau is 1.93 inches more than the actual average annual precipitation during the period of record.

This area is subject to heated periods during the summer and severe drops in temperature during the winter. The average annual temperature is about 56° F. Temperature data are not available for any station in Meade county; hence, the extremes of temperature cannot be given.

Population

According to the 1940 census the population of Meade county was 5,522; an average of about 5.7 inhabitants to the square mile, as against 21.9 for the entire state. Meade, the county seat and largest city in the county, had a population of 1,400 in 1940. Two other cities in the county, Plains (or West Plains) and Fowler, had populations in 1940 of 619 and 563, respectively.

Transportation

The county is crossed by the main line of the Chicago, Rock Island and Pacific Railroad from Chicago to Tucumcari, New Mexico, which traverses the northern part of the county through Fowler, Meade and Plains. The area is covered by a network of modern highways and improved secondary roads. The most heavily traveled highways are U. S. Route 54 through Fowler, Meade and Plains; U. S. Route 160 through Meade and Plains; and Kansas Route 23, which crosses the county from north to south through Meade. The remainder of the county is served by numerous improved county and township roads (pl. 1).

Agriculture

On the basis of agriculture and land utilization Meade county can be divided roughly into three rather distinct areas, or groups of areas, namely: (1) the High Plains area, in the western and northwestern parts of the county, and also some flat upland areas southeast of Meade; (2) broken and dissected areas along the valleys of Cimarron river, Sand creek and Crooked creek, and parts of the areas of sand dunes that are too rugged or too thinly mantled by soil to plow; and (3) the artesian-basin area, and adjacent parts of Crooked creek valley. In any discussion of the agriculture of the county these three divisions must be considered separately because of the considerable variation in conditions existing in each.

In the High Plains part of the county there occurs a nearly unbroken flat surface, which prior to cultivation was covered with a

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continuous blanket of short grass. The water table lies deep beneath this part of the county, in most places more than 100 feet below the surface.

In the broken and dissected areas and in the rugged areas of sand dunes the land is not suitable to cultivation, the native vegetation is quite diverse, and the depth to water level ranges from a few feet to more than 100 feet below the surface. The surface of the artesian basin area is mainly gently rolling to flat, and, although part of this area was originally covered by short grass, some of it supported (and still does) a more luxuriant growth suitable for cutting as prairie hay. Shallow ground water occurs under most of this area and deeper drilling produces flowing artesian wells or artesian wells in which the water rises to within a few feet of the surface.

Prior to the 1880's the entire region had been devoted to stock raising, but during the later part of the nineteenth century there occurred a rapid immigration of farmers. Johnson (1901, p. 681) describes this immigration into the High Plains as follows:

> The movement of settlers into the High Plains was an inroad. The only population there at the time consisted of a few stockmen making common use of the public range. The newcomers were farmers and town builders . . . The farmer's aim heretofore had been agriculture by irrigation along the stream bottoms; the interstream areas were in any case left in his (stockman's) possession undisturbed. But in this case irrigation was not in contemplation; the interstream areas, not the valleys, were invaded, and in some parts of the High Plains, notably western Kansas, the stockmen were completely dispossessed.

This rapid settlement of the High Plains region by farmers probably was precipitated by several wet years and the resulting good crops at the beginning of this period. Before the turn of the century, however, the wet weather gave way to a succession of dry years, and by 1900 the immigration had not only ceased, but there was an exodus of settlers to other regions.

The collapse of this early experiment in wheat farming on the High Plains was almost complete. Johnson (1901, p. 690) in 1900, painted a vivid word picture of the visible evidence of this failure:

> An idea of the magnitude of the scale on which the attempt to farm the High Plains was made, especially in Western Kansas, as well as the great aggregate losses that must have resulted from this attempt, is strikingly to be had from the frequent spectacle of abandoned towns systematically spaced upon the flat uplands in anticipation of a dense but uniform farming population, for which they were to have been points of supply . . . The rectangular subdivision system of the Land Office is indicated almost universally by plowed roadways, blocking out square mile sections, within which the old plowed fields, amounting in the total to millions of acres, are slowly return-

ing to grass, while occasional leaning fence posts, with dangling strands of barbed wire, mark the former lines of many thousand miles of fencing.

Johnson's discussion applies to the High Plains and probably can be considered a good description for the High Plains part of Meade county, particularly as his field headquarters were at the city of Meade.

From 1900 to 1917 little wheat farming was attempted on the High Plains. The shallow ground water in the artesian basin, however, was particularly suitable to alfalfa, and the acreage of that crop increased. Because of the development of the tractor and other modern farming equipment, together with the unusually high prices that were paid for farm products during the first World War, many acres in the High Plains and artesian basin again were planted to wheat during the period from 1917 to 1920, and almost no grazing land was left except in the areas of broken topography and rugged sand dunes. The results might have been a repetition of the earlier farming experiment had it not been for the above normal precipitation and improved methods of dry farming that produced several large crops in the decade between 1920 and 1930.

Beginning in 1930 there followed another severe drought, and crop acreage was again reduced. In an attempt to compensate for this deficiency in rainfall several farmers constructed irrigation wells; also, water from existing flowing wells in the artesian basin was used to irrigate small acreages of crops. This latter procedure is one that could be used to a much greater extent in some parts of the artesian basin without great expense, merely by utilizing water for irrigation that now flows to waste.

At the time of writing (1941) the precipitation has again gone above normal, and this, coupled with generally rising prices, may produce a repetition of conditions that existed from 1917 to 1920.

Of the total land area of the county in 1939, 89.9 percent, or 561,675 acres, was classified as farm land, as against 91.7 percent for the entire state. The average size of the 750 farms was 748.9 acres. The principal crops or usage of farmed land in 1939 in percentage of the total farmed acreage were as follows:

TABLE 1.—*Crops or usage of land in Meade county in 1939, in percentage of total farmed acreage.*

Miscellaneous crops, fallow land, and unplowable pasture	52
Wheat	25
Plowable pasture	19
Sorghum	3
Hay	1

TABLE 2.—*General section of the geologic formations in Meade county, Kansas*

System	Series	Subdivision	Thickness (feet)	Local faunas and floras	Character	Water supply
Quaternary	Recent and Pleistocene	Dune sand	0–50		Well sorted eolian sand.	Occurs entirely above the water table, hence it yields no water to wells.
		—unconformable on older formations—				
		Alluvium and terrace deposits	0–80	*Bison bison*, deer, domesticated animals, and snail fauna	Gravel, sand, silt and clay. Some peaty zones occur in the "Englewood terrace beds" and some very coarse gravel occurs along the Cimarron river.	Locally yields small supplies of water of variable quality.
		—unconformable on older formations—				
		Kingsdown silt	10–45	*Bison bison*	Silt and fine sand, contains nodules and bands of caliche.	Where saturated yields small supplies of water of fair quality.
		—Disconformity—				
	Pleistocene	Meade formation	50–150	Jones fauna, Cragin quarry fauna, Borchers fauna, and snail faunas	Gravel, sand, silt and clay, contains beds and nodules of caliche. Locally contains volcanic ash and cemented zones of sand.	Yield abundant supplies of water of good quality. Supply water to flowing artesion wells.
		—Disconformity—				
Tertiary	Upper and middle Pliocene	Ogallala formation: Rexroad member	50–250	Rexroad fauna, and snail faunas	Sand, silt and clay, contains nodules and beds of caliche. Locally peat occurs near the top	
		—Local disconformity—				
		Ogallala formation	10–125	*Biorbia fossilia* plant remains	Gravel, sandy silt and caliche. Coarse gravel occurs at base and hard silicious limestone at top.	
		—Nonconformity—				
	Lower Pliocene and upper Miocene (?)	Laverne formation	60+	Ostracode fauna, diatom flora, and fragmentary plant remains	Shale, sandstone, limestone and calcareous siltstone, locally contains a hard conglomerate.	Locally are potential sources of water supply, but are practically unexploited owing to their considerable depth.
		—Nonconformity—				
Cretaceous		Cheyenne-Kiowa-Dakota* formations (Known only from test holes)	0–300 ±		Shale, siltstone and sandstone.	
		—Nonconformity—				
Permian	Guadalupian*	Taloga formation* (and part of the underlying Whitehorse group*	100+		Siltstone, shale and sandstone, red, and a few gray beds.	Yields small supplies of hard water.

* Classification of the State Geological Survey of Kansas.

Natural Resources and Industries

The production and treatment of volcanic ash constitutes one of the most important natural resources and industries of the county. In 1940 ash was being produced from several large pits both north and south of Meade, and in the past ash has been produced from many smaller pits in different parts of the county. The volcanic ash occurs in the Meade formation of Pleistocene age.

Sand and gravel are produced from the Ogallala formation along Crooked creek, south of Meade; from the Meade formation at several localities west of the city of Meade; and from terrace deposits along the Cimarron valley.

A rich and fertile soil covers much of the county and makes possible widespread agriculture, and in those areas which have not been cultivated it supports various types of pasture grasses and native hay.

Another important natural resource of the area, with which the remainder of this report is concerned, is ground water.

GEOLOGY

Summary of Stratigraphy

The rocks that crop out in Meade county are all of sedimenntary origin and range in age from Permian to Recent. The oldest rocks exposed in the county are of Permian age and comprise the Taloga formation and part of the underlying Whitehorse group as classified by the State Geological Survey of Kansas. Cretaceous rocks are known from test holes but do not crop out at the surface. Two Tertiary formations, the Laverne (Miocene ? and Pliocene) and the Ogallala (Pliocene), and two Quarternary formations, the Meade (Pleistocene) and the Kingsdown silt (Pleistocene and Recent), crop out in the county. There are also younger terrace deposits, alluvium and dune sand. The Tertiary and Quarternary formations have been described in an earlier report (Frye and Hibbard, 1941) and in the present report the discussion of these rocks is taken in part from that paper.

The outcrops of the formations are shown in plate 1 and a generalized section of the geologic formations of Meade county is given in table 2.

Geologic History and Geomorphology

PALEOZOIC ERA

Paleozoic rocks older than the Permian are nowhere exposed in this area. It is known from wells and test holes in adjacent areas, however, that a considerable thickness of older Paleozoic sedimentary rocks underlies the Permian and, in turn, probably rests upon still older pre-Cambrian rocks.

The history of the area during the Paleozoic era was largely one of deposition in shallow seas interrupted from time to time by periods of erosion. Conditions of sedimentation were not entirely uniform during the Paleozoic, however, as there were many variations in the environment and the types of sediment that accumulated on the sea bottom. In Permian time beds of a continental type were deposited alternately with marine sediments. The shallow inland sea no longer had such free access to the open ocean, and at times may have been cut off from it completely. During this same time the climate of western Kansas appears to have been somewhat more arid than it is at the present time so that evaporation from these isolated inland seas probably exceeded the supply of water from the ocean and from streams. Under such conditions beds of salt and gypsum were formed during the Permian period.

This transition from a marine to a continental environment continued during the Permian period, and continental deposition became predominant near the end of the Permian time, forming the redbeds that crop out in Meade county. By the close of the Paleozoic the seas had completely disappeared; the streams had largely ceased depositing and were eroding the land surface.

MESOZOIC ERA

Early in the Mesozoic era the Paleozoic rocks of this region were uplifted somewhat, and the streams eroded the surface of the Permian rocks during a large part of the Mesozoic era. Before the next extensive deposition occurred the surface had been reduced by subareal erosion to an uneven surface having a relief of only a few hundred feet or less.

During the Cretaceous period, late in the Mesozoic era, the sea invaded this part of Kansas for the last time. The deposition of the sediments comprising the Cheyenne sandstone was initiated on the land surface as the strand line of an advancing sea encroached farther and farther northward. The sea advanced until it completely covered this area, and marine sand, shale and siltstone, comprising the Kiowa shale, were deposited. The sea then retreated to the south and these beds were overlain by deposits of a continental type. These beds do not crop out in the county but have been encountered in test drilling. It is known that in adjacent areas the sea again advanced in late Cretaceous time and sediments were deposited above the Dakota formation. Although none of these rocks have been recognized in test holes in Meade county, it is quite possible that they were spread over this area and were removed by early Teritiary erosion. It is possible, however, that all or part of this area stood out as an island during that time and so received no late Cretaceous deposits.

CENOZOIC ERA

Tertiary Period

Early Tertiary erosion.—The Teritary history of Meade county was initiated by an extensive period of erosion. The total thickness of Cretaceous rocks removed during this period of erosion is not known because it is impossible to determine the original thickness of those rocks in this area. It is known that all of the Cretaceous rocks, and some of the underlying Permian rocks, in the southeastern part of the county were removed. During this extensive interval deposits of Paleocene, Eocene, Oligocene and Miocene age were accumulating elsewhere in western North America.

Late Tertiary deposition.—The earliest Tertiary deposits that have been recognized in this area were laid down during earliest Pliocene and possibly late Miocene time in southwestern Meade county. These deposits, which comprise the Laverne formation (Gould and Lonsdale, 1926, and Frye and Hibbard, 1941), probably were trapped in part in small lakes and on the flood plains of streams. After their deposition and prior to the deposition of the overlying beds of the Ogallala formation these strata were somewhat folded. Whether this folding was due entirely to deep-seated diastrophism or was controlled wholly or partly by solution of the underlying Permian beds followed by differential subsidence of these surficial beds is not known. Following the folding of the strata comprising the Laverne formation, erosion leveled these beds to an irregular surface.

This interval of erosion was followed, during middle Pliocene time, by deposition from aggrading and laterally shifting streams, of the sediments comprising the Ogallala formation. The middle Pliocene part of this formation consists of channel and flood plain deposits

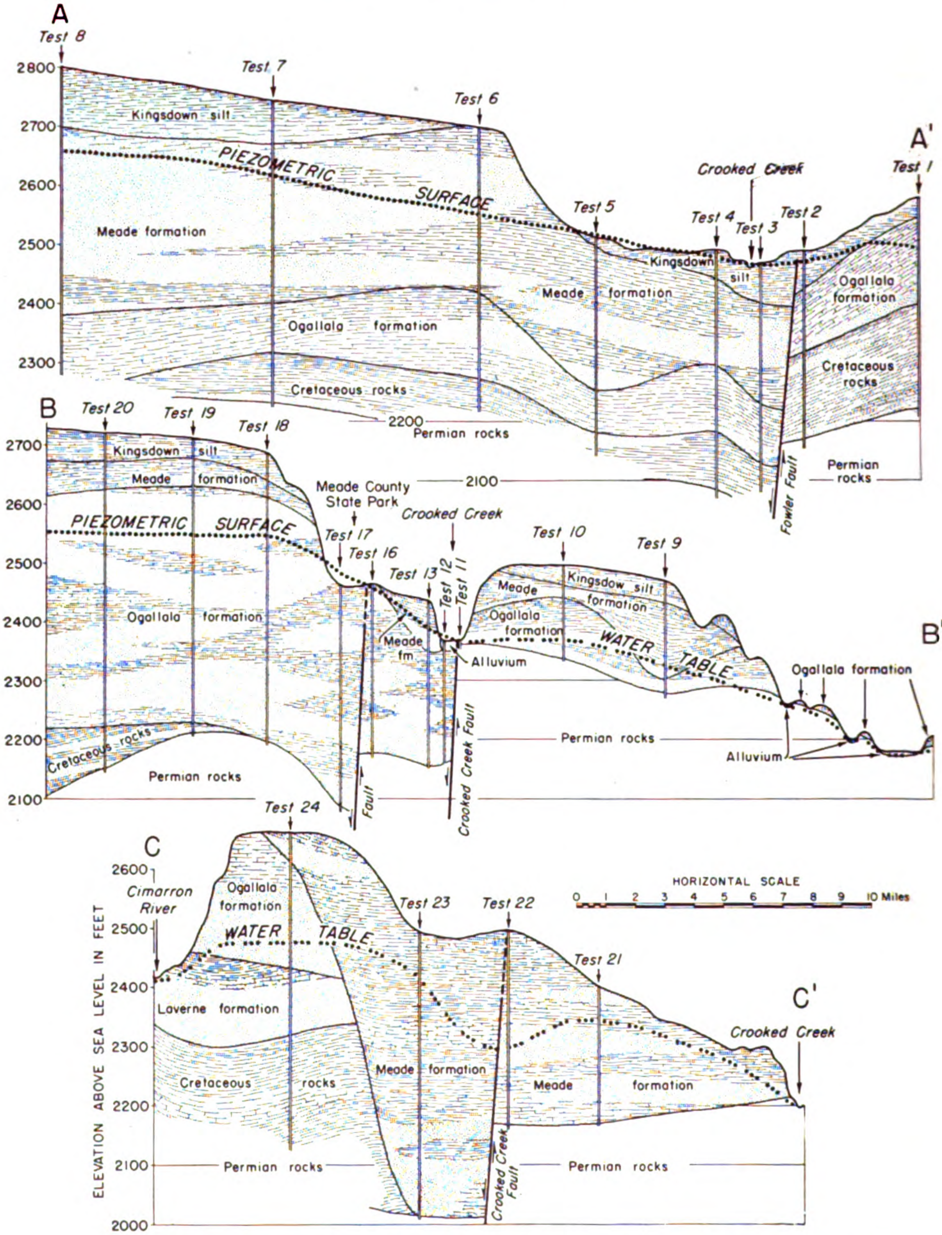

FIG. 4. East-west sections across the Meade basin. A, From the Seward county line to the Clark county line, along the township line at the north edge of the city of Fowler; B, From the Seward county line to the Clark county line through Meade county State Park; C, From the Seward county line to Crooked creek, 3½ miles north of the Oklahoma state line. Locations are shown in plate 1.

that range from moderately well sorted sand and gravel to poorly sorted sandy silt. These deposits were spread over the surface of all, or most of Meade county, and, owing to the iregularities of the preëxisting surface, the thickness ranges within wide limits. At the close of the middle Pliocene the upper surface of these deposits constituted a relatively flat, featureless plain. On or below this surface was developed a widespread bed of caliche that marks the top of the middle Pliocene.

From the close of the middle Pliocene to the present the history of the Meade basin has been somewhat anomalous with respect to the High Plains areas adjacent on the west and north. Earlier workers in this area have disagreed as to the factors that controlled sedimentation in this area during late Pliocene and Pleistocene times. Haworth (1897, pp. 22, 23) believed faulting alone to be the controlling factor, whereas Johnson (1901, pp. 712-732) believed that solution of salt in the underlying Permian rocks, which caused collapse or subsidence of the overlying deposits, was the only process involved in the production of the basin. It seems probable that the structure and topography of this area have been controlled by several factors, of which faulting and deep-seated solution have played almost equally important roles.

The first recognizable faulting in the basin followed immediately after the close of middle Pliocene sedimentation. The interpretation of the faults and stratigraphy, based upon test-hole and surface data, is shown in three east-west sections across the basin (fig. 4). Section A-A′ is taken along the north edge of Fowler, section B-B′ extends through Meade county State Park, and section C-C′ extends between the valleys of Cimarron river and Crooked creek, in south-central Meade county.

A short period of erosion may have intervened between middle and late Pliocene sedimentation, but it is probable that, in part of the basin, beds representing the Rexroad member were deposited conformably upon the middle Pliocene beds of the Ogallala formation. It is possible that some solution of salt and gypsum beds in the underlying Permian rocks deepened the structural trough or produced a series of basins along this zone of faulting, as it is certain that the development of sink holes east of the major faults started about this time. Seemingly, it was this topographic anomaly that allowed the accumulation of the thick sequence of upper Pliocene beds in this area, for in adjacent areas equivalent beds are thin or absent.

The location of the master streams at the close of the middle Pliocene and during the late Pliocene is not known with certainty, but it seems probable that during at least part of this time some sediment from the Rocky Mountain region, in addition to material eroded from the older Tertiary deposits immediately adjacent to the west, was carried into this trough. Most of this material was deposited by streams, but the character of some of the beds suggests ponded water conditions, and the presence of peat seems to imply the existence of small swamps or bogs during a part of this time.

Quaternary period

The close of the Pliocene epoch was marked by renewed movement along the major faults of the area. This warping locally changed stream gradients and deepened the structural-solutional trough, which previously had been nearly filled, and sedimentation was resumed. Over most of the basin the basal Pleistocene sand and gravel was deposited on the slightly eroded surface of the upper Pliocene beds. That part of the basal Pleistocene deposits probably were transported into this area by through-flowing streams from the west seems to be indicated by the fact that the gravels are coarser and contain a much larger percentage of igneous rocks types than those in the Tertiary sediments in adjacent areas that were subject to erosion at that time (Frye and Hibbard, 1941). The early Pleistocene deposits, consisting of sand, gravel, silt, clay, and volcanic ash, completely filled the major basin and spread over the adjacent area east of the Crooked creek fault. During this same time deposits of local origin were accumulating in sink holes east of the Meade basin. Following this extensive early Pleistocene deposition was a period in which the streams flowing across this area were nearly in equilibrium and left only scattered channel fillings and deposits trapped in sinks. All of these early Pleistocene deposits make up the Meade formation.

During the late Pleistocene, streams flowing at the upland level again began aggrading, filled their channels with fine sand, and spread fine sand and silt over their flood plains. These sediments, which comprise in part the Kingsdown silt, now occur widely distributed over the uplands in Meade county. Since the deposition of the water-laid part of the Kingsdown silt the history of this area has been dominated by erosion. The present streams have cut their valleys, terrace deposits were laid down and partly removed, and eolian activity has given rise to sand dunes and widespread loess.

In some localities on the uplands the water-laid and laminated silts of the Kingsdown grade without break upward into loess, which is considered the uppermost part of the Kingsdown silt, thus indicating that, locally, eolian deposition started almost immediately after the high level streams started incising their valleys.

Development of sink holes.—Extensive development of sink holes east of the major fault and on the upthrow side started in the late Pliocene and reached a climax during the Pleistocene (Frye and Schoff, 1942). Sink holes played a major role in the physiographic development of this area during the Quaternary period. It seems desirable, for a better understanding of these features, their contained deposits, and their effect upon the ground-water conditions, to consider in some detail their origin and present surface expression.

It is certain that extensive development of sink holes did not start until late Pliocene time, for at many localities middle Pliocene deposits are exposed along the sides of the sinks and extend around them with no apparent thickening. Due to the fact that the shallowest soluble beds, of sufficient thickness to give rise to these sink holes, are known to occur in the Permian rocks several hundred feet below the present water table, a special type of deep-seated circulation of ground water is required to account for these solutional phenomena. The restriction of the sink holes to the upper Pliocene, Pleistocene and Recent is probably due to the fact that this deep-seated circulation of ground water through the soluble beds was not possible until after the faulting had disturbed the Permian strata and opened passageways for ground-water circulation.

Surface expression of these sinks must have been attained by the collapse or subsidence of the surficial deposit in places where some of the underlying beds have been removed by solution. It is probably true that in some places the surface has subsided slowly for a considerable time; however, the fact that in other places the surface has dropped as rapidly as a collapse is demonstrated by the "Meade salt sink." In March, 1879, a small sink hole formed quite suddenly about 1.5 miles south of Meade (Johnson, 1901, pp. 706, 707). This sink, which is on the eastern side of Crooked creek, on or just east of the major fault, has been referred to as the "Meade salt sink" or "Meade salt well" because, just after its formation, salt water rose in the sink hole to a level within 14 feet of the surface. The water in the sink at the present time is fresh, as indicated by the analysis given in table 7.

Although this sink hole is of small extent, it indicates that solu-

PLATE 3. Meade "salt sink." Sink hole located 1½ miles south of Meade. Photograph made in 1898 or 1899 by W. D. Johnson.

tion of the underlying salt has not entirely ceased, and gives a clue as to the development of sink holes in the past. In the rapid-collapse type of sink, typified by the "Meade salt sink," the walls initially are quite steep, but the steep sides are attacked almost immediately by erosion, and minor gulleys soon develop. As this process proceeds the areal extent of the surface depression increases, the side slopes become more gentle, and the hole gradually is filled. Three photographs that show this progressive development are reproduced in plates 3 and 4. Plate 3 is a view of the "Meade salt sink" taken by W. D. Johnson (1901, pl. 137-B) in 1898 or 1899, and plate 4A is a view of the same sink taken in 1939 from approximately the same point. The modification of the rim and the building of the small delta that have taken place during a period of 40 years are clearly shown. Plate 4B shows what is believed to be a later stage of development in a similar sink in the southeastern part of the county.

Only a few of the sink holes in Meade county are of the simple collapse type; most of them are more complex and comprise two or more sinks immediately adjacent or superimposed, and so the surface expression and contained deposits differ from the simple type. Such a concentration of sink-hole activity may occur in a roughly circular area so that the ultimate surface expression appears as a simple sink. In the complex type of sink, however, different parts of the floor have subsided at different times, at different rates, or both. Sinks of this type that have been dissected (illustrated by the dissected sink southwest of Nye, in Beaver county, Oklahoma) reveal a complex sequence of deposits that dip steeply in diverse directions and that exhibit little apparent continuity from one part of the sink to another. On the contrary, in large dissected sinks of the simple types, such as the sink on the Jones ranch about 8 miles southeast of Meade, the exposed beds dip only slightly; and, in general, there is a rough continuity of beds over much of the basin.

Compound sinks may be formed from several small sinks that have developed quite close together and have gone through their early stages of development independently of one another (Frye and Schoff, 1942). Erosion of the individual sinks ultimately merges them together to form an irregular depression, the floor of which is composed of small connected basins. There are no good examples of this type of sink in Meade county, but the Ashland and Englewood basins of Clark county (adjacent to Meade county on the east) appear to be large examples of this type of sink. Part of the valley

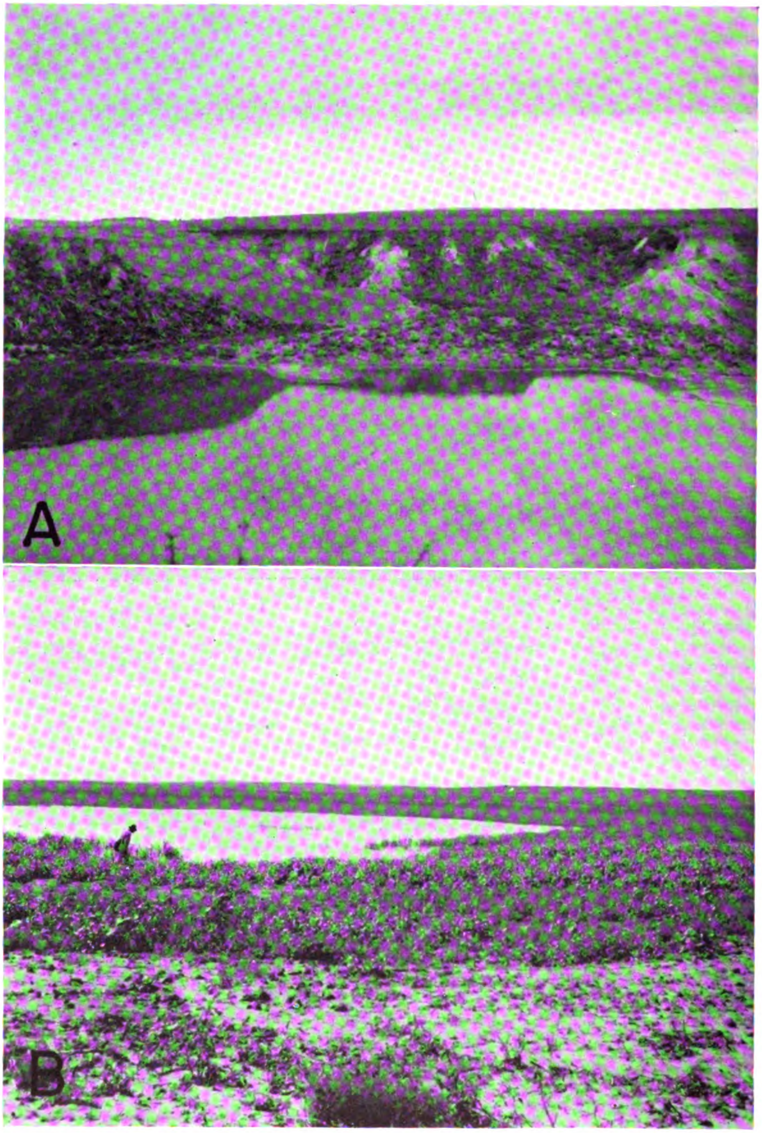

PLATE 4. Sink holes in Meade county. *A,* Meade "salt sink" as it appeared in 1939 (photograph taken from approximately the same angle as the one shown in plate 3). *B,* sink near Lakeland, NW sec. 30. T. 34 S., R. 26 W. (photograph taken August, 1940).

of Crooked creek, between south-central Meade county and the Oklahoma state line, may be considered a special type of compound sink. Through this part of its course Crooked creek follows a series of connected sink holes, now partly dissected, that were apparently captured progressively by the stream.

Meade lake.—After the close of Pleistocene time and the completion of the major solutional subsidence in the area northeast of Meade and west of Fowler, the Meade basin probably was occupied temporarily by a lake. The evidence indicating the existence of a late Pleistocene or early Recent lake in this basin is not conclusive but is strongly suggestive. The main points favoring the existence of such a lake are as follows: (1) The topographic basin had no outlet until the capture of the lower part of Crooked creek valley by a stream, sometime during the late Pleistocene or early Recent, and until that stream had incised its valley to a depth of 50 feet or more at a point near the city of Meade. As the beds in which the valley was cut are of Pleistocene age, the downcutting could not have taken place until very late in the Pleistocene or during the Recent. As shown in figure 2, there is a marked steepening of the gradient of Crooked creek below Meade; whereas, above Meade the profile is quite normal except for the unusual flatness of the segment from Meade to Fowler. (2) The floor of this basin is still subsiding somewhat as indicated by the anomalous position of ponds with respect to the position of the channel of Crooked creek (Frye, 1941). (3) The bluffs along the west side of the basin north of Meade are quite steep and present a profile similar to wave-cut cliffs in relatively nonresistant material. The bluffs bevel the edges of nearly horizontal strata, are at all points two miles or more west of Crooked creek, and are separated from that creek by a long sloping terrace. They bear little resemblance to stream-cut bluffs and cannot be explained by faulting, as test drilling failed to reveal the presence of a fault. (4) An area of sand dunes occurs along the east side of the basin and is best developed north of Fowler. Along the sloping western or basinward side of this dune area occur narrow elongate ridges of sand, now grass covered, that trend roughly parallel to the contours and are nearly symmetrical in cross section. In my opinion these sand ridges were formed as beach ridges along the northeast side of "Meade Lake," and the adjacent area of dunes is directly related to this ancient beach. (5) The outline of the basin suggests the former presence of a lake. Spurs that once projected

PLATE 5. Stream valleys in Meade county. *A*, Sand creek valley, northeast of Jones ranch. Pleistocene beds are exposed along the valley walls, and water-bearing alluvium occurs in the valley bottom. *B*, Natural levee built by a tributary of Crooked creek, about halfway between Meade and Fowler (photograph by H. T. U. Smith).

into the basin are rounded and the outlet of the basin is through a shraply constricted valley near Meade.

The Meade lake was drained when Crooked creek captured the basin at Meade, and, as stated earlier, this capture probably occurred in late Pleistocene or early Recent times. A permanent body of water probably existed in this basin for some time prior to its capture, despite the low rainfall and high rate of evaporation now prevailing in the area, partly because there probably was as large or larger contribution to the lake from ground-water discharge—which is now carried away by surface drainage—as from surface runoff.

Recent deposition.—The Recent history of Meade county has been dominantly one of erosion. In several areas, however, Recent stream deposits were laid down. Much of the floor of the Meade basin is underlain by Recent deposits brought in by Crooked creek and its tributaries. Many shallow depressions on the floor of this basin are being filled by stream-born sediments at the present time. Natural levees (Frye, 1940, p. 16; 1941) have been built by Crooked creek and its tributaries in part of the basin (see pl. 5B); and, as the channels of these streams have shifted laterally, parallel systems of levees have been built within a belt that locally reaches a mile in width.

Very thin alluvium of Recent age occurs along part of Crooked creek valley, south of Meade, and along the Cimarron valley. Alluvium (shown in pl. 5*A*) and low terrace deposits of Recent age occur along Sand creek and some of its tributaries and along some of the minor tributaries to Cimarron river. Sink-hole fillings of Recent age were laid down by minor streams that empty into isolated areas of subsidence.

Physiographic Divisions

Fenneman (1931, pl. 1) has drawn the boundary between the High Plains and the Plains Border sections of the Great Plains physiographic province diagonally north-northeast across Meade county. This division of the county into two parts physiographically—High Plains in the west and northwest and Plains Border in the east and southeast—appears to be very satisfactory. It is presumed that this boundary line is intended to coincide with a distinct break in slope that parallels Crooked creek, south of Meade, and lies several miles to the west of that stream. The part of the county that lies in the High Plains section is a flat, featureless plain, sloping toward the east and southeast, modified only by sand dunes, and, near the Oklahome line, deeply trenched by the valley of the Cimarron river. The part of the county in the Plains Border section includes, in addition to the Meade basin and Crooked creek valley, some undissected upland remnants, locally mantled by dune sand and pitted by sink holes, and a belt of dissected Permian rocks that marks the western edge of the Ashland and Englewood basins.

Smith (1940, pp. 140, 141) has described many physiographic divisions in southwestern Kansas, eight of which either enter or border Meade county. Some of Smith's divisions are based upon rather minute variations of topography and, since they have not been grouped into larger units, tend to obscure the major divisions. Of his upland units I fail to see any valid reason for distinguishing the Haskell area from the Cimarron Bend area. They are both upland areas of quite similar appearance and geologic history and are separated only by the Cimarron valley. The Cimarron valley lowland area, which consists only of the valley of the Cimarron river, does not seem to justify the use of a separate physiographic division. It is true that it is the only important valley in this part of the county, but it seems very doubtful whether valleys should be set aside as separate physiographic divisions distinct from the adjacent uplands. If this practice were followed in an area where many important tributaries entered the master stream it would approach an absurdity. For the foregoing reasons the Haskell and Cimarron bend upland areas, and the Cimarron valley lowland area are here considered minor divisions of the High Plains section.

In Meade county the Plains Border section includes five divisions described by Smith: the Odee and Minneola upland areas, the Meade lowland area, Red Hills, and Cimarron valley area. The Ashland basin is immediately adjacent to the county on the east. These divisions of the Plains Border section seem to have more validity than those of the High Plains section. Most of them have distinctive features of topography and are recognizable in the field. For the sake of simplicity, however, it probably would have been better to include the Odee and Minneola upland areas in one division because they are quit similar topographically, have had a similar geologic history, and are now separated only by the valley of Crooked creek. Also it seems inadvisable to include the valley of Crooked creek east of the Crooked creek fault as a part of the Meade lowland area for the same reasons applied to the Cimarron valley area.

In conclusion, it is my opinion that Meade county is properly divided physiographically into two sections—the High Plains in the west and northwest and the Plains Border in the east and southeast. The Plains Border section includes as minor divisions the Meade area, the Minneola-Odee upland area, the Red Hills, and the Ashland-Englewood basin.

GENERAL FEATURES OF GROUND WATER

Source

Ground water, or underground water, is the water that issues from springs or flowing wells or can be pumped from nonflowing wells. In southwestern Kansas ground water is derived almost entirely from precipitation in the form of snow or rain. Part of the water that falls as snow or rain is carried away to the Gulf of Mexico by the streams; part of it percolates downward into the rocks until it reaches the water table where it joins the body of ground water known as the zone of saturation; and part of it may evaporate or be absorbed and transpired by the vegetation and thus returned directly to the atmosphere.

The ground water percolates slowly through the rocks in directions determined by the topography and geologic structure, until eventually it is discharged through springs or wells, through seeps directly into streams, or by evaporation and transpiration in lowlands bordering the streams. In some parts of the United States, the water has traveled many miles from the area of intake, but in Meade county water derived from shallow wells and gravity springs generally is derived from precipitation in the immediate vicinity, and the water obtained from artesian wells and springs is derived from precipitation in near-by areas to the west and northwest.

Many of the residents of this county fallaciously attribute the source of the water in their artesian wells and springs to melting snows in the Rocky Mountain region, or underflow from the Arkansas river in the vicinity of Cimarron, Kansas. It is true that the underflow of the Arkansas supplies many wells on the flood plain of that river but water moving down that valley probably does not move south under the divide to the Meade basin.

Some of the residents of the county may not believe that the amount of water falling as rain or snow is sufficient to supply the large underground reservoirs. However, one inch of water falling on one square mile amounts to 17,378,720 gallons, and the average annual precipitation in the county is about 18 inches, or approximately 313,000,000 gallons to the square mile. Part of this water reaches the underground reservoir, as described above.

Principles of Occurrence

The rocks forming the outer crust of the earth are generally not entirely solid but contain numerous openings, called voids or interstices, which may contain either liquid or gas, such as water, oil, natural gas, or air. There are many kinds of rocks, and they differ in the number, size, shape, and arrangement of their interstices and hence in the amount of water they are able to hold. The occurrence of ground water in any region is therefore determined by the geology. A detailed treatment of the occurrence of ground water is given by Meinzer (1923) and a shorter treatment referring especially to Kansas has been published by Moore (1940).

The amount of water that can be stored in any rock depends on the porosity of the rock, commonly expressed as the percentage of the total volume of the rock that is occupied by interstices. A rock is said to be saturated when all its interstices are filled with water. Porosity, however, determines only how much water a given rock can hold, not how much it may yield to wells. The permeability of a rock may be defined as its capacity for transmitting water or other fluid under pressure and is measured by the rate at which it will transmit water through a given cross section under a given difference of pressure per unit of distance. A bed of silt or clay may have as high a porosity as a bed of coarse sand, but because of the small size of its interstices it may require the application of great pressure to transmit water; hence, under ordinary hydraulic gradients it may be entirely impermeable. Not all the water in a saturated rock is available to wells, because part of the water is held against the force of gravity by molecular attraction. In a fine-grained rock the molecular attraction is very great and only a small part of the water can be drained out by the force of gravity; whereas, in a coarse sand or gravel having the same porosity, only a small part of the water is retained by molecular attraction and the remainder becomes available to wells.

Gravel and sand are among the most productive water-bearing materials. It is from material of this type that all the water of the Meade artesian basin and much of the nonartesian water in adjacent parts of the county is obtained. As stated, the Tertiary and Quaternary deposits of the county were laid down by streams. As the streams built up the surface over which they flowed, they probably migrated from side to side, so that at any one locality well sorted sand or gravel may alternate with finer, less permeable materials. Thus, the unconsolidated deposits in the area consist principally of layers of fine particles of low permeability that enclose "pipes" and discontinuous sheets of permeable gravel or sand, which serve as arteries of ground water. In much of Meade county wells drilled to a depth of 200 feet or more encounter at least two, and probably more, such water-bearing beds.

The Water Table and Movement of Ground Water

The permeable rocks that lie below a certain level in Meade county and elsewhere are generally saturated with water. These saturated rocks are said to be in the zone of saturation, and the upper surface of the zone of saturation is called the water table. Of the water that falls on the soil some runs off as surface water, some is used by plants or evaporates, and the remainder is slowly drawn down by gravity through the zone of aeration to the zone of saturation, except for a small part that is retained in the pore spaces by molecular attraction. In fine-grained material the earth is always moist several feet above the water table, due to capillarity, and this moist belt is called the capillary fringe. The water retained in the capillary fringe is not available to wells which must be sunk to the water table before water enters them.

In areas where water is confined under pressure and rises in wells above the level of the local water table, water is referred to as artesian and the wells are called artesian wells. In such wells the water level does not represent the water table but is a point on an imaginary surface called the "pressure indicating surface" or "piezometric surface."

Shape and Slope

The water table is not a static, level surface, but rather it is generally a sloping surface that shows many irregularities caused by differences in permeability of the water-bearing materials or by unequal additions of water to the ground-water reservoir at different places.

The shape and slope of the water table in Meade county are shown on the map, plate 1, by means of contour lines drawn on the water table (or piezometric surface). Each point on the water table along a given contour line has the same altitude. These water-table contours show the configuration of the water surface just as contours on a topographic map show the configuration of the land surface. The direction of movement of the ground water is at right angles to these contour lines—in the direction of the greatest slope.

The map shows that the water under the plains moves through the county in a generally southeasterly direction, but that the direction of movement and the slope varies considerably in different places. In discussing the shape and slope of the water table and piezometric surface the county may be divided roughly into two

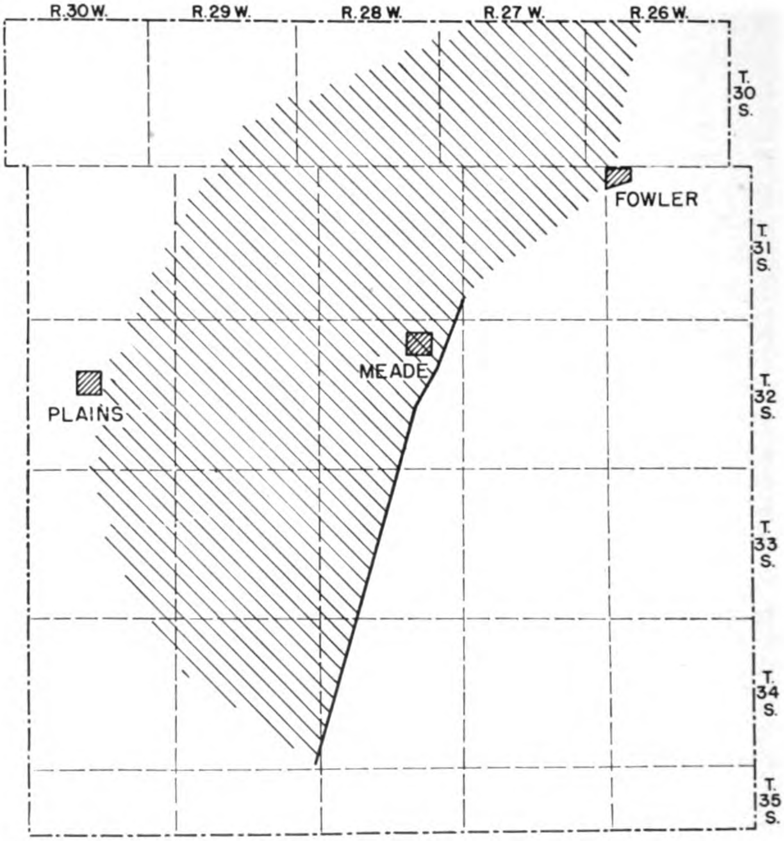

FIG. 5. Map of Meade county showing by hachures the area in which artesian conditions prevail.

parts, namely the area hachured in figure 5, within which artesian conditions prevail, and the remainder of the county in which water-table conditions prevail. East and south of the city of Meade these two areas are sharply distinguished by the Crooked creek fault, which is reflected in the contours by a vertical displacement of the water surface of as much as 40 feet in some places. North, south, and west of the hachured area, however, the piezometric surface merges gradually with the water table and no sharp boundary line is apparent.

The regional slope of the piezometric surface is toward the east-southeast, and ranges from 5 to 8 feet to the mile in the northwestern part of the county to 35 feet to the mile in the central part. Along the Cimarron valley near the Oklahoma state line the regional slope is interrupted and the piezometric surface dips steeply down to the level of the valley floor. General indentations in the contour lines northeast of Meade seem to indicate cones of depression, or areas of pressure release, in localities having many flowing wells. The 2,430-foot contour clearly shows such a feature at the city of Meade. Southeast of Meade County State Park an up-dip warping of the contour lines probably indicates some lowering of the piezometric surface resulting from the discharge of considerable water from artesian springs in the park.

Northeast of Fowler the contours are flexed southward under an area of sand dunes. Water-table conditions exist under the sand dunes just south of the Fowler fault. Although there is no sharp break in slope along the fault line, it may be more distinct than the available data indicate.

The shape of the water table in the eastern and southeastern parts of the county shows a general conformity to the major topographic features. A dome in the south-central part of the county seemingly results from the exceptionally good recharge facilities in the area of sand dunes, and two smaller domes in the southeastern corner and the nose in the east-central part seem to be the result of equally good recharge facilities in filled sink holes. The nose in the east-central part of the county probably would have appeared as a dome prior to the capture of the drainage of this sink by Sand creek.

Slopes on the water table in the eastern part of the county range from less than 5 feet to the mile to more than 50 feet to the mile. The steeper gradients generally prevail in areas in which the water is moving through the Permian redbeds, which have low permeability and low specific yield.

In general the direction of movement of ground water throughout the county is from northwest to southeast. In the southern and eastern parts of the county, however, there are many local deviations from this regional direction of movement that are controlled mainly by the topography. Some of these deviations are discussed below.

RELATION TO TOPOGRAPHY

On the map, plate 2, are shown the depths to water level in Meade county by the use of isobath lines—lines of equal depth to water level. In preparing this map the more general irregularities of the surface topography were taken into account by using areal photographs and the available topographic maps. As shown on this map, the depth to water level ranges from more than 200 feet below the surface to a few feet above the land surface in the flowing well areas. Some inaccuracy has been introduced by small local irregularities on the land surface that are not shown on the topographic maps or areal photographs.

In general, the shape of the water table conforms closely to the broad features of the topography. Cimarron river and Sand and Crooked creeks are entrenched below the level of the adjacent water table, as indicated by the upstream flexures of the contours, hence these streams are receiving water from springs and seepage along their courses. Between Meade and Fowler, however, Crooked creek flows across the artesian basin where, as shown by the map, the course of the stream bears no relation to the shape of the peizometric surface.

Other things being equal, the slope of the water table in any area varies inversely with the permeability of the water-bearing material; that is, the water assumes a steeper gradient in flowing through fine material than through coarse, permeable material providing the same quantity of water is moving through both types of material. This probably explains at least in part the differences in the slope of the water table in different parts of Meade county. Thus, most of the steep slopes in the southeastern part of the county occur in areas in which the water is moving through the Permian redbeds, which have relatively low permeability.

FLUCTUATIONS OF THE WATER TABLE

The water table does not remain in a stationary position but fluctuates up and down much like the water in a surface reservoir. If the inflow to the underground reservoir exceeds the draft the water table will rise; conversely, if the draft exceeds the inflow the water table will decline. Thus the rate and magnitude of fluctuation of the water table depends upon the rate and magnitude at which the underground reservoir is replenished or depleted.

The factors controlling the rise of the water table in Meade county are the amount of rainfall within the county that passes through the soil and descends to the water table, the amount of seepage that reaches the underground reservoir from surface streams, and the amount of water entering the county beneath the surface from areas to the west and northwest. All of these factors depend upon precipitation either in or near the county.

The factors controlling the decline of the water table are the amount of water pumped from wells, the amount of water absorbed directly from the water table by plants (transpiration), the amount of water lost from the ground-water reservoir by evaporation, the loss of water from springs, and the amount of ground water passing beneath the surface into adjacent areas.

Fluctuations caused by precipitation.—The relation between the amount of precipitation and the level at which the water stands in wells is complicated by several factors. After a long dry spell the soil moisture becomes depleted through evaporation and transpiration, and, when a rain does occur, the soil moisture must first be replenished before any water can descend to the water table. During the winter when the ground is frozen the water falling on the surface is hindered from reaching the water table, and during the hot summer some of the water that falls as rain is lost directly into the air by evaporation. Where the water table stands comparatively far below the surface, as it does in part of Meade county, it fluctuates less in response to precipitation than where the water table is comparatively shallow.

The response of water levels to rainfall in an area of shallow, unconfined ground water is relatively fast if the surficial material is sufficiently pervious to allow rapid downward percolation of water, but in areas of deep water where a considerable thickness of material occurs above the water table there is generally considerable lag between the precipitation and the rise in water level, and the rise in water level generally is more gradual and of less magnitude. In artesian areas, where the water migrates laterally several miles from the recharge area, the lag in time is even more pronounced.

Changes in the water levels in wells record the fluctuations of the water table or peizometric surface, which in turn record the recharge and discharge of the ground-water reservoir. In order to determine the character and magnitude of water-level fluctuations in Meade county, 28 wells were selected for observation and periodic measurement of the depth to water levels in them were begun in July, 1939. Measurements in 27 of the wells were made by me during the period July to October, 1939, and August and September, 1940, by Richard B. Christy during the period November, 1939, to April, 1941, and by Woodrow W. Wilson after April, 1941. In addition, one well (37) equipped with an automatic water-stage recorder has been observed weekly by Christopher Sobba. Complete records for these wells are published annually by the Federal Geological Survey (Meinzer and Wenzel, 1941, 1941a). The numbers of the observation wells previously published and the numbers used in this report are given in table 3.

TABLE 3.—*Observation wells in Meade county*

Well No. in this report.	Well No. in Meinzer and Wenzel, 1941, 1942.	Well No. in this report.	Well No. in Meinzer and Wenzel, 1941, 1942.
7	11	220	40
9	2	236	36
12	27	238	77
17	23	275	37
24	3	278	33
28	47	285	34
37	234	297	10
66	45	308	59
100	55	313	16
109	42	317	57
114	41	322	101
118	62	331	76
173	61	332	73
193	88	342	304

The fluctuations of the water level in five typical observation wells in Meade county during the period of record and the precipitation at Plains are shown in figure 6.

With reference to figure 6, it will be noted that none of the wells show a close correlation between the rainfall at Plains and the water level. The water level in well 331 shows marked rises during the summer of 1940 and during the summer and fall of 1941 that coincide with periods of heavy rainfall, but the highest water level during the period of record occurred in the fall of 1939 when only a small amount of rain fell at Plains. This may be explained by the fact that this well is located in a small drainage basin, about 20 miles from Plains, and so the water level may have risen in response to local rainfall that was not recorded at Plains. The only other well that shows any apparent correlation between rainfall and water level is 313. The water level in this well rose sharply during May, 1941, in response to a period of above-normal rainfall.

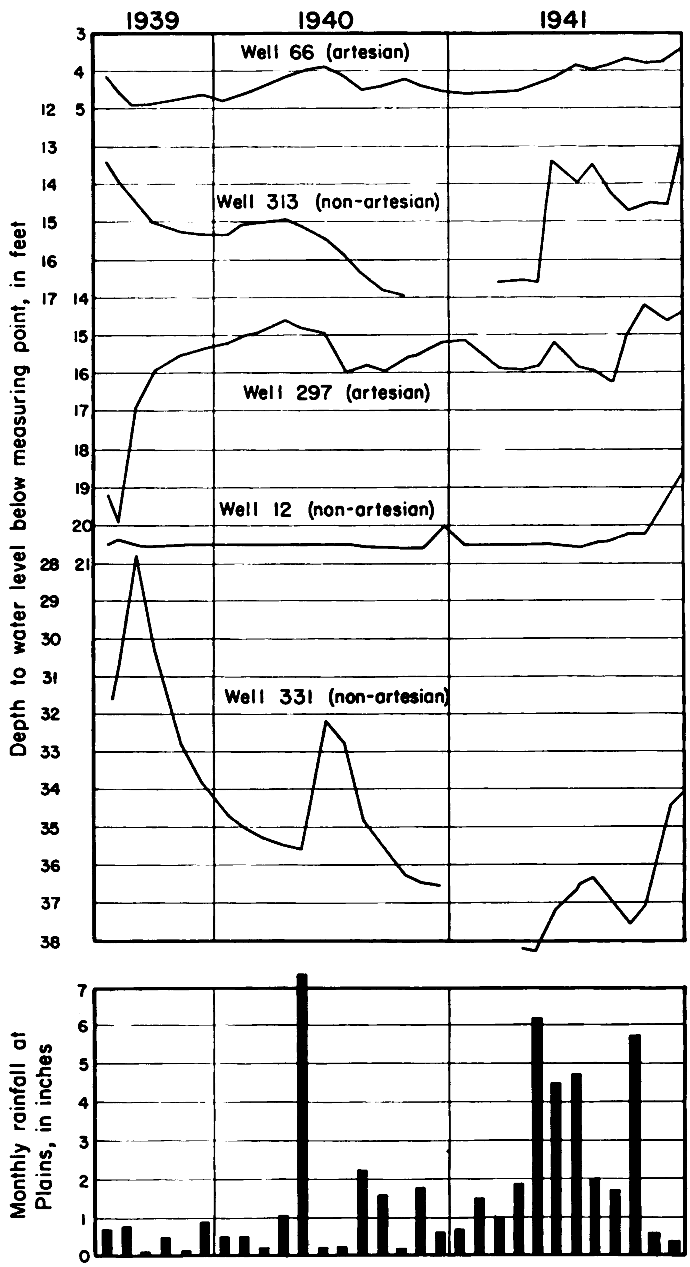

FIG. 6. Hydrographs of five typical observation wells in Meade county and the monthly precipitation at Plains (precipitation data from U. S. Weather Bureau).

Wells 66 and 297 are artesian and show no apparent relation of water level fluctuations to rainfall during the brief period of record. Well 297 is pumped for irrigation during part of the year and the fluctuations in water level shown in figure 6 probably are due to pumping.

Although well 12 is nonartesian it has had no significant fluctuations in water level during the period of record. This may be accounted for by the facts that it is situated in fine-grained sediments, and that several near-by deep irrigation wells may have supplied some artificial recharge during the periods of deficient rainfall.

If a well is heavily pumped the water levels in wells several hundred feet or even a few miles away may be lowered somewhat. After pumping of the well has ceased, the dewatered volume of sediments slowly refills with water and the water level in the well gradually recovers to approximately its former position.

Under artesian conditions the development of the cone of depression (see principles of recovery) and the effect on the water levels in near-by wells take place much more rapidly and are effective over a much larger area than under water-table conditions. As there generally is no dewatering of the water-bearing formation, the recovery under artesian conditions is more rapid than under water-table conditions. The effect of pumping on the piezometric surface is discussed under artesian water and drawdown and recovery curves in the artesian area are shown in figures 8 and 9.

Recharge

Recharge is the addition of water to the underground reservoir and may be accomplished in many different ways. The ground water within practicable drilling depths in Meade county is derived principally from precipitation that falls as rain or snow within the county or on areas to the west of the county. In Meade county there is also some recharge by influent seepage from streams and by subsurface inflow from areas to the west of the county. The latter source of recharge is discussed under Artesian Water.

Recharge from local precipitation

As pointed out above, the primary source of ground water in Meade county is rain or snow that falls on this or adjacent areas. It is a difficult problem, however, to determine with certainty the percentage of the water falling on the area that eventually reaches the water table. The Kingsdown silt, which underlies much of the

High Plains part of the county, is relatively impervious and so serves to retard or prevent the downward percolation of water. Many shallow, undrained depressions on this surface catch and hold rain water and prevent surface runoff. The fact that these shallow depressions, many of which are 150 feet or more above the water table, are occupied by shallow ponds for weeks or even months after a heavy rain seems to indicate that even in these areas the water percolates downward so slowly that most of it evaporates before it has an opportunity of entering the ground. Recent studies of recharge from similar shallow depressions in the High Plains of Texas (White, Broadhurst, and Lang, 1940, pp. 6-8) indicated that recharge from some ponds was quite rapid; whereas, in others, it was slow or nonexistent. The problems of the two areas are not entirely similar, as in the Texas area beds of caliche locally prevent downward movement of water; whereas, in Meade county, caliche does not seem to be effective in this respect, but the same purpose is served by homogeneous deposits of silt. Probably none of the recharge areas in Meade county are as effective as some of the more favorable areas in Texas. On the other hand, however, probably none of the depression ponds in Meade county are as completely sealed off as are some of the ponds studied in Texas.

Rodent burrows and sod cracks probably are important avenues of access for rain water entering the ground. During dry seasons, in certain grassland areas of the High Plains, there may be observed extensive sod cracks in the typical polygonal pattern of flood-plain mud cracks, extending over areas several square miles in extent. Some cracks of more than an inch in width have been observed and have been prodded to depths of nearly four feet.

Sand dunes, such as occur in the southern, southwestern and northeastern parts of the county, are probably effective aids to recharge. The dune sand is quite porous and very little surface drainage has developed in these areas. Rain water enters the sand and generally percolates downward freely. In places where the permeability of the underlying material may not be high, water from recharge is held in the dune sand for a considerable period and at least a part of the water may in time penetrate the underlying material.

Rain that falls on the alluvium along the streams is probably much more effective in recharging the ground-water reservoir than rain falling on the High Plains; however, the total area of alluvium, as shown in plate 1, is relatively small.

RECHARGE FROM STREAMS

It is probably true that during periods of maximum flow in the major streams of the county some water leaves the channels and moves into the adjacent channel and flood plain deposits. This type of recharge is not very effective in this county. The minor intermittent tributaries that lie above the water table have such steep gradients that they contain water only for very short periods of time after rainstorms. At such times, however, the water is moving very swiftly and is heavily laden with sediment, hence there is very little opportunity for water to percolate downward. Thus it appears that very little recharge from streams takes place in Meade county.

DISCHARGE

NATURAL DISCHARGE AT THE SURFACE

Before any wells were drilled the ground-water reservoirs of Meade county were in a state of approximate equilibrium. The average annual recharge was balanced by an approximately equal average annual discharge. The greater part of the natural discharge occurred through springs and seeps along the valleys of Crooked creek and Cimarron river. A part of the water was discharged by direct evaporation and by transpiration from trees, grasses and shrubs in shallow water areas, a very small amount was lost as evaporation from water-table lakes, and the remainder passd southeastward beneath the surface into adjacent areas.

A large percentage of this discharge occurred through artesian springs along Crooked creek and its tributaries, and as seepage into streams from the shallow ground-water body in the Meade basin, as discussed in subsequent chapters. In addition a small quantity of water is discharged from gravity springs along the Cimarron valley. Most of the water issues from sand and gravel overlying beds of clay and silt in the Ogallala and Meade formations, but in the southeastern part of the county the water issues from the basal Tertiary deposits which overlie less permeable Permian redbeds.

Little or no water is discharged by transpiration and evaporation in the High Plains area, as the water table lies more than 100 feet below the surface under this entire area (Pl. 2). These processes are operative along the valleys of permanent streams, however, and in the shallow water area northeast of the city of Meade. That area constitutes a more or less special problem which is discussed in a subsequent section.

DISCHARGE FROM WELLS

At the present time wells constitute one of the prinpical means of discharge of ground water within the county. Discharge from wells occurs both as natural flow at the surface from flowing artesian wells and by pumping from nonflowing wells. Most of the well discharge occurs in the artesian basin and immediately adjacent uplands, and is discussed in a later chapter. Outside of that area only small quantities are pumped from wells for domestic and stock supplies. There is only one large irrigation well (272) and one large municipal well (269) on the High Plains in Meade county.

ARTESIAN WATER

HISTORY OF DEVELOPMENT IN THE MEADE ARTESIAN BASIN

The first flowing artesian well was drilled in the Meade basin in 1886 on the farm of B. F. Cox (NE NE sec. 5, T. 31 S., R. 27 W.). The second flowing well was drilled later in the same year on the Jasper farm (SE SW sec. 33, T. 30 S., R. 27 W.), and in 1887 the third well was drilled on the farm of Frank Sourbeer (SE SE sec. 31, T. 30 S., R. 27 W.). Following the drilling of these three wells, the development of the basin proceeded rapidly, reaching its peak about 1900. By that time several hundred flowing wells had been drilled. Drilling has since continued in the basin, although recently the number of new wells added each year has been very small. Plates 6 and 7 show typical flowing wells of small diameter. The wells on the farm of W. W. Marr (pl. 6*A*) and on the Leach farm (pl. 7*A*) were constructed at about the time of maximum drilling activity in the basin. A well completed in 1939 on the farm of C. F. Wells, about a quarter of a mile west of the second artesian well drilled in the basin, is shown in plate 6*B*; and plate 7*B* shows a test well in Meade County State Park, drilled in 1939, which was cased to a depth of 30 feet and flowed with a head of 17.4 feet above the land surface.

Most of the wells were drilled either by the jetting method or by the hydraulic rotary method. Horse power was quite generally utilized by the early drillers, and the drilling tools were light and incapable of penetrating hard rock. Most of the wells range in diameter from 1½ inches to 3 inches, although there are a few wells of larger diameter. Most of the early wells are uncased, except for about 30 feet of pipe left in the upper part of the hole. In recent years most of the new wells have been cased to their full

PLATE 6. Flowing wells of small diameter. *A*, Well 56 on the farm of W. W. Marr. *B*, Well 81 on the farm of C. F. Wells.

depth. The bottom part of the casing is generally perforated and serves as a screen. It is estimated that approximately 1,000 flowing wells have been drilled in the basin since 1886. Only a few hundred wells, however, are in usable condition at the present time.

Irrigation from pumped wells is a relatively recent development in the Meade basin. With the exception of a well on the Norman farm (NE sec. 6, T. 31 S., R. 27 W.), which was pumped for irrigation purposes in 1909 only, and a well drilled a few years later on the Walker farm (SW sec. 4, T. 30 S., R. 26 W.), but not used extensively until the last few years, the first large, pumped irrigation well in the county was drilled in 1928 by L. L. Meng in the SE sec. 18, T. 30 S., R. 26 W. Since that date ten irrigation wells have been drilled and put into operation in the artesian basin. These wells, with one exception, are in the parts of the basin in which the pressure-head of the ground water is not sufficient to produce flows at the surface. Three typical irrigation wells are shown in plates 8 and 9. Two of these (pls. 8*A* and 9*A*) are situated in the artesian basin and have relatively low lifts, whereas the well shown in plate 8*B* is situated on the High Plains and has a static water level of more than 150 feet below the surface.

Principles of Occurrence

A general discussion of the occurrence of ground water in Meade county is given on pages 36, 37; this discussion, therefore, pertains only to the occurrence of artesian water—ground water that, when encountered in wells, rises above the level of the local water table or, as in part of this area, that rises high enough to flow at the land surface. As shown in figure 4, alternate beds of permeable and relatively impermeable material dip downward beneath the floor of the Meade artesian basin. Water entering the permeable strata northwest of this area at an elevation higher than the floor of the basin moves down the dip between the confining layers of relatively impervious material toward the lowest part of the basin, where it is under artesian pressure. In several parts of the basin the water is under sufficient head to flow at the surface through artesian springs or flowing artesian wells.

Areas of Artesian Flow

The areas in Meade county in which artesian flows could be obtained in 1939 are shown in plate 2. It is evident from the map that the location and shape of the areas of flow are controlled largely by

PLATE 7. Flowing wells. *A,* Well 181 on the farm of M. L. Leach, NE NE sec. 12, T. 31 S., R. 28 W. *B,* Flowing well (310) produced from test well in Meade County State Park. This well was later plugged. Portable drilling machine in background.

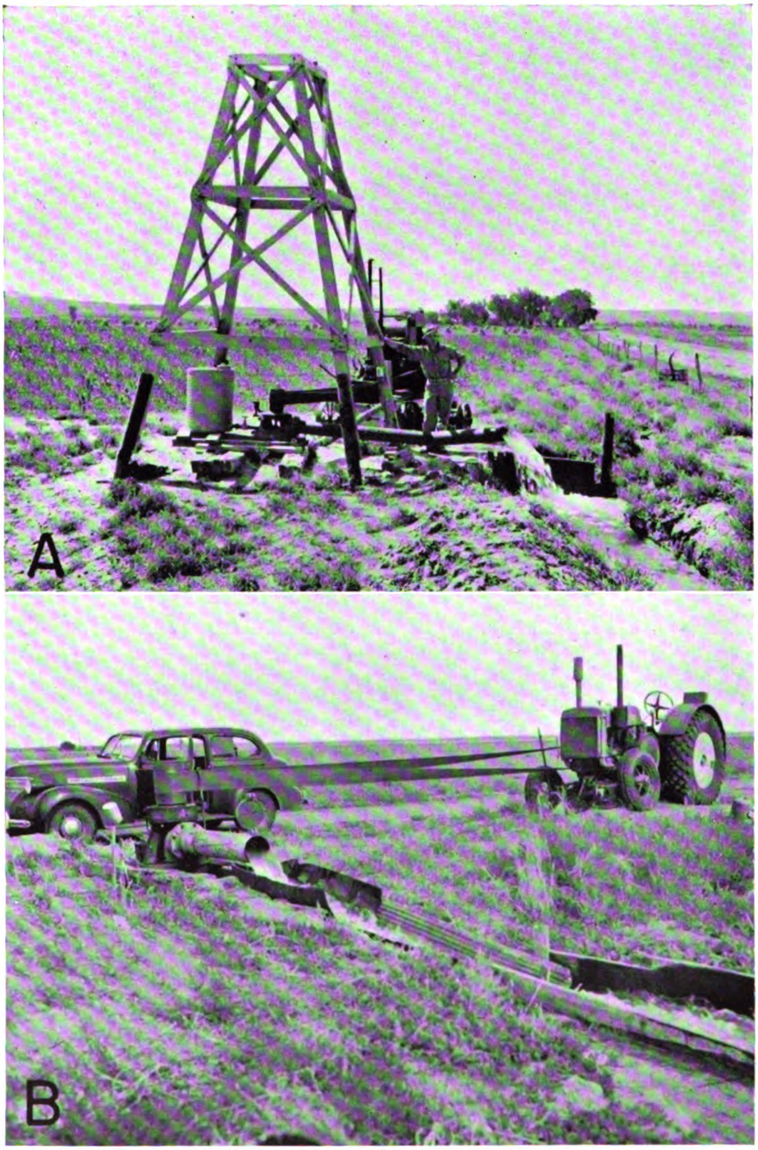

PLATE 8. Irrigation wells in operation. *A*, Well 297 on the farm of Henry Borchers, SW NW sec. 29, T. 33 S., R. 28 W. *B*, Well 272 on the farm of C. W. Holmes, NE sec. 35, T. 32 S., R. 30 W.

the topography, and that the extent of such areas will vary from time to time with the fluctuations of the pressure-head of the artesian water. Little accurate historical information is available as to the former extent of the flowing well area; it is probable, however, that the area has decreased only slightly since the earliest development. There may have been some decrease in the area of flow west of Fowler.

In Meade county there are six distinct areas in which flowing wells can be obtained. These areas are shown in plate 2, and each is discussed briefly below.

Meade district.—The Meade district is by far the largest and most important of the flowing well areas. It includes approximately 33 square miles, in which are found more than 200 flowing wells in usable condition at the present time. This area extends along the valley of Crooked creek in a narrow strip for about 12 miles south of Meade. North of Meade it broadens into the Meade basin proper, extending to within a mile of Fowler on the east, and to within 3½ miles of the Ford county line on the north.

State Park district.—The State Park district, comprising less than 1 square mile, is situated about 10 miles southwest of Meade. Although no permanent artesian wells exist in this district, several large artesian springs supply water for the hatchery ponds at the State Park. During the fall of 1939, four test holes were drilled by the State and Federal Geological Surveys on the grounds of the park. Two of these wells were flushed out and cased to a shallow depth so that measurements of the artesian head could be made. In one well the water rose to a point 17.4 feet above the land surface. All test holes were plugged after these measurements were made.

Berghaus district.—The Berghaus flowing well district embraces about 0.25 square mile in sec. 33, T. 32 S., R. 29 W., most of which is on the Berghaus property along a tributary to Crooked creek about 3 miles north-northwest of Meade County State Park. As the valley bottom is narrow, and the bluffs steep, the strip enclosed within the zero line, plate 2, is narrow. In this district there is one small flowing well, which is situated at the site of a former spring.

Big Springs Ranch district.—A flowing well area of less than 1 square mile occurs along Spring creek on the Big Springs Ranch (secs. 17, 20, and 21, T. 32 S., R. 28W.), 3 miles southwest of Meade. There are several large springs along the valley flat, and three small flowing wells near the Big Springs Ranch house. This district is less than 1 mile from the southern part of the Meade district.

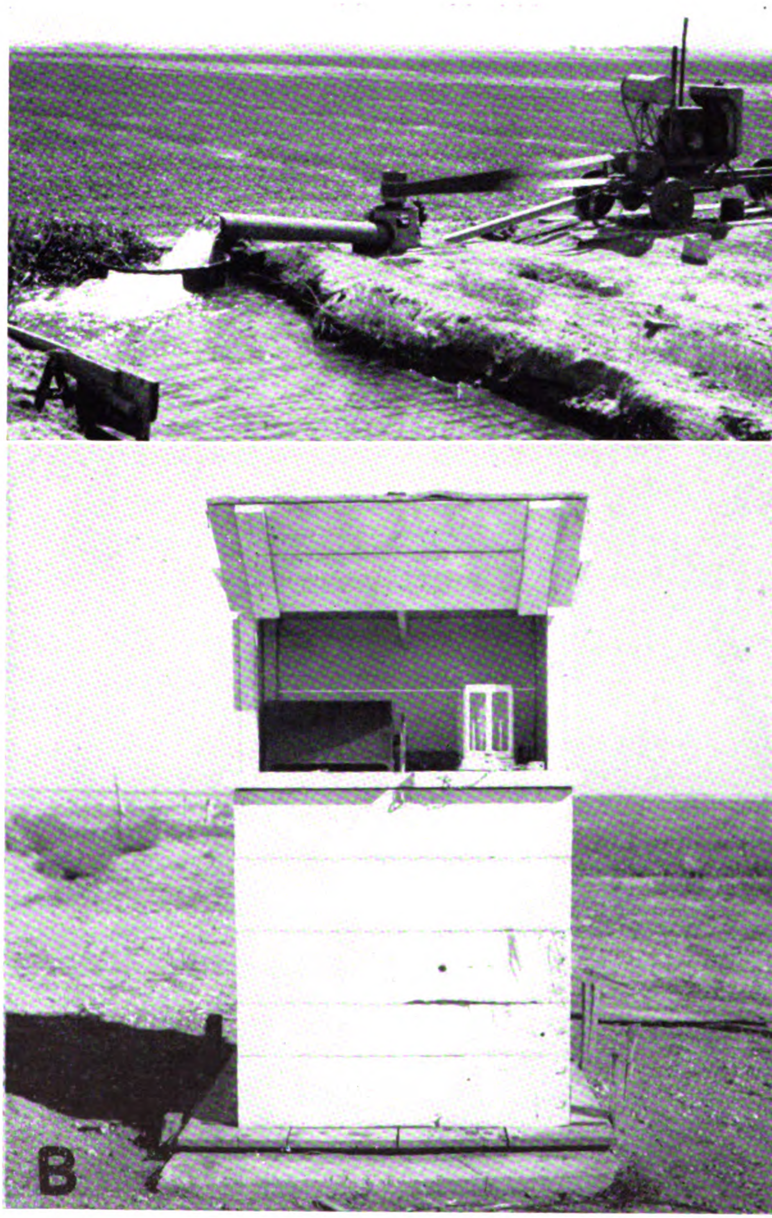

PLATE 9. Irrigation and observation wells on the Christopher Sobba farm, northwest of Fowler. *A*, Irrigation well (38) in operation. *B*, Shelter enclosing automatic water-stage recorder and recording microbarograph in operation at observation well (37), 320 feet north of irrigation well.

Fowler district.—Flowing wells occur along the valley of Crooked creek north of Fowler to the Ford county line, and along the valley of its tributary, Spring creek (secs. 3, 4, 9, 16, 20, and 29, T. 30 S., R. 26 W.). This area is separated from the eastern extension of the Meade district by an area of nonflowing wells in which the water rises to levels within a few feet of the surface. The district includes an area in Meade county of somewhat more than 1 square mile, and in 1939 it contained 13 flowing wells.

Eastern district.—The eastern district, comprising an isolated filled sinkhole, is about 7 miles southeast of Meade. This small area contains water under artesian pressure, and at least one flowing well has been drilled in it. The area of flow is restricted to the valley bottoms of Sand creek and its tributaries, and seems to include less than 0.25 square mile, confined entirely to sec. 4, T. 33 S., R. 27 W. The area of flow seemingly has decreased somewhat as a result of pumping from a well that formerly flowed.

The Piezometric Surface and Movement of Artesian Water

The shape and slope of the piezometric surface has been described in an earlier section. As shown in plate 1, this surface slopes toward the southeast, and the movement of artesian water is in that direction, or at right angles to the contours. The rate of movement is determined by the steepness of the slope and by the character of the material through which the water moves. Thus, water moves from the northwestern part of the county southeastward into the Meade basin, as indicated by the contours on the piezometric surface, and is discharged by springs in the flowing well areas described above and shown in plate 2.

Head of Artesian Water

The hydrostatic level, or static water level, of the artesian water at any point is the level to which the water will rise in a tightly cased well drilled to the artesian reservoir. If the static water level stands above the land surface, the well will overflow at the surface; if a flowing well is tightly cased and capped, the artesian water will exert a pressure that can be measured. The term head, as used in this report, refers to the height, in feet, that the water will rise above the land surface in a tightly cased flowing artesian well. The heads of flowing wells given in plate 2 and elsewhere in this report were measured in the following manner. The discharge pipe was closed by inserting a plumber's soil-pipe test plug of the proper size.

The seal between the test plug and the well casing is effected by a soft rubber collar that is expanded outwardly by turning a large wing nut. A length of garden hose was then attached to the test plug and the open end of the hose elevated until the flow just ceased. The hose was kept in this elevated position so as to prevent flow until all the discernible recovery had taken place. The height of the top of the hose above a fixed point then was determined with a steel tape. Some head measurements may be somewhat inaccurate owing to slight leaks in the equipment or in the casings of the wells. In such wells the heads determined by this method should, therefore, be regarded as minimum heads.

The piezometric surface, or pressure-indicating surface, of an artesian aquifer is an imaginary surface that everywhere coincides with the static level, or head, of the water in the aquifer.

ORIGINAL HEAD

The original head of the artesian water in the Meade basin is not definitely known. The earliest known measurements of head in this area were made by W. D. Johnson (1901, p. 718), who, in 1898 or 1899, visited 209 flowing wells in use in the basin. How many of these wells were actually measured is not known, but he states that the strongest measured head in the basin at that time was 22 feet above the land surface. Conversations that I have had with old residents of the county indicate that in the early days of artesian development, a well from which water would rise above the second floor of a house was regarded as an exceptionally strong flowing well, and that water from many wells would rise only a few feet above the land surface. Also, Haworth, in 1898 (p. 53), states that the heads at that time were ". . . perhaps always less than 20 feet." This seems to imply that Johnson's figure of 22 feet may safely be regarded as the approximate maximum head obtainable in the basin during the earliest period of record.

HEAD IN 1923

Measurements of the pressure head of many artesian wells were made in November and December, 1923, by V. W. Stanbaugh, of the Division of Water Resources, Kansas State Board of Agriculture, and were made available by George S. Knapp, chief engineer of the division. These measurements were made with a calibrated gas proving gauge reading in pounds to the square inch and having a full circle deflection of 15 pounds. The gauge was read to the nearest quarter pound and the gauge was held at the outlet of the well casing. For the purpose of discussion and comparison in this report, these values have been converted to feet of water. The heads of 24 wells measured in this way are given in column 4 of table 4. Owing to the facts that these measurements were recorded only to the nearest quarter pound, and that there are several inherent mechanical inaccuracies in this method of measurement, the 1923

TABLE 4.—*Head measurements of 24 flowing artesian wells in 1923 and 1939, and decline or rise during that period*

LOCATION.	Reported depth of well (feet).	Diameter of well (inches).	Head above measuring point (in feet).		Decline(—) or rise (+).
			1923[a]	1939[b]	Difference between columns 4 and 5.
1	2	3	4	5	6
NW sec. 3, T. 30 S., R. 26 W......	190	2	Weak[cd]	2.7[d]	....
NE sec. 4, T. 30 S., R. 26 W.......	120	2	Weak[cd]	2.0[d]	....
SW sec. 21, T. 30 S., R. 27 W......	170	2	5.8	6.5	+ .7
NE sec. 27, T. 30 S., R. 27 W......	175	3	10.4	7.7	—2.7
NW sec. 27, T. 30 S., R. 27 W.....	180	2	4.6	3.5+	—1.1
NE sec. 29, T. 30 S., R. 27 W......	200	....	8.1	5.8	—2.3
SW sec. 32, T. 30 S., R. 27 W......	175	2	3.5	2.0	—1.5
SE sec. 24, T. 30 S., R. 28 W......	180	2	Weak[cd]	1.5[d]	....
NW sec. 4, T. 31 S., R. 27 W......	350	2	6.4	7.8	+1.4
NW sec. 5, T. 31 S., R. 27 W......	....	2	5.1	5.5	+ .4
NW sec. 6, T. 31 S., R. 27 W......	200	3	3.5	3.6	+ .1
SW sec. 3, T. 31 S., R. 27 W.......	....	3	5.6	7.0	+1.4
SW sec. 5, T. 31 S., R. 27 W.......	....	3	4.6	4.8	+ .2
SW sec. 6, T. 31 S., R. 27 W.......	260	2	10.4	9.2	—1.2
SW sec. 6, T. 31 S., R. 27 W.......	190	2	6.3	2.5	—3.8
SE sec. 6, T. 31 S., R. 27 W........	260	2	5.1	4.5	— .6
NE sec. 8, T. 31 S., R. 27 W........	180	2	10.3	7.6	—2.7
NW sec. 18, T. 31 S., R. 27 W.....	175	....	12.7	5.9	—6.8
NE sec. 12, T. 31 S., R. 28 W......	150	4	6.9	5.7	—1.2
SE sec. 12, T. 31 S., R. 28 W......	140?	3	4.6	4.9	+ .3
NE sec. 13, T. 31 S., R. 28 W......	300	3	15.4	9.6	—5.8
NW sec. 12, T. 32 S., R. 28 W.....	180	2	3.5	.2	—3.3
SW sec. 22, T. 32 S., R. 28 W......	150	2	3.5	2.0	—1.5
NE sec. 4, T. 33 S., R. 28 W.......	180	2	7.4	1.0	—6.4
Average....................	195	....	6.8	5.1	—1.7

a. Heads measured in November and December, 1923, by V. W. Stanbaugh, Division of Water Resources, Kansas State Board of Agriculture. Measurements were made in pounds to the square inch and have been converted to feet. Believed to be accurate within 0.5 foot.

b. Heads measured by the writer in July-September, 1939, by the method described in the text. Accurate to approximately 0.2 foot.

c. Head too weak to register a readable amount on the gage, probably less than 2.5 feet.

d. Not included in average.

heads given in the table should be regarded as accurate only within about 0.5 foot. The strongest head recorded in 1923 was 15.4 feet; no measurement was then made on the wells that showed the strongest heads in 1939, however. From the foregoing, it is estimated that the maximum head in the Meade basin in 1923 was between 18 and 20 feet above the land surface.

HEAD IN 1939

In July, August, and September, 1939, head measurements were made by the writer on 145 flowing wells in Meade county. The location of these wells, and 40 other flowing wells on which flow measurements only were obtained, are shown in plate 2. The strongest head measured in 1939 was 17.4 feet above the land surface, and was obtained in a test well in Meade County State Park. Inasmuch as all the earlier measurements were made in the Meade and Fowler districts, this well cannot be compared with them. The pressure in the strongest two flowing wells measured in the Meade basin proper was sufficient to force water to heights of 17.0 feet and 16.5 feet.

DECLINE IN HEAD

On the basis of present data, the decline in head in the Meade basin during the last 50 years does not seem to have been great. In order to show the extent of this decline, some of the data presented earlier will be reviewed and compared.

As pointed out, the maximum head obtainable in the basin when development was initiated probably was not greater than 22 feet above the land surface, and the maximum head measured in 1939 was 17 feet above the land surface. Thus, it seems that the maximum head measured in 1898 was five feet higher than the maximum head measured in 1939. It is the opinion of the writer that this figure is not accurate and is probably larger than the actual decline in maximum head during this period. This opinion is based on the following facts: (1) Johnson did not give the location of the strongest well that he measured and, thus, it is impossible to know whether this well was among those measured in 1939, if indeed it is still in existence; (2) the earliest measurements were made on relatively new wells, whereas most of the 1939 measurements were made on old wells, some of which are known to be "sanded up," or to have underground leaks in the rusted casing; and (3) the strongest wells at the present time are situated in areas where the concentration of wells seems to be greater than any that existed in the basin 40 years ago; and, as it was impracticable to close in many of the wells while measurements were being made, the well being measured was undoubtedly influenced more or less by the cones of depression, or areas of pressure relief, of the near-by wells. When these facts are considered and given proper weight, it seems safe to conclude that the total decline in maximum head, by 1939, has been less than five feet but more than three feet.

Head measurements made in 1923 are given in table 4. Due to the fact that the strongest heads were not necessarily included in the measurements, no comparison of maximum heads can be made on the basis of these data. Of the wells measured in 1923, however, 24 were remeasured in 1939. As indicated in table 4, the average decline in the head of the 24 wells during the 15½-year period is 1.7 feet. It should be noted, however, that the change in head of individual wells ranged from a slight increase for some wells to a decline of 6.8 feet in one well. It should also be noted that the 1923 measurements were made in the winter, whereas the 1939 measurements were made in the summer and fall. The period of record of the observation wells in the area is not yet sufficiently long to determine with certainty at what times during the year the water in the artesian wells stands at the highest and lowest levels, but the records to date indicate that in general the water level is highest during the spring and early summer and lowest during the fall. It is evident that the decline in artesian pressure has been small.

FLUCTUATIONS IN HEAD

Fluctuations caused by precipitation.—Fluctuations of water level under nonartesian conditions caused by precipitation were discussed in an earlier section, and only those special considerations involved under artesian conditions are mentioned here. Precipitation that falls in the discharge area of an artesian basin has no effect upon the ground-water level, or pressure head, for in such areas the artesian water is effectively sealed from the surface by impervious beds or else the artesian pressure could not be maintained. Under artesian conditions, therefore, it is the precipitation that falls on the intake or recharge area that can produce fluctuations in water level, or head. Thus, the effect of precipitation on water levels must be transmitted a considerable distance through the artesian water-bearing beds. The transmission of water under hydrostatic pressure from a distance, with the accompanying frictional losses, leaks, and other complicating factors, cause the fluctuations in water level or head to lag far behind the time of recharge and to be somewhat "dampened." In order to make any accurate correlation of water-level fluctuations in the artesian basin with the precipitation on the recharge area to the northwest several additional years of water level records will be needed. At the time of writing more than 2 years records of water-level fluctuations in Meade county are available (Meinzer and Wenzel 1941, 1941a). One observation well (100), which penetrates the artesian water outside the flowing well district at a considerable distance from any possible influence by pumping, shows only a slight fluctuation in water level during the entire period of record, and these small fluctuations do not seem to be correlative with periods of rainfall and drought.

Fluctuations caused by changes in barometric pressure.—An automatic water-stage recorder has been maintained on a well (37) owned by Christopher Sobba, and the record shows a pronounced barometric effect. The effect of atmospheric pressure on the water level has been summarized by Meinzer (1932, pp. 140-142) as follows:

> If a shallow well ends in a formation that lies at the surface and is freely permeable throughout, only slight barometric effects or none at all are to be expected, because any change in the atmospheric pressure is transmitted almost as freely to the water table through the permeable material as to the water level in the well . . . if a well ends in an artesian formation and this formation or the overlying confining beds have sufficient strength to resist deformation by slight changes in pressure at the surface, the well will act as a barometer. The fluctuations of its water level will have virtually the same range of fluctuations as would be shown by a water barometer, or 13.5 times the range of a mercury barometer. . . . If a well ends in an artesian formation that has volume elasticity, such as incoherent sand, and is confined beneath beds of soft shale that is impermeable but yields to even slight pressures, its water level will have smaller fluctuations resulting from atmospheric changes than that of a water barometer, and the ratio of the movements in the well to the corresponding movements in the barometer should give a measure of the resistance of the water-bearing and confining beds.

A hydrograph obtained from the automatic water-stage recorder and the inverted barograph obtained from a recording microbarograph located in the same shelter are shown in figure 7. It can be seen from these graphs that the fluctuation of the water surface is only about twice as great as the comparable fluctuations in a column of mercury; hence, this well may be said to have a barometric efficiency of only about 15 percent. It may be concluded either that the resistance to deformation of the artesian aquifer and the confining beds is probably not very great or that the seal effected by the confining beds is not complete.

Fluctuations caused by pumping.—Fluctuations of water level caused by pumping are of particular interest. Data bearing on this problem in the Meade basin are available from several sources. The

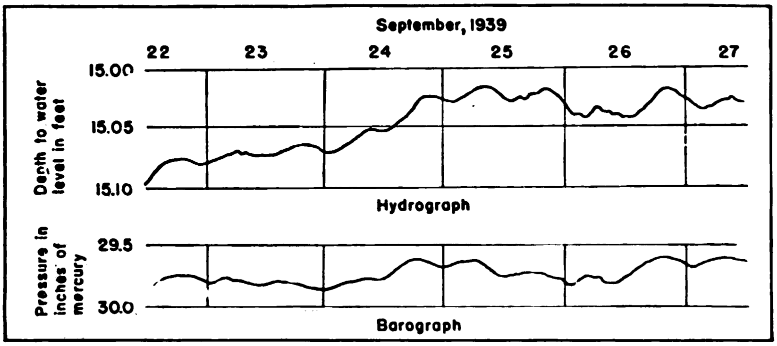

FIG. 7. Hydrograph and inverted barograph obtained at the observation well (37) on the farm of Christopher Sobba, northwest of Fowler.

observation well (37) mentioned above is situated 320 feet from a pumped irrigation well (38), and a hydrograph from the observation well is shown in figure 8, together with the pumping record of the irrigation well. This hydrograph illustrates the speed with which

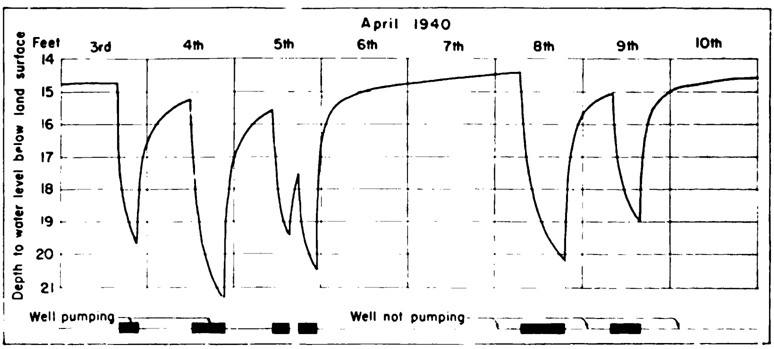

FIG. 8. Hydrograph of observation well (37) and pumpage record of irrigation well (38) 320 feet distant. Located on the farm of Christopher Sobba, northwest of Fowler.

draw-down, or release of pressure, is transmitted through the artesian aquifer, and the extent of the draw-down in the water level at a distance of 320 feet from the pumped well. The irrigation well was pumped at a rate of approximately 850 gallons a minute, and the first period of pumping indicated on the graph represents the first pumping of the irrigation well after a winter of rest. Comparable recovery curves are shown in figure 9 of two of the municipal wells at Meade. The sharp draw-downs and rapid recoveries as shown by these curves, are typical of artesian conditions.

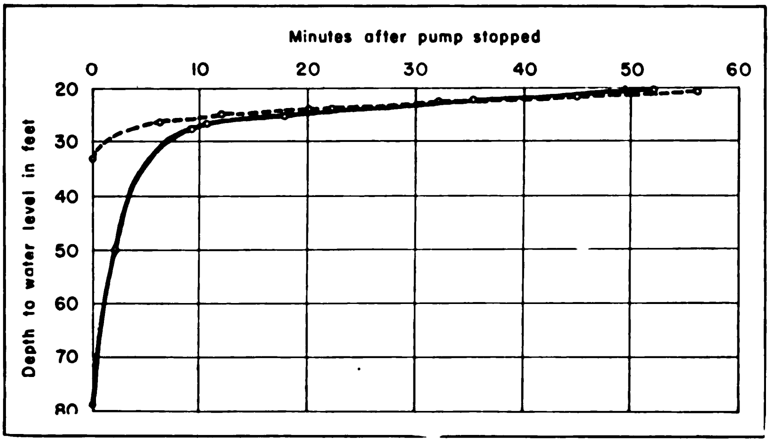

FIG. 9. Recovery curves of two of the municipal wells (244 and 245) at Meade. The solid line represents the pumped well and the dashed line an unpumped well 120 feet distant. Pump was stopped after about 4 hours of pumping. Wells located at east edge of city.

A pumping experiment on a large scale, carried out in the flowing-well area in 1909, was reported to the writer by several residents of Meade county, and is of considerable interest in a study of fluctuations caused by pumping. A 5⅝-inch artesian well was drilled to a depth of 190 feet in the SE NE sec. 6, T. 31 S., R. 27 W. This well was equipped with a centrifugal pump, and pumped for irrigation at a rate of 700 gallons a minute. After this well had been pumped for ten consecutive days, a well three quarters of a mile away ceased flowing. On August 28, 1939, the well located three-quarters of a mile from the pumped well was located and was found to have a head of 4.8 feet above the top of the discharge pipe. It is reported that the discharge pipe in 1909 was lower than it was in 1939, and the well at that time (prior to the near-by pumping) probably had a somewhat higher head than it does now. From the foregoing data it may safely be concluded that the pumping of the irrigation well during 10 days lowered the piezometric surface by more than 4.8 feet over an area of more than 1.75 square miles.

Discharge of Artesian Water

The discharge of water from the artesian water-bearing beds seems to take place in the following three ways: (1) Natural discharge at the surface from springs and seeps and by transpiration and evaporation; (2) discharge from wells by natural flow and by pumping; and (3) underground leakage.

NATURAL DISCHARGE AT THE SURFACE

Springs.—Flow from artesian springs constitutes one of the most important means of discharge of artesian water in the area. The largest springs at the present time are those south of Meade, along valleys tributary to Crooked creek from the west. The largest spring in the county, known as Big Spring, is situated on the Big Springs ranch, about 3 miles southwest of Meade. A view of the discharge channel of this spring is shown in plate 10*A*. From measurements of the cross-sectional area of the discharge channel and the surface velocity of the water the flow from this spring was determined to be about 840 gallons a minute on August 4, 1939. There are several smaller springs along this same valley. The other locality of important spring discharge is in Meade County State Park; here, three springs, located within a few hundred yards of each other, were estimated to have an aggregate discharge of about 680 gallons a minute. Several small springs occur along the western side of the Meade district, both north and south of Meade. The total annual discharge of springs in the area in 1939 was estimated to be about 2,010 gallons a minute, or about 3,240 acre-feet annually. (One acre-foot is the quantity of water required to cover one acre to a depth of one foot, or 325,851 gallons.)

Although the earlier investigators made few, if any, measurements of spring flows in this area, it is evident that since the early development there has been a marked decrease in the total discharge from artesian springs. Haworth (1897, pp. 54, 55) states that, "The most noted area of springs is in the vicinity of Mr. Simms's ranch, a mile and a half north of Fowler." He described these springs as being of such extent that cattle became bogged down in them, and sank entirely out of sight. Only small springs were found there in 1939. Haworth also notes that the springs along Spring creek, on the Big Springs and Crooked L ranches, had an approximate annual flow of 3,000 acre-feet. The total annual discharge from these springs in 1939 was estimated to be only about 1,300 acre-feet. Because of insufficient data it is impossible to determine whether or not there has been a decrease of flow from the springs in the Meade County State Park; owing to the isolated position of these springs, however, it is possible that their discharge has remained about the same during the last 40 years. In addition to the decreased flow from the important springs it is reported that the flow from numerous small springs has decreased considerably or ceased entirely.

It is estimated that the total artesian spring discharge in Meade county has decreased more than 50 percent during the last 45 years, or from more than 7,000 acre-feet a year to about 3,240 acre-feet a year in 1939.

Seepage into streams.—Several of the former springs may now constitute seepages into streams, but the quantity of artesian water discharged in this way appears to be insignificant. The most important seepages are from the body of shallow ground water and are probably supplied in part indirectly from the artesian reservoir. The quantity of artesian water discharged in this way is included in the estimate for underground leakage given below.

Transpiration and evaporation.—There seems to be little or no direct loss of artesian water by transpiration or evaporation. These processes play an important part in the discharge of shallow ground water in the county. The shallow ground water is derived mainly by leakage from the artesian reservoir, however; hence, loss of shallow ground water by transpiration and evaporation might be said to have an indirect bearing on the artesian reservoir. The quantity of water lost by this means is included in the estimate of underground leakage given below.

DISCHARGE FROM ARTESIAN WELLS

Flowing wells.—Flow measurements were made on 180 artesian wells in 1939. These measurements were made by catching the discharged water in a container of known volume—in most cases a one-gallon can—and determining with a stop watch the length of time required to fill the container. Some of the larger flows were measured in five-gallon cans and a few were measured in large drums that had been calibrated by filling from a one-gallon can. The flows were found to range from a few drops a minute to about 100 gallons a minute, and the average discharge was about seven gallons a minute. The total annual discharge from flowing wells in 1939 was about 3,230 acre-feet. In 1898 or 1899, Johnson (1901, p. 726) estimated an aggregate flow of four second feet, which would amount to 2,896 acre-feet annually. These figures indicate only a small increase in the total annual discharge from flowing wells in the area during the last 40 years.

Nonflowing wells.—Of the total discharge of artesian water in 1939, approximately 208,100,000 gallons, or about 630 acre-feet, was brought to the surface by pumping. Most of this water was pumped for municipal, industrial, and irrigation supplies. Owing to the facts that the use of pumped irrigation wells is a relatively new development in the basin, and that the quantity pumped for municipal use has increased, it seems safe to conclude that the quantity of water pumped in this area probably has increased by more than 50 percent during the last 15 years.

Relation of spring flow to well discharge.—It is estimated that the total discharge from artesian springs has decreased by more than 50 percent, or about 3,760 acre-feet annually. The total discharge from artesian wells in the area in 1939 was about 3,860 acre-feet annually (3,230 acre-feet from flowing wells plus 830 acre-feet from pumped wells). This indicates that the total discharge of artesian water in the basin in 1939 was only slightly more than the total discharge prior to the widespread development of artesian wells. This fact is particularly important in considering the relatively insignificant decline in head that seems to have occurred during this same period.

Underground Leakage

An undetermined quantity of water is discharged from the artesian water-bearing beds by upward leakage through the confining beds into the shallow-water reservoir. The fact that the upper seal in this area may not be complete was first recognized by Johnson (1901, p. 727). These confining beds are composed of silt and clay, and a small amount of water under artesian pressure probably migrates upward through them. Leakage also occurs by way of abandoned and improperly constructed wells and along minor faults and fractures produced by the irregular settling of these unconsolidated sediments in response to solution of underlying salt beds. It is probable that recent geophysical exploration for oil has added to the leaks in the upper confining beds. Holes of small diameter were drilled into the surficial deposits and charges of explosive were set off at various depths below the surface, and it is probable that in the subsequent plugging of some of these holes the confining bed was not completely sealed. Some of the natural openings through confining beds are sufficiently large to allow water to issue at the surface as springs. In such places the quantity of water discharge is measurable at the surface and is not included with the underground leakage.

SUMMARY OF DISCHARGE

It is believed that if consideration is given to the water discharged from the artesian water-bearing beds by upward leakage through the confining beds, along faults, and through defective and abandoned wells, the total annual discharge of artesian water may be estimated at about 10,000 acre-feet. The available discharge data are summarized in table 5.

TABLE 5.—*Summary of discharge of artesian water at the surface.*

	Percent of total	*Acre-feet a year*
Springs		
Utilized (Meade county State Park, etc.)	16	1,140
Wasted	30	2,100
Flowing wells		
a. Utilized (Domestic, stock, and irrigation supplies)	25	1,770
b. Wasted	20	1,460
Nonflowing wells		
Municipal and industrial supplies	5	355
Irrigation supplies	4	285
Totals	100	7,110

a. Owing to the fact that in some cases water discharged from an individual well is utilized in serveral ways it is impossible to further subdivide this quantity.

b. This quantity is probably too low as water from wells that were used most of the time was included with domestic, stock and irrigation supplies, although it is known that during part of the year this water runs to waste.

RECHARGE TO THE ARTESIAN BASIN

The general aspects of ground-water recharge in Meade county have been discussed in an earlier section. Nearly all of the recharge to the artesian water-bearing beds must occur some distance to the west and north of the basin proper; in fact, most of the recharge occurs to the west of the county in Gray, Haskell and Seward counties. On the basis of preliminary data (personal communication from B. F. Latta) there seems to be a shallow groundwater divide beneath the sand hills about 10 miles south of Garden City in Finney county. This divide probably represents the northwestern limit of the recharge area effective in replenishing the artesian-water supply in Meade county. The water table in this divide area attains an altitude approaching 2,850 feet; whereas, the altitude of the water table at the northwestern corner of Meade county is about 2,680 feet. Thus, it appears that there is a substantial gradient from southern Finney county, under Haskell county, to the artesian basin in Meade county, but that the underflow of the Arkansas valley is not a source of recharge to the artesian basin. Rain and snow falling on the surface of parts of Haskell county, southwestern Gray county, northeastern Seward county, and the southernmost part of Finney county, however, may replenish the artesian water-bearing beds.

On the basis of the foregoing, the recharge area of artesian water in the five counties involved is estimated to be of the order of 685 square miles. As the total annual discharge of artesian water is estimated to be 10,000 acre-feet, and if the recharge is assumed to be equal to the discharge, this indicates that an average recharge of about 0.27 inches may reach the water table in the areas described. Of the average annual precipitation for this area of 18 inches, therefore, possibly about 1.5 percent joins the ground-water body as a recharge. It must be remembered that this approximate quantity is an average figure and does not apply to every square mile of the area involved. In the area of sand dunes in southern Finney county and northern Haskell county the percentage is probably much greater, and in certain other parts of the area it is probably much less, and locally there may be none at all.

Although the above figures are based on the best data available at the present time, it has not been possible to draw the western limit of the recharge area exactly. That is, there is a strip of High Plains between the Cimarron valley and the sand dune area in eastern Grant county and western Haskell county that may be transmitting water eastward into this area. If this proves to be true the area of recharge should be increased and the percentage decreased. Field work has been started in Grant and Haskell counties by T. G. McLaughlin and, when completed, may supply the answer to this problem.

SHALLOW GROUND WATER IN THE ARTESIAN BASIN

Occurrence

In 1911, Parker (1911, p. 43) wrote that, "The whole artesian valley is supplied with the ordinary ground water, which is found at 5 to 15 feet below the surface. Its abundance is not known, for no one cares to use it." The shallow ground water in the Meade basin is nonartesian, or unconfined. In most wells this water does not rise above the point at which it is first encountered, and so the static water level coincides with the upper surface of the zone of saturation, or the water table.

Shallow water is obtainable over most of the area of the Meade basin (in the Meade, State Park and Big Springs ranch districts); however, there are some localities in which the surficial deposits, down to the shallowest artesian aquifer, are so fine grained that only a very small quantity of water is obtainable from wells. Shallow water also occurs in the alluvium of Cimarron valley, Sand creek valley, and Crooked creek valley.

The Water Table

Detailed information as to the position of the shallow-water table in the Meade basin was not obtained. Since the early development of artesian water in the basin very few shallow wells have been

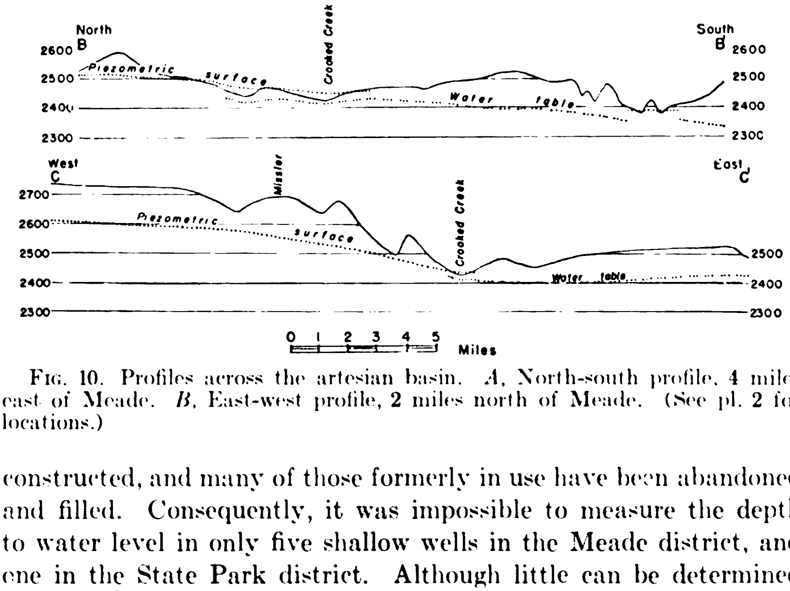

Fig. 10. Profiles across the artesian basin. *A*, North-south profile, 4 miles east of Meade. *B*, East-west profile, 2 miles north of Meade. (See pl. 2 for locations.)

constructed, and many of those formerly in use have been abandoned and filled. Consequently, it was impossible to measure the depth to water level in only five shallow wells in the Meade district, and one in the State Park district. Although little can be determined concerning the shape of the water table from these meager data, a few facts are known. In the northeastern part of the Meade district the water table lies 8 to 30 feet beneath the land surface, and the piezometric surface in most places is 10 to 15 feet above the water table. In the western and southern parts of the basin the difference in elevation of the two surfaces seems to increase. The relationship of the water table to the piezometric surface is shown in figure 10.

In the State Park district at the one well in which a shallow-water measurement was obtained, the depth to water level was 2.8 feet below the land surface, and the artesian head at the same point was 5.2 feet above the land surface.

In contrast to the piezometric surface, the shallow-water table seems to have been depressed considerably since the early settlement of the area. Residents of the area report that many shallow wells in the basin went dry before they were abandoned. Depression of the shallow-water table is also indicated by the progressive decrease of the area on which alfalfa can be grown successfully by natural subirrigation. Alfalfa was the most important crop in the Meade basin 50 years ago. The steady decline in this crop is probably attributable to the somewhat rapid lowering of the water table. The shallow-water reservoir rock has a low permeability and, as the rate of recharge is slow, the water table has seemingly not risen far, if at all, in recent years in spite of the extensive reduction in the acreage of alfalfa.

Recharge

Recharge from local precipitation.—Rainfall on the surface of the basin itself and on the upper drainage basin of Crooked creek plays an important role in recharging the shallow water of the basin. After a heavy rain, water collects in numerous shallow depressions that are scattered over the floor of the basin, and Crooked creek and its tributaries overflow into them. Although the surficial material in most places is relatively impervious and the rate of evaporation from the shallow ponds is rapid, a small part of the precipitation percolates downward, reaching the water table.

Recharge from flowing and irrigation wells.—Downward recharge by percolation of water from the surface is augmented by water discharged upon the surface by flowing wells, many of which are allowed to flow continuously throughout the year. In the irrigated areas water from deep pumped wells is spread over the surface during certain periods of the year; and, although a large part of this water is lost to the atmosphere by evaporation and transpiration, a small part of it probably reaches the water table.

Recharge by leakage through confining beds.—Upward leakage through the confining beds from the artesian aquifers appears to have been the most important source of water for replenishing the shallow water in the past. It occurs as upward migration of artesian water through the sediments themselves and through fractures, minor faults, and openings produced by drilling. Such recharge has not been sufficient to maintain the water table at the surface of the ground owing to the high friction of flow through such restricted passage ways, and the large natural discharge from the shallow water reservoir.

Discharge

Discharge by transpiration and evaporation.—At least since the settlement of the area, transpiration by plants and direct evaporation probably have accounted for a large part of the discharge from the shallow water reservoir. Most ordinary grasses and field crops obtain water for their growth from the upper few feet of soil (Meinzer, 1923a, p. 26). Corn, wheat, and barley probably do not use water from depths of more than seven feet. Alfalfa, on the other hand, develops roots that may penetrate 30 feet or, locally, even much greater depths in order to reach the water table. It is reported that in the early years of settlement alfalfa was raised over the Meade basin generally, but during the last 40 or 50 years production has declined sharply.

Discharge from wells.—Withdrawal of water by wells from the shallow water-bearing beds is quantitatively insignificant now, and probably it has never been very great. A few stock and domestic wells account for the total withdrawal of water by this means.

Seepage into streams.—The part of the total shallow water discharge, not accounted for by transpiration, evaporation, and pumpage from wells, passes as seepage into the surface streams of the area. The total quantity of water thus contributed to the surface streams is not known, but it was formerly larger than it is now. The small amount of seepage into surface streams in 1939 is indicated by the fact that parts of Crooked creek in the Meade basin are dry during part of the year. North of Fowler several fields along the valley flat of Crooked creek have been equipped with tile drainage pipes, the discharge of collected water systems emptying into the creek. The quantity of this induced seepage ranges within wide limits seasonally, but it rarely stops entirely.

RECOVERY OF GROUND WATER

All of the public water supplies and nearly all of the irrigation, domestic and stock supplies in Meade county are obtained from wells. Although a few dug and driven wells are in use, most of the wells in the county are drilled. Several types of drilling methods have been used.

Principles of Recovery

When water is withdrawn from a well there is a difference in head between the water inside the well and the water in the material outside the well. The water table or piezometric surface in the vicinity of a well that is discharging water has a depression somewhat in the form of an inverted cone with the apex at the well. Under artesian conditions this cone is imaginary and its apex is the point of discharge of the well. The draw-down and the diameter of the cone of depression, or pressure release, vary at any given well directly with the quantity of water produced from the well, and may vary considerably among several wells producing the same quantities of water. As a general rule, an artesian well producing the same quantity of water as a nonartesian well from similar material will create a cone of depression whose diameter is several times as large as that of a cone of depression developed under nonartesian conditions.

The specific capacity of a well is its rate of yield per unit of draw-down, and is usually stated in gallons a minute per foot of draw-down. Thus, a well yielding 1,000 gallons a minute with a draw-down of 10 feet would have a specific capacity of 100 gallons a minute per foot of draw-down. When a well is pumped the water level drops rapidly at first and then more slowly, but may continue to decline for several hours or days. In testing the specific capacity of a well, therefore, it is important to continue pumping until the water level remains approximately stationary. When the pump is stopped, the recovery is likewise rapid at first, but tapers off slowly and may continue long after pumping has ceased. For additional details on this subject the reader is referred to Meinzer (1923a, pp. 60-68).

Obviously, since the cost of pumping water increases with the draw-down, material saving in the cost of pumping can be effected by increasing the specific capacity of a well by modern methods of well construction.

Wells

DUG WELLS

In some parts of Meade county there are a few dug wells still in use for domestic and stock supplies. Many of these are quite shallow and obtain meager supplies of water from alluvium along minor stream valleys. Because of their large diameter, dug wells provide large infiltration area and considerable storage of water. They are more apt to fail during dry seasons and are more subject to contamination, however, than the deeper drilled wells. Most dug wells for domestic or stock use are from 2 to 4 feet in diameter and are curbed with stone or wood. One well (215) was dug to the first artesian water-bearing bed, and so has the characteristics of an artesian well.

BORED WELLS

Some of the shallow wells in loose surficial material, such as well 39, have been bored by use of a hand auger. Most of these wells were bored to the water table or a short distance below it and then a screened well point was driven into the bottom. In some wells a 6-inch galvanized-iron casing is placed in the bored part of the well, but in others the walls of the hole are allowed to cave in around the pipe.

DRILLED WELLS

Methods of construction.—Most of the drilled wells in Meade county have been constructed by one of three methods, namely: cable-tool percussion, hydraulic-rotary, or a modified hydraulic jetting method. All of these methods have been used in conjunction with hand augering through the loose surficial material.

Portable cable-tool percussion or "spudding" machines employ a heavy chisel-edged drill bit or other tool suspended by a rope or cable to which a reciprocating motion is imparted by the drilling machine. The drill crushes the rock into small fragments and churns it into suspension in the water that is poured into the well, if water is not encountered in the formation that is being drilled. At intervals the drilling cuttings and sludge are removed from the hole with a bailer or sand pumps. Drilled water wells range in diameter from 4 to 12 inches or more, but wells for domestic and stock use commonly are 6 inches in diameter. Most of the wells drilled into the Permian redbeds and some of the wells in the Tertiary and Quaternary deposits were put down by this method.

In the hydraulic-rotary method a hollow drill stem equipped with a cutting bit is rotated in the hole, and either water or mud is forced down the stem and out of the bit, thus creating an upward circulation of fluid along the sides of the hole which carries the cuttings to the surface. The mud also serves to prevent caving of loose materials until the casing is placed. The diameter of wells drilled by this method ranges from 1½ inches to 2 feet or more. Many of the irrigation wells of large diameter were drilled by this method.

A somewhat specialized type of jetting process was used extensively during the period of maximum drilling activity in the artesian basin, and is still used to a lesser extent in the basin and on the adjacent High Plains. The homemade equipment used is capable of penetrating only relatively unconsolidated deposits. In this process joints of galvanized-iron pipe 1½ or 2 inches in diameter generally are used for the drill stem, and a bit is fitted onto the lower end. Water is pumped down the stem; and, in contrast to the hydraulic-rotary method, the jet of water against the bottom of the hole is an important factor in loosening the material, which is carried to the surface by the upward moving column of water between the stem and the sides of the hole. The drill stem generally is alternately raised and lowered, and rotated in the hole, thus aiding the force of the water in loosening material at the bottom. After the holes are completed about 30 feet of casing generally is driven into place, but many of the wells drilled by this method have no outer casing, particularly the early wells in the artesian basin. There are better methods for jetting wells through the inside of the casing, adding sections of casing as the hole is deepened. The completed hole is thus cased to the bottom and may be screened at the bottom.

Wells in consolidated rocks.—The wells in this area that obtain water from the consolidated Permian rocks are cased through the overlying unconsolidated deposits or weathered rock, and the casing generally is driven several feet or more into the bedrock. Thus, the water may enter the well along its entire uncased portion wherever the rock is water-bearing. Wells finished in this way are called open-end wells because the water enters only below the lower end of the casing. A few of the wells ending in bedrock in Meade county have been cased to their full depth and have perforated casing in the lower part.

Wells in unconsolidated deposits.—Many of the wells in unconsolidated deposits in Meade county were constructed by drilling or boring a hole a short distance below the water table, setting a casing of galvanized iron, and driving a screened well point some distance below the bottom of the hole. Many of the early flowing wells were cased only at the top, although more recently the usual practice has been to case the full depth and to perforate the lower part of the casing.

Several methods have been used to increase the intake area in nonflowing wells and thus increase the yield. The simplest of these methods is to perforate those portions of the casing that are opposite the water-bearing beds. In order to know where to perforate the casing and to permit the selection of the proper size for the perforations, samples of material should be taken every few feet as drilling progresses, and the depth and thickness of water-bearing beds carefully recorded. A more efficient method of increasing the intake area of a well is by the use of well screens. Well screens (or strainers) are manufactured in many different types and sizes. The grain size of the water-bearing material determines the size of openings to be used in the screen. In places where large supplies of water are sought from material not sufficiently coarse to be held back by the screen, a layer of coarser material may be placed around the screen either artificially or by pumping out the finer particles of water-bearing materials, leaving a residual layer of natural gravel. Most so-called gravel-wall or gravel-packed wells in Meade county are constructed by first drilling a somewhat larger hole (30 to 60 inches in diameter) and temporarily casing to the bottom; an inner screen and casing of smaller diameter is lowered into place; the annular space between the two casings is filled with selected gravel of uniform texture; and the outer casing is withdrawn all or part way. The effective diameter of the well is thus greatly increased by the layer of gravel which itself acts as a screen to reduce the entrance velocity and permit the entrance of large supplies of water. It should be remembered that the only advantage attained by this method is to increase the permeability of the material adjacent to the screen; and, where water is supplied from well-sorted gravel, as it is in many parts of Meade county, the addition of gravel around the screen merely increases the cost of construction without increasing the effectiveness of the well.

METHODS OF LIFT AND TYPES OF PUMPS

Water is obtained from many of the domestic and stock wells in Meade county by windmill-operated lift or force pumps. The cylinders or working barrels in lift pumps and force pumps are similar and are located below the land surface either above or below the water surface, but a lift pump is capable of discharging water only at the pump head, whereas a force pump can raise water above this point—as to an elevated tank. Pitcher pumps are used on some dug or bored wells where the water level is within the suction limit. Most of the pitcher pumps and a few of the lift and force pumps are hand operated.

Several types of power-driven pumps are in use on the irrigation and municipal wells in the county. These pumps are, without exception, turbine pumps and are powered by electric motors, stationary gasoline engines and tractor engines. Several large centrifugal pumps have been used in the past, and municipal wells of the city of Meade formerly were pumped by air lift.

Most of the flowing artesian wells are not equipped with pumps, but a few are pumped in order to obtain a larger yield than is obtained by natural flow. Most of the flowing wells discharge onto the surface, into tanks, or are connected with individual home water systems.

Springs

In Meade county a few domestic and stock supplies and some irrigation supplies formerly were derived from springs. In 1939, however, spring water was used extensively only in Meade County State Park, where it supplied the C. C. C. Camp, hatchery ponds, and some irrigation water used on the grounds of the park.

Most of the springs in the county are artesian springs, from which the water issues under artesian pressure. There are also a few gravity springs, however, particularly in the southeastern part of the county, where water issues from the base of the Tertiary deposits where they overlie relatively impervious Permian rocks, and along Crooked creek, where seepages occur from the body of shallow ground water into the stream. With respect to the quantity of water discharged, Meinzer (1923a, p. 53) has devised the following classification of springs for convenient use in the United States.

TABLE 6.—*Meinzer's classification of springs with respect to discharge.*

Magnitude.	Discharge.	Magnitude.	Discharge.
First......	100 second-feet or more	Fifth.....	10 to 100 gallons a minute
Second.....	10 to 100 second-feet	Sixth....	1 to 10 gallons a minute
Third......	1 to 10 second-feet	Seventh..	1 pint to 1 gallon a minute
Fourth.....	100 gallons a minute to 1 second-foot (448.8 gallons a minute)	Eighth...	Less than 1 pint a minute (less than 180 gallons or about 5 barrels a day)

In Meade county there are no springs of first or second magnitude, but one spring on Big Springs ranch, which has a discharge of 840 gallons a minute, and the springs in Meade County State Park, which have an aggregate yield of about 680 gallons a minute, are of third magnitude. The other springs in the county are of fourth magnitude and less.

UTILIZATION OF WATER

Domestic and Stock Supplies

Nearly all of the domestic and stock supplies in rural areas are obtained from wells and springs. Formerly springs and dug wells were the most important source of this water but, for the last 50 years or more, bored wells, and particularly drilled wells, have been relied upon extensively. Dug wells have passed out of use because of the great depth to water in the upland areas, and because they are more subject to pollution and are apt to fail during dry weather. Practically all new wells put down in the county are drilled.

The domestic use of water generally includes drinking, cooking, washing, and, in modern houses, the disposal of sewage. Water from some wells or springs may be dangerously polluted and care should be taken to avoid such water or remove the source of pollution. In Meade county the ground waters are generally satisfactory for all domestic purposes, although some contain an objectionable amount of hardness that makes them unsuitable for washing (see "Quality of Water").

On a few farms and ranches in the county small streams and springs furnish adequate livestock supplies. Most ranchers, however, must rely upon wells for stock water, at least during part of the year. Ground water in sufficient quantity and of adequate quality for stock use can be obtained from nearly any locality in Meade county.

Public Supplies

Three municipalities in Meade county have public water supplies, and all rely exclusively upon ground water.

Meade, the county seat and largest city, is supplied by two gravel-wall wells (244 and 245) situated in the valley of Crooked creek, which are operated by electrically driven turbine pumps. Water is pumped from the wells into two brick reservoirs below the surface of the ground, and from there it is pumped directly into the mains—the excess going to an elevated steel tank. The aggregate capacity of the three reservoirs is 380,000 gallons. The water is untreated and has a total hardness of 178 parts per million, as indicated by the analysis of water from wells 244 and 245, given in table 7. The average daily consumption of water at Meade is about 154,000 gallons.

The city of Fowler is supplied by two gravel-wall wells (116 and 117), situated at the north city limit, which are operated by elec-

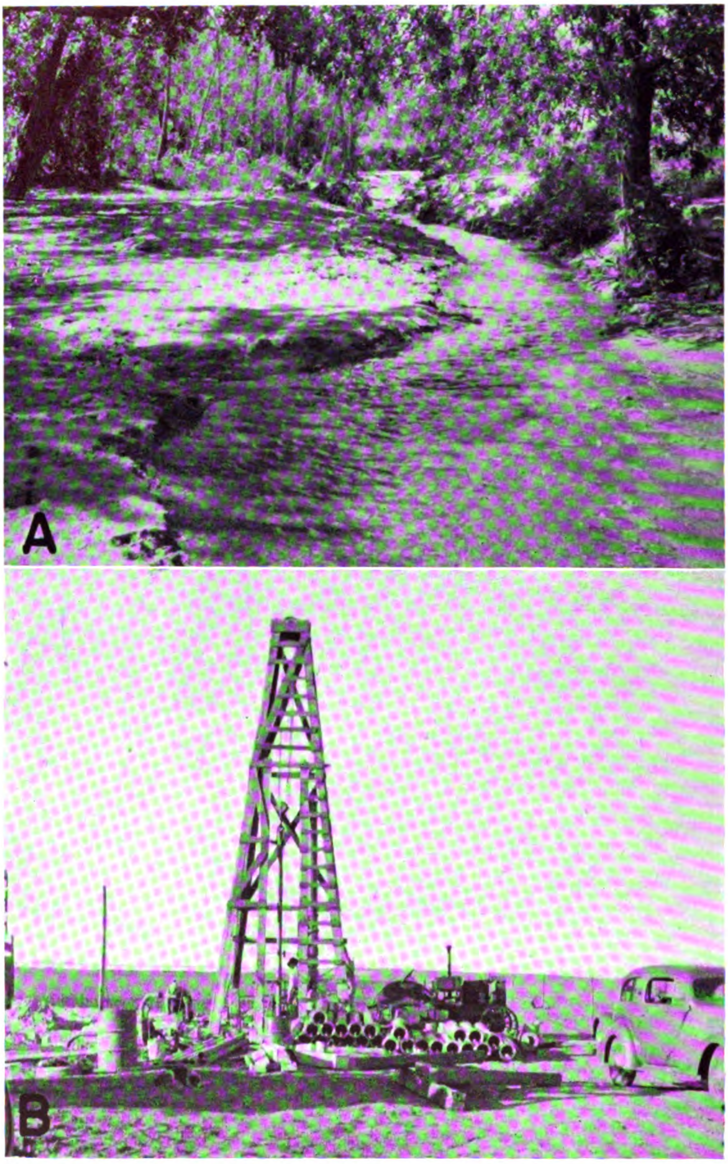

PLATE 10. *A,* Discharge channel of spring on Big Springs ranch, southwest of Meade. Discharge from spring is about 840 gallons a minute. *B,* Construction of typical High Plains irrigation well. This well is located on the farm of C. W. Holmes, NE sec. 32, T. 32 S., R. 30 W.

trically driven turbine pumps. Water is pumped from the wells into the mains, the excess going to a standpipe that holds 70,000 gallons. The water is untreated and has a total hardness of 202 parts per million, as indicated by the analysis of water from wells 116, 117 in table 7. The average daily consumption of water at Fowler is about 83,000 gallons.

The city of Plains is supplied by one gravel-wall well (269) situated on the High Plains in the southwestern part of town, which is operated by an electrically driven turbine pump. Water is pumped from the well into the mains, the excess going to an elevated storage tank that holds 50,000 gallons. The water is untreated and has a total hardness of 702 parts per million, as indicated by the analysis of the water from well 269 in table 7. The average daily consumption of water at Plains is about 29,000 gallons.

The total annual pumpage of ground water for public supplies in Meade county is nearly 360 acre-feet, of which approximately 200 acre-feet is pumped at Meade, 90 acre-feet at Fowler, and 70 acre-feet at Plains. These figures include water sold by the cities for railroad and industrial use.

IRRIGATION SUPPLIES

Water for irrigation may be obtained in several ways in Meade county: by diversion from streams, by pumping from streams, from large springs, from flowing wells, and from pumped wells. In Meade county most of the irrigation water is obtained from flowing wells and pumped wells. Irrigation from flowing wells is carried out only on a relatively small scale, as discussed in the section on artesian water; therefore, the following discussion pertains largely to irrigation from pumped wells. For information concerning the construction and cost of irrigation plants the reader is referred to Davison (1939).

UPLAND AREAS

In 1939 only one large irrigation well (272) was in operation on the High Plains. This well was constructed in 1939 on the C. W. Holmes farm (see pls. 8*B* and 10*B*). It is a gravel-wall well, 18 inches in diameter and 230 feet deep, and the static water level before pumping started was 160 feet below land surface. The well is equipped with a turbine pump powered by a tractor engine, and is reported to yield 450 gallons a minute. This well may prove to be of value in demonstrating whether or not irrigation from wells is practicable in this part of the High Plains.

ARTESIAN BASIN

During the last 14 years irrigation from large pumped wells has received some impetus in the nonflowing part of the artesian basin. During this period eight nonflowing artesian wells of large diameter (including wells 7, 9, 16, 24, 38, 194, and 297) and one flowing well (55) of large diameter have been put into operation and pumped somewhat for irrigation. Nearly all are gravel-wall wells equipped with turbine pumps and powered by gasoline engines.

POSSIBILITIES OF DEVELOPING ADDITIONAL IRRIGATION SUPPLIES

Upland areas.—The future development of irrigation from wells on the High Plains in the northwestern part of the county is largely a matter of economics. Over most of this area an adequate supply of water for irrigation is available to properly constructed wells drilled to a depth of 300 feet or more, but the pumping lift over most of the northwestern part of the county would be in excess of 150 feet, and so it might not be economically profitable to pump water for irrigation except under special conditions.

The upland area east of Crooked creek, in the east-central part of the county, presents much the same problem as the northwestern part, except in this area the thickness of water-bearing gravel is much less, and so one or more test holes generally are needed in order to determine whether or not an adequate supply of water for irrigation is available.

Artesian basin.—During the last several years irrigation from pumped wells has proved to be a profitable venture in certain areas in southwestern Kansas, and in this and adjacent areas the number of irrigation wells and the quantity of water pumped have been increasing. For this reason it is desirable to discuss briefly the probable future ground-water supply of the artesian basin. As pointed out above, during the last 40 years the decline in head seems to have been small and the total discharge of artesian water on the surface seems to have remained nearly constant. It is evident that the maximum quantity of water obtainable in the basin, from wells and springs, without depressing the head sufficiently to restrict the area of artesian flow appreciably, is only about equal to the present total discharge, or about 7,100 acre-feet annually. It has been demonstrated that large-scale pumping in the flowing well area depresses the piezometric surface for a considerable distance around a pumped well. If a large number of pumped wells were installed, it seems altogether possible that the head of the artesian water would be depressed sufficiently to cause all flows in the basin to cease.

The question now arises as to the probable quantity of water available under such conditions of heavy pumping. As pointed out above, the total recharge of the artesian aquifers is equivalent to the total discharge at the surface plus the underground leakage into the body of shallow ground water. This leakage is subsequently lost by transpiration, evaporation, seepage into streams, and, to a very small extent, by pumping. Thus, the maximum quantity of water that could be recovered perennially by pumping from the artesian aquifers is represented by the total surface discharge from wells and springs at the present time plus the quantity lost by underground leakage. This quantity of water appears to be of the order of magnitude of 10,000 acre-feet a year. During the initial stage of such a pumping program withdrawal of water from storage would make a somewhat larger quantity available, but added supply probably could be obtained for a short period of years only.

In considering future irrigation development it should be pointed out that about 3,550 acre-feet of the water a year is now discharged upon the surface by springs and wells and is not used. If this water were all conserved and utilized for irrigation at the same rate as in the extensive irrigation projects in Ford county (average 1.69 acre-feet per acre in 1938, according to personal communication from H. A. Waite), an additional 2,000 acres could be irrigated. On the other hand, it is estimated that if the maximum yield of the area were attained by increased pumping from wells, an additional 4,000 acres could be irrigated—or 2,000 acres more than by use of all existing natural flows. In order to recover this additional quantity of water, however, the piezometric surface would of necessity be lowered enough not only to stop all of the flowing wells but also to stop upward leakage into the shallow water. As has been pointed out, this upward leakage is probably the most important source of recharge to the shallow water reservoir, and therefore this procedure would lower the shallow water table considerably. Before any such development is undertaken in the basin, the possible effect of the lowering of the shallow-water table on crops grown by natural subirrigation should be studied.

The figures for maximum number of acres that could be irrigated by the water now wasted and by additional water that could be made available by a large-scale pumping plan are based on the assumption of complete conservation of the water. I am well aware of the fact that complete utilization of the water in this area is hardly possible, and therefore these estimates of acreages should be regarded as maxima that probably could not be attained in practice.

QUALITY OF WATER

The chemical character of the ground waters in Meade county is shown by the analyses given in table 7. The analyses were made by Robert H. Hess and Elza O. Holmes in the Water and Sewage Laboratory of the Kansas State Board of Health. Forty-four samples of water were collected from representative wells in all parts of the county but mainly from wells in the Meade artesian basin. Most of the wells sampled derived their water from the Ogallala or Meade formations or from alluvium, but a few of the wells tapped the Permian, Laverne, and Kingsdown formations. In addition, three samples of surface water (A, B, and C) were collected, and analyses of water pumped for public supplies at Fowler, Meade, and Plains have been supplied by the State Board of Health.

The fluoride content of the waters was determined by the Modified Sanchis method, and the other constituents given were determined by the methods used by the U. S. Geological Survey.

Chemical Constituents in Relation to Use

The following discussion of the chemical constituents of ground water has been adapted from publications of the United States Geological Survey.

Total dissolved solids.—The residue left after a natural water has evaporated consists of rock materials with which may be included some organic material and a little water of crystallization. Waters with less than 500 parts per million of dissolved solids generally are entirely satisfactory for domestic use, except for the difficulties resulting from their hardness and, in some areas, because of excessive iron corrosiveness. Waters having more than 1,000 parts per million are likely to contain enough of certain constituents to produce a noticeable taste or to make the water unsuitable in some other respects.

The concentration of total dissolved solids in well waters collected in Meade county ranged from 190 to 2,169 parts per million. The waters from all but five of the wells contained less than 500 parts per million of dissolved solids, however, and are suitable for most ordinary purposes. Five wells yielded waters containing between 500 and 1,000 parts per million of dissolved solids, and the water from one well (160) contained more than 1,000 parts.

Hardness.—The hardness of water is the property that generally receives the most attention, and it is commonly recognized by its

TABLE 7.—*Analyses of water from typical wells in Meade county, Kansas*

(Analyzed by Robert H. Hess and Elza O. Holmes *a*. Dissolved constituent given in parts per million *b*. Reacting values (in italics) given in equivalents per million.)

No. on Plate 2.	Location, Depth, and Source.	Date of collection	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)*c*	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total dissolved solids	Hardness (calculated as $CaCO_3$). Total	Carbonate	Noncarbonate
	T. 30 S., R. 26 W.															
1	NE NE sec. 3, 190 feet, Ogallala	9-6-39	60	*d*	63 *3.09*	21 *1.73*	14 *.61*	273 *4.48*	33 *.69*	6.0 *.17*	0.2 *.04*	31 *.05*	276	241	224	17
2	NE NW sec. 3, 110 feet, Ogallala	9-6-39	59	*d*	59 *2.94*	18 *1.48*	18 *.79*	268 *4.40*	26 *.54*	6 *.17*	.8 *.04*	3.5 *.06*	265	221	220	1
9	NW SW sec. 5, 210 feet, Ogallala	9-20-40	60	0.29 *.01*	55 *2.75*	15 *1.23*	11 *.46*	216 *3.54*	29 *.60*	7.5 *.21*	.6 *.03*	3.8 *.06*	320	200	177	23
15	SW NW sec. 16, 150 feet, Ogallala	9-6-39	59	*d*	44 *2.20*	26 *2.14*	15 *.65*	245 *4.02*	33 *.69*	7 *.20*	.7 *.04*	2.7 *.04*	251	217	201	16
23	SW SE sec. 35, 101 feet, Ogallala	9-7-39	60	.82 *.03*	60 *2.90*	11 *.90*	30 *1.29*	259 *4.25*	19 *.40*	14 *.39*	.1 *.01*	8 *.13*	272	196	*c*196	0
	T. 30 S., R. 27 W.															
28	SE SE sec. 8, 57 feet, Meade	9-8-39	61	6.5 *.23*	66 *3.29*	25 *2.06*	21 *.92*	254 *4.17*	79 *1.64*	11 *.31*	1.1 *.06*	5.3 *.09*	342	279	208	71
38	NW NE sec. 23, 290 feet, Meade and Ogallala.	9-7-39	61	*d*	46 *2.30*	12 *.99*	23 *.99*	193 *3.16*	37 *.77*	5.5 *.16*	.5 *.03*	9.7 *.16*	230	165	158	7
39	NW NW sec. 24, 30 feet, Kingsdown	9-7-39	59	.62 *.02*	103 *5.14*	21 *1.73*	26 *1.13*	373 *6.12*	54 *1.12*	22 *.62*	1.1 *.06*	4.9 *.08*	419	345	306	39
57	NE NE sec. 29, 200 feet, Meade and Ogallala.	9-6-39	60	*d*	47 *2.35*	12 *.99*	12 *.52*	195 *3.20*	14 *.29*	6.5 *.18*	.6 *.03*	10 *.16*	200	167	160	7
81	SE SW sec. 33, 160 feet, Meade	9-6-39	60	*d*	48 *2.40*	13 *1.07*	15 *.65*	200 *3.28*	20 *.42*	7.0 *.20*	.7 *.04*	9.7 *.16*	213	174	164	10
	T. 30 S., R. 28 W.															
91	SW SW sec. 25, 175 feet, Meade	9-6-39	62	*d*	47 *2.35*	12 *.99*	18 *.79*	193 *3.16*	28 *.58*	6 *.17*	.7 *.04*	11 *.18*	219	167	158	9
	T. 30 S., R. 29 W.															
107	NW NW NE sec. 3, 90 feet, Meade or Ogallala.	9-14-40	62	.45 *.02*	48 *2.40*	16 *1.32*	2.5 *.11*	210 *3.44*	10 *.21*	2 *.06*	.5 *.03*	5.3 *.09*	190	187	172	15

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Table 7.—Analyses of water from typical wells in Meade county, Kansas—*Continued*

No. on Plate 2.	LOCATION, DEPTH, AND SOURCE.	Date of collection	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)c	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total dissolved solids	Hardness (calculated as $CaCO_3$). Total	Carbonate	Noncarbonate
	T. 31 S., R. 26 W.															
116–117f	NW NW sec. 6, 275 feet, Ogallala	9–25–40	....	d	53 *2.65*	17 *1.40*	10 *.45*	225 *3.69*	28 *.58*	5 *.14*	.7 *.04*	3.1 *.05*	229	202	184	18
	T. 31 S., R. 27 W.															
157	NW SE sec. 11, 200 feet, Meade and Ogallala.	9–6–39	60	d	46 *2.30*	12 *.99*	19 *.83*	188 *3.08*	33 *.69*	6 *.17*	.8 *.04*	8.8 *.14*	220	165	154	11
160	NW NE sec. 14, 22 feet, Alluvium and Kingsdown.	8–15–40	58	d	238 *11.88*	74 *6.08*	390 *16.94*	337 *5.53*	951 *19.78*	325 *9.17*	1.5 *.08*	21 *.34*	2,169	898	276	622
165	SE SE sec. 17, 100 feet, Meade	9–11–39	60	d	47 *2.35*	12 *.99*	18 *.79*	193 *3.16*	33 *.69*	4.5 *.13*	.8 *.04*	7.1 *.11*	219	167	158	9
	T. 31 S., R. 28 W.															
179	NE NE sec. 12, 175 feet, Meade and Ogallala.	9–6–39	61	d	51 *2.54*	14 *1.15*	12 *.53*	209 *3.43*	18 *.37*	8 *.23*	.6 *.03*	10 *.16*	218	185	171	14
197	NE NW sec. 24, 186 feet, Ogallala	9–6–39	63	d	47 *2.35*	12 *.99*	14 *.61*	200 *3.28*	18 *.37*	5.0 *.14*	.6 *.03*	8 *.13*	205	167	164	3
210	NE SW sec. 35, 150 feet, Ogallala	9–6–39	75?	d	49 *2.45*	12 *.99*	11 *.47*	200 *3.28*	17 *.35*	4.5 *.13*	.7 *.04*	6.6 *.11*	201	172	164	8
	T. 31 S., R. 29 W.															
217	SE SE sec. 6, 130 feet, Ogallala	8–20–40	60	2.9 *.10*	49 *2.45*	12 *.99*	16 *.69*	190 *3.12*	33 *.69*	7 *.20*	.5 *.03*	5.8 *.09*	221	177	156	21
	T. 31 S., R. 30 W.															
222	NW SW sec. 4, 163 feet, Ogallala	8–30–40	61	1.5 *.05*	48 *2.40*	12 *.99*	16 *.71*	181 *2.97*	38 *.79*	8.5 *.24*	.7 *.04*	4.0 *.06*	219	172	148	24
	T. 32 S., R. 26 W.															
225	SE SW sec. 3, 36 feet, Alluvium	9–7–39	61	7.1 *.25*	66 *3.29*	15 *1.23*	15 *.63*	223 *3.66*	29 *.60*	19 *.54*	.8 *.04*	19 *.31*	282	239	183	56
229	NW NW sec. 25, 10 feet, Alluvium	9–11–40	67	.8 *.03*	63 *3.14*	15 *1.23*	7.6 *.33*	227 *3.72*	5.1 *.11*	5.0 *.14*	.7 *.04*	43 *.69*	254	220	186	34
	T. 32 S., R. 27 W.															
233	SE NE sec. 5, 113 feet, Ogallala	9–11–39	61	5.0 *.18*	56 *2.79*	21 *1.73*	46 *2.01*	217 *3.56*	65 *1.35*	51 *1.44*	1.3 *.07*	7.1 *.11*	361	235	178	57

Table 7.—Analyses of water from typical wells in Meade county, Kansas—*Continued*

No. on Plate 2.	Location, Depth, and Source.	Date of collection	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)c	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total dissolved solids	Hardness (calculated as $CaCO_3$). Total	Carbonate	Noncarbonate
	T. 32 S., R. 28 W.															
214-245g	NW NE sec. 11, 285 feet, Meade and Ogallala.	1-9-41	....	d	50 *2.50*	13 *1.07*	29 *1.24*	189 *3.10*	35 *.73*	31 *.87*	.7 *.04*	4.4 *.07*	258	178	155	23
246	NW NW sec. 13, 85 feet, Ogallala	9-8-39	62	d	41 *2.05*	13 *1.07*	15 *.66*	189 *3.10*	16 *.33*	6 *.17*	.9 *.05*	8 *.13*	194	156	155	1
247	SW NE sec. 14, 140 feet, Ogallala	9 7-39	60	d	51 *2.54*	12 *.99*	17 *.74*	207 *3.39*	27 *.56*	6 *.17*	.8 *.04*	7.1 *.11*	224	177	170	7
264	NE NW sec. 10, 145 feet, Ogallala	9-9-39	61	6.6 *.24*	57 *2.84*	17 *1.40*	12 *.53*	237 *3.89*	28 *.58*	75 *.21*	.7 *.04*	3.1 *.05*	250	224	194	30
	T. 32 S., R. 29 W.															
265	SW SE sec. 15, 185 feet Ogallala	9-6-40	67	2 *.07*	55 *2.75*	12 *.99*	15 *.67*	206 *3.38*	39 *.81*	4.5 *.13*	.6 *.03*	3.8 *.06*	235	191	170	21
	T. 32 S., R. 30 W.															
269h	SE SW sec. 16, 265 feet, Ogallala	2-5-41	....	d	49 *2.45*	15 *1.23*	22 *.97*	190 *3.12*	57 *1.19*	7 *.20*	.8 *.04*	6.2 *.10*	252	184	156	28
	T. 33 S., R. 26 W.															
276	NE SE sec. 16, 29 feet, Alluvium	9-11-40	63	.63 *.02*	104 *5.19*	34 *2.80*	107 *4.65*	286 *4.69*	60 *1.25*	215 *6.06*	.9 *.05*	37 *.59*	702	401	234	167
	T. 33 S., R. 27 W.															
280	NW NW sec. 4, 44 feet, Meade	9-11-39	60	1.3 *.05*	59 *2.94*	20 *1.64*	20 *.87*	268 *4.40*	26 *.54*	11 *.31*	1.8 *.09*	7.1 *.11*	280	232	220	12
	T. 33 S., R. 28 W.															
289	Cen. N line NE sec. 4, 75 feet, Meade and Ogallala.	9-9-39	61	d	49 *2.45*	14 *1.15*	15 *.64*	199 *3.26*	31 *.64*	8 *.23*	.8 *.04*	4.4 *.07*	222	180	163	17
291	SE SE sec. 14, 153 feet, Ogallala and Permian.	9-8-39	61	.30 *.01*	31 *1.55*	12 *.99*	267 *11.63*	246 *4.03*	85 *1.77*	289 *8.15*	2.0 *.11*	6.6 *.11*	816	128	j 128	0
299	SE NE sec. 31, 63 feet, Ogallala	9-6-39	64	d	61 *3.04*	19 *1.56*	228 *9.91*	228 *3.74*	84 *1.75*	315 *8.88*	.9 *.05*	5.3 *.09*	827	320	187	43

Table 7.—Analyses of water from typical wells in Meade county, Kansas—*Continued*

No. on Plate 2.	Location, Depth, and Source.	Date of collection	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)c	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total dissolved solids	Hardness (calculated as $CaCO_3$). Total	Carbonate	Noncarbonate
	T. 33 S., R. 29 W.															
312	NW NW sec. 24, 59 feet, Ogallala	8-15-40	62	d	52 *2.59*	15 *1.23*	13 *.57*	212 *3.48*	28 *.58*	8.5 *.24*	.7 *.04*	2.9 *.05*	226	191	174	17
	T. 33 S., R. 30 W.															
319	NE SW sec. 31, 206 feet, Ogallala and Laverne.	8-27-40	63	1.2 *.04*	61 *3.04*	16 *1.32*	25 *1.07*	244 *4.00*	53 *1.10*	8 *.23*	.8 *.04*	3.5 *.06*	291	220	200	20
	T. 34 S., R. 26 W.															
321	NW SW sec. 24, 109 feet, Permian	8-19-40	61	.31 *.01*	51 *2.54*	32 *2.63*	15 *.67*	244 *4.00*	51 *1.06*	22 *.62*	1.8 *.09*	4.4 *.07*	300	259	200	59
	T. 34 S., R. 27 W.															
325	SW SE sec. 7, 32 feet, Meade	9-11-40	65	.53 *.02*	67 *3.34*	19 *1.56*	71 *3.08*	267 *4.38*	45 *.94*	92 *2.59*	.9 *.05*	1.1 *.02*	430	246	219	27
327	SE NE sec. 23, 98 feet, Ogallala	9-11-40	61	.81 *.03*	57 *2.84*	19 *1.56*	2.8 *.12*	232 *3.81*	15 *.31*	10 *.28*	1.5 *.08*	2.2 *.04*	224	222	190	32
329	SW SW sec. 33, 122 feet, Meade and Ogallala.	9-4-40	62	.80 *.03*	101 *5.04*	34 *2.80*	95 *4.12*	346 *5.67*	261 *5.43*	27 *.76*	.6 *.03*	4.2 *.07*	697	394	283	111
	T. 34 S., R. 28 W.															
333	SE NW sec. 19, 154 feet, Meade	8-31-40	62	8 *.29*	70 *3.49*	31 *2.55*	58 *2.53*	225 *3.69*	115 *3.22*	53 *1.50*	1.7 *.09*	3.5 *.06*	493	317	184	133
334	NE NE sec. 34, 23 feet, Meade	8-15-40	61	.57 *.02*	89 *4.44*	29 *2.38*	34 *1.48*	415 *6.81*	30 *.62*	25 *.71*	1.1 *.06*	6.2 *.10*	422	342	340	2
	T. 34 S., R. 30 W.															
341	NE NE sec. 26, 220 feet, Ogallala	8-29-40	64	2.1 *.08*	56 *2.79*	16 *1.32*	20 *.87*	203 *3.33*	61 *1.27*	10 *.28*	.8 *.04*	3.8 *.06*	271	210	166	44
	T. 35 S., R. 26 W.															
344	SE NW sec. 4, 80 feet, Ogallala and Permian.	9-6-40	62	.15 *.01*	147 *7.34*	25 *2.06*	29 *1.28*	205 *3.36*	99 *2.06*	176 *4.96*	.4 *.02*	17 *.28*	596	471	168	303
	T. 35 S., R. 27 W.															
347	SW NE sec. 11, 140 feet, Ogallala	9-17-40	62	d	56 *2.79*	10 *.82*	32 *1.39*	250 *4.10*	22 *.46*	12 *.34*	.7 *.04*	3.5 *.06*	261	181	k181	0

Table 7.—Analyses of water from typical wells in Meade County, Kansas—*Concluded*

No. on Plate 2.	Location, Depth, and Source.	Date of collection	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)c	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total dissolved solids	Hardness (calculated as $CaCO_3$). Total	Carbonate	Noncarbonate
	T. 35 S., R. 30 W.															
354	SW SW sec. 10, 57 feet, Alluvium	8-29-40	64	1.1 *.04*	62 *3.09*	18 *1.48*	55 *2.41*	203 *3.36*	75 *1.56*	69 *1.95*	.9 *.05*	3.3 *.06*	387	231	168	63
	T. 32 S., R. 28 W.															
A	SE SE sec. 14, from "Meade Salt sink,' composite of top 4 feet of water.	9-6-40	74	.36 *.01*	39 *1.95*	8.8 *.72*	32 *1.41*	183 *3*	6 *.13*	30 *.85*	1.5 *.08*	1.3 *.02*	211	134	134	0
	T. 33 S., R. 29 W.															
B	SE sec. 15, spring in Meade County State Park.	8-16-40	61	*e*	52 *2.59*	15 *1.23*	17 *.75*	199 *3.26*	46 *.96*	9 *.25*	.8 *.04*	3.8 *.06*	243	191	163	28
	T. 35 S., R. 26 W.															
C	NE NE sec. 4, sample from sink-hole lake, composite of top 3 ft. of water.	9-16-40	75	1 *.04*	22 *1.10*	5.4 *.44*	5.3 *.23*	105 *1.72*	.4 *.01*	0 *0*	.3 *.02*	1.3 *.02*	88	79	*l* 79	0

a. Analyses of samples 1, 2, 15, 23, 28, 38, 39, 57, 81, 91, 157, 160, 165, 179, 197, 210, 217, 225, 233, 246, 247, 264, 280, 289, 296, 299, 312, 321, 334, and B were made by Robert H. Hess; and analyses of samples 9, 107, 116-117, 222, 229, 244-245, 265, 269, 276, 319, 325, 327, 329, 333, 341, 344, 347, 354, A, and C were made by Elza O. Holmes.

b. One part per million is equivalent to 1 pound of substance per million pounds of water or 8.33 pounds per million gallons of water.

c. Calculated.

d. Less than 0.15 part.

e. Total alkalinity, 212 parts per million; excess alkalinity, 16 parts per million.

f. Composite sample from two mills collected from tap at Fowler city water plant.

g. Composite sample from two wells collected from tap at Meade city water plant.

h. Sample collected from Plains city water tank.

j. Total alkalinity, 202 parts per million; excess alkalinity, 74 parts per million.

k. Total alkalinity, 205 parts per million; excess alkalinity, 24 parts per million.

l. Total alkalinity, 86 parts per million; excess alkalinity, 7 parts per million.

effects when soap is used with the water in washing. Calcium and magnesium cause practically all the hardness of ordinary waters. These constituents are also the active agents in the formation of the greater part of all the scale formed in steam boilers and in other vessels in which water is heated or evaporated.

In addition to the total hardness, the table of analyses shows the carbonate hardness and the noncarbonate hardness. The carbonate hardness is that due to the presence of calcium and magnesium bicarbonates. It is removed almost completely by boiling. In some reports this type of hardness is called temporary hardness. The noncarbonate hardness is due to the presence of sulphates or chlorides of calcium and magnesium, but it can not be removed by boiling and has sometimes been called permanent hardness. With reference to use with soap, there is no difference between the carbonate and noncarbonate hardness. In general, the noncarbonate hardness forms harder scale in steam boilers.

Water having a hardness of less than 50 parts per million is generally rated as soft, and its treatment for removal of hardness under ordinary circumstances is not necessary. Hardness between 50 and 150 parts per million does not seriously interfere with the use of water for most purposes, but it does slightly increase the consumption of soap, and its removal by a softening process is profitable for laundries or other industries using large quantities of soap. Waters in the upper part of this range of hardness will cause considerable scale in steam boilers. Hardness of more than 150 parts per million can be noticed by anyone, and if the hardness is 200 or 300 parts per million it is common practice to soften water for household use or to install a cistern to collect soft rain water. Where municipal water supplies are softened, an attempt is generally made to reduce the hardness to from 60 to 80 parts per million. The additional improvement from further softening of a whole public supply is not deemed worth the increase in cost.

The hardness of the samples of well water from Meade county ranged from 128 to 898 parts per million. The softest water analyzed was from well 291 in the Ogallala and Permian, and the hardest water obtained was from well 160 in alluvium and Kingsdown. Of the 50 samples analyzed, 47 percent had a hardness between 100 and 200 parts per million, 36 percent had from 200 to 300 parts, and 11 percent had from 300 to 400 parts. Only 6 percent of the samples had a hardness in excess of 400 parts per million.

Iron.—Next to hardness iron is the constituent of natural waters that in general receives the most attention. The quantity of iron in ground waters may differ greatly from place to place, even though the waters are from the same formation. If a water contains much more than 0.1 part per million of iron, the excess may separate out and settle as a reddish sediment. Iron, which may be present in sufficient quantity to give a disagreeable taste and to stain cooking utensils, may be removed from most waters by simple aeration and filtration, but a few waters require the addition of lime or some other substance.

Most of the water from wells in Meade county contained more than 0.1 part per million of iron. Five samples contained between 1.0 and 2.0 parts per million of iron, and seven samples contained more than 2.0 parts. The water from well 333 had the highest iron content (8 parts per million) of the waters analyzed.

Fluoride.—Although determinable quantities of fluoride are not so common as fairly large quantities of the other constitutents of natural waters, it is desirable to know the amount of fluoride present in waters that are likely to be used by children. Fuoride in water has been shown to be associated with the dental defect known as mottled enamel which may appear on the teeth of children who drink water containing fluoride during the period of formation of the permanent teeth. It has been stated that waters containing 1 part per million or more of fluoride are likely to produce mottled enamel, although the effect of one part per million is not usually very serious (Dean, 1935, pp. 1,269-1,272). If the water contains as much as 4 parts per million fluoride, 90 percent of the children exposed are likely to have mottled enamel and 35 percent or more of the cases will be classified as moderate or worse.

Less than 1 part per million of fluoride was determined in 76 percent of the samples collected from Meade county, and the remaining 24 percent contained from 1 to 2 parts. The maximum fluoride content of 2.0 parts per million was found in a sample of water from well 291.

Water for irrigation.—The suitability of water for use in irrigation is commonly held to depend mainly on the total quantity of soluble salts and on the ratio of the quantity of sodium to the total quantity of sodium, calcium, and magnesium together. The quantity of chloride may be large enough to affect the use of the water and in some areas other constituents, such as boron, may be present in sufficient quantity to cause difficulty. In a discussion of the interpretation of analyses with reference to irrigation in southern California, Scofield (1933) suggested that if the total concentration of dissolved salts is less than 700 parts per million there is not much probability of harmful effects in irrigation use; but, if it exceeds 2,100 parts per million, there is a strong probability of damage to either the crops or the land, or both. Water containing less than 50 percent sodium (the percentage being calculated as 100 times the ratio of the sodium to the total bases, in equivalents) is not likely to be injurious, but if it contains more than 60 percent its use is inadvisable. Similarly, a chloride content of less than 142 parts per million is not objectionable, but more than 355 parts per million is undesirable. It is recognized that the harmfulness of irrigation water is so dependent on the nature of the land, the crops, the manner of use, and the drainage that no hard and fast limits can be adopted.

All but four of the samples of water collected in Meade county are well within the limits suggested by Scofield for safe waters for use in irrigation. Water from wells 276, 291, and 299 contained respectively 702, 816, and 827 parts per million of dissolved solids. Well 160 contained 2,169 parts per million of dissolved solids and probably would not be suitable for irrigation.

Sanitary Considerations

The analyses of water given in table 7 show only the amounts of dissolved mineral matter in the water and do not indicate the sanitary quality of the water.

More than 50 percent of the population of Meade county is dependent on private water supplies from wells, and every precaution should be taken to protect these supplies from pollution. A well should not be located where there are possible sources of pollution nor where surface water can descend to the water table. Every well should be constructed so as to seal off all surface water. As a general rule, dug wells are more subject to contamination from surface water than are drilled wells, owing mainly to the fact that generally they are not effectively sealed at the surface. More than 95 percent of the wells in Meade county are drilled wells.

Relation to Stratigraphy and Structure

The quality of ground waters in Meade county is closely related to the deposits from which the water is obtained, and, to a lesser extent, to the structure of these deposits. The influence of structure on the quality of the water is shown by the relatively high chloride content of ground water along the Crooked creek and Fowler faults. The waters from wells 160, 191, and 199 contained respectively 325, 289, and 315 parts per million of chloride. Such concentrations of chloride are unusually high for this county and probably were caused by brines migrating upward along the fault zones from the underlying Permian rocks.

The typical quality of water in the five principal water-bearing formations in Meade county is shown in figure 11, and is discussed below.

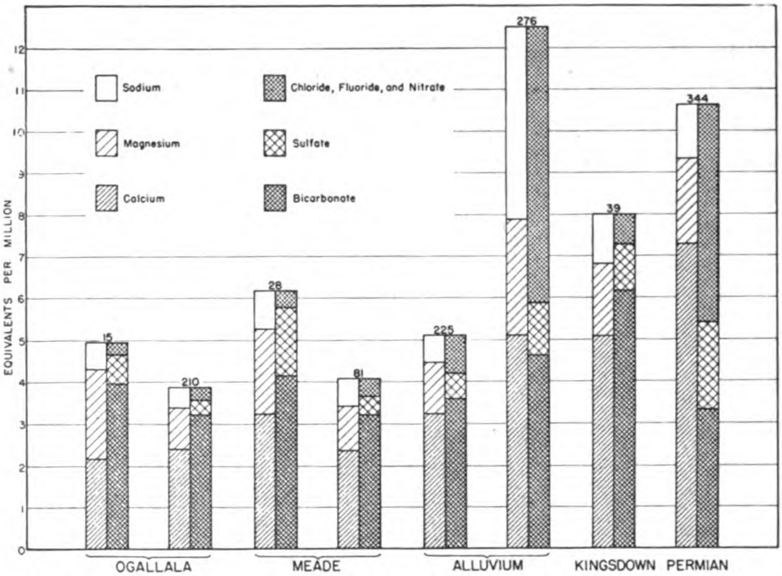

FIG. 11. Analyses of typical waters from the principal water-bearing formations in Meade county.

The range in concentration of significant mineral constituents in waters from the four principal water-bearing formations in Meade county is given in table 8. Owing to the fact that only one unmixed sample of water from the Permian redbeds was analyzed (fig. 11), it was not included in this table. Also waters from the Kingsdown silt and from the alluvium are considered together. With this exception, only unmixed samples of water are included in the table.

Permian redbeds.—Water is pumped from Permian rocks only in the southeastern part of the county. The water contains a large amount of calcium and sulphate and therefore, generally, is excessively hard. These beds are cemented by iron oxide, but the water

TABLE 8.—*Range in concentration of total dissolved solids, hardness, fluoride, and iron in water from the four principal water-bearing formations of Meade county, in parts per million.*

FORMATION.	No. of analyses.	Total dissolved solids.		Total hardness (as $CaCO_3$).		Fluoride (F).		Iron (Fe).	
		Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.
Kingsdown silt and alluvium..	6	2,169	354	898	220	1.5	0.7	7.1	*
Meade formation............	7	430	213	342	167	1.8	.7	8.0	*
Ogallala formation...........	20	361	194	320	156	1.5	.1	6.6	*

* Less than 0.15 part.

has a low iron content because iron present as the ferric oxide is relatively insoluble.

Ogallala formation.—The Ogallala formation on the whole yields water of better quality than the other water-bearing formations in Meade county. The total dissolved solids and total hardness of the Ogallala waters are appreciably lower than in the waters from the Kingsdown silt and alluvium and somewhat lower than in those from the Meade formation. Although there is but slight difference in the iron and fluoride content of the various waters, the Ogallala waters compare favorably with the others.

Meade formation.—On the basis of only seven analyses, it appears that the Meade waters are only slightly higher in total solids and hardness than the Ogallala waters. In general, the quality of water from the Meade formation is somewhat inferior to that from the Ogallala formation.

Kingsdown silt and alluvium.—The quality of waters from the Kingsdown silt and from the alluvium shows the greatest range of any ground waters in the county. The total solids and hardness of waters from these formations in general are considerably higher than waters from either the Ogallala or Meade formations. The iron and fluoride content of waters from the Kingsdown and the alluvium is approximately the same as in waters from the Ogallala and compares favorably with waters from the Meade formation.

WATER-BEARING FORMATIONS

Physical Properties of Water-bearing Materials

Samples of material penetrated by the rotary drilling machine were collected and dried in the field by Perry McNally. When dry, the samples were sacked and taken to the laboratory of the Geological Survey at Lawrence, where they were studied with a binocular microscope. Mechanical analyses and determinations of the coefficient of permeability of selected samples were made by Charles C. Williams. These data are given in table 9.

The samples collected from the test holes were washed to the surface by the drilling mud and, therefore, cannot be regarded as truly representative of the materials as they occur undisturbed in nature. An effort was made to use mud as light as possible. The light mud may have removed some of the finer particles that occur naturally in the sands and gravels. On the other hand, very heavy mud was used in some of the test holes, particularly in the artesian basin, with the result that the samples are believed to contain more mud than they should. Despite these difficulties in sampling, it is believed that the laboratory determinations gave reasonably correct answers, and that the data are sufficiently accurate for comparing the water-bearing character of the several formations.

A mechanical analysis of granular material consists in separating into groups the grains of different sizes and determining what percentage, by weight, each group constitutes. The dried samples were placed in a large mortar and adhering lumps of material gently broken up. Representative samples of the desired size were obtained by repeated quartering. Carefully weighed samples that averaged 75 grams each were put into a set of standard 3-inch screens; the screens were shaken vigorously for 25 minutes in a rotary shaker; and the fractions were weighed on a precision balance.

The permeability of a water-bearing material is its capacity for transmitting water under pressure. The coefficient of permeability, as determined in the field or laboratory, is expressed by O. E. Meinzer as the number of gallons of water a day at 60° F., that is conducted laterally through each mile of the water-bearing bed under investigation (measured at right angles to the direction of flow), for each foot of thickness of the bed, and for each foot per mile of hydraulic gradient (Stearns, 1927, p. 148). The coefficients of permeability given in table 9 were determined by means of a portable field apparatus designed by V. C. Fishel and V. T. Stringfield of the Federal Geological Survey.

The figures given in table 9 indicate that the character and permeability of the several water-bearing formations range between somewhat wide limits. More than 60 percent of the samples analyzed had a coefficient of permeability of more than 100, and two samples had coefficients of more than 1,000.

TABLE 9.—*Physical properties of water-bearing materials from test holes in Meade county, Kansas*

(Collected by Perry McNally; analyzed by Charles C. Williams.)

Test hole number on figure 14.	Depth of sample (feet).	Geologic subdivision.	Mechanical analyses (percent by weight).							Coefficient of permeability.*
			Medium and coarse gravel (larger than 2.0 mm.).	Fine gravel (2.0-1.0 mm.).	Coarse sand (1.0-0.50 mm.).	Medium sand (0.50-0.25 mm.).	Fine sand (0.25-0.125 mm.).	Very fine sand (0.125-0.062 mm.).	Silt and clay (less than 0.062 mm.).	
3	93-100	Meade.....	8.5	42.3	30.2	8.6	3.6	2.7	4.1	170
3	131-140	Meade.....	3.4	22.3	37.2	23.2	6.4	3.2	4.3	64
3	318-330	Ogallala....	5.5	25.5	36.0	21.4	6.8	2.4	2.4	22
5	140-150	Meade.....	9.1	25.9	36.5	22.1	4.4	.8	1.2	160
5	260-270	Meade.....	13.8	42.0	28.5	10.6	2.8	1.2	1.1	61
8	97-107.5	Meade.....	34.8	41.5	17.8	3.9	1.0	.4	.6	450
8	170-180	Meade.....	11.4	39.1	30.5	15.0	2.6	.7	.7	910
8	200-210	Meade.....	10.9	43.7	25.2	15.0	3.3	.9	1.0	249
8	270-280	Meade.....	12.2	35.1	39.2	11.2	1.6	.3	.4	510
8	320-330	Meade.....	2.6	32.4	48.2	14.1	1.8	.4	.5	650
8	420-431	Meade.....	5.5	40.6	36.5	13.2	2.7	.8	.7	12 5
10	129-140	Ogallala....	28.0	37.4	18.4	6.4	4.8	2.2	2.8	143
11	3-8	Ogallala....	34.9	28.3	15.4	12.4	5.6	1.6	1.8	340
11	8-10	Ogallala....	4.3	7.4	14.2	51.7	20.0	1.5	0.9	23
11	12-15.5	Ogallala....	9.1	24.4	26.7	24.4	11.1	2.2	2.1	430
13	71-80	Meade.....	57.4	26.4	7.9	3.0	1.3	1.5	2.5	225
13	260-270	Ogallala....	46.7	42.2	7.7	1.7	0.6	.4	.7	5,300
17	74-85	Ogallala....	12.4	26.3	38.7	19.5	2.5	.2	.4	1,825
17	87-92	Ogallala....	28.6	26.5	31.3	9.3	2.1	.9	1.3	45
17	102-108	Ogallala....	2.1	2.8	31.7	54.6	7.5	.6	.7	305
20	97-105	Ogallala....	8.5	17.2	38.2	28.6	5.8	.8	.9	....
20	170-180	Ogallala....	4.3	5.2	19.7	54.3	14.6	1.3	.6	....
20	220-230	Ogallala....	24.5	44.9	9.8	9.4	6.1	2.5	2.8	....
20	363-370	Ogallala....	7.3	59.6	22.4	8.0	1.5	.5	.7	....
23	330-340	Ogallala....	27.3	36.8	21.5	7.8	3.4	1.6	1.6	....
23	400-410	Ogallala....	4.7	7.6	29.6	44.0	11.2	1.8	1.1	67

* Number of gallons of water a day, at 60° F., that is conducted laterally through each mile of water-bearing bed under investigation (measured at right angles to the direction of flow), for each foot of thickness of the bed and for each foot per mile of hydraulic gradient.

Permian System

GENERAL FEATURES

The oldest rocks exposed in Meade county are of Permian age. They consist of red sandstone, siltstone, and shale, with occasional beds of gray shale and thin beds of gypsum. Permian rocks are known to contain beds of salt and gypsum at a depth of only a few hundred feet below the surface. These beds, which constitute the uppermost Permian strata in Kansas, have been referred by Norton (1939, pp. 1813, 1814) to the Big Basin formation, but are classed by the Kansas Geological Survey as belonging to the Taloga formation (Cragin, 1897, p. 362). Some slightly older beds belonging to the Whitehorse group (as used by the Kansas Geological Survey) may be exposed in Meade county.

With the exception of a few small exposures along Crooked creek valley south of Meade, Permian rocks crop out only in the southeastern part of the county. The total thickness exposed in this county is somewhat more than 100 feet.

WATER SUPPLY

In the southeastern part of the county small supplies of very hard water are obtained from the Permian rocks. Domestic and stock wells penetrate these rocks only to relatively shallow depths, and it is possible that somewhat larger supplies might be obtainable by drilling deeper wells. At a depth of only a few hundred feet or less, however, the chloride content of the Permian water becomes so high as to make it unfit for use. An analysis of a sample of water from the Permian redbeds is shown in figure 11.

Cretaceous System

GENERAL FEATURES

Cretaceous rocks have nowhere been observed cropping out in Meade county. Cretaceous strata have been encountered underlying the Tertiary deposits in several test holes. The thickest beds of Cretaceous rock occur in the northeastern and southwestern parts of the county. In the vicinity of Fowler there occurs more than 200 feet of Cretaceous beds, consisting dominantly of black and blue-gray shale, which is probably equivalent, at least in part, to the Kiowa shale of Clark and Kiowa counties. In southwestern Meade county the Cretaceous deposits attain a maximum thickness of approximately 300 feet, consist dominantly of sand, and contain a few beds of shale. The thick sand may be an equivalent of the Cheyenne sandstone which is known to crop out to the east, or of the Cockrum sandstone, described by Latta (1941) from exposures to the west of this area, or these deposits may contain equivalents of all or most of the pre-Graneros Cretaceous beds, and possibly also some overlying beds.

WATER SUPPLY

The Cretaceous water-bearing beds have not as yet been tapped by water wells in Meade county. The quality of water obtainable from these beds can be judged only by the quality of water obtained from equivalent deposits in adjacent areas. It is probably a safe assumption that water from the Cretaceous rocks will be of satisfactory quality for most uses, although it may be somewhat harder than the waters obtained from the Tertiary deposits in the same vicinity. Judging from the thickness and permeability of these beds in southwestern Meade county, they contain an extensive reserve supply of ground water which might become important if the supply obtainable from the overlying Teritary deposits should ever prove inadequate, and if the greater depth of drilling necessary to obtain water from the Cretaceous deposits becomes economically feasible.

TERTIARY SYSTEM

LAVERNE FORMATION

Character.—The Laverne formation was named and described from a locality in Harper county, Oklahoma, by V. V. Waite in an unpublished manuscript later quoted by Gould and Lonsdale (1926). The deposits constituting this formation consist of gray, fine-grained, thin-bedded sandstone, some of which contains conglomerate; blue-gray to tan, even-bedded shale, and tan, soft, silty limestone, which typically includes a thin bed of gray dense limestone at the top. The soft silty limestone can be cut with a saw and has been quarried for building stone and used in the construction of ranch buildings in the Cimarron valley. A generalized section of the Laverne formation is given in figure 12A. A section of the Laverne measured near the mouth of Wolf canyon, on the south side of the Cimarron valley, is given below.

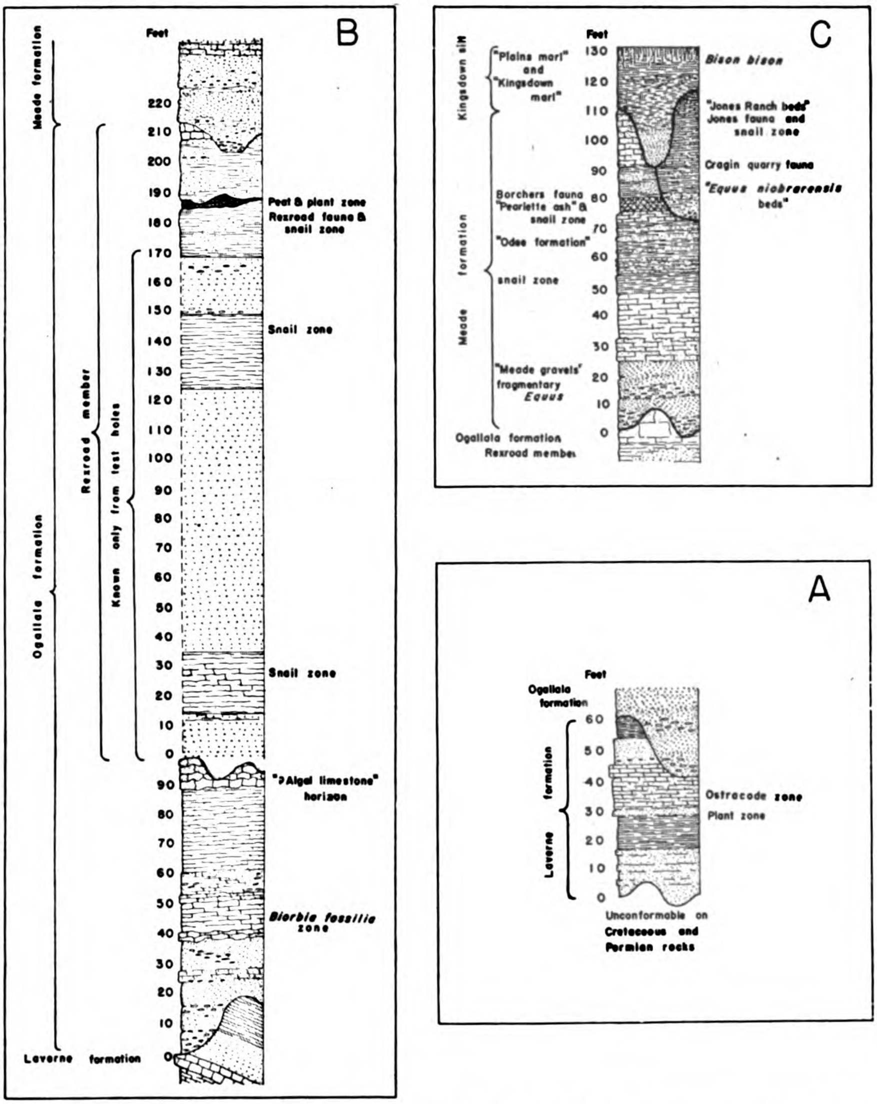

FIG. 12. Generalized sections of the Tertiary and Quaternary deposits of Meade county. *A,* Generalized section of the Laverne formation in Meade and Seward counties, Kansas. *B,* Generalized section of the Ogallala formation in Meade county. The positions of the "algal limestone" horizon, a zone of abundant *Biorbia fossilia,* the Rexroad fauna, and several snail zones are shown. This is a composite section and it should be noted that in those localities in which the middle Pliocene part is well exposed the Rexroad member typically is thin or absent. *C,* Generalized section of the Meade formation and the Kingsdown silt in Meade county. The stratigraphic positions of previously named beds, local vertebrate faunas, and snail zones are shown.

Section of Laverne formation, sec. 7, T. 35 S., R. 30 W.

	Thickness, feet
3. Silt, clay and fine sand, highly calcareous, tan and gray in color. Some beds are chalky, evenbedded, and weather to a punky, friable surface. This rock has been quarried for building purposes and is locally referred to as "saw rock"	15.6
2. Shale, containing some fine sand, thin bedded, brown, gray, red and tan in color	11.4
1. Sand, fine, tan-brown, thin bedded and well indurated. Weathers to a loose sand. The bottom of the interval is partly covered	12.8
Total thickness exposed	39.8

As stated in an earlier report (Frye and Hibbard, 1941, p. 398-401) these beds should be considered a distinct formation rather than a member or zone of the Ogallala formation, as suggested by Hesse (Chaney and Elias, 1936, p. 51), because: (1) The nonconformity that separates the Laverne from the Ogallala is the greatest break in sedimentation recorded in the Pliocene and Pleistocene section. The beds of the Laverne dip at angles as great as 15 degrees and are overlain by horizontal beds of the Ogallala. (2) The lithology of the Laverne is distinct from that of the overlying Ogallala; in fact, on casual inspection these beds more closely resemble the underlying Cretaceous rocks than they do the Ogallala. (3) It is a unit that is easily recognizable and mapable in the field.

Distribution, thickness, and surface form.—The Laverne formation is exposed only in the southwestern corner of the county along the bluffs of the Cimarron valley and small tributary canyons. Sixty feet of Laverne strata are exposed in Meade county, but the base has nowhere been observed. The maximum thickness of this formation in Kansas may exceed 100 feet. It consists mostly of relatively resistant rocks, and steep slopes are developed on its outcrops. Near the Meade-Seward county line hard limestone beds of the Laverne dip below the floor of the Cimarron valley and have caused a noticeable constriction of the valley.

Age and correlation.—These deposits are correlated with the Laverne formation of Oklahoma on the basis of their lithology, fossil content, and stratigraphic position. As stated in an earlier paper (Frye and Hibbard, 1941, p. 403):

> The position of the Laverne formation unconformably below middle Pliocene deposits, and the presence of lower Pliocene fossils in the upper part of the formation, date it as lower Pliocene, and the lower part possibly is upper Miocene in age.

Water supply.—To date there has been only one water well drilled into the Laverne of Meade county. The area of outcrop is in a sparcely populated part of the county, and occurs along the sides of the Cimarron valley which contains water-bearing alluvium. The character of the Laverne formation suggests that supplies sufficient for domestic or stock use could be obtained from it if additional water should ever be needed in this area.

OGALLALA FORMATION

Character and subdivisions.—The Ogallala formation was named by Darton in 1899 (pp. 734, 735, 741, 742, pl. 84) from a locality in southwestern Nebraska. In 1920 Darton (p. 6) referred to the type locality as near Ogallala station in western Nebraska. Smith (1940, pp. 39-94) has recently reviewed the literature dealing with the Ogallala and has discussed its occurrence in southwestern Kansas.

The Ogallala formation consists of clay, silt, sandy silt, caliche, and cross-bedded sand and gravel (pl. 11*B*) which locally is cemented by calcium carbonate to a hard, "mortar bed" type of rock. A generalized section of the Ogallala formation is shown in figure 12*B*. Channel sands and gravels typically occur at the base and are quite variable laterally. At many localities the top of the middle Pliocene part of the Ogallala is marked by a hard bed of caliche, or limestone, which locally is silicified. The bulk of the formation consists of massive sandy silt, pink or tan in color, interbedded with sand, gravel, and caliche. A section of the Ogallala formation measured along Wolf canyon follows:

Section of Ogallala formation, sec. 7, T. 35 S., R. 30 W.

	Thickness, feet
11. Sand and gravel, tan to red-brown, locally capped by a thin bed of caliche	12.0
10. Caliche, ash-gray, contains some sand, dense, hard. Weathers to a vertical nodular face	6.5
9. Silt, sand, and clay, contains a few nodules of caliche, pink, gray, and light tan	21.0
8. Sand and gravel, cross-bedded at base, massive at top. Weathers to a nodular surface	14.4
7. Silt, sand, and clay, buff-tan, loose, massive	6.5
6. Sand, gray and tan, loose	6.0
5. Silt, sand, and clay, pink, tan, and buff, blocky, massive, contains some caliche	13.5
4. Caliche, contains some sand and silt, gray. Weathers to a nodular surface	2.0
3. Silt, sand, and clay, red, tan and gray, partly covered	10.0
2. Sand and gravel, cross bedded, partly cemented	47.2
1. Covered. The Laverne formation occurs below this interval	14.0
Total thickness	153.1

A typical section of the middle Pliocene part of the Ogallala formation and the overlying Meade formation occurs along Crooked creek valley, south of Meade, and is given below:

Section of Meade and Ogallala formations, NW¼ sec. 12, T. 33 S., R. 28 W.

	Thickness, feet
Meade formation	
18. Silt, sand, and some clay, tan to buff-brown, massive. Contains sandy beds and caliche beds. The surface at the top of the bluff is covered with a rubble of caliche cobbles	14.8
17. Sand and silt, gray to gray-tan	5.4
16. Clay, with some silt and sand, light gray, massive. Breaks with a concoidal fracture when dry	4.5
15. Volcanic ash, pearl gray, lenticular, somewhat impure	1.6
14. Silt, clay, and some sand, gray, massive, contains a few calcareous nodules	6.4
13. Volcanic ash, pearl gray, thin bedded and cross bedded	7.1
12. Clay, silt, and some sand, tan-gray and brown-gray, massive. Grades upward into yellowish gray-green sand and contains some mottled, yellow-brown silt. Contains a few thin beds of ash and calcareous nodules	9.5
11. Sand, silt, and coarse gravel, brown, contains abundant nodules. Grades upward into red-brown to tan-maroon sand and silt	8.8
10. Sand, coarse and well sorted at base, grading upward into finer more poorly sorted sand. Calcareous nodules at top	10.1
Total thickness of Meade formation exposed	68.2

	Thickness, feet
Ogallala formation	
9. Caliche, sandy, gray-tan	5.4
8. Silt, fine sand, and some clay, tan to buff, massive	1.6
7. Sand, fine, and some silt, yellow-tan, thin bedded	1.0
6. Sand and silt, reddish-tan, massive	4.0
5. Unexposed	2.9
4. Caliche, sandy, nodular, massive, vertical nodular stringers of caliche and pockets and lenses of pink-tan sandy silt	11.2
3. Sand, silt, and clay, pink-tan. Contains some nodular bands of caliche and some gravel	6.1
2. Sand and gravel, cross-bedded. Contains both tightly cemented and loose zones. The gravel is quite coarse in some beds and contains blocks of red Permian siltstone. Becomes coarser and more poorly sorted upward, and a "mortar bed" occurs at the top	34.6
1. Unexposed. A near-by test hole shows this interval to be occupied by sand and gravel overlying Permian redbeds	11.2
Total thickness of Ogallala formation	78.0

The Ogallala formation in Meade county has been classified (Frye and Hibbard, 1941, p. 399) as consisting of a middle Pliocene member (unnamed) and the upper Pliocene Rexroad member.

Rexroad member.—In 1940 the upper Pliocene beds of central Meade county were named the Rexroad formation by Smith (1940, p. 95) from exposures along a tributary to Crooked creek on the Rexroad ranch, in the same general locality from which the Rexroad fauna was collected by Hibbard (1938). More recently these beds have been included as the Rexroad member of the Ogallala formation for the following reasons (Frye and Hibbard, 1941, p. 407):

(1) On the basis of both surface and subsurface data, it seems evident that in parts of the basin there was continuous sedimentation from middle Pliocene through upper Pliocene time, and in those localities no break is distinguishable; (2) the deposits were trapped in a local basin, and, although there are deposits of equivalent age outside this general area, they are not stratigraphically continuous with the deposits of the Rexroad type locality, and are not genetically related to them; and (3) as Smith (1940, pp. 95-97) has pointed out, the lithology of the Rexroad beds for the most part is indistinguishable from the middle Pliocene part of the Ogallala formation. For these reasons the Rexroad beds do not constitute a mapable unit, except partially in the vicinity of the type locality, where the upper contact, but not the lower, can be mapped.

The lower and thicker part of the Rexroad member does not crop out at the surface in Meade county, so that the thickness and character of the member are known only from test-hole samples and well logs. Where the entire member is present it is about 200 feet thick, but in the deepest part of the basin it may attain a maximum thickness of 250 feet, and east of the Crooked creek fault it is only about 30 feet thick. On the basis of data from test holes, the lower 175 feet of the Rexroad member may be described as comprising alternating beds of sand, silt, and clay. The thickness of individual beds ranges considerably. Two well-defined snail zones were encountered in the test drilling, and the fossils, some of which were brought to the surface unbroken, have aided in the recognition of the beds.

The upper beds of the Rexroad member, which are exposed at the surface, consist of blue-gray, tan, and gray sand, silt, and clay. At many places a bed of soft sandy caliche occurs at the top of the member, and at a few localities a thin bed of peat occurs 20 to 30 feet below the top. The Rexroad member of the Ogallala formation is overlain unconformably by the basal sand or gravel of the Meade formation of Pleistocene age. A generalized section of the Rexroad member in central Meade county is shown in figure 12*B*.

Caliche.—The prevalent occurrence of caliche in the Tertiary and Quaternary deposits of the southern High Plains has presented a puzzling problem since the early work on these beds. Caliche occurs abundantly in these deposits from Texas and New Mexico northward to Colorado and Nebraska. The earlier literature dealing with the caliche problem in Texas has been summarized by Sayre (1937, pp. 65-72) and, in western Kansas, by Smith (1940, pp. 90-92). In southwestern Kansas it has been common practice to refer to beds which contain only a small percentage of calcium carbonate as "caliche" and to use the term more or less interchangeably with "mortar bed." It is my opinion that there occur in these strata two distinct types of calcium carbonate deposits, and that the origin of the two may or may not be similar. The first type consists of irregular beds and nodular bands of chalky calcium carbonate, occurring in both coarse and fine material and transgressing various types of material. This type, to which the use of the term "caliche" is here restricted, almost invariably contains some impurities either of silt, sand, or gravel, and locally contains some chert. The other type, which, for lack of a better name, will be referred to as "mortar bed," consists of cemented zones, beds, or lenses of sand or of sand and gravel. The cementation may have been produced by percolating ground water, localized by the texture of the deposit, or it may have been produced in a manner similar to that described for caliche. Mortar beds locally occur as cemented lenses of sand within a thick sequence of sand and gravel, or of fine sand and silt. The texture of the cemented bed may be either coarser or finer than that of the enclosing material.

The origin of caliche will not be discussed in detail here. However, one hypothesis that seems to fit the conditions existing in this area will be presented. During the latter part of the Pliocene and the Pleistocene, the time during which caliche was being formed in this area, the Rocky Mountain region to the west stood high above the adjacent plains and was being vigorously eroded by competent streams. The streams transporting sediments to the plains area carried in solution calcium carbonate, derived from the igneous and sedimentary rocks being eroded. In the plains region these streams were aggrading—filling their channels, which often shifted in position, and overflowing and spreading deposits over their flood plains. Although it is possible that the first effect of a cold Pleistocene climate was not felt in the Rocky Mountain region until after some caliche formation had taken place, it seems certain that the water flowing from these mountain streams was relatively cold. It is a well-known fact that cold water heavily charged with calcium carbonate will, when heated, lose part of this dissolved material. When flood waters from these streams spread over their broad flood plains the temperature of the water must have been raised sufficiently to cause some precipitation of the dissolved lime. It is also well known that calcium carbonate will be precipitated from an aqueous solution at constant temperature if carbon dioxide is removed. It is certain that grass or other forms of vegetation covered the extensive plain of alluviation, and it is possible that the plants may be able to extract carbon dioxide from the water flooding the surface. Thus, the factors producing deposition of caliche in these sediments seem to be a rise in temperature of the waters of the depositing streams plus the possible extraction of additional carbon dioxide by vegetation. These factors probably were augmented by evaporation and concentration of the solution by drying winds and sun.

After the initial deposition of the carbonate of lime over the aggradational plain, the deposit was acted upon and modified in form by several processes. Downward percolating rainwater may have dissolved some of it and distributed it through the soil, or concentrated it in the form of nodular bands or beds at the base of the soil zone. Successive inundations by flood waters in some places probably mixed the calcium carbonate with clastic material, and in still other places there may have been an upward concentration by capillary action. It is certain that the erosional history of the region has not been such as to have allowed the concentration of calcium carbonate by a gradual erosional lowering of the upland surface, with a progressive concentration of calcium carbonate at the base of the soil profile.

The algal limestone (Elias, 1931, p. 141) or the capping limestone (Smith, 1940, p. 90) presents a special case of calcium carbonate deposition. Elias believed that in northwestern Kansas this limestone was deposited in a widespread shallow lake and that it contains algal structures; Smith, however, has presented considerable evidence against this hypothesis. In some areas it is harder than in others and contains less impurities than typical caliche, but it grades both laterally and vertically into more typical material. Chert occurs in this bed at a few localities and may have been formed by secondary silicification after the extensive deposits of volcanic ash were laid down in this area.

Distribution, thickness, and surface form.—The Ogallala formation crops out over a large area in the southeastern part of the county and in smaller areas in the central and southwestern parts of the county (pl. 1). Throughout the rest of the county it underlies Pleistocene sediments except in a few places where it has been eroded completely. Its maximum thickness of more than 350 feet occurs in the structural depression west of the Crooked Creek fault, and only in this area is the Rexroad member, which here attains a maximum thickness of 250 feet, well developed. The middle Pliocene part of the Ogallala attains a maximum thickness of 125 feet, and is widespread over the county. Little more than 10 feet of Ogallala beds are present along the rims of the major valleys in parts of southeastern Meade county. In the southern and southeastern parts of the county the outcrops of the Ogallala are well indurated and have been eroded to form deep, steep sided canyons.

Age and correlation.—The stratigraphic position of the Ogallala formation unconformably above the lower Pliocene beds of the Laverne formation and below the Pleistocene Meade formation, the presence of fragmentary middle Pliocene vertebrates and plant remains in the lower part of the Ogallala, and the upper Pliocene Rexroad fauna in the Rexroad member (Frye and Hibbard, 1941, pp. 408-410) date the age of the Ogallala formation in Meade county as middle and upper Pliocene. Deposits equivalent in age to the middle Pliocene part of the formation are widespread in western Kansas and adjacent states. The Rexroad member, however, apparently was deposited in response to local structural and physiographic conditions; hence, but few deposits of equivalent age are known to occur in adjacent areas.

Water supply.—The sands and gravels of the Ogallala formation are the most productive sources of ground water in Meade county. More than half of the domestic and stock wells, all of the municipal wells, and most of the irrigation wells draw water from this formation.

The finer materials of the formation generally are porous and hold considerable water, but are not permeable enough to yield water freely. The coarser materials, the gravels in particular, generally yield abundant supplies of water. Mechanical analyses and coefficients of permeability of samples of sand and gravel from the Ogallala in seven test holes are given in table 9. Beds of water-bearing sand and gravel may be found at almost any depth in the formation but as a rule are thicker and more permeable in the lower part. The Ogallala is especially thick and permeable in the structural depression west of the Fowler and Crooked creek faults. All but one of the irrigation wells are situated in this part of the county and have reported yields up to 1,800 gallons a minute.

The Ogallala formation is a large underground reservoir that is only partly filled with water. In the east-central and southeastern parts of the county the Ogallala is relatively thin and lies entirely above the water table, and, therefore, will not yield water to wells. The thickness of saturated material in the Ogallala is shown in cross sections AA′, BB′, and CC′ in figure 4. Logs of the test holes indicate that more than half of the saturated zone in the Ogallala is composed of sand and gravel, so the amount of water available is large.

Twenty-one analyses indicate that the water from the Ogallala formation is moderately hard. With few exceptions the samples contain 150 to 300 parts per million of hardness and 150 to 250 parts per million of bicarbonate. The chloride content generally is less than 25 parts per million. The content of sulphate, fluoride, and iron generally is low. Representative analyses are shown graphically in figure 11, and the 21 analyses are given in table 7.

Quaternary System

MEADE FORMATION

Character and subdivisions.—The "Meade gravels" were named by Cragin (p. 54) in 1896 from exposures in central Meade county. Cragin's "Meade gravels" recently were redefined as the Meade formation (Frye and Hibbard, 1941, p. 411) to include all of the beds of Pleistocene age between the top of the Rexroad member of the Ogallala formation and the base of the Kingsdown silt, and this usage is continued in the present report. This formation consists of gravel, sand, silt, clay, volcanic ash, and caliche. A generalized section of the Meade formation, showing the stratigraphic position of the several previously named units and the local faunas, is given in figure 12*C*.

A thick bed of cross-bedded sand and gravel typically occurs at the base of the formation. These beds grade laterally into finer sands and in some localities are absent. The sand and gravel locally is cemented by calcium carbonate to a hard "mortar bed" or sandstone, as shown in plate 11A, but in most places is unconsolidated. A measured section of the lower part of the Meade formation at a locality where the basal beds of sand and gravel are quite thick is given below.

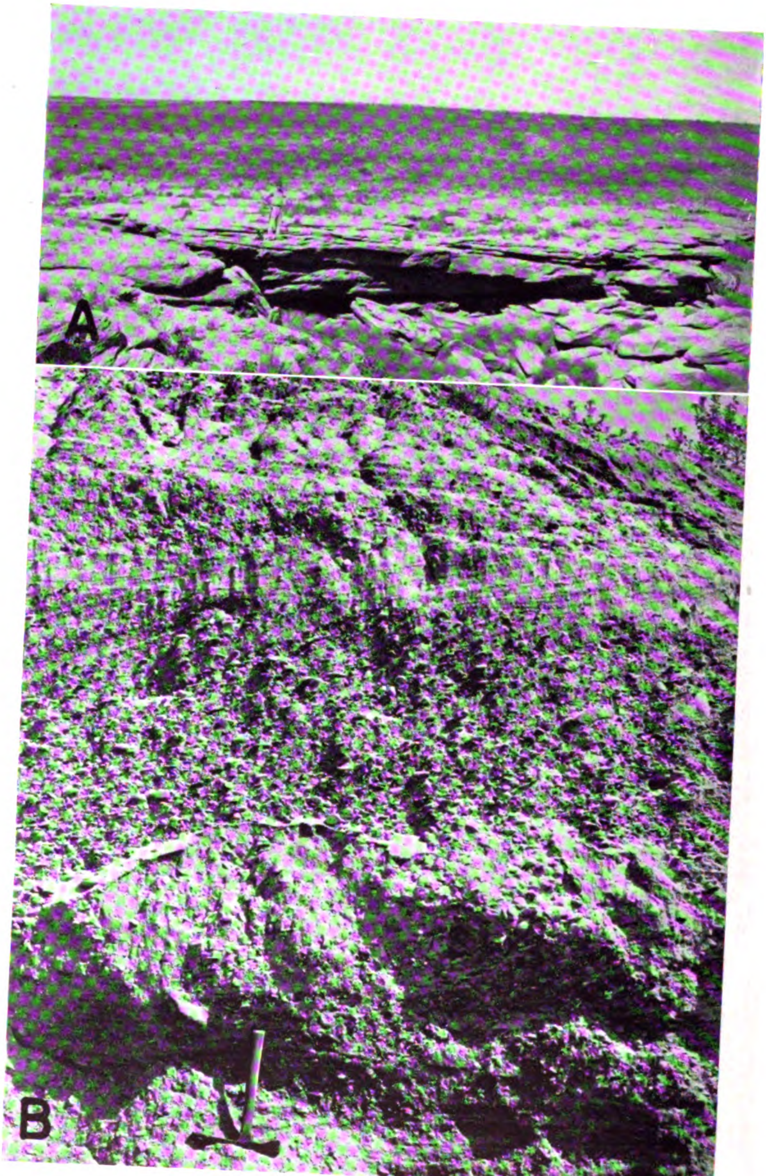

PLATE 11. Sand and gravel in the Meade and Ogallala formations. *A*, Cemented basal sand of the Meade formation, Meade County State Park. *B*, Basal gravel of the Ogallala formation, 8 miles south of Meade on the east side of Crooked creek (photograph by S. W. Lohman).

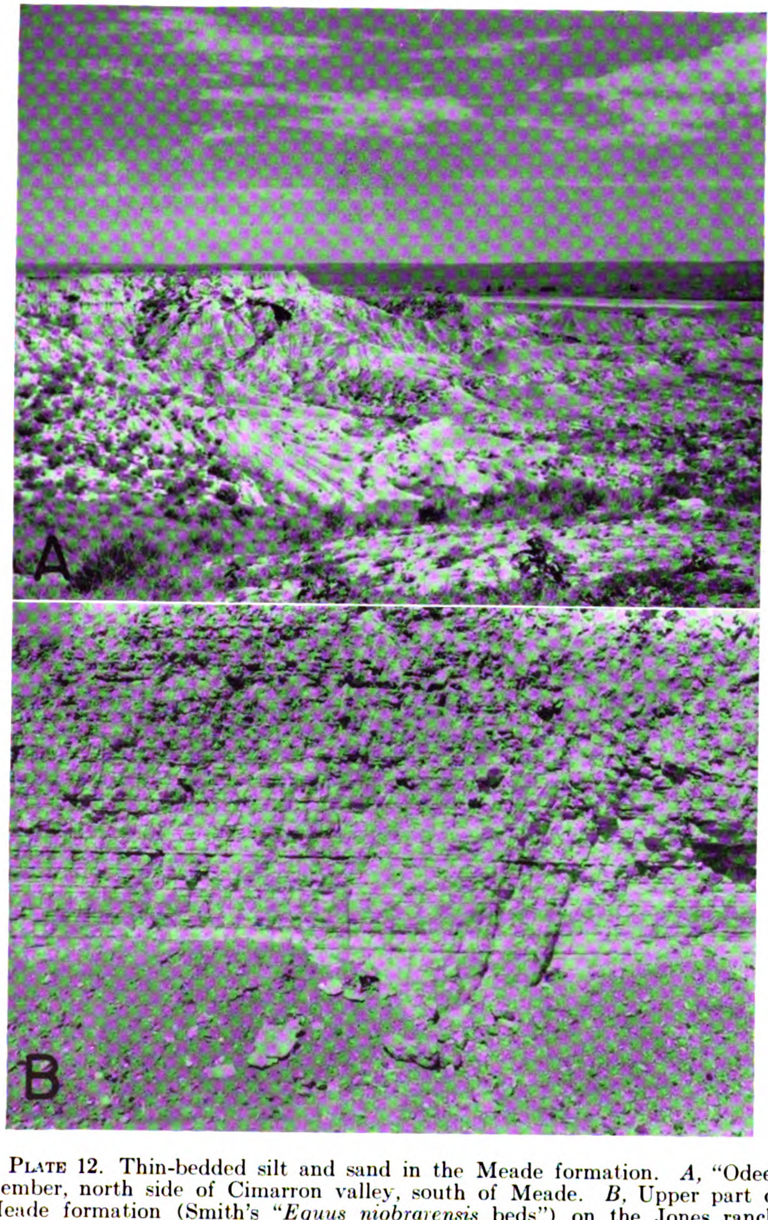

PLATE 12. Thin-bedded silt and sand in the Meade formation. *A*, "Odee" member, north side of Cimarron valley, south of Meade. *B*, Upper part of Meade formation (Smith's "*Equus niobrarensis* beds") on the Jones ranch, southeast of Meade.

Section of Meade and Ogallala formations, NE¼ sec. 33, T. 32 S., R. 29 W.

	Thickness, feet
Meade formation	
8. Clay, silt, and sand, pink-tan and gray. Contains nodules of caliche with a tough bed of caliche at the top	12.5
7. Sand, fine- to medium-grained, tan-brown, contains some silt	5.4
6. Sandstone, medium grained, light gray, tough	2.0
5. Sand, medium, gray-tan, well sorted, cross-bedded	8.4
4. Sand and gravel, cross-bedded. A marked disconformity occurs at the base	36.2
Total thickness of Meade formation exposed	64.5
Ogallala formation, Rexroad member	
3. Clay, silt, and sand, gray-tan and light dull-pink, very calcareous, massive	6.0
2. Silt, sand and gravel, pink-tan, contains nodules and intersecting stringers of caliche. Finer and more calcareous at the top	26.0
1. Clay, silt, sand, and gravel, light cream-gray, tough when dry. Contains a few bands of caliche	3.0
Total thickness of Rexroad member exposed	35.0

The interval above the basal part of the Meade formation comprises beds of thin-bedded clay, silt, and sand, ranging in color from gray, blue-gray, and tan to dark brick red. These beds range greatly in thickness and are best developed and best exposed in the southern part of Meade county, as shown in plate 12*A*. A measured section of this part of the Meade formation exposed in the northern bluff of the Cimarron valley south of Meade is given below.

Section of the Meade formation, SE sec. 34, T. 34 S., R. 29 W.

	Thickness, feet
Meade formation	
21. Soil	3.0
20. Silt, clay, and fine sand, medium gray, blacky. Calcareous nodules occur throughout. A purple-gray zone occurs at the base and a dark gray zone at the top	19.3
19. Silt, pink-tan, massive, alternating with thin-bedded sand, tan and gray	5.2
18. Sand, fine, with some silt, tan-cream, thin bedded	1.2
17. Silt, clay, and sand, tough, pink-tan, contains a few light blue-gray streaks	3.9
16. Sand, fine, and silt, light cream-tan	.4
15. Silt, fine sand, and clay, pink-tan. Contains several bands of light tan silt 0.1 foot thick	11.5
14. Sandstone, nodular surface, hard	.5
13. Sand, gray and light buff, contains orange-yellow streaks, thin bedded	2.2

		Thickness, feet
12.	Silt and clay, massive, purple tan	.8
11.	Sand and silt, tan, gray, and buff, thin bedded	2.6
10.	Silt and clay, purple-tan, blocky	.4
9.	Sand and silt, gray-tan and buff, thin bedded	.6
8.	Silt and clay, purple-tan, blocky	1.0
7.	Sand, fine, and silt, thin bedded in some zones and massive in others, friable, tan in lower part grading upward into yellow-tan	12.5
6.	Sand, fine, and silt, tough, massive, tan-maroon	6.0
5.	Silt, light gray-tan to cream, contains some clay and fine sand	.8
4.	Silt, clay and fine sand, maroon	1.2
3.	Sand, fine and silt, pink-tan, tough	1.2
2.	Silt and clay, contains some fine sand, massive, red-tan. Loose on weathered surface	9.2
1.	Silt and clay, blocky, maroon, weathers to a loose surface	20.8
	Total thickness exposed	104.3

It is within this varicolored zone that Smith's Odee formation occurs (Smith, 1940, pp. 100-108). The "Odee formation" has not proved to be a satisfactory unit for field mapping for the following reasons (Frye and Hibbard, 1941, p. 413):

(1) The formation, as described, has no definite top or bottom; (2) it is essentially a color zone that interfingers with and grades laterally into equivalent beds of different color; and (3) beds of similar appearance at a somewhat different stratigraphic position within the Pleistocene seemingly were trapped in isolated sink holes, and some of these beds cannot be distinguished lithologically from the "Odee" at the type locality.

A section measured near the type locality of the "Odee formation," along a tributary to Crooked creek, is given below.

Section of the Meade formation, NW SE sec. 1, T. 34 S., R. 29 W.

		Thickness, feet
6.	Sand, containing some silt and clay, ash-gray, loose and friable. Contains some small crystals of gypsum and mollusks. Interbedded fine and coarse zones, thin bedded and massive	19.8
5.	Silt, clay, and fine sand, maroon and tan (weathers to purple-gray), blocky. Contains a few crystals of gypsum and bands of blue-gray and yellow-tan clay. A zone abundant in gypsum occurs near the top	9.2
4.	Silt and fine sand, yellow-tan, blocky, contains some small crystals of gypsum	2.0
3.	Silt, fine sand, and clay, maroon. Contains thin beds of gray-cream fine sand	20.7
2.	Silt, fine sand, and clay, yellow-tan, irregular bedding	3.0
1.	Clay and silt, blue-gray	.5
	Total thickness exposed	55.2

In parts of the county the beds described above are overlain by a bed of volcanic ash, which was named the Pearlette ash by Cragin (1896, pp. 53, 54). This ash bed attains a thickness locally of 12 to 14 feet, and has been mined extensively in the county for use as an abrasive and in cleansers. The ash, although locally quite pure, is at many places interbedded with silt and sand and in some places contains nodules of limestone. It is overlain by silt, sand, and caliche. The ash reserves of the county are quite large, and at the present rate of development will last indefinitely. The top of the lower and widespread part of the Meade formation occurs 25 to 30 feet above the horizon of the Pearlette ash, and is marked by a distinct disconformity.

A discontinuous series of channel deposits and associated and isolated sink-hole fillings unconformably overlie the Pleistocene beds described above. These beds were in part included within the "*Equus niobrarensis* beds" and the "Jones ranch beds" by Smith (1940, pp. 108-111), but are now included as the upper part of the Meade formation (Frye and Hibbard, 1941, pp. 400, 411). An exposure of these beds in a dissected sink hole is shown in plate 12B.

Distribution, thickness, and surface form.—Deposits comprising the Meade formation crop out over large areas in central and south-central Meade county (pl. 1). The more or less uniform and widespread lower part of the Meade formation attains a maximum thickness of more than 125 feet, and over most of the area where it is well developed it is 100 feet or more thick. The upper, or channel, phase of the Meade formation is quite variable in thickness, but nowhere has been observed to attain a thickness in excess of 50 to 55 feet.

Except for the cemented phases of the basal sand and gravel, the Meade formation is relatively nonresistant and produces sloping canyon walls and gullied slopes.

Age and correlation.—The Meade formation is Pleistocene in age, as attested by its stratigraphic position above the upper Pliocene Rexroad member of the Ogallala formation and by its included fossils. Several local Pleistocene faunas from this formation have been described by Hibbard (1939a, 1940, 1941), namely the Borchers fauna, the Cragin Quarry fauna, and the Jones fauna. The formation ranges in age vertically from basal Pleistocene well into the upper part of the Pleistocene and is unconformably overlain by the upper Pleistocene and Recent Kingsdown silt.

Water supply.—The Meade formation ranks next to the Ogallala formation in importance as a water-bearing formation in Meade county. Some of the wells in the artesian basin and many wells on the uplands west and south of the basin obtain water from the Meade. Although the basal sand and gravel is locally highly permeable, the sediments of the Meade formation are for the most part slightly less permeable than the water-bearing beds in the Ogallala formation.

Eight analyses indicate that the waters in the Meade formation are moderately hard calcium bicarbonate waters. Although the Meade waters are very similar in quality to the Ogallala waters, they contain somewhat more total solids and hardness. Representative analyses are shown graphically in figure 11, and the eight analyses are listed in table 7.

KINGSDOWN SILT

Character.—The Kingsdown marl was briefly described and named by Cragin in 1896 (p. 54), from exposures in southeastern Ford county and northern Clark county. Smith (1940, pp. 111-116) revived the name, as the Kingsdown formation, redefined it to include only beds of Pleistocene age, and described the occurrence of this formation in southwestern Kansas. He did not specifically include the overlying loess. The Kingsdown silt as used in this report includes the loess which locally overlies the waterlaid beds and in many places cannot be sharply distinguished from them (Frye and Hibbard, 1941, p. 420).

The lower part of this formation consists of thin-bedded, dominantly fine-grained sand that grades upward into silt and sandy silt and loess. In Meade county it unconformably overlies the Meade formation and is channeled into it. The upper part of the formation contains nodules, bands, and stringers of calcium carbonate. The predominant color of these deposits is light tan, although buff and gray beds have been observed.

Distribution, thickness, and surface form.—The Kingsdown silt crops out over most of the High Plains surface in the northern two-thirds of the county and in small areas in the southern part (pl. 1). It also underlies part of the Meade basin, underlies an area of sand dunes in the northeastern corner of the county, and occurs as the upper part of the fill in some of the large filled sink holes.

In Meade county the Kingsdown silt has a maximum exposed thickness of about 45 feet, but it may attain a greater thickness locally under the High Plains surface in the western part of the county where only the upper part is exposed.

The loosely consolidated deposits comprising the Kingsdown generally produce rounded slopes. The upper massive silt and loess will stand in fresh cuts in a nearly vertical bluff, but like most loess, will weather to a rounded slope if the slump and slope wash debris is not removed from the foot of the bluff.

Age and correlation.—The Kingsdown silt was believed by Cragin (1896, p. 54) to be late Pliocene in age, but its stratigraphic position unconformably above the Meade formation restricts its age to uppermost Pleistocene and Recent (Smith, 1940, pp. 111-116; Frye and Hibbard, 1941, p. 420). The only vertebrate fossils recovered from the Kingsdown are of Recent age.

Water supply.—In parts of Meade county, notably the High Plains areas, the Kingsdown silt lies wholly above the water table and hence is dry. Elsewhere in the county, notably the part of the artesian basin north of Fowler and in a few isolated sinks, the basal sands of the Kingsdown are saturated and yield small supplies of water.

Only one sample of water from the Kingsdown was collected for analysis, but analyses of several mixed Kingsdown and alluvium waters are given in table 7. Reported data indicate that the quality of water in the Kingsdown ranges within wide limits, but in general the water is harder than water from the Ogallala or Meade formations.

TERRACE DEPOSITS

Extensive terrace deposits occur along the major valleys in Meade county. The terraces are of considerable physiographic interest, but are for the most part relatively unimportant as a source of ground water. The most prominent terrace occurs along the Cimarron valley. Its crest attains a maximum height of 100 feet or more above stream level, and it is underlain by beds of gravel and sand, and locally some beds of thin-bedded silt. These terrace gravels have been quarried on a fairly large scale near the Oklahoma state line.

The terrace deposits lie unconformably against beds of the Laverne, Ogallala, and Meade formations, and have yielded teeth of *Paraelephos columbi* (Falconer). These facts seem to date this terrace as very late in the Pleistocene and to make it nearly contemporary with the Kingsdown silt, which mantles the uplands to the north of the Cimarron valley. Thus, it seems that the erosion of the lower 80 to 100 feet of the Cimarron valley took place during Recent time, and that at about the close of the Pleistocene the Cimarron valley had a depth of not more than 25 to 50 feet below the upland surface. It may be that the terrace deposits represent the main channel deposits at the time flood plain and eolian sediments were accumulating on the adjacent upland surface.

In Clark county extensive terrace deposits underlie the floor of the Ashland and Englewood basins and extend westward into eastern and southeastern Meade county along Sand creek and adjacent streams. In most places these terrace deposits in Meade county are thin and do not constitute an important source of ground water, although locally along the Meade-Clark county line they contain an appreciable thickness of saturated sand and gravel. The upper part of these deposits are Recent in age (Frye and Hibbard, 1941, p. 420). A typical section of these deposits is given below.

Section of Englewood terrace, NW sec. 35, T. 33 S., R. 26 W.

	Thickness, feet
Terrace deposits	
8. Clay, silt, and some sand, dark gray, massive. Contains considerable carbonaceous material and a few fragments of bone	6.2
7. Clay, silt, and some sand, gray, thin bedded at the base, becoming massive upward. Contains a few small nodules of calcium carbonate	2.3
6. Sand, fine, and silt, brown, thin bedded	.5
5. Silt and sand, light gray, thin bedded	.4
4. Silt and sand, light brick-red, thin bedded. Mottled and streaked with black, a gray and black zone occurs at the top	1.0
3. Sand, some silt, and a few pebbles of caliche, light brick-red, finer upward	6.2
2. Conglomerate of caliche, limestone, blocks of siltstone, and cobbles of dark brown sandstone, in a matrix of pink-tan sand and silt. A distinct unconformity at base	4.5
Total thickness of terrace deposits	21.1
Permian	
1. Siltstone, brick-red	5.0

A low terrace approximately 10 feet above flood-plain level and consisting dominantly of fine sand and silt occurs along Crooked creek valley south of Meade, and a similar terrace occurs locally along the Cimarron valley and some of its tributaries. These terraces are all quite young and, owing to their predominantly fine texture and topographic position, are of little importance as water-bearing deposits.

ALLUVIUM

Recent alluvium occurs on the floor of the basin north of Meade, where natural levees have been built (Frye, 1941), along Crooked creek, Cimarron river, and Sand creek and adjacent streams. The alluvium consists chiefly of sand and sandy silt and is quite thin.

A few wells obtain small supplies of water from the alluvium in Meade county. Most of the water obtained from the alluvium is of good quality, but some is highly mineralized. Four analyses of water from the alluvium, listed in table 7, indicate a considerable range in quality, and show that at least locally the water from the alluvium contains considerable total solids and hardness.

DUNE SAND

Dune sand of Recent age (Frye and Hibbard, 1941, p. 422) occurs on the uplands in the northeastern and southwestern parts of the county, along the valley flat of the Cimarron river, and on the upper surface of the Englewood terrace deposits in the southeastern part of the county (pl. 1). Smith (1940, pp. 127, 128, and 153-168) has given an excellent discussion of the distribution, form, and development of sand dunes in this area.

In every locality known to me the dune sand occurs above the water table and so yields no water to wells. The dune areas are important, however, in the part they play in aiding recharge. The dune sand is quite permeable and rain water enters the sand rather than running off. Thus, the dunes act to hold rain water in the area in which it fell and so give it a much greater opportunity for downward percolation to the water table.

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RECORDS OF TYPICAL WELLS

Descriptions of the wells visited in Meade county are given in the following table (table 10). The wells are listed in order by townships from north to south and by ranges from east to west. Within a township the wells are listed in the order of the sections. All information classed as "reported" was obtained from the owner, tenant, or driller. Depths of wells not classed as "reported" are measured and given to the nearest tenth of a foot below the measuring point described in the table, and depths to water level of non-flowing wells not classed as "reported" are measured and given to the nearest hundredth of a foot.

TABLE 10.—*Records of wells in Meade county, Kansas*

Well No. on plate 2	Location	Owner or tenant	Type of well (1)	Depth of well (feet) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Height above land surface (feet)	Measuring point: Height above sea level (feet)	Water level above (+) or below (—) measuring point (feet)	Date of measurement	Remarks—(Yield of nonflowing wells and discharge of flowing wells given in gallons a minute; draw-down given in feet)
	T. 30 S., R. 26 W.															
1	NE NW sec. 3	M. M. Way	Dr	190	2	P	Sand	Ogallala	F	D	Top of tank, west side	2.0	....	+2.7	7-26-39	See analysis. Discharge 0.3
2	NE NW sec. 3	do	Dr	110	2	P	do	do	F	S	Top of stock tank, east side.	1.6	2,494.7	+6.55	7-26-39	See analysis. Discharge 1.25
3	NE NW sec. 3	do	Dr	60	2	P	do	Pleistocene	F	S	Top of stock tank	2.0	....	+2.8	7-26-39	Discharge 0.3
4	NE NW sec. 4	J. E. Little	Dr	270	2	P	do	Ogallala	F	D	Land surface	.0	....	.0	7-26-39	Well is tapped below land surface in basement of house, and when not pumped will flow 1.5
5	SE NE sec. 4	do	Dr	270	1½	P	do	do	F	S	Top of concrete tank, east side.	2.0	....	+3.9	7-26-39	Discharge 0.6
6	NE SE sec. 4	do	Dr	125	2	P	do	do	F	S	Top of "L" in casing	2.0	....	+2.0	7-26-39	Discharge 0.3
7	NW SW sec. 4	J. E. Luts	Dr	228	16	GI	Sand and gravel	do	T,G	I	Slot at east side pump base	1.2	....	—10.40	7-17-39	Yield 960. Observation well
8	Cen. SW sec. 4	J. E. Little	Dr	120	2	P	Sand	do	F	N	Top of "L" on top of well casing.	3.8	....	+2.0	7-26-39	Discharge 0.3
9	NW SW sec. 5	W. A. Ellson	Dr	210	16	P	Sand and gravel	do	T,T	I	Top of 20-inch oil drum formed in concrete base.	.5	....	—21.40	7-21-39	See analysis
10	NW NE sec. 9	J. E. Little	Dr	250	1¼	P	Sand	do	F	S	Top of casing	1.8	....	+4.6	7-26-39	Discharge 1.5
11	NW NE sec. 9	do	Dr	250	1	P	do	do	F	S	Top edge iron water tank, south side.	.9	....	+1.9	7-26-39	Discharge 0.5
12	SW NW sec. 9	I. C. Rees	B	31.1	4	GI	do	Pleistocene	N	N	Top of casing, west side	2.0	....	—20.46	7-19-39	Observation well
13	NE NW sec. 13	W. T. Krisle	Dr	81.0	5	GI	do	do	Cy,W	S	Top of casing, north side	.3	2,582.4	—78.17	9-31-39	
14	NW NW sec. 15	M. W. Shogrin	Dr	22.5	5	GI	do	do	Cy,W	S	Top of casing, south side	1.0	2,508.1	—15.61	9-31-39	
15	SW NW sec. 16	W. P. Bunyan	Dr	150	1	P	do	Ogallala	F	N	Top of stock tank, north side.	1.0	....	+2.9	8-25-39	See analysis
16	SW SE sec. 18	L. L. Ming	Dr	270	24	GI	Sand and gravel	do	T,T	I	Hole in base of pump	1.0	....	—15.62	8-13-40	

7	SE SE sec. 18	do	Dn	14.4	2½	P	Sand	Pleistocene	N	N	Top of casing, south side	2.5		—11.51	7-19-39	
8	SW SW sec. 22	Fowler State Bank	B	51.0	5	GI	do	do	Cy,W	S	Top of casing, west side	1.0	2,535.2	—44.23	9-31-39	
9	NE NE sec. 26	G. L. Hatfield	Dr	104.8	6	GI	do	do	Cy,W	N	Top of casing, northeast side.	1.0		—104.68	7-19-39	
0	SW SW sec. 29	W. T. Krisle	Dr	125	1	P	do	Ogallala	F	N	Bottom of slot in casing	.3		+.2	8-26-39	Discharge 0.2
1	SW SW sec. 29	do	Dr	125	6	P	do	do	N	N	Top of casing	3.6		—3.3	8-26-39	
2	SE NE sec. 31	J. H. Young	B	14.6	6	GI	do	Pleistocene	Cy,H	N	Concrete pump base, south side.	.7	2,480.9	—14.56	7-19-39	
3	SW SE sec. 35	H. V. Plymole	Dr	101.0	5	GI	do	do	Cy,W	S	Top of square concrete curb, east side.	.5		—91.66	9- 7-39	See analysis
	T. 30 S., R. 27 W.															
4	NW SE sec. 4	H. L. Salmon	Dr	185	16	I	Sand and gravel	Ogallala	T,G	I	Top of casing, east side	.7		—29.75	8-15-39	Yield 850
5	NW NW sec. 8	J. D. Netmore	Dr	96.0	3	P	Sand	Pleistocene	Cy,W	N	Top of casing	1.0		—35.89	10- 5-39	
6	NW SW sec. 15	J. O. Padget	Dr	256	4	P	do	Ogallala	Cy,W	D,S	do	1.0	2,552.2	—15	7-22-39	
7	NW NW sec. 16	E. R. Porter	Dr	143	5	GI	do	do	Cy,W	D,S	Top of pump base	.2	2,614.9	—69.89	10- 6-39	
8	SE SE sec. 18	C. A. Harner	Dr	57.4	4	P	do	Pleistocene	Cy,W	S	Top of casing, north side	1.4		—44.39	7-22-39	
9	SW SW sec. 19	Ellen McBeth	Dr	180	1	P	do	Ogallala	F	S	North edge of stock tank	.6		+.9	8- 9-39	Discharge 0.25
0	SW SW sec. 20	J. F. Boyd	Dr	200	2	P	do	do	F	N	Top of casing	.3		.0	8-20-39	
1	SE SE sec. 20	K. Boyd	Dr	180	2	P	do	do	F	D,S	Top of discharge pipe	2.2		+2.2	8-25-39	Discharge 4
2	SW NW sec. 21	F. E. Calhoon	Dr	175	2	P	do	do	F	D	Top of concrete curb	.0		+2.5	8- 9-39	Discharge 0.75
3	SW SW sec. 21	do	Dr	170	2	P	do	do	F	D,S	Top of 1-inch reducer on 2-inch casing.	1.2	2,529.0	+6.5	8-25-39	Discharge 3.75
4	SW SW sec. 21	do	Dr	170	2	P	do	do	F	S,I						Discharge 11
5	SE SW sec. 22	D. Zortman	Dr	100	2	P	do	Pleistocene	F	S	Top of casing	.2		+8.3	8-25-39	Discharge 1.2
6	SE SW sec. 22	do	Dr	217	2	P	do	Ogallala	F	D	do	1.1	2,511.2	+7.8	8-25-39	Discharge 2
7	NW NE sec. 23	Christopher Sobba	Dr	210	16	I	Sand and gravel	do	N	N	Top of wooden platform, north side.	.15		—15.72	8-31-39	Observation well. Originally pumped for irrigation but abandoned in 1937 owing to collapse of casing
8	NW NE sec. 23	do	Dr	290	16	I	do	Meade and Ogallala.	T,G	I	Slot at east side of pump	.8		—13.56	7-13-39	Yield 950. See analysis
9	NW NW sec. 24	do	B	30	4	GI	Sand	Kingsdown	Cy,H	D	Concrete paving at pump base.	.0		—27	8-19-39	
0	SW NW sec. 26	H. O. Zortman	Dr	267	2	P	do	Ogallala	F	D,S	Top of "T" at top of casing.	1.0	2,504.0	+6.9	8-25-39	Discharge 6.75

Table 10.—Records of wells in Meade county, Kansas—*Continued*

Location	Owner or tenant	Type of well (1)	Depth of well (feet) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Height above land surface (feet)	Measuring point: Height above sea level (feet)	Water level above (+) or below (—) measuring point (feet)	Date of measurement	Remarks—(Yield of nonflowing wells and discharge of flowing wells given in gallons a minute; draw-down given in feet)
SW NE sec. 26	J. C. Schubert	Dr	210	2	P	do	do	F	N	....	....	....	....	....	Discharge 1.4
SE SW sec. 26	J. N. Rogers	Dr	162	2	P	do	do	F	D,S	Land surface	.0	....	+16.5	8-22-39	Discharge 12
SW SE sec. 26	E. L. Walker	Dr	175	2	P	do	do	F	D	Top of concrete sidewalk at well.	.0	....	+15.4	8-22-39	Discharge 10
NW NE sec. 27	H. E. Zortman	Dr	400	3	P	do	do	F	S,I	Top of 2-inch reducer on on 3-inch casing.	.3	....	+15.7	8-25-39	Discharge 29
SW NW sec. 27	Frank Colliday	Dr	340	2	P	do	do	F	D	Top of wooden trough	5.1	....	+4.0	8-25-39	Discharge (through 1-inch pipe) 3.5
SW NW sec. 27	do	Dr	180	2	P	do	do	F	S	Edge of stock tank, east side.	3.0	....	+3.5	8-25-39	Discharge 3.7
SE NE sec. 27	H. E. Zortman	Dr	175	3	P	do	do	F	I	Top of casing	2.5	....	+7.7	8-25-39	Discharge 23
NE SE sec. 27	do	Dr	350	3	P	do	do	F	D	Land surface	.0	....	+18	8-25-39	Discharge 50
NE SE sec. 27	do	Dr	380	3	P	do	do	F	S,I	....	....	....	....	....	Discharge approximately 50
NW SE sec. 27	do	Dr	170	2	P	do	do	F	S	do	.0	....	+10	8-25-39	Discharge 2.25
SE NE sec. 28	G. W. Walker	Dr	350	3	P	do	do	F	D	Top of 1-inch extension	3.7	....	+4.8	8-25-39	Discharge 5
NW SW sec. 28	E. M. Nuss	Dr	350	4	P	do	do	F	N	Top of 4-inch gate valve	1.0	....	+9.0	8- 3-39	Discharge 87
NW SW sec. 28	do	Dr	350	3	P	do	do	F	N	Top of "L" on casing	3.2	....	+6.9	8- 3-39	Discharge 58
NW SW sec. 28	do	Dr	350	2	P	do	do	F	N	Top discharge pipe	1.0	....	+10	8- 3-39	Discharge 9
NE NE sec. 29	W. W. Marr	Dr	200	16	I	Sand and gravel	Meade and Ogallala.	F	I	Top of earthen levee of pond.	1.0	....	+8	7-19-39	Discharge 100
NE NE sec. 29	do	Dr	200	2	P	Sand	do	F	I	Top of casing	.0	....	+6.3	7-19-39	Discharge 15
NE NE sec. 29	do	Dr	200	2	P	do	do	F	I	do	1.5	....	+5.84	7-19-39	Discharge 9. See analysis
NW NE sec. 29	do	Dr	200	2	P	do	do	F	D	Concrete porch floor	.2	....	+8.5	7-19-39	Discharge 3

NW NE sec. 29	do.	Dr	200	2½	P	do.	do.	F	S	Top of overflow pipe from milk shed.	2.0		+5.5	7-19-39	Discharge 6.4
NE NE sec. 30	Frank Marr	Dr	175	2	P	do.	do.	F	D	Top of "L" in casing	1.1		+2.2	8- 9-39	Discharge 0.75
NE SE sec. 30	G. M. Dowell	Dr	160	2	P	do.	do.	F	I	Top of casing	1.8		+6.2	8-20-39	Discharge 6.75
NE SE sec. 30	do.	Dr	350	2	P	do.	Ogallala	F	D	Top of concrete tank, south side.	1.6		+1.7	8-21-39	Discharge 0.9
NE NE sec. 31	Joseph Rocke	Dr	390	4	P	do.	do.	F	S,I	Top of 2-inch reducer	.3	2,523.4	+9.1	8-22-39	Discharge (through 2-inch pipe) 9
NE NW sec. 31	G. L. Harris	Dr	175	2	P	do.	Meade and Ogallala.	F	D,S	Top edge of stock tank, west side.	1.2		+6.6	8- 9-39	Discharge (through ⅝-in. reducer) 6.5
NE NW sec. 31	do.	Dr	200	4	P	do.	do.	F	N	Top of casing					Discharge 7
SE NE sec. 31	Joseph Rocke	Dr	200	3	P	do.	do.	Cy,H	N	do.	.8	2,529.5	+4.17	7-22-39	
SE SE sec. 31	Frank Sourbeer	Dr		3	P	do.	do.	F	S	Top of discharge pipe	2.0		+3.8	7-22-39	Discharge 7
NE NE sec. 32	A. E. Post	Dr	150	2	P	do.	do.	F	S	Top of casing	.4		+3.4	8- 5-39	Discharge 1.75
SW NW sec. 32	C. F. Wells	Dr	340	3	P	do.	Ogallala	F	N	Top of discharge pipe	1.0		+8.8	8- 7-39	Discharge 1.5
SE NE sec. 32	A. E. Post	Dr	150	2	P	do.	Meade and Ogallala.	F	N	Top of casing	.4		+1.9	8- 5-39	Discharge 1.25
NE SE sec. 32	R. L. Marr	Dr	160	2	P	do.	do.	F	N	Top of discharge pipe	1.0		+9.4	8- 5-39	Discharge 22.5
NE SE sec. 32	do.	Dr	160	2	P	do.	do.	F	S,I	do.	1.5		+10.0	8- 5-39	Discharge 37.5
NW SW sec. 32	J. S. Turner	Dr	175	2	P	do.	do.	F	N	Top of gate valve	2.0	2,507.2	+5.3	7-22-39	Discharge 13.5
SW SW sec. 32	do.	Dr	175	2	P	do.	do.	F	D	Top of casing	3.0		+1.72	7-22-39	Discharge 2.25
SW SW sec. 32	do.	Dr	175	2	P	do.	do.	F	S	do.	.5		+2.05	7-22-39	Discharge 4.7
SW SW sec. 32	do.	Dr	175	2	P	do.	do.	F	D	do.	.0		+2.02	7-22-39	Discharge 1.9
SW SW sec. 32	do.	Dr	175	2	P	do.	do.	F	I	do.	.0		+1.8	7-22-39	Discharge 1.9
SW SW sec. 32	do.	Dr	175	2	P	do.	do.	F	D	Land surface	.0		+3.5	7-22-39	Discharge 3
SW NW sec. 33	J. S. Congdon	Dr	160	2	P	do.	do.	F	N	Top of casing	.0		+1.8	8- 5-39	Discharge 1.25
SE SW sec. 33	C. F. Wells	Dr	130	4	P	do.	do.	F	N						Discharge 3
SE SW sec. 33	do.	Dr	160	3	P	do.	do.	F	I	do.	3.9		+8.7	8- 3-39	Discharge 30. See analysis
SE SW sec. 33	do.	Dr	115	2	P	do.	Meade	F	S	do.	2.0		+3.7	8- 3-39	Discharge 6
SE SW sec. 33	do.	Dr	115	1½	P	do.	do.	F	S	Top of discharge pipe	.6		+6.5	8- 3-39	Discharge 11.25

Table 10.—Records of wells in Meade county, Kansas—*Continued*

Location	Owner or tenant	Type of well (1)	Depth of well (feet) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Height above land surface (feet)	Measuring point: Height above sea level (feet)	Water level above (+) or below (—) measuring point (feet)	Date of measurement	Remarks— (Yield of nonflowing wells and discharge of flowing wells given in gallons a minute; draw-down given in feet)
SE SW sec. 33	do	Dr	115	2	P	do	do	F	D,S	Top of "T" at top of casing.	1.6	....	+7.1	8- 3-39	Discharge 22.5. Second flowing well drilled in the county
NW NE sec. 34	Great Amer. Life Ins. Co.	Dr	200	2	P	do	Meade and Ogallala.	F	S	....	....	....	....	....	Discharge 0.3
NW NW sec. 34	Howard Nourman	Dr	175	2	P	do	do	F	N	Top of casing	1.0	....	+12.0	8- 5-39	Discharge 0.5
NW SW sec. 34	C. F. Wells	Dr	190	6	P	do	do	F	N	do	3.5	....	....	8- 5-39	Discharge 3
SW SW sec. 34	do	Dr	190	1½	P	do	do	F	S	Top of tank, south side	2.4	....	+6.4	8- 5-39	Discharge 2.25
SW SW sec. 34	do	Dr	190	2	P	do	do	F	N	Concrete walk, west side of milk shed.	.0	....	+13.9	8- 5-39	Discharge 7.5
SW SE sec. 35	H. M. Copenhaver	Dr	180	24	I	do	do	F	N	Top of tank, south side	1.0	....	+4.7	8-21-39	Discharge (through 1½-inch pipe) 5.75. Well is in shed and is piped to stock tank. Does not flow over top of the casing
NW NW sec. 36	H. J Lawson	Dr	175	2	P	do	Meade	F	N	Top of discharge pipe	1.5	....	+2.78	7-19-39	Discharge from two pipes 4.25 See analysis
SW NW sec. 36	do	Dr	120	2	P	do	do	F	N	Top of "L" in casing	2.2	2,471.2	+4.2	9-22-39	Discharge 0.3
SW NE sec. 36	do	Dr	180	2	P	do	do	F	S	Top of casing	.0	2,471.0	+4.0	8-21-39	Discharge 1.25
NW SE sec. 36	Charley Cheney	Dr	180	1	P	do	do	F	N	Top of "L" in casing	3.6	....	+8.9	8-21-39	Discharge 0.75
NE SW sec. 36	J. E. Law	Dr	180	2	P	do	do	F	S,I	do	3.0	....	....	8-21-39	Discharge 5.75
NE SW sec. 36	do	Dr	140	1½	P	do	do	F	D	Top of discharge pipe	4.0	....	....	8-21-39	Discharge 0.4
T. 30 S., R. 28 W.															
NW NW sec. 10	W. Merkle	Dr	62	3	P	do	do	N	N	Top of casing	.3	2,619.9	—32.99	9- 9-39	Shot hole for geophysical exploration; 10 feet of casing in hole

NE NE sec. 12	J. D. Wetmore	Dr	100	3	P	do.	do.	Cy,W	D,S	Top of casing, west side	1.5		—26	10- 4-39	
NE NE sec. 14	W. Merkle	Dr	68	4	P	do.	do.	Cy,W	S	Top of casing, south side	4.0	2,607.9	—35.34	10- 5-39	
SE SE sec. 15	C. W. Farris	Dr	134.6	3	P	do.	do.	N	N	do.	.6	2,665.0	—86.37	7-24-39	Observation well
SE NE sec. 19	M. E. Pierson	Dr	125	5	GI	do.	do.	Cy,W	D,S	Top of concrete pump base	.5	2,706.2	—112.31	10-10-39	
NW NE sec. 25	C. I. Reeves	Dr	75	5	P	do.	do.	N	N	Top of 14-inch drum, west side.	1.0		— 44.41	10-10-39	Shot hole for geophysical exploration
NW NE sec. 25	do.	Dr	185	3	P	do.	do.	Cy,W	D,S	Top of casing	2.2		—37.94	10-10-39	
SW SW sec. 25	J. S. Turner	Dr	170	2	P	do.	do.	F	S	do.	.3		+7.9	7-24-39	Discharge 4.5
NW SE sec. 26	P. Nation	Du	17.2	24	S	Sand and silt	do.	Cy,W	S	Top of concrete curb	2.0		—16.07	10- 4-39	
NW SW sec. 32	H. C. Hague	Dr	148	5½	GI	Sand	do.	Cy,W	D,S	Top of casing	1.0		—114.24	10-10-39	
T. 30 S., R. 29 W.															
NW NW sec. 3	D. J. Schmidt	Dr	90	3	P	do.	Meade and Ogallala.	Cy,W	D,S	Land surface	.0		—75	9-14-40	See analysis
NE NW sec. 6	E. Adams	Dr	162	5	GI	do.	Ogallala	Cy,H	N	Concrete pump base	.5	2,806.4	—159.82	7-20-40	
SW SW sec. 23	H. Jenkinson	Dr	149.8	3	P	do.	do.	N	N	Top of casing, west side	1.0		—133.42	7-21-40	
NE NW sec. 30	G. E. Gano	Dr	169	5	GI	do.	do.	Cy,W	D,S	Top of casing	.8	2,781.1	—149.2	8-30-40	
NE NE sec. 31	C. B. Moore	Dr	141	5	GI	do.	do.	Cy,W	D	Top of pipe clamp	.5	2,755.9	—132.70	7-22-40	
T. 30 S., R. 30 W.															
SE SE sec. 7	A. J. and L. P. Collingwood.	Dr	153	4		do.	do.	Cy,W	S	Top of casing	.2	2,814.7	—139.4	8-30-40	
SW SW sec. 10	J. T. Dunham	Dr	154.5			do.	do.	Cy,W	D,S	Top of pipe clamp, west side.	2		— 152.5	9-14-40	
NW NW sec. 20	D. L. Shranner	Dr	180.4	5½	GI	do.	do.	N	N	Top of casing, southwest side.	.3	2,822.8	—158.12	7-21-39	
SW SW sec. 31	W. R. Wilson	Dr	160	3	P	do.	do.	Cy,W	D	Top of casing	.3	2,805.0	—149.5	8-30-40	
T. 31 S., R. 26 W.															
NE NW sec. 6	City of Fowler	Dr	275	12	I	do.	do.	T,E	PS	Top air-vent hole in pump-base.	1.5	2,493.5	—30.74	9-29-39	Yield 400. See analysis
NE NW sec. 6	do.	Dr	287	12	I	do.	do.	T,E	PS			2,491.6			Yield 400. Estimated total pumpage for 1938, 30,500,000 gallons
NE NE sec. 7	H. L. Salmon	Dr	50	6	P	do.	Mea e	N	N	Top of casing, east side	.5	2,486.2	—26.61	7-26-39	Observation well
NW SW sec. 10	P. Nation	Dr	148	5	GI	do.	Ogallala	Cy,W	S	Top of casing, west side	1.5	2,562.9	—92.29	9-21-39	
T. 31 S., R. 27 W.															
NW NW sec. 3	L. A. Hoope	Dr	160	2½	P	do.	Meade and Ogallala.	F	N	Top of "T" on casing	3.0		+2.5	8-21-39	Discharge 0.2
NW NW sec. 4	Robinson	Dr	150		P	do.	do.	F	S	Top of discharge pipe	.0		+10.0	8- 5-39	Discharge 6

Table 10.—Records of wells in Meade county, Kansas—*Continued*

Well No.	Location	Owner or tenant	Type of well (1)	Depth of well (feet) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Height above land surface (feet)	Measuring point: Height above sea level (feet)	Water level above (+) or below (—) measuring point (feet)	Date of measurement	Remarks—(Yield of nonflowing wells and discharge of flowing wells given in gallons a minute; draw-down given in feet)
[illegible]	NW NW sec. 4	do	Dr	350	2	P	do	do	F	S,I	Top of dike of pond	2.5	2,477.7	+7.8	8- 5-39	Discharge 7.1
[illegible]	SW SE sec. 4	J. H. Black	Dr	175	6	P	do	do	F	N	Bottom of 1-inch hole in south side of casing	1.3	2,469.9	+0.5	7-29-39	Discharge 0.1
[illegible]	NE NE sec. 5	C. F. Wells	Dr	348	2	P	do	Ogallala	F	D	Land surface	.0	....	+11.2	8- 5-39	Discharge 15. Location of first flowing well drilled in the county
[illegible]	SW NW sec. 5	Frank Marr	Dr	150	4	P	do	Meade and Ogallala.	F	I	Top of discharge pipe	.0	....	+7.7	8- 7-39	Discharge 25
[illegible]	SW NW sec. 5	do	Dr	150	2	P	do	do	F	I	Top of casing	.2	....	+9.7	8- 7-39	Discharge 18
[illegible]	SW NW sec. 5	do	Dr	150	1	P	do	do	F	S	Top of "L" in casing	2.0	....	+5.5	8- 7-39	Discharge 6
[illegible]	SW NW sec. 5	do	Dr	150	2	P	do	do	F	D	Top of concrete trough, west side.	2.2	....	+5.8	8- 7-39	Discharge 15
[illegible]	SW NW sec. 5	do	Dr	240	3	P	do	Ogallala	F	I	....	....	....	....	....	Discharge 20
[illegible]	SE NW sec. 5	do	Dr	150	3	P	do	Meade and Ogallala.	F	I	Top of 2½-inch reducer on 3-inch casing.	.7	....	+7.0	8- 7-39	Discharge 18
[illegible]	SE NE sec. 5	C. F. Wells	Dr	120	2	P	do	do	F	S,I	Top of discharge pipe	3.0	2,469.3	+6.6	8- 5-39	Discharge 11.25
[illegible]	SW SW sec. 5	L. A. Hoope	Dr	....	2	P	do	Meade	F	D,I	Top metal drain pipe	.0	....	+3.2	8-28-39	Discharge 1.25
[illegible]	SW SW sec. 5	do	Dr	....	3	P	do	Meade and Ogallala.	F	D	Top of "T" on casing	1.2	2,477.5	+7.0	8-28-39	Discharge 2.5
[illegible]	SW SW sec. 5	do	Dr	....	2	P	do	do	F	S	Top of concrete tank, south side.	1.3	....	+4.8	8-28-39	Discharge 1.25
[illegible]	NW NE sec. 6	Howard Nourman	Dr	190	5⅝	P	do	do	F	D,I	....	....	....	....	....	Discharge 10
[illegible]	NE NE sec. 6	do	Dr	200	3	P	do	do	F	I	Top of 2-inch reducer on casing.	.0	....	+3.6	10- 5-39	Discharge (through 2-inch pipe) 7.5
[illegible]	SW SW sec. 6	L. A. Hoope	Dr	360	3	P	do	Ogallala	F	S	Top of "L" on casing	1.8	....	+2.7	8- 9-39	Discharge 2.2
[illegible]	NW SW sec. 6	do	Dr	360	3	P	do	do	F	S	Top of "T" on casing	3.2	....	+	8- 9-39	Discharge 6.6

SW SW sec. 6	do	Dr	260	1½	P	do	do	F	D	Concrete walk, east side of house.	.0		+9.2	8- 9-39	Discharge 7.2
SW SW sec. 6	do	Dr	190	2	P	do	Meade and Ogallala.	F	S	Top of tank, west side	2.2		+0.3	8- 9-39	Discharge 1
SE SW sec. 6	do	Dr	260	2	P	do	Ogallala	F	S	Top of tank, east side	1.0		+5.8	8- 9-39	Discharge 2.8
SW SE sec. 6	School district	Dr	260	1½	P	do	do	F	D,I	Top of "L" on casing	2.3	2,483.8	+3.3+	7-29-39	Discharge 10
NE NE sec. 7	Victory Life Ins. Co.	Dr	200	2	P	do	Meade and Ogallala.	F	N						Discharge 0.8
SW NE sec. 7	do	Dr	200	1½	P	do	do	F	N						Discharge 1.4
SW NE sec. 7	do	Dr	65	5	P	do	Meade	F	N						Discharge 2.5
NE SE sec. 7	P. D. Edward	Dr	135	1¼	P	do	do	F	D						Discharge 1.2
NE SE sec. 7	do	Dr	180		P	do	Meade and Ogallala.	F	I	Top of discharge pipe	1.0		+2.6	8-26-39	Discharge 3
NE SE sec. 7	do	Dr	45		P	do	Meade	F	S	Top of concrete trough, north side.	1.3		+2.1	8-26-39	Discharge 0.2
NW SE sec. 7	do	Dr	180	1½	P	do	Meade and Ogallala.	F	S	Top of casing	.5		+3.8	8-26-39	Discharge 8
SW SE sec. 7	do	Dr	180	1½	P	do	do	F	N	do	.0		+17.0	8-25-39	Discharge 19
SE SE sec. 7	do	Dr	180	1½	P	do	do	F	I	do	.0		+12	8-25-39	Discharge 9.9
NE NE sec. 8	Helen Eliason	Dr	180	2	P	do	do	F	S	Top of tank, south side	2.5		+7.6	8-28-39	Discharge 6.5
NW NE sec. 8	do	Dr	180	8	P	do	do	F	N						Discharge 80
NW NE sec. 8	do	Dr	180			do	do	F	N						Discharge 30
NW SE sec. 9	L. S. Mayberry	Dr	200	2	P	do	do	F	N	Top of 1-inch reducer on casing.	1.0		+10+	8-28-39	Discharge (through 1-inch pipe) 5
SW SE sec. 9	do	Dr	200	1½	P	do	do	F	N	Top of concrete tank	1.5		+8.8	8-28-39	Discharge 2.1
NW SW sec. 10	do	Dr	200	2	P	do	do	F	N	Top of concrete tank, west side.	2.0	2,456.4	+6.0	8-28-39	Discharge 3. See analysis
NE NW sec. 11	Fowler State Bank	Dr	160	2	P	do	do	F	N	Top of casing	.0	2,459.7	+3.6	7-26-39	Discharge 0.3
NW SW sec. 11	W. A. Burford	Dr		1½	P	do	Meade	Cy,H	N	do	1.4		−1.6	8-22-39	
NW NE sec. 14	C. R. Cheney	B	22	5	GI	do	Alluvium and Kingsdown.	Cy,W	S	Top of casing, west side	1.0	2,456.6	−8.39	9-21-39	See analysis
SW SW sec. 14	do	B	18	6	GI	do	do	Cy,W	S	Top of casing, south side,	1.5	2,455.2	−13.80	9-20-39	
NW NW sec. 15	M. Sealock	Dr	80	1½	P	do	Meade	F	D,S	Top of casing	1.3		+3.2	8-28-39	Discharge 1.3
NE NE sec. 16	D. Hildebrandt	Du	100	24	W	do	do	Cy, W	N	do	.0	2,451.2	−.5	8-28-39	
NE NE sec. 17	W. R. Lynch	Dr	90	2	P	do	do	F	S	Land surface	.0		+	8-29-39	Discharge 0.5

Table 10.—Records of wells in Meade county, Kansas—*Continued*

ll). te	Location	Owner or tenant	Type of well (1)	Depth of well (feet) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Height above land surface (feet)	Measuring point: Height above sea level (feet)	Water level above (+) or below (—) measuring point (feet)	Date of measurement	Remarks—(Yield of nonflowing wells and discharge of flowing wells given in gallons a minute; draw-down given in feet)
5	SE SE sec. 17	do	Dr	100	2	P	do	do	F	S	Top of discharge pipe	3.0	2,449.1	+2.7	8-28-39	Discharge 1.2
6	NW NE sec. 18	P. D. Edward	Dr	290	2	P	do	Ogallala	F	N	Top of gate valve	1.7	2,471.1	+ .9	8-25-39	Discharge 1.7
7	SW NW sec. 18	M. Schumacker	Dr	175	1½	P	do	Meade and Ogallala.	F	S	Top of tank, north side	1.9		+5.9	8- 8-39	Discharge 1.5. See analysis
8	NW SE sec. 18	Meade State Bank	Dr	150	2	P	do	do	F	N	Top of casing	.2		+11.6	8-25-39	Discharge 3.25
9	NE NE sec. 19	Walter Owbridge	Dr	160	2	P	do	do	F	S	Top of tank, south side	.4		+8.45	7-29-39	Discharge 7.5
0	SW NW sec. 19	O. F. Klein	Dr	200	1	P	do	do	F	N	Top of tank, west side	1.7		+6.4	7-29-39	Discharge 1.25
1	NE SW sec. 20	B. W. DeWitt	Dr	160	2	P	do	do	F	S	Top of casing	2.0		+1.0	8- 7-39	Discharge 1.1
2	SE SE sec. 23	School district	Dr	66	5	GI	do	Meade	Cy,W	S	Top of concrete pump base, east side.	.5	2,483.1	—61.98	9-20-39	
3	NW NW sec. 26	John Meyer	Dr	87.5	6	GI	do	do	N	N	Top of casing, south side	.6		—61.16	7-26-39	
4	NE NE sec. 27	H. W. Eisenbart	Dr	165.5	5	P	do	Meade and Ogallala.	N	N	Top of casing	.3	2,483.2	—57.28	10- 5-39	
	T. 31 S., R. 28 W.															
5	SE NE sec. 1	O. W. McClung	Dr	240	2	P	do	Ogallala	F	S	do	1.1	2,503.9	+1.38	7-22-39	Discharge 1.9
6	SW SE sec. 1	O. W. Fletcher	Dr	140	2	P	do	Meade	F	S	Top of tank, east side	2.0		+5.8	8- 9-39	Discharge 15
7	NE NE sec. 12	M. L. Leach	Dr	160	2	P	do	Meade and Ogallala.	F	S, I	Top of casing	1.6		+2.5	8- 8-39	Discharge 1
8	NE NE sec. 12	do	Dr	160	2	P	do	do	F	D, I	do	.4		+7.4	8- 8-39	Discharge 5.5
9	NE NE sec. 12	do	Dr	175	2	P	do	do	F	S	Top of tank, east side	2.3		+12.1	8- 8-39	Discharge (through ⅝-inch faucet) 8.5
0	NE NE sec. 12	do	Dr	150	4	P	do	do	F	N	Top of casing	.1		+5.7	8- 8-39	Discharge 15
1	NE NE sec. 12	do	Dr	175	2	P	do	do	F	N	do	.0		+12.9	8- 8-39	Discharge (through ⅝-inch hose) 7.5

32	NE SE sec. 12	L. C. Perry	Dr	140	2	P	do	do	F	D, S	Top of tank, north side	1.4		+4.9	8-20-39	Discharge 3
33	NE SE sec. 12	do	Dr	340	2	P	do	Ogallala	F	D	Concrete floor in milk house.	.0		+5.8	8-21-39	Discharge 2.3
34	SW SW sec. 12	Cudahy Packing Co.	Dr	150	2	P	do	Meade and Ogallala.	F	N	Top of discharge pipe	2.5	2,484.8	+12.5	7-29-39	Discharge 22.5
35	NE NE sec. 13	J. W. Davis	Dr	300	3	P	do	Ogallala	F	I	Top of concrete reservoir, northeast corner.	.0		+9.6	7-18-39	Discharge 14.25
86	NE NE sec. 13	do	Dr	300	2½	P	do	do	F	I	Top of concrete reservoir, west edge.	.0		+9.30	7- 8-39	Discharge 1.5
87	NE NE sec. 13	do	Dr	300	2½	P	do	do	F	S, I	Concrete paving	.0	2,472.4	+9.9	7-18-39	Discharge 10.5
88	NE NE sec. 13	do	Dr	250	2	P	do	do	F	D, I	Land surface	.0		+3.7	7-18-39	Discharge 3
89	SW SW sec. 13	R. L. Stacey	Dr	125	3	P	do	Meade and Ogallala.	F	N	Top of casing	.3		+1.2	7-29-39	Discharge 0.1
90	SW SW sec. 13	do	Dr	125	2	P	do	do	F	D	Top of concrete trough in shed.	2.4		+ .32	7-29-39	Discharge 0.1
91	NE SW sec. 14	H. V. Gulick	Dr	100	1½	P	do	Meade	F	S	Top of casing	.2		+4.2	7-29-39	Discharge 0.75
92	NW SW sec. 14	do	Dr	100	1½	P	do	do	F	S	do	.3		+2.8	7-29-39	Discharge 1.25
93	SE SE sec. 14	do	Dr	95.5	6	GI	do	do	N	N	Top of casing, south side	.0	2,537.11	—44.44	7-29-39	Observation well
94	NE SW sec. 23	J. F. Isaac	Dr	264	16	I	do	Ogallala	T, G	I	Top of casing	.0		—28	7-22-39	Yield at 500
95	SW SW sec. 23	W. Calgan	B	4.4	5	GI	Sandy silt	Meade	N	N	Top of casing, south side	.2		—3.94	7-21-39	
96	NE NE sec. 24	J. E. Lockhart	Dr	150	1½	P	Sand	Meade and Ogallala.	F	D, I	Top of concrete tank, south side.	2.0		+ .2	7-29-39	Discharge 1.2
97	NE NW sec. 24	C. E. Andrews	Dr	186	2	P	do	Ogallala	F	D,S,I	Top of casing	1.8		+8.2	8- 8-39	Discharge 2.5. See analysis.
98	NE NE sec. 24	J. E. Lockhart	Dr	150	3	P	do	Meade and Ogallala.	F	D	Concrete paving	.0		+2.3	7-29-39	Discharge 0.75
99	SW NE sec. 24	do	Dr	150	2	P	do	do	F	S	Top of concrete tank, south side.	2.5		+3.8	7-29-39	Discharge 1.5
00	SW SE sec. 24	B. W. DeWitt	Dr	15(?)	2	P	do	Meade	F	S	Top of casing	.7		+3.4	8- 7-39	Discharge 0.2. Location of former spring
01	SW SE sec. 24	do	Dr	65	2	P	do	do	F	S	Top of "T" on casing	4.0		+2.9	8- 7-39	Discharge 7.7
02	NW NE sec. 25	do	Dr	110	2	P	do	do	F	S, I	Top of tank, north end	2.0		+5.2	8- 7-39	Discharge 11.2
03	NW NE sec. 25	do	Dr	85	2	P	do	do	F	S	Top of discharge pipe	.5		+5.5	8- 7-39	Discharge 3.3
04	NW NE sec. 25	do	Dr	65	2	P	do	do	F	D	Top of concrete trough, south side.	1.5		+ .9	8- 7-39	Discharge 0.75
05	NW NW sec. 26	W. Calgan	B	5.2	6	GI	Sandy silt	do	N	N	Top of casing, north side	.0		—4.55	8- 7-39	
06	SE SW sec. 26	A. W. Batman	Dr	175	2	P	Sand	Meade and Ogallala.	F	D, S	Top of "L" on casing	2.0	2,472.6	+1.6	8- 7-39	Discharge 2.5
07	SW NW sec. 27	O. J. Dettle	Dr	78	5	GI	do	Meade	Cy,W	S	Top of concrete pump base.	.5	2,541.4	—48.44	9-22-39	

Table 10.—Records of wells in Meade county, Kansas—*Continued*

Well No. on plate 2	Location	Owner or tenant	Type of well (1)	Depth of well (feet) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Height above land surface (feet)	Measuring point: Height above sea level (feet)	Water level above (+) or below (—) measuring point (feet)	Date of measurement	Remarks—(Yield of nonflowing wells and discharge of flowing wells giver in gallons a minute; draw-down given in feet)
208	NE NW sec. 29	W. K. H. Trust Co.	Dr	139	5	GI	do	do	Cy,W	D, S	Hole in brake drum, top of casing.	.4	2,668.5	—123.42	9-28-39	
209	SW NE sec. 35	E. A. Kobs	Dr	160	2	P	do	Ogallala	F	S	Top of tank, north side	2.5	2,455.6	+3.05	7-28-39	Discharge 0.3
210	NE SW sec. 35	L. F. Schulmaker	Dr	150	1	P	do	do	F	S	Top of iron tank, south side.	1.1		+1.10	7-18-39	Discharge 0.2. See analysis.
211	NE NW sec. 36	Edwards	Dr	125	2	P	do	Meade and Ogallala.	F	S	Top of casing	.2		+1.4	7-28-39	Discharge 0.3
212	SW NW sec. 36	do	Dr	125	2	P	do	do	F	D	Land surface	.0		+2.3	7-28-39	Discharge 0.75
213	SW NW sec. 36	do	Dr	300	2	P	do	Ogallala	F	D	Top of concrete trough, west side.	2.5		+1.2	7-28-39	Discharge 0.4
214	SW NW sec. 36	do	Dr	125	3	P	do	Meade and Ogallala.	F	S	Top of casing	2.0		+2.05	7-28-39	Discharge 1.25
215	SW SW sec. 36	L. H. Russell	Du	114	48	W	do	Meade	Cy,W	S	Top of 6-inch plank across well.	.0	2,440.0	—3.40	8-13-40	
216	SE SE sec. 36	J. S. Hoover	Dr	76	5	GI	do	do	Cy,W	S	Top of casing, west side	1.0	2,479.8	—68.34	9-20-39	
	T. 31 S., R. 29 W.															
217	SE SE sec. 6	M. Staats	Dr	130	3	P	do	Ogallala	Cy,W	D	Top of casing	3.0	2,744.3	—108.00	7-20-39	
218	SW NW sec. 11	A. J. and L. P. Collingwood.	Dr	130	5	GI	do	Meade and Ogallala.	Cy,W	D, S	do	1.2	2,715.4	—122.07	10-10-39	
219	NE NE sec. 25	I. E. Walter	Dr	146	6	GI	do	Ogallala	Cy,W	N	Top of casing, east side	.5	2,697.2	—143.58	9-25-39	
220	SE SE sec. 30	J. A. and D. F. Collingwood.	Dr	173.1	4	P	do	do	N	N	Top of casing, west side	.7	2,734.7	—130.79	7-31-39	
221	NE NE sec. 35	S. C. Hill	Dr	148.5	5	GI	do	Meade and Ogallala.	Cy,W	N	Top of galvanized-iron bucket, east side.	1.0	2,695.3	—136.43	7-21-39	
	T. 31 S., R. 30 W.															
222	NW SW sec. 4	C. G. Wallace	Dr	163	4	P	do	Ogallala	Cy,W	D,S	Top of casing	.2	2,777.7	—138.8	8-30-40	
223	SW SW sec. 10	W. E. Zimmerman	Dr	137	5	GI	do	do	N	N	do	.3	2,766.9	—132.66	7-22-40	

224	SE SE sec. 35	A. J. Collingwood	Dr	159	4	P	do	do	Cy,W	D,S	do	1.0	2,751.7	—148.7	8-30-40	
	T. 32 S., R. 26 W.															
225	SE SW sec. 3	L. Frazier	Dr	36.5	4	P	do	Alluvium	Cy,W	S	Bottom of ¾-inch hole in casing, east side.	2.0	2,363.4	—11.98	9- 7-39	See analysis
226	NE NE sec. 5	Phoenix H. Stk. Land Bank.	Dr	138	5	GI	do	Ogallala	Cy,W	N	Top of concrete pump base	1.0	2,493.4	—104.78	9-20-39	
227	SW SW sec. 9	F. C. Dahm	Dr	134	5	GI	do	do	Cy,W	S	Top of casing, south side	1.0	2,463.0	—104.21	9-21-39	
228	SE SE sec. 21	J. W. McCampbell	B	11	5½	GI	do	Alluvium	Cy,W	S	Top of casing	1.0	2,315.6	—10.4	7-19-40	
229	NW NW sec. 25	J. P. White	Du	10	36	B	do	do	P,H	D,S	Top of casing, north side	1.5	2,248.0	—8.71	9-11-40	See analysis
230	SW SE sec. 28	B. M. Garber	Dr	90	5	GI	do	Ogallala	Cy,W	S	Top of concrete pump base, north side.	.5	2,389.2	—85.42	9-11-40	
	T. 32 S., R. 27 W.															
231	SE SE sec. 1	F. A. Meyer	Dr	129.6	5	GI	do	do	Cy,W	N	Top of casing, east side	.3	2,491.0	—99.18	7-15-39	
232	SE SE sec. 4	C. D. Maxwell	Dr	133	6	GI	do	do	Cy,W	N	Top of casing, north side	.5	2,513.1	—100.92	9-21-39	
233	SE NE sec. 5	H. L. Friesen	Dr	113	4	P	do	do	N	N	Slot at top of casing, south side.	1.0	2,506.8	—88.53	9-11-39	See analysis
234	SE SE sec. 8	P. A. Reimer	Dr	124	5	GI	do	do	N	N	Top of pump base, west side.	2.5	2,534.9	—121.04	9-20-39	
235	NE NE sec. 22	M. L. Hartman	Dr	171.3	4	GI	do	do	Cy,W	S	Top of casing	1.0	2,532.7	—164.29	7-20-39	
236	NW NE sec. 24	T. Steinke	Dr	159.8	5½	GI	do	do	N	N	Top of casing, north side	.5	2,506.7	—158.81	7-20-39	Observation well
237	NW NW sec. 32	J. Bartel	Dr	134	5	GI	do	do	Cy,W	D,S	Top of casing	1.2	....	—118	9-20-39	
	T. 32 S., R. 28 W.															
238	SE NE sec. 4	J. W. Wood	Dr	126	3	P	do	Meade and Ogallala	Cy,W	N	Bottom of "T" in casing	2.6	2,548.4	—65.72	7-28-39	Do
239	SE SE sec. 5	B. H. Fisher	Dr	70	3	P	do	do	Cy,W	D,S	Top of casing	1.2	2,583.7	—67.50	9-26-39	
240	NW SE sec. 9	J. R. Graves	Dr	100	6	P	do	do	Cy,W	S	Top of casing, south side	.5	2,507.9	—42.22	9-26-39	
241	NE NE sec. 11	City of Meade	Dr	180	3	P	do	do	C,E	PS	Top of discharge pipe	.5	....	+1.0	9-28-39	Discharge 4.3
242	NE NE sec. 11	do	Dr	180	2	P	do	do	P,H	C	Top of 3-foot tile tank	2.0	2,432.2	—0.2	9-28-39	
243	NE NE sec. 11	do	Dr	180	2	P	do	do	F	I	Top of "L" in casing	1.0	....	+0.1	9-28-39	Discharge 0.1
244	NE NW sec. 11	do	Dr	278	12	I	Sand and gravel	do	T,E	PS	Hole for water line in base plate of pump.	1.5	....	—20.26	9-28-39	Yield 450. See analysis
245	NE NW sec. 11	do	Dr	285	12	I	do	do	T,E	PS	Top of casing, east side	1.0	2,450.0	—20.98	9-28-39	Yield 450. See analysis. During 1938 approximately 65,185,200 gallons pumped from wells 244 and 245
246	NW NW sec. 13	A. Mertens Estate	Dr	85	5	P	Sand	Ogallala	Cy,W	D,S	Top of casing, west side	.4	2,457.5	—83	9- 8-39	See analysis

Table 10.—Records of wells in Meade county, Kansas—*Continued*

Well No. on plate 2	Location	Owner or tenant	Type of well (1)	Depth of well (feet) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Height above land surface (feet)	Measuring point: Height above sea level (feet)	Water level above (+) or below (—) measuring point (feet)	Date of measurement	Remarks—(Yield of nonflowing wells and discharge of flowing wells given in gallons a minute; draw-down given in feet)
247	SW NE sec. 14	E. F. Bohn	Dr	140	2	P	do	do	F	N	Top of "L" on casing	3.3	....	+3.9	9- 6-39	Discharge 1.3
248	NW SW sec. 14	W. E. Clay	Dr	160	2	P	do	do	F	N	Top of casing	2.0	2,423.0	+2.2	9- 6-39	Discharge 1
249	NW SW sec. 14	do	Dr	90	2	P	do	do	Cy,W	D	Land surface	.0	....	.0	9- 6-39	
250	NE NE sec. 16	C. C. Reiss	Du	29.5	48	S	Sandy silt	Meade	Cy,W	D,S	Top of wooden pump platform	.2	....	—27.98	9-26-39	
251	NE NW sec. 20	Federal Land Bank	Dr	100	2	P	Sand	Meade and Ogallala.	F	D	Top of casing	—1.0	....	+1.1	8- 4-39	Discharge 1.5
252	NE NW sec. 20	do	Dr	100	3	P	do	do	F	D	do	—1.0	2,471.9	+1.1	8- 4-39	Discharge 9
253	NE NW sec. 20	do	Dr	100	1	P	do	do	F	D	do	—1.0	....	+1.1	8- 4-39	Discharge 0.75
254	SW SE sec. 21	E. W. McNaughten	Dr	200	5	GI	do	Ogallala	Cy,H	S	Top of concrete curb	.5	....	—3.25	9- 6-39	
255	SW SE sec. 22	do	Dr	150	2	P	do	do	F	D,S	Top of concrete tank	1.5	2,407.9	+2.0	9- 6-39	Discharge 0.9
256	NW NW sec. 23	F. B. Ross	Dr	62	......	......	do	Meade and Ogallala.	Cy,W	D	Top of concrete curb	.5	2,423.1	—2.0	9- 6-39	
257	SW NW sec. 23	do	Dr	82	2	P	do	do	F	S	Top of tank, west side	1.9	....	+2.8	9- 6-39	Discharge 1.25
258	NE SE sec. 24	J. E. and A. E. Loewen.	Dr	141	5	GI	do	do	Cy,W	D	Top of casing, west side	1.0	2,528.2	—124.96	9-20-39	
259	SW NW sec. 26	I. McSherry	Du	23	42	S	Sandy silt	Meade	Cy,W	D,S	Wooden pump platform	2.5	....	—18.82	8- 8-39	
260	SE SE sec. 31	F. Cramm	B	27	6	GI	Sand	Ogallala	Cy,W	D,S	Top of steel drum	2.2	2,472.1	—16.98	9-26-39	
261	SE NE sec. 32	C. Dye	Dr	158	5	GI	do	Meade and Ogallala.	Cy,W	S	Top of ⅝-in. bolt through pipe clamp.	1.0	2,456.9	—28.98	9-26-39	
262	NE NW sec. 34	J. M. Singley	Dr	125	2	P	do	do	F	N	Top of casing	.0	....	.0	8- 8-39	
263	NW NW sec. 34	E. W. McNaughten	Dr	200	3	P	do	do	F	N	do	2.5	....	+1.4	9- 6-39	Discharge 2.5
	T. 32 S., R. 29 W.															
264	NE NW sec. 10	C. E. Strohl	Dr	145	5	P	do	Ogallala	Cy,W	S	Top of casing, south side	1.0	....	—120	9- 9-39	

65	SW SE sec. 15	J. D. Golliher	Dr	147	3	P	do.	do.	P,W	D,S	Top of concrete curb	.0	2,677.8	—126.02	9- 6-40	See analysis
66	NE NE sec. 33	B. J. Berghause	B	6(?)	2	P	do.	do.	F	S	Top of tank, south side	1.9	....	+5.4	8-19-39	Discharge 1. Located at site of former spring
67	SE NE sec. 36	Continental Assurance Co.	Dr	160	4	P	do.	do.	Cy,W	S	Top of casing, south side	1.0	....	—93.27	9-26-39	
	T. 32 S., R. 30 W.															
68	SE NE sec. 6	S. L. Gorman	Dr	152	5	GI	do.	do.	N	N	Top of drop pipe	3.0	2,771.9	—149.99	7-22-40	
69	NE SW sec. 16	City of Plains	Dr	265	12	I	Sand and gravel	do.	T,E	PS	Air vent on south side of pump base.	—5.0	2,753.7	—153.99	9-28-39	Yield 300. See analysis. During 1938 about 10,560,000 gallons pumped from this well
70	NW NW sec. 21	....	Dr	166	5	GI	Sand	do.	Cy,W	D	Top of pump base	1.0	2,760.8	—162.62	9-28-39	
71	NW SW sec. 33	H. C. Bender	Dr	169	5	GI	do.	do.	N	N	Top of casing	.1	....	—167.8	7-22-40	
72	NE SW sec. 35	C. W. Holmes	Dr	230	18	I	Sand and gravel	do.	T,T	I	do.	.6	2,732.3	—160.2	10-18-39	Yield 440
	T. 33 S., R. 26 W.															
73	SW SE sec. 8	W. F. Fuhrman	Dr	127	5	GI	Sand and siltstone	Ogallala and Permian.	Cy,W	S	do.	1.0	2,261.0	—49.62	9-11-40	
74	SE SE sec. 8	School district	Dr	24	5	GI	do.	Alluvium and Permian.	Cy,H	N	do.	1.0	....	—21.1	9-11-40	
75	SE SE sec. 11	J. H. Clay	Dr	83.5	6	GI	Siltstone	Permian	Cy,W	D	Top of casing, south side	.4	2,161.1	—34.31	7-20-39	Observation well
76	NE SE sec. 16	W. F. Fuhrman	B	29.5	5	GI	Sand and gravel	Alluvium	Cy,W	D,S	Top of casing	.5	2,188.4	—23.39	9-11-40	See analysis
77	NW SW sec. 32	B. O. Gentry	Dr	107	5	GI	Sand	Ogallala	Cy,W	N	Top of concrete pump base	.3	2,359.1	—70.11	7-19-40	
78	NW NW sec. 34	H. L. Woodrubb	Dr	67.7	5	GI	do.	Ogallala and Permian.	N	N	Top of casing, northeast side.	.7	2,259.1	—38.29	7-20-39	Observation well
	T. 33 S., R. 27 W.															
79	NW SW sec. 3	J. A. Williams	B	6	12	GI	do.	Alluvium	N	N	Top of casing	2.2	2,351.4	—2.38	8- 6-40	
80	NW NW sec. 4	I. T. Classen	Dr	44	5	GI	do.	Meade	Cy,W	D	do.	.8	2,392.5	—26.40	9-11-39	See analysis
81	SW SW sec. 4	H. L. Jones	Dr	68	5	GI	do.	do.	Cy,W	S	Top of concrete pump base, north side.	.5	2,357.2	—3 48	9-11-39	
82	NW NW sec. 6	K. L. Wiens	Dr	84	5	GI	do.	do.	Cy,W	N	Top of casing, north side	1.0	....	—68.32	9-18-39	
83	NW SW sec. 7	Baker University	Dr	127	6	GI	do.	do.	Cy,W	N	do.	.8	....	—97.24	9-18-39	
84	NE NE sec. 9	J. J Thiessen	Dr	40	10	I	do.	do.	Cy,W	S	do.	.5	2,339.9	—18.05	9-11-39	Reported to have flowed at the surface when drilled
85	SE SE sec. 17	School district	Dr	169.3	6	......	do.	Ogallala	Cy,W	PS	Hole in base of pump	.8	2,483.0	—147.48	7-20-39	Observation well
86	SE SE sec. 26	J. Bartel	Dr	176	5	GI	do.	Ogallala and Permian.	Cy,W	N	Top of concrete pump base	.5	2,455.7	—160.58	7-19-40	

Table 10.—Records of wells in Meade county, Kansas—*Continued*

ell o. n ite 2	Location	Owner or tenant	Type of well (1)	Depth of well (feet) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed		Method of lift (4)	Use of water (5)	Measuring point			Water level above (+) or below (−) measuring point (feet)	Date of measurement	Remarks—(Yield of nonflowing wells and discharge of flowing wells given in gallons a minute; draw-down given in feet)
							Character of material	Geologic subdivision			Description	Height above land surface (feet)	Height above sea level (feet)			
7	NE SE sec. 31	C. J. Dirks	Dr	86	5½	GI	do	Meade and Ogallala.	N	N	Top of casing, north side	2.0		−29.16	7-27-39	
	T. 33 S., R. 28 W.															
8	SE NE sec. 2	A. Schideier	Dr	181	5	GI	Sand and gravel	do	Cy,W	D	Hole in side of casing, north side.	0.2		−132.88	9-18-39	
9	NE NE sec. 33	Federal Land Bank	Dr	180	2	P	Sand	do	F	N	Top of discharge pipe	.3	2,413.9	+1.0	9- 9-39	See analysis
0	SW SW sec. 4	E. H. Boyer	Dr	35	2	P	do	Meade	Cy,W	D	Land surface	.0		−6	8- 8-39	
1	SW SW sec. 14	A. W. Franke	Dr	153	4	P	do	Ogallala and Permian.	Cy,W	D,S	Hole in base of pump	1.0	2,504.9	−134.19	9- 8-39	Do
2	SE SW sec. 17	W. A. Adams	Dr	55	5	GI	do	Meade	Cy,W	D	Top of casing, east side	.6		−24.89	8- 8-39	
3	NE NW sec. 18	R. A. Harper	Dr	183	4	P	do	Ogallala	Cy,W	S	Top of casing, south side	1.5	2,446.6	−32.09	9-27-39	
4	SE SE sec. 18	County highway	Dr	290	4	N	Sand and gravel	Meade and Ogallala.	N	N	Crown of gravel road	.0	2,440.2	−66.6	9-12-40	Test hole, later plugged
5	NE NE sec. 20	F. Borchers	Dr	30	4	N	Gravel and siltstone.	Ogallala and Permian.	N	N	Land surface	.0	2,363.0	−4.1	9- 4-40	Do
6	NE NE sec. 24	P. P. Ediger	Dr	143	5	GI	Sand	Ogallala	Cy,W	D,S	Top of wooden pump base, north side.	1.0	2,497.1	−127.77	9-18-39	
7	SW NW sec. 29	F. Borchers	Dr	160	16	I	Sand and gravel	Meade and Ogallala.	T,G	I	Top of casing, northeast side.	1.0	2,372.3	−19.15	7-18-39	Observation well
8	SW SW sec. 29	do	Dr	93	4	P	Sand	do	Cy,W	D	Top of casing	2.0	2,362.4	−6.22	7-18-39	
9	SE NE sec. 31	J. H. Borchers	Dr	63	1½	P	do	Ogallala	F	D	Land surface	.0	2,348.0	+4	7-18-39	See analysis. Discharge 2
0	SE NE sec. 31	do	Dr	90	2	P	do	do	F	D	Top of concrete reservoir	1.5		+2.35	7-18-39	
1	SW SW sec. 32	H. Borchers	Dr	96		P	do	do	Cy,W	D	Land surface	.0		.0	7-18-39	
2	SE NE sec. 34	J. Barries	Dr	158.5	6	GI	do	Meade and Ogallala.	N	N	Top of casing, north side	.2	2,409.0	−158.28	7-20-39	
	T. 33 S., R. 29 W.															
3	NW SE sec. 4	T. L. Murphey	Dr	46.5	6	P	do	Ogallala	Cy,W	S	Top of casing	.3		−41.98	10- 4-39	

4	SW SW sec. 9	A. J. Collingwood	Dr	110.5	1½	P	do	do	N	N	Top of casing	.3	2,649.1	−110.45	10-4-39	
5	SE SE sec. 11	K. Bergner	Dr	182	2	P	do	do	N	N	Top of casing, north side	.5	....	−69.32	9-27-39	
6	NW SW sec. 14	Meade Co. State Park	Dr	370	3	N	Sand and gravel	do	N	N	Land surface	.0	2,500.4	−8.1	10-27-39	Test hole, later plugged
7a	NW SE sec. 15	do	Du	3.2	48	N	Sandy silt	Alluvium	N	N	do	.0	2,494.4	−2.8	10-20-39	Mud pit for test hole, later filled
7b	NW SE sec. 15	do	Dr	130	3	N	Sand and gravel	Ogallala	F	N	do	.0	2,494.4	+5.2	10-23-39	Test hole, later plugged. Discharge 5
8	NE NE sec. 20	R. R. Singley	Dr	122	5	GI	Sand	do	N	N	Top of bolt through pipe clamp, west side.	.2	....	−19.18	7-25-39	Observation well
9	NE NW sec. 20	County highway	Dr	480	3	N	Sand and gravel	do	N	N	Land surface	.0	2,682.4	−133.10	8-10-40	Test hole, later plugged
0a	NW NW sec. 23	Meade Co. State Park	Dr	20	3	N	Sand	do	N	N	do	.0	2,465.7	−11.05	10-17-39	Do
0b	NW NW sec. 23	do	Dr	404	3	N	Sand and gravel	do	F	N	do	.0	2,465.7	+17.4	10-21-39	Discharge 8
1	SE SE sec. 23	J. S. Croeman	Dr	230	6	GI	Sand	do	Cy,W	D,S	Top of wooden pump platform.	1.0	2,487.4	−74.26	10-4-39	
2	NW NW sec. 24	Meade Co. State Park	Dr	59	5	P	do	do	Cy,W	PS	Top of concrete curb	.0	2,447.0	−3.70	9-23-39	See analysis
3	SW SW sec. 25	B. A. Cordes	Dr	16.1	5½	GI	do	Meade	Cy,W	N	Top of casing, east side	.1	2,421.5	−13.38	7-18-39	Observation well
4	NE NW sec. 32	R. Carrell	Du	126	3	P	do	Ogallala	Cy,W	D,S	Top of pipe clamp on casing.	1.2	2,613.5	−96.1	8-31-39	
	T. 33 S., R. 30 W.															
5	NW NE sec. 9	W. S. Armentrout	Dr	208.5	4	P	do	do	N	N	Top of casing, south side	1.5	....	−174.06	7-24-39	Do
6	NW SW sec. 13	S. L. North	Dr	183	5	GI	do	do	Cy,W	N	Top of casing	.0	2,715.5	−171.29	10-4-39	
7	SW SE sec. 18	Plains State Bank	Dr	181.4	5	GI	do	do	Cy,W	N	do	3.2	2,725.3	−181.4	7-24-39	
8	NE NE sec. 20	County highway	Dr	580	3	N	Sand and gravel	do	N	N	Top of road grade	2.0	2,721.1	−172.8	7-31-40	Test hole, later plugged
9	NE SW sec. 31	J. W. Cardwell	Dr	206	5½	GI	do	Ogallala and Laverne.	Cy,W	S	Top of hole in pump base, east side.	1.0	2,708.6	−188.08	8-25-40	See analysis
0	SE SE sec. 32	W. H. Bond	Dr	205	4	......	do	do	Cy,W	D,S	Top of casing	.2	2,705.8	−181.7	8-23-40	
	T. 34 S., R. 26 W.															
1	NW SW sec. 24	C. E. Cox	Dr	109	6	GI	Siltstone	Permian	Cy,W	N	Top of pipe clamp, south side.	2.2	2,176.0	−61.69	7-27-39	See analysis
2	NE NE sec. 29	West and Higinbotham	Dr	110	5½	GI	Sand	Ogallala	N	N	Top of casing, south side	.3	....	−87.92	8-2-39	
3	NW NW sec. 30	M. K. Rogers	Dr	75	5½	GI	do	do	Cy,W	S	Top of casing	2.0	....	−25.23	8-20-40	
4	SW SE sec. 32	I. A. Ratslaff	Dr	54	2	P	Siltstone	Permian	N	N	do	7.0	2,199.2	−13.1	10-8-40	
	T. 34 S., R. 27 W.															
5	SW SE sec. 7	M. Klots	B	32	......	......	Sand	Meade	Cy,W	D,S	Top of concrete pump base	.2	....	−24.12	9-11-40	Do
6	NE NE sec. 21	V. V. Long	Dr	45	6	GI	do	Ogallala	N	N	Top of casing	.5	2,252.1	−33.6	10-8-40	
	NE NW sec. 23	P. Johannsen	Dr	98	6	GI	do	do	Cy,W	S	Top of casing, east side	.8	2,376.1	−91.01	9-11-40	Do

Table 10.—Records of wells in Meade county, Kansas—*Concluded*

Well No. on plate 2	Location	Owner or tenant	Type of well (1)	Depth of well (feet) (2)	Diameter of well (in.)	Type of casing (3)	Principal water-bearing bed		Method of lift (4)	Use of water (5)	Measuring point			Water level above (+) or below (—) measuring point (feet)	Date of measurement	Remarks—(Yield of nonflowing wells and discharge of flowing wells given in gallons a minute; draw-down given in feet)
							Character of material	Geologic subdivision			Description	Height above land surface (feet)	Height above sea level (feet)			
28	NE SE sec. 24	C. Desmarias	Dr	54	5½	GI	do	do	Cy,W	N	do	2.5	....	—37.79	8-20-40	
29	SW SW sec. 33	A. R. Winters	Dr	122	5	GI	do	Meade and Ogallala.	Cy,W	S	Top of sawed off pump base.	1.5	2,359.4	—107.86	9- 4-40	Do
30	SW SW sec. 34	W. Roemer	Dr	104	.....	.....	do	do	Cy,W	S	Top of pipe clamp	1.0	2,339.1	—92.04	9-16-40	
	T. 34 S., R. 28 W.															
31	NE NE sec. 3	R. L. L. Barnstable	Dr	95.2	5	GI	do	Meade	Cy,W	N	Top of casing, east side	1.6	2,380.4	—31.47	7-27-39	
32	SE NE sec. 11	A. M. and O. M. Eubank.	Dr	....	5½	GI	do	do	Cy,W	N	Top of casing, north side	.3	....	—33.49	7-27-39	Observation well
33	SE NW sec. 19	W. Merkle	Dr	160	4	P	do	do	P,W	D	Top of casing	.2	2,503.1	—136.7	8-31-40	
34	NE NE sec. 34	C. W. Waddel	Dr	23	8	GI	do	do	Cy,W	S	do	.4	2,366.9	—19.08	9- 8-39	See analysis
	T. 34 S., R. 29 W.															
35	SE NE sec. 3	G. C. Ely	Dr	159	4	P	do	Meade and Ogallala.	Cy,W	N	do	2.5	2,495.9	—93.33	10- 5-39	
36	NE NW sec. 30	H. G. Adams	Dr	117	6	GI	do	Meade	Cy,W	D,S	do	1.0	2,502.4	—86.45	8-31-40	
37	NW SW sec. 36	R. E. Adams	Dr	210	4	P	do	do	Cy,W	N	Top of casing	1.5	2,509.7	—184.75	8-31-40	
	T. 34 S., R. 30 W.															
38	NE NE sec. 9	M. E. Pierson	Dr	193	4	P	do	Ogallala and Laverne.	Cy,W	N	do	.5	2,697.5	—189.78	8-22-40	
39	NW SE sec. 12	M. C. Roads	Dr	189	4	P	do	Meade and Ogallala	Cy,W	S	do	3.2	2,663.5	—172.7	8-22-40	
40	SE SE sec. 20	J. W. Powell	Dr	203	4	P	do	Ogallala and Laverne.	Cy,W	S	do	1.0	2,686.2	—173.05	8-23-40	
41	NE NE sec. 26	A. W. Adams	Dr	220	8	I	do	Ogallala	Cy,W	S	do	2.5	2,658.2	—207.35	8-29-40	See analysis
42	NW SE sec. 27	do	Dr	240	6	GI	do	do	N	N	Top of bolt through pipe clamp.	2.5	2,666.5	—220.13	10- 4-39	
43	SW NW sec. 29	M. E. Holmes	Dr	121	5	GI	do	Ogallala and Laverne.	Cy,W	N	Top of casing, north side	1.0	....	—115.24	8-26-40	

T. 35 S., R. 26 W.															
SE NW sec. 4	W. Wyatt	Dr	80	5	GI	do	Ogallala and Permian.	Cy,W	D,S	Top of concrete curb	1.5	2,311.1	—66.36	8-20-40	Do
SE NW sec. 18	W. F. Sutherland	Dr	172	5½	GI	do	Meade and Ogallala.	Cy,W	N	Top of casing	2.0	2,341.1	—166.47	9-17-40	
T. 35 S., R. 27 W.															
SW NE sec. 7	H. Werdeman	Dr	65.5	5	GI	do	Meade	N	N	do	.5	2,334.5	—64.8	9-4-40	
SW NE sec. 11	West and Higginbotham	Dr	140	6	GI	do	Ogallala	Cy,W	S	Top of hole in base of pipe clamp.	.6	2,329.0	—123.04	9-17-40	Do
NE NE sec. 14	do	Dr	72	6	GI	do	Meade and Ogallala.	N	N	Top of concrete pump base, west side.	.0	2,358.9	—65.75	9-17-40	
T. 35 S., R. 28 W.															
NW NW sec. 2	L. Frazier	Dr	139	4½	P	do	Meade	Cy,W	N	Top of casing	2.0	2,381.6	—79.86	7-19-40	
NW NW sec. 5	H. Borchers	Dr	103	4	P	do	do	Cy,W	D,S	do	.5	2,433.5	—63.38	7-19-40	
NE SE sec. 9	B. Dore	Dr	114	3	P	do	do	N	N	do	.1	2,373.2	—100.79	7-19-40	
SW SE sec. 12	R. R. Dickey	Dr	98	6	GI	do	do	N	N	Top of casing, east side	.8	2,355.6	—70.34	9-14-40	
T. 35 S., R. 30 W.															
NW NE sec. 10	A. W. Adams	Dr	91	4	P	do	Alluvium and Ogallala.	N	N	Top of casing	.0	2,480.5	—59.75	8-29-40	
SE SW sec. 10	do	Dr	57	6	GI	do	Alluvium	N	N	do	2.0	2,421.7	—39.9	8-29-40	See analysis

1. B, bored; Dn, driven; Dr, drilled; Du, dug.
2. Measured depths given in feet and tenths; reported depths given in feet.
3. B, barrel; C, concrete; GI, galvanized-iron; I, iron or steel, slip joint or welded; N, none; P, iron pipe or oil well casing; S, stone; W, wood.
4. Pumps: C, centrifugal; Cy, cylinder; F, natural flow; N, none; P, pitcher; T, turbine. Power: E, electric motor; G, gasoline engine; H, hand; T, tractor; W, wind.
5. C, community; D, domestic; I, irrigation; In, industrial; N, none; PS, public supply; S, stock.
6. Measured water levels given in feet, tenths, and hundredths; reported water levels given in feet.

LOGS OF TEST HOLES

The logs of 24 test holes drilled by the hydraulic-rotary drilling machine, owned and operated by the State and Federal Geological Surveys are given below. These test holes were drilled during the course of the present investigation in Meade county. The samples obtained from the test holes were studied in the field by Perry McNally and were examined microscopically in the laboratory by Charles C. Williams and me. Many fossils were recovered from some of these samples. The vertebrate material is being studied by C. W. Hibbard and the snails by A. B. Leonard of the University of Kansas. When their studies have been completed some revision in the correlations made may be necessary. The locations of the test holes are shown in figure 13.

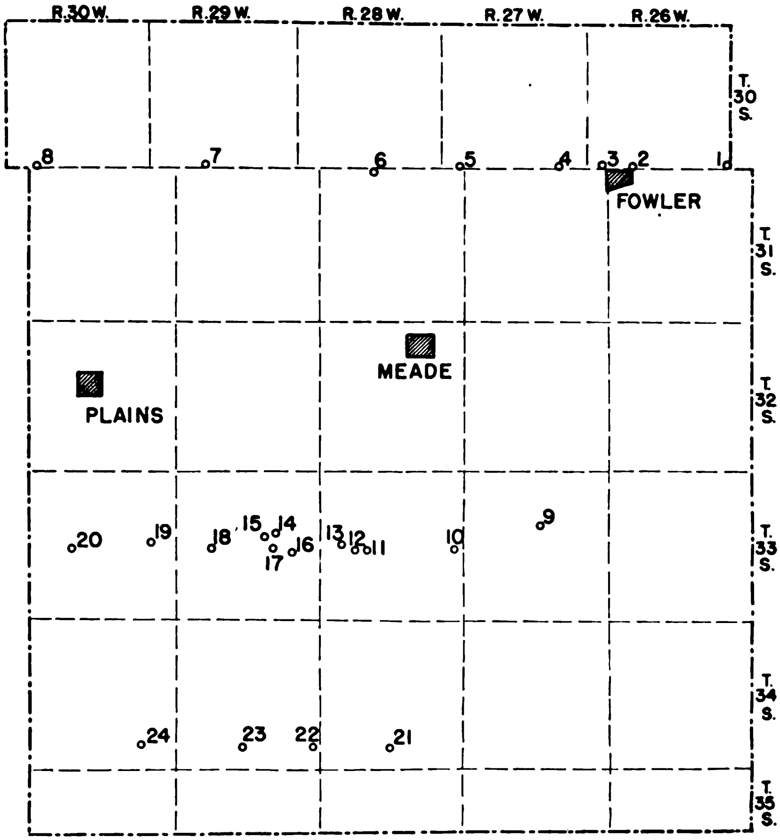

FIG. 13. Map of Meade county showing locations of test holes drilled as part of the field work for this report.

1.—*Log of test hole 1, 115 feet north and 4 feet west of the SE corner sec. 36, T. 30 S., R. 26 W. Surface altitude, 2,578 feet.*

	Thickness, feet	Depth, feet
Soil, sandy, brown	4	4
Kingsdown silt		
Sand, silt, and caliche, tan	33	37
Ogallala formation		
Sand, fine, and nodules of caliche, brown	7	44
Sand, containing some silt and a few nodules of caliche, brown to buff	26	70
Gravel, poorly sorted	8	78
Silt, sand and caliche, tan and gray	92	170
Sand, containing some silt and clay, brown	6	176
Sand and silt, contains some caliche, pink-brown	4	180
Sand and some gravel, brown	3	183
Cretaceous		
Shale, sandy, light gray and blue-gray	117	300
Limestone and shale, interbedded, gray	20	320
Shale, dark blue-gray and gray	37	357
Permian		
Siltstone, maroon	13	370

2.—*Log of test hole 2, 135 feet north and 5 feet west of the SE corner sec. 32, T. 30 S., R. 26 W. Surface altitude, 2,489 feet.*

	Thickness, feet	Depth, feet
Soil, sandy, brown	6	6
Kingsdown silt		
Silt and fine sand, yellow-brown	6	12
Sand, silt and some nodules of caliche, tan	48	60
Ogallala formation		
Sand and gravel, poorly sorted, brown	10	70
Sand, silt and caliche, yellow-brown, gray and tan	63	133
Silt, sand and caliche, yellow-tan	22	155
Sand and silt, tan	5	160
Sand, brown	17	177
Cretaceous		
Shale, gray and blue-gray	27	204
Sand, medium to coarse	22	226
Shale, blue-gray	86	312
Sandstone, light gray	6	318
Permian		
Siltstone, pink-brown	8	326
Limestone, light gray	3	329
Siltstone, pink-brown	11	340

3.—*Log of test hole 3, SE corner SW, sec. 31, T. 30 S., R. 26 W. Surface altitude, 2,464 feet.*

	Thickness, feet	Depth, feet
Soil, brown	6	6
Kingsdown silt		
Sand, fine, silt, and some caliche, tan and gray	33	39
Sand, fine, and silt, gray and tan	31	70
Meade formation		
Silt, sand and clay, dark gray	23	93
Sand, gray	12	105
Sand and silt, gray-tan, contains fragments of fossils	26	131
Sand, contains fragments of fossils	29	160
Silt, clay and fine sand, gray	15	175
Clay, silt and gravel, gray	5	180
Sand and fine gravel	10	190
Silt, clay and fine sand, gray, fragments of fossils	20	210
Silt and fine sand, some caliche, gray	59	269
Ogallala formation		
Sand and caliche, tan	49	318
Sand and gravel, contains some silt, brown	16	334
Sand, fine, and silt, yellow-brown	8	342
Cretaceous		
Shale, blue-gray	48	390

4.—*Log of test hole 4, 140 feet north and 25 feet west of the SE corner, sec. 35, T. 30 S., R. 27 W. Surface altitude, 2,482 feet.*

	Thickness, feet	Depth, feet
Soil, yellow-tan	8	8
Kingsdown silt		
Silt and fine sand, gray to gray-tan	32	40
Meade formation		
Sand, fine, and silt, blue-gray	19	59
Silt and fine sand, some gypsum, gray	36	95
Silt, fine sand and clay, blue-green-gray	33	128
Sand, fine, and silt, yellow-tan	29	157
Sand, with caliche pebbles and silt, orange-tan-brown	22	179
Sand and gravel, poorly sorted	21	200
Ogallala formation		
Sand, caliche and some gravel, gray	22	222
Caliche and sand, gray	31	253
Sand and caliche, gray	17	270
Sand, silt, and caliche, light tan	20	290
Sand and fine gravel, brown	15	305
Cretaceous		
Shale, blue-gray to gray-black	94	399
Sandstone, fine, light blue-gray	6	405
Permian		
Siltstone, red-brown	15	420

5.—Log of test hole 5, 950 feet west and 120 feet north of the SE corner, sec. 31, T. 30 S., R. 27 W. Surface altitude, 2,504 ± feet.

	Thickness, feet	Depth, feet
Soil, light brown	6	6
Kingsdown silt		
Sand, fine, and silt, yellow-brown to tan	16	22
Meade formation		
Caliche, sand and silt, gray	12	34
Volcanic ash, impure (poor sample)	2	36
Silt and fine sand, green-gray, contains fragments of fossils	34	70
Silt, fine sand and caliche, light blue-gray	20	90
Silt and clay, gray	10	100
Silt and fine sand, variegated color, contains fragments of fossils	34	134
Sand, well rounded, brown	16	150
Sand, fine to medium, brown	24	174
Sand and silt, contains some caliche, gray to pink-brown,	53	227
Caliche, sand and silt, pink-tan	13	240
Sand, fine, and silt, brown	10	250
Sand, contains some silt pebbles of caliche, and gravel, brown	20	270
Ogallala formation		
Sand, cemented with caliche, brown	19	289
Sand, fine, and silt, gray, loosely cemented with caliche	11	300
Caliche, sand and silt, gray	33	333
Sand, silt and caliche, gray	5	338
Cretaceous		
Sandstone, fine, and silty, yellow-tan	20	358
Siltstone and shale, olive-green, blocky	12	370

6.—Log of test hole 6, 90 feet south of the SW corner, sec. 34, T. 30 S., R. 28 W. Surface altitude, 2,700 ± feet.

	Thickness, feet	Depth, feet
Soil, sandy, brown	8	8
Meade formation		
Sand and caliche pebbles, tan-brown	10	18
Sand, brown to gray	7	25
Sand, fine, and caliche, light gray to brown	9	34
Sand, silt, and caliche, light gray	6	40
Sand, medium, some beds partly cemented with caliche	56	96
Silt, sand and caliche, tan	5	101
Sand, fine to medium, brown	18	119
Sand, medium to coarse, contains some caliche, brown	31	150
Silt and some sand, dark gray	7	157
Silt and fine sand, dark gray, contains some ostracodes	30	187
Silt and fine sand, yellow-green-gray	58	245
Sand and gravel, brown	18	263

	Thickness, feet	Depth, feet
Silt and caliche, gray	8	271
Silt, sand and caliche, gray	14	285
Silt and caliche, interbedded and variegated	5	290
Ogallala formation		
Sand, fine to medium, tan, partly cemented with caliche	50	340
Sand and fine gravel, brown	34	374
Silt and fine sand, tan	7	381
Sand, silt and gravel, partly cemented with caliche, gray	39	420
Sand and gravel, gray to light tan	8	428
Cretaceous		
Shale, yellow-tan	52	480

7.—Log of test hole 7, 75 feet north and 20 feet east of the SW corner, sec. 33, T. 30 S., R. 29 W. Surface altitude, 2,750 ± feet.

	Thickness, feet	Depth, feet
Soil, brown	2	2
Kingsdown silt		
Silt, fine sand and caliche, tan to brown	48	50
Sand, brown	20	70
Meade formation		
Silt and sand, cemented with caliche	4	74
Gravel, fine, and sand	25	99
Silt, sand and caliche, tan and light gray	16	115
Sand, silt and clay, yellow-tan	43	158
Sand and gravel, brown	48	206
Silt and sand, yellow-tan	6	212
Sand and fine gravel, brown	38	250
Silt, sand and clay, gray	20	270
Sand, coarse, brown	40	310
Sand, and interbedded fine gravel, silt, clay and caliche	20	330
Sand and fine gravel, gray	10	340
Sand, fine, and silt, gray, contains some caliche	20	360
Ogallala formation		
Caliche, contains silt and fine sand, gray	12	372
Silt, clay and fine sand, cemented with caliche, tan	38	410
Sand and some silt, brown	14	424
Sand, silt and caliche, gray	10	434
Cretaceous		
Silt and clay, blocky, yellow-tan	37	471
Sandstone, fine, gray	7	478
Permian		
Siltstone, maroon	3	481

8.—Log of test hole 8, 100 feet south and 20 feet east of the NW corner, sec. 6, T. 31 S., R. 30 W. Surface altitude, 2,795 ± feet.

	Thickness, feet	Depth, feet
Soil, brown	1	1
Kingsdown silt		
Silt and fine sand, gray-tan	7	8
Sand, fine to medium, brown	4	12
Sand, fine, and silt, contains some caliche, gray-tan	79	91
Meade formation		
Sand and silt cemented with caliche, brown	6	97
Sand and gravel, brown	11	108
Silt, fine sand and caliche	2	110
Sand and gravel, brown and tan	232	342
Sand, fine, silt and caliche, gray	18	360
Silt, fine sand and caliche, gray	31	391
Sand, gray	21	412
Sand, fine, silt and caliche, pink-tan	8	420
Sand, brown	11	431
Ogallala formation		
Sand and some silt, cemented with caliche	19	450
Silt, fine sand and caliche, tan	20	470
Sand, fine, silt and caliche, gray, contains some plant remains	20	490
Silt, caliche and fine sand, tan and gray	23	513
Caliche, silt and fine sand, yellow, contains some thin beds of sandstone and pink-red beds of clay	17	530

9.—Log of test hole 9, 65 feet south and 30 feet east of the NW corner, sec. 15, T. 33 S., R. 27 W.

	Thickness, feet	Depth, feet
Soil, brown	4	4
Kingsdown silt		
Silt, fine sand and some caliche, tan	7	11
Sand, fine, silt and caliche, tan	23	34
Meade formation		
Caliche, contains some silt and fine sand, tan	17	51
Sand, contains some caliche, brown	10	61
Sand, fine, silt and caliche	69	130
Sand, contains some silt and caliche, brown	17	147
Sand and fine gravel, brown	8	155
Ogallala formation		
Sand cemented with caliche, tan	14	169
Sand, brown, contains some silt	17	186
Permian		
Siltstone, red	14	200

10.—*Log of test hole 10, 50 feet south and 10 feet west of the NE corner, NW sec. 24, T. 33 S., R. 28 W.*

	Thickness, feet	Depth, feet
Soil, blackish, brown	2	2
Kingsdown silt		
Silt, fine sand and caliche, tan	31	33
Meade formation		
Sand, brown to pink-brown	22	55
Sand, medium, to fine gravel, contains a little caliche	16	71
Ogallala formation		
Caliche, fine sand and silt, pink-brown	36	107
Sand, fine to medium, tan-brown	13	120
Sand, fine, and silt, brown	9	129
Silt, fine sand and caliche, tan	15	144
Sand, fine to medium, silt and caliche, brown	11	155
Silt, sand and gravel, pink-red-brown	8	163
Permian		
Siltstone, maroon	7	170

11.—*Log of test hole 11, NE NE sec. 20, T. 33 S., R. 28 W. Surface altitude 2,363 feet*

	Thickness, feet	Depth, feet
Ogallala formation		
Sand and gravel, tan	17	17
Permian		
Siltstone, red and gray	13	30

12.—*Log of test hole 12, NE NW sec. 20, T. 33 S., R. 28 W.*

	Thickness, feet	Depth, feet
Alluvium		
Sand, gravel and silt, brown	19	19
Ogallala formation		
Sand, blue-gray, contains some silt, caliche and fragments of wood	34	53
Silt and sand, gray and tan, contains shell fragments	20	73
Sand and caliche, brown	83	156
Sand, fine, silt, and caliche, pink-brown	9	165
Sand, and gravel, brown	36	201
Silt, sand and gravel, red-brown	5	206
Permian		
Siltstone, red	4	210

13.—*Log of test hole 13, 100 feet west of the SE corner sec. 18, T. 33 S., R. 28 W. Surface altitude, 2,440 feet.*

	Thickness, feet	Depth, feet
Soil and caliche, brown	6	6
Meade formation		
Sand, fine to medium, gray, contains some silt and caliche,	6	12
Silt, caliche, and fine sand, buff	54	66
Sand, silt, and gravel, tan	5	71
Sand and gravel, brown	24	95
Ogallala formation		
Silt, fine sand, and clay, gray	25	120
Sand and gravel, gray	8	128
Silt, fine sand, and clay, gray	12	140
Silt, sand, and caliche, gray	22	162
Sand and gravel, brown and tan, contains some silt and caliche	87	249
Sand and fine gravel, brown	30	279
Permian		
Siltstone, red	11	290

14.—*Log of test hole 14, NW SW sec. 14, T. 33 S., R. 29 W.*

	Thickness, feet	Depth, feet
Ogallala formation		
Sand, contains some silt and gravel, tan	11	11
Sand, silt, and caliche, tan	19	30
Sand and gravel, tan	26	56
Caliche, sand, and silt, tan to gray	44	100
Sand, tan	50	150
Silt, clay, and caliche, tan	2	152
Sand and gravel, tan, contains some caliche	199	351
Permian		
Siltstone and shale, brick-red	19	370

15.—*Log of test hole 15, NW SE sec. 15, T. 33 S., R. 29 W.*

	Thickness, feet	Depth, feet
Soil, sandy, brown	4	4
Ogallala formation		
Sand, gravel, and caliche, tan	4	8
Sand, fine, silt and caliche, gray-green	11	19
Silt, sand, and caliche, tan and gray	28	47
Sand and gravel, tan	68	115
Silt, gray	15	130

16.—*Log of test hole 16, SE NE sec. 23, T. 33 S., R. 29 W.*

	Thickness, feet	Depth, feet
Soil, sandy, brown-black	2	2
Ogallala formation		
Sand, fine, and silt, tan	11	13
Sand and pebbles of caliche, tan	6	19
Silt and fine sand, gray	2	21
Sand and fine gravel, tan, contains some silt and caliche	21	42
Silt, fine sand, and caliche, gray, contains some fragments of fossils	138	180
Sand and gravel, tan	30	210
Silt and fine sand, blue-gray, contains fossil fragments	29	239
Sand, gravel and caliche, tan	25	264
Sand, pebbles of gravel and shale, cemented with caliche, red	11	275
Silt, sand, and caliche, brick-red	10	285
Permian		
Shale, red-brown	15	300

17.—*Log of test hole 17, NW NW sec. 23, T. 33 S., R. 29 W.*

	Thickness, feet	Depth feet
Ogallala formation		
Sand and silt, tan and buff	7	7
Silt, fine sand, and some caliche, gray-brown	45	52
Sand, fine, silt, and caliche, buff, contains fragments of fossils	19	71
Sand, tan	37	108
Silt and fine sand, fossiliferous, tan	32	140
Silt, carbonaceous material, and sand, fossiliferous	80	220
Silt and sand, light gray	20	240
Sand, fine gravel, and caliche	20	260
Silt, sand and caliche, gray	20	280
Sand, fine, silt and caliche, gray	10	290
Silt, fine sand, and caliche, red and gray	40	330
Sand and gravel, contains some caliche	30	360
Silt, sand, gravel, and caliche, red and gray	10	370
Permian		
Siltstone, red	20	390

18.—*Log of test hole 18, 45 feet west and 20 feet south of the NE corner NW sec. 20, T. 33 S., R. 29 W. Surface altitude, 2,682 feet.*

	Thickness, feet	Depth, feet
Soil, sandy	4	4
Kingsdown silt		
Silt, fine sand, and caliche, yellow-tan	25	29
Sand, fine, brown	19	48
Meade formation		
Silt, fine sand, and caliche, buff	26	74
Ogallala formation		
Sand, brown, contains some gravel and caliche	91	165
Silt and fine sand, tan	5	170
Sand and fine gravel, brown	88	258
Silt, sand, and caliche, blue-gray	39	297
Sand, gray-tan	13	310
Sand, fine to medium, silt, and caliche, gray	50	360
Sand, gray	101	461
Sand and silt cemented with caliche, gray	16	477
Permian		
Siltstone, red	13	490

19.—*Log of test hole 19, 90 feet south and 40 feet east of the SW corner sec. 13, T. 33 S., R. 30 W. Surface altitude, 2,716 feet.*

	Thickness, feet	Depth, feet
Soil, sandy, brown	4	4
Kingsdown silt		
Silt, sand and caliche, tan	26	30
Meade formation		
Sand, fine to medium, tan, contains some silt and caliche,	25	55
Gravel and sand, brown	22	77
Ogallala formation		
Silt, fine sand and caliche, tan	21	98
Sand and fine gravel, partly cemented with caliche, brown,	118	216
Silt and fine sand, gray	7	223
Sand, fine, to fine gravel, brown	21	244
Silt and fine sand, gray	17	261
Sand and gravel, brown and gray	39	300
Sand, gray and brown, contains some silt	20	320
Sand and gravel, brown	37	357
Silt interbedded with sand, gray and brown	42	399
Sand and gravel, brown	61	460
Silt, clay and fine sand, buff	18	478
Cretaceous		
Shale, buff-brown to pink-tan	20	498
Permian		
Siltstone, maroon-red	12	510

20.—*Log of test hole 20, 66 feet south and 6 feet west of the NE corner sec. 30, T. 33 S., R. 30 W. Surface altitude, 2,721 feet.*

	Thickness, feet	Depth, feet
Soil, sandy, brown	3	3
Kingsdown silt		
Silt, fine sand, and caliche, tan and gray	40	43
Meade formation		
Sand, fine, cemented with caliche, brown	6	49
Sand, fine, silt and caliche, brown and gray	44	93
Ogallala formation		
Sand and gravel, poorly sorted, and some caliche, brown,	54	147
Silt and sand, yellow-brown	8	155
Sand, medium, gray	35	190
Silt and sand, brown and gray	19	209
Sand, gray, contains some gravel and caliche	33	242
Sand and silt, gray and brown	17	259
Silt, clay, and fine sand, blue-gray, contains some fragments of fossils	50	309
Sand and fine gravel, gray, contains a few thin beds of silt and caliche	68	377
Silt, clay and sand, tan	32	409
Sand and gravel, gray and brown	55	464
Silt, clay, and fine sand, buff and gray	31	495
Cretaceous		
Sandstone and shale, interbedded	67	562
Sandstone, coarse, brown	10	572
Permian		
Siltstone, red	8	580

21.—*Log of test hole 21, 70 feet south and 60 feet west of the NE cornor, sec. 33, T. 34 S., R. 28 W.*

	Thickness, feet	Depth, feet
Dune sand, medium to fine, brown	6	6
Soil, yellow-brown	3	9
Meade formation		
Sand, fine to medium, brown	6	15
Silt and some fine sand, brown	2	17
Sand, medium, pink-brown	10	27
Silt and fine sand, pink-brown	54	81
Sand and caliche, brown and gray	19	100
Sand and fine gravel, brown	18	118
Silt, sand, and caliche, gray	33	151
Sand, pink-tan	49	200
Sand, silt, and caliche, gray and tan	34	234
Permian		
Siltstone, red	6	240

22.—*Log of test hole 22, 50 feet west and 20 feet south of the SE corner sec. 25, T. 34 S., R. 29 W.*

	Thickness, feet	Depth, feet
Dune sand, brown	4	4
Soil, gray to black	8	12
Meade formation		
Sand, fine, and silt, tan and gray, contains some caliche	62	74
Sand, fine, red, contains some silt	5	79
Gypsum and pink-tan silt and clay	11	90
Silt and clay, pink-tan and gray-green, contains some gypsum	20	110
Silt, fine sand, and caliche, gray and tan	51	161
Sand and gravel, brown, and some calcihe	19	180
Sand, fine, gray, and some gravel, silt and caliche	50	230
Sand, medium, brown	7	237
Sand, fine, and silt, tan	16	253
Sand, fine to medium, brown, and some silt	55	308
Silt and fine sand, pink-tan, and some caliche	5	313
Sand and fine gravel, brown	5	318
Permian		
Siltstone, red	12	330

23.—*Log of test hole 23, NE corner sec. 33, T. 34 S., R. 29 W.*

	Thickness, feet	Depth, feet
Soil, dark tan	2	2
Meade formation		
Silt, caliche, and fine sand, pink-tan	71	73
Silt and caliche, blue-gray	77	150
Sand, fine, silt and caliche, tan	50	200
Silt and clay, tan-brown	120	320
Sand and fine gravel, brown	26	346
Silt, clay, and fine sand, tan-brown	24	370
Sand, gray and tan, contains some silt and caliche	113	483
Permian		
Siltstone, red	17	500

24.—*Log of test hole 24, 1,620 feet west of the SE corner sec. 26, T. 34 S., R. 30 W.*

	Thickness, feet	Depth, feet
Soil, sandy, brown	1	1
Meade formation		
Caliche, and some silt and fine sand	7	8
Silt, fine sand, and caliche, purple-brown	1	9
Sand and gravel, brown	27	36
Ogallala formation		
Silt, fine sand, and caliche, gray	17	53
Sand, tan, contains some silt and caliche	14	67
Sand, and some silt and gravel, partly cemented by calcium carbonate	160	227

Laverne formation		
Silt and fine sand, yellow and gray	5	232
Limestone, gray, contains silt and sand	8	240
Sandstone, fine and medium, yellow	15	255
Sand, fine and medium, silt, and caliche, gray-brown	91	346
Cretaceous		
Shale, sandy, calcareous, tan-brown and blue-gray	85	431
Shale and sandstone interbedded, brown	48	479
Limestone and shale, gray-tan	8	487
Shale, sandy, buff	43	530

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19-4845

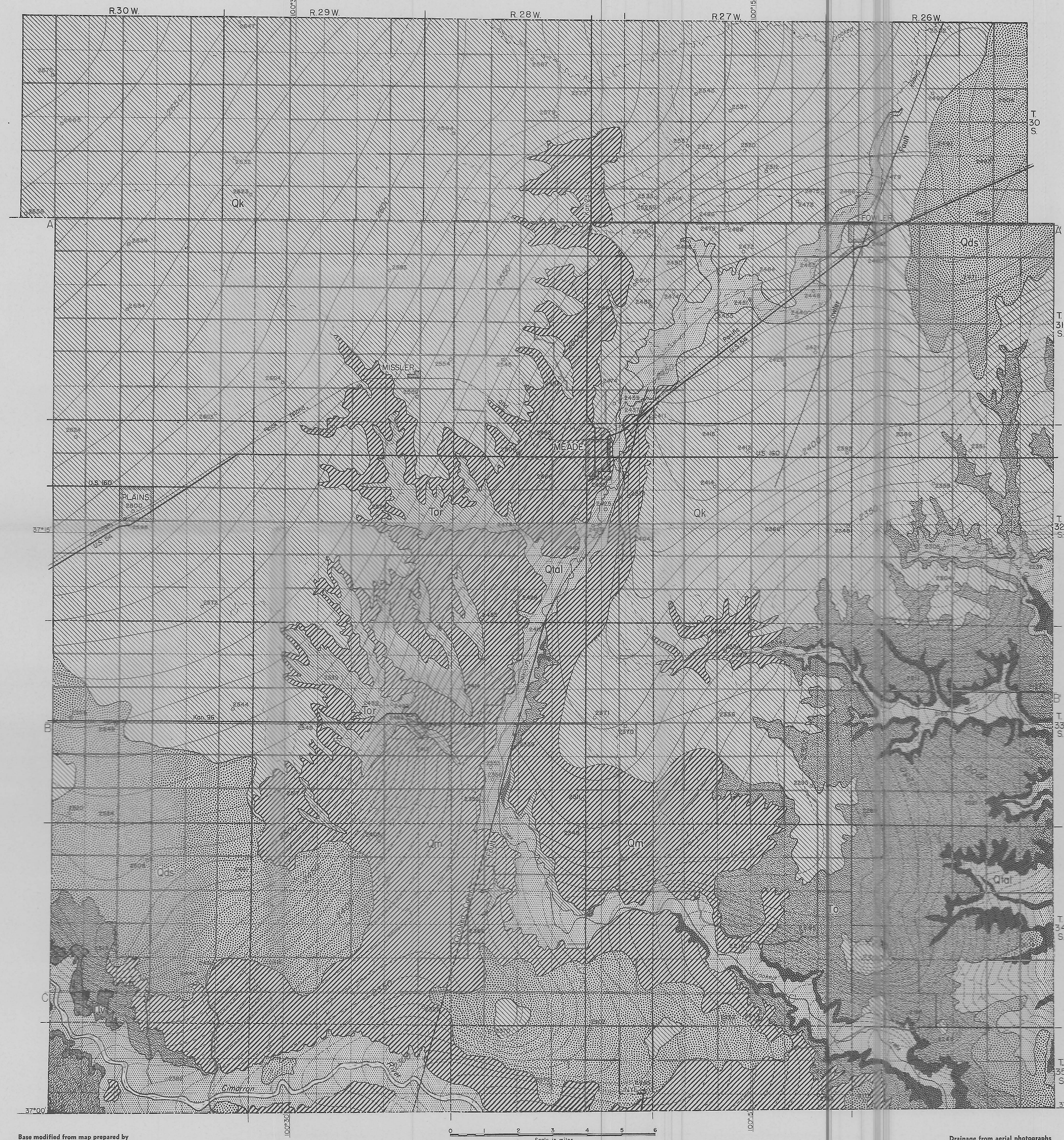
State Geological Survey
of Kansas

MAP OF MEADE COUNTY

Showing Geology and Water-Table Contours, 1940

by John C. Frye

Bulletin 45
Plate 1



Base modified from map prepared by Kansas State Highway Department

Drainage from aerial photographs of the U. S. Dept. of Agriculture

EXPLANATION

QUATERNARY

RECENT

Qds — **Dune sand**
Quartz sand. Sand dunes are above water table and do not supply water directly to wells, but are important catchment areas for ground-water recharge.

Qtal — **Terrace deposits and alluvium**
Gravel, sand, and silt. Locally yield moderate supplies of water having a wide range in quality.

PLEISTOCENE

Qk — **Kingsdown silt**
Stratified and massive silt and sand. Locally yields moderate supplies of hard water, but in some upland areas it retards ground-water recharge.

Qm — **Meade formation**
Sand, gravel, silt, clay, and volcanic ash. Yields large supplies of water of good quality to wells that range in depth from about 50 to more than 200 feet. Supplies irrigation wells and flowing wells in part of the county.

TERTIARY

PLIOCENE

Tor — **Ogallala formation (Rexroad member)**
Sand, gravel, silt, clay, peat, and caliche. Yields large supplies of water of good quality west of Crooked Creek fault. Supplies irrigation wells and flowing wells in part of the county.

To — **Ogallala formation (undifferentiated)**
Sand, gravel, silt, and caliche. Yields large supplies of water of good quality to wells that range in depth from about 50 to more than 250 feet in part of the county, but in some places in the southeastern part of the county it is above the water table.

MIOCENE (?) AND PLIOCENE

Tlv — **Laverne formation**
Shale, limestone, and sandstone. A potential source of water of unknown quality in the southwestern part of the county.

PERMIAN

Permian rocks (undifferentiated)
Red and gray siltstone, shale and fine-grained sandstone. Yield small supplies of hard water to wells in the southeastern part of the county.

Contour interval 10 feet

—2600— Water-table contours based on instrumental levels

--2300-- Water-table contours in areas of dissected topography, based on instrumental levels.

2252 Well location. Number refers to altitude of water level.

Federal or State road

County or Township road

Section line (no road)

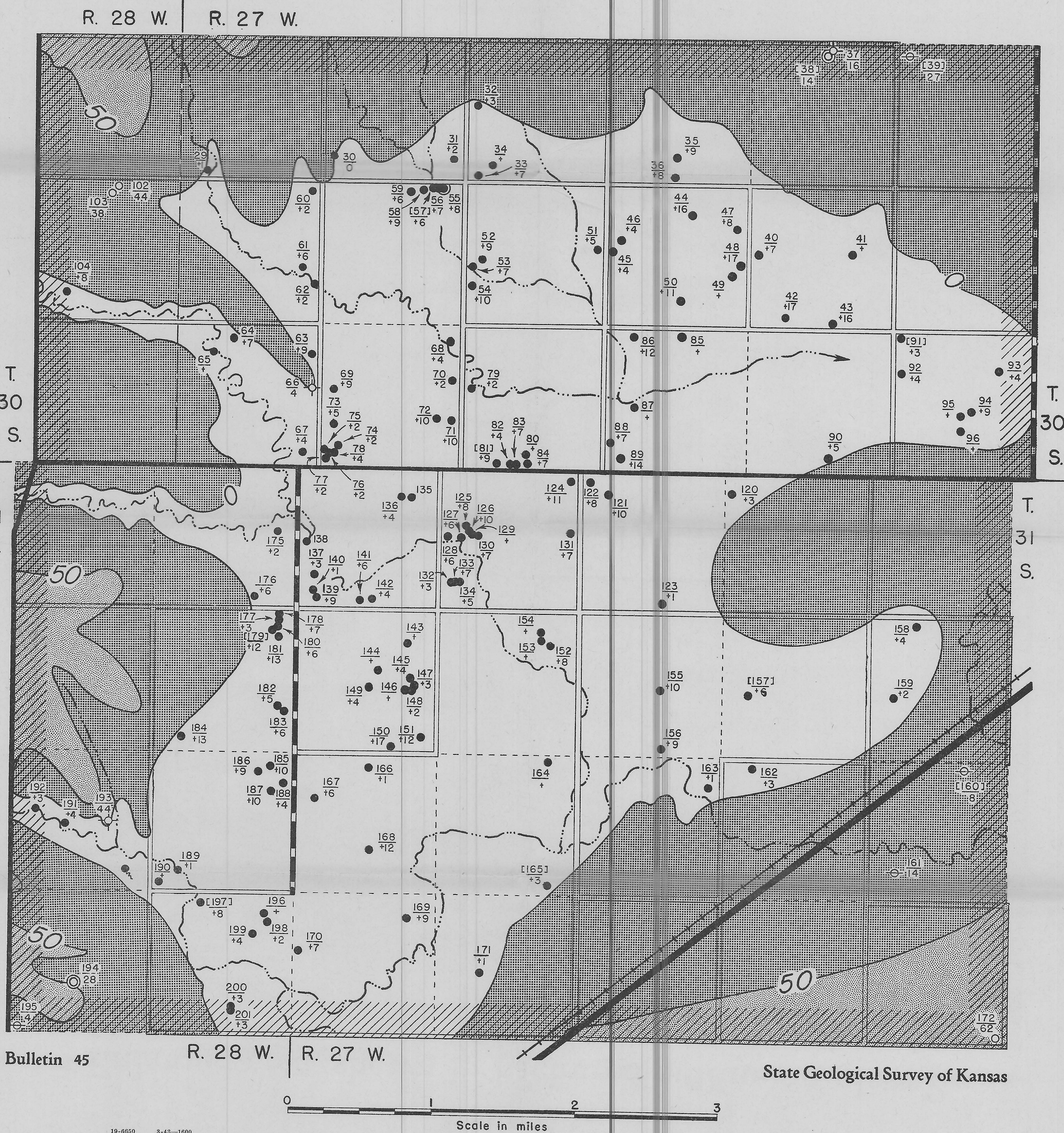
Road under construction

County line (no road)

Township line (no road)

Plate 2a.

Enlarged area, shown in hachured outline on plate 2.



State Geological Survey of Kansas

19-6650 3-43—1600

State Geological Survey
of Kansas

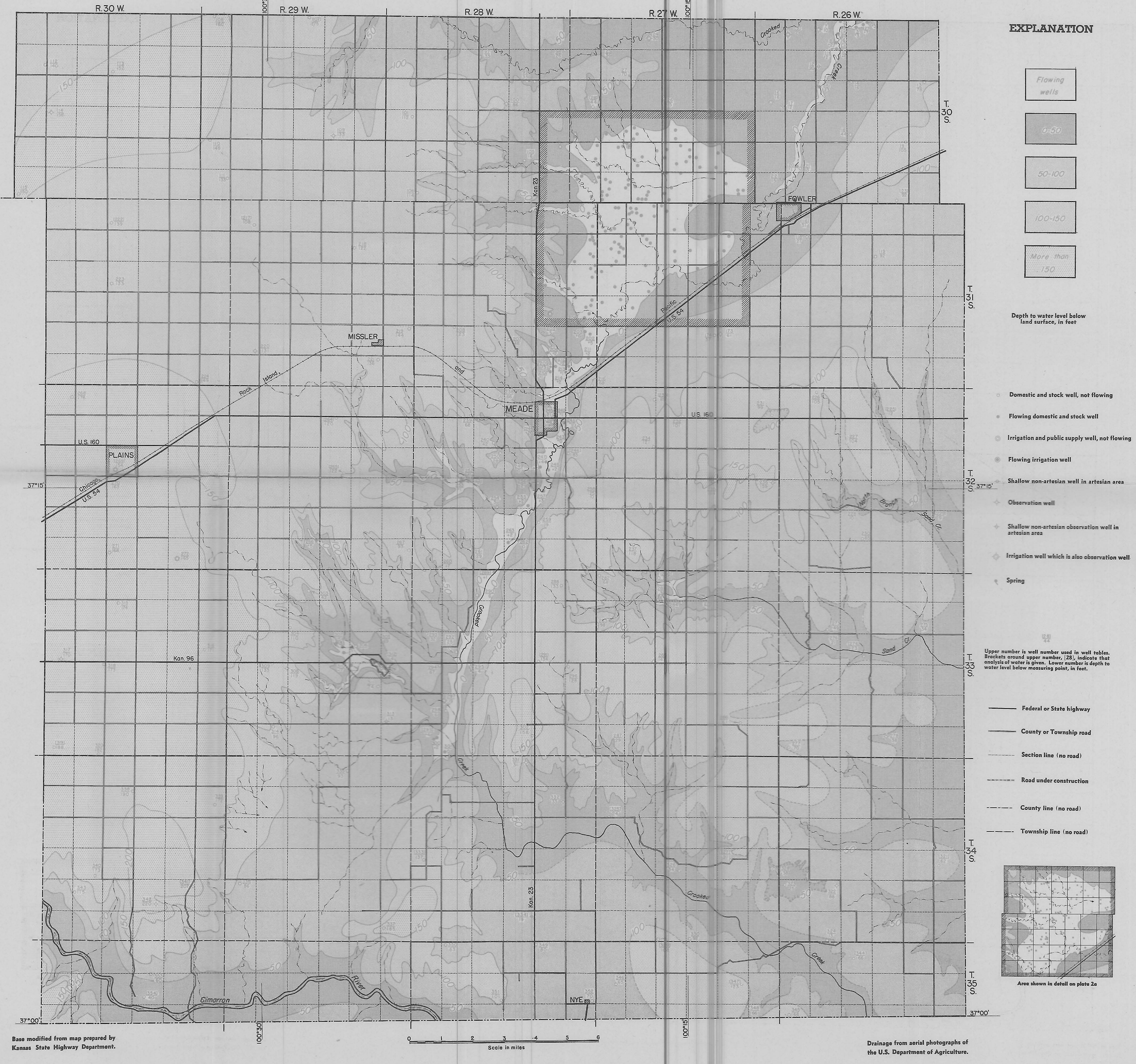
Bulletin 45
Plate 2

MAP OF MEADE COUNTY

Showing the Depths to Water Level and the Location of Wells for Which Records Are Given

by John C. Frye

1940



Base modified from map prepared by Kansas State Highway Department.

Drainage from aerial photographs of the U.S. Department of Agriculture.