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BULLETIN 55

GEOLOGY AND GROUND-WATER RESOURCES OF FINNEY AND GRAY COUNTIES, KANSAS

By BRUCE F. LATTA
with analyses by
E. O. HOLMES

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

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GEOLOGY AND GROUND-WATER RESOURCES OF FINNEY AND GRAY COUNTIES, KANSAS

By Bruce F. Latta

ABSTRACT

This report describes the geography, geology, and ground-water resources of Finney and Gray counties in southwestern Kansas. Finney and Gray counties have a total area of about 2,160 square miles, and in 1940 had a population of 14,865. The area consists of relatively flat to gently rolling upland plains which are disrupted in places by the valleys of Arkansas and Pawnee rivers and Crooked creek and by accumulations of wind-blown sand. In the northwestern part of the area is the Finney basin—a broad, shallow, asymmetrical depression extending from the Arkansas valley northward into Scott county. The climate is subhumid to semiarid, the average annual precipitation being about 21 inches. Farming and some cattle raising are the principal occupations in the area. Irrigation is practiced extensively in the Arkansas valley and in some parts of the uplands.

The exposed rocks are sedimentary and range in age from Upper Cretaceous to Recent. A map showing the areas where the different rock formations crop out is included with the report. Most of the area is underlain by permeable Quaternary and Tertiary sands and gravels, much of which is saturated and yields relatively large quantities of water to wells. In the northeastern or "panhandle" part of Finney county, Pawnee river has cut below the Tertiary sediments and exposed Cretaceous shales and limestones (Niobrara formation and Carlile shale), which locally yield meager quantities of water to wells.

The report contains a map of the area showing by means of shading the depth of water level. The water table ranges in depth from less than 5 feet in parts of the Arkansas valley to about 200 feet on the uplands south of the valley in eastern Gray county. A map showing by means of contours the shape and slope of the water table is also included with the report. This map shows that ground water moves through Finney and Gray counties in a general easterly direction. The gradient of the water table ranges from about 3 feet to the mile in the Finney basin to as much as 35 or 40 feet to the mile in northwestern Finney county. The map also shows that ground water moves into the Arkansas valley from both sides and that slight ground-water divides exist both north and south of the Arkansas valley throughout most of its course in this area.

The ground-water reservoir is recharged principally by precipitation that falls within the area, by the addition of water from Arkansas river in the western part of the area, and by ground water moving in from adjacent areas. Ground water is discharged from the ground-water reservoir mainly by movement eastward and southeastward into adjacent areas, by evaporation and

transpiration in areas of shallow water table, by seepage into Arkansas river, and by wells. Some water is discharged by springs and seeps along Pawnee river and its tributaries. All of the domestic, stock, public, and industrial water supplies and a part of the irrigation water supplies are obtained from wells.

Most of the wells in the area are drilled, but some are dug, driven, or bored. Of the 244 irrigation-well pumping plants visited in the area in 1940, 183 were in the Arkansas valley and 61 were on the uplands either north or south of the valley. In 1939, they supplied about 32,000 acre-feet of water to irrigate approximately 21,860 acres (includes land irrigated by surface water and by a supplementary supply of ground water). The most favorable areas for future irrigation development are parts of the Arkansas valley, the Finney basin, and the uplands in west-central Gray county.

The ground water in Finney and Gray counties, although generally hard, is suitable for most ordinary uses. The waters from the Pliocene (Ogallala formation) and undifferentiated Pleistocene deposits and terrace gravels are similar in composition and hardness. Waters from the alluvium generally are very hard. Waters from the Dakota formation are relatively soft, and are believed to have been softened naturally by a base-exchange process.

The principal water-bearing formations in this area are alluvium and the Pliocene (Ogallala formation) and undifferentiated Pleistocene deposits. A few wells obtain water from the Dakota formation, Carlile shale, Niobrara formation, and the terrace gravels. The character and water supply of each formation are discussed in the report.

The field data upon which most of this report is based are given in tables, and include records of 543 wells and springs, and chemical analyses of the water from 55 representative wells. Logs of 60 test holes, water wells, and oil and gas wells in the area are given, including 29 test holes put down by the State and Federal Geological Surveys.

INTRODUCTION

Purpose and Scope of the Investigation

The Geological Survey, United States Department of the Interior, and the State Geological Survey of Kansas, with the coöperation of the Division of Sanitation of the Kansas State Board of Health and the Division of Water Resources of the Kansas State Board of Agriculture, started an extensive program of ground-water investigations in the western part of the State in July, 1937. In 1938, investigations were begun in parts of western Kansas where irrigation from wells was being carried on or was potentially important. This report presents the results of a study made during the summer and fall of 1940 to determine the availability and quality of ground water and to study and map the various rock formations in Finney and Gray counties.

The universal use of ground water for domestic, municipal, and industrial supplies, the extensive use of ground water for irrigation in the Arkansas valley, and the increasing development of irrigation from deep wells on the upland plains in the two counties has made it necessary that a better understanding of the hydrology and geology of this area be acquired.

The investigation was made under the general administration of R. C. Moore and K. K. Landes, State Geologists, J. C. Frye, acting State Geologist, 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.

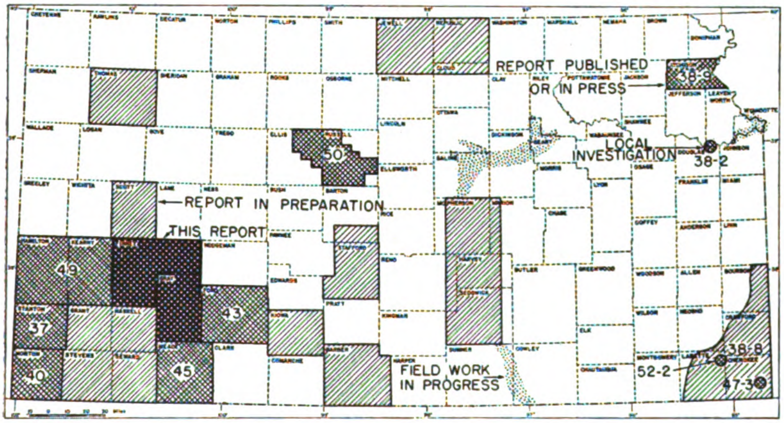


Fig. 1. Index map of Kansas showing the area covered by this report and other areas for which coöperative ground-water reports have been published or are in preparation.

Location and Extent of the Area

Finney and Gray are adjacent counties in southwestern Kansas and together they embrace a total of 60 townships, or about 2,160 square miles. Finney is the larger of the two counties and has an area of about 1,300 square miles. The location of Finney and Gray counties with respect to adjoining counties is shown in figure 1.

Previous Geologic and Hydrologic Work

Numerous studies have been made in the past dealing with the geology and ground-water resources of the area under consideration. The most important of these studies are listed below in chronological order.

In 1892, Colonel Nettleton (1892, pp. 26, 27, appendix no. 10) reported on the results of some underflow surveys along the Platte and Arkansas river valleys, and included a discussion and plat of a north-south profile of the water table extending across Finney county and passing through Garden City. In 1897, Haworth (1897) described the geology and physiography of western Kansas, and included a discussion of Arkansas river. He also published the log of a well drilled near Garden City (Haworth, 1897, p. 27). That same year Haworth (1897a) published the results of an investigation of the underground waters of southwestern Kansas which included all of Gray county and about the southern half of Finney county. A report of the Board of Irrigation Survey and Experiment to the Legislature of Kansas for the years 1895 and 1896 was also published in 1897, which contained the log and water-supply data for a State-financed test well in Gray county (Sutton, 1897, pp. 18, 19). In the same report, Haworth (1897b) gave a general account of the geology of underground water in western Kansas. A few years later, Johnson (1901, 1902) reported on the utilization of the High Plains, including in his report brief descriptions of the slope of the water table near Garden City (Johnson, 1902, p. 647) and early attempts at irrigation near Garden City (Johnson, 1902, pp. 639, 668). In 1902, Slichter published a report entitled "Motions of Underground Waters" in which he included a hydrograph of the city well at Garden City (Slichter, 1902, p. 68).

In 1905, Darton (1905, pp. 297, 298, and 300) published a preliminary report on the geology and ground-water resources of the Central Great Plains in which he gave a general description of the water supply in Finney and Gray counties. In the same year, Burgess and Coffey (1905) published the results of a soil survey of the Garden City area.

In 1904, Slichter (1906) made an intensive investigation of the underflow of Arkansas river in Finney and Kearny counties. He reported in detail on the velocity and origin of the underflow, fluctuations of the ground-water level, and quality of the water. He also made pumping tests on a number of pumping plants in the valley to determine the specific capacity of the wells and cost of pumping.

The quality and availability of water in Finney and Gray counties was studied and reported on by Parker (1911, pp. 87-90, 99, 100) in 1911. In 1912, Coffey and Rice (1912) published a report containing the results of a reconnaissance soil survey of the western half of Kansas, including Finney and Gray counties. In 1913, Haworth (1913) described the well waters in Kansas and included in his report a brief description of Arkansas river and a discussion of ground water in the Tertiary rocks of western Kansas.

A preliminary report on the ground-water resources of the shallow-water basin in Scott and Finney counties was published by Moss (1933) in 1933. In 1935, Theis, Burleigh, and Waite (1935) described briefly the water-bearing formations and the availability of ground water in the entire southern High Plains. In 1937, Smith (1937) contributed a preliminary paper on Pleistocene gravels in southwestern Kansas in which he described gravel terraces along the Arkansas valley and listed two vertebrate fossils collected from gravel pits in Finney county (Smith, 1937, p. 289). In 1938, the Division of Water Resources of the Kansas State Board of Agriculture released a report (Anon., 1938) containing the results of tests of deep-well pumping plants with particular emphasis on fuel consumption. Two of the plants tested are in Finney county and one is in Gray county. A practical report dealing with the construction and costs of irrigation pumping plants in Kansas was published by Davison (1939) in 1939. This report contains a description of different types of pumping plants, the conditions for which each is best adapted, construction methods, and a discussion of construction costs. A report on the cost of pumping for irrigation was published that same year by McCall and Davison (1939); this report includes data on several tests of irrigation pumping plants in the area under consideration. In 1940, Smith (1940) described the Tertiary and Quaternary geology of southwestern Kansas, including Finney and Gray counties. A report giving a general description of the ground-water resources of Kansas was published by Moore (1940) in the same year. Included in this report is a chapter on the shallow-water basin in Scott and Finney counties by H. A. Waite (Moore, 1940, pp. 73, 74). Also in 1940, a report was published (Meinzer and Wenzel, 1940, pp. 138-145, 158-161) on water levels and artesian pressures in the United States in 1939, which contains chapters on the observation-well programs in Finney and Gray counties. A similar report (Meinzer and Wenzel, 1942, pp. 45-52, 61-66) was published in 1942 for the year 1940, and additional reports of this series will be published annually.

A report published in 1942 on the availability of ground-water supplies for national defense industries in Kansas includes descriptions of the availability of ground-water supplies in Finney and Gray counties (Lohman and others, 1942, pp. 37-42, 55-57).

Methods of Investigation

The investigation on which this report is based was begun in the fall of 1939 when about five weeks were spent in the area locating observation wells in which monthly water-level measurements have since been made. The principal part of the investigation, however, was not undertaken until the summer and fall of the following year, during which time about three months were spent in Finney county and about one and one-half months in Gray county. Approximately 540 wells and springs were visited, and the total depth and depth to water level were measured in about 310 of the wells. All measurements were made using a steel tape from a fixed measuring point at the top of each well. Additional information concerning the nature and thickness of the water-bearing material, yield of the wells, drawdown, and the use and general character of the water was obtained from many well owners, tenants, and well drillers. Information on the amount of water pumped and the number of acres irrigated from wells during 1939 was obtained for most of the irrigation plants.

Samples of water collected from 27 representative wells in Finney county and 24 representative wells in Gray county were analyzed by E. O. Holmes, chemist, in the Water and Sewage Laboratory of the Kansas State Board of Health at Lawrence. The Kansas State Board of Health also furnished analyses of water for the four public water supplies in the area, making a total of 55 analyses for the two counties.

The altitudes of the measuring points of the wells in Finney county were determined with a spirit level by John LaDuex, assisted by Milton Sears; those in Gray county were determined by the Topographic Branch of the United States Geological Survey at the time that altitudes were being established in preparation for topographic mapping. The same two men, John LaDuex and Milton Sears, did this work aided by several men supplied by the Works Progress Administration.

During the investigation, 25 test holes were drilled by Ellis D. Gordon, Perry McNally, and Laurence Buck, and 3 test holes were drilled by James Cooper, Nick Fent, and Milford Klingaman, using a portable hydraulic-rotary drilling rig owned by the State and Federal Geological Surveys. Samples from the test holes were collected and studied in the field by Perry McNally and later were examined in the office by me. Additional logs of wells drilled in the area were obtained from the Garden City Company, the Soil

Conservation Service, drilling companies, independent well drillers, and from landowners.

Pumping tests on six wells in the area were conducted by Melvin Scanlan of the Division of Water Resources, Kansas State Board of Agriculture, and Woodrow Wilson of the Federal Geological Survey. The results of these tests are given on pages 52-54 of this report. Measurements of the yield and drawdown made on many irrigation wells were furnished by Kenneth McCall of the Division of Water Resources, Kansas State Board of Agriculture, by P. H. Browne, representative of the Johnston Pump Company, and by E. E. Stoeckly, engineer of the Garden City Company. These measurements are given on pages 107 and 108.

Field data were compiled on county highway maps prepared by the State Highway Department. The base maps for plates 1 and 2 were prepared from the same maps that were used in the field. The locations of the roads were corrected from field observation, and the drainage was corrected from aerial photographs obtained from the United States Department of Agriculture, Agricultural Adjustment Administration. The areal geology shown on plate 1 was taken in part from the state geologic map (Geologic Map of Kansas, 1937) and modified by me from field observations. Considerable use was made of the aerial photographs in outlining the boundaries of the various geologic formations. Plate 2 shows the locations of all wells and springs visited during the course of the investigation. The locations of wells and springs within the sections are based upon speedometer distances taken at the time they were visited. Two numbers are shown opposite most of the well symbols on plate 2, the upper one corresponding with that used in the well tables and in the text, and the lower one indicating the depth to water level below the land surface. Where there are many wells in one section the depth to water level is given only for a few representative wells, but all wells are numbered. Brackets around a well number indicate that the water from that well has been sampled and that an analysis is given in this report (tables 20 and 21). The wells and springs are numbered in order by townships from north to south and by ranges from east to west. Within a township they are numbered in the same order as the sections.

ACKNOWLEDGMENTS

I am indebted to the many residents of Finney and Gray counties who so willingly supplied information concerning their wells; to Lester Pelner, Ray Stevenson, J. A. Becraft, Rall McGraw, George Slocum, L. M. Waddell, and the Soil Conservation Service for furnishing well logs and other necessary data pertaining to wells; to T. A. Blair, chief engineer for the Atchison, Topeka, and Santa Fe Railway, for supplying information on the railroad wells in the area; and to J. A. Roby, city engineer at Garden City, D. B. Rabourn, city engineer at Montezuma, V. E. Reese, city engineer at Copeland, and Mr. Crusinberry, city engineer at Cimarron, for giving data concerning the municipal wells in their respective cities.

Unpublished data relating to wells were made available by George S. Knapp, chief engineer for the Division of Water Resources of the Kansas State Board of Agriculture. Kenneth D. McCall and Milburn H. Davison, engineers for the same agency, conducted pumping tests on several irrigation wells in the area and made available the results of these tests. Mr. McCall also spent several days in the field with me giving invaluable aid in locating observation and irrigation wells. The Division of Water Resources also furnished water-level data for a well in the Arkansas valley on which they maintain an automatic water-stage recorder.

Thanks are due E. E. Stoeckly and W. E. Levitt of the Garden City Company for furnishing information concerning the many wells owned by that company, and P. H. Browne, Johnston Pump Company, for releasing the results of pumping tests that he conducted on irrigation wells in this area. I also acknowledge the helpful assistance given by Forrest Luther of Cimarron, during my work in Gray county. I am grateful to Claude W. Hibbard, curator of vertebrate paleontology of the Dyche Museum of Natural History, University of Kansas, and A. B. Leonard, assistant professor of zoölogy, University of Kansas, for their helpful identifications of fossil material collected during this investigation.

The manuscript for this report has been critically reviewed by S. W. Lohman, O. E. Meinzer, W. D. Collins, L. K. Wenzel, and E. W. Lohr of the Federal Geological Survey; J. C. Frye and J. M. Jewett of the State Geological Survey of Kansas; George S. Knapp of the Division of Water Resources, Kansas State Board of Agriculture; and Paul D. Haney and Ogden S. Jones of the Division of Sanitation, Kansas State Board of Health. The geologic names used

in this report were checked by the Committee on Geologic Names of the Federal Survey. The manuscript was edited by Edith H. Lewis and the illustrations were drafted in final form under the supervision of Eileen Martin.

GEOGRAPHY

Topography and Drainage

All of the area herein described lies in the High Plains section of the Great Plains physiographic province except the northeastern or panhandle part of Finney county, which lies in the Plains Border section. The total relief of the area is approximately 640 feet. The highest point, the northwestern corner of Finney county, has an altitude of about 3,090 feet, and the lowest point, where Pawnee river leaves the area, has an altitude of about 2,450 feet. Locally, however, the relief does not exceed 300 feet.

The area may be divided into six physiographic divisions, which exhibit differences in topography, drainage, and origin (fig. 2)—upland plains, Pawnee river drainage basin, Crooked creek drainage basin, Finney basin, sand hills, and the Arkansas valley area. These divisions are similar to those proposed by Smith (1940, pp. 140, 141). Descriptions of each division are given below and explanations of origin are discussed in the section on geologic history.

Upland plains.—More than a third of the total area in Finney and Gray counties consists of nearly flat to gently rolling upland plains, which slope toward the east at an average gradient of less than 10 feet to the mile. Two areas of upland plains are separated by the Arkansas valley and by the sand hills bordering the Arkansas valley on the south (fig. 2). The uplands north of the Arkansas valley begin at the prominent escarpment in the eastern side of the Finney basin and slope very gently eastward at an average gradient of about 7.5 feet to the mile. The area south of the Arkansas valley is a broad, flat area bounded on the north by low-lying sand hills and on the south by the Crooked creek drainage basin. The slope of the surface is more gentle than the slope of the upland surface north of the valley, and averages only about 5 feet to the mile.

A common feature of the nearly flat upland plains is the occurrence of many shallow undrained depressions which range in diameter from a few tens of feet to more than a mile. Short tributaries lead into many of these depressions from any or all directions. After heavy rains many of the depressions hold water, thus becoming temporary lakes or ponds. The relation of these depressions to ground-water recharge is discussed on page 73. The flatness of the upland plains is in some places broken by accumulations of wind-blown sand (pl. 1). Such areas, however, are of small extent and do not compare with the large area of sand hills south of the Arkansas valley.

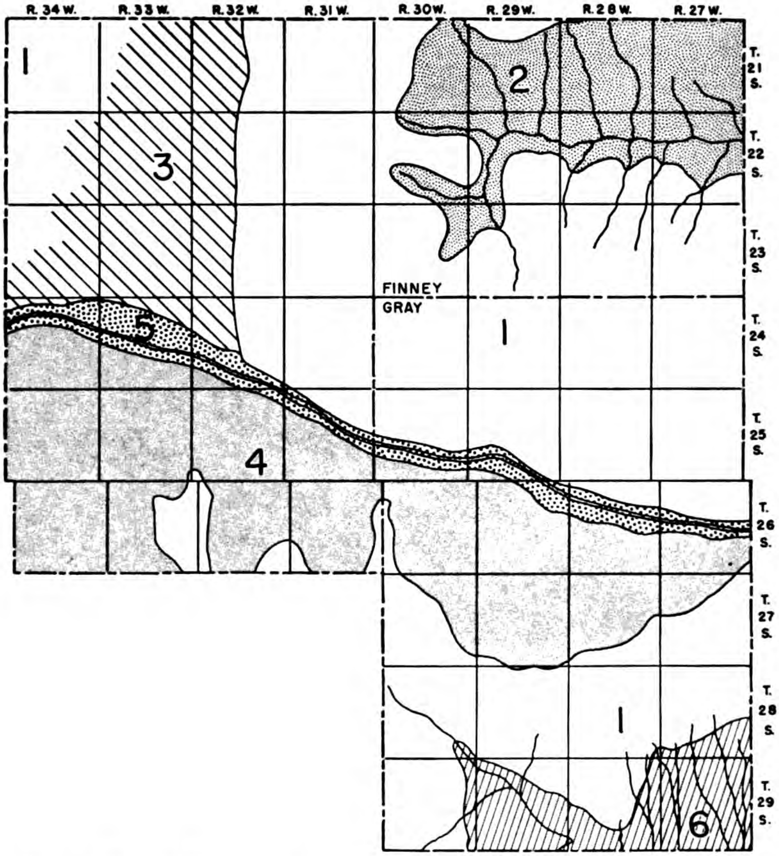


FIG. 2. Map of Finney and Gray counties showing physiographic divisions. (1) Upland plains; (2) Pawnee river drainage basin; (3) Finney basin; (4) sand hills; (5) Arkansas valley area; and (6) Crooked creek drainage basin.

Pawnee river drainage basin.—This physiographic division comprises that area in the "panhandle" of Finney county that is drained by Pawnee river and its tributaries. The surface of this area was at one time continuous with that of the upland plains, but has since been deeply dissected by Pawnee river and its tributaries. Erosion has cut below the Tertiary silts, sands, and gravels, and has exposed shale (Carlile) and limestone (Niobrara formation) of Cretaceous age (pl. 1) resulting in a rugged topography having a local relief of more than 250 feet. The Carlile shale, which is exposed on both sides of the Pawnee valley, has been reduced to moderate slopes which in many places are nearly barren of vegetation. On the north side of the valley, the Carlile shale is overlain by limestone (Niobrara formation) which makes a prominent escarpment above the moderate shale slopes. Limestone is not present on the south side of the valley, so the slopes are gentle to moderate except where the shale is capped by "mortar beds" of the Ogallala formation which form an escarpment similar to that formed by limestone.

The Pawnee valley proper ranges in width from a quarter of a mile to more than a mile and is bordered by an unusually large number of short, narrow tributary valleys. Pawnee river is characterized by a shallow channel and relatively broad meanders. After leaving Finney county, Pawnee river flows eastward and joins Arkansas river at Larned in Pawnee county.

Crooked creek drainage basin.—In the southern part of Gray county, Crooked creek and its tributaries have cut their valleys down below the general level of the high plains, producing an area of many small valleys and narrow divides. The total relief in this dissected area is about 250 feet; however, the maximum local relief does not exceed 150 feet and is much less than this in most places. The tributary valleys are short and straight and have roughly V-shaped cross-profiles. The divides between the tributary valleys are narrow, flat areas seldom more than 1 or 2 miles in width, and have southward-sloping axes.

Crooked creek in this part of its course is an ephemeral stream, which flows only after rains. Its valley is relatively flat and ranges from an eighth to a half of a mile in width, including in places a narrow terrace that is 5 to 10 feet above the general level of the flood plain. Crooked creek heads in east-central Haskell county and flows southeastward across the southwestern part of Gray county. After crossing the county line it swings northeastward into southwestern Ford county where it makes a "hairpin" turn and flows south-southwestward through Meade county. In south-central Meade county, it turns again and flows southeastward finally joining Cimarron river in Oklahoma.

Finney basin.—The Finney basin is a broad, shallow depression in the northwestern part of Finney county extending from the Arkansas valley northward into Scott county. It is continuous with the Scott basin* (Waite, in press) of central Scott county. The eastern limit of the depression is in most places abrupt, being marked by a conspicuous escarpment which is 50 feet or more high. On the west, however, there is no sharp limit to the depression. Its western flank slopes upward gradually to merge with the High Plains surface. Thus, it is an asymmetrical depression (fig. 3C).

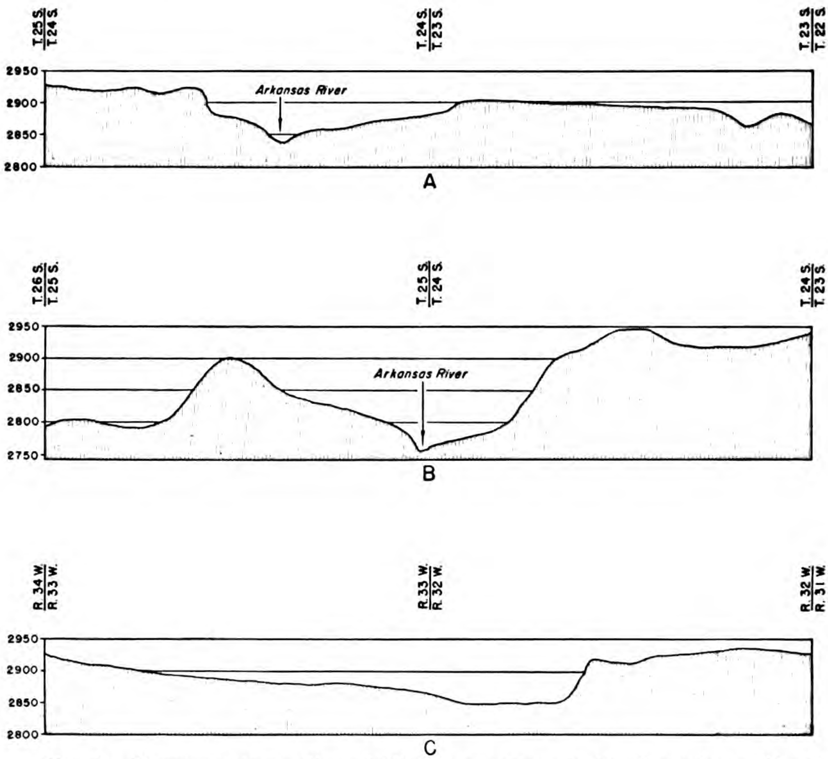


Fig. 3. Topographic profiles of Finney county. *A,* North-south profiles 2 miles east of Holcomb; *B,* North-south profile along west side of Range 31 west; *C,* East-west profile across the Finney basin, 5 miles north of Garden City.

The Finney basin is topographically continuous with the Arkansas valley although there is no surface drainage from the Finney basin into the Arkansas valley (Smith, 1940, p. 19). Short, ephemeral streams flowing southeastward from Kearny county gradually disappear on the west slope of this depression. The importance of such streams to the recharge of the ground-water reservoir is discussed on page 77. Superimposed on the surface of this large depression

* Called Modoc basin on topographic map of Scott City quadrangle.

are many small shallow depressions and marshy areas (pl. 3A) which, like those on the upland surface, temporarily hold water after rains.

Sand hills.—Bordering the Arkansas valley on the south is a wide lowland belt covered by sand hills that is intermediate in level between the river valley on the north and the upland plains on the south (pl. 3C). This belt of sand hills is a part of the Finney sand plain described by Smith (1940, p. 145). The width of the belt of sand hills ranges from about 18 miles in western Finney county and northern Haskell county to less than 3 miles at the eastern edge of Gray county. This area is characterized by typical sand-dune topography having moderate slopes and hills separated by small basins. Some of the hills stand 50 feet or more above the depressions. The greater part of this area is well covered by vegetation (pl. 4A) and is thus protected from wind erosion. A few areas of bare sand, however, are subject to wind attacks (pl. 4B). Only one stream crosses the sand hills in this area—a short tributary of Arkansas river in the extreme eastern part of Gray county where the belt of sand hills is the narrowest. Other than this stream there is no surface drainage. The rainfall in this area collects in the numerous basins and hollows where a large part of it seeps into the ground and ment area for ground-water recharge is discussed on page 68.

Arkansas valley area.—The Arkansas valley area includes the present flood plain of Arkansas river and visible gravel terraces bordering the flood plain. Arkansas river rises in the Rocky Mountains in central Colorado and follows an easterly course through eastern Colorado and western Kansas. It enters Finney county at a point about 20 miles south of the northwestern corner of the county, flows east-southeastward, and leaves Gray county at a point about 21 miles north of the southwestern corner of Gray county. The average gradient of the river as it crosses this area is about 7 feet to the mile.

It is interesting to note that the channel of the Arkansas is higher than the channels of Smoky Hill and Pawnee rivers to the north and Cimarron river to the south. Smith (1940, p. 19) points out that the Arkansas enters the state at a much lower altitude than either the Smoky Hill or Cimarron but descends less rapidly eastward. There are no large streams entering the Arkansas in this area. The upland surface a few miles north of Arkansas river slopes away from the valley. As a result, Buckner creek, a tributary of Pawnee river,

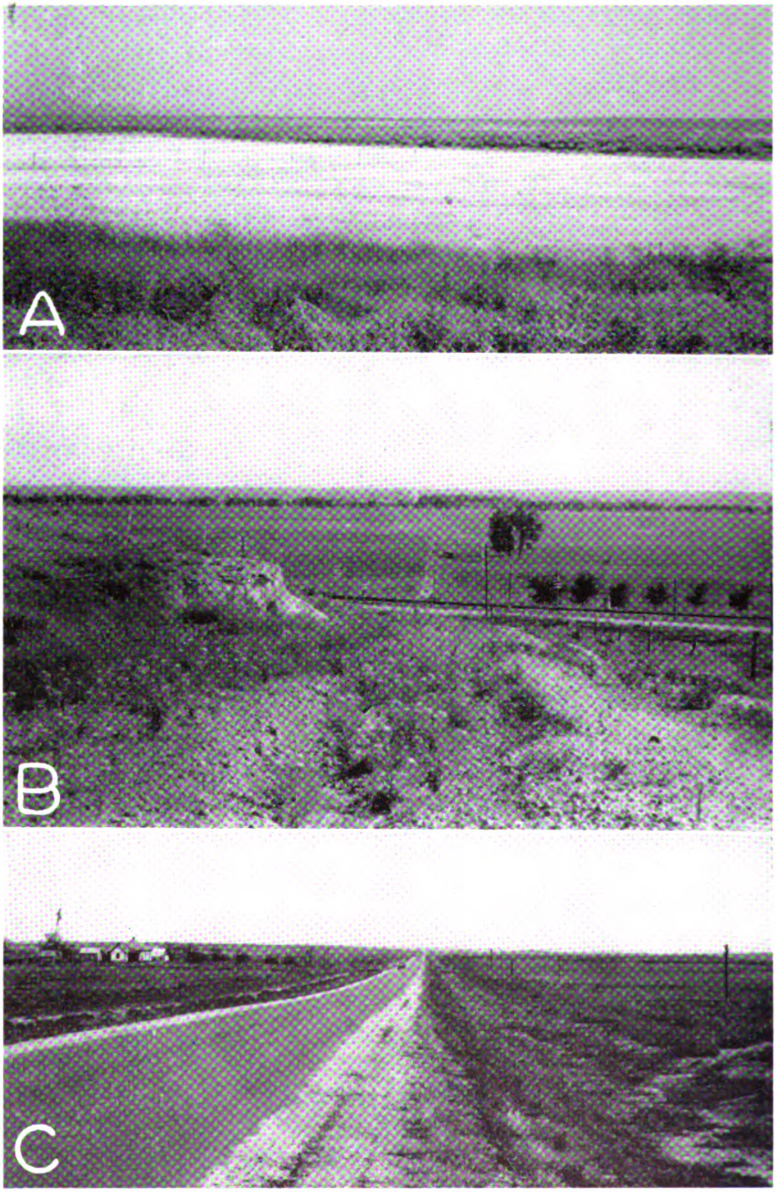


PLATE 3. *A,* Shallow depression in the Finney basin in the SE¼ sec. 7, T. 23 S., R. 32 W. Such depressions are common in the Finney basin and on the upland areas in Finney and Gray counties. *B,* View looking south across the Arkansas valley from a point about half a mile west of Pierceville. *C,* View looking north across low sand hills into the Arkansas valley. Taken from a point 8 miles south of the Arkansas valley on Kansas highway 23.

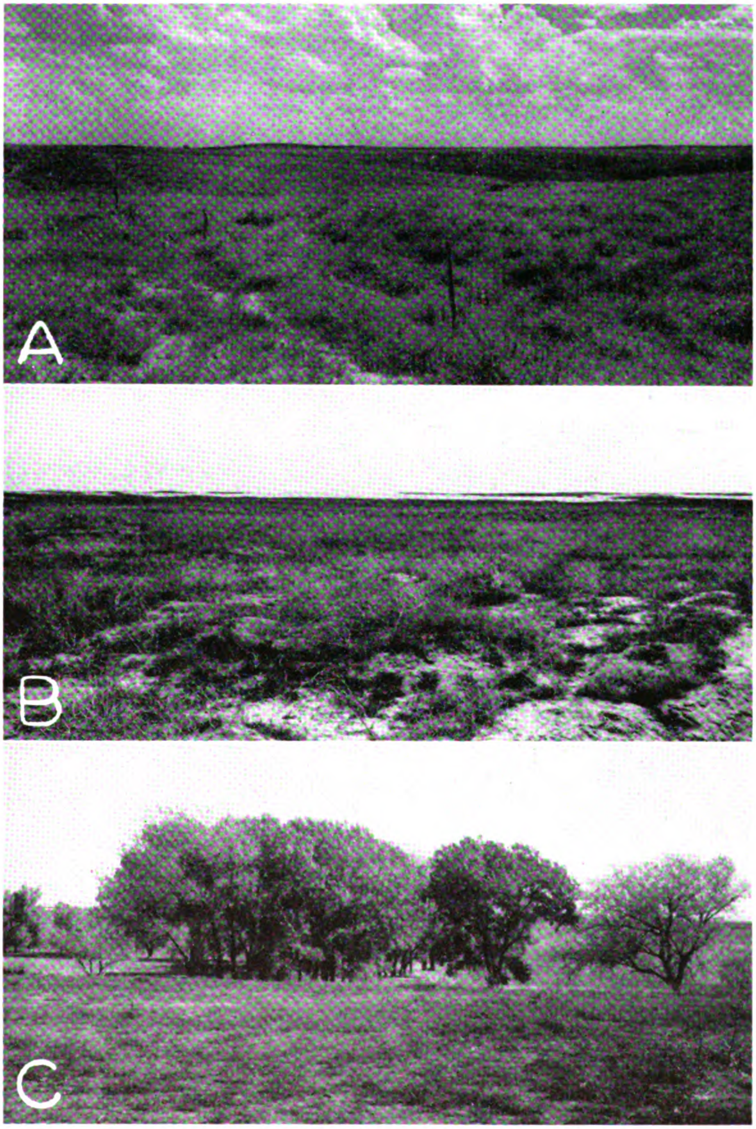


PLATE 4. *A*, Grass-covered sand hills south of Garden City, looking southwestward from a point about 4 miles south of Garden City. *B*, View looking southward across the sand hills in southern Finney county. Note the area of bare sand in the distance. Taken from the NE corner sec. 4, T. 26 S., R. 33 W. *C*, Spring area in the Pawnee valley in the NE¼ sec. 15, T. 23 S., R. 30 W. Groves of trees and abundant vegetation in Finney and Gray counties generally indicate a spring or shallow water area.

heads within a mile of a short tributary valley of Arkansas river and within 3 miles of the river itself.

The width of the Arkansas valley ranges from about 1 mile at a point a few miles upstream from Pierceville to about 3.5 miles near Garden City. The northern limit of the valley east of the Finney basin is marked by a very pronounced bluff composed in most places of resistant "mortar beds" (pl. 3B). From Garden City westward, however, the northern limit of the valley is much less conspicuous, being in places topographically continuous with the Finney basin (figs. 3A and 3B). Sand hills control the southern limit of the valley, where the slopes in general are more gentle than those on the northern side.

Two terraces occur along the Arkansas valley in this area, but both terraces are seldom conspicuous at the same locality. The lower terrace, which lies 4 to 8 feet above flood-plain level, is prominently displayed near Garden City and south of Holcomb. The higher terrace, which lies 15 to 25 feet above flood-plain level, is a prominent feature of the southern side of the valley, but occurs only as obscure remnants on the northern side. Most of the surface of this terrace on the south side of the valley is masked by dune sand so the exposed width, which does not exceed a quarter of a mile, is only a small part of the entire terrace.

Population

The population of Finney and Gray counties has fluctuated greatly since the first census was taken in 1890. The total population of the two counties in 1890 was 5,765; in 1900, 4,733; in 1910, 10,029; in 1920, 12,385; and in 1930, 17,225.

According to the 1940 census, the population of Finney county was 10,092 and the population of Gray county was 4,773, a total of 14,865 for both counties. Garden City, the largest city in the area and the county seat of Finney county, had a population of 6,285 in 1940; and Cimarron, the county seat of Gray county, had a population of 1,004. Other towns in Gray county and their populations are Ingalls, 187; Montezuma, 340; Copeland, 262; and Ensign, 202. Population figures are not available for Holcomb and Pierceville, which are small towns in the Arkansas valley in Finney county.

Alfalfa, Tennis, and Friend, in Finney county, and Charleston and Haggard, in Gray county, serve as supply stations for farmers and as grain-shipping points. Lowe, Peterson, and Wolfe are beet-loading stations in west-central Finney county, and Kalvesta is a small community near the Finney-Hodgeman county line on U. S. highway 50 N. Early maps and some highway and property maps of Finney county show several small communities that are now abandoned because of the shifting of population toward the railroads. These include Plymell in southern Finney county, and Eminence, Essex, and Ravanna in the northeastern part of Finney county. Although these towns are now completely gone, the names are still used to designate the localities.

Transportation

The area is served by a main line of the Atchison, Topeka, and Santa Fe Railway. It follows the Arkansas valley and passes through Cimarron, Ingalls, Charleston, Pierceville, Garden City, and Holcomb. A branch line crosses the southern part of Gray county and serves Ensign, Haggard, Montezuma, and Copeland. This line runs from Dodge City to a junction at Satanta in Haskell county, from which one branch goes southwestward to Boise City, Oklahoma, and the other branch goes westward to Prichett, Colorado. Another branch line runs from Garden City to Scott City, thence eastward to Great Bend, where it again connects with the main line. This line passes through Alfalfa, Tennis, and Friend. The Garden City Western Railroad, a short line owned and operated by the Garden City Company, is used exclusively for transporting sugar beets from the area northwest of Garden City to the sugar factory at Garden City.

Several hard-surfaced federal and state highways pass through Finney and Gray counties. U. S. highway 50 follows the Arkansas valley eastward to Garden City. U. S. highway 50 N continues from Garden City northeastward through Kalvesta to Great Bend, and U. S. highway 50 S follows the valley eastward, passing through Dodge City. U. S. highway 83 traverses Finney county from north to south, passing through Garden City. State highway 23 passes from north to south through Cimarron, and state highway 45 crosses the southern part of Gray county from northeast to southwest, passing through Ensign, Montezuma, and Copeland.

In addition to the hard-surfaced highways, the area has many county roads which are graveled and kept in passable condition throughout the year. Gravel or dirt roads are found on nearly every section line except in the sand-hills area and in the dissected area north of Pawnee river. Although such roads become temporarily impassable at different times of the year owing to drifting sand, snow, or mud, they are generally in good condition.

Agriculture

In 1940, 79.5 percent of the land area in Finney county and 98.3 percent of the land area in Gray county was in farms (16th U. S. Census, 1940). The principal crops grown in Finney and Gray counties and the change in acreage for each crop since 1919, as given by the federal census, are given in table 1.

Table 1.—*Acreage of principal crops in Finney and Gray counties, Kansas, from 1919 to 1939*

Crop	1919	1924	1929	1934	1939
Wheat	125,387	210,520	412,806	154,580	191,597
Grain sorghum	?	?	46,925	11,549	40,401
Hay	25,158	21,341	18,917	23,579	7,715
Sugar beets	1,364	6,021	5,084	6,420	4,656
Barley	16,164	28,841	25,380	2,728	2,929
Corn	?	35,913	72,957	419	579

In northern and northwestern Finney county and in the northern and the extreme southern parts of Gray county, wheat raising by dry-farming methods is the dominant enterprise. In the irrigated areas in the Arkansas valley and the Finney basin, alfalfa, sugar beets, and grain sorghums are the important crops. The principal crops grown on the sandy soils south of the sand hills are grain sorghums and some wheat. A limited acreage of truck crops and practically all of the alfalfa in the area are grown in the Arkansas valley.

During the period from 1932 to 1938, partial or complete crop failures were more common than crop successes. The failure during these years can be attributed to drought and wind erosion. The rainfall at Garden City was from 1.4 to 11.4 inches below normal each year during this period, and dust storms were more frequent and intense than at any time since the area was settled. Local dust storms have been known in western Kansas since the country was first settled, but it was not until the recent drought that they became so frequent and so severe (Smith, 1940, p. 29). During the recent drought many farmers were forced to abandon their farms and move to other parts of the county because of crop failures and low grain prices. From 1920 to about 1935 there was a steady increase in the number of farms and a decrease in the average size of the farms, but from 1935 to 1940 the number of farms decreased and the average size of the farms increased. These changes are shown in table 2.

TABLE 2.—*Changes in number and average size of farms in Finney and Gray counties, Kansas, from 1920 to 1940*

YEAR	Number of farms	Average size of farms (acres)
1920	1,450	727
1925	1,650	651
1930	1,799	629.5
1935	1,964	570.5
1940	1,745	692

The recent increase in the size of farm units is probably the result of the uncertain crop yield from year to year and the increased use of tractors, which, owing to the flatness of the plains, has made it possible for one man to farm large acreages.

Irrigation was started in this area shortly after it was settled and has become an important phase of agriculture. Today irrigation from diversion canals and wells is common in the Arkansas valley and in the low area north of Garden City. A total of 21,861 acres was irrigated from wells in the two counties in 1940.

NATURAL RESOURCES AND INDUSTRIES

The only sizable industry in this area other than agriculture is sugar refining. Sugar beets from a wide area in Kansas are shipped to the Garden City Company in Garden City, the only sugar refinery in the state. Although the refinery has a capacity of more than 100,000 tons of beets a season, it has seldom, if ever, been required to handle this amount. The total beet production for the state was only about 50,000 tons in 1914 (Darton, 1916, p. 39); 50,771 tons in 1929; 59,873 tons in 1934; and 54,881 tons in 1939 (U. S. Census). In 1940, however, the sugar company operated nearly to capacity. In recent years beet production in the area has been limited to some extent by federal crop control programs.

Finney county has three gas wells and two oil wells (Ver Wiebe, 1938, pp. 55, 56; 1940, pp. 35, 36; 1941, pp. 17, 43, 44). Neither gas nor oil have been discovered in Gray county. Gas was first discovered in Finney county in December, 1932, on the O. J. Brown land in sec. 16, T. 25 S., R. 34 W. The gas was found in several limestones of Permian age between depths of 2,635 and 2,774 feet. The second gas well was drilled in June, 1936, on the land of C. C. Hamlin in sec. 31, T. 24 S., R. 34 W. In this well, gas-bearing zones were found between depths of 2,418 and 2,700 feet. In August of the same year, a well was completed on the Jones lease in sec. 34, T. 26 S., R. 34 W., and found gas-bearing zones between depths of 2,749 and 2,755 feet.

The Northern Natural Gas Company takes the gas from the Brown well, which had an open-flow capacity of 15,504,000 cubic feet per day and a pressure of 425 pounds to the square inch. Its allowable flow for the month of September, 1940, was 14,560,000 cubic feet. Gas from the Hamlin well is sold to the Tri-County Gas Company. This well, which had an open-flow capacity of 13,600,000 cubic feet per day and a pressure of 427 pounds, had an allowable flow of 14,266,000 cubic feet for the month of September, 1940. The Jones well has an open-flow capacity of 6,235,000 cubic feet per day and a pressure of 445 pounds. In 1940 it was not connected with a pipe-line outlet.

The three wells in Finney county together with several gas wells in southern Kearny county were originally designated the Holcomb gas field. In 1938 they were incorporated in the large Hugoton gas field, and the production is prorated with the rest of that field.

Oil was discovered in Finney county in 1938 by a wildcat well drilled on the Eva Nunn ranch in sec. 27, T. 21 S., R. 34 W. The well produces from the "Mississippi lime" between depths of 4,654 and 4,658 feet. It was rated as being capable of producing 600 barrels a day. In 1939, a second well was brought in south of the Nunn well on the Gobelman ranch in sec. 34, T. 21 S., R. 34 W. After acidization, the well had an initial production of 1,724 barrels a day. These two wells are in the Nunn field, which had produced 87,100 barrels of oil by the end of 1940. About 8 miles north of the Nunn field lies the Shallow Water oil field of Scott county. Several wells have been drilled in northeastern Finney county, but as yet no oil or gas has been discovered in that area.

Other mineral resources of the area include sand, gravel, limestone, and raw materials for rock wool. Thick deposits of sand and gravel are found in the alluvium and terrace deposits along the Arkansas and Pawnee valleys. Such deposits have been exploited for use in road surfacing, in concrete, and in gravel-packing water wells. Stone has been quarried to a limited extent in both Finney and Gray counties to supply local needs. In northeastern Finney county the Fort Hays limestone member of the Niobrara formation has been quarried and used in building homes and in the construction of the dam for the Finney county state lake. A relatively thin limestone bed in the Jetmore (?) chalk member of the Greenhorn limestone has been quarried to a small extent in the NW¼ sec. 17, T. 29 S., R. 27 W., in southern Gray county. The locations of all developed sand and gravel pits and stone quarries are shown on plate 1.

The remainder of this report is concerned with ground water, one of the most important natural resources of this area.

Climate

The climate of this area is of the subhumid to semiarid type involving slight to moderate precipitation, moderately high average wind velocity, and rapid evaporation. During the summer the days are hot, but the nights are, in general, cool and comfortable. The hot summer days are alleviated by good wind movement and low relative humidity. The winters, as a rule, are characterized by moderate weather with occasional severe cold periods of short duration and relatively little snowfall.

The average mean annual temperature at Garden City is 54.7° F. The highest temperatures occur during the three summer months, the monthly mean being 73.4° F. in June; 78.6° F. in July; and 77.6° F. in August. January and December are generally the coldest months, the mean monthly temperature being 30.9° F. in January and 31.8° F. in December. The average growing season, that is the average interval between the last killing frost in the spring and the first killing frost in the fall, is about 173 days, and has ranged from about 135 to about 200 days.

The mean annual precipitation at Garden City is 20.22 inches and at Cimarron it is 21.43 inches. Deviations from the mean, however, are frequent. At Garden City the recorded annual precipitation has ranged from a minimum of 8.87 inches in 1937 to a maximum of 34.81 inches in 1923; at Cimarron the recorded annual precipitation has ranged from a minimum of 10.68 inches in 1934 to a maximum of 35.33 inches in 1928. A large proportion of the precipitation falls as torrential rains that are separated by long dry periods. About 75 percent of the total annual precipitation falls during the crop-growing season from April through September (fig. 4). The normal rainfall during June, the wettest month, is about 3.15 inches; during January, the driest month, it is only about 0.35 inch.

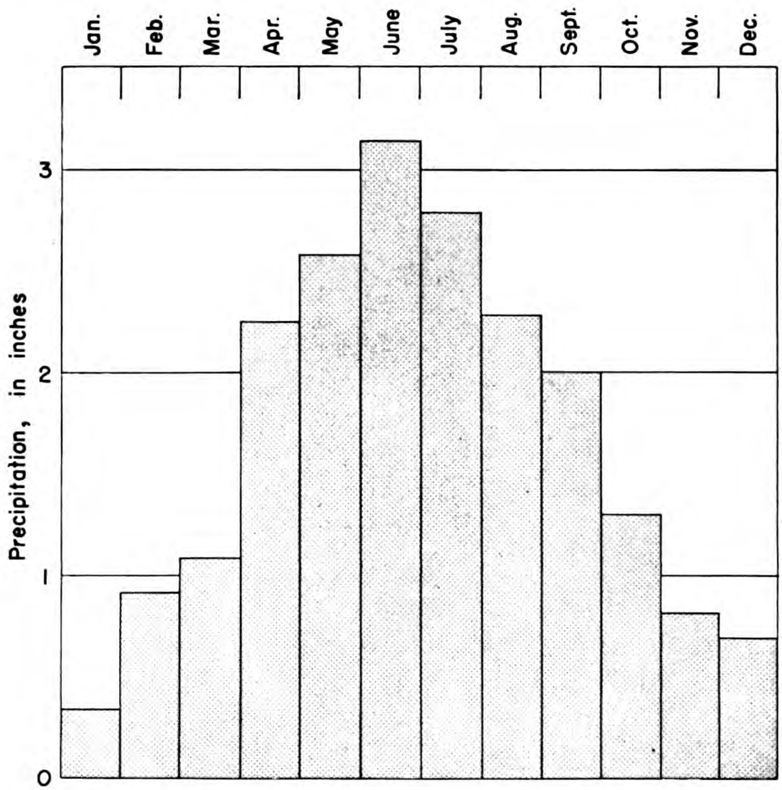


FIG. 4. Normal monthly distribution of rainfall at Garden City.

Precipitation in this area seems to follow more or less irregular cycles in which periods of excessive moisture alternate with periods of deficient moisture or drought. The periods of deficient rainfall generally are of longer duration than those of excessive rainfall. The annual precipitation and the cumulative departure from normal precipitation at Garden City and Cimarron are shown graphically in figures 5 and 6.

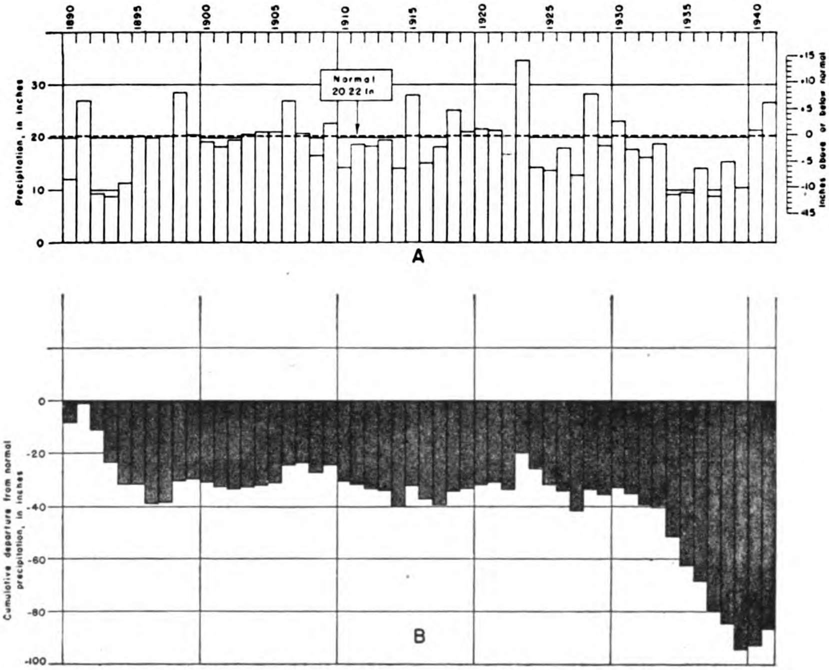
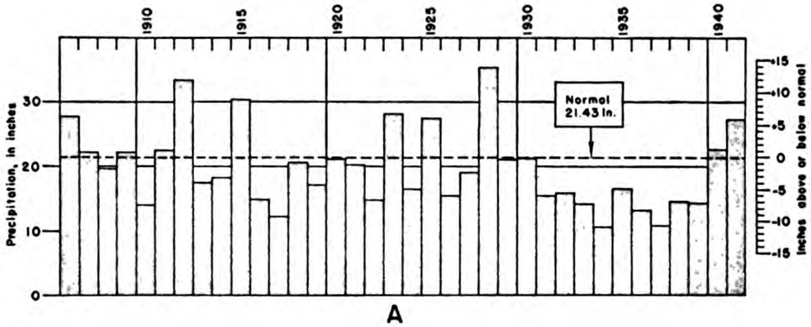


FIG. 5. Graphs showing (*A*) the annual precipitation at Garden City, Finney county, Kansas, and (*B*) the cumulative departure from normal precipitation at Garden City. (From records of U. S. Weather Bureau.)



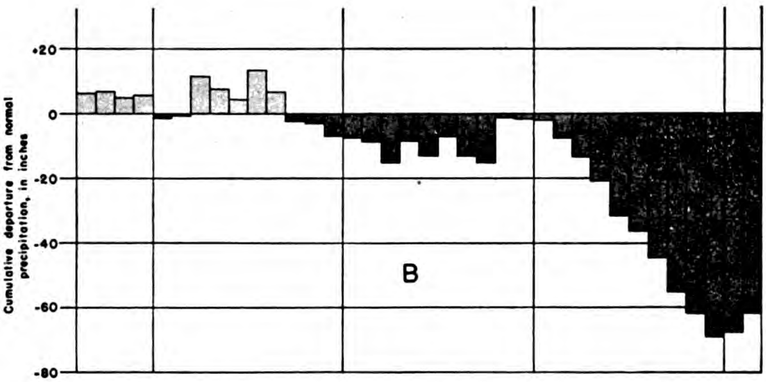


FIG. 6. Graphs showing (*A*) the annual precipitation at Cimarron, Gray county, Kansas, and (*B*) the cumulative departure from normal precipitation at Cimarron. (From records of U. S. Weather Bureau.)

GEOLOGY

Summary of Stratigraphy

The rocks that crop out in Finney and Gray counties are all of sedimentary origin and range in age from Upper Cretaceous to Recent. Outcrops of the formations are shown on plate 1. The oldest rocks exposed at the surface in this area are Upper Cretaceous in age and comprise parts of the Greenhorn limestone, Carlile shale, and the Niobrara formation. Tertiary deposits of silt, sand, and gravel (Ogallala formation), which overlie the Cretaceous beds over most of Finney and Gray counties, are exposed only along parts of the Arkansas valley, along the Pawnee valley, and on the uplands north of the Pawnee valley. Clay (the Laverne (?) formation and/or the Woodhouse (?) clays of Elias) occurs locally above the Cretaceous beds in northwestern and southern Finney county and in northwestern Gray county.

Undifferentiated deposits of clay, silt, sand, and gravel of Pleistocene age, Pleistocene terrace deposits, and Quaternary alluvium and dune sand cover most of the surface in this area.

Information on the unexposed rocks that lie beneath Finney and Gray counties has been obtained from test holes drilled during the course of the investigation, from logs of oil and gas test wells, and from exposures of these rocks in near-by areas. They include shales and sandstones of Cretaceous age that underlie the Greenhorn limestone over all of this area and Paleozoic limestones and shales with lesser amounts of sandstone, gypsum, anhydrite, and salt that are encountered beneath the Cretaceous deposits.

A generalized section of the geologic formations of this area is given in table 3.

Geology History

PALEOZOIC ERA

Very little is known about the conditions that existed in this area during the Paleozoic era. Logs (logs 58-60) of several oil and gas wells, however, indicate that the area is underlain by nearly 6,000 feet of sediments deposited during this era, and that all of the Paleozoic systems are represented except possibly the Silurian and Devonian.

Thick limestones and dolomites, some shale, and very little sandstone were deposited prior to the Permian period. The area was probably covered by moderately deep seas during most of the Pale-

TABLE 3.—*Generalized section of the geologic formations of Finney and Gray counties, Kansas*

System	Series	Subdivision	Thickness (feet)	Physical character	Water supply
Quaternary	Recent and Pleistocene	Alluvium and terrace deposits *unconformable on older formations*	0–68	Very coarse gravel, sand, and silt comprising stream deposits in the Arkansas valley, Pawnee valley, and the valleys of other smaller streams. Very coarse gravels occur as terrace deposits along the Arkansas and Pawnee valleys. Terrace gravels occur beneath dune sand south of the Arkansas valley.	The alluvium yields large supplies of water to wells in the Arkansas valley and lesser amounts in the other stream valleys; supplies many irrigation and a few industrial wells in the Arkansas valley. Some waters from the alluvium are very hard, containing from 211 to 1,641 parts per million of hardness. Terrace gravels yield water of good quality to a few stock and domestic wells south of the Arkansas valley.
		Dune sand *unconformable on older formations*	0–70	Fine- to medium-grained wind-blown sand. Covers a large area south of the Arkansas valley and occurs in smaller areas north of the Arkansas valley.	Occurs above the water table; therefore, it yields no water to wells. The dunes, however, serve as important catchment areas for recharge from local precipitation.
	Pleistocene	Undifferentiated deposits *unconformable on older formations*	0–300+	Consolidated and unconsolidated lenses of clay, silt, sand and gravel that are lithologically similar to materials of the Ogallala formation. Contain nodules and beds of caliche and locally volcanic ash.	The sands and gravels of the Ogallala formation and Pleistocene undifferentiated beds are the most important sources of water in Finney and Gray counties. Most of the domestic and stock wells on the uplands, many of the irrigation and industrial wells, and all of the municipal wells derive water from these deposits. Irrigation wells tapping these deposits yield as much as 1,770 gallons a minute. The water, although hard, is of good chemical quality.
Tertiary	Pliocene	Ogallala formation *unconformable on older formations*	0–250	Calcareous silts, sands, and gravels, much of which is cross-bedded. Both consolidated and unconsolidated. Contains nodules and beds of caliche.	
	Lower Pliocene and Upper Micocene (?)	Laverne (?) formation *unconformable on older formations*	0–91.5	Tan, brown, and gray silty blocky clay and clay shale, containing some medium-grained sand to fine gravel. Encountered only in test holes 15 and 16 in southern Finney county.	Sands and gravels locally are potential sources of water supply, but they have not been exploited because of their great depth.
Cretaceous	Gulfian*	Niobrara formation: Smoky Hill chalk member	0–225	Alternating beds of soft chalky shale and chalk containing some thin beds of bentonite. Not exposed in Finney and Gray counties.	Relatively impermeable. Not known to yield water to wells in Finney and Gray counties.
		Niobrara formation: Fort Hays limestone member	55–80	Thick massive beds of chalk and chalky limestone separated by thin beds of chalky shale. Exposed over wide area in northeastern Finney county.	Supplies limited amount of water to few wells and springs in Finney county. Water occurs in fractures and solution openings. Not an important water-bearer.

TABLE 3.—Generalized section of the geologic formations of Finney and Gray counties, Kansas—*Concluded*

System	Series	Subdivision	Thickness (feet)	Physical character	Water supply
Cretaceous	Gulfian*	Carlile shale: Codell sandstone member	260±	Dark gray to black noncalcareous sandy shale and shaly sandstone. Encountered in test holes 1, 3, and 4.	Two wells (1 and 8) obtain meager supplies of water from the Codell in Finney county. In most places adequate supplies of water may be obtained from higher formations.
		Carlile shale: Blue Hill shale member		Dark gray, bluish-black, and black noncalcareous shale containing thin seams of gypsum and in the upper part a zone of septarian concretions. Exposed in wide strip along the Pawnee valley in northeastern Finney county.	Three unused wells (46, 47, and 57) tap the Blue Hill shale member. Because of the low permeability of the material the wells were abandoned.
		Carlile shale: Fairport chalky shale member		Calcareous shale containing thin beds of chalk or chalky limestone and few thin beds of bentonite. Not exposed in Finney and Gray counties.	Not known to yield water to wells.
		Greenhorn limestone	130	Light to dark gray, thin, chalky and crystalline limestones separated by thicker beds of light to dark gray chalky shale that contain thin beds of bentonite. Exposed in small area in southeastern Gray county.	Reported to yield small supplies of water to wells in southeastern Gray county.
		Graneros shale	50±	Gray noncalcareous shale containing interbedded lenses of sandstone and sandy shale. Not exposed in Finney and Gray counties.	Relatively impermeable. Not known to yield water to wells.
		Dakota formation	50-200 (?)	Light gray, tan, buff, red, and brown fine- to medium-grained sandstone and light gray, yellow-tan, and brown shale, sandy shale, and clay. Not exposed in Finney and Gray counties.	Sandstones yield moderate supplies of soft water to a few wells in southeastern Gray county.
	??				
	Comanchean*	Kiowa (?) shale	44-100+	Gray, bluish-black, black, and yellowish-gray shale containing a few thin beds of gray limestone and sandstone. Not exposed in Finney and Gray counties.	Relatively impermeable. Not known to yield water to wells in Finney and Gray counties.
		Cheyenne (?) sandstone	70±	Cross-bedded, fine- to coarse-grained, light gray to yellow quartz sandstone, containing interbedded gray to black silty and sandy shale. Not exposed in Finney and Gray counties.	Not known to yield water to wells in Finney and Gray counties.
		unconformity			

* Classification of the State Geological Survey of Kansas.

ozoic era. Thick limestones, such as are found in the deep oil and gas test wells, were deposited in these seas. The land, however, was not covered by the sea continuously, for records indicate that deposition in the seas was interrupted from time to time by erosion. A great variety of sediments was deposited during the Permian period, consisting chiefly of red shale, sandstone, and sandy shale but containing also beds of salt, gypsum, anhydrite, and limestone. Alternating submergence and emergence of the land probably continued into the early part of the Permian period, but during the latter part of the period there was a widespread emergence that produced shallow basins and low plains. The great mass of red clay and sand that forms the upper part of the system in this area probably was laid down on this type of topography. The coarser materials were deposited by streams; the finer materials probably were deposited in shallow basins or bayous and on wide mud flats. The climate seems to have been somewhat more arid than it is now, for the deposition of sand and clay was interrupted at different times by the chemical precipitation of salt and gypsum, which are products of evaporation in shallow bodies of water. Continential deposition was predominant during the latter part of the Permian period, and by the close of the period the shallow seas had withdrawn completely. The streams that had been depositing sediments began to erode the land surface. This summary of Permian history is based largely on a report by Darton (1920, p. 7).

MESOZOIC ERA

Triassic and Jurassic periods.—The Triassic and Jurassic periods are not represented by rocks in this area. During these periods the Permian rocks were subjected to erosion as a result of an uplift of the Paleozoic rocks which occurred early in the Mesozoic era. It is possible, however, that there was some deposition during the early part of the Mesozoic era but that later erosion completely removed the sediments prior to Cretaceous sedimentation.

Cretaceous period.—The oldest Cretaceous sediments found in the area consist predominantly of quartz sand (Cheyenne (?) sandstone) and, according to Twenhofel (1924, p. 19), represent either shallow-water marine or stream deposition. Following the deposition of sand, the land was submerged and covered by a moderately deep sea in which was deposited the dark clay that in part comprises the Kiowa (?) shale. Thin sandstones and shell-limestones interbedded in the shale were deposited during minor fluctuations of sea level. A recurrence of conditions similar to those that existed when the Cheyenne was deposited occurred in later Cretaceous time; that is, the sea retreated and continental deposits of sand and clay, represented by the Dakota formation, were laid down. The sandy surface of the Dakota was then covered by the sea and the deposition of the dark clay and sand that forms the Graneros shale began.

During the remainder of Cretaceous time or at least until the close of Niobrara time, the land was covered almost continuously by shallow to moderately deep seas. Following the deposition of the Graneros shale the alternating beds of clay and limestone that form the Greenhorn limestone were deposited. Following this nearly 400 feet of clay which now forms the Carlile shale was deposited. The lower clays of the Carlile are calcareous (Fairport chalky shale member), but the upper clays are nearly barren of any calcareous matter (Blue Hill shale member). During a short interval toward the close of the time when the Carlile was deposited, the sea probably retreated somewhat and sand and sandy clay were deposited in some areas (Codell sandstone member). This was followed by an abrupt change to moderately deep-sea conditions when several hundred feet of calcareous sediments (Niobrara formation) were deposited. Thin beds of bentonite in the Greenhorn limestone, Carlile shale, and Niobrara formation indicate that at different times volcanic ash was blown into the seas in which these sediments were being deposited. The ash upon settling was deposited as thin beds in the clays of these formations and subsequently was altered to bentonite.

No Cretaceous sediments later than the Niobrara formation are now found in this area, although they might very possibly have been deposited and subsequently removed by erosion. In the late Cretaceous or early Tertiary period the strata in western Kansas were tilted, for at the present time they dip gently toward the northeast.

CENOZOIC ERA

Tertiary period.—During the early part of the Tertiary period the strata in the northern part of the area were gently folded, resulting in a synclinal trough which trends north and south. This trough extends from the Arkansas valley in western Finney county northward into Scott county. In this area it is known as the Finney basin (Smith, 1940, p. 138) and it is continuous with the Scott basin in Scott county (Waite, in press).

At about the same time a long period of erosion was begun. During this period of erosion hundreds of feet of Cretaceous sediments were stripped off. In the southern part of the area all of the Cretaceous strata down to and including part of the Dakota formation were eroded away. During this same period of erosion the trough in northern Finney county was deepened appreciably, exposing the Carlile shale on the western flank. The present shape of the Finney basin in cross section is shown by section B-B′ in figure 8, and the areal shape is indicated in figure 7 by contour lines drawn on the pre-Tertiary surface.

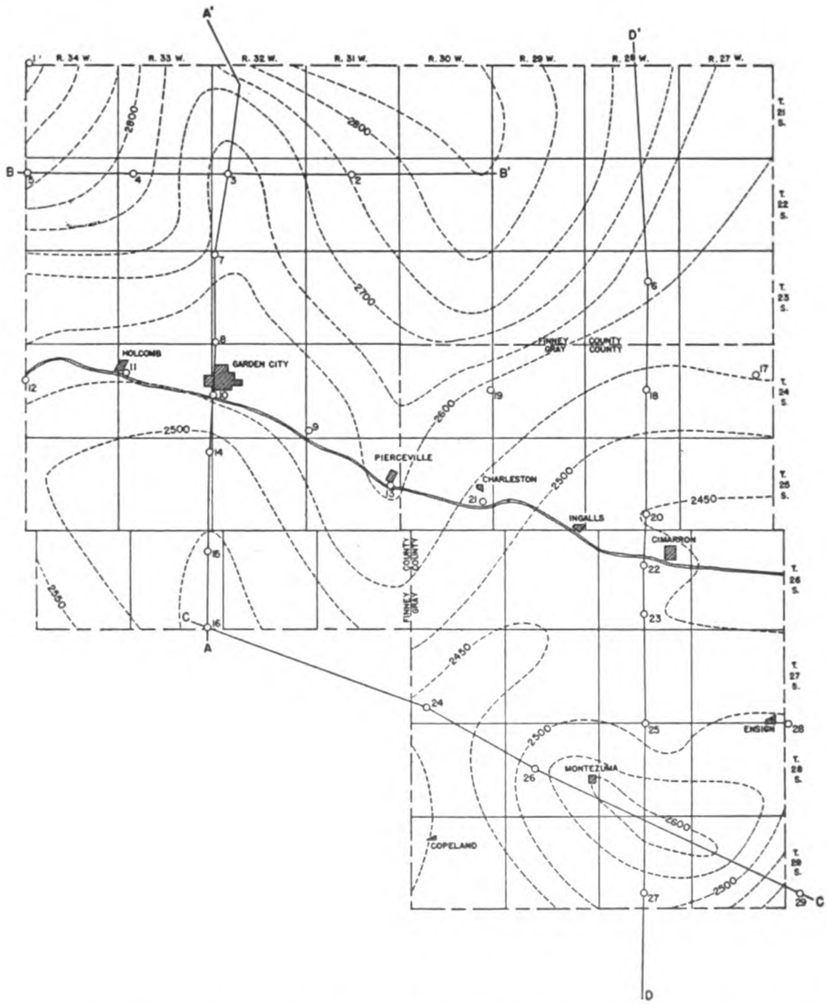


FIG. 7. Map of Finney and Gray counties showing by means of contours (dashed lines) the shape and slope of the pre-Tertiary surface, location of test holes (numbered circles), and location of cross sections shown in figures 8 and 9.

Figure 7 indicates the existence of at least two valleys in this area prior to the deposition of Ogallala sediments. One probably drained from north to south through the western part of Finney county following the structural trough mentioned above. The other valley seemingly entered the area at a point east of Cimarron and drained southwestward through central Gray county. The two valleys probably met in northern Haskell county and joined a through-flowing master stream somewhere farther south.

The oldest Tertiary deposits that were laid down in this area are of late Miocene (?) and early Pliocene age. These deposits, which consist chiefly of clay and comprise the Laverne (?) formation, probably were laid down in lakes and on the flood plains of streams. A period of stream erosion followed the deposition of these clays. A reversal of conditions from stream erosion to stream deposition occurred during the Pliocene epoch. Widely shifting streams deposited rock debris from the mountains to the west over the entire High Plains surface. These deposits, consisting of clay, silt, sand, and gravel, make up the Ogallala formation. The surface upon which these sediments were deposited was very irregular and had much more relief than the present land surface (see figs. 7, 8 and 9). By the close of Ogallala time both the valley areas, including the trough in northern Finney county, and the high areas had been buried beneath these sediments, resulting in a nearly flat eastward-sloping surface. The deposition of the Ogallala sediments closed the Tertiary period of deposition.

Quaternary period.—During very late Pliocene or early Pleistocene time there was renewed downwarping in northern Finney county that again produced a basin over the pre-Ogallala trough. The large lowland area south of Arkansas river in southern Finney county, which is now covered by sand hills, was produced by subsidence that probably was contemporaneous with the downwarping in northern Finney county. The downwarping and subsidence in this area probably occurred contemporaneously with faulting and folding in other parts of western Kansas. Faulting took place in the Meade basin in Meade county during late Pliocene or early Pleistocene time (Frye, 1942, p. 26) and, according to McLaughlin (1943, p. 36), strata in southern Hamilton and Kearny counties were faulted at about the same time.

A short period of erosion probably followed or was contemporaneous with the crustal movements that took place in western Kansas. This period or erosion, however, was less severe than the

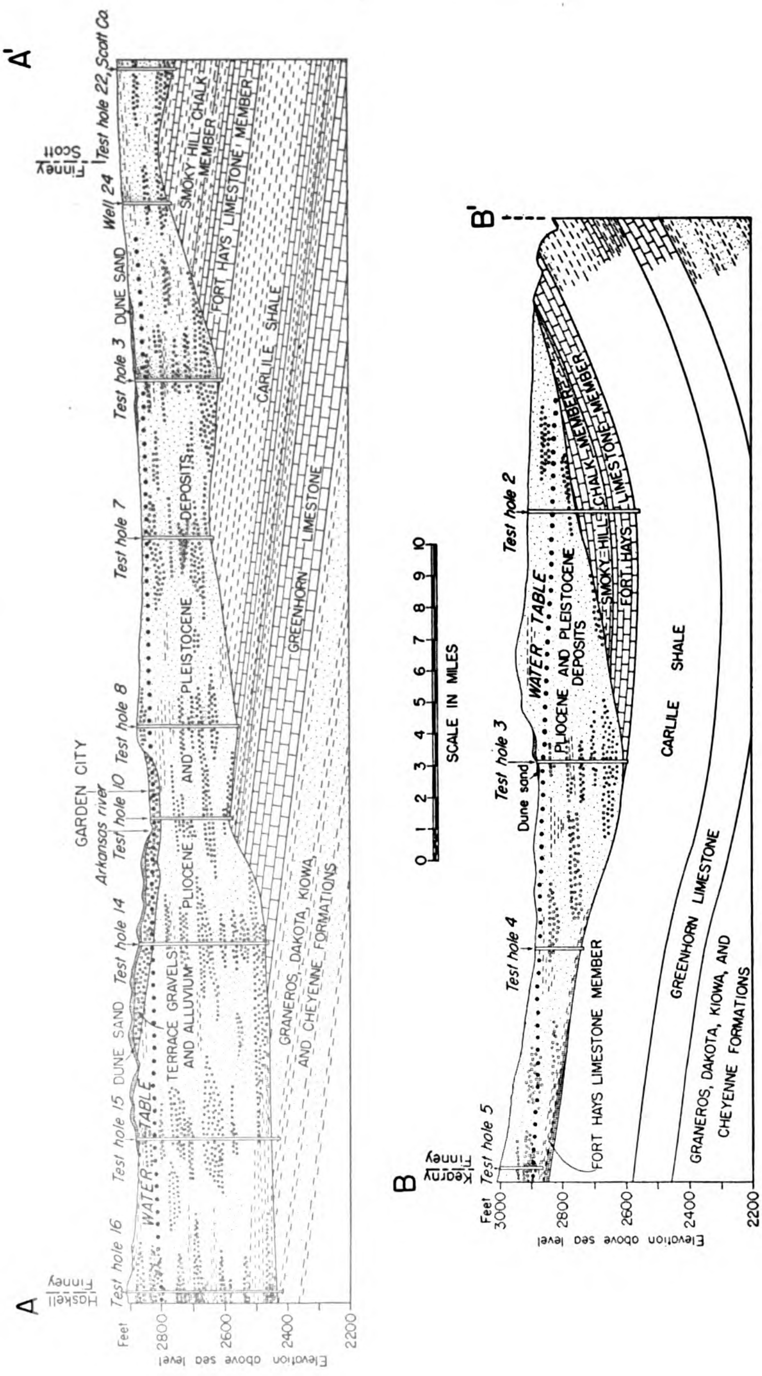


FIG. 8. Geologic profiles through Finney county, along lines A-A' and B-B' in figure 7.

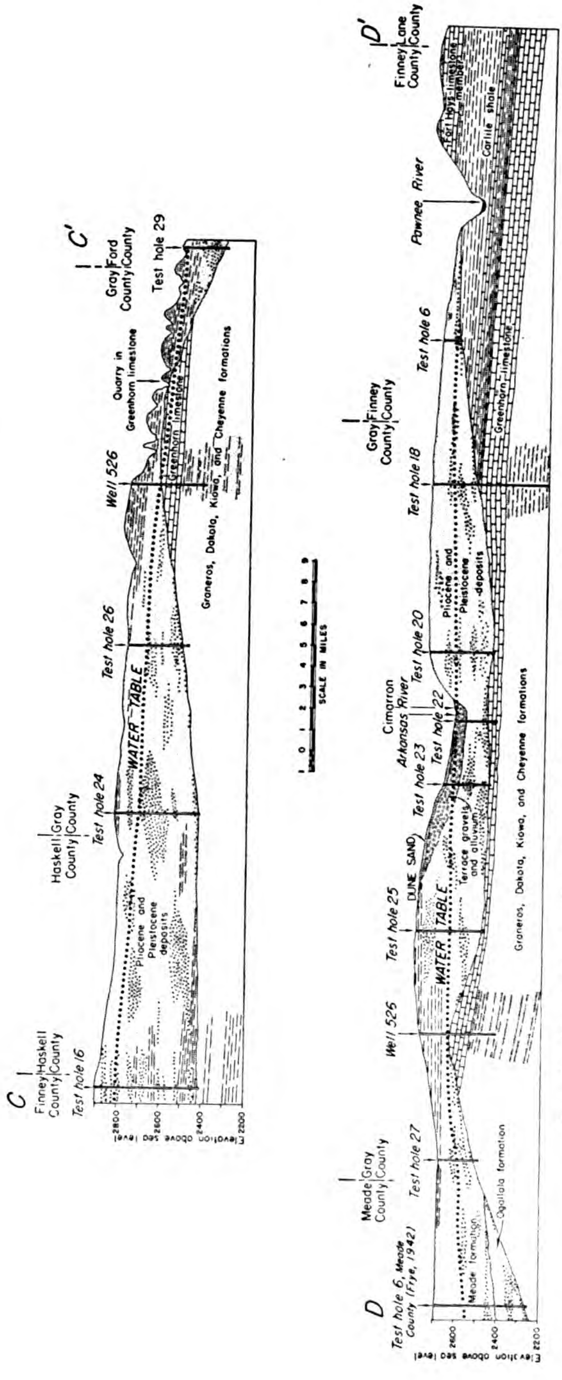


Fig. 9. Geologic profiles through Gray county, along lines C-C' and D-D' in figure 7.

erosion that preceded the deposition of the Ogallala formation, for the resulting surface had slight relief compared with the pre-Ogallala surface.

During Pleistocene time water-laid sediments of clay, silt, sand, and gravel were deposited. These deposits completely filled the Finney basin and the lowland area south of Arkansas river and spread out over the entire surface of this and adjoining areas. These sediments make up the larger part of the undifferentiated Pleistocene deposits described on pages 171-177, and are equivalent to the Meade formation and part of the Kingsdown silt of the Meade basin. Following the deposition of the Pleistocene beds there must have been renewed downwarping or areal subsidence in the Finney basin and in the area now occupied by the sand hills, for at the present time these two areas are topographically much lower than the surrounding uplands. It is hard to conceive of these areas as being products of stream erosion alone. Smith (1940, p. 138) makes the following statements concerning the Finney basin:

> It has no surface drainage outlets, displays no evidence whatever of ancient stream channels, and is dotted with innumerable minor depressions and undrained basins, some of which are almost a mile in length. It obviously cannot be explained as a product of stream erosion, and consequently can be attributed only to post-Ogallala downwarping.

The low area now occupied by sand hills, however, probably is the result of both areal subsidence and stream erosion. Thick Pleistocene terrace gravels beneath the sand hills south of the present Arkansas river indicate that the course of the ancestral Arkansas river during the late Pleistocene time was far south of its present course. At one time it probably flowed within a few miles of the southern edge of the present sand hills. As a result of subsidence, the river migrated gradually northward until it reached its present position. As the river migrated northward it left thick deposits of coarse sand and gravel that now form the terraces along the south side of the valley. Although erosion was the dominant factor in the history of this area from late Pleistocene time to the present, sedimentation was not entirely absent. Wind-blown sand has accumulated to form the dunes or sand hills in the broad lowland belt south of the Arkansas valley and in some localities in the Finney basin and on the uplands north of the valley. At about the same time a thin mantle of eolian loess, consisting mostly of silt and clay, was deposited on the upland areas of the two counties. The loess is equivalent to the uppermost part of the Kingsdown silt

(Pleistocene and Recent) of Meade county. The most recent sedimentation has taken place in the valleys where alluvial silt, sand, and gravel have been deposited in the channels and on the flood plains of the streams.

In northeastern Finney county, Pawnee river and its tributaries have eroded valleys deep enough to expose the Fort Hays limestone member of the Niobrara formation and the Carlile shale; in southern Gray county erosion by a tributary of Crooked creek has exposed the Greenhorn limestone (fig. 9). These streams and their tributaries are still eroding their valleys at the present time. Arkansas river has not been able to cut below the Ogallala formation in this area, however, and there is some evidence that within historic time the river actually has been depositing rather than eroding (Smith, 1940, pp. 173, 174).

During Recent time many shallow depressions have developed on the surface in this and surrounding areas. Although they occur nearly everywhere on the upland surface, they are especially numerous in the Finney-Scott basin. The origin of the depressions is not known with certainty, but they are thought to be the result of subsidence due to solution in underlying beds. Smith (1940, p. 171) suggests that they are due to the solution of calcareous beds in the Cretaceous rocks, or, in some areas, to the solution of salt or gypsum in Permian or early Mesozoic formations. This theory seems to explain satisfactorily the origin of large sinks such as the "Salt well" in Meade county and Big Basin and St. Jacob's well in western Clark county, but it is difficult to understand how the many small depressions dotting the uplands could have originated as a result of solution in deep-lying beds. The theory proposed by Johnson (1901, pp. 703, 704) seems to account more plausibly for the origin of these small, shallow depressions. He states that:

> Appearances indicate basining of the alluvial surface as a consequence, first, of rain water accumulation in initial faint unevennesses of the plain; second, of percolation of this ponded surface water downward to the ground water in largely increased amount from these small areas of concentration, rather than from the whole surface uniformly, with the result that the alluvial mass is appreciably settled beneath the basins only. . . . this settlement takes place as the combined effect of mechanical compacting of the ground particles and chemical solution of the more soluble particles.

GROUND WATER

Principles of Occurrence

The following discussion on the occurrence of ground water has been adapted from Meinzer (1923, pp. 2-102), and the reader is referred to his report for a more detailed discussion of the subject. For a general discussion of the occurrence of ground water in Kansas the reader is referred to State Geological Survey Bulletin 27 (Moore, 1940).

Ground water, or underground water, is the water that supplies springs and wells. The rocks that form the outer crust of the earth are at very few places solid throughout, but contain numerous open spaces, called voids or interstices. These open spaces are the receptacles that hold the water that is found below the surface of the land and is recovered in part through wells and springs. There are many kinds of rocks, and they differ greatly in the number, size, shape, and arrangement of their interstices and, hence, in their properties as containers of water. Therefore, the character, distribution, and structure of the rocks of any region determine the occurrence of water.

The amount of water that can be stored in any rock depends upon the volume of the rock that is occupied by open spaces, that is, the porosity of the rock. The porosity is 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. The porosity of a sedimentary rock is controlled by (1) the shape and arrangement of its constituent particles, (2) the degree of assortment of its particles, (3) the cementation and compaction to which it has been subjected since its deposition, (4) the removal of mineral matter through solution by percolating waters, and (5) the fracturing of the rock, resulting in joints and other openings. Well-sorted deposits of unconsolidated silt, sand, or gravel have a high porosity regardless of the size of the grains. Poorly-sorted deposits have a much lower porosity because the small grains fill the voids between the large grains, thus reducing the amount of open space. The pore space in some well-sorted deposits of sand or gravel may gradually be filled with cementing material, thus gradually reducing the porosity.

The capacity of a rock to hold water is determined by its porosity, but its capacity to yield water is determined by its permeability. The permeability of a rock may be defined as its capacity for transmitting water under hydraulic head, and is measured by the rate at which it will transmit water through a given cross section under a given difference of head per unit of distance. Rocks that will not transmit water may be said to be impermeable. Some deposits, such as well-sorted silt or clay, may have a high porosity, but because of the minute size of the pores will transmit water only very slowly. Other deposits, such as well-sorted gravel containing large openings that are freely interconnected, will transmit water very readily.

Part of the water in any deposit is not available to wells because it is held against the force of gravity by molecular attraction—that is, by the cohesion of the water itself and by its adhesion to the walls of the pores. The ratio of the volume of water that a rock will yield by gravity, after being saturated, to its own volume is known as the specific yield of the rock.

Below a certain level, which in Finney and Gray counties ranges from the surface to about 210 feet below the surface, the permeable rocks are saturated with water under hydrostatic pressure. These saturated rocks are said to be in the zone of saturation, and the upper surface of this zone is called the water table. Wells dug or drilled into the zone of saturation will become filled with ground water to the level of the water table.

The permeable rocks that lie above the zone of saturation are said to be in the zone of aeration. As water from the surface percolates slowly downward to the zone of saturation, part of it is held in the zone of aeration by the molecular attraction of the walls of the open spaces through which it passes. In fine-grained material there is invariably a moist belt in the zone of aeration just above the water table, and this moist belt is known as the capillary fringe. Although water in the zone of aeration is not available to wells, much of the water in the upper part of the zone may be withdrawn by the transpiration of plants and by evaporation from the soil.

Rock Types and Their Water-bearing Properties

The outer crust of the earth is made up of various kinds of material ranging from unconsolidated deposits such as clay, silt, sand, and gravel to consolidated rocks such as shale, limestone, and sandstone. All of these materials, whether they are firm and hard or loose and soft, are called "rocks." All of the rocks encountered in drilling wells in Finney and Gray counties are of sedimentary origin. There are, however, many different types of sedimentary rocks that range greatly in character and in their ability to store and transmit water. The chief types of sedimentary rocks encountered in this area are clay, silt, sand, gravel, sandstone, limestone, and shale. A brief discussion of the water-bearing properties of each is given below.

SAND AND GRAVEL

In Finney and Gray counties more wells obtain water from sand and gravel than from any other source. Unconsolidated deposits of sand and gravel are found in the alluvium in all of the larger stream valleys, in the Pleistocene terrace deposits, in the undifferentiated Pleistocene deposits, and in the Ogallala formation.

Gravel is far superior to any other type of material in its ability to store and yield water. A great range in the water-bearing properties of various kinds of gravel is found, however. This difference is controlled by the degree of assortment and the degree of cementation of the gravel. Coarse, clean, well-sorted gravel has a high porosity, high permeability, and high specific yield. It has the ability to absorb water readily, to store it in large quantities, and to yield it to wells freely. In some deposits, however, clay, silt, or sand is mixed with the gravel, thus reducing its porosity, permeability, and specific yield. Most of the gravel deposits in Finney and Gray counties contain some silt and sand, but nevertheless yield water very freely. Some of the gravel deposits in the undifferentiated Pleistocene deposits and the Ogallala formation have been tightly cemented with a lime carbonate, thus making them worthless as producers of water. The tightly cemented zones are relatively thin, however.

Sand ranks next to gravel as a water bearer. The same factors causing variations in the water-bearing properties of gravels will cause variations in the water-bearing properties of sand. Sand differs from gravel in having smaller interstices; therefore, it will conduct water less readily and will give up a smaller proportion of its water to wells. Sand also consists of smaller particles, which are more readily carried by the water into the wells, thus causing difficult problems in connection with drilling and pumping. Proper well construction is especially important where the main source of water is from fine sand. A discussion of well construction is given on page 92.

The distribution, character, thickness, and water-yielding capacity of the sand and gravel deposits in this area are described under the chapter on geologic formations and their water-bearing properties.

SANDSTONE

The Dakota formation contains the only water-bearing sandstones tapped by shallow wells in this area. All of the wells tapping the Dakota formation in this area are in southeastern Gray county, and supply water for domestic and stock use. Sandstones also occur in the underlying Cheyenne sandstones, but no water wells are known to tap the Cheyenne in this area.

Sandstone ranks next to sand in its ability to store and transmit water. The factors determining the water-bearing properties of a sandstone are the size of grain, degree of assortment, and degree of cementation. A coarse-grained well-sorted sandstone generally will yield water freely, whereas an equally well-sorted very fine-grained sandstone holds a relatively large part of its water and surrenders the rest very slowly. A loosely cemented very fine-grained sandstone also is undesirable because of the tendency of the grains to enter wells, thus causing damage to the pumps and often clogging the wells (see page 93). The degree of assortment of the sand grains in a sandstone affects the water-bearing properties of the sandstone in the same way as in a gravel deposit. Fine sand, silt, or clay in a coarse-grained sandstone greatly decreases the porosity and permeability of the sandstone. The interstices of sandstone are small and are, therefore, easily closed by precipitates from percolating water. Many sandstones are so thoroughly cemented that they will not yield water from the original openings between their grains. Tightly cemented sandstone may, however, contain joints and fractures that hold water.

Sandstones in the Dakota formation range considerably in their capacity as water-bearers. A complete discussion of the character and water supply of the Dakota formation is given on pages 145-148 of this report.

LIMESTONE

Limestone, although inferior in this area to gravel, sand, or sandstone as a water bearer, supplies water to a few wells in this area where the more desirable types of rocks are absent or where they lie above the water table and are therefore barren of water. Such wells tap limestones in the Fort Hays limestone member of the Niobrara formation (p. 159). This limestone member also supplies water to several springs in the northeastern part of Finney county (p. 160).

Water occurs in limestone in fractures or in solution openings that have been dissolved out of the rock by water containing dissolved carbon dioxide. The occurrence of fractures and solution openings is very irregular, making it difficult to predict where water will be found in a limestone. One well drilled to limestone may encounter water-filled fractures or solution openings and have a good yield, whereas another well drilled only a few feet from the first well may not encounter any fractures or solution openings and yield little or no water. In drilling for water in an area underlain by limestone, it is generally necessary to put down several test holes to locate water-bearing fractures or solution openings before the final well can be drilled.

SHALE

Several wells in this area obtain all or a part of their water from shale. All of the wells known to obtain water from shale tap the Blue Hill shale member of the Carlile shale. Most of the wells have very small yields. Shales occur in all of the Cretaceous formations in this area. Shale is one of the most unfavorable of rocks from which to obtain water. Shale, if not too tightly indurated, may have a fairly high porosity and contain much water. The interstices between the individual particles are so small, however, that the water is held by molecular attraction and hence is not available to wells. Available water in shale is found only in joints and along bedding planes. Descriptions of various shales encountered by drilling in this area are given in the chapter on geologic formations and their water-bearing properties.

Permeability of the Water-bearing Materials

The permeability of a water-bearing material—that is, its capacity to transmit water under hydraulic head—may be determined in the field by tests of ground-water velocity or by discharging-well methods.

GROUND-WATER VELOCITY METHOD

In 1904, Slichter (1906, pp. 7-16) made tests of the velocity of the underflow in the Arkansas valley 2 miles west of Garden City and at Holcomb * in Finney county. The method developed and used by Slichter consists of driving several small wells into the water-bearing formation in such a manner that the movement of water is from one well toward one or more of the other wells. A salt is introduced into the up-gradient well and the electrolyte thus

* Referred to as Sherlock in Slichter's report.

formed is allowed to move down-gradient toward the other wells, where its arrival is detected electrically. The rate of movement of the electrolyte and hence the rate of movement of the ground water is computed from the elapsed time between the introduction of the salt in the up-gradient well and its detection in a well located down-gradient. Slichter made several tests at each location and found that the natural velocity of the ground water 2 miles west of Garden City ranged from 1.3 to 10.3 feet per day and averaged 6.6 feet per day. He found that the natural velocity of the ground water at Holcomb ranged from 2.0 to 22.9 feet per day and averaged 8.9 feet per day. The wells used in making the velocity tests ranged from 11 to 65 feet in depth, and tapped only the alluvial deposits of the valley.

Slichter did not compute permeability after determining the natural velocity of the ground water. Permeability can be computed, however, by using the equation $P_m = \frac{7.48\,pvC_t}{I}$, in which P_m is Meinzer's coefficient of permeability, p is the porosity of the water-bearing material, v is the velocity of the ground water in feet per day, and I is the hydraulic gradient in feet per foot (Wenzel, 1942, p. 71). The coefficient of permeability as defined by Meinzer is expressed 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 average hydraulic gradient 2 miles west of Garden City is 7.5 feet to the mile or 0.00142 foot per foot, and the average velocity of the ground water as determined by Slichter was 6.6 feet per day. The temperature of the ground waters in the area where Slichter's work was done averages about 60° F., so that no correction for temperature is needed. By using an assumed porosity of 30 percent and substituting these values in the above equation, the coefficient of permeability of the water-bearing materials 2 miles west of Garden City is computed to be about 10,400.

Using the same equation, but substituting 8.9 feet per day for v, the coefficient of permeability of the water-bearing material at Holcomb is computed to be about 14,000.

THEIS RECOVERY METHOD

Theis (1935) developed the following formula for determining permeability from the recovery of the water level in a well:

$$T = \frac{264q}{s} \log_{10} \frac{t}{t^1}$$

in which T = coefficient of transmissibility
q = pumping rate, in gallons a minute
t = time since pumping began, in minutes
t^1 = time since pumping stopped, in minutes
s = residual drawdown at the pumped well, in feet, at time t^1

The coefficient of transmissibility is the product of the field coefficient * of permeability and the thickness of the saturated portion of the aquifer. The Theis formula is based on the assumption that if a well is pumped at a constant rate of discharge for a known period and then left to recover, the residual drawdown at any instant will be the same as if the discharge of the well had been continued, but a recharge well having the same (flow) had been introduced at the same point at the instant the discharge actually stopped (Wenzel, 1942, p. 95). It does not assume equilibrium conditions.

The value of $\frac{\log_{10} t/t^1}{s}$ is determined graphically by plotting $\log_{10} t/t_1$ against corresponding values of s. Most of the points should fall on a straight line and this straight line should pass through the origin. If the straight line does not pass through the origin, it may be made to do so by empirically applying a correction factor to t. With the empirical correction factor the Theis formula is as follows: $T = \frac{264q}{s} \log_{10} \frac{t \pm c}{t^1}$ where c is the value whose magnitude is such that the straight line determined by plotting $\log_{10} \frac{t \pm c}{t^1}$ against s will pass through the origin (Wenzel, 1942, p. 96).

Pumping tests to determine the permeability of the water-bearing material by the Theis recovery method were made on six wells in the Finney-Gray area. The field tests were conducted by Woodrow Wilson, of the Federal Geological Survey, and Melvin Scanlan, of the Division of Water Resources, Kansas State Board of Agricul-

* The field coefficient of permeability differs from Meinzer's definition of coefficient of permeability chiefly in that it does not include a temperature correction.

ture. The results of one test were obviously in error so they have been omitted from this discussion. In computing the results of the other five tests, it was necessary to apply the correction factor to make the straight lines pass through the origin. The results of the five tests are given in table 4.

SUMMARY

The coefficients of permeability of the alluvium in the Arkansas valley determined by using the ground-water velocity method were 10,400 and 14,000, as compared with 1,030 computed for well 454 by the Theis recovery method. The latter figure, 1,030, is probably more nearly of the right order of magnitude. Certain inherent errors of the ground-water velocity method as used by Slichter may be pointed out. Errors in determining the velocity of the ground water may have been caused by an increase in the hydraulic gradient caused by the rise of water in the up-gradient well at the time the salt was introduced and by the fact that the water-bearing material under study is highly lenticular, allowing greater velocity along certain "pipes" of more permeable material. The wide range in velocities obtained by Slichter indicates that certain measurements were made along "pipes" of this kind, and other measurements were made along "pipes" of material having a very low permeability. For lenticular material of this type, it would be very difficult to evaluate the ground-water velocities obtained in order to arrive at an average velocity.

Wells 160 and 450 tap the same water-bearing formations, but the computed coefficient of permeability of the material at well 450 is about 2½ times greater than that of the material at well 160. A comparison of the specific capacities and the thickness of water-bearing materials at the two wells also show that the water-bearing material at well 450 has a greater permeability than the material at well 160. Well 160 has a specific capacity of 32, and the thickness of the water-bearing material is about 160 feet; whereas the thickness of water-bearing material at well 450 is about 148 feet, yet well 450 has a specific capacity of 46.

Artesian Conditions

Artesian water is ground water under sufficient pressure to rise above the point at which it is encountered in wells. A well that flows at the land surface is known as a flowing artesian well.

Artesian conditions exist where a water-bearing bed is overlain by an impermeable or relatively impermeable bed that dips from its

TABLE 4.—*Results of pumping tests made on wells in Finney and Gray counties using the Theis recovery method for determining permeability*

Well number and/or location	Water-bearing formation	Length of time well was pumped (minutes)	Average discharge of well during test (gallons a minute) (g)	Specific capacity (gallons a minute per foot of drawdown)	Correction applied to *t* (c)	Coefficient of transmissibility (*T*)	Approximate thickness of water-bearing beds	Coefficient of permeability[1] (P*f*)
Well 454, NW NW sec. 10, T. 26 S., R. 28 W	Alluvium	225	592	35	—210	38,200	37	1,030
Well 160, SW SE sec. 36, T. 23 S., R. 34 W	Alluvium and undifferentiated Pliocene and Pleistocene deposits	170	1,141	32	—95	64,000	160	400
Well 450, SE cor. NW sec. 17, T. 26 S., R. 27 W	do	210	970	46	+500	154,185	148	1,040
[2] U. S. Army well, NW NW SW sec. 27, T. 24 S., R. 31 W	Undifferentiated Pliocene and Pleistocene deposits	307	441	33	+325	47,500	120	395
[2] U. S. Army well, NE NW SE sec. 27, T. 24 S., R. 31 W	do	338	272	12	—170	27,000	116	235

1. The temperature of the ground water in Finney and Gray counties ranges from 57° to 62° F. Corrections for temperature have been omitted because they would not materially alter the results.
2. Well drilled after the field investigation was completed.

outcrop to the discharge area (Sayre, 1937, p. 22). Water enters the water-bearing bed at the outcrop and percolates slowly downward to be held in the water-bearing bed by the overlying confining bed. Down the dip from the outcrop area, the water exerts considerable pressure against the confining bed. When a well is drilled through the confining bed into the water-bearing bed the pressure is released and the water rises in the well. If the water is under sufficient pressure, and if the altitude of the land surface is lower than the altitude of the outcrop of the water-bearing bed, the water may rise high enough to flow at the surface. In places where there are lenses or beds of relatively impermeable clay or silt at the level of the water table, the water encountered below such lenses or beds will rise to the level of the surrounding water table, but such water is under normal pressure and is not artesian.

There is only one flowing well (119) in this area to my knowledge. It is on the R. J. Ackley land in the SW¼ SW¼ sec. 4, T. 23 S.,

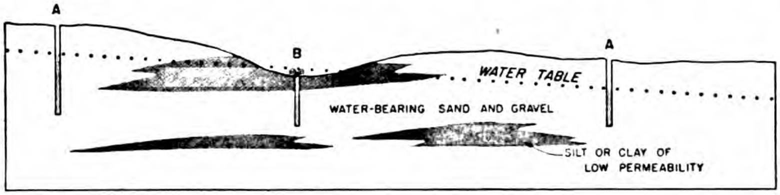


FIG. 10. Diagrammatic geologic section across an upland depression showing relationship between a flowing well and a nonflowing well.

R. 33 W., and is reported to be between 70 and 80 feet deep. Figure 10 illustrates the probable geologic conditions that cause this well to flow. Well A in the illustration is situated on the uplands under normal water-table conditions. Well B, however, is situated in a depression, the surface of which is below the water table. Water encountered in the sands and gravels below the lens of impermeable silt or clay will rise above the land surface to the level of the surrounding water table. Such water is under normal pressure and is not artesian. Well 119 furnishes water to a pond which covers a part of the depression. The level of the water in the pond probably is below the level of the surrounding water table, for the amount of water lost by transpiration and evaporation is greater than the amount of water supplied by the well. If no water were lost through transpiration and evaporation, the water level in the pond should be at the same level as the surrounding water table.

Artesian water has been encountered by wells in areas adjacent to the Finney-Gray area. The largest area of flowing wells in the state is in the Meade basin in central Meade county, which adjoins Gray county on the south. There were more than 200 flowing wells in the Meade district in 1939 (Frye, 1942, p. 52). Most of the artesian water in the Meade basin is obtained from Pliocene deposits, but some comes from Pleistocene beds. According to Frye (1942, p. 49):

> . . . 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.

Small flowing wells in southwestern Ford county obtain artesian water from the Rexroad member of the Ogallala formation (Pliocene) and from overlying Pleistocene beds (Waite, 1942, p. 50). Waite (1942, p. 50) also reports a small flowing well in the Arkansas valley, about 3 miles east of the Gray-Ford county line, which obtains artesian water from the Ogallala formation. The Dakota formation (Cretaceous) supplies artesian water to wells in some areas. Moss (1932, pp. 45, 46) reports that there are several flowing wells from the Dakota formation in Sawlog creek valley in southern Hodgeman county.

The Water Table and Movement of Ground Water

SHAPE AND SLOPE

The water table is defined as the upper surface of the zone of saturation except where that surface is formed by an impermeable body (Meinzer, 1923a, p. 32). It may also be regarded as the boundary between the zone of saturation and the zone of aeration. The water table is not a level surface, but rather it is generally a sloping surface which shows many irregularities caused by differences in transmissibility 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 Finney and Gray counties are shown on plate 1 by means of contour lines drawn on the water table. 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 topographic contours show the configuration of the land surface. The direction of movement of the ground water is at right angles to the water-table contour lines—in the direction of the greatest slope.

Plate 1 shows that the ground water is moving through Finney and Gray counties in a general easterly direction, but that the direction of movement and the slope vary considerably in different places. The average gradient of the water table is about 7 feet to the mile. In the northwestern part of Finney county and the southeastern part of Gray county, the slope is much greater than this, being as much as 35 or 40 feet to the mile in northwestern Finney county and 25 or 30 feet to the mile in southeastern Gray county. In contrast to these two areas, the water table in the Finney basin in northern Finney county is nearly flat, sloping only about 3 feet to the mile.

The slope of the water table in any area in general 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 material, provided the same quantity of water is moving through both types of material. This explains in part the differences in the slope of the water table in different parts of this area. In the northwestern part of Finney county, where the water-table slope is steep, the water in the upper part of the zone of saturation occurs in chalk and limestone of the Niobrara formation. As the water moves eastward it enters the permeable unconsolidated sand and gravel of the undifferentiated Pleistocene deposits and the Ogallala formation, and the gradient becomes greatly reduced. The steeper gradients in southeastern Gray county seemingly also are caused by differences in the permeability of the water-bearing materials. Throughout most of Gray county the water in the upper part of the zone of saturation occurs in the permeable sands and gravels of the undifferentiated Pleistocene deposits or the Ogallala formation. As the water moves eastward in southern Gray county it enters the less permeable fine-grained sandstones of the Dakota formation (fig. 9 CC^1), hence the gradient becomes steeper. Continuing southeastward the water again enters sands and gravels of the undifferentiated Pleistocene deposits, and the gradient becomes more nearly as it was before entering the Dakota formation.

The prominent ridge on the water table, shown by the downslope flexure of the contours in southeastern Gray county, also is caused by differences in permeability. In the western part of T. 29 S., R. 27 W., and in the eastern part of T. 28 S., R. 27 W., the water moves through sandstones of the Dakota formation. Between these two areas, however, the water moves through sand and gravel in the undifferentiated Pleistocene deposits. Because the permeability of the sand and gravel is much greater than the permeability of the sandstone, much of the water is deflected around the high sandstone areas and moves through the sand and gravel. This increase in the amount of water passing through the sand and gravel has caused a ridge to be formed on the water table.

Irregularities in the shape of the water table may also be caused by the unequal addition of water to the ground-water reservoir at different places. Plate 1 shows two other rather prominent ridges on the water table—one in T. 22 S., R. 34 W., indicated by the flexure of the contours toward the northeast, and one in T. 23 S., R. 34 W., indicated by the downslope flexure of the contours. Influent seepage from the two ephemeral streams (p. 77) that end in the northern part of T. 22 S., R. 34 W., and from the Great Eastern irrigation canal (p. 77) probably is responsible for the northernmost ridge on the water table. The southern ridge probably is caused by influent seepage from the Great Eastern irrigation canal alone. Plate 1 shows a mound on the water table in the northeastern part of T. 26 S., R. 27 W. This is a depression area that holds water after rains. Some of the water probably seeps downward to the underground reservoir, where it builds up a mound on the water table (p. 73). These ridges and mounds are formed by water percolating downward because the frictional resistance offered by the small openings in the water-bearing material prevents the water from spreading out rapidly as it would on the surface of a body of free water, such as a lake. As soon as the descending water reaches the water table it joins the main body of ground water.

The slight downslope flexure of the contours south of Arkansas river indicates that a very broad, low ridge has been formed on the water table beneath the sand hills. This is especially prominent southwest of Holcomb and south of Pierceville. Part of the water that falls on the sand hills during heavy showers seeps downward to the underground reservoir (p. 68), and has thus formed a broad ridge on the water table beneath the sand hills in the same manner that the smaller ridges north of Arkansas river were formed.

The slope of the water table and the direction of movement of the ground water also are influenced by the discharge of water into streams. The contours on plate 1 show that the water table slopes rather uniformly toward the Arkansas valley from both sides and also slopes downstream, indicating that water flows into the valley from both sides and thence down the valley. The contours also indicate that slight ground-water divides exist both north and south of the Arkansas valley throughout most of its course in this area.

Arkansas river in eastern Finney county and throughout Gray county is an effluent stream; that is, it is a perennial stream whose channel has been cut down below the water table and is thereby gaining water from the zone of saturation. This movement of water from the underground reservoir to the channel of the river has caused a trough to be formed on the water table that follows the course of Arkansas river, as indicated by the upstream flexure of the contours. It will be noted that the contours in Gray county and eastern Finney county change direction as they cross the channel of the river, but that from a point a few miles east of Garden City to the western Finney county line the contours do not change direction where they cross the river. The contours still flex upstream in this area, but they change direction in the valley either north or south of the river channel. Throughout this part of its course the water table was below the channel of the river at the time the water-level measurements were made for the water-table map. Under these conditions, this part of the river would furnish water to the underground reservoir, thereby forming a temporary ridge on the water table beneath the river channel. Heavy pumping for irrigation in this part of the valley, however, has caused a trench to be formed on the water table as indicated by the upstream flexure of the contours. If there were no heavy withdrawals of water from the underground reservoir beneath the valley, the contours probably would be straighter. A map of the water table between Garden City and Deerfield based on measurements made during the summer of 1904 shows the water-table contours crossing the Arkansas valley as nearly straight lines (Slichter, 1906, fig. 1). At the time this map was made the withdrawal from the underground reservoir beneath the Arkansas valley was relatively small compared with what it is now. It will be noted that no contours were drawn in the northeastern or "panhandle" part of Finney county. This area is underlain by Cretaceous shales and limestones and does not have normal water-table conditions. Wells in this area obtain water from limestone or shale, or from alluvium in the stream valleys.

RELATION TO TOPOGRAPHY

The topography of the land surface is one of the chief factors controlling the depth to water level in Finney and Gray counties. A map (plate 2) has been prepared showing the depths to water level in Finney and Gray counties 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 aerial photographs and the available topographic maps. Some inaccuracy has been introduced by local irregularities of the land surface which are not shown on the topographic maps or aerial photographs.

As shown on the map, the depth to water level in this area ranges from less than 5 feet to about 200 feet. The relation between the water table and the land surface is shown in the four geologic sections in figures 8 and 9.

For purposes of detailed descriptions of the ground-water conditions, Finney and Gray counties may be divided into the following areas based upon the depth to water level: valley shallow-water areas, Finney basin shallow-water area, sand hills shallow-water area, upland areas of intermediate depth to water, and the Ensign deep-water area. Special ground-water conditions exist in the area of Cretaceous rocks in northeastern Finney county; therefore, it is described separately as the Pawnee area.

Valley shallow-water areas.—The Arkansas valley is the most important shallow-water area in Finney and Gray counties. The width of the valley ranges from about 1 mile near Pierceville to about 3½ miles near Garden City. In the Arkansas valley the measured depths to water level ranged from 3 to about 22 feet. Many domestic, stock, irrigation, public supply, and industrial wells are located in the valley. More water is pumped from wells in the valley than from any other area in the two counties. The greatest concentration of wells is in the vicinity of Garden City, where there are as many as 14 wells in a single section. Most of the irrigation wells obtain water from coarse gravel in the alluvium. Other wells are deeper and obtain water from either the undifferentiated Pleistocene deposits or the Ogallala formation.

Smaller and less important shallow-water areas occur in the narrow valleys of Crooked creek and its tributaries in southern Gray county and Buckner creek in northeastern Gray county. The depth to water level in these smaller valleys ranges from about 10 feet in the bottoms of some of the valleys to 50 feet on the slopes bordering the valleys. A few wells in these areas obtain water from alluvium, but most of the wells tap undifferentiated Pleistocene deposits or the Ogallala formation. Ground-water conditions in the valleys of Pawnee river and its tributaries are discussed under the heading Pawnee area on page 62.

Finney basin shallow-water area.—This area of shallow water extends from the Arkansas valley in western Finney county northward to the Finney-Scott county line, and is continuous with the shallow-water basin in Scott county. Its eastern and western limits are roughly marked by the 50-foot depth-to-water line on plate 2. The surface topography of the Finney basin has been described on page 21. Measured depths to water level in this area ranged from 9 to 50 feet below the land surface. Domestic, stock, and irrigation wells in this area obtain water from undifferentiated Pleistocene deposits or from the Ogallala formation. Many wells, especially the deep irrigation wells, tap both the undifferentiated Pleistocene beds and the Ogallala. The zone of saturation in the Finney basin ranges from 100 to about 300 feet in thickness, and attains its greatest thickness in the southern part near the Arkansas valley. The possibilities of developing additional supplies of water for irrigation in this area are discussed on page 119.

Sand hills shallow-water area.—The sand hills shallow-water area borders the Arkansas valley on the south and is that area lying between the Arkansas valley and the 50-foot depth-to-water line (pl. 2). In Gray county it is a narrow belt not more than 2½ or 3 miles wide, but in Finney county it is as much as 5 miles wide. Because of local relief in the sand hills, the depth to water level varies greatly, and depends on the location of the well. The depth to water level in a well in a basin between dunes will be less than if the well were located on the top of a dune. It was for this reason that the 50-foot depth-to-water line was dashed in southern Finney county. The depth to water level in the wells visited in this area did not exceed 50 feet. The wells in the sand hills shallow-water area obtain water from the Pleistocene terrace gravels that underlie the sand hills or from the undifferentiated Pleistocene beds.

Upland areas of intermediate depth to water.—In by far the greater part of Finney and Gray counties the depth to water level ranges from 50 to 150 feet below the surface. South of the Arkansas valley is a large area of intermediate depth to water, which includes most of the sand hills and uplands in central Gray county and all of southern Finney county. Wells in this large area tap the undifferentiated Pleistocene beds and/or the Ogallala formation, and the depth to water level in them ranges from 50 to 150 feet. The depth to the water table in the sand-hills part of this area may vary greatly within short distances because of local relief of the dune topography.

Two areas of intermediate depth to water level are found north of the Arkansas valley. The largest of the two includes all of northern Gray county, the southern part of the "panhandle" of Finney county, and all of central Finney county. Measured depths to water level in this area ranged from 57 to 130 feet. All of the wells derive water from the undifferentiated Pleistocene deposits or from the Ogallala formation or from both.

A third area of intermediate depth to water lies north of the Arkansas valley and west of the Finney basin shallow-water area. The depth to water level in this area ranges from 50 feet to a maximum known depth of 97 feet. Most of the wells tap the Ogallala formation, and a few may obtain water from undifferentiated Pleistocene beds. Wells 38 and 40, however, obtain water from the Fort Hays limestone member of the Niobrara formation (Cretaceous). In a small area surrounding these wells the Ogallala formation is thin and lies above the water table. In places in the extreme northwestern part of this area it is difficult to obtain any water, because Cretaceous limestones and shales are so near the surface.

Ensign deep-water area.—The only area in Finney and Gray counties in which the depth to water level is greater than 150 feet is in east-central Gray county in the general vicinity of Ensign (pl. 2). Measured depths to water level in this area range from 150 to 207 feet. Most of the wells obtain water from undifferentiated Pleistocene beds or from the Ogallala formation. One well (500), however, obtains water from sandstone in the Dakota formation. This well is reported to be 420 feet deep and the measured depth to water level in 1940 was 207 feet.

Pawnee area.—The ground-water conditions in the Pawnee river drainage basin in the "panhandle" of Finney county differ from those found elsewhere in Finney and Gray counties. Most of this area is underlain by limestone or shale of Cretaceous age. Where unconsolidated silt, sand, and gravel does occur, it is relatively thin and generally will not supply water to wells. A few wells obtain water from the Fort Hays limestone member of the Niobrara formation (wells 2, 7, and 11) and a few obtain water from the Blue Hill shale member of the Carlile shale (wells 1, 8, 46, and 57).

Water is not found everywhere in limestone and shale (p. 49), and the wells that obtain water from such rocks have very small yields. For a complete description of these wells the reader is referred to the table of well records at the end of this report. Most of the wells in the Pawnee area are shallow and obtain water from alluvium in the valleys. The depth to water level in the valleys of Pawnee river and its tributaries generally is less than 25 feet. Springs occur in some of the valleys that have been cut below the water table (p. 87). The springs issue from limestone (Fort Hays limestone member of the Niobrara) or Pleistocene gravels where they are in contact with Cretaceous rocks.

FLUCTUATIONS IN WATER LEVEL

General considerations.—The water table in any area 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 depend upon the net rate at which the underground reservoir is replenished or depleted.

The principal factors controlling the rise of the water table in Finney and Gray counties are the amount of precipitation that passes through the soil and descends to the water table, the amount of water added to the ground-water reservoir by seepage from Arkansas river and other streams, and the amount of water entering the counties beneath the surface from areas to the west. The principal factors controlling the decline of the water table are the amount of water pumped from wells, the amount of water lost through transpiration and evaporation where the water table is shallow, the discharge of water through springs, the amount of water discharged by effluent seepage into Arkansas river, and the amount of water leaving the county beneath the surface toward the east. The factors causing the water table to rise are discussed in detail in the chapter on Ground-water recharge and the factors causing the water table to decline are discussed in the chapter on Ground-water discharge.

In the fall of 1939, 27 wells in Finney county and 26 wells in Gray county were selected as observation wells, and monthly measurements of water level in them were begun in order to obtain information concerning the fluctuations in storage of the underground reservoir. Since July, 1936, the Division of Water Resources of the Kansas State Board of Agriculture has maintained an automatic water-stage recorder on well 269 in Finney county. Complete water-level records of this well have been made available by Mr. G. S. Knapp, Chief Engineer. The descriptions and the 1939 water-

TABLE 5.—*Numbers of Finney county observation wells used in this report and corresponding numbers given in Water-Supply Papers 886, 908, and 938*

Well No. in this report	Well No. in Water-Supply Papers 886, 908, and 938	Well No. in this report	Well No. in Water-Supply Papers 886, 908, and 938
10	6	266	17
25	5	269	1
39	24	270	10
69	11	339	16
77	4	350	18
89	20	353	28
95	21	354	12
110	23	361	13
138	3	371	8
143	19	382	27
164	22	383	14
168	26	387	2
189	25	389	7
246	15	398	9

TABLE 6.—*Numbers of Gray county observation wells used in this report and corresponding numbers given in Water-Supply Papers 886, 908, and 938*

Well number in this report	Well No. in Water-Supply Papers 886, 908, and 938	Well number in this report	Well No. in Water-Supply Papers 886, 908, and 938
410	13	484	24
414	9	486	22
432	1	491	28
433	19	498	3
437	15	502	12
440	20	507	6
443	26	512	23
445	25	514	17
455	4	515	29
462	8	523	14
473	27	531	11
477	21	535	18
479	7	541	16

level measurements for all observation wells are given in the 1939 annual water-level report of the Federal Geological Survey (Meinzer and Wenzel, 1940, pp. 138-145, 158-161) and subsequent water-level measurements have been published in ensuing water-level reports (Meinzer and Wenzel, 1942, pp. 45-52, 61-66; 1943, pp. 60-65, 71-75). Tables 5 and 6 correlate the observation-well numbers used in this report with those given in Water-Supply Papers 886, 908, and 938. The location and description of each well appears in the table of well records at the end of this report.

Ground-water Recharge

Recharge is the addition of water to the underground reservoir and may be accomplished in several different ways. All ground water within a practical drilling depth beneath Finney and Gray counties is derived from the water that falls as rain or snow either within the area or on near-by areas to the west. Once the water becomes a part of the ground-water body it moves down the slope of the water table, later to be discharged at some point farther downstream.

The underground reservoir beneath this area is recharged by local precipitation within the area, by seepage from streams and irrigation canals, and by subsurface inflow from areas to the west.

RECHARGE FROM LOCAL PRECIPITATION

The average annual precipitation in Finney and Gray counties is about 19 inches, but probably only a small part of this amount reaches the zone of saturation owing to several complicating factors. The depth of the water table below the surface determines in part the amount and frequency of this recharge. Where the water table stands comparatively far below the surface, as it does in parts of Finney and Gray counties, it fluctuates less in response to precipitation than it does in areas like the Arkansas valley where the water table is comparatively shallow.

The relation between the fluctuations of water levels and the depth to the water level in wells is shown by the hydrographs of wells 432, 531, and 541 in figure 11. Well 432 is a shallow well in the Arkansas valley. The water level in this well responds readily to the rains that fall on the valley surface. Wells 531 and 541 are upland wells in southern Gray county. The depth to water level in well 531 is about 60 feet and in well 541 about 138 feet. Because of the greater depth to water level in well 531, it fluctuates less in response to precipitation than does the water level in the shallow valley well (432). According to the hydrograph shown in figure 11, the water level in well 541 seems to be unaffected by precipitation. It is true that the

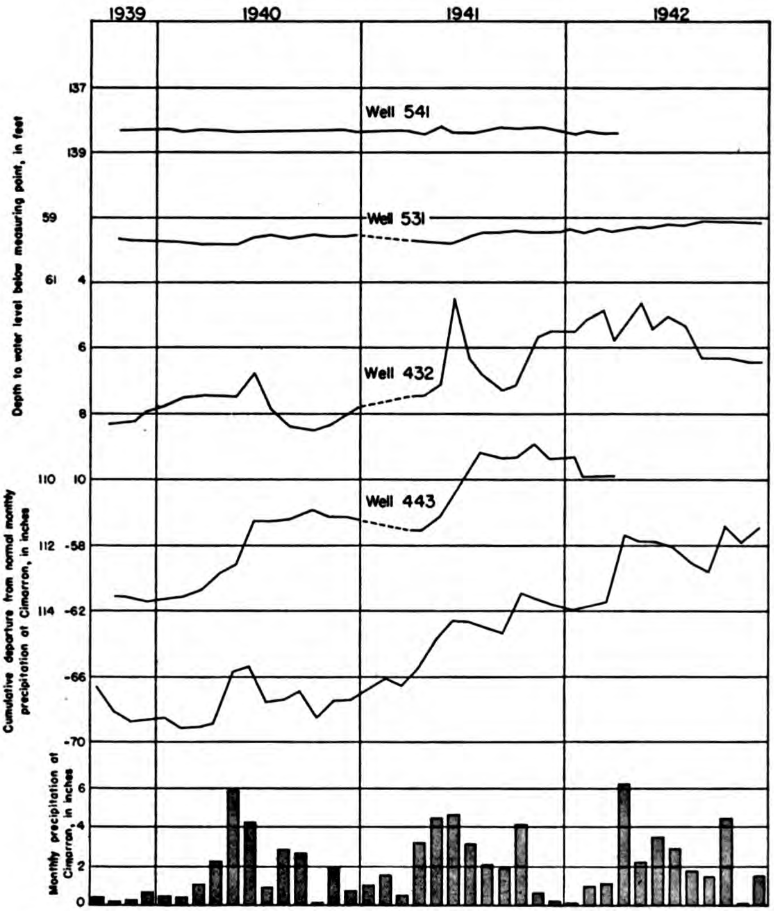


FIG. 11. Hydrographs showing the relation between the monthly fluctuations of the water levels in four wells in Gray county and the monthly precipitation at Cimarron. Precipitation data from U. S. Weather Bureau.

water level in a well in which the depth to water is great will not readily respond to precipitation, but over a long period of years there should be some comparison between the water level in a deep well and the precipitation, even though it would not be as marked as in a shallow well.

Of the total precipitation, part is lost by evaporation into the air, part is lost through runoff, and part is used by growing plants. Thus, only a part of the precipitation enters the interstices of the soil and only part of this reaches the zone of saturation. When the amount of water absorbed by the soil is greater than can be held against the pull of gravity, a part of the water will move downward to the zone of saturation. At the end of the growing season in the fall of the year, the moisture in the upper part of the soil zone is usually depleted. Evaporation and transpiration by plants remove most of the moisture in this zone, thereby causing a deficiency in soil moisture. Moisture in the depleted soil zone is replenished by fall and winter precipitation. Water that enters the interstices of the soil during the fall and winter remains there until the moisture deficiency is satisfied or until the growing season begins. There is relatively little evaporation and transpiration during the fall and winter. If there is sufficient precipitation, the moisture deficiency is taken care of and recharge to the zone of saturation takes place. If, however, the precipitation is small, all the water may be retained in the soil, and there will be no ground-water recharge.

The amount of water lost through evaporation into the air varies from one season to the other, the rate of evaporation being greatest in the summer when temperatures are highest. In an average year, more than half the total precipitation in this area comes during the summer from May through August, when the rate of evaporation is greatest. The average rates of evaporation from a free water surface for the months of the growing season based on 30-year records at the Garden City Experimental Farm are as follows: April, 6.68 inches; May, 8.46 inches; June, 10.25 inches; July, 11.90 inches; August, 10.42 inches; September, 8.10 inches (Smith, 1940, p. 28). It seems likely, therefore, that a rather large percentage of the annual precipitation in this area is lost through evaporation.

The amount of water leaving the area by runoff in streams is probably comparatively small. The duration and intensity of the rainfall, the slope of the land surface, and the type of soil and vegetation principally determine the amount of local runoff from precipitation. The runoff from a gentle rain as a rule is much smaller than the runoff from a heavy downpour, hence the amount of ground-water recharge from a gentle rain of long duration generally is greater than the recharge from a heavy downpour of short duration, provided all other factors are equal.

The slope of the land is an important factor in determining the amount of runoff, and in general the steeper the slope the greater the runoff. Steep slopes occur along the major streams in this area; otherwise the slopes of the land surface are relatively gentle. Large areas in Finney and Gray counties lack any but local surface drainage. This is true of the area of sand hills south of the Arkansas valley, the Finney basin, and much of the upland plains.

Runoff is greater in places where the soil is tightly compacted and consists of fine relatively impermeable material than in places where the soil is sandy and loosely compacted. The latter type of soil allows a part of the water to percolate into the ground, thus decreasing the amount of surface runoff.

The loss of precipitation by runoff in the Arkansas river drainage basin is very small. According to records of the Division of Water Resources of the Kansas State Board of Agriculture, the average annual net runoff in the Arkansas river drainage area above Garden City for the period October 1, 1928, to September 30, 1939, was only 0.09 inch (excluding water diverted by irrigation canals west of Garden City). The average annual net runoff in the Pawnee river drainage basin above Larned for the same period was 0.298 inch (Anon., 1937, pp. 401, 402, 490, 491; 1940, pp. 249, 303). Thus the loss by runoff amounts to a relatively small part of the total precipitation.

The most favorable areas in Finney and Gray counties for ground-water recharge from precipitation are the sand hills, the shallow-water areas in stream valleys, and the shallow surface depressions on the uplands and in the Finney depression.

Recharge in areas covered by dune sand.—The large area covered by dune sand south of Arkansas river and the smaller areas covered by dune sand north of the river offer unusually good opportunities for recharge from precipitation. Much of the rain that falls on the dune-covered areas is absorbed by the sand and for that reason there is little runoff, as is evidenced by the almost total absence of drainage lines. The water that enters the interstices of the sand percolates downward rapidly, thus escaping evaporation.

Recharge in Arkansas valley.—The bottom lands of the Arkansas valley also offer exceptional opportunities for ground-water recharge from precipitation. As stated above, the percentage of the precipitation that is lost by runoff is very small. According to Slichter (1906, p. 53), there is no runoff from precipitation in the area between Garden City and Deerfield. If so, the rainfall that is not lost through evaporation and transpiration must pass through the sandy porous soil and percolate downward to the water table.

Recharge by precipitation on the valley floor is evidenced by the fact that following rains there is a rapid rise of the water levels in the wells situated in the valley. The fluctuations of the water level in two observation wells (246 and 350) in Finney county, the

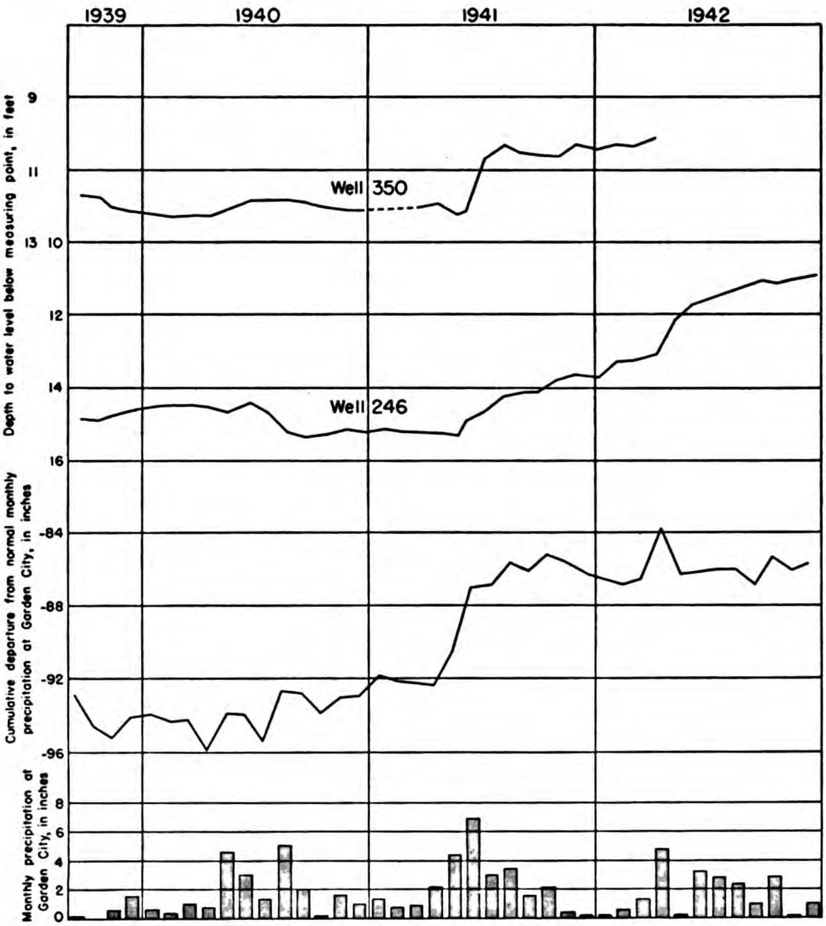


FIG. 12. Hydrographs showing the relation between the monthly fluctuations of the water levels in wells 246 and 350 and the monthly precipitation at Garden City. Precipitation data from U. S. Weather Bureau.

cumulative departure from normal monthly precipitation at Garden City, and the monthly precipitation at Garden City are shown in figure 12. Both wells are shallow, unused irrigation wells in the Arkansas valley. Well 246 is about 1.75 miles north of Arkansas river and well 350 is about 0.75 mile south of the river. Figure

11 shows the fluctuations of the water levels in four observation wells in Gray county, the cumulative departure from normal monthly precipitation at Cimarron, and the monthly precipitation at Cimarron. Well 432 in figure 11 is in the Arkansas valley about a quarter of a mile north of the river.

During a normal year the water table in the Arkansas valley in this area reaches its highest stage in June or July, and its lowest

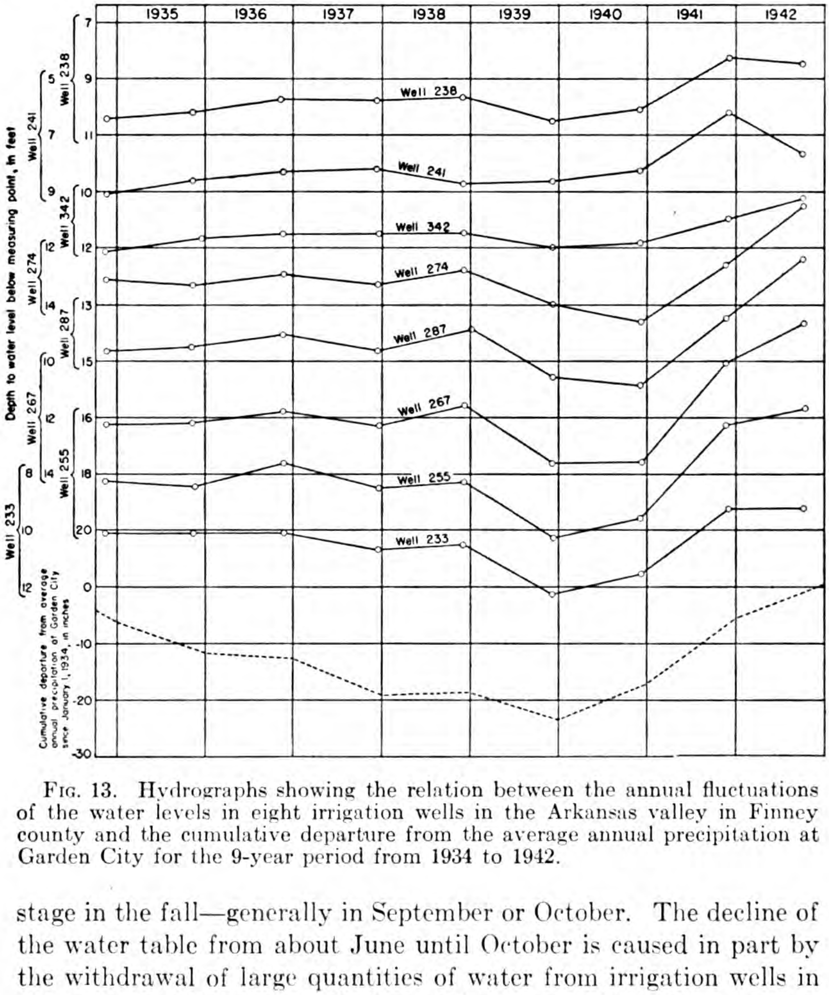


FIG. 13. Hydrographs showing the relation between the annual fluctuations of the water levels in eight irrigation wells in the Arkansas valley in Finney county and the cumulative departure from the average annual precipitation at Garden City for the 9-year period from 1934 to 1942.

stage in the fall—generally in September or October. The decline of the water table from about June until October is caused in part by the withdrawal of large quantities of water from irrigation wells in the valley and in part by the heavy draft created by the vegetation during the growing season. The water levels in all wells do not follow this routine behavior every year, for other factors may affect them. Many of the valley wells in Finney county deviated from their routine behavior in 1941 owing in part to the abnormally high rainfall during May, June, July, and August and in part to the resulting decrease in withdrawal of water for irrigation. The rainfall as recorded at Garden City for the 4-month period from May through August was 6.67 inches above normal. The result of this on the water levels in wells is shown by the hydrographs of wells 246 and 350 in figure 12.

Figure 13 shows the relation between the annual fluctuations of the water levels in eight irrigation wells in the Arkansas valley in Finney county and the cumulative departure from the average annual precipitation at Garden City for the period from 1934 to 1942. The depths to water level in the wells were measured each year in October, November, or December after the wells had ceased pumping. Kenneth McCall, engineer for the Division of Water Resources of the Kansas State Board of Agriculture, made all measurements from 1934 through 1940. Woodrow Wilson of the Federal Geological Survey measured the depths to water level in the wells in 1941 and 1942. The hydrographs in figure 13 seem to show a direct correlation between the fluctuations of the water levels in the irrigation wells and the cumulative departure from the average annual precipitation. The fluctuations of the water levels, however, have not been due entirely to precipitation, but have been due partly to the withdrawal of water for irrigation.

Wells 233, 255, 267, 274, and 287 are located in or near the heavily pumped areas surrounding Garden City and Holcomb. Wells 238, 241, and 342 are farther from the heavily pumped areas. The cumulative deficiency in precipitation for the period from 1934 to the end of 1939 was 18.15 inches. For this same period the five wells in the heavily pumped areas showed net declines in water level ranging from 0.9 foot to 2.13 feet, the average net decline being about 1.5 feet. Of the three wells outside the heavily pumped areas, well 238 showed a net decline of only 0.1 foot for the same period and wells 241 and 342 had net rises of 0.39 foot and 0.13 foot, respectively. In summary, the wells in the heavily pumped areas showed an average net decline in water level of about 1.5 feet, whereas those outside the heavily pumped areas showed an average rise in water level of 0.14 foot for the period of below average rainfall from 1934 to 1939. It is obvious from these figures that much of the decline in water levels in the wells in the heavily pumped areas was the result of the cumulative deficiency of precipitation and also of the heavy withdrawals of water for irrigation. In studying the factors producing a 9-year decline in the ground-water levels in the shallow-water basin in central Scott county, Waite (1941, p. 775) found that somewhat more than half of the decline resulted from the effects of pumping and the rest from the deficiency in precipitation.

The amount of water withdrawn annually by pumps in the Arkansas valley generally varies indirectly with the precipitation. In 1939, when the precipitation was 4.48 inches below the annual average for the 9-year period, approximately 27,120 acre-feet of water was pumped from wells in the Arkansas valley in Finney county for irrigation. As a result of the deficiency in precipitation and the heavy withdrawal of water for irrigation, all of the wells in the heavily pumped areas showed sharp declines in water level in 1939. In 1940, however, the precipitation was 6.57 inches above the annual average. As a result of this increase in precipitation and the accompanying decrease in pumpage, six of the eight irrigation wells (fig. 13) showed a rise in water level in 1940. The average net rise in water level for the eight irrigation wells was about 0.17 foot in 1940. In 1941, the precipitation was 11.57 inches above the annual average, and the average net rise in water level for the eight irrigation wells amounted to about 2.27 feet.

That the annual recharge from precipitation in the Arkansas valley is high is further substantiated by the following discussion. Slichter (1906, p. 24) calculated the underflow in a narrow part of the valley near Hartland and found it to be about 2,100 acre-feet a year. At this point the river has cut its valley into relatively impermeable Cretaceous rocks; the alluvium is only 2,250 feet wide and has an average thickness of about 33 feet. Slichter stated that the above figure for the underflow "represents the maximum that can be claimed in a high estimate." McLaughlin (1943, p. 77) estimated that the "underflow" near Hartland is much less than 2,100 acre-feet a year and probably is about 1,000 acre-feet a year. Nearly 20,000 acre-feet of water is withdrawn annually for irrigation in the Arkansas valley in eastern Kearny county (McLaughlin, 1943, p. 77), and approximately 30,000 acre-feet of water is withdrawn annually from wells in the Arkansas valley in western Finney county—a total of about 50,000 acre-feet. An annual "underflow" of 1,000 acre-feet of water a year obviously would be entirely inadequate to supply either the 50,000 acre-feet that is withdrawn annually from wells in the valley in eastern Kearny county and western Finney county or the large quantity of water that is transpired by plants.

The average annual loss in the flow of Arkansas river between Syracuse and Garden City amounts to about 25,000 acre-feet (p. 77, table 7). If it is assumed that most of this loss takes place east of Hartland, then Arkansas river would contribute about 25,000 acre-feet of water a year to the ground-water reservoir in eastern Kearny county and western Finney county. If this assumption is incorrect, then the river probably would contribute less than 25,000 acre-feet of water a year to the ground-water reservoir. The remainder of the water pumped from wells (about 24,000 acre-feet a year) and transpired by plants probably is derived largely from precipitation.

Recharge in depressions.—Shallow depressions, or sinks, are common in the Finney basin and on the uplands in this area. Following heavy rains, water collects in these depressions and forms temporary ponds. The water in some of the ponds disappears in a short time, whereas in others it remains for several weeks or months. Whether or not such intermittent ponds can furnish water to the underground reservoir depends entirely on the character of the underlying deposits. If the underlying deposits are sufficiently permeable, recharge will take place and the water will soon disappear from the pond; otherwise, water will stand in the pond until it is all evaporated. In studying similar depressions in the High Plains of Texas, White, Broadhurst, and Lang (1940, p. 7) found that:

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

Similar conditions probably exist in some of the depressions in this area. Mud cracks were noticed in the dry bed of some of the depressions, but to what depth they extend is not known.

The water table mound shown in sec. 2, T. 26 S., R. 27 W., on plate 1 was formed by water percolating to the water table from a shallow upland depression. Fluctuations of the water level in well 443 (fig. 11), which is situated in the depression, reflect this recharge. The water level in this well, even though it is about 112 feet below the surface, responds readily to precipitation. Normally the water level in a well in which the depth to water level is this great would not fluctuate as much in response to precipitation as does the water level in this well. After each heavy rain this depression becomes filled with water, and a part of the water that accumulates in the depression seeps through the soil and percolates downward to the water table. Upon reaching the water table the water at once starts to move from higher to lower altitudes, and the mound gradually becomes smoothed out. After each heavy rain the mound is again formed and the process is repeated. Other depressions on the uplands probably act as catchment areas for recharge in the same manner as the one just described, and the water table beneath them probably shows similar fluctuations.

Summary.—From the foregoing discussion, it can be seen that the amount and frequency of recharge from precipitation varies greatly from one locality to another, depending entirely on local conditions. Theis, Burleigh, and Waite (1935, pp. 2-3) believe that—

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

In areas such as the sand hills (dune-covered areas) and the shallow-water area along the Arkansas valley, the amount of recharge from precipitation is undoubtedly much greater than half an inch of water a year, but on the upland surface where the water table lies at greater depth the recharge from precipitation probably is less than half an inch a year. Much of the upland surface in Finney and Gray counties is mantled by loess, which greatly impedes if not prohibits the downward movement of water from the surface.

In many places the descending water will not recharge the underground reservoir directly beneath the area of intake, for the water, upon reaching a bed of impervious clay, silt, or caliche, must take a lateral course until it comes to an opening or pervious zone before continuing its downward course. In all probability the water follows a very irregular course from the surface to the water table.

RECHARGE FROM STREAMS

Two factors determine whether or not a stream is capable of supplying water to the underground reservoir. First, the water surface of the stream must be above the water table; and second, the material between the stream channel and the water table must be sufficiently permeable to permit water to percolate downward. If the water surface of the stream is lower than the water table and the materials forming the sides of the channel are permeable, the process is reversed; that is, the ground-water reservoir will discharge water into the stream. A stream that contributes water to the zone of saturation is said to be an influent, or losing, stream; a stream that receives water from the zone of saturation is said to be an effluent, or gaining, stream.

The greatest amount of recharge from streams in this area comes from Arkansas river. East of a point a few miles downstream from Garden City, Arkansas river is a perennial stream fed by ground

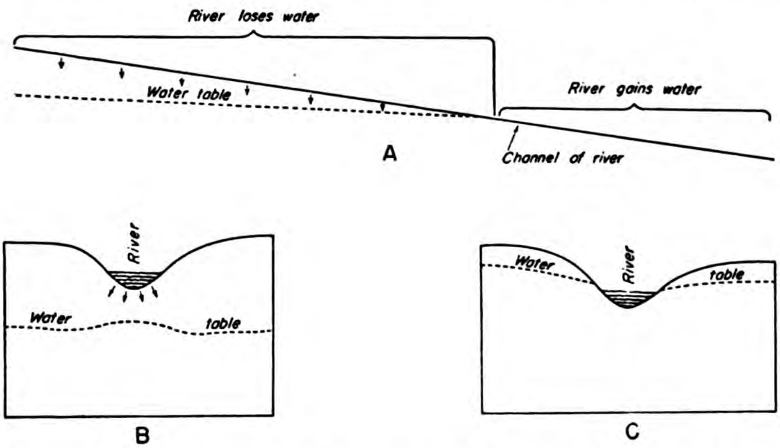


FIG. 14. Diagrammatic section showing relationship between Arkansas river and the water table. *A*, Longitudinal section showing (right) how river gains water and (left) how it loses water. *B*, Transverse section across influent part of river. *C*, Transverse section across effluent part of river.

water, and, therefore, cannot, under normal conditions, contribute to the zone of saturation. Upstream from this point, however, Arkansas river, because the water table is lowered by pumping, loses water to the underground reservoir during certain periods and receives water from the underground reservoir during other periods. The relationship between Arkansas river and the water table is shown diagrammatically in figure 14. During periods of below-normal rainfall and heavy withdrawals of water for irrigation, the water table in Finney county declines below the level of the channel of the river, and water moves from the river into the ground-water reservoir (fig. 14B). During periods of above-normal rainfall and light withdrawals of water for irrigation, the water table rises above the level of the channel of Arkansas river and the river gains water from the underground reservoir (fig. 14C).

The greatest amount of recharge probably occurs after the river has been dry for some time. While the river is dry, the water table beneath its bed and adjoining lands is lowered not only by withdrawals of water for irrigation but also by evaporation and transpiration. When the river starts to flow again, the surface of the stream is considerably higher than the water table, and water moves from the river into the zone of saturation. After the water table

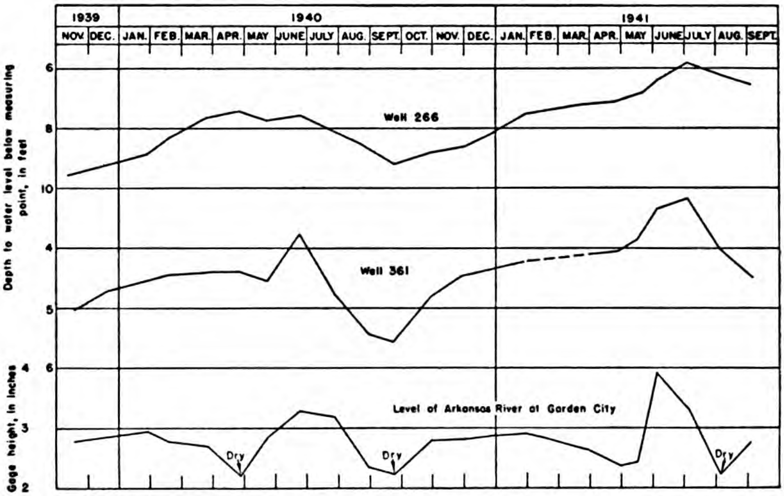


FIG. 15. Hydrographs showing the monthly water levels in wells 266 and 361 and the monthly stages of Arkansas river, in 1940 and 1941. The stages of the river shown are for the same days the water levels in the wells were measured.

rises to the level of the stream, there is little loss from the river, and when the discharge of the river decreases, ground water moves back into the river.

Water is transmitted slowly through the ground; therefore, there is somewhat of a lag between the fluctuations of the river and fluctuations of the adjacent water table. The longer the river maintains its high stage, the farther back from the river will the water table be affected. The monthly water levels in wells 266 and 361 are plotted in comparison with the monthly stage of Arkansas river in figure 15. Both wells are shallow and are situated in the valley a quarter of a mile or less from the river. The wells in figure 15 are close enough to the river so that the fluctuations in their water levels follow very closely fluctuations of the water surface in the river.

The high stages caused by floods are usually of short duration and, therefore, do not affect the ground-water levels very far back from the river. Slichter (1906, p. 39) made water-level observations in test wells adjacent to the river during a flood on July 27, 1904. He found that the water levels in wells within 900 feet of the river fluctuated quite accurately with the changing level in the river, but that the water level in a test well half a mile from the river showed no effect of the flood.

Further evidence of recharge from Arkansas river is furnished by comparing the discharge measurements of the river at Syracuse and Garden City and computing the loss or gain in flow between these two stations (table 7). Between October 1, 1922, and September 30, 1942, the average annual net loss of water between Syracuse and Garden City was about 25,300 acre-feet. Most of this water was lost between Hartland and Garden City. Transpiration by plants and evaporation into the air account for part of the loss in stream flow, but a large part of the loss must be attributed to ground-water recharge. The area between Hartland and Garden City offers excellent opportunities for recharge from the river. The valley in this area is very wide and is underlain by 33 to 40 feet of alluvial sand and coarse gravel, beneath which there is 225 to 320 feet of Pleistocene and Pliocene silt, sand, and gravel. The large draft on the ground-water supply made by the great concentration of irrigation wells in this part of the valley causes the water table to decline each year during the pumping season. If there was no pumping in this area, the water table probably would be built up to the level of the river and there would be little or no loss from the river.

Arkansas river is not the only stream in this area that contributes water to the zone of saturation. The northeastward flexure of the water-table contours in T. 22 S., R. 34 W., Finney county (pl. 1), indicates that the two ephemeral streams ending in that area and the Great Eastern irrigation ditch (p. 58) contribute water to the ground-water reservoir. Throughout most of each year these streams are dry, but during times of heavy rains in areas to the west they carry a large volume of water. The channels of these streams lie above the water table, and the deposits beneath the channels are sufficiently permeable to allow water to percolate downward. A large part of the water carried by these streams is

TABLE 7.—*Annual discharge of Arkansas river at Syracuse, Garden City, and Larned; diversion of water by canals; loss or gain of stream flow, between Syracuse and Garden City for the twenty-year period from Oct. 1, 1922, to Sept. 30, 1942; and loss or gain of stream flow between Garden City and Larned for the eighteen-year period from Oct. 1, 1922, to Sept. 30, 1940*[1]

Water year (October 1 through Sept. 30)	Annual discharge at Syracuse (acre-feet)	Annual discharge at Garden City (acre-feet)	Loss (—) or gain (+) between Syracuse and Garden City				Annual discharge at Larned (acre-feet)	Loss (—) or gain (+) between Garden City and Larned	
			Total (acre-feet)	Diversion into canals[2] (acre-feet)	Net loss or gain exclusive of diversion			Acre-feet	Percentage of discharge at Garden City
					Acre-feet	Percentage of discharge at Syracuse			
1922–1923	594,000	484,000	—110,000	— 88,761	—21,329	3.6	459,000	—25,000	5.2
1923–1924	533,000	562,581	+ 29,581	— 48,537	+78,118	14.7	544,757[3]	—17,824	3.0
1924–1925	252,000	113,000	—139,000	— 65,327	—73,673	29.2	85,800	—27,200	24.1
1925–1926	106,000	15,600	— 90,400	— 58,867	—31,533	29.7	46,600	+31,000	198.7
1926–1927	356,000	204,000	—152,000	— 88,040	—63,960	18.0	243,000	+39,000	19.1
1927–1928	310,000	236,000	— 74,000	— 50,280	—23,720	7.7	247,000	+11,000	4.7
1928–1929	232,000	133,000	— 99,000	—105,830	+ 6,830	2.9	158,000	+25,000	18.8
1929–1930	152,000	42,600	—109,400	— 84,670	—24,730	16.3	77,500	+34,900	81.9
1930–1931	219,000	120,000	— 99,000	— 60,650	—38,350	17.5	187,000	+67,000	55.8
1931–1932	64,100	11,700	— 52,400	— 42,190	—10,210	15.9	41,600	+29,900	255.5
1932 1933	161,000	50,000	—111,000	— 86,360	—24,640	15.3	53,200	+ 6,200	12.4
1933–1934	68,900	11,960	— 56,940	— 42,140	—14,800	21.5	22,690	+10,730	89.7
1934–1935	221,600	81,720	—139,880	— 79,840	—60,040	27.1	109,700	+27,980	34.2
1 35–1936	323,800	199,400	—124,400	— 93,370	—31,030	9.6	162,900	—36,500	18.3
1936–1937	117,500	37,290	— 80,210	— 67,180	—13,030	11.1	45,100	+ 7,810	20.9
1937–1938	199,200	32,940	—166,260	—124,060	—42,200	21.1	42,820	+ 9,880	30.0
1938–1939	80,800	21,550	— 59,250	— 58,590	— 660	0.8	38,340	+16,790	77.9
1939–1940	24,880	1,340	— 23,540	— 14,622	— 8,918	36.3	54,678	+53,338	3,980.4
1940–1941	234,500	93,925	—140,575	—109,990	—30,585	13.0	....	....	....
1941–1942	1,411,610	1,223,380	—188,240	—110,321	—77,909	5.5	....	....	....

1. From records of the Division of Water Resources, Kansas State Board of Agriculture.
2. Includes Amazon, South Side, Great Eastern, Farmer's, and Garden City canals.
3. Includes estimated flow of 100,000 acre-feet for January and February.

emptied into shallow surface depressions, whence it disappears partly by evaporation and partly by seepage into the ground.

No evidence for recharge from the other streams in this area is apparent on the water-table contour map, but Pawnee river, Crooked creek, and other smaller streams undoubtedly supply some water to the underground reservoir.

RECHARGE FROM IRRIGATION WATER

Ground-water recharge from irrigation water is accomplished in two ways—by seepage from canals and ditches and by downward percolation after the water has been spread on fields.

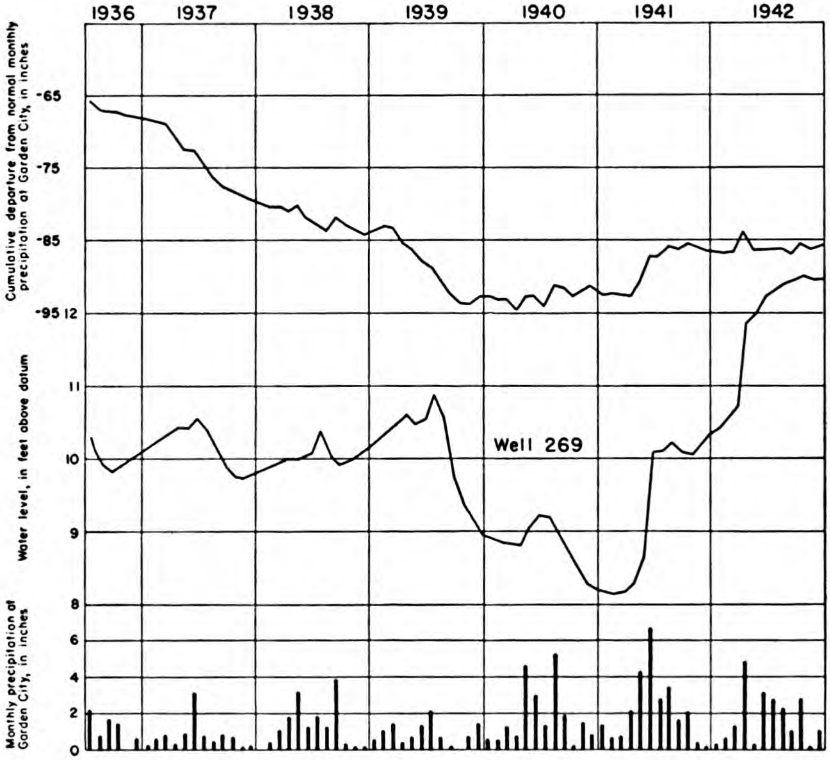


FIG. 16. Hydrograph of well 269 showing changes in water level caused by returned irrigation water, by precipitation, and by pumping. Water-level data supplied by the Division of Water Resources, Kansas State Board of Agriculture.

The irrigation canals and ditches in this area are above the water table, and seepage from them probably takes place whenever they are filled with water. The amount of ground-water recharge from irrigation water that has been spread on fields probably is small except in areas where the water table is shallow. Water pumped from irrigation wells generally is carried in ditches and spread over fields that lie at considerable distances from the well. In the immediate vicinity of the pumping well the water table declines, but in the area where the water returns to the ground-water reservoir the water table rises temporarily.

The hydrograph of well 269 illustrates the effect of returned irrigation water, precipitation, and pumping on the water level in a well (fig. 16). A continuous automatic water-stage recorder has been maintained on well 269 since July 17, 1936, by the Division of Water Resources of the Kansas State Board of Agriculture. Complete water-level records of this well have been made available through the courtesy of Mr. G. S. Knapp, chief engineer. Well 269 is a shallow well in the Arkansas valley in the vicinity of several irrigation wells (pl. 2). The highest water level in this well is reached each year during the pumping season in July or August as a result of recharge from returned irrigation water and from spring precipitation. The small peaks occurring in July or August are the result of irrigation water returning to the underground reservoir in the vicinity of the well. The rise in water level caused by returned irrigation water, however, is only temporary, for the water soon starts moving from the area of recharge to the cones of depression produced by the pumping wells. Water moving into the cones of depression while and after the wells are being pumped causes a decline in the water levels of all wells in the pumping area. This decline was especially noticeable in 1939, which was characterized by abnormally low precipitation and unusually heavy pumpage. As a result of the light pumpage and nearly normal precipitation in 1938, the water level in well 269, after reaching its peak the latter part of July, declined only until about October 1, at which time it again started rising. There was not sufficient precipitation in 1939 to recharge the underground reservoir and, as a result of the heavy withdrawals for irrigation, the water level declined until the supply was replenished by precipitation the following summer (1940). In 1941, the water level rose rapidly in response to the heavy precipitation. Pumpage in 1941 was comparatively light; therefore, the temporary rise in water level caused by the return of irrigation water was small and the decline that followed was small.

In an unpublished report * by the Bureau of Agricultural Eco-

* Water facilities area plan for the Arkansas valley in western Kansas, Water Utilization Section, Division of Land Economics, Bureau of Agricultural Economics, U. S. Dept. of Agriculture, 1939.

nomics it was estimated that 10 percent, or 7,500 acre-feet, of surface irrigation ditch water annually returns to the ground-water reservoir by deep percolation from irrigation canals between the Colorado-Kansas state line and Garden City.

There is probably little recharge from the irrigation water spread on fields on the uplands where the water table is deeper, except where the water collects in depressions or where crops are excessively watered. Irrigation water may increase recharge from precipitation by supplying a part of the moisture needed to overcome the deficit that may exist in the belt of soil moisture.

RECHARGE BY SUBSURFACE INFLOW

The movement of the ground water in this area, as indicated by the slope of the water table (pl. 1), is in an easterly direction; hence recharge from precipitation or stream flow that occurs in areas to the west eventually moves into this area and contributes to the available supply of ground water.

Much of the water contained in the Dakota formation probably entered the formation in areas of outcrop west of Finney county. Sandstone of the Dakota formation is exposed over wide areas in western Las Animas county, Colorado, and adjacent areas and undoubtedly absorbs water directly from rainfall and from streams that cross the outcrops. It is likely that a part of the water thus absorbed by the sandstone travels down the dip into Kansas, and probably migrates into the overlying Ogallala formation at places where the two formations are in contact and especially where the Dakota is thin (Latta, 1941, p. 41). The small rainfall in southeastern Colorado and the capacity of the sandstone to transmit water laterally limit the amount of recharge received in this manner.

SUMMARY OF GROUND-WATER RECHARGE

Most of the annual recharge to the ground-water reservoir beneath this area is derived from precipitation that falls on the surface in these two counties and from seepage from streams and irrigation ditches, especially Arkansas river at times when it is influent. The available data indicate that the recharge for the entire area is only a small percentage of the total precipitation. Areas such as the Arkansas valley, the sand hills, and the Finney basin receive much more recharge than the upland areas.

Ground-water Discharge

Water is discharged from the underground reservoir that lies beneath Finney and Gray counties by transpiration and evaporation, seepage into streams, springs, underflow that leaves the area, and by wells. Other things being equal, the stage of the water table and the season of the year are the principal factors controlling the rate at which ground water is discharged. Transpiration and evaporation of water from the zone of saturation are confined exclusively to those areas where the water table is very shallow, such as the Arkansas valley. The greatest amount of water withdrawn from the underground reservoir by wells is in the vicinity of Garden City where the greatest amount of irrigation is carried on. Seepage of ground water into streams occurs only along Arkansas and Pawnee rivers, and discharge by springs is confined to the area occupied by Pawnee river and its tributaries. In areas where the water table lies at great depth there is no natural discharge except for the water that is moving laterally out of the area beneath the surface. A few domestic and stock wells pump water from the ground-water reservoir in such areas, but the amount of water withdrawn in this way is relatively small.

Water-table contours on the map (pl. 1) indicate that water is slowly moving out of the county beneath the surface toward the east. The amount of water leaving Finney and Gray counties in this way is approximately equal to the amount of water that enters the area from the west plus additions to, or subtractions from, the ground-water reservoir that occur within the two counties.

Before the development of wells in Finney and Gray counties, the annual natural discharge of ground water probably was approximately equal to the annual recharge. The artificial discharge of water by wells has interrupted this balance between natural discharge and recharge. Through a period of many years, however, there will be a readjustment of natural discharge to take into account the artificial discharge of water by wells, and after this readjustment takes place there will again be an approximate balance between annual discharge and annual recharge. Such a readjustment of discharge, however, may result in a gradual regional lowering of the water table. This regional lowering of the water table probably will be very slight, for the amount of water in underground storage is very large.

TRANSPIRATION AND EVAPORATION

Water may be taken into the roots of plants directly from the zone of saturation or from the capillary fringe, and discharged from the plants by the process known as transpiration (Meinzer, 1923a, p. 48). The depth from which plants will lift ground water varies with different plant species and different types of soil. The limit of lift by ordinary grasses and field crops is not more than a few feet, but some types of desert plants have been known to send their roots 60 feet or more below the surface to reach the water table (Meinzer, 1923, p. 82). Most ordinary grasses and field crops obtain water only from the upper few feet of soil. Plants such as corn, wheat, and barley probably obtain water from depths not exceeding 7 feet. Alfalfa is unusual in that it will send its roots to a depth of 20 or 30 feet in order to obtain water.

Discharge of ground water by transpiration from the zone of saturation or from the capillary fringe in Finney and Gray counties is limited to the stream valleys and to the deeper depressions in the Finney basin where the water table is within 10 or 15 feet of the land surface. Water-loving trees, particularly cottonwoods, are found along most of the stream valleys and around some of the depressions in the Finney basin. Where cottonwood trees occur, the depth to water generally does not exceed 20 feet (Meinzer, 1927, p. 58). In the Arkansas valley the discharge of ground water from the zone of saturation by transpiration is limited to areas adjacent to Arkansas river where the water table is comparatively close to the surface.

The amount of water discharged annually by plant transpiration is probably negligible in those areas where the water table lies more than 20 feet below the surface; however, in the Arkansas valley and parts of the Finney basin, where the water table is shallow, the amount of ground water discharged by plants is large. Wenzel (Lugn and Wenzel, 1938, p. 151) estimated that in the Platte river valley between Chapman and Gothenburg, Nebraska, an average of 12 inches of supplemental water is used annually by plants whose roots extend to the zone of saturation, or about 12 times the quantity of water that was at that time pumped annually from wells.

In areas where the water table is shallow, some ground water from the zone of saturation evaporates directly into the atmosphere. Water discharged in this manner is drawn from the zone of saturation and is evaporated from the capillary fringe. If the capillary fringe does not extend to within a few feet of the land surface, no water is lost from the zone of saturation by evaporation. The depth to ground water over most of Finney and Gray counties is great enough so that in most areas no water is lost by evaporation. The greatest loss of ground water by evaporation occurs in the bed of Arkansas river when it is dry. Some water probably is discharged by evaporation from the underground reservoir in those depressions in the Finney basin where the water table is very shallow. The rate of evaporation of ground water is determined principally by the type of soil, the depth to the water table, and weather conditions, all of which have great variations in Finney and Gray counties.

SEEPAGE INTO STREAMS

A stream that stands lower than the water table may receive water from the zone of saturation, and is known as an effluent stream (fig. 14). Arkansas river is the only stream in this area that gains water from the main ground-water reservoir. Part of Pawnee river receives effluent seepage, but the water comes from the alluvium in the Pawnee valley which is isolated from the main underground reservoir by an outcrop area of a relatively impermeable Cretaceous shale.

Except at flood stages, Arkansas river is a gaining stream throughout its course in Gray county and eastern Finney county. During the 18-year period from October 1, 1922, to September 30, 1940, (table 7) the river gained in flow between Garden City and Larned each year except four (1922-1923, 1923-1924, 1924-1925, 1935-1936). Part of this gain in flow was supplied by runoff from precipitation, and a part came from the ground-water reservoir as effluent seepage.

There is a delicate balance between the level of Arkansas river and the adjacent water table throughout most of Finney county. Fluctuations of the water table or changes in discharge of the river may cause the Arkansas to become either a losing or gaining stream. During certain periods the bed of Arkansas river in Finney county is dry and lies above the water table (p. 75). During these periods a large part of any water flowing in the river after heavy rains sinks into the alluvium and joins the underground reservoir. At other times the Arkansas in Finney county is a gaining stream and receives water from the underground reservoir.

DISCHARGE FROM SPRINGS

Some water is discharged through springs along Pawnee river and its tributaries as described on pages 87, 88, but springs are not known to occur in any other area in Finney and Gray counties. All of the springs are along the escarpment of the High Plains and appear at or near the contact between the water-bearing sands and gravels of the Ogallala formation and the underlying Cretaceous shales and limestones. Although all of the springs occur in valleys none of them has sufficient flow to give rise to streams. It is probable that there is a large amount of seepage along the escarpment that is not noticeable, the water probably being lost by evaporation and transpiration faster than it seeps out of the ground. The water-table contours (pl. 1) show that much more water is being discharged along the escarpment than is indicated by the few small springs that were observed.

DISCHARGE FROM WELLS

In 1939, more than 38,000 acre-feet of water was pumped from irrigation, industrial, and public supply wells in the two counties. Additional water is withdrawn by domestic and stock wells, but the total amount of water pumped from these wells is comparatively small.

When a well is pumped, the water table in the vicinity of the well declines and takes a form similar to an inverted cone, called the cone of depression. When pumping stops, the cone of depression is gradually filled with water from adjacent areas. As a result, the regional water table declines slightly until the surface of the water table again becomes practically smooth. After the end of the pumping season in Finney and Gray counties, the regional water table tends gradually to assume a form similar to the form it had before pumping began. The regional water level in the reservoir, however, generally is lower than it would have been had there been no pumping.

Pumping a well lowers the water level not only in the pumped well but also in all wells that are within the area of influence (area affected by the cone of depression). The influence of a pumping well on the water level of a near-by well is shown by the hydrograph of well 138 in figure 17. Well 138 is about 300 yards from a large irrigation well (139). The hydrograph is based upon monthly water-level measurements; therefore, it does not show the changes in water level that occur between measurements.

The time and length of the pumping season in this area vary from year to year, depending mainly on the amount and distribution of precipitation. The main pumping season usually extends from May or June through September or October, although some wells are pumped at other times during the year. The low water levels in wells in the pumping area usually are reached at or near the end of the pumping season. After pumping has stopped, there is a period of recovery during which time the water table gradually rises.

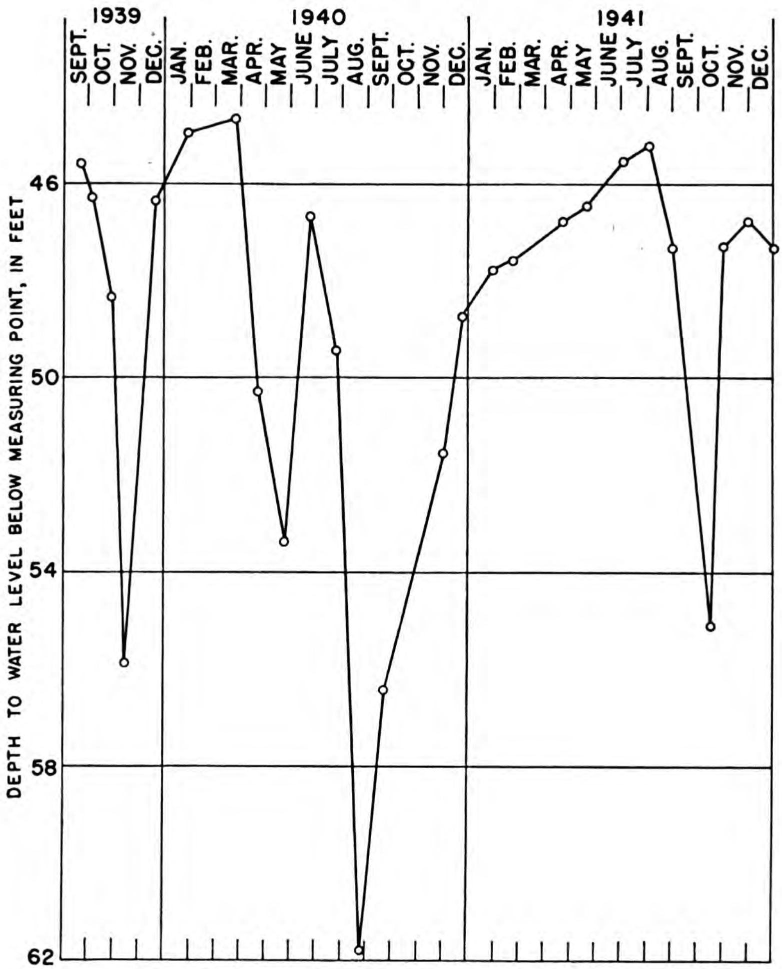


FIG. 17. Hydrograph of well 138 showing changes in water level caused by a near-by pumping well.

After a season of heavy pumping, the water table is usually lower than it was at the beginning of the pumping season. This lowering of the water table during the pumping season is not permanent, for the water table generally rises as a result of the recharge caused by precipitation that falls during nonpumping seasons. If heavy pumping and a deficiency in annual precipitation continue year after year, there will be a cumulative decline in the regional water table (pp. 71, 72, fig. 13). If the precipitation is great enough during the growing season to supply the necessary moisture to the crops, there will be little or no heavy pumping and the water table will not decline appreciably; if the precipitation is greater than the needs of the crops, the water table may actually rise.

Recovery of Ground Water

SPRINGS

Eleven springs and seepage areas were observed along Pawnee river and its tributaries (pl. 2). Small supplies of water are recovered from most of these springs for stock use.

All of the springs observed in this area are gravity springs; that is, the water does not issue under artesian pressure but discharges by gravity along an outcrop of the water table. According to Meinzer (1923a, p. 51), the water of a gravity spring percolates from permeable material or flows from large openings in a rock formation, under the action of gravity, as a surface stream flows down its channel. Gravity springs may be further classified as depression springs, where waters flow to the surface from permeable material simply because the surface extends down to the water table; as contact springs, whose waters flow to the surface from permeable material over the outcrop of less permeable or impermeable material that retards or prevents the downward percolation of the ground water and thus deflects it to the surface; and as fracture springs, whose waters flow to the surface from fractures in the rocks (Meinzer, 1923a, pp. 50-52). These different types of springs may grade into one another. The springs observed in Finney county are either contact springs or fracture springs. The contact springs (nos. 44, 45, 51, and 52 on pl. 2) all occur on the valley slopes or bottoms of tributaries south of Pawnee river. These springs issue from permeable beds of sand and gravel at the base of the Ogallala formation near its contact with the underlying Carlile shale. There are other seepage areas along tributaries of Pawnee river which are not shown as springs on the map (pl. 2). There generally is not visible discharge of water at such seeps, but the vegetation near the contact is more luxuriant, indicating that the plants are using the ground water as fast as it is being discharged.

The fracture springs all occur along the western and northwestern edges of the Cretaceous outcrop area (nos. 15, 16, 17, 18, 63, 66, and

103 on pl. 2). These springs issue from fractures in the Fort Hays limestone member of the Niobrara formation. The openings in most of the fracture springs are more or less sheetlike. The Fort Hays limestone member of the Niobrara dips beneath the water-bearing beds of the Ogallala formation. Part of the ground water that percolates eastward through the Ogallala formation enters fractures and bedding planes in the underlying limestone. Springs occur where these water-bearing fractures or bedding planes have been exposed at the surface by erosion.

The estimated discharges of the springs ranged from less than 1 gallon a minute to 2 or 3 gallons a minute.

WELLS

Principles of Recovery from Wells

The following discussion on the principles of recovery of ground water has been adapted in part from Lohman (1938, pp. 54-56).

When water is withdrawn from a well there is a difference in head between the water inside the well and the water in the surrounding material at some distance from the well. The water table in the vicinity of a well that is discharging water has a depression resembling in form an inverted cone, the apex of which is at the well. This depression of the water table is known as the cone of influence or cone of depression, and the surface area affected by it is known as the area of influence. In any given well the greater the pumping rate the greater will be the drawdown (depression of the water level, commonly expressed in feet) and the greater will be the diameter of the cone of influence and of the area of influence.

The specific capacity of a well is its rate of yield per unit of drawdown and is usually stated in gallons a minute per foot of drawdown. For example, well 131 has a measured yield of 1,100 gallons a minute with a drawdown of 18.5 feet. Its specific capacity, therefore, is 59.5 gallons a minute per foot of drawdown.

When a well is pumped, the water level drops rapidly at first and then more slowly, but it may continue to drop 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 water level rises rapidly at first, then more slowly, and may continue to rise long after pumping has ceased. The recovery curve of well 454 is shown in figure 18.

The character and thickness of the water-bearing materials have a definite bearing on the yield and drawdown of a well, and in turn on the specific capacity of a well. Drawdown increases the height that the water must be lifted in pumping a well, thus increasing the cost of pumping (p. 93). If the water-bearing material is coarse and of a fairly uniform size, it will readily yield large quantities of water to a well with a relatively small drawdown; if the water-

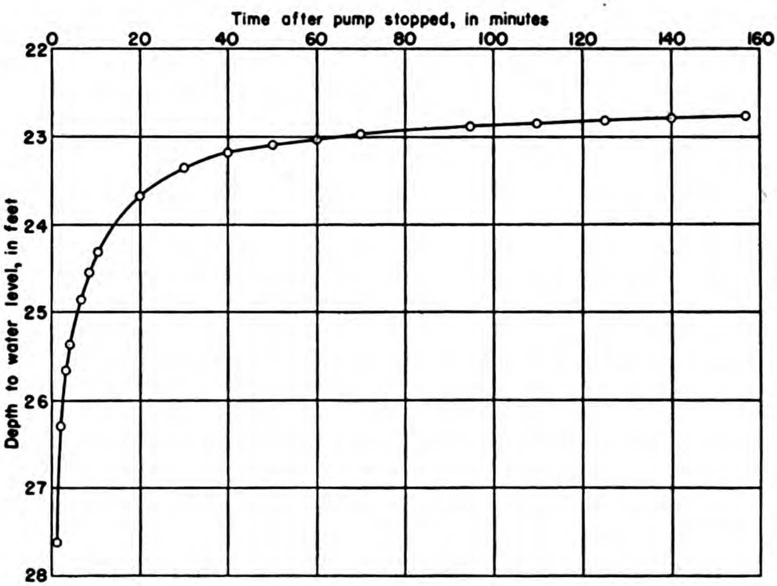


Fig. 18. Recovery curve of well 454, in the Arkansas valley in central Gray county. Well was pumped at a rate of 592 gallons a minute prior to recovery period.

bearing material is fine and poorly sorted, it will offer more resistance to the flow of water into a well, thereby decreasing the yield and increasing the drawdown. Other things being equal, the drawdown of a well varies inversely with the permeability of the water-bearing material.

The specific capacity of wells, particularly in unconsolidated materials, generally can be greatly increased by the employment of special methods of well construction, as described on pages 93-96.

Methods of Lift

Most of the farm wells in Finney and Gray counties from which domestic and stock supplies are obtained are equipped with lift or force pumps, which are operated by windmills or by hand. A few are operated by small engines or electric motors. Some of the farms have small pneumatic pressure systems in which the water is forced against air pressure into an airtight tank from which it flows under pressure to any part of the home or farm buildings.

Most of the irrigation wells in the Arkansas valley are equipped with centrifugal pumps of the horizontal type, although there are a few wells equipped with vertical centrifugal or turbine pumps. Centrifugal pumps can be used only where the depth to water level below the pump plus the drawdown does not exceed the working suction limit. All of the upland irrigation wells and a few of the deeper irrigation wells in the Arkansas valley are equipped with turbine pumps. Most of the centrifugal or turbine pumps used for irrigation are powered by electric motors, but a few are powered by stationary gasoline engines, natural-gas engines, Diesel engines, or tractors. A few of the pumps are operated by engines using butane for fuel.

All industrial wells in the area, including the railroad wells, are equipped either with horizontal centrifugal or turbine pumps driven by electric motors. Most of the municipal wells in the area are equipped with turbine pumps driven by electric motors. The pump on one municipal well (539) at Copeland, however, is driven by a natural-gas engine. One well (119) in Finney county flows at the surface (p. 55) and, therefore, does not have to be pumped.

Dug Wells

Dug wells are wells that have been excavated by hand, generally with pick and shovel. In places where the walls will not stand alone, dug wells are cribbed with casings of wood, rock, concrete, or metal. As a rule, dug wells are more subject to surface contamination than are properly constructed drilled wells. Moreover, as dug wells generally extend only a few feet below the water table, they are more likely to go dry during periods of drought than the deeper drilled wells. Most dug wells tap rather poor water-bearing material, but because of their large diameter they have a large infiltration area and large storage capacity.

Of a total of about 390 wells visited in Finney county, 10 were dug wells. Of the 10 dug wells, 7 supply water for domestic and stock use and 3 were not in use. Of the 143 wells visited in Gray county, only one (525) was a dug well and two (wells 402 and 492) were dug wells that had been deepened by drilling. Well 525 is a shallow domestic and stock well dug in alluvium. Wells 402 and 492 are irrigation wells that were dug down to about the water level, below which a smaller diameter hole was drilled and cased into water-bearing sand and gravel.

Bored Wells

Bored wells are put down by means of an auger turned by hand or gasoline power. They are generally shallow wells of small diameter put down in soft unconsolidated materials. Of about 530 wells visited in Finney and Gray counties, 25 are known to be bored wells. Most of these wells are less than 25 feet in depth, although a few are more than 50 feet in depth. Most of them are 6 inches or smaller in diameter. About 20 of the 25 bored wells are in stream valleys or in the Finney basin where water is found in soft unconsolidated material at shallow depth. All of the bored wells are used to furnish small water supplies for domestic and stock use.

Driven Wells

In many of the stream valleys containing alluvium, particularly the Arkansas valley, and in the Finney basin a few driven wells are used for domestic and stock supplies. Driven wells are adapted only to soft granular formations, which are easily penetrated by the drive point in places where the water table is within 10 or 15 feet of the surface. They generally consist of a $1\frac{1}{4}$- or $1\frac{1}{2}$-inch pipe with a screened drive point at the bottom. Most of them are equipped with hand-operated pitcher pumps attached directly to the pipe. Some of them, however, have a cylinder in a pit just above the water table, and are equipped with lift or force pumps.

Drilled Wells

There are two common methods of drilling wells, by percussion and by the hydraulic-rotary method. A portable cable-tool drill rig mounted on a truck is generally used in the percussion method. This method of drilling consists of raising and lowering a heavy bit on the end of a steel cable, which is threaded over a sheave at the top of a tower or mast. The crushed material in the bottom of the hole is mixed with water and removed by means of a bailer. In the hydraulic-rotary method, the hole is made by the rapid rotation of a bit on the bottom of a string of drill pipe. In this method removal of the cuttings is accomplished by circulating mud-laden fluid down through the drill pipe and up through the annular space between the drill pipe and the hole. The cuttings are brought to the surface as fragments suspended in the mud. The mud also serves to plaster the walls of the hole, thereby preventing caving until the casing is installed.

Most of the stock and domestic water supplies and all irrigation, municipal, and industrial water supplies in Finney and Gray counties are obtained from drilled wells.

Construction of wells in consolidated deposits.—A few drilled wells in the "panhandle" of Finney county and in southeastern Gray county obtain water from consolidated rocks—shale, limestone, or sandstone. Most of these are open-end wells; that is, the hole is cased through the overlying unconsolidated material and a few feet into the consolidated rocks, but the lower part of the hole is not cased. Holes drilled into consolidated rocks, particularly in shale or limestone, will as a rule stand open without casing. In drilling in sandstone, however, it may be necessary to case the hole from top to bottom to prevent caving. The yields of drilled wells in the various consolidated rock formations are discussed on pages 143, 145, 146, 153, 156, and 159.

Construction of wells in unconsolidated deposits.—More than 95 percent of the wells visited in Finney and Gray counties obtain water from unconsolidated deposits. It is necessary to case these wells the full depth of the hole in order to prevent caving of the walls. In some wells the casing has been perforated in the lower part; in other wells the casing is open only at the bottom. Perforating the casing greatly increases the area of intake, and thus the specific capacity of the well is increased and the entrance velocity of the water is reduced. Well screens are used in some wells to prevent fine sand from entering the well and to increase the intake area.

The dominant type of domestic and livestock well in this area is a cased drilled well containing a separate pipe and cylinder for conducting the water to the surface. Tubular wells predominate in some parts of the uplands in the northern half of Gray county, however. A tubular well is a drilled well with no separate pump pipe. The pipe that conducts the water to the surface acts also as the casing. Wells of this type generally are 2 to 4 inches in diameter and consist of a galvanized-iron pipe at the bottom of which is attached a screened point and a brass-lined cylinder. The submerged cylinder is connected with a pump at the surface by rods within the pipe. The principal advantage of tubular wells is the lower cost.

The chief disadvantage of this type of well is the difficulty in pulling the pipe to repair the cylinder. There is also danger of the hole caving while the repairs are being made.

Many of the larger municipal, industrial, and irrigation wells in this area are gravel-packed wells. In constructing this type of well, a hole of large diameter (48 to 60 inches) is first drilled and temporarily cased. A well screen or perforated casing of a smaller diameter than the hole (12 to 25 inches) is then lowered into place and centered opposite the water-bearing beds. Blank casing extends from the screen to the surface. The annular space between the inner and outer casings then is filled with carefully sorted gravel—preferably of a grain size just slightly larger than the openings in the screen or perforated casing, and also just slightly larger than that of the water-bearing material. The outer casing is then withdrawn part way in order to uncover the screen and to allow the water to flow through the gravel packing from the water-bearing material.

The logs of some of the test holes drilled during the investigation reveal that in places the water-bearing materials are sufficiently coarse and well sorted so that gravel-packed wells are not required in order to obtain large yields. In such places less expensive wells employing well screens or slotted casings, but without gravel packing, may be used satisfactorily. In places where the water-bearing materials are fine-grained, however, the gravel-packed wells have several advantages that offset the greater initial cost. The envelope of selected gravel that surrounds the screen greatly increases the effective diameter of the well, and hence decreases the velocity of the water entering the well. This reduction in velocity prevents the movement of fine sand into the well and increases the production of sand-free water. Owing to the increased effective area offered by this type of construction, the entrance friction of the water is reduced and hence the drawdown may be reduced appreciably. As stated above, a reduction in drawdown, at a given yield, increases the specific capacity and reduces the cost of pumping.

Several methods have been used in constructing irrigation wells in Finney and Gray counties. Some wells have been put down by the owners, but most of them were put down by professional well drillers. Generally one or more test holes of small diameter are put down before drilling is started on the final well. Information gained from test drilling is important as a guide in determining the depth and type of irrigation well to be constructed at a particular site.

The most common drilling methods used in this area are the sand bucket method, orange-peel bucket method, and the hydraulic-rotary method. The method used depends on the depth of the well and the character of the material through which the well is drilled, and may be governed also by the type of equipment that is available. The sand bucket method generally is best suited for areas where the water level lies at shallow depths and, therefore, is widely used in the Arkansas valley. This method is limited to use in sand or gravel and is not satisfactory where a large amount of clay or hard material is encountered. The most common type of sand bucket consists of a cylinder, with a check valve at the bottom, enclosing a plunger attached at the top to a rope or cable. Portable rigs, generally mounted on trucks, or a tripod and pulley are used to operate the bucket.

Another method employed in drilling irrigation wells of large diameter is the orange-peel bucket method. When either of the above methods are used, an open pit generally is dug by hand or bored with an auger down to the water table or to loose sand, whichever is encountered first. Sectional casing is then installed and from then on the well is put down by removing the material from the hole by using the sand bucket or orange-peel bucket. The casing is forced down as the material is removed from the hole.

A third method of putting down irrigation wells is the hydraulic-rotary method which is described on pages 91, 92. This is the quickest and generally the most practical method for putting down deep wells. Most of the upland wells and the deep valley wells in this area have been drilled by this method. In drilling a well by the hydraulic-rotary method no casing is used until the drilling has been completed, as the drilling mud prevents the walls of the hole from caving. A casing slightly smaller than the hole is placed in the well after the well has been drilled to the desired depth. If it is to be a gravel-packed well, the space between the hole and the casing is filled with gravel of the proper size.

Casings used for most irrigation wells in this area range from 16 to 24 inches in diameter and are of various types. The most common type of casing used for irrigation wells is made of perforated galvanized iron. Boiler steel and used oil-well casing are sometimes used, particularly in deep wells. Many irrigation wells are cased with concrete rings manufactured locally. The casings are assembled a few rings at a time as the well is being drilled. Vertical iron rods or cables that pass through holes in the rings act as guides in lowering the rings into the well. In one type of concrete casing the water enters the well through spaces between the rings; in another type each ring has vertical slots through which the water enters the well. A few irrigation wells have been cased with casing made from old oil drums. Casing perforated by a manufacturer according to specifications, however, is most satisfactory.

The most common type of irrigation pumping plant in the Arkansas valley consists of two or more wells connected to one centrifugal pump by a common suction pipe laid in the ground just above the water table. These are commonly called "battery wells" (pl. 6), and are constructed only where the depth to water level is comparatively small—generally less than 20 feet. In most installations the wells are put down about 40 feet apart in a straight line at right angles to the direction of the movement of the ground water. Pits are dug to the water table and later walled up with cement blocks or concrete. A perforated casing, generally of galvanized iron, is sunk in each well through the water-bearing beds using a sand bucket. Pump pipes are placed in each well and connected by a pipe laid in a trench or tunnel between the wells. A horizontal centrifugal pump is set in a pit just above the water table in the middle of the line of wells. It is important that the wells in a battery be spaced far enough apart so that there will be as little interference between wells as possible (p. 111, table 16).

The number of wells in a battery commonly ranges from 2 to 16. Table 8 shows the number of wells in battery-well plants in this area and the number of each recorded during the investigation.

TABLE 8.—*Number of battery-well plants in the Arkansas valley in Finney and Gray counties classified according to the number of wells in a battery*

Number of wells in battery	Number of plants	Number of wells in battery	Number of plants
2	38	10	3
3	28	11	1
4	15	12	2
5	12	13	1
6	14	14	1
7	1	16	1
8	7		

In 1940, there were 119 single-well irrigation plants in Finney and Gray counties. About 60 of the 119 wells are deep upland wells, 4 are deep valley wells, and 57 are shallow wells in the valley. The four deep irrigation wells (160, 198, 276, 450) in the valley are so constructed that they draw water not only from the shallow alluvium but also from sands and gravels in the Pleistocene beds and in the Ogallala formation. The wells are 95, 140, 170, and 274 feet in depth. Single-well plants of this type are capable of yielding 1,000 gallons a minute or more.

Assuming that a well of the best possible construction is employed, then the maximum amount of water that can be withdrawn from the well is fixed by nature and nothing can be done to make the well yield more than the water-bearing material will provide. The problem for the driller is to construct each individual well in such a manner as to obtain the greatest yield with the smallest amount of drawdown that is possible under the existing conditions.

According to McCall and Davison (1939, p. 29) drawdown can be kept to a minimum in several ways.

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

A report (Davison, 1939) containing a description of different types of pumping plants, the conditions for which each is best suited, construction methods, and a discussion of construction costs is available from the Kansas State Board of Agriculture, Topeka, Kan., and the reader is referred to this publication for details of well construction. The reader is also referred to a report by Rohwer (1940) in which he describes the various methods of irrigation-well construction. This report may be obtained from the Superintendent of Documents, Washington, D. C.

Utilization of Water

During the course of the investigation information was obtained on 543 wells and springs in Finney and Gray counties. All known irrigation, public supply, and industrial wells in the two counties were visited, and all available data concerning them were obtained. No attempt was made to obtain data on all the domestic and stock wells. Of the wells listed in the well tables (pp. 184-224), 129 are out of use, either temporarily or permanently. The water supplies of the others are as follows: entirely domestic, 59; entirely stock, 40; domestic and stock, 48; irrigation, 244; public supply, 9; and industrial, 13. One well (269) drilled by the Division of Water

Resources of the Kansas State Board of Agriculture is being used exclusively as an observation well. The principal uses are described below.

DOMESTIC AND STOCK SUPPLIES

Most of the rural residents of Finney and Gray counties derive their domestic supplies from drilled wells of small diameter equipped with lift or force pumps operated by windmills or by hand. A few obtain domestic supplies from dug wells or from bored wells. In the valley areas where the water table is shallow, some domestic supplies are obtained from driven wells equipped with hand-operated pitcher pumps. Livestock supplies are generally derived from drilled wells equipped with windmills. In the northeastern part of Finney county, springs that yield sufficient water for livestock are found. On many of the upland farms, the same well commonly furnishes water for domestic use and for watering livestock. Most of the domestic and livestock wells yield only a few gallons of water a minute.

The ground waters in this area, although hard, generally are satisfactory in chemical character for most domestic uses (see Quality of water).

INDUSTRIAL SUPPLIES

The industrial uses of ground water in this area include cooling, manufacture of ice, water for steam boilers, and use in the refining of sugar from sugar beets. The suitability of ground water for industrial use depends upon its chemical character and temperature. Water used in boilers should be relatively free from foaming and scale-forming constituents. The ground water in much of the area is not of suitable chemical character for boiler use and it is, therefore, necessary to treat the water to reduce the hardness. Some ground water is used for cooling in the area. The advantage of using ground water for this purpose is its relatively low uniform temperature throughout the year. The temperature of the water in 50 representative wells was found to range from 57 degrees to 62 degrees F. and averages about 59 degrees F. Some homes and business houses in Garden City are known to use water from small wells for air-conditioning, but no attempt was made to obtain records or pumpage estimates for these wells.

The largest single user of ground water for industrial use in the area is the Garden City Company at Garden City. The water is used chiefly for steam to generate electricity at the power plant and in the manufacture of beet sugar. The Garden City Company is situated in the Arkansas valley in the southwestern part of Garden City. The water supply is obtained from three deep wells (304-306), four batteries (307-310) of four shallow wells each, and one battery (311) of three shallow wells. Two of the deep wells (305 and 306) are gravel-walled wells 24 inches in diameter and 180 feet deep; the other (304) is 16 inches in diameter and 260 feet deep. All of the deep wells obtain water from sand and gravel in the Ogallala formation. Each well is equipped with a deep-well turbine pump powered by an electric motor. The reported yields of the wells are 300, 500, and 600 gallons a minute. Water from these wells is reported to be relatively soft.

The shallow wells are 21 inches in diameter, are gravel-walled, and are 48 feet in depth. Each battery of wells is equipped with a horizontal centrifugal pump operated by an electric motor. The water supplied by the shallow wells is derived from coarse alluvial gravels and has a high mineral content. The yields of the shallow-well plants range from 900 to 1,500 gallons a minute.

In 1939, the Garden City Company pumped nearly 130,000,000 gallons of water from the three deep wells and about 1,700,000,000 gallons from the shallow wells. Most of this water was pumped during the fall when the sugar factory was in operation.

The Garden City Ice Company at Garden City utilizes water from two wells in the manufacture of ice. One well (220) is 125 feet deep and is equipped with a 1½-inch centrifugal pump powered by an electric motor. This well derives water from Pleistocene deposits or the Ogallala formation and yields about 15 gallons a minute. Water from this well is used to make ice. Because of the hardness of the water, lime treatment is used. About 4,500 gallons of water a day are pumped from this well during the summer months. The other well is 35 feet deep and obtains water from coarse gravel in the alluvium. It is equipped with a 3-inch centrifugal pump and an electric motor and is reported to yield 175 gallons a minute. Untreated water from this well is used in the cooling coils at the ice plant. About 252,000 gallons of water are pumped from this well each day during the summer.

The Atchison, Topeka and Santa Fe railway has wells at Garden City, Cimarron, and Montezuma that supply water for locomotive boilers. The railroad well (222) at Garden City is 202 feet deep and taps the Ogallala formation. The harder water in the alluvium has been cased off. The well is equipped with a 6-inch centrifugal pump powered by an electric motor and is reported to yield 250 gallons a minute. Because of the hardness of the water, it is necessary to add lime and phosphate to prevent the formation of scale in the boilers.

The railroad well (460) at Cimarron is 129 feet deep and also derives its water from the Ogallala formation, the water in the overlying alluvium having been cased off. The well is equipped with a centrifugal pump and electric motor and yields about 85 gallons a minute with a draw-down of about 22 feet. The water is treated in the same manner as that from the well at Garden City.

The Santa Fe well (510) at Montezuma, in southern Gray county, is 300 feet deep, is 10 inches in diameter, and is gravel packed. The water level in the well is reported to be 118 feet below land surface. The well is equipped with a deep-well turbine pump and electric motor and is reported to yield only 45 gallons a minute with a draw-down of 32 feet.

Based on reports and estimates, about 1,945,000,000 gallons of water was pumped from industrial wells in Finney and Gray counties in 1939. Of this amount, about 1,937,000,000 gallons was pumped from wells at Garden City, in Finney county, and 8,000,000 gallons from wells in Gray county.

PUBLIC SUPPLIES

The cities of Garden City, Cimarron, Montezuma, and Copeland have public-water systems supplied by ground water pumped from wells. The smaller communities in the area are supplied from private wells, each family having a well of its own. Descriptions of the public-water supplies follow.

Garden City.—Garden City (population, 6,285) is supplied by seven deep wells (181, 208, 223), all of which are in the Arkansas valley within the city limits and all of which derive water from the Ogallala formation, the water in the alluvium having been cased off. Well 181 is 258 feet deep, is gravel packed, is equipped with an electrically driven turbine pump, and has a reported yield of 650 gallons a minute. Well 208 is 299 feet deep, is gravel packed, is equipped with an electrically driven turbine pump, and is reported to yield 500 gallons a minute with a drawdown of about 17 feet. Well 223 consists of five gravel-packed wells, each 250 feet deep, connected by suction lines to four horizontal centrifugal pumps. Three of the pumps are driven by electric motors; the other pump is driven by a natural-gas engine and is used only in emergencies.

Any number of the pumps can be operated at the same time and water can be withdrawn from one or all of the wells. The capacity of the pumps ranges from 500 to 600 gallons a minute.

Water is pumped from the wells directly into the mains, the excess going into a 215,000-gallon standpipe. The daily capacity of the system is about 4,500,000 gallons. The maximum daily consumption at Garden City is 1,500,000 gallons, and the average daily consumption is 600,000 gallons. An analysis (181) of a composite sample of water from the city wells is given in table 20. Although the water is hard, it is not treated.

Cimarron. — Cimarron (population, 1,004) is supplied by two wells (459 and 461) that tap the Ogallala formation. The wells are 180 feet deep, the upper part of each well being cased off to prevent entrance of water from the alluvium. Each well is equipped with a turbine pump driven by an electric motor. Well 459 has a reported yield of 190 gallons a minute and is used most of the time. Well 461 is seldom used, for if it is pumped to capacity (175 gallons a minute) fine sand enters the well. When it becomes necessary to use this well, it is pumped at the rate of about 90 gallons a minute.

Water is pumped from the wells directly into the mains, the excess going into a 126,000-gallon standpipe situated on the river bluff north of town. The daily capacity of the system is about 288,000 gallons. No figures on consumption of water were obtainable. An analysis (459) of a sample of the water is given in table 21. The water is moderately hard and is not treated.

Montezuma.—Montezuma (population, 340) is supplied by two wells (511 and 513) that tap sand and gravel in the Pleistocene deposits. The wells are 160 and 170 feet deep and are equipped with turbine pumps powered by electric motors. Well 511 has a reported capacity of 100 gallons a minute with a drawdown of about 18 feet. The water level at Montezuma is about 112 feet below the surface. The city engineer reports that the water level in well 513 drops below the bottom of the intake pipe when the pump is operated to its full capacity, which is about 50 gallons a minute. For this reason the well is used only in emergencies. Well 511 is capable of supplying the quantity of water needed by the city, but the water contains an objectionable amount of fine sand. The existing wells are not properly constructed so as to exclude the fine sand. The logs of three test holes indicate that a satisfactory well could be put down within the city limits (see logs 26a, 26b, and 26c). The city is contemplating drilling a new well at one of these test-hole locations.

Water is pumped from the wells directly into the mains, the excess going into a 50,000-gallon elevated steel storage tank. The average daily consumption at Montezuma is about 50,000 gallons. An analysis (511) of the water is given in table 21. The water is moderately hard, otherwise it is of good chemical quality and is not treated.

Copeland.—The water supply of Copeland (population, 262) is obtained from one 16-inch well (538) 248 feet deep, and one 15-inch well (539) 252 feet deep. The water is derived from the Ogallala formation or the Pleistocene deposits, or from both. Both wells are equipped with turbine pumps, the one in well 538 being driven by an electric motor and the one in well 539 being driven by a natural-gas engine. The wells are each reported to yield 50 gallons a minute.

Water is pumped from the wells directly into the water mains, the excess water going to an elevated steel storage tank having a capacity of 50,000 gallons. The daily capacity of the system is about 140,000 gallons. Figures on the consumption of water at Copeland were not obtainable. The water is moderately hard, but otherwise is of good quality. (See analysis 538, table 21.)

Based upon reports and estimates, the amount of water pumped from public supply wells in Finney and Gray counties during 1939 was about 240,000,000 gallons.

IRRIGATION SUPPLIES

Agriculture is the principal and most important industry of this area. One of the primary requisites of any agricultural area is an adequate supply of moisture to meet the growth requirements of the crops raised. For this reason it has been necessary to find means of supplementing the low precipitation in this area with irrigation. The first practice developed was gravity irrigation, or irrigation by direct diversion from the river through ditches (pl. 5B). This practice grew until it reached its present state of development about 1900 (Anon., 1939). In 1940, there were 11 ditches that diverted water from Arkansas river and irrigated land in western Kansas. Water from 7 of these ditches is used to irrigate land in Finney and Gray counties. Table 9 gives the names of these ditches, the location of headgates, and the total number of acres irrigated by each ditch in 1939.

TABLE 9.—*Diversion ditches along Arkansas river in western Kansas showing location of headgates and total acreage irrigated by each in 1939*

Ditch	Location of headgate	Total number of acres irrigated[1]	
		On upland	In valley
Amazon canal.......	5 miles west of Hartland, Kans.	9,400	600
Great Eastern canal,	2 miles east of Hartland, Kans...	15,550	450
South Side ditch.....	About 0.75 mile east of Finney-Kearny county line..........	0	10,000
Farmer's ditch......	0.5 mile west of Finney-Kearny county line.................	8,400	1,360
Garden City ditch...	1.5 miles east of Finney-Kearny county line.................	0	1,000
Pierceville ditch.....	South of Pierceville............	0	400
Ingalls ditch........	Above Ingalls, Kans...........	0	1,000

1. Anon., 1939.

TABLE 10.—*Annual diversions of the five major diversion ditches in western Kansas for the fifteen-year period from October 1, 1924, to September 30, 1939, in acre-feet*[1]

Water year (Oct. 1 to Sept. 30)	Amazon ditch	Great Eastern ditch	South Side ditch	Farmer's ditch	Garden City ditch
1924–1925.........	16,200	26,000	12,400	10,400	327
1925–1926.........	14,500	25,200	10,800	7,990	377
1926–1927.........	22,200	31,600	12,000	15,000	7,240
1927–1928.........	14,800	17,400	10,300	4,480	3,300
1928–1929.........	14,500	53,200	15,300	18,100	4,730
1929–1930.........	16,400	38,800	7,780	15,400	6,290
1930–1931.........	16,100	27,700	9,610	5,460	1,780
1931–1932.........	8,530	14,400	6,580	10,400	2,280
1932–1933.........	22,900	28,500	13,700	17,400	3,860
1933–1934.........	8,220	17,300	6,920	7,740	1,960
1934–1935.........	20,470	27,540	12,840	17,160	1,830
1935–1936.........	42,340	23,160	7,220	17,390	3,260
1936–1937.........	22,730	22,090	9,100	11,790	1,470
1937–1938.........	28,740	53,460	20,340	18,870	2,650
1938–1939.........	23,080	10,890	14,710	7,390	2,520

1. From records of the Division of Water Resources, Kansas State Board of Agriculture.

The acreage listed in this table includes the total number of acres irrigated by each ditch and not just the acreage irrigated in Finney and Gray counties. Table 10 gives the annual diversions of each of the five major ditches since 1924.

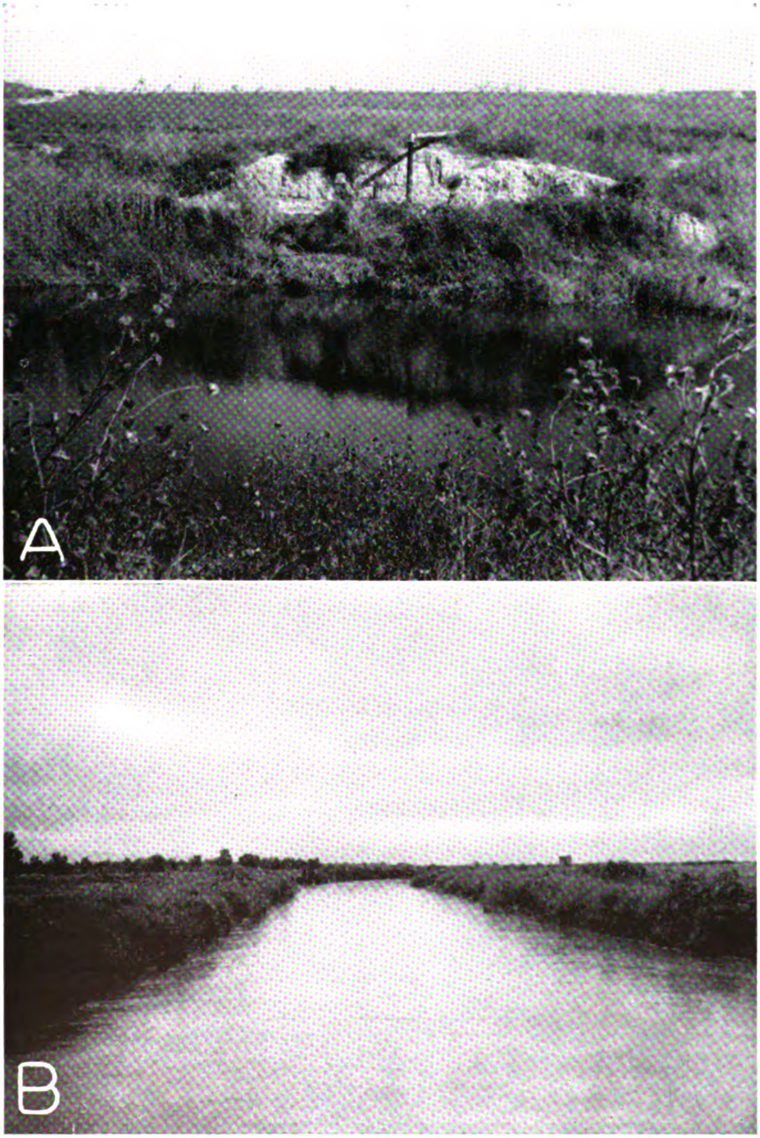


PLATE 5. *A*, River pumping plant used to pump water from Pawnee river. Situated above a dam across the river in the NE¼ sec. 15, T. 22 S., R. 27 W. *B*, View of the South Side irrigation ditch about half a mile below its headgate south of Hartland, Kearny county, Kansas. Water from the South Side ditch is used to irrigate land south of the river in eastern Kearny county. Photograph by Thad G. McLaughlin.

The use of surface water from Arkansas river for irrigation has not been too successful for several reasons. Arkansas river does not have a consistent flow but is characterized by flash floods of large volume followed by long periods of very low flow. The flash floods are useless for irrigation because the land can only take a certain amount of water at any one time and the water should be distributed according to crop requirements throughout the growing season (Anon., 1939). Much of each flood flow, therefore, passes downstream unused.

It has been pointed out by the Bureau of Agricultural Economics (Anon., 1939) that there has been overdevelopment in the use of surface water for irrigation in western Kansas. The development of the use of surface water continued until all available river flow had become so overappropriated that it was necessary to adjudicate the rights to the use of water. Overdevelopment reached the point where there was more land under the ditches than could be irrigated with the water available. As a result some ditches were abandoned and the available water had to be rationed to the others. At the present time the Division of Water Resources of the Kansas State Board of Agriculture performs the duties connected with allocating the water.

In 1905-1908 the Bureau of Reclamation constructed 13 irrigation-well plants in the Arkansas valley just west of the Kearny-Finney county line (McLaughlin, 1943, p. 88). Each plant comprises five wells ranging in depth from 30 to 60 feet. The water is pumped into a concrete ditch, is siphoned under Arkansas river, and is carried to a booster station about 1 mile east of Deerfield, where the water is pumped into the Great Eastern canal on the upland. According to McLaughlin (1943, p. 88), approximately 3,500 acre-feet of water was withdrawn from the ground-water reservoir by these wells in 1939. The Great Eastern canal carries the water into Finney county where it is used to irrigate land on the uplands in the western part of the county. In Finney county the development of ground water pumped from wells began about 1915, continued rather steadily from 1920 to 1930, and development increased rapidly from 1930 to the present time.

During the summer and fall of 1940, an inventory was made of the irrigation wells in Finney and Gray counties, and estimates were obtained of the total pumpage and number of acres irrigated. Detailed records of all irrigation wells are given in tables 22 and 23 and the locations of the wells are shown on plate 2. Records were obtained for 244 irrigation wells in this area. The total reported area irrigated from these wells in 1940 was 21,860 acres, an average of about 89½ acres to the well. Of the 244 irrigation wells, 183 are in the Arkansas valley and 61 are on the uplands either north or south of the Arkansas valley. Table 11 shows the number of irrigation wells, irrigated acreage, and the average number of acres per well by counties and by topographic position.

TABLE 11.—*Number of irrigation wells recorded and acreage irrigated with water from wells in Finney and Gray counties in 1940*

Topographic situation	Finney county			Gray county		
	Number of wells	Acres irrigated	Average number of acres per well	Number of wells	Acres irrigated	Average number of acres per well
Valley	161	11,579	71.9	22	1,420	64.5
Upland	51	7,655	150.1	10	1,207	120.7

It will be noted in this table that the average number of acres irrigated by each well is greater for the upland wells than it is for the wells in the valley. This difference is not the result of greater yields from upland wells, but is due to the great number of small irrigation wells in the valley that decreases the average acreage per well. Another factor causing the difference in average acreage is the greater use of surface water from diversion ditches for irrigation on the uplands. Many of the small irrigation wells in the Arkansas valley in the vicinity of Garden City irrigate only 1 to 15 acres. Large wells in the valley, however, irrigate as much as 200 acres or more. In table 12 the number of irrigation wells in Finney and Gray counties are classified according to the irrigated acreage. There are more small irrigation wells in this area than are listed in table 12, but no attempt was made to obtain records for all of the very small irrigation wells concentrated in and near Garden City.

An attempt was made to determine the quantity of water pumped annually from irrigation wells in the Arkansas valley and on the uplands in Finney and Gray counties. Reported estimates were obtained from well owners. For wells that are pumped by electricity in Finney county pumpage estimates were computed from records

TABLE 12.—*Number of irrigation wells in Finney and Gray counties in 1940 classified according to acreage irrigated*

	1 to 10 acres	11 to 50 acres	51 to 100 acres	101 to 200 acres	201 to 300 acres	Over 300 acres	Number of idle wells
Valley wells:							
Finney county......	31	43	37	26	7	5	12
Gray county........	1	9	4	5	1	0	2
Totals..........	32	52	41	31	8	5	14
Upland wells:							
Finney county......	0	3	5	19	1	12	11
Gray county........	0	1	4	2	2	0	1
Totals.	0	4	9	21	3	12	12

supplied by the Garden City Company of the total number of kilowatt-hours of electricity consumed in 1939. Mr. Kenneth D. McCall, engineer for the Division of Water Resources of the Kansas State Board of Agriculture, assisted in obtaining these data. The estimated total quantity of water pumped for irrigation in Finney and Gray counties in 1939 was about 32,000 acre-feet. Of this amount, about 29,000 acre-feet was pumped from wells in the Arkansas valley and 3,000 acre-feet was pumped from upland wells. Annual pumpage for irrigation varies from year to year—the amount of pumpage varying indirectly with the amount of precipitation. Pumpage during 1939 was probably much more than the average annual pumpage in these counties, for the rainfall during 1939 was far below normal.

Yields of irrigation wells.—The yields of irrigation wells in Finney and Gray counties range widely. Small wells used to irrigate trees or small gardens yield only a few gallons a minute, whereas larger wells yield from 500 to as much as 3,750 gallons a minute. Most of the yields of irrigation wells given in the table of well records were reported by the owners or tenants of the wells, but the yields of many of the irrigation wells were measured by K. D. McCall and M. H. Davison, of the Division of Water Resources of the Kansas State Board of Agriculture, by P. H. Browne of the Johnston Pump Company, and by E. E. Stoeckly, engineer for the Garden City Company. In 1941 and 1942, Melvin Scanlan of the Division of Water Resources of the Kansas State Board of Agriculture, and Woodrow Wilson of the Federal Geological Survey made several pumping tests on irrigation wells in this area. The yields of wells determined by pumping tests are given in tables 13 and 14 and in the tables of well records (tables 22 and 23).

A Cipolletti weir or a Collins flow gage was used in making measurements of the discharge. Drawdowns in pumping wells were measured by an electrical contact device. When the pumps were not running, a steel tape was used for measuring the water levels. The yields of the single-well irrigation plants ranged from 348 to 1,770 gallons a minute and the specific capacities ranged from 10 to 141. The drawdown in most wells ranged from 6.2 feet to about 50 feet. Well 150, however, had a drawdown of 135 feet, which is uncommonly large.

TABLE 13.—*Yield, drawdown, and specific capacity of single-well irrigation plants in Finney and Gray counties, Kansas*[1]

Well No. (pl. 2, tables 22 and 23)	Location	Type of pump[2]	Type of power[3]	Discharge (gallons a minute)	Drawdown (feet)	Specific capacity (gallons a minute per foot of drawdown)
24	Upland well—Finney county,	T	B	1,770	30	59
27	do	T	B	850	34[4]	25
112	do	T	E	990	19.5	50.8
128	do	S	E	1,260	33	38.2
129	do	T	E	400	21	19
131	do	T	E	1,100	18.5	59.5
135	do	T	E	970	24	40.4
150	do	T	E	1,400	135[5]	10
152	do	T	E	640	37[4]	17
155	do	T	E	1,080	45	24
				1,150	50	23
276	Valley well—Finney county	T	E	1,058	7.5	141
336	do	C	E	348	6.2	56.1
402	Upland well—Gray county	T	G	1,020	13.2	77.3
450	Valley well—Gray county	C	E	996	16.4	60.7
496	Upland well—Gray county	T	G	875	11.3	77.4
534	do	T	NG	475	25.9	18.3

1. Wells 112, 128, 129, 131, 150, 152, 276, 336, 402, 450, 496, and 534 tested by Division of Water Resources, Kansas State Board of Agriculture; wells 24, 27, and 135 by P. H. Browne, Johnston Pump Company; well 155 by E. E. Stoeckly, engineer for the Garden City Company. Woodrow Wilson, U. S. Geol. Survey aided in testing well 276.

2. C, centrifugal; T, turbine; S, submersible turbine.

3. B, butane; E, electric, G, gas engine; NG, natural gas.

4. Estimated.

5. Old well; drawdown reported

All of the battery-well plants on which pumping tests were made are in the Arkansas valley. The plants consist of from 2 to 14 shallow wells connected to one horizontal centrifugal pump (pl. 6). Drawdowns were measured in only 9 of the 16 battery-well plants. The aggregate discharge of these wells ranged from 520 to 2,790 gallons a minute and the average drawdown ranged from 6.7 feet

TABLE 14.—*Results of pumping tests of battery-well plants*[1] *in the Arkansas valley in Finney county (tests by Division of Water Resources, Kansas State Board of Agriculture)*

Well No. (pl. 2, tables 22 and 23)	No. of well	Discharge (gallons a minute)		Average drawdown (feet)	Specific capacity (gallons a minute per foot of drawdown)	
		Entire battery	Average per well		Entire battery	Average per well
195	4	1,590	397.5	....	....	....
196	5	2,065	413	8.0	258	51.6
233	4	1,040	260	10.3	101	25.3
238	12	2,790	232.5	8.1	344.4	28.7
248	14[2]	1,580	112.9	7.6	207.9	14.3
274	6	1,735	289.2	11.6	149.6	24.9
		1,500	250	10.2	147.1	24.5
287	6	1,565	260.8	6.7	233.6	38.9
291[3]	2	569	284.5	11.8[4]	48.2	24.1
331	2	1,096	548	....	....	....
332	3	565	188.3	....	....	....
333	5	1,300	260	11.2	116	23.2
334	4	840	210	11.5	73.1	18.2
335	8	800	100	....	....	....
338	6	520	86.6	....	....	....
343	12	1,800–2,200	150–183.3	....	....	....
344	3	950	316.6	....	....	....

1. All plants equipped with centrifugal pumps powered by electric motors.
2. Rebuilt to use only five wells.
3. Woodrow Wilson, U. S. Geol. Survey, assisted on this test.
4. Drawdown measured in one well only.

to 11.8 feet. The average specific capacity for each well in a battery ranged from 14.3 to 51.6. Table 15 gives the range in discharge of battery-well plants according to the number of wells composing the plants. The table includes discharges reported by owners and tenants and measured discharges, and indicates the wide range in discharge obtained from battery-well plants having the same number of wells.

There are many factors that determine the yield of wells. Probably the most important factors are the construction; the diameter of the well casing; the type of casing and perforations; the development and finishing of the well, whether gravel-packed or not; the age of the well; the character and thickness of the water-bearing material; and, for battery wells, the spacing of the wells. The quality of the water may also be an important factor, for water that readily forms incrustations may eventually fill the perforations in the well casing, thus causing a decrease in the yield of the well.

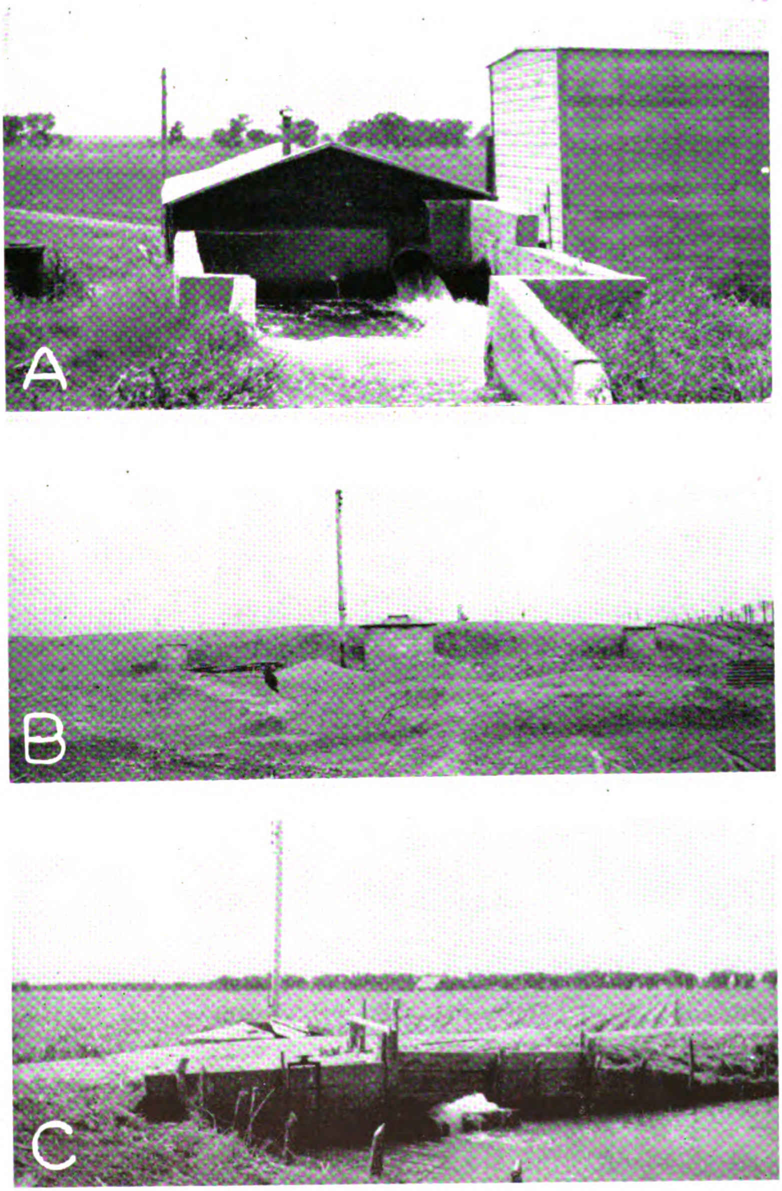


PLATE 6. Irrigation wells in the Arkansas valley in Finney county, Kansas. *A,* Well 241 in operation. Battery of 10 shallow wells connected to one horizontal centrifugal pump. *B,* Battery of three wells (166) connected to one horizontal centrifugal pump. Pump installed in middle well pit. *C,* Well 166 discharging into reservoir.

TABLE 15.—*Range in discharge of battery-well plants according to number of wells in plant. (Includes both measured and reported discharges.)*

Number of wells in battery	Number of plants	Range in discharge (gallons a minute)
2	30	200–1,100
3	22	150–2,000
4	9	300–1,600
6	10	400–2,000
6	13	400–3,750
7	1	(1,150)
8	5	800–1,300
10	2	(3,750–3,750)
12	2	(2,000–2,790)
14	2	(1,000–1,580)
16	1	(1,200)

The yield from a battery of wells may be much greater than the yield from a single well, but the yield of each well is less than if the other wells were not being pumped. If the desired quantity of water is not obtained at first, more wells may be added to the battery.

TABLE 16.—*Interference of wells in a battery-well plant (McCall and Davison, 1939, table 4)*

(a) Wells pumped separately:

Wells	Individual capacity, gallons a minute	Well spacing
A	736	A—56 feet—B—92 feet—C—73 feet—D
B	758	
C	718	
D	823	

(b) Wells pumped in pairs:

Wells	Spacing	Total individual capacity, gallons a minute	Capacity when pumped together, gallons a minute	Difference	Percent interference
A–B	56	1,494	1,281	213	14.2
C–D	73	1,541	1,408	133	8.6
B–C	92	1,476	1,365	111	7.5
A–C	148	1,454	1,378	76	5.2
B–D	165	1,581	1,532	49	3.1
A–D	221	1,559	1,558	1	0

(c) Four wells pumped together:

Wells	Spacing	Total individual capacity, gallons a minute	Capacity when pumped together, gallons a minute	Difference	Percent interference
		3,035	2,325	710	23.4

The yield does not increase proportionately with the number of wells, however, because of mutual interference between wells. McCall and Davison (1939, p. 34) made a series of tests on a battery-well plant to determine the interference between the wells. The plant tested is located in the Arkansas valley near Garden City and consists of four wells which average 42 feet in depth. Table 16 is taken from the report by McCall and Davison (1939, table 4) and shows the results of their tests.

Depth and diameter of irrigation wells.—The depths of irrigation wells in this area are given in table 17 and are summarized below.

Most of the upland irrigation wells in Finney county range from 200 to 360 feet in depth, but a few are less than 150 feet deep. In Gray county, most of the upland wells range from 100 to 200 feet

TABLE 17.—*Irrigation wells in Finney and Gray counties classified according to depth*

Depth (feet)	Number of wells in the Arkansas valley			Number of wells on the uplands		
	In Finney county	In Gray county	Total	In Finney county	In Gray county	Total
10– 20	3	....	3	....	....	....
21– 30	14	1	15	....	....	....
31– 40	52	7	59	....	....	....
41– 50	54	10	64	....	....	....
51–100	22	3	25	4	....	4
101–150	3	....	3	3	7	10
151–200	....	1	1	6	2	8
201–250	....	....	....	9	1	10
251–300	2	2	....	12	....	12
301–360	....	....	....	15	....	15

in depth, and only one well is more than 200 feet deep. Most of the irrigation wells in the Arkansas valley in this area are only 30 to 50 feet deep, although some are 50 to 100 feet deep and a few exceed 100 feet in depth. Eighteen of the irrigation wells in the valley are less than 30 feet in depth.

The diameter of the irrigation wells in Finney and Gray counties are given in table 18 and are summarized below.

The diameters of the irrigation wells range from 2 inches to 36 inches. Of the 58 upland irrigation wells for which the dimensions are known, 40 are 16 inches in diameter and 8 are 18 inches in di-

TABLE 18. *Irrigation wells in Finney and Gray counties classified according to diameter*

Diameter (in inches)	Number of wells in the Arkansas valley			Number of wells on the uplands		
	In Finney county	In Gray county	Total	In Finney county	In Gray county	Total
2	....	....	....	....	1	1
6	....	....	....	1	....	1
10	1	....	1	....	....	....
12	10	....	10	....	1	1
13	....	....	....	1	....	1
14	6	2	8	1	....	1
15	26	1	27	2	....	2
16	65	8	73	34	6	40
17	1	....	1	....	....	....
18	29	2	31	8	....	8
19	2	1	3	....	1	1
20	8	5	13	....	....	....
22	1	....	1	....	....	....
24	1	1	2	1	1	2
28	....	1	1	....	....	....
30	1	....	1	....	....	....
36	....	1	1	....	....	....

ameter. Most of the valley irrigation wells are 16 inches in diameter, but many are 15 or 18 inches in diameter.

Types of pumps on irrigation wells.—All of the upland irrigation wells and four of the valley wells are equipped with turbine pumps having from two to five stages, or bowls. The turbine pumps range in size from 4 to 10 inches, but 6- and 8-inch are the most common sizes. Some of the older upland irrigation wells owned by the Garden City Company are equipped with large old-style turbine pumps (pl. 7A). The newer turbine pumps are much smaller and generally are more efficient (pl. 7 B). One upland well (128) is equipped with a submersible turbine pump (pl. 8A) in which the electric motor is housed in a water-tight compartment just above the bowls of the pump.

All but four of the irrigation wells in the Arkansas valley in this area are equipped with centrifugal pumps ranging in size from 1½ to 14 inches. Most of these are of the horizontal type—only two being vertical centrifugal pumps. The most common sizes of centrifugal pumps are 4-, 5-, 6-, and 8-inch.

A few irrigation wells used to irrigate small gardens or trees are equipped with cylinder pumps powered by windmills.

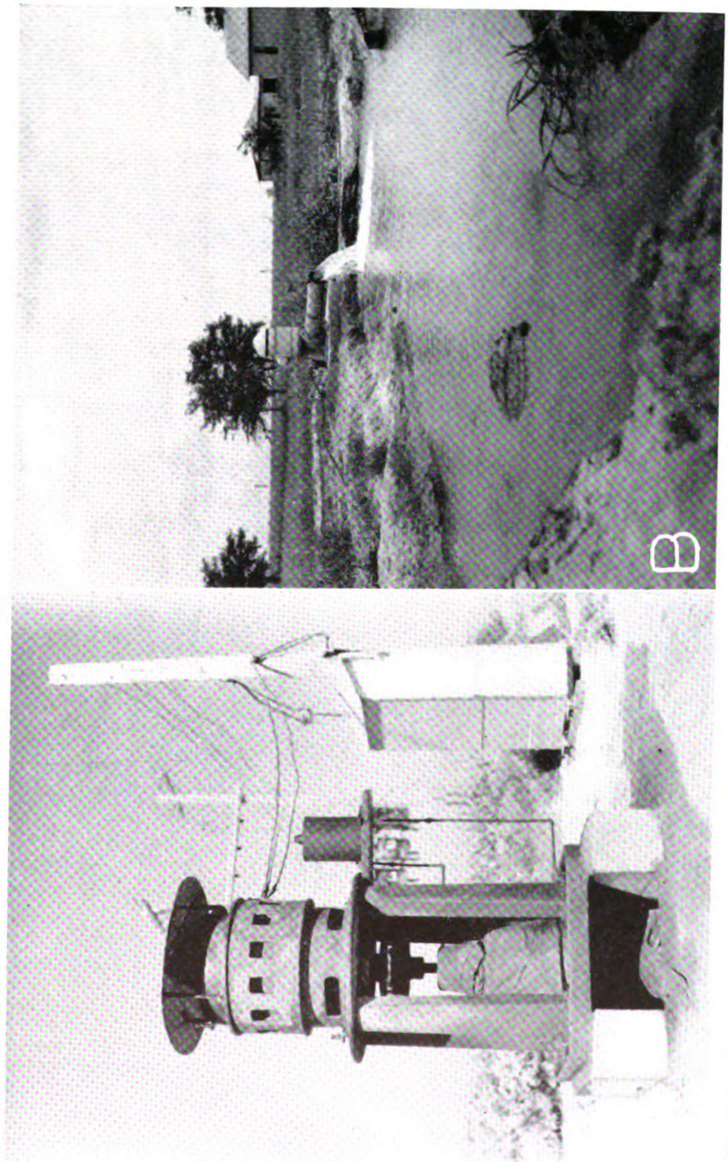


PLATE 7. Deep irrigation wells on the uplands in Finney county, Kansas. *A*, Well (132) equipped with old-style turbine pump powered by a 100-horsepower electric motor. *B*, Well (340) equipped with new turbine pump powered by 25-horsepower electric motor. **Photograph by Thad McLaughlin.**

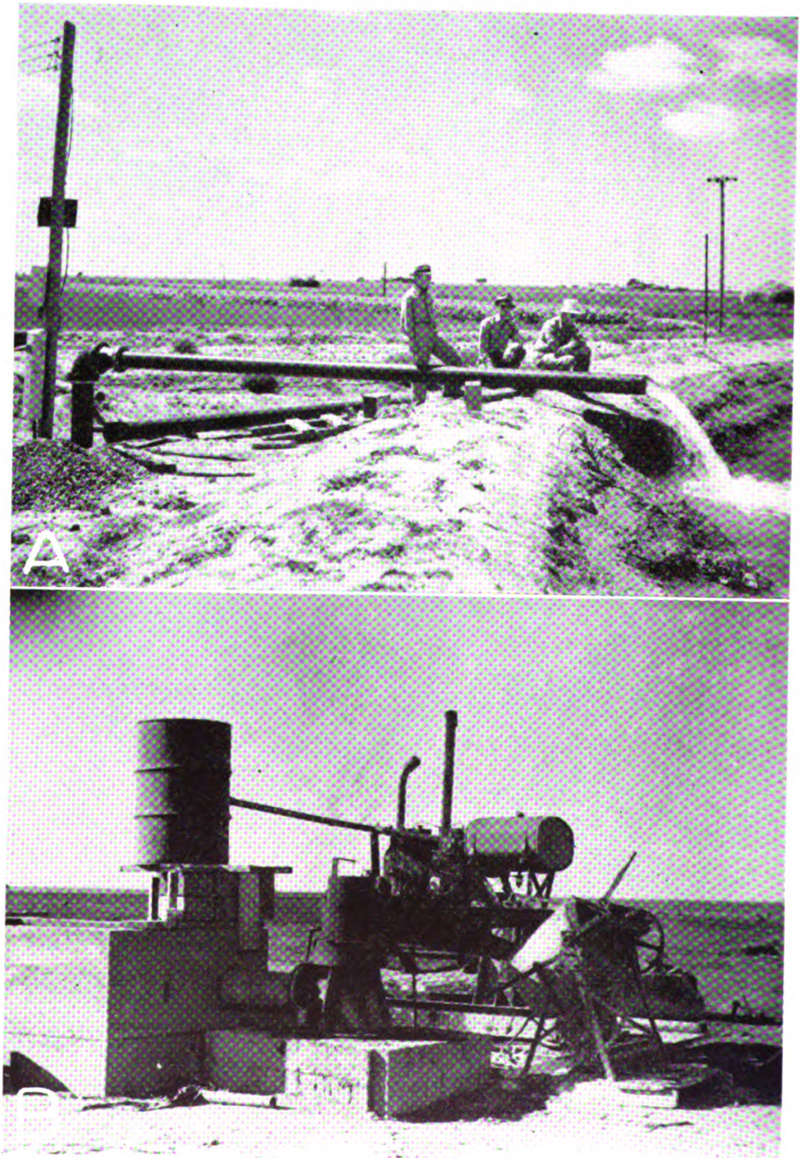


PLATE 8. Upland irrigation wells. *A,* Well (128) in Finney county, equipped with submersible turbine pump. Well discharging about 1,100 gallons a minute. (Photograph by S. W. Lohman). *B,* Well (515) in Gray county equipped with turbine pump powered by combine engine.

TABLE 19. *Types of power used for operating irrigation wells in Finney and Gray counties, Kansas*

Type of power	Number of wells in the Arkansas valley	Number of wells on the uplands	Total number of wells
Electric motor	154	40	194
Gasoline engine	23	8	31
Tractor	6	1	7
Natural gas engine	....	2	2
Butane engine	2	....	2
Diesel engine	....	1	1
Windmill	....	1	1
None	1	5	6
Totals	186	58	244

Type of power used for operating irrigation wells.—The types of power used to operate irrigation wells in Finney and Gray counties are given in table 19. Most of the wells are operated by electric motors using power supplied mainly by the Garden City Company. Where electricity is not available the pumps generally are powered by gasoline engines or by tractors. Most of the gasoline engines used to operate irrigation wells have been removed from old cars or combines (pl. 8B), but some are of the type built for stationary use. Two wells (488, 534) have natural-gas engines, two (wells 227 and 439) have engines using butane gas for fuel, one (well 492) has a Diesel engine, and one (well 434) is operated by a windmill.

Irrigation water pumped from streams.—Pumping water from streams for irrigation is practiced to a small extent in this area, principally along Pawnee river (pl. 5A). Dams have been constructed across Pawnee river in a few places to impound the water so it can be pumped to higher ground where it is used to irrigate crops. A few attempts have also been made to pump water from Arkansas river for irrigation use. No pumpage or acreage figures were obtained for the river pumping plants.

POSSIBILITIES OF DEVELOPING ADDITIONAL IRRIGATION SUPPLIES FROM WELLS

The amount of water that can be pumped from an underground reservoir without causing excessive permanent lowering of the water table depends on the capacity of the reservoir and on the amount of annual recharge to the reservoir. If water is withdrawn from an underground reservoir by pumping faster than water enters it, the water levels in wells will decline and the supply eventually will be depleted. The amount of water that can be withdrawn annually from the ground-water reservoir over a long period of years without causing depletion of the available supply is termed the safe yield of the reservoir. The feasibility of developing additional water supplies from wells for irrigation in Finney and Gray counties is dependent upon the safe yield of the underground reservoir and upon other geologic, hydrologic, and economic factors.

The question of whether further irrigation is possible or practical in a specific area is of extreme importance, not only to the present irrigators but also to those persons who may contemplate investing money in an irrigation well. Overdevelopment in an irrigation area will cause lowering of the water table, thereby increasing the total pumping lift. This is important to those who own irrigation wells, for the cost of lifting water to the surface increases in proportion to the total pumping lift. The most important question to the farmer who is contemplating the construction of an irrigation well is whether or not the ground water can be developed and pumped to the surface at a cost low enough to permit a profit from the crops produced. The depth to water level determines in part the original cost of the well and the cost of operation. The height a given quantity of water must be lifted is a prime factor in determining the cost of operating a well. The economic success of an irrigation project often hinges on this point. It is generally not possible to state the limit of economical pumping lift in a given locality, for it depends on such factors as the cost of fuel for operating the pump, efficiency of the pump, kind and price of the crops being irrigated, and the skill and management of the individual. In 1902, Johnson (1902, p. 668) made the following statement:

> The economical pumping lift at Garden (Garden City, Kan.) under present conditions, can hardly be said to reach 20 feet. Under the more favorable conditions of future development and a local market this will probably not be increased by more than 50 percent. That is, 25 feet appears to be about the limit of height above the water plane at which irrigation farming from wells can profitably be conducted—at least on a commercial basis.

Since this statement was made, the economical pumping lift in the vicinity of Garden City has increased more than 100 percent above the maximum figure given by Johnson, owing to modern developments in well construction, higher efficiency of modern pumps, type and increased price of crops being irrigated, and reduced cost of fuel for pumping.

The character and thickness of the water-bearing beds determine in part the original cost of constructing a well and the cost of operating the pumps after the well is completed. If the water-bearing beds are composed of somewhat fine materials, it may be necessary to gravel-pack the well which increases the original cost. If the water-bearing materials are sufficiently coarse, less expensive wells employing well screens or perforated casings without gravel packing can be constructed.

The possibilities for developing additional water supplies for irrigation in six different areas in Finney and Gray counties are discussed below.

Arkansas valley.—Available data indicate that the capacity of the underground reservoir in the Arkansas valley in this area is large enough to withstand more pumping for irrigation, particularly in those parts of the valley in which there is now but little pumping. The valley area has the advantage that water is available from the alluvium and also from sands and gravels of Pliocene (Ogallala formation) and Pleistocene age beneath the alluvium. The water table in the valley is shallow (pl. 2) so that pumping lifts are low. Moreover, the conditions for recharge are more favorable in the valley than any other area in Finney and Gray counties.

Information as to the safe yield of the ground-water reservoir is obtained by a study of the relations of water levels in observation wells in the valley to the amount of pumpage. If the water levels in the wells remain stationary during a long period of pumping, it may be concluded that the rate of recharge has been approximately equal to the rate of discharge, including both natural discharge and artificial discharge by wells. If at the end of any long period the water levels return approximately to the position they had at the beginning of the period, the record of pumpage furnishes a measure of the recharge minus the natural loss. The hydrographs shown in figure 13 indicate that there has been no persistent downward trend of the water table in the heavily pumped part of the valley in the area surrounding Garden City and Holcomb during the period from November, 1934, to December, 1942. The fluctuations of the water table in the Arkansas valley are of a seasonal type (fig. 15).

The precipitation at Garden City has averaged 6.85 inches below normal for the 9-year period from 1931 through 1939—the longest consecutive period of subnormal precipitation in the 53-year record of the station. In 1934, 1935, and 1937 the annual precipitation at

Garden City was more than 10 inches below normal, and in 1939 it was 9.77 inches below normal—the four driest years since 1894. Thus, during the 9-year period the water levels in the valley declined partly as a result of below-normal precipitation and partly as a result of increased pumpage. In 1940, the precipitation was 1.28 inches above normal and in 1941 it was 6.57 inches above normal. The water levels in most of the wells in the Arkansas valley showed a net rise for each of these years. By the end of 1941 the water levels in the eight irrigation wells (fig. 13) had reached their highest levels since the records were started in 1934. The trends in water levels during the period of record indicate, therefore, that the pumpage has not exceeded the safe yield.

In 1939, the sixth driest year on record, a total of about 34,870 acre-feet of water was pumped from wells in the Arkansas valley in Finney and Gray counties. Of this amount, about 27,100 acre-feet of water was pumped from wells in the valley in Finney county to irrigate about 11,580 acres of crops. This amount of pumpage probably is considerably above the annual average. The water-level fluctuations during the period seem to indicate that the present rate of pumping is not depleting the ground-water reservoir and that some additional pumping can be undertaken without exceeding the safe yield. To prevent local overdevelopment, however, care should be taken in locating and spacing the new wells.

Conditions seem to be favorable for additional pumping from wells in several parts of the Arkansas valley in this area, and almost all of the valley in Gray county could safely withstand additional irrigation development. In 1940, there were only 22 irrigation wells in the valley in Gray county and only 1,420 acres were irrigated. There are still many acres of flat bottom land in the valley in Gray county that could be irrigated by pumping from wells if care were taken in selecting areas having favorable soils. Properly constructed shallow wells in the alluvium may be expected to yield up to 500 gallons a minute, or possibly more in local areas; yields as high as 1,500 gallons a minute could be expected from a battery of shallow wells. Deep test drilling indicates that the basal part of the Ogallala formation in this area contains a variable thickness of coarse, unconsolidated gravel capable of yielding water freely to wells (see logs of test holes 21 and 22 and pp. 163, 164). A single deep well of the proper construction may be expected to yield up to 1,500 gallons a minute. Logs of two test holes indicate that the water-bearing material in the Ogallala in this area contains enough fine sand to warrant the use of gravel-packed wells (p. 93). In some places, however, the water-bearing material might be sufficiently free from fine sand so that gravel packing the wells would not be necessary.

Throughout this part of the valley the water surface in the river generally is below the water table so that water is discharged from the ground-water reservoir into the river and leaves the area as surface flow. Lowering the water table by additional pumping would decrease the amount of ground-water lost to the river, and if the water table were lowered below the level of the river channel some of the surface flow would be added to the ground-water reservoir. Hence, additional pumping in this part of the valley, instead of depleting the ground-water supply, would aid in salvaging much of the water that now leaves the county as stream flow.

That part of the Arkansas valley in eastern Finney county from a point about 3 miles downstream from Garden City to the Gray county line also could withstand additional irrigation development. The same considerations applied to the valley in Gray county also apply to this area. The valley in eastern Finney county is much narrower, however, so that there is much less land suitable for irrigation. Logs 9 and 13 illustrate the character of the water-bearing material in this part of the valley and indicate that the known thickness of the water-bearing material ranges from about 130 feet near Pierceville to more than 210 feet in the western part of the area. At the present time there are only ten irrigation wells in this part of the valley, all but two of which are north of the river. The soils south of the river are quite sandy, and for this reason are not as favorable for irrigation as the less sandy soils north of the river.

Some additional pumping from wells for irrigation might prove successful in the valley on the south side of the river west of Holcomb. In 1939, there were only five active irrigation plants (wells 341, 342, 348, 349, and 351) in this part of the valley. Well 342 consists of a battery of ten shallow wells and is reported to yield 3,700 gallons a minute. Well 348 consists of two shallow wells and is reported to yield about 800 gallons a minute. Wells having comparable yields probably could be constructed. Preliminary test holes should provide the necessary information to determine whether a deep or shallow well should be constructed and whether or not the well should be gravel-packed.

Finney basin.—The Finney basin includes the large area of shallow water north of the Arkansas valley in western Finney county. This area of shallow water extends northward to the central part of Scott county where it is known as the Modoc basin. The depth to water level in the Finney county part of the shallow-water basin is nearly everywhere less than 50 feet, and over a large part of the basin it is less than 25 feet. In 1940, there were about 100 deep irrigation wells in the shallow-water basin in Scott county, and about 50 in Finney county. Of the 50 irrigation wells in the basin in Finney county, more than 40 are situated in a belt 2 to 4 miles wide bordering the Arkansas valley. North of this there are only a few scattered wells.

Much of this large area contains land that could be successfully irrigated from deep wells. The water-bearing formations in this area (the Ogallala formation and the undifferentiated Pleistocene deposits) have a total thickness of from about 120 feet in the western part to about 250 feet in the deepest part of the structural basin (fig. 8 BB′). The water-bearing materials range in texture from fine sand to coarse gravel, but the character and thickness of these materials vary greatly from place to place even within a short distance, so that some wells encounter more and better water-bearing materials than others (see logs 2, 3, 4, 7, and 30). Before putting down an irrigation well, several test holes of small diameter should first be drilled in order to determine whether or not saturated materials of the proper character and thickness are available. The test-hole data also will indicate whether or not gravel packing is necessary, and if not, what size screen should be used or what size perforations should be made in the casing.

The existing irrigation wells in the Finney basin range from about 150 to almost 350 feet in depth. The measured yields from these wells range from 400 to 1,770 gallons a minute with drawdowns ranging from 18.5 feet to 135 feet (table 12, p. 106). Well 24, the only active irrigation well in the northern part of the Finney basin, was drilled in 1940 and is 155 feet deep (log 30). The water level in this well is about 30 feet below land surface. During a pumping test conducted by P. H. Browne, representative of the Johnston Pump Company, the well discharged 1,770 gallons a minute with a drawdown of about 30 feet. Before drilling this well, several test holes were drilled in order to determine the best possible site for the well.

Uplands in north-central Finney county.—In north-central Finney county north of the valley is a large upland area in which the depth to water level is between 50 and 100 feet (pl. 2). Very little information is available concerning the character and thickness of the water-bearing deposits in this area, but available data indicate that the saturated deposits are comparatively thin. Test hole 2 (log 2), in the southwest corner of sec. 3, T. 22 S., R. 31 W., encountered only 16 feet of water-bearing sand and gravel. An east-west geologic profile across the central part of this area (fig. 8 BB′) shows that the saturated part of the unconsolidated deposits are about 160 feet thick near the Finney basin, but that they become much thinner toward the east. In the extreme eastern part of the area, all of the unconsolidated deposits lie above the water table.

Only two irrigation wells (27 and 60) have been drilled in this area. Well 27, in the westernmost part of the upland area near the Finney basin, is 199.5 feet deep, is gravel-packed, and the water level is about 76 feet below land surface. During a pumping test conducted by P. H. Browne, representative of the Johnston Pump Company, the well discharged 850 gallons a minute with a drawdown of about 34 feet. Before drilling well 27, a well was drilled about 1 mile to the north, but the water-bearing sand and gravel encountered was too thin to permit the completion of a successful well. Well 60, in the easternmost part of the upland area, is 118 feet deep and the water level is about 70 feet below the land surface. The well is reported to yield 300 gallons a minute.

From the foregoing facts, it may be concluded that the western part of the upland area in north-central Finney county is more favorable for irrigation development than the eastern part, and that the success or failure of an irrigation well in this area depends largely on local conditions. The drilling of several test holes of small diameter before putting down the final well probably is more important in this area than in any other area discussed.

Uplands in northeastern Gray county.—In the part of northeastern Gray county northeast of the 100-foot depth to water line (pl. 2) the water table is everywhere less than 100 feet below the surface, and in the valley of Buckner creek it is less than 25 feet below the surface. The relief of the surface in the vicinity of Buckner creek and its tributaries is too great for irrigation; however, much of the land surrounding the valleys might be favorable for irrigation. Wells in this area obtain water from sand and gravel in the Ogallala formation, the character and thickness of which is indicated by the logs of two test holes (17 and 18) and the north-south geologic profile in figure 9 (DD′). According to available data, the Ogallala attains its maximum thickness—about 250 feet—in the southern part of this area and thins to 100 feet or less in the northeastern part.

In 1939 there was only one active irrigation well (402) in this area, in sec. 6, T. 24 S., R. 27 W. This well is gravel-packed, is 105 feet deep, and the depth to water level is about 65 feet. During a pumping test conducted by Kenneth D. McCall, engineer, Division of Water Resources, Kansas State Board of Agriculture, the well discharged 1,020 gallons a minute with a drawdown of 13.2 feet.

Although the conditions here are not as favorable as in other areas, it is believed that irrigation from wells could be practiced successfully in parts of the northeastern Gray county area. Additional wells of proper construction in favorable localities could be expected to yield 500 to 1,500 gallons a minute. Because of the variable nature of the water-bearing materials in the Ogallala formation, it would be necessary to drill test holes before locating any large wells.

West-central Gray county.—Another area favorable for additional irrigation development is that south of the sand hills and north of Crooked creek in west-central Gray county. This is a relatively flat upland area in which the depth to water level ranges from about 60 feet to about 115 feet. A test hole drilled in the northeast corner of sec. 31, T. 27 S., R. 30 W., encountered 404 feet of unconsolidated material (undifferentiated Pleistocene deposits and Ogallala formation) above the Dakota formation (see log 24). Almost 200 feet of this material consisted of saturated sand and gravel. The Pleistocene deposits and the Ogallala formation thicken toward the north and west in this area (fig. 9 CC′).

In 1940, there were six irrigation wells (492, 493, 494, 496, 515, and 516) in this area (pl. 2). All of these wells are equipped with turbine pumps powered by gasoline or Diesel engines, and most of them are gravel packed. The wells are 110 to 165 feet deep, and the depth to water level in them ranges from about 64 feet to about 110 feet. The yields of these wells range from about 800 to 1,100 gallons a minute.

Well 496 is typical of the wells that can be developed in this area. It is a gravel-packed well 135 feet deep in which the water level is 68 feet below the surface. Coarse water-bearing gravel was reported between the depths of 72 and 135 feet. During a pumping test conducted in 1940 by Kenneth D. McCall, engineer, Division of Water Resources, Kansas State Board of Agriculture, this well yielded 875 gallons a minute with a drawdown of 11.3 feet after 4.5 hours of pumping.

The ground-water reservoir beneath this area is large enough to withstand additional pumping from wells. Periodic measurements of the water level in well 515 in the southern part of the area have been made since December, 1939. From December 14, 1939, to December 4, 1940, the water level in well 515 showed a net rise of 1.08 feet, and from December 4, 1940, to December 26, 1941, there was a net rise of 0.19 foot; thus, there has been no decline in the water table in this area as a result of the pumping of water from irrigation wells. Irrigation development could safely be expanded in this area without endangering the ground-water supply. Properly constructed deep wells could be expected to yield 800 to 1,000 gallons a minute without excessive drawdown. In local areas as much as 1,500 gallons a minute probably could be developed from a single well.

Crooked creek area.—In the area occupied by Crooked creek and its tributaries in southern Gray county the depth to water level is from less than 25 feet to 100 feet (pl. 2). A test hole drilled in the northwest corner of sec. 34, T. 29 S., R. 28 W., encountered 164.5 feet of unconsolidated silt, sand, and gravel of Pleistocene age above the Cretaceous bedrock. About 62 feet of this consisted of water-bearing sand and gravel, the thickness of which probably increases toward the west and northwest.

The character and thickness of the water-bearing deposits in southern Gray county are favorable for the development of irrigation wells of moderate yields. The surface relief in this area, however, is in general too great to permit successful irrigation. In 1940, there was only one irrigation well (534) in southern Gray county. It is 138 feet deep and the depth to water level is about 99 feet. The well penetrated only about 15 feet of water-bearing sand and gravel —the rest of the material below the water table consisted of relatively impermeable silt, clay, and caliche (see log 56). During a pumping test conducted by Kenneth D. McCall, engineer, Division of Water Resources, Kansas State Board of Agriculture, the well yielded 475 gallons a minute with a drawdown of 25.9 feet.

Quality of Water

The chemical character of the well waters in Finney and Gray counties is shown by the analyses of water from 55 representative wells given in tables 20 and 21. Figure 19 shows graphically the chemical character of typical waters from the Ogallala formation and undifferentiated Pleistocene deposits and from the alluvium.

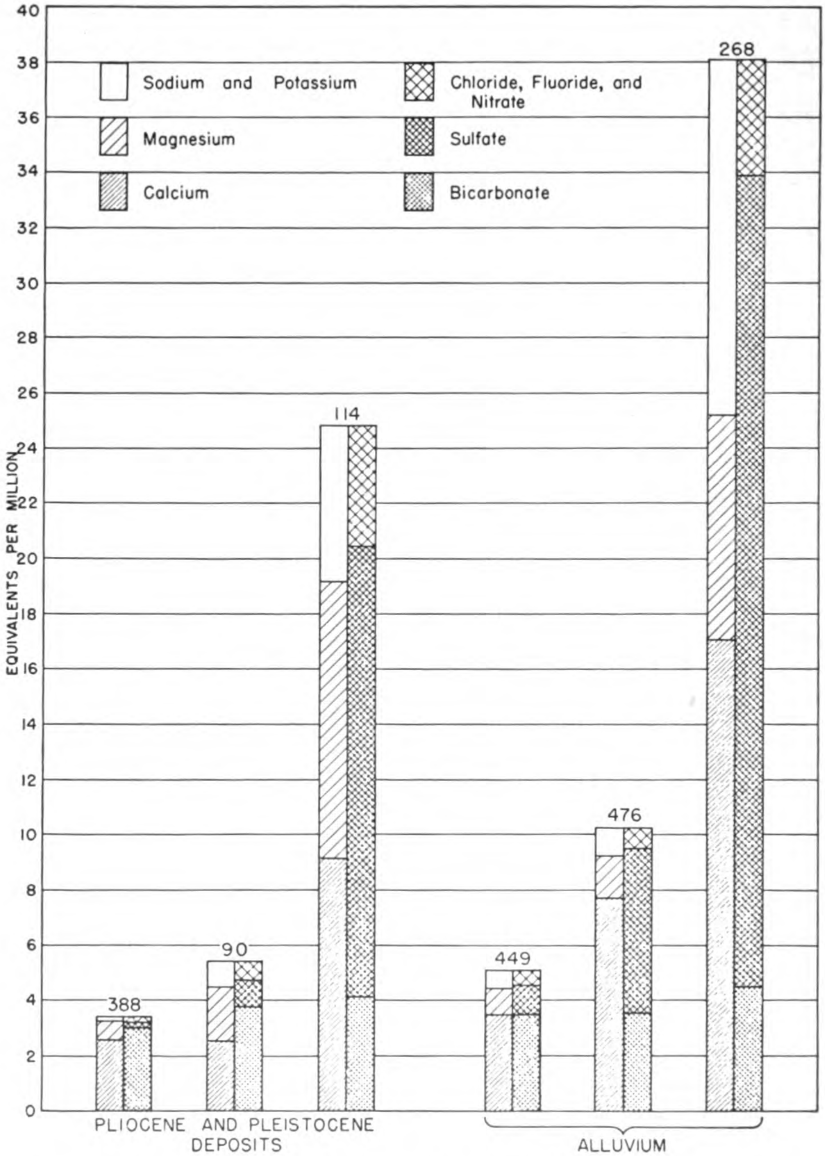


FIG. 19. Analyses of typical waters from the Ogallala formation and undifferentiated Pleistocene deposits and from the alluvium in Finney and Gray counties, Kansas.

All of the samples of water were collected by me except those from public supply wells. E. O. Holmes, chemist, analyzed the samples in the Water and Sewage Laboratory of the Kansas State Board of Health. The analyses show only the dissolved mineral content of the waters and do not in general indicate the sanitary condition of the waters. The chemical constituents of the waters 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 adopted in part from publications of the United States Geological Survey.

TABLE 20.—*Analyses of water from typical wells in Finney county, Kansas*

Analyzed by E. O. Holmes. Parts per million[a] and equivalents per million[b] (in italics)

No. on plate 2	LOCATION	Depth (feet)	Geologic source	Date of collection, 1940	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total dissolved solids (c)	Hardness (calculated as $CaCO_3$)		
																Total	Carbonate	Noncarbonate
1	*T. 21 S., R. 27 W.* SW SW sec. 9	100d	Codell	Oct. 14	59	0.44	57 *2.84*	17 *1.40*	18 *0.76*	228e *3.74*	27 *0.56*	3.8 *0.10*	1.4 *0.07*	8.0 *0.13*	259	213	207	6
12	*T. 21 S., R. 30 W.* NW corner sec. 5	44.1	Ogallala	Oct. 17	57	.09	101 *5.04*	24 *1.97*	53 *2.31*	347 *5.69*	99 *2.06*	50 *1.41*	.9 *.05*	7.1 *.11*	509	350	284	66
31	*T. 21 S., R. 33 W.* NE NW sec. 13	39.5	Pleistocene	do	58	.99	47 *2.35*	26 *2.14*	73 *3.19*	290 *4.76*	104 *2.16*	21 *.59*	2.2 *.12*	2.9 *.05*	422	227	227f	0
38	*T. 21 S., R. 34 W.* SE NE sec. 21	85d	Fort Hays	do	58	.28	54 *2.69*	25 *2.06*	20 *.88*	266 *4.36*	35 *.73*	12 *.34*	1.0 *.05*	9.3 *.15*	290	238	218	20
41	SW NE sec. 36	55	Ogallala	Oct. 26	57	.17	66 *3.29*	31 *2.55*	50 *2.17*	245 *4.02*	121 *2.52*	46 *1.30*	1.6 *.08*	5.8 *.09*	444	293	201	92
55	*T. 22 S., R. 29 W.* SW NW sec. 12	19.5	Alluvium	Oct. 14	59	2.0	157 *7.83*	67 *5.51*	56 *2.42*	390 *6.40*	379 *7.88*	38 *1.07*	1.2 *.06*	22.0 *.35*	917	671	320	351
65	*T. 22 S., R. 30 W.* SW NW sec. 29	69.5	Ogallala	Oct. 17	59	1.8	77 *3.84*	32 *2.63*	50 *2.16*	217g *3.56*	195 *4.06*	27 *.76*	2.3 *.12*	3.1 *.05*	499	327	182	145
73	*T. 22 S., R. 32 W.* NW corner sec. 27	94.1	Pleistocene	do	59	5.2	63 *3.14*	24 *1.97*	40 *1.72*	227 *3.72*	105 *2.18*	27 *.76*	1.6 *.08*	5.3 *.09*	385	265	186	79
90	*T. 23 S., R. 27 W.* NE SE sec. 21	140d	Ogallala	Oct. 14	59	.35	51 *2.54*	24 *1.97*	21 *.91*	228 *3.74*	48 *1.00*	17 *.48*	1.4 *.07*	8.0 *.13*	285	226	187	39
98	*T. 23 S., R. 29 W.* SE SE sec. 11	97.0	do	do	59	.61	37 *1.85*	23 *1.89*	35 *1.50*	224 *3.67*	29 *.60*	25 *.71*	3.3 *.17*	5.8 *.09*	271	188	183	5

	T. 23 S., R. 32 W.																	
114	SW SW sec. 20	23.5	Pleistocene	Oct. 26	59	.44	183 *9.13*	122 *10.03*	130 *5.63*	250 *4.10*	786 *16.35*	147 *4.15*	2.1 *.11*	4.8 *.08*	1,500	959	205	754
	T. 23 S., R. 33 W.																	
125	SW corner sec. 18	68.5	do	Oct. 18	58	.29	118 *5.89*	93 *7.64*	142 *6.18*	246 *4.03*	558 *11.61*	135 *3.81*	2.3 *.12*	8.4 *.14*	1,180	677	202	475
141	SE corner sec. 35	240d	Ogallala and Pleistocene	Oct. 15	59	.06	207 *10.33*	81 *6.66*	186 *8.10*	246 *4.03*	867 *18.03*	97 *2.74*	1.1 *.06*	14 *.23*	1,576	850	202	648
	T. 24 S., R. 31 W.																	
165	NW NW sec. 31	32	Alluvium	do	60	.02	120 *5.99*	50 *4.11*	195 *8.47*	290 *4.76*	596 *12.40*	43 *1.21*	1.4 *.07*	8.0 *.13*	1,158	505	238	267
	T. 24 S., R. 32 W.																	
181h 208 223	SW SE sec. 7 NE SW NW sec. 17 NW SW sec. 18	258d 299d 250d	Ogallala (composite sample from wells 181, 208, and 223).	Jan., '41	......	.04	88 *4.39*	21 *1.73*	46 *1.98*	189 *3.10*	208 *4.33*	21 *.59*	.7 *.04*	2.0 *.04*	481	306	155	151
226	SE SW sec. 19	71.0	Terrace gravel	Oct. 24	61	2.4	66 *3.29*	9.0 *.74*	1.6 *.07*	171 *2.80*	13 *.27*	12 *.34*	.3 *.02*	42 *.67*	232	206	140	66
233	NE NW sec. 21	45	Alluvium	Oct. 15	58	.02	249 *12.43*	100 *8.22*	170 *7.40*	282 *4.62*	960 *19.97*	104 *2.93*	1.8 *.09*	27 *.44*	1,753	1,033	231	802
	T. 24 S., R. 33 W.																	
262	SW NW sec. 7	220d	Ogallala	Oct. 24	61	.02	43 *2.15*	17 *1.40*	23 *.98*	194 *3.18*	50 *1.04*	7.0 *.20*	.9 *.05*	4.0 *.06*	242	178	159	19
268	SW NW SE sec. 8	36.2	Alluvium	Oct. 18	59	.07	342 *17.07*	99 *8.14*	297 *12.89*	275 *4.51*	1413 *29.39*	140 *3.95*	1.2 *.06*	12 *.19*	2,442	1,261	225	1,036
297	NW SW sec. 12	45d	do	Oct. 16	58	.04	386 *19.26*	165 *13.56*	390 *16.97*	264 *4.33*	1920 *39.94*	178 *5.02*	2.5 *.13*	23 *.37*	3,197	1,641	216	1,425
317	SW SW sec. 13	45.5	do	do	57	.01	246 *12.28*	101 *8.30*	316 *13.72*	246 *4.03*	1281 *26.65*	124 *3.50*	1.2 *.06*	4.0 *.06*	2,196	1,029	202	827
	T. 24 S., R. 34 W.																	
336	SE NE sec. 2	81d	do	Oct. 14	59	.03	212 *10.58*	107 *8.80*	219 *9.54*	253 *4.15*	996 *20.72*	130 *3.67*	1.4 *.07*	19 *.31*	1,811	969	208	761
338	SW NW sec. 3	37-50	do	Oct. 15	60	.06	193 *9.63*	107 *8.80*	213 *9.26*	190 *3.12*	988 *20.55*	133 *3.75*	1.6 *.08*	12 *.19*	1,743	922	156	766
349	NW NW sec. 16	35d	do	Oct. 18	62	.27	307 *15.32*	101 *8.30*	253 *11.00*	263 *4.31*	1288 *26.79*	107 *3.02*	1.4 *.07*	27 *.43*	2,216	1,182	215	967
352	NE corner sec. 25	52.5	Terrace gravel	Oct. 18	61	.20	74 *3.69*	12 *.99*	6.2 *.27*	217 *3.56*	16 *.33*	12 *.34*	.4 *.02*	43 *.70*	272	235	178	57
	T. 25 S., R. 31 W.																	
362	SW SE sec. 15	24.5	Alluvium	Oct. 15	60	.08	71 *3.54*	8.2 *.67*	6.4 *.28*	188 *3.08*	6.8 *.14*	22 *.62*	.2 *.01*	40 *.64*	249	211	154	57
	T. 26 S., R. 31 W.																	
381	NE corner sec. 30	97.5	Pleistocene	Oct. 16	61	.04	53 *2.64*	8.3 *.68*	17 *.73*	203 *3.33*	21 *.44*	3.5 *.10*	.3 *.02*	10 *.16*	215	166	166	0

TABLE 20.—Analyses of water from typical wells in Finney county, Kansas—*Concluded*

No. on plate 2	LOCATION	Depth (feet)	Geologic source	Date of collection, 1940	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total dissolved solids (c)	Hardness (calculated as $CaCO_3$)		
																Total	Carbonate	Noncarbonate
388	*T. 26 S., R. 32 W.* SW NW sec. 31	120.5	Pleistocene	Oct. 16	60	2.9	52 *2.59*	8.2 *.67*	3.9 *.17*	184 *3.02*	9.5 *.20*	3.5 *.10*	.3 *.02*	5.3 *.09*	178	163	151	12
392	*T. 26 S., R. 33 W.* NE corner sec. 9	78.5	do	Oct. 18	60	1.1	56 *2.79*	11 *.90*	3.2 *.14*	207 *3.39*	13 *.27*	2.5 *.07*	.3 *.02*	4.9 *.08*	196	187	170	17

a. One part per million is equivalent to 1 pound of substance per million pounds of water and is equal to 8.33 pounds per million gallons.
b. Equivalents per million.
c. Calculated.
d. Reported.
e. Sample contains 12 parts per million of carbonate (CO_3).
f. Total alkalinity, 238 parts per million; excess alkalinity, 11 parts per million.
g. Sample contains 2.4 parts per million of carbonate (CO_3).
h. Sample collected from city tap at Garden City by J. A. Roby, city engineer.

TABLE 21.—*Analyses of water from typical wells in Gray county, Kansas*

Analyzed by E. O. Holmes. Parts per million[a] and equivalents per million[b] (in italics)

No. on plate 2	LOCATION	Depth (feet)	Geologic source	Date of collection, 1940	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total dissolved solids (c)	Hardness (calculated as $CaCO_3$)		
																Total	Carbonate	Noncarbonate
401	*T. 24 S., R. 27 W.* SE SW sec. 2	100.7	Ogallala	Dec. 7	57	0.57	59 *2.94*	24 *1.97*	19 *.83*	210 *3.44*	72 *1.50*	20 *.56*	2.2 *.12*	7.5 *.12*	309	246	172	74
407	*T. 24 S., R. 28 W.* SE NE sec. 5	112.5	do	do	57	.62	68 *3.39*	23 *1.89*	22 *.94*	212 *3.48*	86 *1.79*	25 *.71*	1.7 *.09*	9.3 *.15*	342	264	174	90
416	*T. 24 S., R. 30 W.* SE cor. SW sec. 16	150.5	do	Dec. 9	58	.03	75 *3.74*	26 *2.14*	42 *1.83*	211 *3.46*	155 *3.22*	30 *.85*	1.2 *.06*	7.5 *.12*	442	294	173	121
424	*T. 25 S., R. 27 W.* SW cor. SE sec. 33	146d	do	Dec. 12	57	.28	59 *2.94*	23 *1.89*	13 *.56*	195 *3.20*	67 *1.39*	22 *.62*	1.1 *.06*	7.5 *.12*	290	242	160	82
429	*T. 25 S., R. 29 W.* SE SE sec. 1	117.0	do	Dec. 7	58	2.0	89 *4.44*	23 *1.89*	15 *.64*	194 *3.18*	128 *2.66*	35 *.99*	.7 *.04*	6.2 *.10*	396	316	159	157
434	NE NW sec. 36	126.0	do	do	58	1.0	94 *4.69*	27 *2.22*	32 *1.39*	178 *2.92*	205 *4.26*	36 *1.02*	.8 *.04*	3.5 *.06*	488	346	146	200
441	*T. 25 S., R. 30 W.* SE SW sec. 24	15d	Alluvium	Dec. 10	60	.02	164 *8.19*	96 *7.89*	96 *4.18*	228 *3.74*	626 *13.02*	85 *2.40*	1.9 *.10*	62 *1.00*	1,245	804	187	617
449	*T. 26 S., R. 27 W.* SW SE sec. 15	12.0	do	do	57	4.0	69 *3.44*	12 *.99*	15 *.66*	210 *3.44*	52 *1.08*	10 *.28*	.4 *.02*	17 *.27*	284	222	172	50
457	*T. 26 S., R. 28 W.* SE NE sec. 10	53d	do	Dec. 11	58	e	76 *3.79*	22 *1.81*	34 *1.46*	214 *3.51*	139 *2.89*	20 *.56*	.8 *.04*	3.5 *.06*	402	280	176	104
459	SE NW sec. 11	180d	Ogallala	Sept.	......	e	51 *2.54*	10 *.82*	20 *.86*	180 *2.95*	49 *1.02*	6.0 *.17*	.5 *.03*	3.5 *.06*	230	168	148	20
472	NW cor. NE sec. 35	60d	Terrace gravel	Dec. 10	57	4.2	60 *2.99*	9.7 *.80*	17 *.75*	226 *3.71*	26 *.54*	5.0 *.14*	.3 *.02*	8.0 *.13*	243	190	186	4

TABLE 21.—Analyses of water from typical wells in Gray county, Kansas—*Concluded*

No. on plate 2	LOCATION	Depth (feet)	Geologic source	Date of collection, 1940	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total dissolved solids (c)	Hardness (calculated as $CaCO_3$) Total	Carbonate	Noncarbonate
	T. 26 S., R. 29 W.																	
476	SW NW sec. 2	14.5	Alluvium	Dec. 11	61	1.3	154 *7.69*	19 *1.56*	23 *.99*	217 *3.56*	286 *5.95*	16 *.45*	1.7 *.09*	12 *.19*	622	462	178	284
478	NE NE sec. 22	86.5	Pleistocene	Dec. 9	59	1.3	60 *2.99*	10 *.82*	13 *.55*	202 *3.31*	20 *.42*	13 *.37*	.3 *.02*	15 *.24*	234	190	166	24
	T. 26 S., R. 30 W.																	
480	SW NW sec. 1	70d	Terrace gravel	Dec. 10	59	.15	59 *2.94*	9.8 *.81*	15 *.63*	208 *3.41*	22 *.46*	10 *.28*	.4 *.02*	13 *.21*	233	188	170	18
	T. 27 S., R. 27 W.																	
485	SE NE sec. 14	142d	Pleistocene	Dec. 7	59	.04	58 *2.89*	8.4 *.69*	13 *.58*	222 *3.64*	13 *.27*	3.5 *.10*	.4 *.02*	8.0 *.13*	215	179	179f	0
	T. 27 S., R. 29 W.																	
490	NE SW sec. 5	104	do	Dec. 9	58	.10	59 *2.94*	8.8 *.72*	19 *.84*	226 *3.71*	21 *.44*	6.3 *.18*	.4 *.02*	9.3 *.15*	237	183	183g	0
	T. 27 S., R. 30 W.																	
497	NW SW sec. 29	121.5	Ogallala and Pleistocene	do	58	.42	50 *2.50*	8.1 *.67*	10 *.43*	187 *3.07*	14 *.29*	1.5 *.04*	.3 *.02*	11 *.18*	189	158	154	4
	T. 28 S., R. 27 W.																	
499	NE NE sec. 9	168.0	do	Dec. 10	58	.66	55 *2.74*	12 *.99*	10 *.44*	188 *3.08*	30 *.62*	12 *.34*	.4 *.02*	6.6 *.11*	221	186	154	32
500	NE NW sec. 24	420d	Dakota	Dec. 7	59	3.9	8.0 *.40*	4.7 *.39*	150 *6.55*	266 *4.36*	119 *2.48*	9.5 *.27*	4.2 *.22*	.9 *.01*	433	40	40h	0
	T. 28 S., R. 28 W.																	
504	SW NW sec. 3	186.0	Ogallala and/or Pleistocene	Dec. 10	58	.24	54 *2.69*	10 *.82*	14 *.61*	202 *3.31*	25 *.52*	5.3 *.15*	.3 *.02*	7.5 *.12*	217	176	166	10
	T. 28 S., R. 29 W.																	
511 i 513	SW NE sec. 24 NE SW sec. 24	170d 170d	Pleistocene (composite sample from wells 511 and 513).	Oct.	......	.01	54 *2.69*	9.6 *.79*	14 *.62*	188 *3.08*	25 *.52*	10 *.28*	.5 *.03*	12 *.19*	219	174	154	20
514	NW NE sec. 31	103.5	Pleistocene	Dec. 7	58	.77	55 *2.74*	18 *1.48*	13 *.56*	200 *3.28*	39 *.81*	19 *.54*	.7 *.04*	6.6 *.11*	252	211	164	47
	T. 29 S., R. 27 W.																	
524	NW NE sec. 28	89.5	do	do	59	.28	51 *2.54*	18 *1.48*	4.8 *.21*	234 *3.84*	7.1 *.15*	5.3 *.15*	.5 *.03*	4.0 *.06*	208	201	192	9

526	*T. 29 S., R. 28 W.* NE NE sec. 4........	365d	Dakota................	Dec. 9	59	1.1	27 *1.35*	10 *.82*	70 *3.06*	207 *3.39*	75 *1.56*	5.5 *.16*	1.8 *.09*	1.8 *.03*	236	108	108 j	0
532	*T. 29 S., R. 29 W.* SE NE sec. 8........	68.0	Pleistocene............	do	58	.75	62 *3.09*	17 *1.40*	15 *.63*	251 *4.12*	27 *.56*	9.5 *.27*	.5 *.03*	8.9 *.14*	266	224	206	18
538k, 539	*T. 29 S., R. 30 W.* SE NW sec. 8........	248d, 252d	Ogallala and/or Pleisto-cene.	Mar.	......	e	47 *2.35*	8.3 *.68*	11 *.47*	171l *2.80*	12 *.25*	2.5 *.07*	.3 *.02*	10 *.16*	183	152	150	2

a. One part per million is equivalent to 1 pound of substance per million pounds of water and is equal to 8.33 pounds per million gallons.
b. Equivalents per million.
c. Calculated.
d. Reported.
e. Less than 0.1 part per million.
f. Total alkalinity, 182 parts per million; excess alkalinity, 3 parts per million.
g. Total alkalinity, 186 parts per million; excess alkalinity, 3 parts per million.
h. Total alkalinity, 218 parts per million; excess alkalinity, 178 parts per million.
i. Sample collected from city tap at Montezuma by city engineer.
j. Total alkalinity, 170 parts per million; excess alkalinity, 62 parts per million.
k. Sample collected from city tap at Copeland by city engineer.
l. Sample contains 6.0 parts per million of carbonate (CO_3).

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 some water of crystallization. Waters containing less than 500 parts per million of dissolved solids are generally entirely satisfactory for domestic use, except for the difficulties resulting from their hardness and, in some areas, excessive iron corrosiveness. Waters having more than 1,000 parts per million are generally not satisfactory, for they are likely to contain enough of certain constituents to produce a noticeable taste or to make the water unsuitable in some other respects.

The water from four of the wells (388, 392, 497, and 538) sampled contained less than 200 parts per million of dissolved solids. The waters from 36 of the 55 wells sampled contained between 200 and 500 parts per million of dissolved solids, the waters from three wells (12, 55, and 476) contained between 500 and 1,000 parts, the waters from eight wells (114, 125, 141, 165, 233, 336, 338, and 441) contained between 1,000 and 2,000 parts, and the water from four wells (268, 297, 317, and 349) contained more than 2,000 parts. The greatest concentration of dissolved solids—3,197 parts per million—was found in the water from well 297.

Hardness.—The hardness of water, which is the property that generally receives the most attention, is most commonly recognized by its effects when soap is used with the water in washing. Calcium and magnesium cause virtually all the hardness of ordinary waters. These constituents are also the active agents in the formation of the greater part of the scale formed in steam boilers and in other vessels in which water is heated or evaporated.

In addition to the total hardness, the table of analyses shows the carbonate hardness and the noncarbonate hardness. The carbonate hardness is that due to the presence of calcium and magnesium bicarbonates. It is almost completely removed 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, and it cannot be removed by boiling and has sometimes been called permanent hardness. With reference to use with soaps, 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 the 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 on steam boilers. Hardness above 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 cisterns to collect soft rain water. Where municipal water supplies are softened, an attempt is generally made to reduce the hardness to 60 or 80 parts per million. The additional improvement from further softening of a whole public supply is not deemed worth the increase in cost.

The ground waters of Finney and Gray counties are practically all hard—only two samples (analyses 500 and 526) had less than 150 parts per million of hardness. The other 53 samples ranged in hardness from 152 to 1,641 parts per million. Sixteen of the samples analyzed had between 150 and 200 parts per million of hardness, 24 samples had between 200 and 500 parts, eight samples had between 500 and 1,000 parts (analyses 55, 114, 125, 141, 165, 336, 338, and 441), and five samples had more than 1,000 parts (analyses 233, 268, 297, 317, and 349). The greatest concentration of hardness was 1,641 parts per million (analysis 297).

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 derived 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.

Twenty-one of the 55 samples of water from Finney and Gray counties contained only 0.1 part per million or less of iron, and all but four of the samples had less than 3 parts per million. The water from well 500 had 3.9 parts per million of iron, the water from well 449 had 4.0 parts, that from well 472 had 4.2 parts, and that from well 73 had 5.2 parts.

Fluoride.—Although determinable quantities of fluoride are not so common as fairly large quantities of the other constituents of natural waters, it is desirable to know the amount of fluoride present in waters that are likely to be used by children. Fluoride in water has been shown to be associated with the dental defect known as mottled enamel, which may appear on the teeth of children who drink water containing fluoride during the period of formation of the permanent teeth. 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 1 part per million is not usually very serious (Dean, 1936). If the water contains as much as 4 parts per million of 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.

Of the 55 samples of ground water collected in this area, 28 contained 1.0 part per million or more of fluoride; of these, 20 contained 1.0 to 2 parts, seven contained 2 to 3 parts, and the sample of water from well 500 contained 4.2 parts. The fluoride content of samples of water from the Ogallala formation and from undifferentiated Pleistocene deposits is shown in figure 21 and discussed on pages 170 and 171.

Water for irrigation.—The suitability of water for use in irrigation is commonly believed to depend mainly on the total quantity of soluble salts and the ratio of the quantity of sodium to the total quantity of sodium, calcium, and magnesium. 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) suggests 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 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.

The waters from 13 of the wells sampled in this area contained more than 700 parts per million of dissolved solids, and the waters from wells 268, 297, 317, and 349 contained more than 2,100 parts per million. All but two of the samples contained less than 50 percent sodium (including potassium); these two (analyses 500 and 526) contained more than 60 percent. Analyses 500 and 526, however, are of samples of water from wells that tap the Dakota formation and are not in an area where water is pumped for irrigation use. All of the samples analyzed contained less than 355 parts per million of chloride, and most of them contained less than 142 parts.

According to the limits given by Scofield, it would seem that the waters from wells 268, 297, 317, and 349 are unsuited for irrigation use because of their large concentration of dissolved solids. Under certain conditions waters of this type may be injurious. Scofield (1933) recognizes, however, that no hard and fast limits can be adopted because the harmfulness of irrigation water is so dependent on the nature of the land, the crops, the manner of use, and the drainage.

The use of ground water for irrigation has been practiced in Finney and Gray counties for more than 25 years with no reported harm to the soils or crops.

SANITARY CONSIDERATIONS

The analyses of water given in the tables show only the amounts of dissolved mineral matter in the water and do not indicate the sanitary quality of the water. The water in a well may contain mineral matter that imparts an objectionable taste or odor and yet be free from harmful bacteria and entirely safe for drinking. On the other hand, the water in a well may be clear and pleasant to the taste and yet contain harmful bacteria.

It is well recognized that every precaution should be used to protect domestic and public water supplies from pollution by organic material. Much of the population of Finney and Gray counties is dependent on private water supplies from wells, and it rests chiefly with the drillers and individual well-owners to observe precautions in constructing wells to insure a safe and wholesome water supply. It is obvious that a well should not be located where there are possible sources of pollution nor where surface water can descend to the water table. The drainage from cesspools and privies is particularly dangerous. Every well should be so constructed 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.

NATURAL SOFTENING OF WATERS IN THE DAKOTA FORMATION BY BASE-EXCHANGE

The soft sodium bicarbonate waters from the Dakota formation are believed to result from a natural softening process in which calcium bicarbonate water has exchanged part of its calcium and

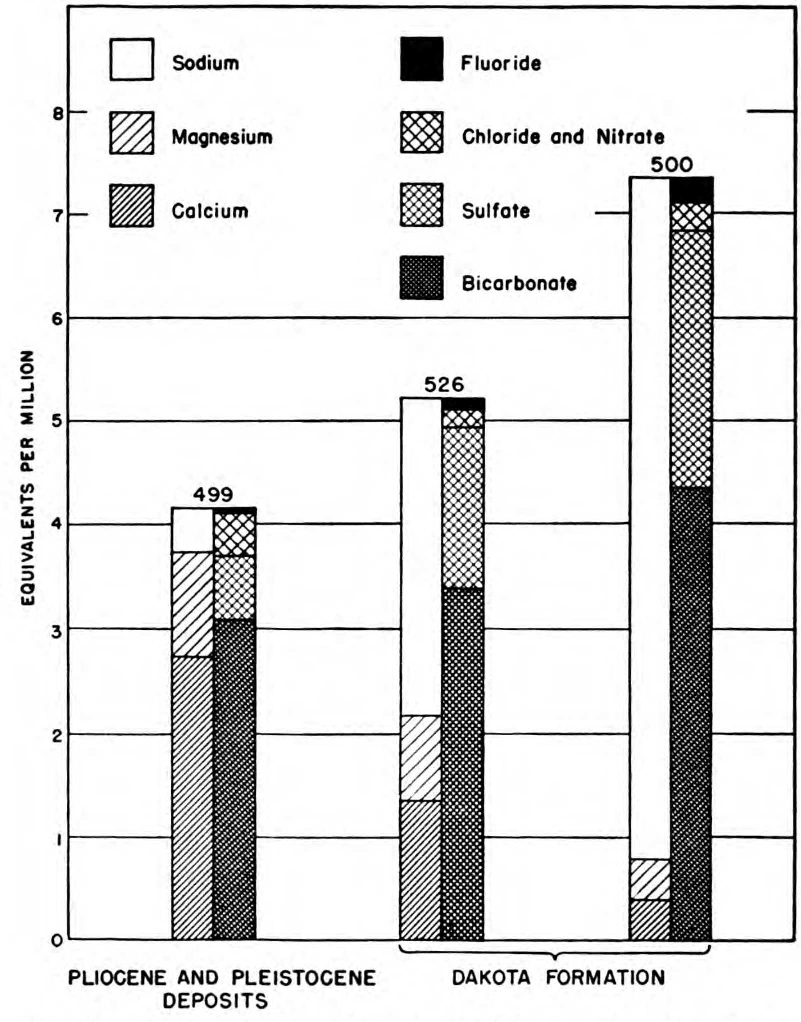


FIG. 20. Analyses of waters from the Ogallala formation (499) and the Dakota formation (500 and 526) illustrating natural softening of the water in the Dakota formation by base-exchange. Numbers refer to analyses in table 21.

magnesium for sodium by a base-exchange process. The chemical character of two samples (analyses 500 and 526) of water from the Dakota formation and one sample (analysis 499) from the Ogallala formation, which directly overlies the Dakota over much of southern Gray county, is shown by figure 20. Waters in the Ogallala formation are typically moderately hard calcium and magnesium bicarbonate waters (p. 169), and it seems probable that before the natural softening by base-exchange took place the waters of the Dakota formation were somewhat similar in quality to the waters of the Ogallala formation.

Similar natural softening by base-exchange has been described by Renick (1924) in Rosebud county, Montana, and by Piper (1933, pp. 85-87) in southwestern Pennsylvania. Renick (1924, p. 69) believes that in the Montana area leverrierite is the principal mineral causing the natural softening of the water, but recognizes that other hydrated aluminum silicates, such as kaolin, feldspar, and mica, also are capable of exchanging wholly or in part their sodium and potassium for other bases. The base-exchange silicates which are active in southwestern Pennsylvania are thought by Piper (1933, pp. 85, 86) to be the clay-forming minerals of the montmorillonite and hydro-mica groups.

The principal base-exchange silicates active in the Dakota formation in the area under consideration presumably are the clay-forming minerals of the montmorillonite group, although other minerals such as feldspar, mica, and koalin might also be taking part in the exchange. No samples of the Dakota from this area have been analyzed, but Norman Plummer, ceramist for the State Geological Survey of Kansas, collected samples of clay from outcrops of the Dakota formation in central and northern Kansas and had them analyzed by R. E. Grim, petrographer, Illinois Geological Survey. Plummer (personal communication) reports that in general the clays analyzed contained about 75 percent kaolinite, and that the remaining 25 percent consisted chiefly of illite (group of micalike clay minerals) but also in small part of clay minerals of the montmorillonite group. Base-exchange is thought to have occurred at places where the water-bearing sandstones are in contact with clay beds or by contact with the admixed clay in the sandstones themselves.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Pre-Permian Rocks

Comparatively meager data are available concerning the strata beneath the Permian rocks in Finney and Gray counties. The nearest outcrops of these older rocks are in the central and eastern parts of the state, more than 200 miles east of the area under consideration. These older rocks dip westward beneath younger strata and, therefore, are known in western Kansas only from deep oil and gas tests.

Only five wells have been drilled deep enough to penetrate pre-Permian strata beneath Finney and Gray counties. The oldest rocks encountered by deep drilling are sandy cherty dolomites (Arbuckle limestone) of Cambro-Ordovician age. Moss (1932, p. 39) states that the Arbuckle limestone probably is more than 300 feet thick beneath most parts of Ness and Hodgeman counties, but in places may be thin or entirely missing. The Champlin Refining Company's oil test in the NE¼ SW¼ sec. 34, T. 28 S., R. 29 W., Gray county, penetrated 119 feet of Arbuckle limestone at a depth of 6,386 feet to 6,505 feet. Two deep oil tests in Finney county encountered the Arbuckle limestone; the National Refining Company's test in the SW¼ sec. 13, T. 23 S., R. 30 W., penetrated the Arbuckle at a depth of 5,608 feet to 5,872 feet, and a test drilled in sec. 24, T. 22 S., R. 29 W., penetrated it at a depth of 5,470 feet to 5,556 feet (Ver Wiebe, 1938, p. 56). None of these tests were drilled through the Arbuckle limestone, so the total thickness is not known.

Rocks belonging to the Ordovician system were encountered above the Arbuckle limestone in the three deep oil tests mentioned above. The upper part of the Ordovician in this area, where present, consists of cherty, dolomitic limestone (Viola limestone), and the lower part consists of sand and sandy shale (Simpson group). It is doubtful whether these Ordovician rocks are present everywhere beneath Finney and Gray counties, for pre-Mississippian erosion has probably removed part or all of them locally. The Viola limestone was encountered at a depth of about 6,190 feet in the oil test drilled in sec. 34, T. 28 S., R. 29 W., and the Simpson group was penetrated at a depth about 6,350 feet. In the oil test drilled in sec. 13, T. 23 S., R. 30 W., the Viola was encountered at a depth of 5,405 feet and the Simpson at 5,580 feet (Ver Wiebe, 1938, p. 56). In sec. 24,

T. 22 S., R. 29 W., the Viola was topped at 5,315 feet and the Simpson at 5,460 feet (Ver Wiebe, 1938, p. 56).

Rocks of Mississippian age are found unconformably overlying the Viola limestone. No strata of Silurian or Devonian age have been recognized in deep drillings in this area. The Mississippian system is characterized by massive limestone, which is sandy and oölitic near the top and contains cherty zones lower down (Ver Wiebe, 1940, p. 37). In the Atlantic Refining Company's Eva Nunn well, in sec. 27, T. 21 S., R. 34 W., the top of the limestone was reached at 4,616 feet. The well was drilled to a total depth of 4,718 feet but did not reach the base of the limestone. An oil test drilled in sec. 13, T. 23 S., R. 30 W., encountered the limestone at a depth of 4,742 feet to 5,405 feet, and an oil test drilled in sec. 24, T. 22 S., R. 29 W., encountered it at a depth of 4,655 feet to 5,315 feet (Ver Wiebe, 1938, p. 56). The oil test in southern Gray county in sec. 34, T. 28 S., R. 29 W., encountered limestone of Mississippian age between depths of about 5,125 feet and 6,180 feet.

Overlying the limestone of Mississippian age in this area is more than 1,200 feet of strata belonging to the Pennsylvanian system. The Pennsylvanian rocks consist predominately of limestone with interbedded gray, black, and red shales. Ver Wiebe (1938, p. 54) states that the upper part (Wabaunsee group) of the Pennsylvanian in this area is very limy, but contains thin shale beds and thin sandy zones. The next lower group of rocks (Shawnee group) consists predominately of limestone, which is cherty in the lower part. The Shawnee group is about 300 feet thick in most places in Finney county. The Shawnee group is underlain by a series of shales belonging to the Douglas group. Below these shales is from 400 to 500 feet of limestone (Lansing-Kansas City-Bronson age), which contains a great deal of chert.

Red rock, sandy shales, and thin limestone beds are found beneath the thick limestones. Ver Wiebe (1938, p. 54) believes that this shaly zone probably represents the Marmaton group * of eastern Kansas, but part may be equivalent to the Cherokee shale of southeastern Kansas. A conglomerate has been found at the base of the Pennsylvanian system in some wells (Ver Wiebe, 1938, p. 54).

* As defined by the Kansas Geological Survey.

Permian System

UNDIFFERENTIATED REDBEDS

Character.—Rocks belonging to the Permian system are not exposed in Finney and Gray counties and, as the only data available are the logs of a few oil and gas tests drilled in this area, no detailed description of the lithology can be given. The upper part of the Permian system (Guadalupian-Leonardian series), which is chiefly nonmarine in origin, is composed of red siltstone, shale, and sandstone with lesser amounts of salt, gypsum, anhydrite, limestone, and dolomite. The lower part, or Wolfcampian series, is largely marine in origin and is composed chiefly of limestone, dolomite, and shale, but also contains some sandstone and anhydrite.

Distribution and thickness.—Permian rocks underlie all of Finney and Gray counties. The nearest outcrops, however, are in Meade and Clark counties, Kansas, where the upper series (Guadalupian) of strata is exposed at the surface. The thickness of the Permian rocks as obtained from the logs of oil tests is approximately 2,300 feet in Finney county. No data are available on the thickness of the Permian strata in Gray county, but it is thought to be somewhat thicker there than in Finney county. Approximately 3,000 feet of Permian sediments are reported to underlie Ford county (Waite, 1942, p. 135), which adjoins Gray county on the east.

Correlation.—The Permian strata underlying Finney and Gray counties are known to include representatives of all groups from the Whitehorse to the Admire. The Quartermaster group, which overlies the Whitehorse group and includes the Taloga formation and the Day Creek dolomite, may be present in some areas, but has not been encountered in any of the oil and gas wells drilled to date. Norton (1939, p. 1763) has recognized beds younger than the Whitehorse in an oil well drilled about 3 miles north of Finney county, in sec. 14, T. 20 S., R. 33 W., Scott county.

The classification and nomenclature of the Permian strata used in this report follow those given by the State Geological Survey of Kansas (Moore, 1940, pp. 42-44) and differ somewhat from the classification and nomenclature used in other reports.

Water supply.—No wells obtain water from Permian beds in Finney and Gray counties. Deep wells drilled to the Permian probably would find some water in the sandstone formations, but experience in other areas indicates that the water would be too highly mineralized for most uses. The great depth and the poor quality of the water has prohibited the drilling of water wells to the Permian. In most places in Finney and Gray counties, there is an abundance of water in the overlying rocks.

Cretaceous System

INTRODUCTION

Cretaceous rocks including the Greenhorn limestone, Carlile shale, and Niobrara formation are exposed at the surface in Finney and Gray counties. The outcrops of these formations are shown on plate 1. Cretaceous rocks lying below the Greenhorn limestone are not exposed in this area and, therefore, are known only from subsurface data.

Various classifications have been applied to the series of Cretaceous sandstones and shales that lie below the Graneros shale in Kansas and adjacent areas. In February, 1942, several conferences were held in Lawrence by geologists of the State and Federal Surveys to discuss and adopt a uniform classification for these Cretaceous rocks. It was proposed to retain the use of the terms Cheyenne sandstone and Kiowa shale, and to restrict the term Dakota formation to include only those nonmarine beds classed as Upper Cretaceous that lie between the base of the Graneros shale and the top of the Kiowa shale. The term Dakota formation was formally adopted for use in all counties in the main area of outcrop in central Kansas. It was decided to retain use of the term Cockrum sandstone in Stanton and Morton counties (Latta, 1941; McLaughlin, 1942). For a more complete review of the history of the naming of these early Cretaceous units the reader is referred to a report by Waite (1942, pp. 135-137). Plummer and Romary (1942, p. 319) have redefined and subdivided the Dakota formation according to the present usage of the State Geological Survey of Kansas. Usage of the term Dakota formation is followed in the present report on Finney and Gray counties.

CHEYENNE(?) SANDSTONE

Character.—The Cheyenne(?) sandstone does not crop out in Finney or Gray counties, and it has been penetrated only by deep oil and gas wells. Few data concerning the character and thickness of the Cheyenne(?) sandstone have been gained from the study of the logs of these wells owing to the lack of detail. The formations encountered below the Greenhorn limestone and above the Permian redbeds are similar in character and, therefore, are generally logged as one unit by oil-well drillers and described as a "group" by oil geologists.

The nearest outcrop of the Cheyenne sandstone is in south-central Kansas in Kiowa, Barber, and Comanche counties. Here the Cheyenne sandstone consists dominantly of light gray to yellow quartz sandstone, but contains minor amounts of sandy shale. Although light gray and yellow are the dominant colors, the sandstone in places is white or is stained tan, brown, red, and purple. The grains of the sandstone range in size from very fine sand to fine gravel. In some beds the texture of the sandstone is very fine, but other beds are conglomeratic—containing small pebbles of weathered chert, quartz, and clay. Locally a thin pebble zone occurs near the base of the formation. Common in this zone are pebbles of gray and pink quartzite, chert, and quartz that are as large as 3 inches in diameter. Pyrite crystals, needles of selenite, and concretions of limonite are locally common. The bedding of the sandstone is very irregular and discontinuous, cross bedding being extremely common throughout the formation. The formation as a whole is made up of lenses of limited lateral extent. Interbedded with the lenses of sandstone are pockets and lenses of sandy shale, and in places the sandstone grades laterally into sandy shale.

Distribution and thickness.—The presence of the Cheyenne(?) sandstone beneath Finney and Gray counties is inferred by the great thickness of sediments lying below the Greenhorn limestone and above the Permian redbeds, and by the presence of this sandstone beneath adjoining areas. According to McLaughlin (1943, p. 118), the Cheyenne sandstone underlies all of Hamilton and Kearny counties, where it ranges in thickness from 33 to about 65 feet. A test hole drilled near the southwestern corner of Ford county penetrated at least 70 feet of sediments that have been tentatively assigned to the Cheyenne sandstone (Waite, 1942, p. 139). In southeastern Kiowa county, where the Cheyenne sandstone is exposed, the thickness ranges from about 30 to 50 feet. The variable thickness of the Cheyenne sandstone may be attributed to the uneven erosion surface upon which it was deposited.

Age and correlation.—On the basis of scanty data, it is thought that a part of the sequence of sandstones and shales encountered above the Permian redbeds in this area is correlative with the Cheyenne sandstone of the type locality in southeastern Kiowa county. No data are available concerning the exact age of these beds in Finney and Gray counties, however. The Cheyenne sandstone at the type locality represents the oldest Cretaceous formation found in Kansas. Fossils collected from this sandstone in Texas county, Oklahoma, and other areas were identified and found to be Washita (Lower Cretaceous) in age (Schoff, 1939, p. 55).

Origin.—Owing to the lack of outcrops and to the meager well-log data, it is impracticable to discuss the origin of the Cheyenne (?) sandstone in Finney and Gray counties. Schoff (1939, p. 55) found marine pelecypods in this sandstone in Texas county, Oklahoma, which he says is conclusive evidence of marine origin. He also states that—

> The fine- to medium-grained sand of which the sandstone is composed suggests deposition in moderately shallow water off shore, rather than on or near the beach, where wave activity is ordinarily greatest.

The discontinuity of bedding, the cross-lamination, the assortment of the sands, the presence of land plants, and the absence of shells of marine animals in the sandstone in south-central Kansas suggested a continental stream origin to Twenhofel (1924, pp. 18-20). It is altogether possible that both writers are correct in their interpretations, and that the origin of the Cheyenne sandstone or its equivalent is not everywhere the same but that at some places it may be continental and at others marine.

Water supply.—No wells have penetrated the Cheyenne (?) sandstone in this area in search of a water supply because of the great depth to which they would have to be drilled. Sufficient quantities of water for most purposes generally are obtained from higher formations.

A few wells in the Arkansas valley in Hamilton county obtain water from the Cheyenne sandstone—artesian water being encountered by wells that tap the sandstone at Coolidge. The wells are 285 to 325 feet deep but the water rises nearly to or above the land surface (McLaughlin, 1943, p. 119). There are also wells at Syracuse and Kendall that obtain water from the Cheyenne sandstone. The water from the Cheyenne sandstone in Hamilton county is moderately hard, but is satisfactory for most purposes. Water from the Cheyenne sandstone in southeastern Kiowa county, however, is usually too highly mineralized for ordinary uses.

KIOWA (?) SHALE

Character.—There are no surface exposures of the Kiowa (?) shale in the area under discussion. All of the oil and gas tests drilled in Finney and Gray counties probably penetrated the Kiowa (?) shale, but owing to the lack of detail in the logs of these tests the Kiowa (?)

shale cannot be differentiated from other Cretaceous formations. Test hole 18 (see log 18) in northern Gray county penetrated 267 feet of Cretaceous sediments below the base of the Greenhorn limestone, a part of which probably is equivalent to the Kiowa(?) shale. The lithology of the shales in this sequence differs somewhat from the Kiowa shale at the type locality in Kiowa county, Kansas. If the Kiowa shale or equivalent is not present in this test hole, the Dakota formation must be much thicker here than it is in adjacent areas. The Kiowa at the type locality in southeastern Kiowa county consists of shales with interbedded thin limestones. The shales in the lower part are black and are so thinly laminated that they are often referred to as paper shales. In the upper part the shales generally are gray to blue and are more limy than the shales in the lower part. Fossils are rare in the black shales, but they commonly are found in the upper lighter-colored shales. Thin beds of limestone consisting almost entirely of oyster shells are found throughout the formation. A few sandstone beds and lenses are found in the Kiowa shale, and gypsum, generally in the form of selenite, is common throughout.

Distribution and thickness.—The Kiowa(?) shale probably underlies most or all of Finney and Gray counties. McLaughlin (1943, p. 120) believes that the Kiowa shale underlies all of Kearny county, which borders Finney county on the west, and Waite (1942, p. 140) states that the shale underlies the southern part of Ford county, but it is not definitely known whether or not it is present under the northern part of Ford county. A bluish-gray shale containing fragments of fossils encountered in the Phillips-Hausman well, in sec. 30, T. 22 S., R. 22 W., Hodgeman county, was referred by Moss (1932, pp. 33, 34) to the Kiowa shale. Test holes drilled in northern Haskell county penetrated dark shales which probably belong to the Kiowa shale (McLaughlin, oral communication).

No data concerning the thickness of the Kiowa(?) shale are available from the area being described, but data from near-by areas indicate that the thickness ranges considerably. The Kiowa shale was 44 feet thick in a test hole drilled in sec. 27, T. 29 S., R. 26 W., in southwestern Ford county (Waite, 1942, p. 140). According to McLaughlin (1943, p. 120), the thickness of the Kiowa in Hamilton county ranges from 49 feet near Coolidge to 131 feet in the southeastern part of the county. A thickness of 160 feet is reported for the Kiowa shale in a section at Avilla Hill in southern Comanche county (Twenhofel, 1924, p. 25).

Water supply.—The Kiowa(?) shale, except for the sandy horizons, is relatively impermeable and supplies little or no water to wells. No wells are known to derive water from the Kiowa(?) shale in Finney and Gray counties.

DAKOTA FORMATION

Character.—The Dakota formation is not exposed in Finney and Gray counties, but was encountered in six test holes drilled during the course of the present investigation (see logs 15, 16, 18, 24, 26, and 27). The logs of these test holes indicate that the Dakota formation consists of sandstone and shale or clay, and that the larger part of the formation is composed of light gray, yellow-tan, yellow, and brown shale and sandy shale. Sandstone concretions and charcoal are found in the shale in some places (see log 26). Interbedded with the shale and clay are beds of fine- to medium-grained sandstone that range in color through light gray, tan, buff, red, reddish-brown, and brown. The beds of sandstone encountered by test drilling ranged in thickness from a few inches to about 15 feet. The sandstones probably occur as lenses of limited extent and not as massive beds of great geographic extent. Iron oxide seems to be the dominant cementing agent in the sandstones.

By studying the outcrops of the Dakota formation in Hamilton county, McLaughlin (1943, p. 121) found that 40 to 45 percent of the formation consists of varicolored clay. Gray to buff, fine-grained, irregularly bedded sandstone constitutes the rest of the formation in Hamilton county. The ratio of sandstone to clay in the Dakota formation differs from place to place. Only about one-fourth of the formation is sandstone in Ness and Hodgeman counties (Moss, 1932, p. 32). This same ratio exists throughout most of the outcrop area of the Dakota formation in the central and northern part of the state.

The topmost beds of the Dakota formation grade into the overlying Graneros shale so that there is no sharp contact between the two. In southern Finney county and parts of southern Gray county, pre-Ogallala erosion has removed all Cretaceous sediments above the Dakota formation so that silts, sands, and gravels of the Ogallala formation (Pliocene) unconformably overlie the Dakota formation (figs. 8 and 9). The Dakota formation is underlain conformably by the Kiowa(?) shale.

Distribution and thickness.—The Dakota formation underlies all of Finney and Gray counties, but is not exposed at the surface.

In addition to the six test holes listed above, the Dakota formation has been encountered by all oil and gas tests drilled in the two counties and by wells 500 and 526 (see logs 52 and 56) in southern Gray county. Possibly other wells in southern Gray county not visited during the investigation also penetrate beds of the Dakota formation. The nearest outcrop of the formation is near Hartland in Kearny county; other outcrops are in southern Hamilton county and western Stanton county on the west and in southern Hodgeman county and northern and east-central Ford county on the east. The formation is also exposed at the surface in a small area in south-central Kansas and throughout a large area in the central and northern part of the state (Moore and Landes, 1937).

No dependable data are available concerning the thickness of the Dakota formation in the area being described. The test holes and wells that encountered the formation penetrate only the upper part, and the logs of the oil and gas tests are not sufficiently detailed to permit differentiation of the Cretaceous formations. The thickness of the Dakota formation in Hamilton county ranges from 130 feet in the southern part of the county to 314 feet at Kendall in the eastern part of the county (McLaughlin, 1943, p. 121). The Dakota formation penetrated by a test hole in sec. 27, T. 29 S., R. 26 W., in southwestern Ford county, was only 56 feet thick, but in the northeastern part of Ford county a water well penetrated about 235 feet of the Dakota (Waite, 1942, p. 144). It can be seen from these examples that, because of the lenticular nature of the Dakota formation, its thickness ranges within wide limits.

Age and correlation.—The age and correlation of the Dakota formation are briefly discussed under the introduction to the section on the Cretaceous system on page 141.

Water supply.—At most places in Finney and Gray counties, adequate supplies of water are obtained from formations above the Dakota formation, but in a few places in the southeastern part of Gray county the sediments above the Dakota contain very little or no water and it is necessary to penetrate the Dakota in order to obtain an adequate supply. In these places the water table is below the sands and gravels of Pliocene and Pleistocene age that supply water to most of the wells in other areas in Finney and Gray counties (fig. 9). Two (wells 500 and 526) of the 543 wells visited in Finney and Gray counties obtain water from the Dakota formation. Both of these wells are in the southeastern part of Gray county.

Well 500, in the NW¼ sec. 24, T. 28 S., R. 27 W., is a domestic well 421 feet deep. According to George Slocum, driller, water-bearing sandstone (Dakota formation) was encountered in this well at a depth of 408 to 421 feet (see log 52). The water rose about 200 feet above the point at which it was first encountered. On December 4, 1940, the depth to water level in the well was measured and found to be 204.1 feet below land surface.

Well 526, in the NE¼ sec. 4, T. 29 S., R. 28 W., penetrated two sandstones separated by 59 feet of blue-black shale. According to the driller, the upper sandstone, which was encountered between depths of 280 and 292 feet, was very hard and yielded but little water. The lower sandstone, encountered between depths of 351 and 365 feet, was reported to be softer and coarser grained than the upper sandstone and to yield an adequate supply of water to the well. When the water-bearing sandstone was penetrated, the water rose more than 200 feet in the well. The depth to water level in the well is reported to be 130 feet below land surface.

Although water in the Dakota formation generally rises under artesian pressure, the water rises to a level approximately equal to that of the normal water table; hence there are no flowing wells in this area. The Dakota formation supplies water to flowing artesian wells in near-by areas, however. Flowing wells in Sawlog valley in southern Hodgeman county obtain water from the Dakota formation (Moss, 1932, pp. 45, 46). The wells start near the top of the formation and obtain artesian water at a depth of about 200 feet. Waite (1942, p. 145) reports that a flowing well (520, Ford county) in the NW¼ sec. 35, T. 29 S., R. 26 W., in southwestern Ford county, obtains a part of its water from the Dakota formation. A flowing well at Coolidge in western Hamilton county is in the Dakota formation (McLaughlin, 1943, p. 126).

Analyses of the waters from the two wells (500 and 526) that tap the Dakota formation in Gray county are shown graphically in figure 20. The waters from both wells are soft sodium bicarbonate waters having respectively 433 and 296 parts per million of total dissolved solids, 150 and 70 parts of sodium and potassium, 266 and 207 parts of bicarbonate, and 40 and 108 parts of hardness. The analyses indicate that the water in the Dakota formation in this area has undergone a natural softening process in which calcium bicarbonate water has exchanged its calcium and magnesium for sodium by a base-exchange process. A detailed discussion of the process of base-exchange is given on pages 136 and 137. Both waters analyzed contain fluoride in undesirable amounts; the water from well 500 had 4.2 parts per million of fluoride and the water from well 526 had 1.8 parts.

GRANEROS SHALE

Character.—Conformably overlying the Dakota formation is the Graneros shale, which consists of gray, noncalcareous shale and a few thin beds or lenses of sandstone and sandy shale. The Graneros shale is not exposed in Finney and Gray counties, and only one test hole (No. 18) penetrated the formation. The top of the Graneros shale was encountered at a depth of 350 feet in test hole 18 (log 18). Generally there is a sharp lithologic break between the noncalcareous Graneros shale and the overlying calcareous beds of the Greenhorn limestone. The contact between the Graneros shale and the underlying Dakota formation is not distinct in many places, but consists of a transition zone in which sandstones and shales of the Dakota formation grade upward into sandstones and sandy shales of the Graneros shale. It was not practicable, therefore, to determine the lower contact of the Graneros in test hole 18.

The nearest exposure of the Graneros shale is along Sawlog creek in northern Ford county and southern Hodgeman county. The shale in northern Ford county generally is dark bluish-gray to black, but contains numerous flakes of yellow sandstone and an abundance of selenite crystals (Waite, 1942, p. 146). Transparent crystals of selenite, some of which are 6 inches or more in length, generally are found strewn along the outcrops. Interbedded in the shale are many thin lenses of sandy shale, sandstone, sandy limestone, and ironstone concretions.

The Graneros shale in Hamilton county consists of gray-black, fissile, argillaceous shale with a 5- to 16-inch bed of bentonitic clay about 10 feet below the top (McLaughlin, 1943, p. 126). It also contains 5 to 6 feet of thin-bedded fossiliferous limestone 20 to 22 feet above the base of the formation.

Distribution and thickness.—The Graneros shale probably underlies all but the southern part of Finney and Gray counties, as shown by the geologic profiles in figures 8 and 9. The Graneros shale is 21 to 36 feet thick in Ness and Hodgeman counties (Moss, 1932, p. 31), a few feet to about 43 feet thick in Ford county (Waite, 1942, p. 148), 61 feet thick in Hamilton county (McLaughlin, 1943, p. 128), and about 200 feet thick in Otero county, Colorado (Dane, Pierce, and Reeside, 1937, p. 210). The thickness of the shale in Finney and Gray counties is not known, but it probably is between 40 and 50 feet. According to Dane, Pierce, and Reeside (1937, p. 210) the Graneros probably thickens westward at the expense of the overlying Greenhorn limestone, for the Greenhorn seems to be much thinner in Colorado than in western Kansas.

Water supply.—No wells are known to obtain water from the Graneros shale in Finney and Gray counties. The quantity of water contained in the shale and interbedded lenses of sandstone probably is small because of the relatively low permeability of the sediments.

GREENHORN LIMESTONE

Character.—The Greenhorn limestone consists of thin chalky and crystalline limestones separated by thicker beds of chalky shale that contain thin beds of bentonite. In the upper part of the formation limestone concretions occur in the shales. The limestones and shales are light to dark gray when they are brought up in a drill hole and the bentonites are light pearly-gray. Weathering changes the color of the limestones to tan, buff, or orange-tan and the shales to tan, light gray, or orange-tan. The bentonites weather to red-brown or orange. The Greenhorn limestone grades upward into chalky shale beds of the overlying Fairport chalky shale member of the Carlile shale, but is sharply separated from the underlying Graneros shale.

The Greenhorn limestone has been divided into four members in central-western Kansas which, from top to bottom, are the Pfeifer shale, Jetmore chalk, Hartland shale, and Lincoln limestone members. Only a small part of the Greenhorn is exposed in the Finney-Gray area. The following descriptions of the lithologic character of the members have been adapted in part from Moss (1932, pp. 26-31), who described in detail the members in Ness and Hodgeman counties.

The Pfeifer shale member of the Greenhorn limestone consists of chalky shale and some thin limestone beds and limestone concretions. At the top of the member is a chalky limestone known as the "Fence-post" limestone, which is resistant to erosion and generally forms a ledge. The Pfeifer weathers to a tan or cream color. In western Hodgeman county its thickness is 19 feet. The lower part of the member is exposed in a quarry in the NW¼ sec. 17, T. 29 S., R. 27 W., in southeastern Gray county (pl. 9), where the following section was measured.

Section of the Pfeifer shale and Jetmore (?) chalk members of the Greenhorn limestone in a quarry in the NW¼ sec. 17, T. 29 S., R. 27 W., Gray county.

	Thickness, feet
Pleistocene	
Greenhorn limestone	
Pfeifer shale member	
6. Shale, chalky, thinly laminated, yellow, buff, and brown	1.0
5. Limestone, hard, chalky, yellow-tan	0.3
4. Shale, chalky, thinly laminated, buff to brown	0.4
3. Limestone, chalky, yellow to white	0.3
2. Shale, chalky, thinly laminated, yellow to white, containing thin beds of red-orange bentonite	2.5
Jetmore (?) chalk member	
1. Limestone, hard, chalky, fossiliferous, yellow-tan	1.7
Total thickness exposed	6.2

The Jetmore chalk member of the Greenhorn limestone consists of a series of thin chalky limestone beds separated by chalky shales. The chalky limestones are 3 to 6 inches thick and weather to white or light tan. The shales are 1 to 2 feet thick and weather to tan or orange-tan. Capping the member is a hard, fossiliferous limestone called "shell rock," which contains an abundance of the pelecypod *Inoceramus labiatus*. Bed 1 in the measured section given above contains an abundance of this fossil and probably represents the capping bed. The Jetmore chalk member is the most resistant part of the Greenhorn limestone, and where exposed it forms a prominent ledge. At the type locality south of Jetmore in central Hodgeman county the member is 22 feet thick.

The two lower members of the Greenhorn limestone, the Lincoln limestone and Hartland shale members, are not easily differentiated in this area. The upper part of the Lincoln-Hartland members consists of calcareous shale and thin beds of chalky limestone, and the lower part consists of chalky shale and thin beds of crystalline limestone. A few beds of bentonite 1 to 5 inches thick occur in the lower part of the Greenhorn. The upper part of the Lincoln-Hartland members weathers to light tan or gray and the lower part to orange-tan or buff. The aggregate thickness of the two members is about 80 feet.

Bass (1926, pp. 66-69) recognized only three members of the Greenhorn limestone in Hamilton county—the Bridge Creek limestone, Hartland shale, and Lincoln limestone members. According to Bass (1926, p. 69), the uppermost 25 feet of the Bridge Creek member of Hamilton county is equivalent to the Pfeifer shale member of Ellis county, and the remainder of the Bridge Creek member

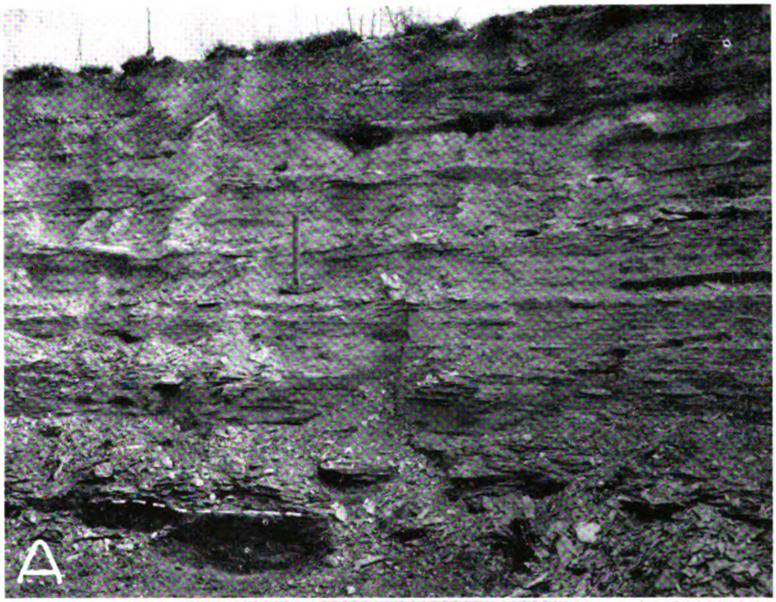


PLATE 9. *A*, A part of the Pfeifer shale (above dashed line) and Jetmore(?) chalk (below dashed line) members of the Greenhorn limestone. In a quarry in NW¼ sec. 17, T. 29 S., R. 27 W., Gray county. *B*, A part of the Fort Hays limestone member of the Niobrara formation. In a draw in the SE¼ sec. 22, T. 21 S., R. 30 W., Finney county.

probably represents the Jetmore chalk member of central-western Kansas.

The harder limestone beds of the Greenhorn have been quarried in some places and used for fence posts and building stone. The "Fencepost" limestone has been used extensively for fence posts, buildings, road culverts, and other works. The hard limestone bed at the top of the Jetmore(?) chalk member of the Greenhorn has been quarried in the NW¼ sec. 17, T. 29 S., R. 27 W., in southeastern Gray county, where it has been used mostly as a building stone by farmers living near by.

Distribution and thickness.—The area of outcrop of the Greenhorn limestone in the Finney-Gray area covers less than a quarter of a square mile in southeastern Gray county (pl. 1). The section exposed here includes the lower part of the Pfeifer shale member and the upper 1.7 feet of the Jetmore(?) chalk member. The Greenhorn underlies most of the area north of Arkansas river in Finney and Gray counties and a large area south of the river in Gray county. It has been removed by pre-Pliocene erosion in the southern part of Finney county and in the extreme southern, east-central, and western parts of Gray county (figs. 8 and 9). In a large area in central Gray county, the Greenhorn limestone is unconformably overlain by Pliocene (Ogallala formation) deposits and only the lower part of the Greenhorn is present (fig. 9, DD′).

The thickness of the Greenhorn limestone in the Finney-Gray area is about 130 feet.

Age and correlation.—The section of Greenhorn limestone exposed in the quarry in the NW¼ sec. 17, T. 29 S., R. 27 W., in southeastern Gray county, has been correlated with the Pfeifer shale and Jetmore (?) chalk members of the Greenhorn on the basis of lithology and fossil content. Because of its hardness and abundant content of the fossil *Inoceramus labiatus*, the lower bed (bed 1) in this section is correlated with the hard "shell rock" found in other areas at the top of the Jetmore chalk member. The chalky shale and interbedded thin limestone beds found above bed 1 in the section are lithologically similar to beds of the Pfeifer shale member in other areas.

Where the Greenhorn limestone is buried and is known only from drill cuttings, it is generally not possible to differentiate between the members. The lower beds of the Fairport chalky shale member of the Carlile shale are similar in character to the upper beds of the Greenhorn limestone making it difficult to determine the Carlile-

Greenhorn contact by the study of drill cuttings. The base of the Greenhorn limestone is easily identified from drill cuttings by a change from calcareous shale and limestone of the basal part of the Greenhorn to noncalcareous softer and darker clay-shale of the Graneros shale.

Water supply.—According to Mr. George Slocum, well driller, water is generally found in the chalky limestone (Greenhorn) that lies above the dark shales in the vicinity of the quarry in southeastern Gray county. The water probably occurs in fractures and solution openings in the limestone. The water-yielding capacity of the formation probably is comparatively low; however, small supplies might be obtained by wells penetrating this formation. None of the wells visited in the Finney-Gray area are known to obtain water from the Greenhorn limestone, but there may be a few wells in southeastern Gray county that obtain water from this formation.

CARLILE SHALE

Character.—The Carlile shale, which conformably overlies the Greenhorn limestone, consists predominantly of dark blue to black, noncalcareous, fissile clay-shale, chalky shale, and thin beds of chalky limestone. It is composed of three members, which are, from oldest to youngest, the Fairport chalky shale member, the Blue Hill shale member, and the Codell sandstone member.

The Fairport shale member of the Carlile constitutes about the lower one-third of the formation. It is not exposed in the Finney-Gray area, but was encountered in test holes 8, 9, 10, 13, 18, 19, and 21. The drill cuttings indicate that this lowest member of the Carlile shale consists predominantly of dark gray to black and yellow-tan calcareous shale containing some gray limestone, flakes of calcite, and hard, fine-grained concretions. Exposures of the Fairport shale member in Ness and Hodgeman counties show thick beds of chalky shale alternating with thin beds of chalk or chalky limestone (Moss, 1932, p. 23). The shale and chalk beds are tan, orange-tan, buff or light gray. Many thin, flat concretions occur in the lower part of the Fairport shale member and a few beds of bentonite occur in the shale. On a fresh surface the bentonite is white but weathers to a rusty-brown. The member contains many poorly preserved fossils. According to Moss (1932, p. 26), the most common fossils are *Inoceramus fragilis*, *Prionotropis woolgari*, *Ostrea congesta*, *Globigerina*, *Gumbelina*, and *Serpula plana*.

The Blue Hill shale member of the Carlile constitutes most of the upper two-thirds of the Carlile shale in the Finney-Gray area. The

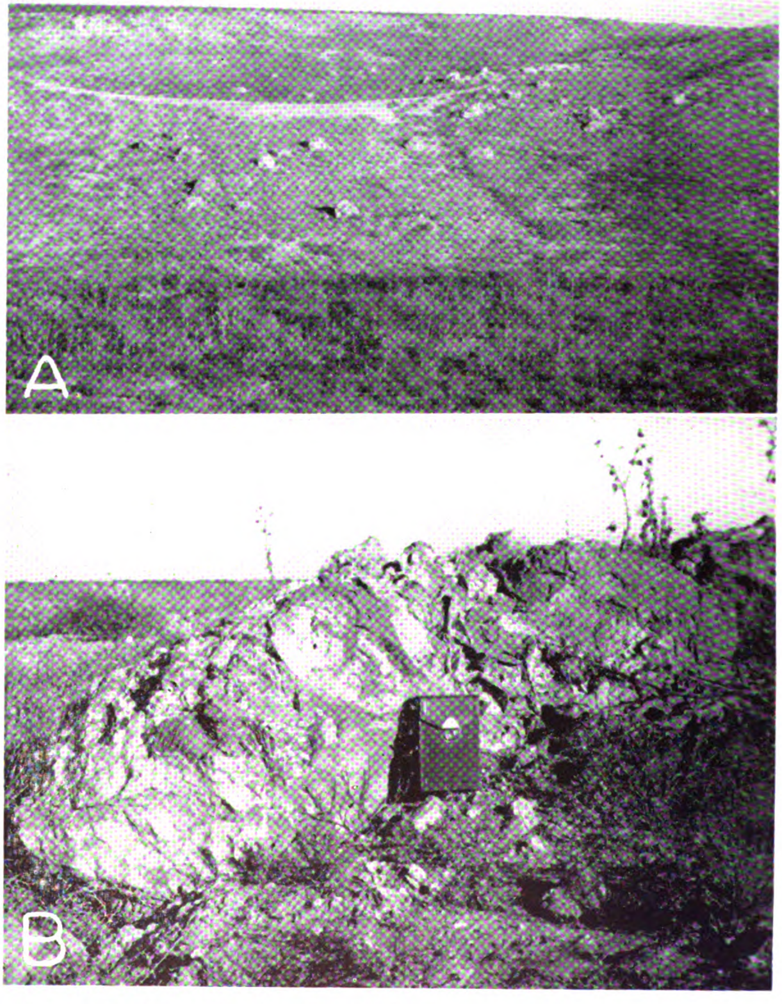


PLATE 10. Concretions in the Blue Hill shale member of the Carlile shale. *A,* Slope strewn with large septarian concretions that have weathered out of the shale. (NW¼ sec. 13, T. 22 S., R. 29 W., Finney county.) *B,* Close-up view of one of the concretions shown above. Note the septaria of calcite just above the camera case.

upper part of the member is exposed in a wide strip along the Pawnee valley in northeastern Finney county (pl. 1), and was encountered by test holes 1, 2, 6, and 7. The member consists of dark gray, bluish-black, and black noncalcareous shale containing thin seams of gypsum, selenite (gypsum) crystals, and in the upper part a zone of large septarian concretions. The Blue Hill shale member forms relatively steep, and in many places barren, slopes on the north side of Pawnee river, where it is overlain by the Fort Hays limestone member of the Niobrara formation. On the south side of the valley the Fort Hays limestone member of the Niobrara has been removed by erosion, and as a result the slopes formed by the Blue Hill shale member of the Carlile shale are gentle and in most places sparsely covered by vegetation. In places the slopes are strewn with large calcareous septarian concretions (pl. 10), which generally are several feet in diameter—the largest one observed in this area being about 6 feet long and about 2 feet in diameter. They are composed of bluish-gray, dense limestone with septaria of calcite. Some have a cone-in-cone structure developed as a layer on the outside surface. Moss (1932, p. 23) states that *Prionotropis woolgari, Inoceramus fragilis,* and species of *Scaphites* are commonly found in the concretions.

At the top of the Carlile shale is a sandy zone, which is equivalent to the Codell sandstone member of other areas. The term Codell sandstone bed was originally used in Ellis county as the name of the sandy bed at the top of the Blue Hill shale member (Bass, 1926, p. 28). Dane, Pierce, and Reeside (1937, p. 215) pointed out, however, that it was not desirable to apply names to units of less than member rank and, therefore, considered the Codell sandstone in eastern Colorado as a member of the Carlile shale, equivalent in rank to the Blue Hill shale and Fairport chalky shale members. Moore (1940, pp. 39, 40) also considers the Codell sandstone as a member of the Carlile shale. The Codell sandstone member in the Finney-Gray area consists of dark gray to black, noncalcareous, sandy shale and shaly sandstone. No true sandstone was noted in this area. The Codell sandstone member of the Carlile was encountered by test holes 1, 3, and 4.

The following measured section indicates the character of the Blue Hill shale member of the Carlile shale and the Fort Hays limestone member of the Niobrara formation. No sandy shale or sandstone (Codell sandstone member) was noted at the top of the Carlile shale at this locality.

Section of Fort Hays limestone member of the Niobrara formation and Blue Hill shale member of the Carlile shale in the N½ sec. 2, T. 22 S., R. 29 W., Finney county.

	Thickness, feet
Niobrara formation	
Fort Hays limestone member	
2. Limestone, chalky, fossiliferous, white. Weathers into small blocks	48.5
Carlile shale	
Blue Hill shale member	
1. Shale, fissile, blue-gray, containing large septarian concretions, thin seams of gypsum, and selenite crystals	92.0
Total thickness exposed	140.5

Distribution and thickness.—The Carlile shale is present either at the surface or below the surface nearly everywhere in Finney and Gray counties north of the 2,550-foot contour line shown in figure 7. All of the Carlile shale south of this line and part of the Carlile north of this line was eroded away during the period of erosion that preceded the deposition of Tertiary sediments (figs. 8 and 9). Only the upper part of the Carlile shale is exposed along the Pawnee valley in the "panhandle" or northeastern part of Finney county (pl. 1).

The base of the Carlile shale is not exposed in the Finney-Gray area and none of the test holes penetrated the entire formation, so the total thickness is not known with certainty. A core hole drilled by the Phillips Petroleum Company north of Ransom in Trego county encountered 261 feet of Carlile shale (Moss, 1932, p. 24). According to Bass (1926, pp. 26, 30), the Carlile shale is about 300 feet thick in Ellis county where the Fairport chalky shale member of the Carlile ranges in thickness from 85 to 115 feet and the Blue Hill shale and Codell sandstone members together are 175 to 215 feet thick. The sandy shale of the Codell sandstone member is as much as 34.5 feet thick in the northwestern corner of Finney county (see log 1), but seems to be absent entirely in other parts of Finney and Gray counties. In Ness and Hodgeman counties, the sandy beds at the top of the Carlile shale are as much as 41 feet thick, but the sand generally is confined to the upper 15 to 20 feet (Moss, 1932, p. 22).

Water supply.—Because of their low permeability, most parts of the Carlile shale contain little or no water available to wells. No wells are known to obtain water from the formation in Gray county and only five (wells 1, 8, 46, 47, and 57) of the 400 wells visited in Finney county tap this formation. Wells 1 and 8 obtain meager supplies of water from a sandy shale in the Codell sandstone member, and wells 46, 47, and 57 tap the Blue Hill shale member. Of these five wells only well 1 is in use.

The Codell sandstone member of the Carlile yields adequate supplies of water to domestic and stock wells in other areas where it contains beds of permeable sandstone. In this area, however, the Codell sandstone member consists almost entirely of sandy shale having a relatively low permeability. The Blue Hill shale and Fairport chalky shale members of the Carlile consist almost entirely of shale, and in most places do not yield sufficient water to supply wells. Any movement of water through the Carlile shale would take place largely through bedding planes and fissures.

Of the five wells that tap the Carlile shale in Finney county, only one well (1) tapping the Codell sandstone member was sampled for analysis. The water from this well is a moderately hard calcium bicarbonate water containing 57 parts per million of calcium, 228 parts of bicarbonate, 259 parts of dissolved solids, 213 parts of hardness, and 1.4 parts of fluoride. This water is very similar in quality to that found in the Ogallala formation.

NIOBRARA FORMATION

Character.—The Niobrara formation consists of beds of chalky limestone, chalk, and chalky shale, and unconformably overlies the Carlile shale. The Niobrara is divided into two members—the Fort Hays limestone member below and the Smoky Hill chalk member above.

The Fort Hays limestone member is composed of thick massive beds of chalky limestone and chalk separated by thin beds of chalky shale (pl. 9 B). The limestone and chalk beds range in thickness from less than a foot to about 6 feet. The shale partings in most places are less than 4 inches thick. Weathered exposures of the Fort Hays limestone member are white, tan, or cream. The limestone in the lower part of the member generally is harder and less chalky than that found higher up in the member. In the N½ sec. 2, T. 22 S., R. 29 W., in northeastern Finney county, the lower part of the member is exposed at the top of a high hill where it forms a protective cap on the less resistant Carlile shale. Here the lower part of the Fort Hays limestone member consists of white, relatively hard limestone that weathers into small tabular pieces. Because of its resistance to erosion, the Fort Hays limestone member, where exposed, generally forms an escarpment. Exposures of the member in most places are strewn with pebbles of chalk which obscure the outcrop.

The contained fossils include *Inoceramus deformis, Ostrea congesta,* and abundant foraminifera (Moss 1932, p. 21).

The contact of the Fort Hays limestone member of the Niobrara with the underlying Carlile shale is marked by an abrupt change from the light-colored calcareous beds of the Fort Hays limestone member to the dark-colored noncalcareous beds of the Carlile shale. In places the contact is marked by a zone of sandy, noncalcareous shale (Codell sandstone member of Carlile shale).

Conformably overlying the Fort Hays limestone member is the Smoky Hill chalk member of the Niobrara formation. The Smoky Hill chalk member is not known to crop out in this area, but was encountered in test holes 1 and 2 (see logs 1 and 2). It consists of alternating beds of soft chalky shale and chalk. Where unweathered the beds are light to dark gray, but on weathered exposures they are white, tan, buff, or yellowish-pink (Moss, 1932, p. 15). Cuttings from test holes indicate that the beds all have the same general appearance and nearly the same hardness, but on weathered exposures even the thinnest beds stand out. According to Moss (1932, p. 15), the slight differences in the composition of different beds are brought out through differential erosion. Thin beds of bentonite and pyrite concretions are common in the member. The bentonite beds are light-colored when unweathered, but weather to a rusty-brown.

Both vertebrate and invertebrate fossils occur in the Smoky Hill chalk. Most of the large museums of the world have vertebrate fossils on exhibit that were taken from this member in central and western Kansas. They include birds, dinosaurs, crocodiles, mosasaurs, turtles, and fish. *Inoceramus grandis* and *Ostrea congesta* are most abundant among the larger invertebrates (Moss, 1932, p. 19). Foraminifera, chiefly *Globigerina* and *Gumbelina,* are abundant in the chalky beds, and, according to Moss (1932, p. 19), probably make up more than half of the calcareous material of the chalk.

It is generally difficult to determine the contact between the two members of the Niobrara formation on the basis of test-hole or well cuttings. On weathered exposures, however, differences of hardness and general lithology are more apparent. In comparing the two members, Bass (1926, p. 24) states that the Fort Hays limestone member seems slightly coarser in texture and is somewhat harder, that the individual beds are much thicker than those of the Smoky Hill chalk member, and that the percentage of shale is much smaller in the Fort Hays limestone member.

Distribution and thickness.—Only the Fort Hays limestone member of the Niobrara formation is exposed in the Finney-Gray area. It is exposed in a wide band above the Carlile shale north of Pawnee river in northeastern Finney county (pl. 1). Both members of the formation are present beneath younger sediments in the northern part of Finney county except in parts of the buried trough in the western part of the county (fig. 8). The Niobrara formation has been completely removed by erosion in Gray county except possibly in the extreme northwestern corner, where the lower part of the Fort Hays limestone member may be present under the Ogallala formation.

The thickness of the Niobrara formation in Logan county, Kansas, where it is overlain conformably by the Pierre shale, is approximately 800 feet (Moss, 1932, p. 15). Pre-Ogallala erosion, however, has truncated the Niobrara to the south and east so that the maximum remaining thickness of the formation in Finney county is only about 300 feet. Only the lower part of the Smoky Hill chalk member of the Niobrara formation is present in this area. The greatest thickness is in the north-central part of Finney county, where it is approximately 225 feet. The Fort Hays limestone member of the Niobrara is 55 feet thick at the northwestern corner of Finney county (see log 1). Moss (1932, p. 21) found the member to be 80 feet thick in Ness county, which adjoins Finney county on the northeast. No complete sections of the member are exposed in the outcrop area in Finney county, but it is thought that the thickness of the member in northeastern Finney county also is approximately 80 feet.

Water supply.—The Niobrara is not an important water-bearing formation in Finney and Gray counties. The beds of soft chalky shale and chalk that make up the Smoky Hill chalk member are relatively impervious and do not supply water to any wells in this area. The beds of chalky limestone of the Fort Hays limestone member, however, are moderately hard and, therefore, are subject to fracturing. These fractures and resulting solution openings afford passageways for the movement of ground water within the member. The success of a well penetrating the Fort Hays member depends entirely on whether or not fractures or solution openings are encountered. (See p. 49.)

Four of the recorded wells in Finney county obtain water from the Fort Hays limestone member of the Niobrara, two of which (wells 38 and 40) are in the northwestern part of Finney county where the Pliocene and Pleistocene sands and gravels are above the water table and, therefore, are barren of water. Both are dug wells and are reported to yield adequate supplies of water for domestic and stock use. Well 40 reportedly yielded a sufficient quantity of water for the drilling of two near-by oil wells. Wells 2 and 7 obtain water from the Fort Hays limestone member in the area of outcrop. Well 2, a dug stock well, is reported to have a very small yield, and well 7, which is a 6-inch drilled well, was abandoned because the yield was too small even for stock use.

Many small springs (nos. 15, 16, 17, 18, 63, 66, and 103) are fed by fractures in the Fort Hays limestone member in its area of outcrop in northeastern Finney county. The springs are all in the bottom or on the sides of draws tributary to Pawnee river. The estimated discharges of the springs range from about one pint to 3 or 4 gallons a minute. Twin Spring (66), in the SE¼ sec. 34, T. 22 S., R. 30 W., became famous in the early days as a stopping point for travelers. It was called Twin Spring because there were two openings through which water was discharged. In 1940, however, water was discharging from only one opening. The water issues from a fracture in the limestone at the rate of 2 or 3 gallons a minute.

One sample of water was collected from a well (38) tapping the Fort Hays limestone member. The water from this well is very similar to the sample of water from the Codell sandstone member of the Carlile shale and to many from the Ogallala formation. It had 290 parts per million of total solids, 238 parts of hardness, 54 parts of calcium, 266 parts of bicarbonate, and 1.0 part of fluoride. The content of iron and chloride was negligible.

Tertiary System

Laverne(?) Formation

Test holes 15 and 16 in southern Finney county encountered beds of clay and clay-shale above the Dakota formation that are of questionable age. Lithologically these deposits are unlike both the underlying Dakota formation and the overlying Ogallala formation. They consist of tan, brown, and gray silty blocky clay and clay-shale (see logs 15 and 16). About 18 feet of brown medium sand to fine gravel was encountered 12.5 feet above the base of the clay beds in test hole 16. The thickness of the clay was 47.5 feet in test hole 15 and 91.5 feet in test hole 16. A detailed microscopic study of the samples did not reveal any fossils.

On the basis of lithologic similarity and stratigraphic position these deposits are tentatively correlated with the Laverne formation, which is exposed above the Cretaceous rocks in southern Meade and Seward counties, Kansas, and in Beaver county, Oklahoma. The Laverne formation consists 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 (Frye and Hibbard, 1941, p. 398). Vertebrate fossils, ostracodes, and diatoms have been collected from the formation. According to 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.

Except for the sand and gravel phase encountered in test hole 16, the Laverne(?) formation in this area is relatively impermeable and probably would yield little or no water to wells.

OGALLALA FORMATION

The clay, silt, sand, and gravel below the terrace gravels, loess, dune sand, and alluvium and above the Cretaceous bedrock in Finney and Gray counties have in the past been referred to the Ogallala formation of Pliocene age. Sufficient evidence is available, however, to show that all of these clastic deposits are not of Pliocene age, but that a part of them are Pleistocene in age. A discussion of the age of the Ogallala formation is given below and a discussion of the age of the Pleistocene deposits is given on page 174.

The materials of Pliocene and Pleistocene age are lithologically similar; for this reason it was necessary to map them as a single unit in Finney and Gray counties (pl. 1). Although the contact between the Ogallala formation and the Pleistocene deposits could not be traced accurately in the field, sufficient data are available for describing them separately and for giving the approximate thickness and general distribution of each.

Character.—The Ogallala formation consists chiefly of calcareous silts, sands, and gravels, the proportions of which may differ greatly from place to place. In general, the materials making up the formation are poorly sorted, and gradations from one lithologic type to another may take place within short distances, both laterally and vertically. Individual beds of silt, sand, or gravel are characteristically lenticular and the individual lenses overlap one another

PLATE 11. *A,* Alternating beds of consolidated and unconsolidated sand and gravel of the Ogallala formation. Note the cross-bedding. North bluff of Arkansas valley in the NE¼ sec. 9, T. 25 S., R. 31 W. *B,* Old channel in the undifferentiated Pleistocene deposits. Note soil zone. View taken in railroad cut about 1.2 miles west of Ingalls.

irregularly (figs. 8 and 9). The materials are generally but not everywhere unconsolidated. Some of the beds of sand and gravel have been cemented with calcium carbonate and resemble old mortar (pl. 11A).

Silt containing only very small amounts of clay make up the finer materials of the Ogallala formation. Fine sand generally is intermixed with the silt. Lenses of sandy silt ranging in thickness from a few inches to more than 50 feet are common and are likely to be found in any part of the formation. Many beds of silt are impregnated with lime giving them a white to light gray color. Where lime is not present, the color of the silt is tan, brown, buff, or gray.

Two test holes (4 and 5) in northwestern Finney county and one test hole (19) in northwestern Gray county encountered beds of mottled gray and yellow and greenish yellow noncalcareous clay at the base of the Ogallala formation. The thickness of these clays ranges from 18 feet in test hole 19 to 28.5 feet in test hole 5. Elias (1931, pp. 155-158) observed similar clays in the lower half of the Ogallala formation in Wallace county, Kansas, and named them Woodhouse clays.

Sand probably is the most abundant material in the Ogallala formation, and is found throughout the formation. Few beds occur in the formation that do not contain some sand, and many beds consist predominantly of sand. Although the degree of sorting varies, the beds of sand generally are poorly sorted, the texture ranging from fine- to coarse-grained. A few lenses of sand encountered by test drilling were relatively well sorted and free from other constituents, but most of them were poorly sorted, containing silt and some clay, and a few contained gravel. The sands consist predominantly of well-rounded to subangular quartz grains, but there are a few grains of feldspar and of dark minerals. Some of the sand is brown, red-brown, or light gray, but most of it is tan.

The coarser materials of the Ogallala formation are composed of fine to very coarse gravel. Gravels may be found in almost any part of the formation from the base to the top. In some areas in southwestern Kansas the gravels in many of the thicker sections are reported to be coarser, thicker, and more persistent at the base (Smith, 1940, p. 41). Coarse gravel was encountered at the base of the formation in only 2 of the 26 test holes drilled in Finney and Gray counties, sand and gravel was encountered at the base in 12 test holes, and silt and sand was encountered at the base in 12 test holes. Gravel found at or near the base of the formation generally contains abundant pebbles of weathered Cretaceous sandstone, limestone, chalk, and shale. Gravels higher up in the formation are composed of material derived from crystalline igneous and metamorphic rocks, such as granite, quartz, and feldspar. The pebbles are well rounded to angular, and are white, gray, brown, yellow, red, or red-brown. The gravels are rarely clean, but generally contain much sand or silt.

Caliche is common in the Ogallala formation and occurs as cementing material, pipy concretions, nodules, or irregular beds. The caliche is white to gray and generally is fairly soft. The thickness of bedded caliche in the Ogallala is very irregular and in this area ranges from a few inches to about 6 feet. The greatest thickness of caliche, 6 feet, was encountered in test hole 4 (see log 4). In some places, the Ogallala formation is capped by a hard limestone bed, which has been referred to as the capping limestone by Smith (1940, p. 44). It is commonly massive, weathers to a knobby, cavernous, or irregular surface, and has a maximum thickness of 5 feet. A bed of hard white limestone about 1 foot thick occurs at the top of a thin section in a draw in the SW¼ sec. 12, T. 23 S., R. 28 W., Finney county (see measured section below). This limestone probably represents the capping limestone of other areas.

The following measured sections indicate the general lithology of the Ogallala formation at the surface:

Section of Ogallala formation in a draw in the SW¼ sec. 12, T. 23 S., R. 28 W., Finney county.

	Thickness, feet
3. Limestone, hard, white	1.0
2. Silt, sandy, compact, reddish-brown, containing scattered pebbles of chalk	4.0
1. Silt, loosely cemented, white and pink, containing many pebbles of chalk and limestone	3.0
Total thickness exposed	8.0

Section of Ogallala formation in the north bluff of Arkansas valley in the NE¼ sec. 9, T. 25 S., R. 31 W., Finney county (pl. 11A).

Surface covered with loose gravel.

Ogallala formation	Thickness, feet
13. Sand, fine to medium, containing some coarse gravel; lime-cemented; light gray	8.0
12. Sand, coarse, and gravel; lime-cemented; containing zones and lenses of loose sand and gravel	15.0
11. Sand coarse, to very coarse gravel; lime-cemented; hard. Forms small ledge	0.2

		Thickness, feet
10.	Sand and gravel; loose	0.5
9.	Sand, coarse, to very coarse gravel; lime-cemented; hard. Forms small ledge	2.0
8.	Sand, fine to coarse, loose, yellow-tan	1.0
7.	Sand, fine, to very coarse gravel; lime-cemented	3.0
6.	Sand, fine, to very coarse gravel; loose; containing cemented root-shaped stringers	2.5
5.	Silt, fine sand, and some coarse sand and gravel; lime-cemented; medium hard; lensing	2.0
4.	Sand, fine, and silt; compact (no cementing agent); tan.	1.0
3.	Sand, fine, and silt; lime-cemented; medium hard. Forms small ledge	0.5
2.	Silt, and fine to medium sand; loose; reddish-tan; lensing	1.5
1.	Sand, fine, lime-cemented, gray to white	1.0
	Total thickness exposed	38.2

Distribution and thickness.—Because of the difficulty of distinguishing the Ogallala formation from the undifferentiated Pleistocene deposits, it is possible to give only the approximate areal distribution of the Ogallala. Exposures of the Ogallala formation occur above the Cretaceous rocks along Pawnee valley and its tributary draws and in places along the north bluff of the Arkansas valley east of Garden City. Most of the upland surface in Finney and Gray counties is underlain by deposits of Pleistocene age. The Ogallala formation, however, is found beneath younger deposits over most of the area. It is absent in the area in southern Gray county occupied by the buried Cretaceous hill shown on figures 7 and 9. Test hole 27 (log 27) on the south flank of the buried hill failed to encounter any beds belonging to the Ogallala formation. It is probable that this hill was at one time completely covered by sediments of the Ogallala formation, but that these sediments were removed during post-Ogallala erosion. The Ogallala also may be absent along parts of the west flank of the Finney trough near the Kearny county line, for most of the sediments encountered in test hole 5 (log 5) are thought to be Pleistocene in age.

The thickness of the Ogallala formation ranges within wide limits owing chiefly to the uneven surface on which the sediments were deposited. In Finney county, the Ogallala probably attains its greatest thickness in the buried trough in the northern part of the county (fig. 8 BB′). Test hole 3, which is near the deepest part of the trough, penetrated 160 feet of Ogallala below undifferentiated Pleistocene beds. The bedrock floor rises both toward the east and the west, so that the formation thins in both directions and probably is absent altogether in places on the west flank near the Kearny county line. The formation thins southward even though the bedrock floor declines in that direction. In test hole 16 on the Finney-Haskell county line, only 77 feet of sediments were penetrated that have been referred to the Ogallala formation. At one time the Ogallala formation probably was much thicker in southern Finney county, but most of it was removed by post-Ogallala erosion.

In Gray county, the Ogallala formation probably attains its greatest thickness just north of the Arkansas valley, where from 200 to 250 feet of the Ogallala was penetrated in test hole 20. The bedrock floor rises to the north and south and as a consequence the Ogallala is much thinner in the northern and southern parts of the county. In southern Gray county, the Ogallala thins to a featheredge against the side of the buried Cretaceous hill. Test hole 24 in west-central Gray county penetrated 404 feet of Pliocene and Pleistocene sediments, but probably less than 200 feet of these sediments belong to the Ogallala formation.

Origin.—The materials of the Ogallala formation were deposited by widely shifting streams that had their origin in the Rocky Mountains. Smith (1940, pp. 85, 86) describes the mode of deposition of the Ogallala formation as follows:

> The deposition of the Ogallala was mainly of the channel and floodplain type. The coarser beds of sand, gravel, and grit represent channel deposits. . . . The finer materials are best interpreted as representing floodwater deposits formed by the overflow of shallow channels, perhaps approaching the character of sheet-floods locally. No recognizable deposits of eolian sand or silt have been found in the Ogallala in the area studied, but the presence of ventifacts indicates that there must have been appreciable wind action. . . .
>
> The deposition of the Ogallala formation began with the change from stream degradation to aggradation. . . . During the early stages of deposition, there was a topography of moderate relief. The main valleys were occupied by through-going streams from the Rocky Mountains, and the valley bottoms were mantled by normal floodplain deposits. . . . Deposition probably began with the filling of stream channels, leading to more frequent overflow and thus to the upbuilding of the floodplains. This soon led to shifting of the channels themselves, and probably to the development of anastomosing patterns. As filling progressed, the valley flat overlapped farther and farther on the slopes of the bordering hills. . . . Relief was lowered, the valley plains grew broader, and finally the divides were overtopped, and there followed overlapping and coalescing of the depositional zones of individual streams.

This manner of deposition explains the lenticular character of the materials and the many other irregular features of the formation.

Most of the materials in the Ogallala formation had their source in the Rocky Mountains. The silts and clays were derived from soils and weathering products in the mountain area. Most of the abundant limy material was derived from weathering of Paleozoic limestones and of calcic minerals in the crystalline rocks of the mountain area, but some of the limy material may have been provided by weathering *in situ* after deposition (Smith, 1940, p. 79). Theis, Burleigh, and Waite (1935, p. 1) agree that the coarse materials in the Ogallala were laid down by streams, but believe that the finer structureless sediments were deposited by the wind.

Age and correlation.—The Ogallala formation was named and described by Darton (1899, pp. 732, 734) in the latter part of the last century, and its age was given as late Tertiary or Pliocene(?). The type locality of the formation is near Ogallala station in western Nebraska (Darton, 1920, p. 6).

The United States Geological Survey classifies the Ogallala formation as Pliocene. Smith (1940, pp. 75, 76), however, classified the Ogallala of southwestern Kansas as middle Pliocene insofar as it is represented by exposures at the surface. The overlying beds that contain upper Pliocene fossils in Meade county were assigned by Smith to the upper Pliocene and called the Rexroad formation. In 1941, Frye and Hibbard (1941, p. 407) placed all middle and upper Pliocene beds in Meade county in the Ogallala formation, and designated the upper Pliocene beds as the Rexroad member of that formation. The lithology of the Rexroad member is for the most part indistinguishable from that of the middle Pliocene beds. Although they may be present, no upper Pliocene beds were recognized in Finney and Gray counties.

To my knowledge, only one vertebrate fossil has been taken from the Ogallala formation in Finney and Gray counties. C. W. Hibbard (personal communication) reports that a Pliocene horse tooth was recovered from the Ogallala formation at a depth of about 50 feet during the drilling of a water well at Garden City. Vertebrate fossils also have been collected from the Ogallala formation in near-by areas. Waite (1942, p. 160) reports that during the drilling of an irrigation well in the SW¼ sec. 6, T. 27 S., R. 26 W., Ford county, a Pliocene horse tooth was recovered from the Ogallala formation at a depth of 113 feet. The tooth was identified by C. W. Hibbard as a right molar of *Pliohippus* cf. *interpolatus*. Probably the largest collection of Ogallala fossils have come from excavations near Optima in Texas county, Oklahoma, about 17 miles south of the Kansas line, where, according to Schoff (1939, p. 62), about 10,000 horse teeth and between 900 and 1,000 bones of various animals, all of middle Pliocene age, were found.

Fossil grass and hackberry seeds collected from the Ogallala formation have been described by Elias (1932, pp. 333-340). Fragments of grass and hackberry seeds were found in test hole 1 in the southwestern corner of Scott county between depths of 103.5 and 119 feet. From comparisons with forms described by Elias, the grass seeds are believed to be *Biorbia fossilia* and the hackberry seeds are believed to be *Celtis willistoni.*

The Rexroad member in Meade county is more fossiliferous than the middle Pliocene part of the Ogallala, and has yielded snails, mollusks, fish, amphibian, reptile, bird, and mammal remains (Frye and Hibbard, 1941, p. 408).

Water-supply.—Because the water-bearing properties of the Ogallala formation and undifferentiated Pleistocene deposits are similar and because it is difficult and in many places impossible to differentiate between the two in the subsurface, it is thought best to combine the descriptions of their water-bearing properties.

The sand and gravel of the Ogallala formation and the undifferentiated Pleistocene deposits are the most important sources of ground water in Finney and Gray counties. Most of the domestic and stock wells on the uplands, many of the irrigation and large industrial wells, and all of the public-supply wells derive water from these deposits. Although water is available at shallow depths in the alluvium in the Arkansas valley, many well owners have drilled their wells deeper to tap the Ogallala formation and undifferentiated Pleistocene deposits. All upland irrigation wells and a few irrigation wells in the Arkansas valley derive their water from the Ogallala and the Pleistocene deposits. These deposits also supply water to four springs (44, 45, 51, and 52) in the Pawnee river drainage basin (p. 87).

The finer materials are generally porous and hold much water, but are not permeable enough to yield water freely. The coarser materials, the gravels in particular, are very good water bearers and generally yield abundant supplies of water. The yields of wells tapping these deposits range from a few gallons a minute for small domestic and stock wells to as much as 1,770 gallons a minute for an irrigation well (24). Irrigation wells that obtain water from these deposits yield 10 to 141 gallons a minute per foot of draw-down.

The Ogallala formation and the Pleistocene deposits together make up a large underground reservoir that is only partly filled with water. Probably a greater thickness of the reservoir was saturated at one time, but streams such as Arkansas and Pawnee rivers have cut below the zone of saturation and are draining part of the water from the reservoir. In a small area in southern Gray county and in parts of northwestern Finney county, the Ogallala and the Pleistocene beds are comparatively thin and lie entirely above the water table. The thickness of saturated material, as shown by the cross sections in figures 8 and 9, ranges greatly. The greatest thickness of saturated material, about 360 feet, is in southern Finney county. Logs of test holes indicate that a large percentage of the saturated zone in the Ogallala and the Pleistocene deposits is composed of sand and gravel, so the amount of water available is large.

The samples of water analyzed from the Ogallala formation and undifferentiated Pleistocene deposits were of two types—the most common being a calcium bicarbonate water and the least common a calcium-magnesium sulphate water. Of the 33 samples of water analyzed from the Ogallala and undifferentiated Pleistocene beds, 28 were calcium bicarbonate waters. Of the 28 samples of calcium bicarbonate waters analyzed, 4 had less than 200 parts per million of total solids, 15 had between 200 and 300 parts, and 9 had between 300 and 509 parts. The calcium content of these samples was rather uniform; 27 samples had between 37 and 89 parts per million and the other sample had 101 parts. The bicarbonate content was between 171 and 200 parts per million in 10 samples, between 200 and 300 parts in 17 samples, and 347 parts in one sample.

The calcium-magnesium sulphate waters analyzed were in general more highly mineralized than the calcium bicarbonate waters. Two of the five samples of calcium-magnesium sulphate waters analyzed had 481 and 488 parts per million total solids, but three samples had 1,180, 1,500, and 1,576 parts. The calcium content of the five samples ranged from 88 to 207 parts per million and the sulphate content ranged from 205 to 867 parts per million. The three highly mineralized calcium-magnesium sulphate waters were collected from wells in the irrigation area north of Garden City. It is possible that the high sulphate content of these waters is due to surface irrigation water percolating into the ground-water reservoir.

Analyses of typical waters from the Ogallala formation and Pleistocene deposits are shown graphically in figure 19. Numbers 388 and 90 are typical of the calcium bicarbonate waters and number 114 is one of the harder, more highly mineralized calcium-magnesium sulphate waters.

The iron content of the water in the Ogallala and Pleistocene deposits in general seems to be relatively low. Of the 33 samples, 26 had less than 1 part per million of iron, 5 had from 1.0 to 2.9 parts, and one had 5.2 parts.

The fluoride content of the waters in the Ogallala and undifferentiated Pleistocene deposits was higher north of Arkansas river than south of the river. The areal distribution of fluoride in these waters is shown in figure 21. All but one of the analyses of water

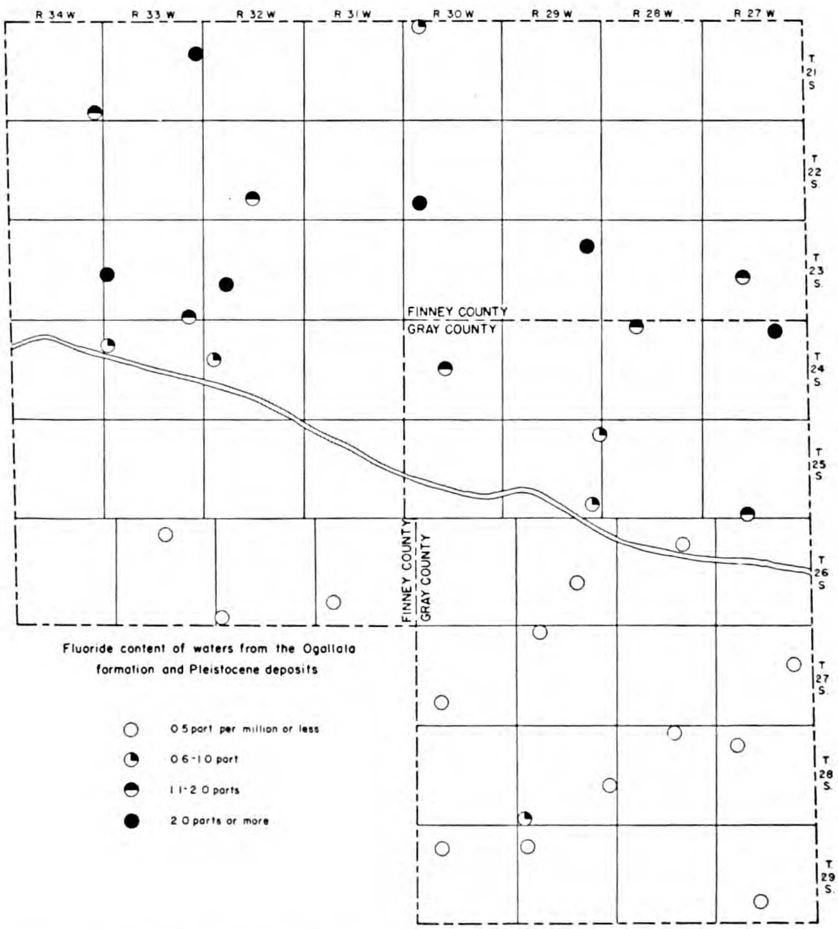


FIG. 21. Fluoride content of waters in the Ogallala formation and undifferentiated Pleistocene deposits in Finney and Gray counties, Kansas.

north of the river indicated more than 0.6 part per million of fluoride and about three-fourths of the analyses indicated more than 1 part per million, whereas all but one of the samples of water collected south of the river contained 0.5 part per million of fluoride or less.

Quaternary System

UNDIFFERENTIATED PLEISTOCENE DEPOSITS

Overlying the Ogallala formation in this area are deposits of clay, silt, sand, and gravel that are lithologically similar to the Ogallala formation, but are of Pleistocene age. Because of lack of data, it was not possible to subdivide these deposits into smaller units, so they are referred to as undifferentiated Pleistocene deposits. These deposits have been included as part of the Ogallala formation by previous investigators.

Character.—The undifferentiated Pleistocene deposits consist of interbedded lenses of calcareous clay, silt, sand, gravel, and caliche. The proportions of the different sediments vary from place to place, and gradations from one lithologic type to another generally take place within short distances, both laterally and vertically. The sands and gravels of the undifferentiated Pleistocene deposits commonly are cross-bedded.

The finer materials of the Pleistocene deposits consist of clay and silt. The only known exposure of clay in this area occurs in a draw about 1.4 mile west of Ingalls in Gray county, where about 7 feet of mottled green and brown clay is exposed, the upper part of which contains nodules and thin layers of soft to very hard caliche. A section measured at this locality is given below. Clay was encountered in seven of the 26 test holes (1, 3, 4, 8, 15, 16, and 26) drilled in Finney and Gray counties. The clay ranges from pure clay to silty and sandy clay, and is tan, yellow-tan, gray, blue-gray, and black. The individual beds range in thickness from 2.5 to 46 feet. Many of the clay beds contain small invertebrate fossils.

Lenses of silt and sandy silt ranging in thickness from a few inches to about 65 feet were penetrated in test drilling. Although silt is likely to be encountered in any part of the Pleistocene deposits, it is thicker and more persistent at the top. Test hole 26 in southern Gray county penetrated nearly 80 feet of silt and sandy silt below the surface before encountering any coarser materials. The two test holes (logs 28 and 29) in southwestern Ford county penetrated 90 feet of silt and sandy silt, which has been referred to the Kingsdown silt of Pleistocene and Recent age (Waite, 1942, pp. 162-166). The silt is tan, brown, yellow, green, reddish-tan, or gray. Many of the lenses are very calcareous and are white to light gray.

The sands in the Pleistocene deposits cannot be distinguished lithologically from the sands of the Ogallala formation. They are generally poorly sorted and range in texture from very fine- to coarse-grained and generally contain a few pebbles. The sands are composed principally of well-rounded to subangular grains of quartz, but also contain some feldspar and dark minerals. The dominant colors of the sands are tan, reddish-tan, and brown.

Fine to very coarse gravels make up the coarser sediments of the Pleistocene. Lenses of clean gravel are not numerous, but lenses of intermixed sand and gravel are common. The thickness of most of the gravel lenses encountered in test holes in this area ranges from a few feet to about 25 feet. Test hole 16 in southern Finney county, however, penetrated 85 feet of fine to coarse gravel between depths of 30 and 115 feet. Many thin lenses of silt and sand also occur in this interval. The gravels are composed chiefly of granite, feldspar, and quartz pebbles. Pebbles of sandstone, limestone, chalk, and shale, which are abundant in the basal gravels of the Ogallala, are only a minor constituent of the Pleistocene gravels. Water-worn pebbles of caliche and "mortar bed" that were derived from the Ogallala formation are commonly found in the Pleistocene gravels. Locally the sand and gravels are loosely to tightly cemented by calcium carbonate.

Caliche is found throughout the Pleistocene deposits as nodules, stringers, pipy concretions, or irregular beds intermixed or interbedded with the clay, silt, sand, and gravel. The color of the caliche is white to gray. In some places it is soft and powderlike, but in other places it is hard and concretionary. Although not common, a few beds of white to gray hard limestone occur in the Pleistocene deposits. Two beds of limestone are exposed in a draw and road cut about 1.2 miles west of Ingalls in Gray county. One bed of limestone near the top of the section is 0.5 foot thick and contains small grains of clear quartz (see measured section below). The other limestone bed, which is at the bottom of the section, is 2.5 feet thick. The weathered surface of the lower limestone is rough and cavernous.

Locally the Pleistocene deposits contain beds of volcanic ash. Several large deposits of ash in the Meade formation (Pleistocene) in Meade county are being mined commercially. To my knowledge, the only deposit of volcanic ash in the Finney-Gray area is that exposed on the side of a small draw in the NW¼ sec. 35, T. 29 S., R. 27 W., in southern Gray county. The ash is white to light gray and is loosely consolidated. The total thickness of the ash is not known, for all but about a foot of the deposit is covered.

The following measured sections indicate the lithology of the Pleistocene deposits at the surface.

Section of undifferentiated Pleistocene deposits in a draw and in a road cut along highway US 50S, about 1.2 miles west of Ingalls, Gray county

	Thickness, feet
9. Silt and clay; sandy; green-gray; containing splotches of lime	2.0
8. Limestone, sandy, medium hard, white	0.5
7. Silt, sandy, red, impregnated with irregular stringers and nodules of white lime	15.0
6. Sand, fine, to coarse gravel; lime-cemented; compact; gray.	4.0
5. Sand, gravel, and pebbles; cross-bedded; tan to brown. Some pebbles are 2 or 3 inches in length	15.0
4. Sand, coarse, to very coarse gravel; loose; tan	4.0
3. Gravel, coarse, containing some pebbles 3 inches in length.	1.0
2. Sand, coarse, to very coarse gravel; loose; tan	2.0
1. Limestone, porous, hard, gray. Weathered surface is rough and cavernous	2.5
Total thickness exposed	46.0

Section of undifferentiated Pleistocene deposits in a draw and a road cut along US highway 50S, about 1.4 miles west of Ingalls, Gray county

	Thickness, feet
8. Sand, fine to coarse, red-tan and gray, impregnated with white lime in irregular stringers and splotches	10.0
7. Clay, silt, sand, and fine gravel; poorly sorted	5.0
6. Sand and gravel; lime-cemented. Forms bench	6.0
5. Sand, medium, to very coarse gravel; cross-bedded; having irregular, loose to compact lime-cemented zones	15.0
4. Clay, mottled, green and brown, containing nodules and thin layers of soft to very hard caliche	2.0
3. Clay, mottled, green and brown	5.0
2. Caliche, hard, white	0.5
1. Sand, fine and medium, gray to green-gray	3.0
Total thickness exposed	46.5

Distribution and thickness.—Pleistocene deposits are present nearly everywhere in Finney and Gray counties except in the Pawnee river drainage area, where Pawnee river and its tributaries have removed them and exposed Pliocene and Cretaceous rocks. In the

Arkansas valley they are covered by alluvium, and south of the valley they are covered by dune sand. The Pleistocene deposits probably are very thin north of Arkansas river in the extreme eastern part of Gray county, and they probably are missing entirely beneath the Arkansas valley in eastern Gray county.

The thickness of the Pleistocene deposits ranges from a featheredge to 300 feet or more. The maximum thickness in this area was encountered in test hole 16 in southern Finney county, where 313.5 feet of sediments tentatively have been assigned to the Pleistocene. In the Finney basin the Pleistocene deposits attain a maximum thickness of about 105 feet in the deepest part of the trough (test hole 3) and thin eastward and westward. In Gray county the thickness of the Pleistocene ranges from a featheredge to about 200 feet.

Origin.—Most of the materials in the undifferentiated Pleistocene deposits represent channel and flood plain sediments that were laid down in much the same manner as the materials of the Ogallala formation. These sediments were derived from areas of Ogallala and Cretaceous deposits to the west and from the Rocky Mountains.

Age and correlation.—The Pleistocene deposits of southwestern Kansas formerly were included with the Pliocene deposits and referred to the Ogallala formation. In 1940, Smith (1940, pp. 99-129) pointed out that there were thick deposits of Pleistocene age in southwestern Kansas, particularly in Meade and Clark counties. At that time Smith named several units, discarded or redefined some of the earlier names, and left part of the Pleistocene section unnamed. In 1941, Frye and Hibbard (1941) completed a study of the Pliocene and Pleistocene stratigraphy of the Meade basin, which is about 15 miles south of the Finney-Gray area. As a result of this study, they (Frye and Hibbard, 1941, pp. 410-420) described the Meade formation of Pleistocene age and the Kingsdown silt of Pleistocene and Recent age. The materials herein described as undifferentiated Pleistocene are believed to represent extensions of both the Meade formation and the Kingsdown silt, and may also include some material of Recent age in the upper part of the Kingsdown silt.

The presence of water-worn caliche and "mortar-bed" pebbles and volcanic ash indicate Pleistocene age for these deposits in Finney and Gray counties. The abraded pebbles of caliche and "mortar bed" are common in Pleistocene gravels, but have not been noted in basal gravels of the Ogallala formation (Frye and Hibbard, 1941, p. 405). The occurrence of volcanic ash in southern Gray county is further evidence suggesting a Pleistocene age for deposits in that area, for this ash probably is of the same age as the ash in the Meade formation in Meade county which contains undoubted Pleistocene fossils.

In addition to the lithologic evidence, there is fossil evidence that indicates Pleistocene age for these deposits. The following mollusks were collected by Thad G. McLaughlin from a bed of silty clay in the SE¼ NE¼ sec. 3, T. 27 S., R. 31 W., in the northeastern corner of Haskell county, and were identified by A. B. Leonard of the University of Kansas:

Mollusks collected from a bed of silty clay in the SE¼ NE¼ sec. 3, T. 27 S., R. 31 W., Haskell county, Kansas

Aquatic forms
- *Menetus exacuous* (Say)
- *Gyraulus cristatus* (Linnaeus)
- *Gyraulus* cf. *hirsutus* (Gould)
- *Gyraulus parvus* (Say)
- *Lymnea parva* (Lea)
- *Lymnea palustris* (Muller)
- *Lymnea humilis* (Say)
- *Lymnea caperata* (Say)
- *Pisidium* species

Terrestrial forms
- *Succinea grosvenori* Lea
- *Vertigo* cf. *morsei* Sterki
- *Pupilla muscorum* (Linnaeus)
- *Vallonia* cf. *costata* (Müller)
- *Discus anthonyi cronkhitei* (Pilsbry)

Mollusks and other fossils were recovered from several of the test holes drilled in Finney and Gray counties as listed below. Identifications were made by A. B. Leonard.

Fossil material recovered from test holes in Finney and Gray counties

Test hole No.	Depth below land surface (feet)	Fossils
1............	1.5–12.5	Fragments of snails
3............	41 –57	do
4............	8 –19	do
5............	1 – 9	*Vallonia* cf. *costata, Helisoma* sp.
	17 –20	*Vallonia costata, Gastrocopta* sp.
7............	15 –30	Unidentified snails
15............	9.5–24.5	do
16............	10 –18	*Vallonia costata*, fragmentary rodent bones
	18 –30	*Vallonia costata, Discus* sp.
	280 –290	Ostracodes
23............	10 –16	*Vallonia costata*

Many of the mollusks given in the preceding lists are identical with forms found in the Meade formation of Meade county where they are associated with Pleistocene vertebrates. According to

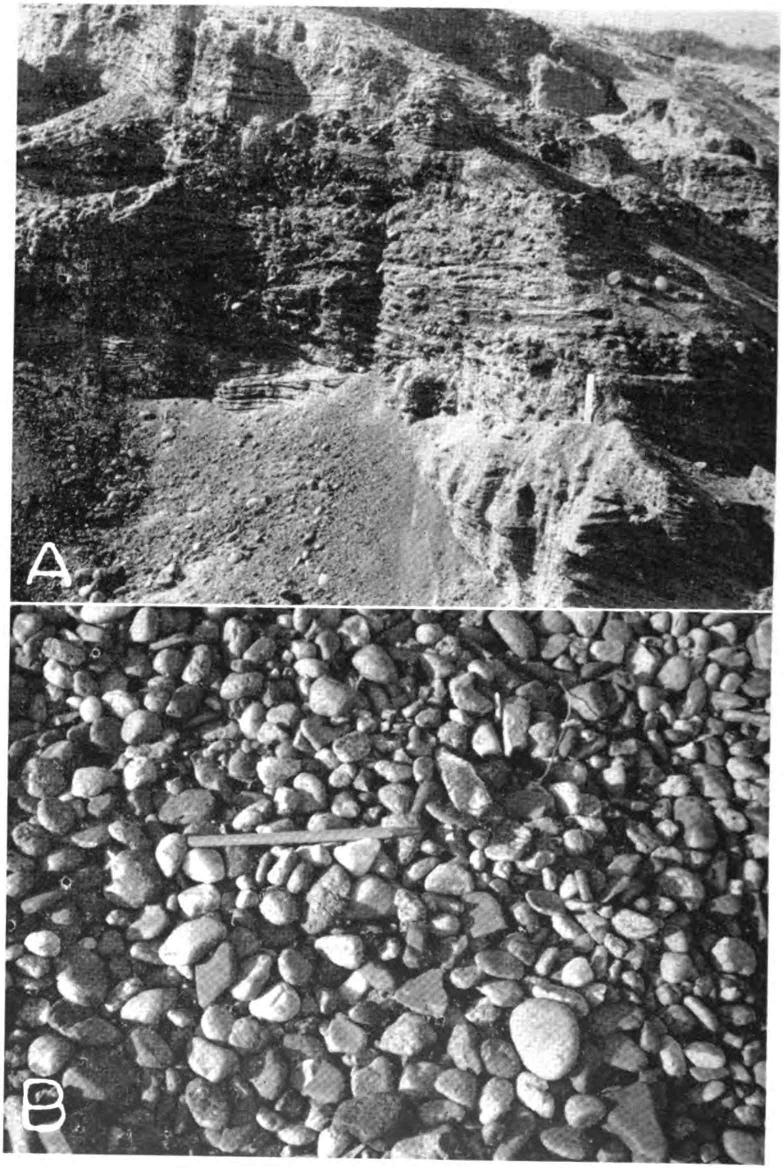


PLATE 12. *A*, Cross-bedded terrace sands and gravels exposed in a gravel pit in the SW¼ sec. 30, T. 24 S., R. 32 W., about 2 miles south of Garden City. *B*, Close-up view of screened terrace gravels taken from a pit in the SW¼ sec. 14, T. 26 S., R. 28 W., about 1 mile south of Cimarron.

Leonard (personal communication), the ostracodes recovered from test hole 16 are similar to forms taken from the Rexroad member of the Ogallala formation in Meade county, but the vertical range is not known.

The only known vertebrate fossils found in the undifferentiated Pleistocene deposits of this area are the fragmentary rodent bones recovered from test hole 16 and a fragmentary horse tooth collected from a railroad cut 1.7 miles west of Ingalls. This material was submitted to C. W. Hibbard of the University of Kansas for identification, but because of the fragmentary condition of the material he could make no further identification.

Water supply.—The water supply of the undifferentiated Pleistocene deposits and the Ogallala formation are discussed together on pages 168-171.

TERRACE GRAVEL

Character.—Terrace deposits are widely distributed along Arkansas valley and to a lesser extent along Pawnee valley. The terrace deposits along Arkansas valley are well exposed in several commercial gravel pits near Garden City, Cimarron, and Pierceville (pl. 1). These deposits consist of unconsolidated cross-bedded fine sand to very coarse gravel (pl. 12). The fine sand to medium gravel is composed chiefly of subrounded to well-rounded grains of quartz containing some grains of feldspar and dark minerals. Pebbles of quartz, feldspar, granites and other igneous rocks, sandstones, and concretionary material make up the coarser gravels. Many of the pebbles in the coarse gravels are 2 inches in their greatest diameter, and some are as large as 4 inches. The fine and coarse material generally occur as overlapping lenses. Locally these deposits are stained rusty brown or black. Clay balls ranging in diameter from about 1 inch to 8 inches occur locally in the lenses of coarse gravel.

Moss (1932, p. 12) recognized and described terrace deposits along the Pawnee valley in western Hodgeman county. Similar deposits were noted along the south side of the Pawnee valley in Finney county. These deposits are shown to good advantage in a gravel pit in the SE¼ sec. 25, T. 22 S., R. 27 W., where about 18 feet of cross-bedded sand and gravel is exposed. The sand and gravel are composed predominantly of grains and pebbles of quartz and granite. Granite pebbles are most abundant and generally are a bright red. Pebbles of quartzite, chert, schist, and dark-colored igneous rocks occur in smaller amounts. Most of the pebbles are well-rounded and range in diameter from less than one-half inch to 3 inches. Angular blocks of "mortar bed" occur in the lenses of coarser material.

Distribution and thickness.—Terrace gravels border the present flood plain of Arkansas river in Finney and Gray counties. Because the exposed width of the terrace gravels is narrow, they have been mapped with the alluvium (pl. 1). The principal terrace lies 15 to 25 feet above flood-plain level and is most prominent along the south side of the valley. Good exposures of the gravel occur in several pits at the edge of the terrace. On the south side of the valley the presence of the gravel between good exposures is suggested at some places by the topographic expression of the terrace. In other places, however, even the terrace is obscured by erosion or masked by dune sand. The width of the terrace along the south side of the valley is not known because the southern boundary is covered by dune sand. It is believed, however, that the terrace extends nearly to the southern edge of the dune sand in this area. South of Garden City, terrace gravels are exposed in a pit about 1.5 miles south of the edge of the terrace and were encountered in a test hole drilled about 3.5 miles south of the edge (see log 14). South of Cimarron, terrace gravels were penetrated by a test hole drilled about 2 miles south of the edge of the terrace.

The thickness of the terrace gravels along the Arkansas valley is known only from the two test holes that penetrated these deposits. At test hole 14 south of Garden City the terrace gravels are 37 feet thick, and at test hole 23 south of Cimarron they are 68 feet thick (see logs 14 and 23).

The terrace gravels along the Pawnee valley are not widespread and occur only on the south side of the valley near the Finney-Hodgeman county line. They lie about 140 feet above the present flood plain of Pawnee river. The position of the gravel indicates that it is a remnant of a former terrace of Pawnee river.

Origin.—The terrace gravels along the Arkansas valley were deposited by Arkansas river and those along the Pawnee valley by Pawnee river sometime during the Pleistocene period when the two rivers were flowing at a higher level than they are at present. Most of the material constituting the deposits along the Arkansas valley was derived from the Rocky Mountains. The gravels along the Pawnee valley probably were derived from areas of Tertiary and other rocks to the west.

Age and correlation.—Vertebrate fossils of Pleistocene age have been taken from the terrace gravels along the Arkansas valley. These include remains of elephant, horse, bison, squirrel, prairie dog, and fragmentary bird and fish bones. Several teeth and a large tusk taken from the Smith Brothers gravel pit at the edge of the terrace south of Garden City were identified by C. W. Hibbard and E. S. Riggs as being *Paraellephas* cf. *columbi* (Falconer). A tooth identified as *Equus* sp. was also taken from this pit. Smith (1940, p. 125) collected fragmentary *Bison* and *Equus* material from the terrace deposits and states—

> . . . it is probable also that the *Bison willistoni* (believed by O. P. Hay to be *Bison alleni*), *Elephas primigenius*, and *Equus excelsus*, reported by Martin from the vicinity of Garden City, were found in the terrace fill.

Mrs. H. T. U. Smith found a jaw bone in a gravel pit 1 mile east and three-quarters of a mile north of Garden City. It was originally identified by Hibbard as the lower jaw of *Citellus elegans* (Kennicott), but he later found it to be *Citellus richardsonii* (Sabine).

The greatest number of vertebrate fossils taken from the terrace deposits in this area were discovered and collected by Allen Graffham in two gravel pits in sec. 9, T. 24 S., R. 32 W., northeast of Garden City, and were identified by C. W. Hibbard. A small milk tooth of *Paraelephas* cf. *columbi* (Falconer); three skulls, four lower jaws, and limb bones of *Citellus richardsonii* (Sabine); and three upper and two lower molars of *Equus* were found near the top of the sand and gravel in a pit in the NW¼ NE¼ of this section. A skull of *Cynomys ludovicianus* (Ord) was found in the same pit at the base of the silt that overlies the sand and gravel. Seven lower jaws and part of a skull of *Cynomys ludovicianus* (Ord) and two skulls and two lower jaws of *Citellus richardsonii* (Sabine) were taken from the base of the silt in a gravel pit in the NW¼ SE¼ of the same section. A lower molar of *Equus* and fragmentary bird and fish bones also were taken from the sand and gravel in this pit.

These fossils indicate a late Pleistocene age for the terrace gravels along the Arkansas valley. No fossils have been found in the terrace gravels along Pawnee valley, but their topographic position and lithology suggest that they also are of Pleistocene age.

Water supply.—The terrace gravels along the south side of the Arkansas valley in many places are above the water table and, therefore, are not water bearing. Near the river, however, the lower part of the terrace gravels is saturated and supplies water to a few wells (figs. 8 AA′ and 9 DD′). Seven stock and domestic wells (226, 352, 451, 471, 472, 473, and 480) that probably obtain water from these deposits were visited in Finney and Gray counties. The depths of the wells range from about 40 feet to 71 feet, and the depth to water level ranges from about 31 to about 70 feet below the surface.

Four samples of water were collected from wells (226, 352, 472, and 480) obtaining water from the terrace gravels (Pleistocene) that underlie the sand hills south of Arkansas valley; these were found to be remarkably uniform in mineral content. The total dissolved solids in the four samples analyzed ranged from 232 to 272 parts per million and the total hardness ranged from 188 to 235 parts. The waters were all moderately hard calcium bicarbonate waters, containing from 59 to 74 parts per million of calcium, 171 to 226 parts of bicarbonate, and only from 13 to 26 parts of sulphate. The fluoride content in all four samples was 0.4 part per million or less. The iron content of the samples showed a greater range in concentration than any other constituent, ranging from a low of 0.2 part per million to 4.2 parts.

No wells obtain water from the terrace gravels along the Pawnee valley in Finney and Gray counties, for they are everywhere above the water table.

DUNE SAND

Dune sand of Quaternary age is widely distributed along the south side of Arkansas valley in Finney and Gray counties, and occurs in smaller areas north of the valley in Finney county (pl. 1). It is composed predominantly of fine- to medium-grained quartz sand and contains smaller amounts of silt, clay, and coarse sand. The sand has been accumulated by the wind to form small hills, some of which are 60 or 70 feet high, and low mounds. Most of the sand hills are covered by vegetation, but locally there are areas of bare sand that are being subjected to the action of the wind. The origin of the sand is uncertain, but the near-by Pliocene and Pleistocene deposits and terrace deposits probably were important sources for the sand. Smith (1940, pp. 127, 128; 153-168) has given an excellent description of the dune sand in southwestern Kansas, including a discussion of its origin; the reader is referred to this paper for further details.

No wells obtain water from the dune sand in Finney and Gray counties, for it is everywhere above the water table. Because the sand is loose and highly permeable, the sand dunes probably serve as important catchment areas for ground-water recharge from local rainfall (p. 68).

ALLUVIUM

Alluvium of late Quaternary age occurs in Arkansas valley, Pawnee valley and its larger tributaries, and Crooked creek valley (pl. 1). The alluvium in Crooked creek valley and the tributary valleys of Pawnee river is thin and occurs only as very narrow bands along the present channels; therefore, it is not shown on the geologic maps.

The alluvium consists of stream-laid deposits that range in texture from clay and silt to sand and very coarse gravel. The upper 2 to 6 feet of the alluvium in Arkansas valley consists of silt and fine to coarse sand that has been deposited over the flood plain in time of flood or under normal conditions in the channel of the stream. Beneath the finer surficial deposits are layers of coarse granitic sand and gravel that are slightly older but of similar origin. The lithology of the coarser alluvial deposits is similar to the lithology of the terrace gravels described above. The alluvium grades into the terrace gravels, so the lower part of the valley fill in some places is probably of late Pleistocene age and represents the basal part of a cut and fill terrace deposit.

The thickness of the alluvium in the Arkansas valley in Finney and Gray counties as revealed by test drilling ranges from about 30 feet to 59 feet, and is thickest in central and eastern Gray county (logs 9, 10, 11, 12, 13, 21, and 22). The thickness of the alluvium, however, ranges considerably both along and across the valley.

The alluvium in Pawnee valley consists of 10 to 15 feet of silt and clay underlain by coarse sand and gravel. The coarser deposits are composed chiefly of limestone and chalk pebbles of Cretaceous age, but also contain some granitic sands and gravels. Silts and clays are intermixed with the coarser deposits. The thickness of the alluvium along Pawnee valley ranges from a few feet to an estimated maximum of about 30 feet. The alluvium in the valleys tributary to Pawnee valley is similar to the Pawnee valley alluvium but in most places is much thinner.

The alluvium in Crooked creek valley in southern Gray county consists chiefly of sand and sandy silt, and probably is not more than a few feet thick. It is unimportant as a source of water.

The alluvial sands and gravels in Arkansas valley make up the most permeable deposits in Finney and Gray counties, and wells that tap them yield large quantities of water. The alluvium is the source of supply for many irrigation, domestic, and stock wells, and for a few industrial wells. The yields of the wells tapping the alluvium in the Arkansas valley range from a few gallons a minute to about 3,750 gallons a minute. The alluvium in the Pawnee valley and its tributaries has a low permeability because of the large amount of silt and clay it contains. It will supply sufficient water for domestic and stock purposes, however, and is important because it is the only shallow source of water in parts of the Pawnee river drainage basin.

Thirteen analyses indicate that several types of waters may be obtained from the alluvium in the Arkansas valley. Three of the 13 samples analyzed were moderately hard calcium bicarbonate waters (analyses 362, 449, and 457) whereas the other 10 were very hard waters with sulphate as the chief constituent. Three types are shown graphically in figure 19. Number 449 is a moderately hard calcium bicarbonate water, number 476 is a moderately mineralized calcium sulphate water, and number 268 is a highly mineralized water of mixed type.

The three calcium bicarbonate waters analyzed were similar in chemical character and in mineral content to waters from the Ogallala formation and the Pleistocene deposits. All three of these samples were collected from wells east of the heavily irrigated area around Garden City. Two of the wells (263 and 449) are on the south side of the river and one (well 457) is north of the river.

The other waters from the Arkansas valley alluvium are the hardest waters found in Finney and Gray counties. With but one exception (analysis 476), all of these waters contained in excess of 500 parts per million of sulphate and seven of the ten samples analyzed contained more than 900 parts. Only one of the samples had less than 1,000 parts per million of total dissolved solids, five samples had between 1,000 and 2,000 parts, and three samples had more than 2,000 parts. Five of the samples analyzed had from 462 to 1,000 parts per million of total hardness, and five samples had from 1,000 to 1,641 parts. All of the waters in the upper range of mineral concentration were collected from wells in the heavily irrigated area surrounding Garden City.

The fluoride content of the three samples of calcium bicarbonate water from the alluvium was less than 1.0 part per million, whereas each of the other waters analyzed contained more than 1.0 part and one sample (297) had 2.5 parts. Ten of the 13 samples from the alluvium contained less than 0.09 part per million of iron, one had 0.27 part (analysis 349), and two had more than 1.0 part (analyses 449 and 476).

RECORDS OF TYPICAL WELLS AND SPRINGS

Descriptions of the wells and springs visited in Finney and Gray counties are given in tables 22 and 23. The wells and springs in each county 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 tables, and depths to water level not classed as "reported" are measured and given to the nearest hundredth of a foot.

TABLE 22.—*Records of wells and springs in Finney county, Kansas*

No.	LOCATION	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed		Method of lift (5)	Use of water (6)	Measuring point			Depth to water level below measuring point (feet) (7)	Date of measurement, 1940	Remarks (Yield given in gallons a minute; drawdown in ft.)
							Character of material	Geologic subdivision			Description	Distance above (+) or below (—) land surface (feet)	Height above sea level (feet)			
	T. 21 S., R. 27 W.															
1	SW SW sec. 9	Renner Livestock Co.	Du	100	40	N	(?)	Codell (?)	Cy,W,H	D,S	....	....	....	....	....	
2	NE NW sec. 10	W. D. McKinley	Du	30.5	....	N	(?)	Fort Hays	Cy,W	S	Top edge of opening in platform east side	+0.5	2,609.4	18.54	Oct. 21	
3	NW NW sec. 14	C. Miller	Du, B	21.5	6	GI	(?)	Alluvium	Cy,W	N	Top edge of opening in concrete platform, south side	+ .5	....	13.46	Oct. 23	Unused stock well.
4	SE SE sec. 24	J. Coval	B	21.9	5	GI	Gravel	do	Cy,W	D	Top of casing, south side	+ .4	2,495.1	18.24	Oct. 21	Gravel composed mostly of limestone pebbles.
5	SW SW sec. 28	H. A. Morgan	Du	17.4	36	C	(?)	do	P,H	D,S	Top of concrete curb, west side	+ .5	2,553.8	10.20	do	
6	NE NW sec. 34	W. S. Hays	B	22	6	GI	Gravel	do	Cy,W,H	D	....	....	....	14	....	Gravel composed of limestone pebbles; encountered blue shale (Blue Hill) at depth of 25 ft.
	T. 21 S., R. 28 W.															
7	NW SW sec. 6	J. W. Ogden	Dr	44.3	6	GI	"Sandy shale,"	Ft. Hays	N	N	Top of iron plate covering casing	+ .4	2,779.4	39.64	Oct. 29	Unused stock well; reported to have had very small yield when in use.
8	NW NE NW sec. 15	J. B. Dickey	Du	65.5	40	N	do	Codell	N	N	Top of concrete lid, east side	0	2,715.2	61.57	Oct. 23	Unused domestic well.
	T. 21 S., R. 29 W.															
9	SE NE sec. 15	G. W. Finnup	B	20	6	GI	(?)	Alluvium	Cy,W	D	....	....	....	16	....	
0	NW SW SW sec. 36	T. A. Meakel	Dr	28	8	GI	(?)	do	N	N	Top of casing, east side	+2.0	2,613.1	18.79	Oct. 29	Unused stock well; observation well.

T. 21 S., R. 30 W. SW SE NW sec. 1	L. M. Lane	Du	18	48	R	Clay	Alluvium and/or Fort Hays	Cy,W	S	Top of pipe coupling, east side	+2.1	2,790.4	11.23	Sept. 12	Soil and sand (alluvium) reported between depths of 0-12 feet and yellow "soapstone" (Fort Hays) between depths of 12-20 feet; small yield reported.
NW cor. NW sec. 5	F. T. Carl	Dr	44 1	6	GI	(?)	Ogallala	Cy,W	D,S	Top of casing, east side	+ .1	2,861.5	35.84	do	
NW NW sec. 9	H. H. Nickel	Dr	90	6	GI	(?)	do	Cy,W	N	Top of casing, east side	+ .1	2,868.6	58.38	do	Unused domestic well.
NW SW NW sec. 20	A. A. Doerr	B	73 8	6	GI	Sand	do	Cy,W	D	Top of opening in concrete platform	+1.3	2,882.2	59.44	do	Water reported to be soft.
NE SE sec. 22	J. Deal	Sp	......	......	......	Limestone	Fort Hays	F	S	......	......	......	......	......	Estimated yield 2-3.
NE SW sec. 25	K. M. Winters	Sp	......	......	......	do	do	F	S	......	......	......	......	......	
NW SW sec. 25	do	Sp	......	......	......	do	do	F	N	......	......	......	......	......	Dry part of year.
SE NW sec. 26	Jellison Trust Co	Sp	......	......	......	do	do	F	S	......	......	......	......	......	Estimated yield, ½-1.
SE cor. SW sec. 30	W. Drees	Dr	84.2	6	GI	(?)	Ogallala	Cy,W	D	Top of tin plate covering casing	+2.7	2,891.2	70.39	Sept. 11	
SE SE sec. 36	J. D. Cathcart	Du	27	30	R	(?)	Alluvium	Cy,W	D	Top of wooden well platform	0	......	21±	Oct. 21	Water dripped on tape, depth to water level only approximate.
T. 21 S., R. 31 W. NE cor. NW sec. 8	F. L. Brayfagle	Dr	73.3	......	......	(?)	Ogallala	Cy,W	S	Top of tin plate covering casing	+ .8	2,903.4	57.39	Sept. 13	
SW SW sec. 13	M. M. Felkner	Dr	83 8	5.5	GI	(?)	do	Cy,H	N	Top of north pipe clamp, south side	+ .3	2,904 8	73 15	Oct. 26	Unused domestic well.
SW cor. SW sec. 16	E. E. Joyce	Dr	99	......	......	(?)	do	Cy,W	N	Top edge of bolt hole in pump base	+1.5	2,927.5	87.73	Sept. 13	Do
T. 21 S., R. 32 W. NW NE sec. 8	W. R. E. Hall	Dr	155	16	OW	Gravel	do	T,B(8)	I	......	0	......	30	......	Measured yield in 1940 with test pump 1,770; total lift 60.75 feet (9); well drilled during fall of 1940; see log.
SE cor. NW NW sec. 19,	E. Alberta Reeves	Dr	33.5	6	GI	(?)	Pleistocene	N	N	Top of casing, west side	+1.0	2,894.8	23.32	Sept. 20	Abandoned domestic well; observation well.
NW NW sec. 22	Townley M. & H. Co	Dr	78.5	4	I	(?)	do	Cy,W	N	Top of casing, east side	+3.0	2,936.2	72.96	Oct. 12	Unused domestic well.
NE NE SE sec. 33	J. Landgraf	Dr	199.5	18	BS	Sand and gravel	Ogallala and Pleistocene	T,B(8)	I	Top of casing, south side	+ .5	2,930.5	76.79	do	Measured yield Dec., 1940, with test pump 850; estimated drawdn. 34. (9)

TABLE 22.—Records of wells and springs in Finney county, Kansas—*Continued*

LOCATION	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (−) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement, 1940	Remarks (Yield given in gallons a minute; drawdown in ft.)
T. 21 S., R. 33 W.															
SE SW sec. 1	E. F. Ware	Dr	77.9	16	BS	(?)	Pleistocene	N	N	Top of casing, south side	+1.0	....	25.32	Oct. 8	Abandoned irrigation well; pump removed.
NW SW NE sec. 2	Farm M. & H. Co.	Dr	125	16	BS	(?)	do	N	N	Top of wooden platform	0	2,910.6	24.43	Sept. 16	Do
SW cor. NW sec. 5	G. W. Armantrout	Dr	62	6	GI	Sand and gravel	do	Cy,W	N	Top of casing, west side	−3.7	2,930.5	41.35	do	Unused domestic well.
NE cor. NW sec. 13	A. E. Jones	Dr	39.5	5	GI	(?)	do	Cy,W	S	Bottom edge of pump flange, southeast side	0	2,906.8	29.95	do	
SW NW NW sec. 15	E. S. Downing	Dr	30.8	6	GI	(?)	do	N	N	Top of casing, south side	+ .8	2,884.0	9.49	do	Abandoned domestic well.
NE cor. SE sec. 28	W. E. Stone	Dr	120.4	24	BS	(?)	Ogallala and Pleistocene	T	N	Top of casing, east side	+ .4	2,901.1	25.45	do	Unused irrigation well; power unit removed.
SE SE sec. 30	W. M. Jewell	Dr	60	8	GI	(?)	do	Cy,W	N	Top of 2-inch board beneath pump	0	2,893.4	14.03	do	Unused domestic well.
SE NE sec. 35	P. A. Lindner	Dr	38.5	6	OW	(?)	Pleistocene	Cy,H	N	Top of east pipe clamp, west side	+1.5	2,895.9	25.57	Aug. 24	Do
T. 21 S., R. 34 W.															
SE SW SW sec. 2	J. R. Bosworth	Dr	61.5	6	GI	(?)	Ogallala	Cy,H	N	Top of casing, west side	0	2,958.9	60.9	Aug. 26	Do
SW cor. NW sec. 4	F. Baker	Dr	102.5	6	GI	(?)	do	Cy,W,H	D	Top of casing, north side	+ .5	3,014.0	86.26	Sept. 16	
SE NE sec. 21	J. E. Sprenkle	Du	85	48	W	"Soft, chalky rock"	Fort Hays	Cy,W	D	....	....	2,871.2	82	....	Reported to have "good" yield.
NE cor. NE sec. 24	C. N. Ingle	Dr	39.5	6	GI	(?)	Ogallala	Cy,W	N	Top of north pipe clamp, south side	+ .5	2,914.5	34.18	Sept. 20	Unused school well; observation well.

NE SE SE sec. 27	H. Gobleman	Du	69	48	N	"Chalk rock"	Fort Hays	Cy,W	D,S				67		Reported to have "good" yield; "chalk rock" reported between depths of 50-90 feet, blue shale at 90 feet; water reported to be of good quality.
SW NE sec. 36	L. W. Mauhe	B	55	6	GI	Sand and gravel	Ogallala	Cy,W	S	Top of west pipe clamp, east side	+1.0	2,921.8	42.77	Oct. 24	
T. 22 S., R. 27 W.															
SW SW sec. 4	Federal Land Bank	Du	24.5	36		(?)	Alluvium	Cy,W,H	D,S	Top of wooden platform	+1.5	2,493.9	16.37	Oct. 21	
SW SE sec. 10	L. R. Byler	Dr	45.5	8	GI	(?)	do	Cy,W	D	Top of casing, north side	+1.5	2,476.6	25.22	Oct. 23	Water reported to be of poor quality.
SE NE sec. 18	K. M. Winter	Sp				Sand and gravel	Pleistocene	F	S						Water piped to stock tank.
NW SW sec. 18	W. C. Erkie	Sp				do	do	F	S						
SW NE sec. 24	I. M. Finnup	Dr	73.4	5	GI	(?)	Blue Hill	Cy,H	D	do	+ .5	2,574.8	72.10	Oct. 21	
SE SE sec. 25	do	Dr	59.7	5.5	GI	(?)	(?)	N	N	Top of casing, southwest side	+ .8	2,590.1	41.14	do	Abandoned domestic and stock well.
T. 22 S., R. 28 W.															
SW SE sec. 8	W. J. Conner	B	39.1	5	GI	Sand and gravel	Alluvium	Cy,W,H	D	Top of concrete platform	+ .5	2,554.6	26.05	do	Reported to have "good" yield.
NE cor. SW sec. 10	H. W. Menke	Dr	28.5	6	GI	(?)	do	Cy,W	D	Top of casing, east side	+ .5	2,533.5	23.57	Sept. 20	Water reported to be hard.
NW NW sec. 12	H. W. Parson	Dr	41.5	5	GI	(?)	Alluvium (?)	Cy,H	D,S	Top of metal plate covering casing	0	2,526.1	38.14	Oct. 21	
NW SE sec. 13	W. C. Erkie	Sp				Sand and gravel	Pleistocene	F	S						
NW NE sec. 20	O. G. Boots	Sp				do	do	F	S						
SW SW sec. 25	D. H. Holden	Du	29.5	48	R	do	Ogallala and/or Pleistocene	Cy,W	N	Top of wooden cover over well.	+ .5	2,590.2	20.49	Oct. 23	Unused stock well.
T. 22 S., R. 29 W.															
NW SW sec. 8	J. B. Cook	B	50	6	GI	Gravel	Ogallala	Cy,W	D				40		
SW NW sec. 12	T. E. Meakel	B	20.5	3.5	GI	do	Alluvium	Cy,H	N	Top of casing, south side	+1.0	2,578.6	12.19	Oct. 19	Unused domestic well.
NW cor. NW sec. 14	W. A. Phipps	Dr	38.3	6	GI	(?)	(?)	N	N	Top of casing, west side	+ .3	2,640.9	28.54	Oct. 21	Do
NW SE sec. 16	E. Boots	Dr	61.5	6	GI	(?)	Blue Hill	N	N	Top of casing, northeast side	+ .5	2,654.8	53.56	do	Do
NE cor. SE sec. 18	C. Litzberger	Dr	43.9	5.5	GI	Gravel	Ogallala	Cy,W	D,S	Top of casing, north side	+1.4	2,646.5	35.81	do	
SE NE sec. 29	L. E. Bond	Dr	51.8	5	GI	(?)	Alluvium	Cy,W	D	Top of casing, south side	+2.3	2,639.5	20.68	Oct. 23	

Table 22.—Records of wells and springs in Finney county, Kansas—*Continued*

. 2	Location	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement, 1940	Remarks (Yield given in gallons a minute; drawdown in ft.)
	T. 22 S., R. 30 W.															
)	SE NE NW sec. 7	H. C. Morton	Dr	118	16	BS	Gravel	Ogallala	T,G	I				70		Reported yield 300.
1	SW NW NW sec. 7	do	Dr	76.5	6	GI	(?)	do	Cy,W	D	Top of casing, north side	+ .5	2,883.3	72.59	Sept. 11	
2	NW NW NE sec. 19	I. J. Schmidt	Dr	74.5	6	GI	(?)	do	N	N	Top of casing, east side	+1.0	2,872.8	70.33	do	Abandoned domestic well.
:	NW NW sec. 21	Rumford, et al	Sp				Limestone	Fort Hays	F	S						Several small springs at this locality.
i	NE NE sec. 28	P. B. Brandt	Dr	53.7	5	GI	(?)	do	N	N	Top of casing, noth side	+ .5	2,826.5	46.54	Oct. 21	Unused stock well.
5)	SW SW NW sec. 29	P. Theissen	Dr	69.5	6	GI	Sand and gravel	Ogallala	Cy,W	D,S	do	0	2,861.5	65.92	Sept. 11	Water contains much fluoride.
6	SE NE sec. 34	O. A. Hund	Sp				Limestone	Fort Hays	F	S						Estimated yield 2-3.
	T. 22 S., R. 31 W.															
7	SW cor. SW sec. 6	O. A. Ottmanns	Dr	104.8	6	OW	(?)	Ogallala	Cy,W	D,S	Lower edge of opening on south side of casing.	+ .3	2,932.5	96.50	Sept. 13	
8	NE cor. NE sec. 16	J. Reinhardt	Dr	83.5	6	GI	(?)	do	Cy,W	D	Top of north pipe clamp, south side.	0	2,901.5	81.14	Sept. 11	
9	NE SE SE sec. 24	P. A. Wiens	Dr	85.0	6	GI	(?)	do	Cy,W	N	Top of casing, west side	0	2,879.9	76.65	Sept. 20	Unused dom. and stock well; observation well.
)	SW cor. SW sec. 30	G. P. Louth	Dr	122.8			(?)	do	Cy,W	N	Top of east pipe clamp, west side.	+ .3	2,945.9	119.39	Sept. 13	Unused domestic well.
	T. 22 S., R. 32 W.															
:	NE NW sec. 9	R. Greathouse	Dr	85	4	GI	(?)	Pleistocene	Cy,W	D,S				57		
2	SW cor. SW sec. 13	W. H. Muret	Dr	115.5	6	OW	(?)	Ogallala	Cy,W	N	Top of casing, north side	+1.0	2,943.7	109.48	Sept. 13	Unused domestic well.

)	NW cor. NW sec. 27	Pioneer Savings and Loan Co.	Dr	94.1	6	GI	(?)	Pleistocene	Cy,W	D	Top of casing, east side	+ .1	2,916.2	69.24	do	
	T. 22 S., R. 33 W.															
	SW cor. SE sec. 5	School District	B	18			(?)	do	Cy,H	D	Top of concrete platform.	0	2,889.7	12.10	Sept. 3	School well; total depth not known; casing obstructed by cylinder at depth given.
	SW SW SW sec. 6	Liberty Life Ins. Co.	B	32.3	6	GI	(?)	do	Cy,W	N	do	+ .5	2,904.0	23.41	Aug. 26	Unused domestic and stock well.
	NE NE NW sec. 11	Santa Fe	Dr	102.5	6	GI	(?)	do	Cy,H	D	Top of casing, north side	0	2,895.4	29.20	Sept. 16	
	SW cor. SW sec. 18	Garden City Co.	Dr	112.5	24	BS	(?)	Ogallala and Pleistocene.	N	N	Top of concrete pump base.	+1.0	2,912.5	35.67	Sept. 20	Unused irrigation well; observation well.
	NW SW sec. 19	do	Dr	210	18,26	BS	Sand and gravel	do	T, E	I	Top of square steel-base plate on pump.	+2.0	2,913.0	39.61	Nov. 1	Gravel-packed well; reported yield 1,800.
	SW NW NW sec. 30	do	Dr	210	18,26	BS	do	do	T, E	I				35		Reported yield 1,000.
	NW cor. SW sec. 30	do	Dr	200	18,26	BS	do	do	N	N	Top of pump base	+2.5	2,919.3	46.98	Aug. 26	Unused irrigation well.
.	NW NW NW sec. 36	D. E. Evers	B	20.3	6	GI	(?)	Pleistocene	N	N	Top of casing, north side	+1.2	2,865.3	19.75	Aug. 24	Abandoned stock well.
	T. 22 S., R. 34 W.															
2	SE cor. SE sec. 5	W. D. Burnett	Dr	100.5			(?)	Ogallala	Cy,W	N	Top of metal plate covering casing.	0	2,978.4	97.19	Oct. 24	Unused domestic well.
3	NE cor. NE sec. 21	Harnett and Evans	Dr	36.0	6	GI	(?)	Pleistocene	Cy,W	N	Top of casing, north side	+ .5	2,945.6	34.14	Sept. 14	Unused stock well.
1	SW cor. SE sec. 24	Garden City Co.	Dr	200	18,26	BS	Sand and gravel	Ogallala and Pleistocene.	T, E	I				45		Reported yield 600.
	SW NW NE sec. 25	do	Dr	205	16,25	BS	do	do	T, E	I				45		Reported yield 1,500-1,600; gravel-packed well
	SW NW SW sec. 26	T. Miller	Dr	74.5	6	GI	(?)	Ogallala	Cy,W,H	D,S	Top of casing, east side	+ .5	2,939.7	50.29	Sept. 14	
	NE cor. NW sec. 30	B. Thornzen	Dr	83.5	6	GI	(?)	do	N	N	do	+1.0	2,992.3	73.38	Aug. 26	Abandoned domestic well.
	T. 23 S., R. 27 W.															
	SW SW sec. 4	G. P. Wilson	B	35	6	GI	Sand and gravel	do	Cy,W	D				33		
	SW cor. SW sec. 12	C. R. Rixon	Dr	72.5	6	GI	(?)	do	Cy,W	N	Lower edge of pump base, north side.	+ .5	2,627.8	68.86	Sept. 20	Unused dom. and stock well; observation well.
)	NE SE sec. 21	Lindas Lumber Co.	Dr	140	2	GP	Sand and gravel	do	Cy,W	D				95		Tubular well.
	NE SE NE sec. 24	J. G. English	Du	47.8	6	GI	(?)	do	Cy,W	D,S	Lower edge of wooden block under pump base.	+ .3	2,592.6	37.54	Nov. 5	
	NE NE SE sec. 36	Anna Krug	Dr	79.0	6	GI	(?)	do	Cy,W,H	N	Top of 6-inch casing, north side.	+1.5	2,623.8	71.48	do	Unused domestic well.

TABLE 22.—Records of wells and springs in Finney county, Kansas—*Continued*

No. on pl. 2 (1)	Location	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement, 1940	Remarks (Yield given in gallons a minute; drawdown in ft.)
	T. 23 S., R. 28 W.															
93	SE cor. SE sec. 3	Kansas State Bank	Dr	64	2	GP	Sand and gravel	Ogallala	Cy,W	D,S	....	....	....	52	....	Tubular well; water bearing sand and gravel reported between depths of 55 and 64 feet, blue shale below 64 feet.
94	SE NW sec. 12	W. D. Sinclair	B	12.5	6	GI	(?)	Alluvium	Cy,W	S	Top of wooden pipe clamp.	+ .5	2,629.2	10.45	Oct. 23	
95	NE NE sec. 18	Lena Ramsey	Dr	133.6	6	GI	(?)	Ogallala	Cy,W	S	Lower edge of hole, east side of casing.	+ .6	2,765.2	100.40	Oct. 29	Observation well.
96	SW NW SW sec. 35	I. E. Englart	Dr	85.7	....	....	(?)	do	Cy	N	Top of pipe clamp, west side.	+1.3	2,735.5	84.10	Nov. 5	Unused domestic well.
	T. 23 S., R. 29 W.															
97	SW NW sec. 9	L. M. Pope	Dr	35.5	6	GI	(?)	do	N	N	Top of casing, west side	+1.0	2,670.6	27.06	Oct. 23	Unused stock well.
(98)	SE SE sec. 11	I. N. Blanton	Dr	97.0	6	GI	(?)	do	Cy,W,H	D	Top of casing, east side	0	2,749.2	78.89	Oct. 19	
99	SW SE sec. 17	B. H. Harms	Dr	54.8	5	GI	(?)	do	Cy,W	N	Top of casing, west side	+ .3	2,739.5	37.07	Oct. 10	Unused domestic well.
100	SW SE sec. 24	G. York	Dr	106.9	3.5	GP	(?)	do	Cy,W	N	Top of 3.5-inch pipe, south side.	+2.9	2,769.9	96.49	do	Unused tubular domestic well; accuracy of water-level measurement questionable.
101	SW SE SW sec. 33	First National Bank, Spearville, Kansas.	Dr	89.7	2	GP	(?)	do	Cy	N	Top of 2-inch pipe	+4.0	2,777.3	79.90	do	Do
	T. 23 S., R. 30 W.															
102	NW NE NE sec. 5	J. E. Friesen	Dr	77.5	6	GI	(?)	do	Cy,W	D	Top of casing, south-west side.	0	2,852.8	70.86	Sept. 11	
103	SE NE sec. 15	T. H. Endicott	Sp	....	....	....	Limestone	Fort Hays	F	S	....	....	....	....	....	Area of several small spgs.

104	NW NW NW sec. 17	M. Carter	Dr	79.7	6	GI	(?)	Ogallala	Cy,W	D	Top of casing, north side.	+ .2	2,848.1	73.35	Sept. 11	
105	SW cor. SW sec. 31	J. H. Gerhardt, Jr.	Dr	135.7	6	GI	Fine sand	do	Cy,W	D	Top of south pipe clamp north side.	+ .2	2,885.5	121.18	do	
106	NW NE sec. 34	Wheat Growers Mutual Insurance Co.	Dr	89.5	5.5	GI	(?)	do	Cy,W	D	Top plank over casing,	0	2,802.9	67.71	Oct. 10	
	T. 23 S., R. 31 W.															
107	SE SE SW sec. 8	J. W. Nolan	B	49.5	6	GI	(?)	do	N	N	Top of casing, south side	+ .5	2,877.2	48.55	Sept. 13	Unused stock well.
108	NW cor. NW sec. 26	J. Kisner	Dr	120	6	GI	Sand and gravel	do	Cy,W	D,S				80		
109	NW NW NW sec. 29	H. Kohrs	Dr	103.5	6	GI	(?)	do	N	N	Top of casing, north side	+ .5	2,907.1	99.43	Sept. 11	Abandoned domestic and stock well.
	T. 23 S., R. 32 W.															
110	SE cor. SW SE sec. 4	J. E. Ely	Dr	59.5	6	GI	(?)	Pleistocene	Cy,W	N	Top of metal plate covering casing.	+ .5	2,882.1	45.69	Sept. 28	Unused domestic well; observation well.
111	SE NW sec. 17	Elsie V. Kerfoot	Dr	25.0	6	GI	(?)	do	Cy,W	N	Top of casing, north side	+2.0	2,844.8	8.63	Sept. 13	Unused stock well.
112	NW cor. SW sec. 19	H. R. Hawk	Dr	314	16	BS	(?)	Ogallala and Pleistocene.	T,E	I	Top of floor of pump house.			38.25	Oct. 25	Gravel-packed well; measured yield 990, drawdown 19.5 (10).
113	NW SW sec. 20	C. Zirkle	Dr	172	18	C	Sand and gravel	Pleistocene	T,E	I	Top of concrete casing, south side.	+4.0	2,844.5	9.59	Oct. 18	
(114)	SW SW sec. 20	do	B	23.5	5	GI	(?)	do	Cy,W	S	Top of casing, east side	0	2,844.5	10.42	Oct. 26	Water reported hard.
115	SW SW sec. 23	C. E. Boyd	Dr	222	16	BS	Sand and gravel	Ogallala	T,E	I	Top of casing, south side	−1.3		91.83	Feb. 21 (11)	Measured yield 472, drawdown 31.8 (10).
116	SW cor. NW sec. 31	C. A. Danner	Dr	260	18	BS	do	Ogallala and Pleistocene.	T,E	I				40		Gravel-packed well; reported yield 750, estimated drawdown 40.
117	SW NW NE sec. 32	J. A. Black	Dr	93	16	BS	(?)	Pleistocene	T,E	I				13		Gravel-packed well; reported yield 850.
118	NW NW SW sec. 32	Dr. Miner	Dr	170	16	BS	(?)	do	T,E	I	Top edge of opening in pump base.	+1.0	2,871.8	36.19	Aug. 14	Gravel-packed well; reported yield 600.
	T. 23 S., R. 33 W.															
119	SW SW sec. 4	R. J. Ackley	Dr	70-80	2	GP	(?)	do	N							Flowing well, see p. 00.
120	SW SE sec. 9	Hercules Life Ins. Co.	Dr	47.5	6	GI	(?)	do	Cy,H	N	Top of wooden plank beneath pump base.	+1.0	2,890.7	26.07	Sept. 16	Unused domestic well.
121	NW cor. SW sec 10	W. Wheeler	Dr	268	16	BS	Gravel	Ogallala and Pleistocene.	T,E	I				35		Gravel-packed well; reported yield, 1,000; black clay reported between depths of 268-289 feet, and black shale below 389 feet.

TABLE 22.—Records of wells and springs in Finney county, Kansas—*Continued*

[illegible]	LOCATION	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement, 1940	Remarks (Yield given in gallons a minute; drawdown in ft.)
	T. 23 S., R. 33 W.															
22	NW NW SW sec. 11	School District	B	21.7	6	GI	(?)	Pleistocene	Cy,H	N	Top of casing, north side	+ .2	2,872.6	16.76	Aug. 24	Unused school well.
23	SE SW SW sec. 14	W. Wheeler	Dr	310	16	BS	Gravel	Ogallala and Pleistocene	T,E	I	....	....	....	50	....	Gravel-packed well; reported yield 1,300, drawdown 39.
24	NW NW SW sec. 15	E. T. Borgman	Dr	300	16	BS	(?)	do.	T,E	I	Top of casing, west side	+ .5	2,891.8	33.37	Aug. 12	New well; reported yield 1,260 with test pump
25)	SW cor. SW sec. 18	Garden City Co.	Dr	68.5	6	GI	(?)	Pleistocene	Cy,W	D,S	Top of wooden platform	+ .5	2,911.6	22.65	Sept. 3	
26	SW SW SE sec. 21	A. J. Johnson	Dr	300+	16	BS	(?)	Ogallala and Pleistocene	T,E	I	....	....	....	....	....	Reported yield 560, total lift 105 feet.
27	NW cor. SW sec. 24	E. Caldwell	Dr	340	16	BS	(?)	do.	T,E	I	....	....	....	30	....	Gravel-packed well; reported yield 800–900, drawdown 39.
28	SW cor. SE sec. 25	C. A. Danner	Dr	330	16	BS	Gravel	do.	S,E	I	....	....	....	36	....	Gravel-packed well; measured yield 1,260, drawdown 33(10).
29	SW NW NW sec. 26	R. Stevenson	Dr	240	16	BS	Sand and gravel	do.	T,E	I	....	....	....	42	....	Reported yield 900, drawdown 43. Measured yield 400, drawdown 21(10).
30	SW cor. SE sec. 26	C. A. Danner	Dr	332	16	BS	(?)	do.	T,E	I	....	....	....	50	....	Gravel-packed well; reported yield 900, drawdown 37.
31	SW cor. SE sec. 28	A. K. Boxler	Dr	310	16	BS	(?)	do.	T,E	I	Top of floor of pumphouse.	+ .5	....	43.20	Oct. 25	Gravel-packed well; measured yield 1,100, drawdown 18.45 (10).

2	NW NW SE sec. 29	Garden City Co.	Dr	285	18, 24	BS	Sand and gravel	do.	T,E	I				55		Reported yield 900; old-style turbine pump driven by 100 H.P. direct-connected electric motor.
3	SW SW NW sec. 30	do.	Dr	41.5	6	GI	(?)	Pleistocene	Cy,W	D,S	Top of wooden platform	+1.0	2,920.0	36.74	Sept. 3	
4	SE SE SW sec. 32	G. H. Sanders	8 Dr	30	16	GI	Gravel	Alluvium	C,E	I				15		Battery of 8 shallow wells; reported aggregate yield 800–900.
5	NW cor. SE sec. 34	L. E. Joseph	Dr	341	16	BS	Gravel	Ogallala and Pleistocene	T,E	I				48		Gravel-packed well; measured yield 970, drawdown 24(9).
6	NW NE SE sec. 35	R. M. Jones	Dr	340	16	BS	Sand and gravel	do.	T,E	I				48		Gravel-packed well; reported yield 1,000.
7	NW cor. SE sec. 35	do.	Dr	300	16	BS	do.	do.	T,E	I				48		Do
8	SW SW sec. 35	Nora Will	Dr	97.5	3	I	(?)	Pleistocene	N	N	Top of casing, north side	+1.0	2,893.9	48.69	Dec. 24	Unused stock well; observation well.
9	NW SE SW sec. 35	R. M. Jones	Dr	300	16	BS	Sand and gravel	Ogallala and Pleistocene	T,E	I				45		Gravel-packed well; reported yield 1,000.
0	SW SE SE sec. 35	do.	Dr	240	16	BS	do.	do.	T,E	I				50		Do
11)	SE cor. SE sec. 35	do.	Dr	240	16	BS	do.	do.	T,E	I	Top of casing, north side	+1.0	2,889.6	48.38	Dec. 14	Gravel-packed well; reported yield 1,000.
	T. 23 S., R. 34 W.															
2	NE NE sec. 6	J. W. Marsteller	Dr	88.5			(?)	Ogallala	Cy,W	N	Upper edge of bolt hole in pump base	+ .5	2,989.0	69.22	Oct. 10	Unused domestic well.
3	SE cor. SE sec. 10	H. E. Ramsey	Dr	45.5	6	GI	(?)	Ogallala and/or Pleistocene	Cy,W	N	Top of casing, south side	0	2,938.3	31.85	Sept. 20	Unused domestic and stock well; observation well.
4	SE SE SE sec. 12	J. Bosworth	Dr	53.0	6	GI	(?)	do.	Cy,W,H	D,S	Top of 3 by 3-inch plank beneath pump	+1.0	2,925.6	34.91	Sept. 3	
5	SW SE NE sec. 18	Garden City Co.	Dr	305	16, 25	BS	Sand and gravel	Ogallala	T,E	I	Top of square steel-base plate, north side	+3.0	2,983.5	56.76	Nov. 1	Gravel-packed well; reported yield 1,500, drawdown 33.
6	NW NW sec. 19	do.	Dr	284	16	BS	do.	do.	T,E	I				42		Gravel-packed well; reported yield 1,250, drawdown 25.
7	SW NW NW sec. 22	do.	Dr	319	24	BS	Sand	do.	N	N	Top of concrete pump base.	+ .5	2,956.2	35.93	Aug. 27	Abandoned irrigation well; pump removed.
8	NE NE sec. 25	do.	Dr	265	16	BS	Sand and gravel	Ogallala and Pleistocene	T,E	I				35		Gravel-packed well; reported yield 1,350, drawdown 42; when pumping 1,270, drawdown is 30.

TABLE 22.—Records of wells and springs in Finney county, Kansas—*Continued*

No. on pl. 2 (1)	LOCATION	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement, 1940	Remarks (Yield given in gallons a minute; drawdown in ft.)
	T. 23 S., R. 34 W.															
[illegible]	SW NE sec. 27	Garden City Co.	Dr	305	16	BS	Sand and gravel	Ogallala	T,E	I				46		Gravel-packed well; reported yield 1,200, drawdown 60–70.
[illegible]0	NE NW NW sec. 29	do.	Dr	260	13, 24	BS	do.	do.	T,E	I				42		Old-style turbine pump driven by a 100 H. P. direct-connected electric motor; reported yield 1,370, drawdown 140±.
[illegible]	NW NW NW sec. 29	do.	Dr	87.5	6	GI	(?)	do.	Cy,H	D	Lower edge of pump base, east side	+ .9	2,972.7	42.91	Oct. 10	
[illegible]	SW NW NE sec. 30	H. Meyer	Dr	190	16	BS	(?)	do.	T,E	I				45		Gravel-packed well; reported yield 600–700.
[illegible]	NW cor. NW sec. 31	Garden City Co.	Dr	250	18, 25	BS	Sand and gravel	do.	T,E	I				50		Old-style turbine pump-driven by a 100 H. P. direct-connected electric motor; reported yield 540, drawdown 130±.
[illegible]	SE cor. NE sec. 32	do.	Dr	52.0	6	GI	(?)	do.	Cy,W	S	Lower edge of pump base, west side	+1.0	2,964.6	46.79	Oct. 10	
[illegible]	NW SW NW sec. 33	do.	Dr	268	16	BS	Sand and gravel	do.	T,E(8)	I	Top of casing	+ .5		48.5	Oct. 10	Gravel-packed well drilled in Sept., 1940; measured yield in 1940 with test equipment 1,080, drawdown 45; measured yield 1,150, drawdown 50(12).
[illegible]	NW NW SW sec. 33	do.	Dr	189	16	BS	do.	do.	N	I				48		Gravel-packed well drilled in Oct., 1940; pump not installed yet.

7	NW cor. NE sec. 34	do.	Dr	271	16	BS	do.	do.	T,E	I	....	....	....	60	....	Gravel-packed well; reported yield 1,250, drawdown 20±.
3	SE cor. SE sec. 34	do.	Dr	59.5	5.5	GI	(?)	do.	Cy,W,H	D	Top edge of bolt hold in pump base	+1.0	2,905.4	56.45	Oct. 10	
9	NW NW NW sec. 36	J. Burgardt	Dr	297	16	BS	(?)	do.	T,E	I	....	....	....	....	....	Gravel-packed well; reported yield 900.
0	SW SW SE sec. 36	L. E. Joss	Dr.	274	16	BS	(?)	Ogallala and alluvium	T,E	I	....	....	....	16	....	Gravel-packed well drilled during summer of 1940; reported yield 1,160.
	T. 24 S., R. 31 W.															
	NW NW NE sec. 10	C. Drach	Dr	114.8	6	GI	(?)	Ogallala	Cy	N	Top of casing, southeast side	+ .3	2,887.8	108.08	Sept. 11	Abandoned domestic well.
2	SE SE sec. 14	H. Harms	Dr	265	......	BS	Gravel	do.	N	I	....	....	....	....	....	New irrigation well drilled in Dec., 1940.
3	SE SE sec. 14	do.	Dr	132	6	GI	Coarse gravel	do.	Cy,W	D	....	....	....	102	....	Casing set on clay.
4	NW SW SW sec. 18	J. Eichhorn	Dr	125.0	6	OW	(?)	do.	Cy,W	N	Top of south pipe clamp, north side	+2.0	2,915.9	120.32	Sept. 20	Unused stock well; observation well.
5)	NW NW NW sec. 31	G. L. Webster	Dr	32	15	GI	Gravel	Alluvium	C,E	I	....	....	....	....	....	Reported yield 750, drawdown 11.
6	NE NW SW sec. 31	W. E. Hicks	3 Dr	47	20	C	do.	do.	C,E	I	Top of concrete curb, east side	+3.0	2,797.0	14.75	Aug. 24	Southernmost well of a battery of 3 wells; reported aggregate yield 1,000–1,150, drawdown 24±.
	T. 24 S., R. 32 W.															
7	NW NW SE sec. 3	Garden City Exp. Sta.	6 Dr	50	16	GI	Sand and gravel	Alluvium (?)	C,E	I	Top of concrete well curb, south side	+ .9	2,831.6	17.30	Dec. 14	Battery of 6 wells; measured first well east of pumphouse; reported aggregate yield 1,000, drawdown 18±.
8	SW cor. NE SE sec. 3	do.	Dr	196	26	BS	do.	Ogallala and Pleistocene	N	N	Top of casing, northwest side	+ .9	2,885.7	70.69	Nov. 30	Unused irrigation well; observation well.
9	SW cor. NW sec. 4	L. M. Marshall	Dr	70	6	GI	Fine silty sand	Pleistocene	Cy,W	I	Top of pipe clamp	+1.0	2,864.9	42.54	Sept. 13	Used to irrigate lawn and trees; small yield reported.
0	SW SE NE sec. 4	G. G. Finley	Dr	113.5	16	BS	Gravel	do.	T,E	I	....	....	....	38	....	Reported yield 600, drawdown 34.
1	SW SW SE sec. 4	S. W. Neeley	Dr	120	24	GI	(?)	do.	T,E	I	....	....	....	36	....	Reported yield 750.
2	NW SW NW sec. 5	W. E. Stone	Dr	212	16	BS	(?)	Ogallala and Pleistocene	T,E	I	....	....	....	25	....	Reported yield 700.
	SE NE sec. 6	Valley View Cemetery	Dr	280	16	BS	(?)	do.	T,E	I	....	....	....	....	....	Gravel-packed well; used to irrigate lawn and trees.

TABLE 22.—Records of wells and springs in Finney county, Kansas—*Continued*

No. on pl. 2 (1)	LOCATION	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.) (4)	Type of casing (4)	Principal water-bearing bed		Method of lift (5)	Use of water (6)	Measuring point			Depth to water level below measuring point (feet) (7)	Date of measurement, 1940	Remarks (Yield given in gallons a minute; drawdown in ft.)
							Character of material	Geologic subdivision			Description	Distance above (+) or below (—) land surface (feet)	Height above sea level (feet)			
	T. 24 S., R. 32 W.															
[illegible]	SE NE NE sec. 6	Monthey	2 Dr	30	16	GI	Gravel	Alluvium	C,E	I	....	....	....	12	....	Reported yield, 400.
[illegible]	NW SW NW sec. 7	Hebrew Bros	2 Dr	26 and 64	16 and 12	GI	do	do	C,G	I	....	....	....	12–14	....	
[illegible]	W SW NW sec. 7	C. L. Niquette	Dr	65	15	GI	do	do	C,E	I	....	....	....	17	....	Reported yield, 420.
77	SW NE SE sec. 7	Garden City Nursery	3 Dr	38	15	GI	do	do	C,E	I	Top of concrete well curb, south side	+1.0	2,835.5	13.77	Nov. 1	Southernmost well of a battery of 3 wells; reported aggregate yield 735.
78	NW SW SW sec. 7	C. C. Snyder	3 Dr	32	16 and 24	GI and C	do	do	C,G	I	....	....	....	18	....	Battery of 3 wells; two wells are cased with 24-inch concrete casing and the other is cased with 16-inch galvanized-iron casing; reported aggregate yield, 1,000, drawdown 8±.
[illegible]	SW SW sec. 7	....	Dr	35	12	GI	do	do	C,G	I	....	....	....	....	....	
80	SE SW sec. 7	G. W. Dale	3 Dr	30	16	GI	do	do	C,G	I	....	....	....	20	....	Battery of 3 wells; reported aggregate yield 500.
[illegible]	SW SE sec. 7	City of Garden City	Dr	258	12, 30	GI	(?)	Ogallala and Pleistocene	T,E	P	....	....	....	16	....	Upper water sealed off; gravel packed from depth of 150 feet to bottom; reported yield 650.
82	SW SE SE sec. 7	R. I. Goss	Dr	40	....	....	Gravel	Alluvium	C,E	I	....	....	....	....	....	Casing covered at surface so water level could not be measured; reported yield 500.

183	SE SW SW sec. 8	S. G. Webber	3 Dr	25	16	GI	(?)	do.	C,E	I	...	...	...	12	...	Battery of 3 wells; reported aggregate yield 750.
184	SW SE SW sec. 8	L. Johnston	3 Dr	40	16	GI	(?)	do.	C,E	I	...	...	...	...	...	Battery of 3 wells; reported aggregate yield 700.
185	SE SE SW sec. 8	J. H. Mai	5 Dr	20, 100	16	GI	(?)	Pleistocene and alluvium	C,E	I	...	...	...	...	...	Battery of 2 shallow and 3 deep wells; reported aggregate yield 800.
186	NW NE sec. 9	L. E. Worf	2 Dr	65, 67	16	GI, C	Gravel	Alluvium	C,E	I	...	...	...	...	...	Battery of 2 wells; reported aggregate yield 500.
187	SW SW SW sec. 9	W. McKelvey	2 Dr	25	18	GI	do.	do.	C,E	I	...	...	...	8	...	Battery of 2 wells; reported aggregate yield 350.
188	NW SW SE sec. 9	J. A. Becraft	3 Dr	75, 102	16	C	Medium to coarse sand	Pleistocene and alluvium	C,E	I	...	...	...	13	...	Battery of 3 wells; reported aggregate yield 1,200.
189	SW cor. SW sec. 10	G. H. Mack	B	14.3	6	GI	(?)	Alluvium	N	N	Top of casing, south side	+3.8	2,825.7	9.99	May 23	Abandoned well; observation well from Sept., 1939, to May, 1940.
190	NE NE NE sec. 15	McGaugh Bros.	2 Dr	85, 90	16	C	(?)	Pleistocene and alluvium	C,E	I	...	...	...	20	...	Battery of 2 wells; reported aggregate yield 1,000.
191	NE cor. NW sec. 15	R. E. McGaugh	3 Dr	33, 45, 45	16	GI	(?)	Alluvium	C,E	I	...	...	...	10	...	Battery of 3 wells; reported aggregate yield 1,000.
192	W NW NE sec. 16	V. R. Mayo	2 Dr	60, 66	18	GI	(?)	do.	C,E	I	...	...	...	12	...	Battery of 2 wells; reported aggregate yield 650.
193	NE NW NW sec. 16	J. P. Schoenberger	Dr	22, 8	10	BS	(?)	do.	C,E	I	Top of casing, south side	+ .3	...	11.49	Aug. 10	Used to irrigate small garden.
194	N NW NW sec. 16	W. F. Wilford	Dr	...	20	OB	(?)	do.	C,G	I	...	...	...	11	...	Used only occasionally.
195	NW SE NE sec. 16	V. R. Mayo	4 Dr	51, 88	20	C	(?)	do.	C,E	I	...	...	...	12	...	Battery of 4 wells; measured aggregate yield 1,590 (10).
196	SW cor. NW sec. 16	H. George	5 Dr	42	20	C	(?)	do.	C,E	I	...	...	...	15	...	Battery of 5 wells; reported aggregate yield in 1940 with 8-in. pump driven by a 15 H. P. motor, 1,800; measured yield July, 1939, with 10-in. pump driven by a 35 H. P. motor, 2,065; average drawdown 8.01 (10).

TABLE 22.—Records of wells and springs in Finney county, Kansas—*Continued*

...	Location	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement, 1940	Remarks (Yield given in gallons a minute; drawdown in ft.)
	T. 24 S., R. 32 W.															
7	NW NE SE sec. 16	Green	4 Dr	......	14	GI	(?)	Alluvium	C,E	I	......	......	......	......	......	Battery of 4 wells; reported to be in poor condition.
8	NE NW SE sec. 16	A. W. Zick	Dr	140	12	GI	(?)	Ogallala and alluvium	C,E	I	......	......	......	10	......	
9	NW NW SE sec. 16	T. Reed	Dr	40	14	GI	(?)	Alluvium	VC,G	I	......	......	......	12	......	
0	W NW SW sec. 16	H. Halsey	3 Dr	40	20	GI	(?)	do	C,E	I	......	......	......	15	......	Battery of 3 wells; reported aggregate yield 700, av. drawdown 8.
1	NW SW SW sec. 16	D. D. Doty	5 Dr	42	18	GI	Sand and gravel	do	C,E	I	......	......	......	15	......	Battery of 5 wells; reported aggregate yield 2,000.
2	NW SW SE sec. 16	H. N. Davidson	Dr	38	18	GI	(?)	do	C,E	I	......	......	......	13	......	Reported yield 800.
3	SW cor. SE sec. 16	do	Dr	25	16	GI	(?)	do	C,E	I	Top of casing, north side	—3.5	......	9.22	Oct. 12	
4	W NW NE sec. 17	G. Shawo	2 Dr	31.0	16	GI	(?)	do	C,G	I	Top of well-house curb, south side	0	......	16.3	Aug. 8	Battery of 2 wells; reported aggregate yield 600.
5	SE NE NW sec. 17	E. H. Gardiner	2 Dr	36	15	GI	(?)	do	C,G	I	......	......	......	......	......	Battery of 2 wells; reported aggregate yield 700.
6	NW NE NW sec. 17	H. F. Harms	Dr	......	......	......	(?)	do	C,G	I	......	......	......	......	......	Used to irrigate small garden.
7	NE NW NW sec. 17	C. F. Warnke	3 Dr	32	17	GI	(?)	do	C,E	I	......	......	......	14		Battery of 3 wells; reported aggregate yield 800.

)	NE SW NW sec. 17	City of Garden City	Dr	299	12, 30	GI	Sand and gravel	Ogallala and Pleistocene	T,E	P				16		Upper water sealed off; gravel packed from depth of 150 feet to bottom; reported yield 500; drawdown 16±; see log.
9	SE SW NW sec. 17	A. C. Gingrich	Dr	35	16	GI	(?)	Alluvium	C,E	I				18		
)	SW SW NE sec. 17	H. Eichorn	Dr				(?)	(?)	C,E	I						
!	SW SE NE sec. 17	J. A. Brock	2 Dr	45	15	C	(?)	Alluvium	C,E	I				13		Battery of 2 wells; reported aggregate yield 800.
2	NW NE SE sec. 17	C. Weldon	Dr	35	15	GI	(?)	do.	C,E	I						Reported yield 260.
3	SE NE SE sec. 17	E. M. Fischer	Dr	33	15	GI	(?)	do.	C,T	I						Reported yield 280.
4	SW NE SE sec. 17	J. F. Dibben	Dr				(?)	do.	C,E	I						
5	SE NE SW sec. 17	C. R. Craytor	Dr	30	15	GI	(?)	do.	C,E	I						Reported yield 750.
6	SE NE SW sec. 17	J. Seymour	Dr	35	16	GI	(?)	do.	C,E	I				12		Reported yield 500.
7	NW SE SW sec. 17	R. E. Tremain	2 Dr	42	30	OB	(?)	do.	C,E	I				12		Battery of 2 wells.
8	NW SE SE sec. 17	E. M. Fischer	Dr	33	18	GI	(?)	do.	C,T	I						Reported yield 750.
9	SE SE SE sec. 17	Kansas Highway Com.	Dr	30	16	GI	(?)	do.	C,E	I						Used to water lawn and trees.
0	NE SW sec. 18	Garden City Ice Co.	Dr	125			(?)	Ogallala and Pleistocene	C,E	In				15		Water used to make ice; add small amount of lime to water.
1	NE SW sec. 18	do.	Dr	35			(?)	Alluvium	C,E	In				16		Water used for cooling; reported yield 175, drawdown 9±.
2	SW NE SW sec. 18	Santa Fe Railway	Dr	202	8, 10, 13		Sand and gravel	Ogallala and Pleistocene	C,E	In				10		Upper water sealed off; reported yield 250, small drawdown; water treated with lime and phosphate, to prevent scaling in boilers; see log.
23)	SE NW SW sec. 18	City of Garden City	5 Dr	250	12, 30	GI	(?)	do.	C,E	P				16		Five wells equipped with 4 pumps; any combination of pumps can be used to draw from the 5 wells; reported yield 500-600 per pump; water not treated.

Table 22.—Records of wells and springs in Finney county, Kansas—*Continued*

No. on pl. 2 (1)	Location	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement, 1940	Remarks (Yield given in gallons a minute; drawdown in ft.)
	T. 24 S., R. 32 W.															
[illegible]	SE NW sec. 19	City of Garden City	2 Dr	32	15	GI	Gravel	Alluvium	C,E	I	....	....	....	9	....	Battery of 2 wells; reported aggregate yield 1,000, drawdown 6 after pumping 10 hours; water reported to be hard; temperature, 57° F.
5	SE NW sec. 19	do	4 Dr	37	15	GI	do	do	C,E	I	....	....	....	12	....	Battery of 4 wells; reported aggregate yield 1,250, drawdown 7 after pumping 10 hours; water also used to fill swimming pool; temperature, 57° F.
26)	SE SW sec. 19	F. E. Stewart	Dr	71.4	6	GI	Sand and gravel	Terrace gravel,	Cy,H	D	Top of casing, south side	+ .4	2,872.0	46.74	Sept. 4	Fine sand reported between depths of 0-40 feet, sand and gravel from 40-92 feet.
7	NE cor. NE sec. 20	R. M. Jameson	6 Dr	45	18	GI	Gravel	Alluvium	C,B	I	Top of concrete curb, south side	+ .5	2,825.6	12.62	Nov. 1	Battery of 6 wells; measured first well south of pumphouse; reported aggregate yield 4,000.
8	NW NW NE sec. 20	E. Stoeckly	Dr	40	16	GI	(?)	do	VC,E	I	....	....	....	18	....	Reported yield 1,450, drawdown 15.
9	NE NE NW sec. 20	do	2 Dr	35	16	GI	(?)	do	C,E	I	....	....	....	12	....	Battery of 2 wells; reported aggregate yield 1,100, drawdown 13.
[illegible]	NE NW NW sec. 20	do	Dr	35	......	......	(?)	do	C,E	I	....	....	....	10	....	Reported yield 450.
[illegible]	NW NE NE sec. 21	B. Collins	Dr	32	15	GI	(?)	do	C,E	I	....	....	....	8	....	Reported yield 400, drawdown 8.

SW NE NE sec. 21	do.	Dr	38	19	GI	(?)	do.	C,T	I	....	....	....	8	....	
NE cor. NW sec. 21	R. M. Jameson	4 Dr	45	18	GI	(?)	do.	C,E	I	Top of concrete curb	0	2,822.5	11.59	Dec. 6	Battery of 4 wells; measured first well west of pumphouse; measured aggregate yield August, 1939, 1,040; average drawdown 10.28 (10).
NE NE NW sec. 22	F. Ramirez	4 Dr	40	16	GI	(?)	do.	C,E	I	Top of concrete cover, west side	+1.0	....	11.23	Aug. 30	Battery of 4 wells; measured first well south of pumphouse; reported aggregate yield 1,600.
SW NW NW sec. 22	W. H. von Treba	3 Dr	45	19	GI	(?)	do.	C,E	I	Top of concrete curb	0	2,818.3	11.34	Aug. 8	Battery of 3 wells; measured first well north of pumphouse; reported aggregate yield 2,000.
SE NW sec. 22	F. Moseley	3 Dr	38	16	GI	(?)	do.	C,E	I	....	....	....	10	....	Battery of 3 wells; reported aggregate yield 1,000.
SE cor. NW sec. 22	E. F. Renick	5 Dr	40, 50	16	GI,C	(?)	do.	C,E	I	....	....	....	....	....	Battery of 5 wells; reported aggregate yield 1,600.
NW SW SW sec. 23	W. F. Wolf	12 Dr	38–40	16	GI	(?)	do.	C,E	I	Top of concrete curb, south side	+ .5	2,811.3	10.10	Dec. 6	Battery of 12 wells; measured first well south of pumphouse; measured aggregate yield August, 1939, 2,790; average drawdown 8.14 (10).
NW NW SW sec. 25	A. A. Mercer	3 Dr	42	16	GI	(?)	do.	C,E	I	....	....	....	9	....	Battery of 3 wells; reported aggregate yield 1,500.
NE NW NW sec. 26	W. S. Renick	2 Dr	44.5	16	GI	(?)	do.	C,E	I	Top of concrete curb, north side	+ .5	....	11.11	Aug. 8	Northernmost well of battery of 2 wells; reported aggregate yield 1,000.
SE NE sec. 36	S. Schulman	10 Dr	43	16	GI	(?)	do.	C,G	I	Top of concrete curb, west side	0	2,795.3	8.32	Nov. 1	Westernmost well of battery of 10 wells; reported aggregate yield 3,750, average drawdown 15±.
T. 24 S., R. 33 W.															
SW SW SW sec. 1	E. Stoeckly	8 Dr	42, 68, 86	18, 20	GI,C	Sand and gravel	do.	C,E	I	Top of concrete curb	+ .5	2,853.6	16.43	Sept. 5	Battery of 8 wells; measured third well south of pumphouse; reported aggregate yield 900.
SW cor. SE sec. 1	L. Angeles	4 Dr	23	14	GI	(?)	do.	C,E	I	....	....	....	16	....	Battery of 4 wells; reported aggregate yield 300.

Table 22.—Records of wells and springs in Finney county, Kansas—*Continued*

). 1 2)	Location	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement, 1940	Remarks (Yield given in gallons a minute; drawdown in ft.)
	T. 24 S., R. 33 W.															
4	SW cor. SE SE sec. 1	O. Sonderegger	5 Dr	20	16	GI	Gravel	Alluvium	C,E	I	....	....	....	12	....	Battery of 5 wells; reported aggregate yield 400.
5	SE SE SE sec. 1	B. A. Sperry	3 Dr	18	16	GI	(?)	do.	C,E	I	....	....	....	12	....	Battery of 3 wells; reported aggregate yield 150.
6	SW cor. SW sec. 2	F. A. Edwards	12 Dr	24.5	15	GI	Sand and gravel	do.	C	N	Lower edge of concrete well cover	+1.0	2,858.6	15.32	Oct. 28	Southernmost well of battery of 12 wells; unused irrigation well; power removed; observation well.
7	NW SE NE sec. 3	R. Stevenson	2 Dr	80, 90	16, 12	GI,BS	....	Pleistocene and alluvium	C,G	I	....	....	....	....	....	Battery of 2 wells; reported yield 700–800.
8	SW cor. NW sec. 4	D. E. Hate	5 Dr	35	18, 24	C	Sand	Alluvium	C,E	I	Top of concrete curb	+ .6	2,873.1	14.97	Dec. 6	Battery of 5 wells; measured second well north of pumphouse; wells being reconditioned in December, 1940; measured aggregate yield July, 1939, from 14 wells, 1,580; av. drawdown 7.57 (10).
9	NW cor. SE sec. 4	H. L. Frye	3 Dr	90	16	C	Sand and gravel	Pleistocene and alluvium	C,E	I	....	....	....	14	....	Battery of 3 wells; reported aggregate yield 1,000, average drawdown 15±.
)	NW cor. SW sec. 4	E. H. McBeth	5 Dr	18, 22	16	GI	(?)	Alluvium	C,E	I	....	....	....	12	....	Battery of 5 wells; estimated aggregate yield 700–800.

NW SW SE sec. 4	H. L. Frye	12 Dr	24.7	15	GI	(?)	do	C,E	N	Top of casing, west side	+1.7	2,864.5	11.55	Aug. 2	Battery of 12 abandoned irrigation wells; measured fifth well south of pumphouse.
SW NW NW sec. 5	W. B. Connely	14 Dr	40	16	GI	Sand	do	C,E	I	Top of concrete curb, west side	+ .3	2,880.7	14.53	Dec. 14	Battery of 14 wells; measured third well north of pumphouse; reported aggregate yield 1,000; plant in poor condition.
NW NW SW sec. 5	L. McCoy et al	13 Dr	34	15	GI	Sand and gravel	do	C,E	I	Top of concrete curb, south side	+ .5	......	14.96	Nov. 1	Southernmost well of battery of 13 wells.
SW SE NE sec. 6	E. L. McCoy	2 Dr	60, 285	16	......	(?)	Ogallala-alluvium	T,E	I	......	......	......	14	......	Battery of 1 deep and 1 shallow well; reported aggregate yield, 800–900.
SW SW sec. 6	M. Mitchell	11 Dr	31	16	GI	(?)	Alluvium	C,E	I	Top of concrete curb	+ .5	......	19.74	Dec. 6	Battery of 11 wells; measured first well north of pumphouse; wells reported to be too shallow and in poor condition.
SW SE SW sec. 6	W. Holmstrom	Dr	30	16	GI	(?)	do	C,E	I	......	......	......	18	......	Used to irrigate trees; reported to have a small yield.
SW SW SE sec. 6	E. L. McCoy	8 Dr	45	16	GI	(?)	do	C,E	I	......	......	......	14	......	Battery of 8 wells; reported aggregate yield 1,300.
NE NE NW sec. 7	W. J. Nolan	6 Dr	......	16	GI	Sand and gravel	do	C,E	I	do	0	......	19.78	Nov. 1	Southernmost well of battery of 6 wells; reported aggregate yield 1,500.
NE NE NW sec. 7	Holcomb Consol'd Sch.	2 Dr	......	......	......	(?)	do	C,E	I	......	......	......	......	......	Battery of 2 wells; reported aggregate yield 450.
NE NW NW sec. 7	do	2 Dr	35	......	......	(?)	do	C,E	I	......	......	......	......	......	Battery of 2 wells; reported aggregate yield 200.
NW NW NW sec. 7	C. McQueen	Dr	30	14	GI	(?)	do	C,E	I	......	......	......	......	......	Small yield reported.
NW SW NW sec. 7	Tri-County Gas Co.	Dr	220	4	I	Coarse gravel	Ogallala	Cy,E	D	......	......	......	15	......	
SE NE SE sec. 7	Pyramid Life Ins. Co.	2 Dr	......	16	GI	Gravel	Alluvium	C,E	I	......	......	......	16	......	Battery of 2 wells; reported aggregate yield 650.
SW NE SE sec. 7	do	2 Dr	......	16	GI	(?)	do	C,E	I	......	......	......	16	......	Do
NW cor. SE sec. 7	do	2 Dr	......	16	GI	Gravel	do	C,E	I	......	......	......	15	......	Battery of 2 wells; reported aggregate yield 700.

Table 22.—Records of wells and springs in Finney county, Kansas—*Continued*

2	Location	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement, 1940	Remarks (Yield given in gallons a minute; drawdown in ft.)
	T. 24 S., R. 33 W.															
	SE SW NW sec. 7	....	B	12	6	GI	(?)	Alluvium	Cy,W	N	Top of casing, east side	+2.0	2,878.5	8.85	Oct. 28	Unused stock well; observation well.
	SW NW NW sec. 8	J. Paul Jones	10 Dr	43.5	18	GI	(?)	do.	C,E	I	Top of concrete curb, north side	0	2,877.4	13.62	Dec. 6	Battery of 10 wells; measured fourth well south of pumphouse.
)	SW cor. NW SE sec. 8	F. Anderson	4 Dr	36.2	18	GI	(?)	do.	C,E	I	Top of concrete cover over well	0	2,873.6	12.55	Aug. 26	Battery of 4 wells; measured first well south of pumphouse; reported aggregate yield 1,500.
	NE NE NE sec. 9	Mrs. A. M. Reid	Dr	21.5	15	GI	Gravel	do.	N	O	Top of casing, east side	+ .4	2,862.4	11.48	Oct. 28	Well equipped with a Stevens 90-day automatic water-stage recorder maintained by the Division of Water Resources, Kansas State Board of Agriculture.
	NW NW NE sec. 9	L. R. McBeth	Dr, Dn	92.5	1.5	GP	(?)	Pleistocene	P,H	N	Top of edge of pump, north side	+2.0	2,866.5	13.88	Oct. 28	Unused domestic well; observation well.
	SE SW NW sec. 9	E. H. McKibben	4 Dr	36	18	GI	(?)	Alluvium	C,E	I	....	....	....	12	....	Battery of 4 wells.
	SW SW SW sec. 9	F. Anderson	5 Dr	......	18	GI	(?)	do.	C,E	I	....	....	....	....	....	Battery of 5 wells; reported aggregate yield 1,800.
	SE SW SE sec. 9	do.	3 Dr	40	18	GI	(?)	do.	C,E	I	....	....	....	12	....	Battery of 3 wells; reported aggregate yield 1,000.
	SW NW NE sec. 10	C. G. Melcum	6 Dr	30	22	GI	(?)	do.	C,E	I	Top of concrete curb	+ .5	2,861.0	14.62	Dec. 6	Battery of 6 wells; measured second well south of pumphouse; reported aggregate yield 1,500.

5	SE NW NW sec. 10	B. Garnand	2 Dr	40	18	GI	(?)	do.	C,E	I				20		Battery of 2 wells; reported aggregate yield 900.
6	NE SW SW sec. 10	McNaughtan Land Co.	Dr	95	16	GI	(?)	Pleistocene and alluvium	T,E	I				16		Gravel-packed well; measured yield in 1940, 1,020, drawdown 9 (9).
7	NW NE NE sec. 11	R. M. Jones	16 Dr	25-28	18	GI	(?)	Alluvium	C,G	I				12		Battery of 16 wells; reported aggregate yield 1,200.
8	SW NW NE sec. 11	J. Kunz	6 Dr	25	18	GI	(?)	do.	C,E	I				12		Battery of 6 wells; reported aggregate yield 600.
9	SW NW NW sec. 11	R. L. Fye	8 Dr	32	15	GI	Sand and gravel	do.	C,E	I				16		Battery of 8 wells.
0	SW SW NW sec. 11	E. M. Sullivan	3 Dr	45	18	GI	(?)	do.	C,G	I				15		Battery of 3 wells.
1	SE SW NE sec. 11	Lincoln School	Dr	40	15	GI	(?)	do.	C,E	I				18		Used to water trees.
2	NE SE NE sec. 11	E. Forrest	2 Dr	35			(?)	do.	C,E	I						Battery of 2 wells; reported aggregate yield 400.
3	NE NW SE sec. 11	G. Mangan	2 Dr	45	16	GI	(?)	do.	C,E	I						Battery of 2 wells, estimated aggregate yield 400.
4	SW NE SE sec. 11	H. L. Divine	Dr	40	20	C	(?)	do.	C,E	I	Top of 2 by 4-inch sill	+ .2		17.08	Dec. 6	
5	NW NW SE sec. 11	Horlacher	Dr		15	GI	(?)	do.	C,E	I				15		
6	NE NE SW sec. 11	Crawford	Dr	20	18	GI	(?)	do.	C,E	I						
7	NW NW SW sec. 11	H. R. Shaffer	6 Dr	45	18	GI	(?)	do.	C,E	I	Top of concrete curb	+ .5		15.94	Dec. 6	Battery of 6 wells; measured first well north of pumphouse; measured aggregate yield July, 1939, 1,565, average drawdown 6.68 (10).
8	SW cor. SE sec. 11	M. M. Bland	5 Dr	25	16	GI	(?)	do.	C,E	I				17		Battery of 5 wells; reported aggregate yield 1,500.
9	SE NE SE sec. 11	do.	2 Dr	30	16	GI	(?)	do.	C,E	I				20		Battery of 2 wells; reported aggregate yield 750.
0	SW cor. NE NE sec. 12	A. L. Becker	6 Dr	26	16	GI	(?)	do.	C,E	I				13		Battery of 6 wells; reported aggregate yield 750, drawdown 10±.
1	NW NE NW sec. 12	L. Angeles	2 Dr	40	14	GI	Sand and gravel	do.	C,E	I				16		Battery of 2 wells; reported aggregate yield 500.
2	NW NW NW sec. 12	J. G. Patterson	2 Dr	82	18	GI	(?)	Pleistocene and alluvium	C,E	I				14		Battery of 2 wells; reported aggregate yield 800.
3	NE SW SE sec. 12	A. C. Kincaid	6 Dr	40	18	GI	(?)	Alluvium	C,E	I						Battery of 6 wells; reported aggregate yield 900.

TABLE 22.—Records of wells and springs in Finney county, Kansas—*Continued*

No. (1)	LOCATION	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement, 1940	Remarks (Yield given in gallons a minute; drawdown in ft.)
	T. 24 S., R. 33 W.															
94	NW SW SE sec. 12	S. Pappas	Dr	40	16	GI	Sand and gravel	Alluvium	C,E	I				18		Reported yield 600.
95	SE NW SW sec. 12	J. A. Johnson	Dr	40	16	GI	Gravel	do	C,E	I				14		Reported yield 300.
96	NW NW SW sec. 12	M. Frye	6 Dr	40	18	GI	Sand and gravel	do	C,E	I				12		Battery of 6 wells; reported aggregate yield 650.
97)	SW NW SW sec. 12	N. Merrill	Dr	45	15	GI	(?)	do	C,E	I				17		Reported yield 500.
98	do	do	2 Dr	45	15	GI	Gravel	do	C,E	I				17		Battery of 2 wells; reported aggregate yield 800, average drawdown 6.
99	SE SW SW sec. 12	H. Hoffman	4 Dr	42	16	GI	Sand and gravel	do	C,E	I				12		Battery of 4 wells.
[illegible]	SW SW SE sec. 12	O. Harmon	Dr	42	18	GI	(?)	do	C,E	I	Top of casing, north side	—7.5	2,839.3	11.85	Dec. 14	Reported yield 400, measured drawdown 9.9.
[illegible]	SW SW SE sec. 12	P. Harris	6 Dr	40	15	GI	(?)	do	C,E	I						Battery of 6 wells; reported aggregate yield 400.
12	SE SW SE sec. 12	do	Dr	40	15	GI	(?)	do	C,E	I				18		Reported yield 250.
13	NE SE SE sec. 12	H. Weldon	Dr				(?)	do	C,E	I						
14	SW NW sec. 13	Garden City Company	Dr	260	16	BS	(?)	Ogallala	T,E	In						Reported yield 600; water reported to be soft.
[illegible]	do	do	Dr	180	24	BS	(?)	do	T,E	In						Gravel-packed well; reported yield 500.
[illegible]	do	do	Dr	180	24	BS	(?)	do	T,E	In						Gravel-packed well; reported yield 300 with old style pump and motor.

7	do.	do.	4 Dr	48	21	C	(?)	Alluvium	C,E	In						Battery of 4 gravel-packed wells; reported aggregate yield 1,500.
8	do.	do.	4 Dr	48	21	C	(?)	do.	C,E	In						Battery of 4 gravel-packed wells; reported aggregate yield 900.
9	do.	do.	4 Dr	48	21	C	(?)	do.	C,E	In						Battery of 4 gravel-packed wells; reported aggregate yield 1,200.
0	do.	do.	4 Dr	48	21	C	(?)	do.	C,E	In						Do
1	do.	do.	3 Dr	48	21	C	(?)	do.	C,E	In						Battery of 3 gravel-packed wells; reported aggregate yield 1,200.
2	NW SW NE sec. 13	E. Stoeckly	Dr	40	16	GI	(?)	do.	C,E	I						Reported yield 750.
3	SW SW NE sec. 13	Garden City Company	Dr	40	16	GI	(?)	do.	C,E	I						Reported yield 650.
4	SE NE SE sec. 13	T. Ekart	Dr	32	12	GI	(?)	do.	C,G	I				14		
5	NW NW SE sec. 13	O. Gann	3 Dr	35	16	GI	(?)	do.	C,E	I						Battery of 3 wells.
6	SW NW SE sec. 13	G. R. Batchelder	Dr	33	18	GI	(?)	do.	C,E	I				13		Reported yield 350.
17)	NE SW SW sec. 13	J. Landgraph	6 Dr	45.8	15	GI	(?)	do.	C,E	I	Top of concrete curb, north side	+ .3	2,845.0	17.06	Aug. 6	Battery of 6 wells; measured second well north of pumphouse; reported aggregate yield 1,500.
8	SW SW SE sec. 13	H. Kelley	Dr	37	16	GI	(?)	do.	C,E	I				14		Reported yield 400, drawdown 6±.
9	SE SE SE sec. 13	R. Yockey	Dr	30	16	GI	(?)	do.	VC,E	I				14		Reported yield 250.
0	NW NW NW sec. 14	Garden City Company	5 Dr	30.8	14	GI	(?)	do.	C,E	I	Top of concrete curb, north side	+1.3	2,855.8	17.64	Aug. 5	Battery of 5 wells; measured well situated 5 yds. east of pumphouse; reported aggregate yield 1,400.
1	NW SW NW sec. 14	D. E. Evers	2 Dr	40	12	GI	(?)	do.	C,E	I						Battery of 2 wells.
2	NW SW NW sec. 14	do.	3 Dr	50	12	GI	(?)	do.	C,E	I						Battery of 3 wells.
3	SW SE NE sec. 14	A. L. Blake	2 Dr	35			(?)	do.	C,E	I						Battery of 2 wells.
4	SW NE SE sec. 14	C. M. Piper	Dr	67	16	C	(?)	do.	C,E	I				16		
5	NE NW SE sec. 14	H. O. Reeves	Dr	40	16	GI	(?)	do.	C,E	I				20		Reported yield 300.

Table 22.—Records of wells and springs in Finney county, Kansas—*Continued*

[illegible]	Location	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement, 1940	Remarks (Yield given in gallons a minute; drawdown in ft.)
	T. 24 S., R. 33 W.															
6	NE NE SW sec. 14	H. Hoffman	2 Dr	42	18	GI	(?)	Alluvium	C,E	I				13		Battery of 2 wells.
7	NW cor. SW sec. 14	P. Mai	3 Dr	60	18	GI	(?)	do	C,E	I						Battery of 3 wells; estimated aggregate yield 2,000.
8	NW NE NE sec. 15	Finney County	2 Dr	50	18	GI	(?)	do	C,E	I						Battery of 2 wells.
9	NE SE NE sec. 15	do	2 Dr	50	18	GI	(?)	do	C,G	I						Do
[illegible]	NW NW NE sec. 22	Mrs. M. C. Tait	B	18.5	6	GI	(?)	do	Cy,W	S	Top of south pipe clamp, north side	+1.0	2,856.8	13.30	Oct. 16	
1	NE NW NE sec. 24	F. Finnup	2 Dr				(?)	do	C,E	I				16		Battery of 2 shallow wells; measured aggre. yield in 1940, 1,096 (10).
	T. 24 S., R. 34 W.															
[illegible]	SW SW SW sec. 1	C. E. Caldwell	3 Dr	37	16	GI	(?)	do	C,E	I	Lower edge of concrete cover	+ .5	2,896.4	15.53	Nov. 1	Southernmost well of battery of 3 wells; measured aggregate yield in 1940, 565 (10).
3	Cent. SE SE sec. 1	O. A. Schopf	5 Dr	55, 73	16, 20	GI,C	Sand and gravel	Pleistocene and alluvium	C,E	I				18		Battery of 5 wells; measured aggregate yield July, 1939, 1,300; average drawdown 11.24 (10).
4	NW NW NE sec. 2	H. Brown	4 Dr	80	16, 20	C	(?)	do	C,E	I				18		Battery of 4 wells; measured aggregate yield in 1939, 840; avg. drawdown 11.5 (10).

335	SW NW NW sec. 2	G. Potter	8 Dr	50	15	GI	(?)	Alluvium	C,E	I				9		Battery of 8 wells; measured aggregate yield in 1940, 800 (10).
336)	SE SE NE sec. 2	H. Brown	Dr	81	20	C	(?)	Pleistocene and alluvium	C,E	I	Top of concrete curb	0		14.58	Oct. 23	Measured yield in 1940, 348; drawdown 6.2 (10).
337	SW NE SE sec. 2	L. L. Jones	4 Dr	40			(?)	Alluvium	C,E	I						Battery of 4 wells; reported aggregate yield 600.
338)	SW cor. NW sec. 3	G. Potter	6 Dr	37-50	15	C	Gravel	do	C,E	I	Top of concrete curb, west side	+ .5	2,911.0	12.25	Dec. 14	Battery of 6 wells; measured first well north of pumphouse; measured aggregate yield in 1940 520 (10).
339	NW NE NE sec. 6	G. L. Meeker	Dr	52	6	GI	(?)	Pleistocene	Cy,H	N	Top of wooden platform	+1.0	2,970.2	41.26	Oct. 28	Unused domestic well; observation well.
340	SW NW NW sec. 6	Dr. Bailey	Dr	360	14	BS	Sand and gravel	Ogallala and Pleistocene	T,E	I	Top of casing, north side	0	2,974.7	39.43	Aug. 6	Gravel-packed well; reported yield 800.
341	SW SW NE sec. 8	W. E. Stone	8 Dr	40			(?)	Alluvium	C,E	I				12		Battery of 8 wells; reported aggregate yield 1,000.
342	NE NW SW sec. 9	do	10 Dr	40	12	GI	(?)	do	C,E	I	Top of concrete curb	0	2,913.9	11.84	Dec. 6	Battery of 10 wells; measured third well north of pumphouse; reported aggregate yield 3,700.
343	NE NW NE sec. 10	L. L. Jones	12 Dr	32	20	C	(?)	do	C,E	I						Battery of 12 wells; measured aggregate yield in 1940, 1,800-2,200 (10).
344	NW NW NE sec. 11	do	3 Dr	42, 42, 60		C	(?)	do	C,E	I						Battery of 3 wells; measured aggregate yield in 1940, 950 (10).
345	NE NE NE sec. 12	J. V. Crist	Dr	32	12	GI	(?)	do	C,E	I				20		Reported yield 400, drawdown 12±.
346	NE NE NW sec. 12	E. A. Farnsworth	Dr	34	12-14	GI	Gravel	do	C,E	I				12		Reported yield 200.
347	SE SW NW sec. 12	J. Landgraph	6 Dr	42			do	do	C,E	I	Top of concrete curb, south side	0		17.98	Aug. 7	Northernmost well of battery of 6 wells; estimated aggregate yield, 2,500.
348	NW cor. NW sec. 14	O. J. Brown	2 Dr	43	15	GI	(?)	do	C,E	I				10		Battery of 2 wells; reported aggregate yield 800.
349)	NE NW NW sec. 16	C. Smith	3 Dr	35	16	GI	(?)	do	C,E	I				10		Battery of 3 wells.
350	NW NW NW sec. 17	A. Finnup	8 Dr	35	16	GI	(?)	do	C,E	N	Lower edge of concrete cover	0	2,925.7	12.09	Oct. 28	Unused irrigation well; northernmost well of battery of 8 wells; **observation well.**

TABLE 22.—Records of wells and springs in Finney county, Kansas—*Continued*

No. on pl. 2 (1)	LOCATION	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement 1940	Remarks (Yield given in gallons a minute; drawdown in ft.)
351	*T. 24 S., R. 34 W.* NW NW SW sec. 18	Phoenix Joint Stock Lan Bank	8 Dr	44.5	15	GI	(?)	Alluvium	C,E	I	Top of concrete curb, north side	0	2,933.3	11.62	Aug. 6	Battery of 8 wells; measured second well north of pumphouse.
(352)	NE cor. NE sec. 25	A. Layman	Dr	52.5	6	GI	(?)	Terrace gravel	Cy,W	S	Top of pipe clamp	+1.0	2,925.8	42.77	Sept. 10	
353	SW SE SE sec. 36	do	Dr	38.5	6	GI	(?)	Pleistocene	N	N	Top of casing, northeast side	+1.0	2,922.3	36.59	Oct. 28	Unused stock well; observation well.
354	*T. 25 S., R. 31 W.* NW SE NE sec. 3	Nellie Handy	Dr	115.5	6	GI	(?)	Ogallala	Cy,W,H	S	Top of wooden plank beneath pump	0	2,867.1	107.97	do	Used occasionally; observation well.
355	SW NW NE sec. 5	Bowie Investment Co.	B	19.3	.....	.....	(?)	Alluvium	Cy,W	S	Top of pipe clamp	+ .3	2,784.8	13.55	Sept. 12	
356	NE NE NW sec. 9	H. G. Marmon	B	13.5	.....	.....	(?)	do	Cy,W	S	do	0	2,768.0	5.95	Sept. 10	
357	SW SW SW sec. 11	C. Weldon	5 Dr	.....	.....	.....	(?)	do	C,E	I	.....	.....	.....	.....	.....	Battery of 5 wells covered by flood-plain deposits.
358	NW NW SE sec. 13	Weldon Land Co.	2 Dr	50	16	GI	(?)	do	C,E	I	.....	.....	.....	12	.....	Battery of 2 wells.
359	SE NE SW sec. 13	E. Wehrley	3 Dr	36-40	16	GI	(?)	do	C,E	I	.....	.....	.....	15	.....	Battery of 3 wells; reported aggregate yield 600.
360	do	do	2 Dr	38	16	GI	(?)	do	C,E	I	.....	.....	.....	15	.....	Battery of 2 wells; reported aggregate yield 500.
361	NE SE SW sec. 13	do	Dr	6.5	24	OB	Sand and gravel	do	N	N	Top of casing, east side	+1.0	2,743.2	4.83	Oct. 28	Unused stock well; observation well.
(362)	SE SW SE sec. 15	F. Douglas	Dr	24.5	5	GI	(?)	do	Cy,W	S	.....	.....	.....	15	.....	
363	SE SE SE sec. 15	J. Douglas	Dr	20	16	GI	(?)	do	C,T	I	.....	.....	.....	4	.....	

64	NW NE NW sec. 23	F. Douglas	Dr	15	16	GI	(?)	do	C,T	I	Top of casing, south side	—3.0	2,747.5	.3	Aug. 13	Water reported to be very hard.
65	SE cor. SE sec. 32	School District	Dr	68.8	6	GI	(?)	Pleistocene	Cy,H	D	Top of casing, north side	+ .3	2,827.3	57.77	Sept. 6	School well.
66	NW SW SW sec. 36	S. Bailey	Dr	63.0	5.5	GI	(?)	do	Cy,W	N	Top of pipe clamp	0	2,807.8	60.43	Oct. 24	Unused domestic well.
67	SW NE NE sec. 30	F. M. Karr	Dr	88.8	6	I	(?)	do	Cy,W,H	D	Top of casing, south side	+ .8	2,902.4	83.53	Sept. 3	
68	SE SW SE sec. 31	E. A. Solze	Dr	77.0	6	I	(?)	do	Cy,H	D,S	Top of casing, west side	0	2,884.6	65.54	do	
69	SE SW SE sec. 34	W. H. Wilkson	Dr	61.1			(?)	do	Cy,W	N	Lower edge of pipe coupling	+3.1	2,858.2	59.55	Sept. 23	Unused domestic well.
	T. 25 S., R. 33 W.															
70	NE NE NE sec. 12	W. J. Johnson	Dr	57.5	5	I	(?)	do	Cy,W	S	Top of pipe clamp	+1.0	2,877.3	49.00	Sept. 7	
71	SW cor. NE SE sec. 13	O. G. Reeve	Dr	84.5	6	GI	(?)	do	N	N	Top of casing, south side	+1.5	2,899.4	75.92	Sept. 20	Abandoned stock well; observation well.
72	SW SE SE sec. 31	L. L. Jones	Dr	82.8	6	GI	(?)	do	N	N	do	+2.2	2,941.5	79.21	Sept. 4	Abandoned domestic well.
73	NE NW SE sec. 32	M. Ingler	Dr	81	15	GI	Sand and gravel	do	T,T	I				60		Reported yield 700.
	T. 25 S., R. 34 W.															
74	SW SW SW sec. 5	J. A. Hyde	Dr	56	4	I	(?)	do	Cy,W	S				50		
75	NE NE NW sec. 6	E. Butler	Dr	53.5	5	GI	(?)	do	Cy,W,H	N	Top of casing, west side	+2.0	2,874.8	48.03	Sept. 10	Unused domestic and stock well.
76	NW cor. NW sec. 25	L. M. McCoy	Dr	85.5	6	GI	(?)	do	Cy,W	N	Top of pipe clamp	+2.0	2,954.8	83.01	Sept. 4	Do
77	SW SE SW sec. 34	School District	Dr	87.5	8	GI	(?)	do	Cy,H	N	Top of casing, southwest side	+ .5	2,967.3	83.08	do	Unused school well.
	T. 26 S., R. 31 W.															
78	NW cor. NW sec. 7	J. Kisner	Dr	87.8	6	GI	(?)	do	Cy,W	D	Top of metal plate over casing	+ .5	2,844.6	69.71	Sept. 7	
79	SE cor. NE sec. 18	C. A. Samuel	Dr	76.5	6	GI	(?)	do	Cy,W	D,S	Top of casing, north side	+2.0	2,838.0	74.56	Sept. 6	
80	NE cor. SE sec. 23	F. Shay	Dr	90.2	5	GI	(?)	do	Cy,W	D,S	Top of casing, south side	+ .2	2,825.1	86.62	Oct. 24	Water reported to be soft.
381)	NE cor. NE sec. 30	School District No. 78	Dr	97.8	6	GI	(?)	do	Cy,W	D	Top of casing, north side	+ .3	2,838.4	78.44	Sept. 7	School well.
82	SE cor. SW SE sec. 34	Farmers and Bankers Life Ins. Co.	Dr	90.5	6	GI	(?)	do	N	N	do	+ .5	2,817.6	76.16	Sept. 20	Unused domestic well; observation well.
	T. 26 S., R. 32 W.															
83	NE SE NE sec. 4	J. A. Hunter	Dr	52.5	6	GI	(?)	do	Cy,W,H	N	Top of metal plate over casing	0	2,845.9	47.12	do	Do
84	SW NW SW sec. 18	J. B. Blackburn	Dr	80.5	6	GI	(?)	do	Cy,W	D,S	do	+ .5	2,888.6	77.16	Sept. 3	
85	SE cor. SE sec. 26	J. J. Duesing	Dr	99.5	6	GI	(?)	do	Cy,W	D	Top of casing, north side	+1.0	2,853.7	81.45	Sept. 7	

TABLE 22.—Records of wells and springs in Finney county, Kansas—*Concluded*

No. on pl. 2 (1)	Location	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement, 1940	Remarks (Yield given in gallons a minute; drawdown in ft.)
	T. 26 S., R. 32 W.															
386	SW SW SW sec. 28	G. W. Finnup	Dr	92.5	5	I	(?)	Pleistocene	Cy,W	D,S	Top of casing, north side	+1.0	2,875.4	83.95	Sept. 6	
387	NE cor. NW NE sec. 30	M. B. Smith	Dr	112.5	8	GI	(?)	do	N	N	Top of casing, northwest side	+ .5	2,913.3	109.57	Sept. 20	Abandoned domestic well; observation well.
(388)	NW SW NW sec. 31	C. Snodgrass	Dr	120.5	6	GI	(?)	do	Cy,W	D,S	Top of concrete pump base	0	2,898.9	98.17	Sept. 7	
	T. 26 S., R. 33 W.															
389	NE cor. NW sec. 2	M. Russell	Dr	86.5	6	GI	(?)	do	N	N	Top of casing, southwest side	0	2,906.3	77.85	Sept. 20	Abandoned domestic well; observation well.
390	NW NE NW sec. 3	F. Drussel	Dr	69.5	6	GI	(?)	do	Cy,W	S	Top of casing, north side	+1.0	2,900.7	64.82	Sept. 4	
391	NE NW NE sec. 5	M. Thomas	Dr	84.5	6	GI	(?)	do	Cy,W	S	Top of pipe clamp	+1.5	2,927.9	77.97	do	
(392)	NE cor. NE sec. 9	School District	Dr	78.8	6	GI	(?)	do	Cy,W	D	Top of casing, south side	+ .3	2,899.0	63.15	Sept. 5	School well.
393	NE NE SW sec. 10	F. Drussel	Dr	77	15	GI	Fine sand	do	T,G	I	....	....	....	57	....	Reported yield, 700 gallons a minute.
394	NE cor. NW sec. 11	M. Russell	Dr	87.7	6	GI	(?)	do	Cy,W	D	Top of pipe flange	+1.0	2,896.2	72.19	Sept. 6	
395	NW SW NE sec. 19	J. W. Nolan	Dr	87.5	6	GI	(?)	do	Cy,W	S	Top of casing, north side	+1.5	2,923.0	77.57	Sept. 5	
396	SW SW SW sec. 22	Quivera School Dist	Dr	112.0	5	GI	(?)	do	Cy,W	D	Top of casing, south side	0	2,931.7	104.98	do	School well.
397	SE NW NW sec. 33	A. Aitkins	Dr	119.5	6	I	(?)	do	N	N	Top of casing, west side	+2.5	2,941.2	115.55	Sept. 6	Abandoned domestic and stock well.
	T. 26 S., R. 34 W.															
398	NW NE NW sec. 2	L. L. Jones	Dr	74.5	6	GI	(?)	do	N	N	Top of casing, northeast side	+1.5	2,945.5	73.15	Sept. 20	Unused stock well; observation well.

NW NE SE sec. 22....	G. E. Dillon..........	Dr	83.0	6	GI	(?)............	do..........	Cy,W	N	Top of casing, north side	0	2,943.2	78.75	Sept. 6	Unused domestic well.
T. 27 S., R. 33 W.(13)															
NE NE NE sec. 2....	....	Dr	119.8	6	GI	(?)............	do..........	Cy,W	N	Top of casing, northeast side	+1.3	2,919.5	112.71	Sept. 3	Unused domestic well.

Well number in parentheses indicates that analysis of water is given in table 19.

B, bored well; DD, dug and drilled well; Dn, driven well; Dr, drilled well; Du, dug well; Sp, spring.

Reported depths below the land surface are given in feet; measured depths are given in feet and tenths below measuring points.

BS, boiler steel; C, concrete; GI, galvanized sheet iron; GP, galvanized-iron pipe; I, iron; N, none; OB, oil barrels; OW, oil-well casing; R. rock; W, wood.

Method of lift: C, horizontal centrifugal; Cy, cylinder; F, natural flow; N, none; P, pitcher pump; S, submersible turbine; T, turbine; VC, vertical centrifugal. Type of power: B, butane; E, electric; G, gas engine; H, hand operated; T, tractor; W, windmill.

D, domestic; I, irrigation; In, industrial; N, not being used; O, observation; P, public supply; S, stock.

Measured depths to water level are given in feet, tenths, and hundredths; reported depths to water level are given in feet.

Testing equipment; permanent pump and power not installed yet.

Pumping test conducted and results furnished by P. H. Browne, representative of the Johnston Pump Company.

). Pumping test conducted and results furnished by the Division of Water Resources, Kansas State Board of Agriculture.

1. Measured in 1942.

2. Pumping test conducted and results furnished by the Garden City Company.

3. Located in Haskell county.

TABLE 23.—*Records of wells in Gray county, Kansas*

	Location	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement, 1940	Remarks (Yield given in gallons a minute; drawdown in ft.)
	T. 24 S., R. 27 W.															
1)	SE SE SW sec. 2	J. B. English	Dr	100.7	5	GI	Gravel	Ogallala	Cy,W	D	Top of casing, west side	+1.2	2,663.3	84.80	Nov. 8	
	SW NW NE sec. 6	B. Davidson	Du, Dr	105	19	GI	Sand and gravel	do	T,G	I	Lower edge of opening, east side of pump	+1.0	2,701.6	65.29	Nov. 5	Gravel-packed well; reported yield 1,020, drawdown 13.2 (8); shale (Carlile) reported at depth of 120 feet.
	SE cor. SE sec. 15	Superior School Dist	Dr	65.5	6	GI	(?)	do	Cy,H	D	Top of casing, south side	+1.0	2,651.6	51.61	Nov. 15	School well.
	SE cor. SW sec. 20	R. R. Davis	Dr	63.0	2	GP	(?)	do	Cy,W	N	Lower edge of opening, west side of pump	+3.5	2,689.6	53.87	do	Unused tubular domestic well; accuracy of water-level measurement questionable.
	SW SW sec. 23	C. H. Moore	Dr	25.5	4	GI	(?)	do	Cy,W	N	Top of casing, east side	0	2,636.4	24.36	do	Unused stock well.
	SE cor. SW sec. 35	M. W. Hopkins	Dr	72.3	5	GI	(?)	do	Cy,W	D,S	Top of pipe clamp	+ .3	2,666.6	66.02	Nov. 14	
	T. 24 S., R. 28 W.															
7)	SE SE NE sec. 5	F. G. Warner	Dr	112.5	7	GI	(?)	do	Cy,W	D,S	Top of metal plate covering casing	0	2,756.6	94.23	Nov. 8	
	SW NW NW sec. 20	M. Collingwood	Dr	102.7	......	......	(?)	do	Cy,W	N	Lower edge of bolt hole, south side of pump	+1.2	2,763.9	100.18	Nov. 9	Unused domestic well
	SE SW SE sec. 21	J. H. Timkin	Dr	104.4	5	GI	Fine sand	do	Cy,W,H	D	Lower edge of bolt hole, east side of pump	+1.4	2,745.2	89.70	do	Original reported depth 110 feet.
	SW NW NW sec. 24	G. Bowser	Dr	94.8	6	GI	(?)	do	Cy,W	N	Top of pipe clamp	+ .8	2,719.6	77.78	Nov. 5	Unused domestic well; observation well

T. 24 S., R. 29 W.														
SE cor. SE sec. 3	G. Newbury	Dr	99.5	5	GI	(?)	do	Cy,W	D,S	Top of casing, south side	+1.0	2,777.1	92.56	Nov. 8	Water level reported to have been 75 feet below surface in 1928.
NW NW SW sec. 9	L. M. Miller	Dr	97.0	2	GP	(?)	do	Cy,W	N	Top of 2-inch pipe, west side	+3.0	2,782.8	87.29	Nov. 11	Unused tubular domestic well; accuracy of water-level measurement questionable.
SE SE NE sec. 12	K. H. Hubert	Dr	103.0	5	GI	(?)	do	Cy,W,H	D,S	Top of casing, east side	0	2,763.1	90.65	Nov. 8	
NE SE NE sec. 24	L. Naftziger	Dr	102.5			(?)	do	Cy,W,H	N	Top of opening, west side of pump jacket	+1.5	2,761.8	90.86	Nov. 5	Unused domestic and stock well; observation well.
SE NE NE sec. 28	G. M. Kerr	Dr	120.7	5	GI	(?)	do	Cy,W,H	N	Top of casing, east side	+ .2	2,797.0	109.69	Nov. 18	Unused domestic well.
T. 24 S., R. 30 W.															
SE cor. SW sec. 16	C. W. Hall	Dr	151.8	4	I	Gravel	do	Cy,W	S	Top of pipe clamp	+1.3	2,862.4	124.59	Nov. 23	
NE NW NW sec. 30	S. Stukey	Dr	132	6	GI	Coarse gravel	do	Cy,W,H	D,S	Top of casing, north side	+ .5	2,872.5	121.57	Dec. 9	Fine sand reported from depths of 100-112 feet and coarse gravel from depths of 112-132 feet.
SE cor. SE sec. 33	A. M. Thompson	Dr	146.0	2	GP	(?)	do	Cy,W	N	Top edge of pump jacket	+3.0	2,859.3	130.60	Nov. 23	Unused tubular domestic well; accuracy of water-level measurement questionable.
T. 25 S., R. 27 W.															
SE SE NW sec. 3	R. W. English Est	Dr	117.5	6	GI	(?)	do	Cy,W	D,S	Top of concrete platform	+2.0	2,667.2	63.23	Nov. 14	
SW NW NW sec. 12	J. G. Kornelsen	Dr	72.3	5	GI	Sand	do	Cy,W	D	Top of casing, east side	+ .3	2,652.5	55.48	do	Water dripped on tape; accuracy of water-level measurement questionable.
SE NW NW sec 18	C. H. Moore Est	Dr	131.5	5.5	GI	(?)	do	Cy,W	D,S	do	+1.0	2,731.0	110.14	Nov. 9	
NW SW SW sec. 21	B. W. Marshall	Dr	261.5	16	OW	(?)	do	N	N	Top of casing	+ .5	2,724.0	120.25	Oct. 31	Unused irrigation well; drilled in 1938; no pump installed.
SE cor. SE sec. 22	E. L. Feasler	Dr	117.8	6	GI	Fine sand	do	Cy,W	D,S	Lower edge of hole in pump base	+1.3	2,695.2	104.29	Nov. 14	Casing bottomed on clay.
SW cor. SE sec. 33	H. J. Saln	Dr	146	3	GP	(?)	do	Cy,W,H	D,S			2,722.8	115		
NW NW NW sec. 36	E. W. Bennett	Dr	121.5	5	GI	(?)	do	Cy,W	D	Top of casing, west side	+ .5	2,688.9	109.12	Nov. 15	

TABLE 23.—Records of wells in Gray county, Kansas—*Continued*

Location	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (−) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement, 1940	Remarks (Yield given in gallons a minute; drawdown in ft.)
T. 25 S., R. 28 W.															
NE cor. NE sec. 2	L. G. Unruh	Dr	105.1	3	GP	(?)	Ogallala	N	N	Top of 3-inch pipe, west side	+4.1	2,736.8	100.23	Nov. 9	Unused tubular domestic well.
SE SE NE sec. 5	H. Gaede	Dr	104.5	3	GI	(?)	do	Cy,W	N	Top of casing, south side	+1.0	2,752.7	96.95	do	Unused domestic well.
SW SW NW sec. 36	W. Youst	Dr	148.5	3	I	Fine sand	do	Cy,W,H	D,S	Top of casing, east side	−3.0	2,746.7	128.66	do	
T. 25 S., R. 29 W.															
SE SE SE sec. 1	A. F. Penner	Dr	117.7	5	GI	(?)	do	Cy,W	D,S	Top of pipe clamp	+ .7	2,766.3	100.23	Nov. 15	
NW SW NW sec. 14	B. R. Fauley	Dr	118.5	5	GI	(?)	do	Cy,W	N	do	+0.5	2,777.1	106.68	do	Unused domestic well.
NE NE NE sec. 20	A. Crawford	Dr	138.0	6	GI	(?)	do	Cy,W	N	Top of casing, east side	+2.0	2,802.4	124.02	Nov. 18	Unused domestic well.
SW SW SW sec. 20	G. A. Hard	B	12.5	5.5	GI	(?)	Alluvium	Cy,W	N	Top of casing, south side	+1.0	2,688.3	8.40	Nov. 4	Unused stock well; observation well.
SE NW NW sec. 35	M. E. Kraushaar	Dn	18.5	1.5	GP	(?)	do	N	N	Top of pipe	+1.5	2,671.1	14.87	do	Do
NW NE NW sec. 36	Ingalls Cemetery	Dr	126.3			(?)	Ogallala	Cy,W	I	Top of bolt hole in pipe flange	+ .3	2,763.0	109.79	Nov. 18	New well.
T. 25 S., R. 30 W.															
SE cor. SE sec. 10	T. C. Boyd	Dr	145.5	5	GI	(?)	do	Cy,W,H	D	Top of casing, east side	0	2,844.2	131.49	Dec. 9	
NW SW SW sec. 16	T. Riordan	Dr	36.5	6	GI	(?)	do	Cy,W,H	N	Top of casing, south side	+ .5	2,755.9	35.60	Oct. 5	Unused domestic well.
Center NW SW sec. 17	N. C. Diven	Dr	43.1	6	GI	(?)	do	Cy,W	D,S	do	+ .3	2,762.3	36.19	Aug. 29	Observation well.
NW cor. NW sec. 20	A. Larson	3 Dr	41.5	16	GI	Sand and gravel	Alluvium	C,–	I	Top of concrete curb, south side	+1.0	2,735.7	9.49	Nov. 11	Southernmost well of battery of 3 wells; drilled during summer, 1940.

SW NW NW sec. 21	M. L. McGehee	4 Dr	34	14	C	do.	do.	C,B	I	...	...	...	8	...	Battery of 4 wells; reported aggregate yield 1,500, drawdown 12.
SE SW NE sec. 23	R. and E. Fischer	6 Dr	35.6	18	GI	do.	do.	C,G	N	Top of wagon hub over well	+ .5	2,723.2	22.03	Nov. 4	Northernmost well of battery of 6 unused irrigation wells; observation well.
NE SE SW sec. 24	W. F. Renick	B	16.5	6	GI	(?)	do.	Cy,W	S	Top of casing, west side	+1.5	2,704.7	9.90	Dec. 11	
SW SW SE sec. 25	H. Jones	B	11.5	5	GI	(?)	do.	Cy,W	N	Top of casing, east side	+1.0	2,698.8	5.92	Nov. 27	Unused stock well.
T. 26 S., R. 27 W.															
NE NE SE sec. 2	A. Adams	Dr	134.7	3	I	(?)	Ogallala	N	N	Top of casing, north side	+2.6	2,694.3	111.10	Nov. 5	Unused domestic well; observation well.
NW SE sec. 8	J. H. Wettick	Dr	45	20	C	Coarse gravel	Alluvium	C,G	I	...	...	...	12	...	Reported yield 700.
SE cor. NW SW sec. 10	C. Sturevant	Dr	48.9	3	I	Sand and gravel	Ogallala	Cy,W	S	Top of 3-inch pipe	+2.5	2,609.3	36.65	Oct. 18	Tubular well.
SW cor. SW sec. 10	do.	Dr	32	20	C	Coarse gravel	Alluvium	C,G	I	Top of casing	—4.2	2,574.2	2.43	Nov. 13	Reported yield 1,200, drawdown 10.
SW NW NW sec. 13	C. E. Butcher	4 Dr	34	15	GI	Sand and gravel	do.	C,G	I	Top of 15-inch casing	—5.0	2,563.0	4.87	Nov. 12	Battery of 4 wells; measured well in pump pit.
SW SE sec. 14	J. C. Keech	Dr	29.5	20	C	do.	do.	T,G	I	Top of concrete casing	+1.5	2,572.3	10.40	Nov. 11	
SW SW SE sec. 15	G. N. Davis	B	13.0	6	GI	(?)	do.	Cy,W	S	Top of casing, west side	+1.0	2,567.7	5.60	Dec. 10	
SE cor. NW sec. 17	E. J. Basset	Dr	170	16-19	GI	Sand and gravel	Ogallala and alluvium	C,E	I	Top of casing, east side	—3.5	2,588.3	1.64	Nov. 11	Gravel-packed well; reported yield 900.
NE NE NW sec. 25	I. J. Gilleland	Dr	40.3	5.5	GI	do.	Terrace gravel	Cy,W	D,S	Top of casing, west side	+ .7	2,594.3	31.48	May 20, 1939	
SW cor. SW sec. 28	Federal Land Bank	Dr	52.5	4	GI	(?)	...	Cy,H	D	Top of casing, south side	+ .5	2,640.9	48.49	Nov. 14	
T. 26 S., R. 28 W.															
NW SE SW sec. 6	L. W. Olmstead	Dr*	40	28	C	Sand and gravel	Alluvium	C,G	I	Top of casing, west side	—7.0	2,638.7	3.22	Nov. 27	Reported yield 800, drawdown 20.
NW SW NW sec. 10	F. Luther	Dr	60	36	GI	(?)	do.	C,E	I	...	...	...	20	...	
NW cor. SW NE sec. 10	do.	Dr	58	24	GI	(?)	do.	T,E	I	Top of steel I-beam	—2.0	2,637.4	18.05	Nov. 4	Reported yield 900, observation well.
SE SE NE sec. 10	W. C. Miller	Dr	40	20	GI	Coarse gravel	do.	C,G	I	...	...	...	23	...	
do.	do.	Dr	53	2.5	GP	(?)	do.	Cy,W	D	...	...	...	19	...	
SW NW sec. 11	G. A. Egbert	4 Dr	54	20	GI	Coarse gravel	do.	C,E	I	...	...	...	20	...	Battery of 4 wells.
NW SE NW sec. 11	**City of Cimarron**	Dr	180	8	OW	Sand and gravel	Ogallala	T,E	P	...	...	...	14	...	Reported yield 190.

Table 23.—Records of wells in Gray county, Kansas—*Continued*

Location	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement, 1940	Remarks (Yield given in gallons a minute; drawdown in ft.)
T. 26 S., R. 28 W. NW SW NE sec. 11	Santa Fe	Dr	129	8-12	OW	Brown sand	Ogallala	C,E	R	..					Water is treated to prevent boiler scale; reported yield 85, drawdown 22.
NW SE NE sec. 11	City of Cimarron	Dr	180	8	OW	Sand and gravel	do	T,E	P				10		Reported yield 90; reported that if pumped to capacity (175 gallons a minute) it will pump sand.
NE NW SE sec. 11		Dr	17.5	1.5	GP	do	Alluvium	P	N	Top of pump spout	+2.5	2,612.1	9.15	Dec. 4	Unused domestic well; observation well.
NE NW SW sec. 11	A. O. U. W	2 Dr	32.66	16	GI	Coarse gravel	do	C,E	I				12		Battery of 2 wells; reported aggregate yield 700.
NE SW NW sec. 12	S. J. Vandine	2 Dr	44	16	GI	do	do	C,E	I				20		Battery of 2 wells; reported aggregate yield 750.
NW SE NW sec. 12	do	4 Dr	45	16	GI	do	do	C,E	I				24		Battery of 4 wells.
NW SW NE sec. 12	F. Luther	7 Dr	44.5	16	GI	(?)	do	C,E	I	Top of wooden plank over well	+ .5	2,623.1	27.61	Nov. 5	Battery of 7 wells; measured first well south of pumphouse; reported aggregate yield 1,150.
NE SE NE sec. 12	D. Egbert	3 Dr	45	18,18, 24	GI	(?)	do	C,E	I						Battery of 3 wells.
SW cor. SW sec. 12	J. D. Lee	Dr	34	18	OB	Coarse gravel	do	C,G	I				7		
SW NW NE sec. 14	Payne	3 Dr	40	16	GI	(?)	do	C,T	I				6		Battery of 3 wells; reported aggregate yield 800.

SW SW NE sec. 14	S. Robins	6 Dr	30-32	14	GI	(?)	do	C,E	I	Top of casing, north side	−1.0	2,609.5	3.84	Nov. 27	Battery of 6 wells; measured first well south of pumphouse.
NE NE sec. 29	F. W. Charlet	Dr	73.5	2	GP	(?)	Terrace gravel	Cy,W	N	Top of 2-inch pipe	+3.5	2,707.5	70.75	Nov. 23	Unused tubular domestic well.
NW cor. NE sec. 35	F. L. Anderson	Dr	60	2	GP	Gravel	do	Cy,W	S				45		Tubular well.
NW SE NW sec. 36	H. E. Hettrick	Dr	69	3	GP	(?)	do	Cy,W	N	Top of pipe cap	+3.0	2,674.4	59.18	Nov. 4	Unused tubular stock well; observation well.
T. 26 S., R. 29 W.															
SW NE NE sec. 2	C. B. Barton	Dr	40	16	GI	Coarse gravel	Alluvium	C,G	I				20		Reported yield 480, drawdown 10.
SE NE NE sec. 2	J. Goddard	3 Dr	39	19	GI	do	do	C,E	I				11		Battery of 3 wells; reported aggregate yield 14—1,600, average drawdown 16.
NE SW NW sec. 2	Alberta Achorn	B	16.5	8	GI	Gravel	do	Cy,W	S	Top of casing, west side	+2.0	2,668.2	12.25	Dec. 11	
NW cor. SW sec. 7	C. M. Davis	Dr	100.4	6	GI	(?)	Ogallala	Cy,W	N	Top of pipe clamp	+1.0	2,785.6	89.91	Dec. 4	Unused stock well; observation well.
NE NE NE sec. 22	Federal Land Bank	Dr	86.5	5	GI	Fine sand	Pleistocene	Cy,H	D	Lower edge of pump base	+ .5	2,745.8	78.77	Nov. 23	
SE SW SE sec. 36	P. Brietenbach	Dr	85.5	5.5	GI	(?)	do	Cy,N	N	Top of pipe clamp	+1.0	2,734.7	78.09	Dec. 4	Unused domes. and stock well; observation well.
T. 26 S., R. 30 W.															
SW SW NW sec. 1	H. A. Jones	Dr	70	3	I	(?)	Terrace gravel	Cy,W	D,S				52		
SE NE NE sec. 18	E. Welch	Dr	63.2	2	GP	(?)	Pleistocene	Cy,W	N	Top of pump jacket, east side	+4.2	2,785.7	59.15	Nov. 27	Unused tubular domestic well; accuracy of water-level measurement questionable.
NE NE NE sec. 21	C. C. Snyder	Dr	110.5	5	GI	(?)	do	Cy,W	N	Top of casing, west side	+ .5	2,818.8	100.82	do	Unused domestic well.
SE cor. SE sec. 30	M. I. Cessna	Dr	66.8	2	GP	(?)	do	Cy,W	N	Lower edge of opening on east side of pump	+2.8	2,787.5	56.57	Nov. 23	Unused tubular stock well; accuracy of water-level meas. questionable.
T. 27 S., R. 27 W.															
NW cor. NE sec. 3	J. W. Herb	Dr	78.3	5	GI	(?)	do	Cy,W	N	Top of casing, southwest side	+ .3	2,656.8	76.79	Dec. 4	Unused domestic well; observation well.
SE SE NE sec. 14	J. L. Brock	Dr	142	4	I	(?)	do	Cy,W	D				130		
SW SE SE sec. 15	C. Salen	Dr	139.5	4	I	(?)	do	Cy,W	N	Top of casing, west side	+ .5	2,706.7	127.01	Dec. 4	Unused domestic well; observation well.
SW cor. NW sec. 19	C. E. Eckles	Dr	135.5	4	I	(?)	do	Cy,W	N	Top of casing, north side	+1.0	2,726.0	115.34	do	Unused domestic well.
SW SW sec. 25	A. Slocum	Dr	200	16	OW	Fine to coarse gravel	Ogallala	T,NG	I	Lower edge of opening, southeast side of pump	+1.5	2,732.1	166.95	Nov. 16, 1937	Gravel-packed well; reported yield 800, drawdown 20 after pumping 11 hours.

TABLE 23.—Records of wells in Gray county, Kansas—*Continued*

Location	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (−) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement 1940	Remarks (Yield given in gallons a minute; drawdown in ft.)
T. 27 S., R. 28 W. NW cor. NE NE sec. 3	H. C. Kipp	Dr	79.5	3	I	(?)	Pleistocene	N	N	Top of 2-inch pipe	+2.5	2,700.2	74.32	Oct. 10, 1939	Unused tubular domestic well; accuracy of water-level measurement questionable.
T. 27 S., R. 29 W. NE NE SW sec. 5	E. E. Addison	B	104	5	GI	Coarse gravel	do	Cy,W	D	Top of casing, west side	+ .5	2,766.4	78.39	Nov. 29	
SE cor. SE sec. 14	W. H. McLaughton	Dr	87.8	3	GP	(?)	do	Cy,W	N	Top of 3-inch pipe	+2.5	2,750.7	82.33	Dec. 4	Unused tubular domestic well; observation well.
T. 27 S., R. 30 W. NW NW NW sec. 8	C. H. Arensman	Du, Dr	110	12,15, 40	C,GI	Coarse gravel	Ogallala and/or Pleistocene	T,D	I	Top of concrete curb, west side	+ .5	2,792.1	70.38	Dec. 5	Cased with 40-inch concrete casing to depth of 70 feet, 15-inch galvanized iron casing between depths of 70-90 feet, and 12-inch galvanized iron casing between depths of 90-110 feet; reported yield 1,100.
SW NE NE sec. 9	L. W. Korf	Dr	130	16	OW	Gravel	do	T,G	I				70		Gravel-packed well.
SW cor. SE sec. 10	M. D. Frazier	Dr	120	16	OW	Coarse gravel	do	T,G	I	Top of opening in pump base	+ .5	2,771.4	63.70	Dec. 5	Coarse gravel reported between depths of 60-120 feet; reported yield 900, drawdown 14.
NW NE NE sec. 19	R. Garvin	Dr	90.5			(?)	Pleistocene	Cy,W	D	Top of pipe clamp	+ .7	2,807.4	87.63	Nov. 6	

496	NE NW NW sec. 23	Haskinson Bros	Dr	135	16	OW	Coarse gravel	Ogallala and/ or Pleistocene	T,G	I	Top of pump base, west side	+1.0	2,772.6	68.13	Oct. 12	Gravel-packed well; coarse gravel reported between depths of 72-135 feet; measured yield 875, drawdown 11.26 (8).
497)	SW NW SW sec. 29	D. O. Graves	Dr	121.7	......	......	(?)	do	Cy,W	D,S	Top of metal pipe clamp	+ .2	2,821.4	106.26	Nov. 6	
	T. 28 S., R. 27 W.															
498	NE SW NW sec. 7	N. A. Mens	Dr	201.0	6	GI	(?)	do	Cy,W	N	Lower edge of 2 by 8-inch plank under pump	0	2,781.1	164.77	Nov. 4	Unused stock well; observation well.
499)	NW NE NE sec. 9	Menke Estate	Dr	171.0	3	I	(?)	do	Cy,W	S	Top of casing, south side	+3.0	2,763.8	168.61	Nov. 14	
500)	NE NE NW sec. 24	R. C. Houser	Dr	421	3-4	I	Sandstone	Dakota	Cy,W	D	Top of casing, north side	+3.1	2,755.4	207.20	Dec. 4	Water-bearing sandstone reported between depths of 408-421 feet.
501	NE NE NE sec. 25	F. L. Crabb	Dr	178.6	4	I	(?)	(?)	Cy,W	D,S	Top of casing, north side	+ .7	2,716.6	170.55	June 15, 1939	
502	SE SE SE sec. 26	Mary Hill	Dr	138.5	6	I	(?)	Ogallala (?)	Cy,W	N	Top of casing, east side	+ .5	2,711.4	133.79	Nov. 4	Unused domestic well; observation well.
503	SW SW NW sec. 29	A. C. Hitz	Dr	140	5	GI	Sand and gravel	Ogallala	Cy,W	D	Top of opening in pump flange	0	2,744.9	115.08	Nov. 29	
	T. 28 S., R. 28 W.															
504)	NW SW NW sec. 3	W. B. Jones	Dr	187.0	4	I	(?)	Ogallala and/ or Pleistocene	Cy,W,H	D	Top of casing, east side	+1.0	2,805.0	168.13	Nov. 28	
505	SW SW SW sec. 21	J. D. Asher	Dr	198	6	GI	(?)	do	Cy,W	D,S	Lower edge of opening in pump jacket	+1.5	2,797.6	150.32	Nov. 7	
506	NW SW SW sec. 24	G. V. Denton	Dr	165.1	3.5	I	(?)	do	Cy, W	N	Top of casing, north side	+1.1	2,774.4	145.35	Dec. 4	Unused domestic well.
	T. 28 S., R. 29 W.															
507	SE NE NE sec. 5	S. Dirks	Dr	91.5	5.5	GI	(?)	Pleistocene	N	N	Top of casing, east side	+ .5	2,773.3	88.16	Nov. 4	Abandoned domestic well; observation well.
508	SW SW SW sec. 12	S. J. Schmidt	Dr	146.3	5.5	GI	(?)	do	Cy,W	D,S	Top of metal pipe clamp	+ .3	2,806.3	139.27	Nov. 7	
509	NW NW NE sec. 21	F. A. Williams	Dr	129.3	5	GI	(?)	do	Cy,W	D,S	do	+ .3	2,787.7	112.65	do	
510	SE NW sec. 24	Atchison, Topeka, & Santa Fe Ry.	Dr	300	8-10	......	Clay, sand, and gravel	Ogallala and Pleistocene	T,E	R	......	......	......	118	......	Gravel-packed well; reported yield 45, drawdown 32; see log.
511)	SW NE sec. 24	City of Montezuma	Dr	170	8	OW	Gravel	Pleistocene	T,E	P	......	......	......	112	......	Water-bearing gravel reported between depths of 118-170 feet; reported yield 100, drawdown 18.
2	NW SE sec. 24	Fry	Dr	122.2	5	GI	(?)	do	N	N	Top of casing, east side	0	2,783.0	111.65	Dec. 4	Abandoned domestic well in town of Montezuma; observation well.

TABLE 25.—Records of wells in Gray county, Kansas—*Continued*

No. on pl. 2 (1)	LOCATION	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement, 1940	Remarks (Yield given in gallons a minute; drawdown in ft.)
	T. 28 S., R. 29 W.															
513	NE NE SW sec. 24	City of Montezuma	Dr	160	8	OW	Gravel	Pleistocene	T,E	P	....	....	....	112	....	Located beneath elevated water tank in Montezuma; reported yield 50.
(514)	NE cor. NW NE sec. 31	V. E. Yeager	Dr	103.5	6	GI	(?)	do	Cy,W	D,S	Top edge of bolt hole in pump flange	+ .4	2,762.5	85.25	Nov. 4	Observation well.
	T. 28 S., R. 30 W.															
515	NE SE NW sec. 2	A. F. Hohner	Dr	165	16	GI	Sand and gravel	do	T,G	I	Top of opening in pump base	+1.0	2,811.5	111.17	Dec. 4	Reported yield 800, drawdown 20; observation well.
516	SE SE SE sec. 10	P. Koehn	Dr	151	16	GI	Coarse gravel	do	T,G	I	....	....	....	....	....	Gravel-packed well; coarse gravel reported between depths of 141-151 feet.
517	SE SE NE sec. 13	E. B. Soice	Dr	120.5	....	....	(?)	do	Cy,W	D	Lower edge of bolt hole in pump jacket	+1.0	2,804.0	113.59	Nov. 7	
518	SE SE SW sec. 16	J. H. Schmidt	Dr	104.5	....	....	(?)	do	Cy,W	D,S	Top of pipe clamp	+ .5	2,787.6	85.99	Nov. 4	
519	NE NW NW sec. 23	A. Tucker	Dr	140.0	5	GI	(?)	do	Cy,W	D	Top of bolt hole in pipe flange	0	2,795.3	101.11	Nov. 7	
	T. 29 S., R. 27 W.															
520	NW NW NW sec. 8	F. E. Fox	Dr	70.5	5	GI	(?)	(?)	N	N	Top of concrete pump base	+ .5	2,647.0	69.29	Nov. 29	Abandoned casing.
521	NW NW NE sec. 11	C. E. Mooman	Dr	90.5	5	GI	(?)	Pleistocene	Cy,W	S	Top of southeast bolt hole in pipe flange	0	2,663.2	82.89	do	
522	SE SE SE sec. 23	J. B. Eccleston	Dr	54.8	5.5	GI	(?)	do	Cy,W	S	Top of concrete pump base	+ .3	2,577.1	44.36	Nov. 4	
523	SE cor. SW SE sec. 25	Sarah Marney	Dr	51.5	3	I	(?)	do	Cy,H	N	Top of casing, west side	+ .5	2,572.2	46.36	do	Unused domestic well; observation well.

524)	NW NW NE sec. 28	Mrs. J. Knoeber	Dr	89.5	5.5	GI	(?)	do	Cy,W	D	Lower edge of opening in pump base	+ .5	2,634.9	83.36	do	
525	SE SW SE sec. 36	W. R. Reece	Du	23.9	40		(?)	Alluvium	Cy,W	D,S	Top of wooden platform	+1.0	2,545.1	22.91	June 21, 1939	
	T. 29 S., R. 28 W.															
526)	SE NE NE sec. 4	H. Flair	Dr	365	4	I	Sandstone	Dakota	Cy,W	D,S				130		See log.
527	NW SW SW sec. 4	J. H. Mitchell	Dr	151.8	5	GI	Coarse sand	Pleistocene	Cy,W	D	Lower edge of opening in north side of pump jacket	+1.3	2,786.5	142.42	Nov. 7	Coarse sand reported between depths of 150-152 feet; red sandstone reported encountered at a depth of 152 feet.
528	NW NE NE sec. 15	J. L. Blackwelder	Dr	111.7	5	GI	(?)	do	Cy,W	D,S	Top of metal pipe clamp	+ .2	2,721.4	98.15	do	
529	SW NW SW sec. 22	T. E. Tuckwood	Dr	92.8	5	GI	(?)	do	Cy,H	N	Top of casing, west side	+ .3	2,706.3	81.95	Nov. 4	Unused domestic well.
530	SE SW SE sec. 25	L. Gamble	Dr	78.7	3	I	(?)	do	N	N	Top of casing, south side	+ .2	2,636.4	68.05	do	Unused domestic well.
531	SE NE NE sec. 35	J. D. Wetmore	Dr	62.0	5.5	GI	(?)	do	N	N	Top of casing, east side	+1.0	2,630.6	59.60	Dec. 4	Unused stock well; observation well.
	T. 29 S., R. 29 W.															
(532)	SE SE NE sec. 8	V. E. Yeager	Dr	68.5	5	I	(?)	do	Cy,W	D	Top of casing, south side	+ .5	2,717.6	55.79	Dec. 5	Well is about 40 feet above floor of creek.
533	NE NE NE sec. 11	J. H. Miller	Dr	125.8	5	I	(?)	do	Cy,W	N	Top of casing, north side	+ .3	2,758.6	106.47	do	Formerly used to irrigate fruit trees and garden.
534	NW NW NE sec. 12	E. Lupton	Dr	138	24	GI	Sand and gravel	do	T,NG	I				99		Gravel-packed well; measured yield in 1940, 475, drawdown 25.9 (8); owner reports that the yield has since increased to 600; see log.
535	NE SE NE sec. 25	School District	Dr	58.4	5	GI	(?)	do	N	N	Top of casing, south side	+ .8	2,672.5	49.66	Dec. 4	Unused school well; observation well.
536	SW NW NW sec. 34	E. J. Bookwalter	Dr	113.5	5	GI	Sand	do	Cy,W	D,S	Top of casing, west side	+ .5	2,731.0	95.28	Nov. 6	
	T. 29 S., R. 30 W.															
537	NW NE NE sec. 5	T. Tyler	Dr	140.8	4	GI	Medium gravel	do	Cy,W,H	N	Top of casing, north side	+ .3	2,802.4	110.60	do	Unused domestic well.
538	SE SE NW sec. 8	City of Copeland	Dr	248	16	OW	(?)	Ogallala and/or Pleistocene	T,E	P				153		Gravel-packed well; reported yield 50; west city well.
539	do	do	Dr	252	15	OW	Coarse gravel	do	T,NG	P	Top of opening south side of pump	+ .5	2,818.2	153.43	Nov. 28	Gravel-packed well; reported yield 50; east city well.
540	SE cor. NE sec. 13	Farmers and Bankers Life Insurance Co.	Dr	74.5	4	GI	Sand	Pleistocene	Cy,W,H	D	Top of casing, south side	+ .5	2,707.1	43.57	Dec. 5	

TABLE 23.—Records of wells in Gray county, Kansas—*Concluded*

No. on pl. 2 (1)	LOCATION	Owner or tenant	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement, 1940	Remarks (Yield given in gallons a minute; drawdown in ft.)
	T. 29 S., R. 30 W															
541	NE cor. NW sec. 19	E. Wallace	Dr	142.5	5.5	GI	(?)	Pleistocene	Cy,W,H	N	Top of casing, east side	+ .5	2,823.9	138.36	Dec. 4	Unused domestic well; observation well.
542	SW SW SW sec. 26	L. J. Schmidt	Dr	104.5	4	GI	(?)	do	Cy,W	N	Top of casing, north side	+1.0	2,756.5	92.94	Nov. 6	Unused domestic well.
543	SW NW NW sec. 31	D. Woodson	Dr	151.5			(?)	do	Cy,W	N	Lower edge of pump flange	0	2,824.7	144.79	do	Do

1. Well number in parentheses indicates that analysis of water is given in table 20.
2. B, bored; Dn, driven; Dr, drilled; Du, dug.
3. Reported depths to water level are given in feet below the land surface; measured depths are given in feet and tenths below the measuring point.
4. C, concrete; GI, galvanized iron; GP, galvanized pipe; I, iron; OB, oil barrels; OW, oil well.
5. Method of lift: C, horizontal centrifugal; Cy, cylinder; N, none; P, pitcher pump; T, turbine. Type of power: B, butane; D, Diesel engine; E, electric; G, gas engine; H, hand operated; N, none; NG, natural gas; T, tractor; W, windmill.
6. D, domestic; I, irrigation; N, not in use; P, public supply; R, railroad; S, stock.
7. Measured depths to water level are given in feet, tenths, and hundredths; reported depths to water level are given in feet.
8. Pumping test conducted and results furnished by the Division of Water Resources, Kansas State Board of Agriculture.

LOGS OF TEST HOLES AND WELLS

On the following pages are listed the logs of 59 wells and test holes in Finney and Gray counties, one test hole (1) in Scott county, one test hole (12) in Kearny county, and two test holes (28 and 29) in Ford county. Logs 1 to 29 are of test holes drilled by the State and Federal Geological Surveys (fig. 7). Logs 30 to 60 include logs of test holes drilled by other agencies and well drillers, logs of water wells (pls. 3 and 4), and partial logs of oil tests.

Lithologic terms used in the driller's logs have been retained. The term "gyp" has been used by many drillers to describe the harder lime-cemented beds in the Ogallala formation and undifferentiated Pleistocene beds. "Quicksand" and "pack sand" have been used by some drillers to describe loose fine sand, and "sand rock" has been used to describe sandstone. Many of the softer unconsolidated beds of the Ogallala formation and Pleistocene deposits have been logged as clay, but in those wells from which cuttings are available for study most of the so-called clay was found to be silt.

Because of lack of detail in the driller's logs of oil tests, no attempt was made to correlate these logs (58-60).

1. Log of test hole 1 in the SE¼ SW¼ sec. 32, T. 20 S., R. 34 W. (Scott county), drilled by State and Federal Geological Surveys, 1940. Surface altitude, 3,089.5 feet. (Authority, samples studied by Perry McNally, H. A. Waite, Bruce F. Latta, and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, dark	1.5	1.5
Undifferentiated Pleistocene deposits		
Silt and sand, fine; limy; tan; containing gastropods	11	12.5
Silt and sand, fine; pinkish brown; containing thin limy zones	5.5	18
Caliche, soft, tan to light gray	6	24
Sand, fine to medium, pinkish brown; containing some silt,	2.5	26.5
Caliche, soft, tan-gray; and clay, limy	6.5	33
Clay, tan-gray	5	38
Sand, medium, to gravel, medium; brown	16.5	54.5
Ogallala (?) formation		
Sand and gravel; lime-cemented; gray	4	58.5
Sand, medium, to gravel, coarse; brown; contains a few lime-cemented zones	37	95.5
Silt, sandy, light gray-yellow	8	103.5
Silt, sandy, lime-cemented, soft, light gray; contains lenses of brown, fine to medium sand and fragments of *Celtis willistoni* (?) and *Biorbia fossilia* (?)	15.5	119

	Thickness, feet	Depth, feet
Niobrara formation		
Smoky Hill chalk member		
Chalk, silty, soft, light yellow to light gray	15	134
Shale, chalky, soft, dark blue-gray; contains few fragments of white bentonite	6	140
Shale, chalky, dark blue-gray; contains interbedded lighter gray hard sandy shale	14	154
Fort Hays limestone member		
Shale, chalky, dark gray to white	10	164
Chalk, light gray to white	3	167
Shale, chalky, light gray to dark gray	5	172
Chalk, light gray to white	12	184
Shale, chalky, dark gray	1	185
Chalk, light gray to white	15	200
Shale, chalky, light gray to white	19	219
Carlile shale		
Codell sandstone and Blue Hill shale members		
Shale, sandy, noncalcareous, dark gray	33	252
Shale, sandy, light to dark gray	1.5	253.5
Shale, clayey, noncalcareous, dark gray to black	16.5	270

2. Log of test hole 2 in the SW corner sec. 3, T. 22 S., R. 31 W., Finney county, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,902.1 feet. (Authority, samples studied by Perry McNally and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Soil, silty, dark	2	2
Undifferentiated Pleistocene deposits and Ogallala formation		
Silt and sand, fine; tan to brown	28	30
Caliche, sandy, light gray and light tan	10	40
Sand and gravel; limy; tan; containing nodules of white caliche	4	44
Sand, fine to medium, lime-cemented	4	48
Silt and sand, fine; yellow-tan	5	53
Sand and gravel; silty; tan	34.5	87.5
Silt and sand, fine; limy; light tan	7.5	95
Sand and gravel; brown	4	99
Silt and sand, fine; limy; tan to brown	19	118
Sand and gravel; limy; tan; and light gray to white soft caliche	16	134
Silt and sand, fine; tan	14	148
Niobrara formation		
Shale, chalky, white to yellow-tan	18	166
Shale, chalky, light to dark gray; contains thin yellow-tan chalk beds	84	250
Shale, chalky, white to light gray; and chalk; interbedded with dark gray shale. Contains little sand in lower part,	40	290
Shale, calcareous, gray; and limestone, chalky white	55	345
Carlile shale		
Blue Hill shale member		
Shale, noncalcareous, hard, dark blue-gray	15	360

3. Log of test hole 3 at the SE corner sec. 6, T. 22 S., R. 32 W., Finney county, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,878.2 feet. (Authority, samples studied by Perry M. McNally and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Soil, sandy, dark	0.5	0.5
Undifferentiated Pleistocene deposits		
Clay and silt; fine sandy; tan	29	29.5
Sand, medium, to gravel, fine; brown	11.5	41
Clay, silty, light green-gray to brown; containing gastropod shell fragments	16	57
Silt and sand, fine; green-gray	15	72
Sand, gravel, and abraded caliche pebbles	3	75
Caliche, gray; and sand, fine, gray to greenish-gray	7	82
Sand, medium, to gravel, fine; brown	5	87
Clay, silty, sticky, light gray	18	105
Ogallala(?) formation		
Sand, fine, lime-cemented, light gray to white	15	120
Silt, sandy, limy, tan to light gray	4	124
Sand and gravel; limy; tan	5	129
Sand and gravel, lime-cemented, hard	7	136
Sand, fine, silty, gray and brown	24	160
Gravel, fine to medium, brown	21	181
Silt and sand, fine; limy, tan	9	190
Sand and gravel; limy; tan	21.5	211.5
Sand and gravel; containing abundant Cretaceous chalk pebbles	28.5	240
Gravel, white; contains Cretaceous chalk pebbles	8.5	248.5
Silt, yellow; and caliche	18	266.5
Niobrara formation		
Fort Hays limestone member		
Chalk, silty, yellow	8	274.5
Carlile shale		
Codell sandstone member		
Shale, sandy, noncalcareous, blue-gray	5.5	280

4. Log of test hole 4 in the NW corner sec. 8, T. 22 S., R. 33 W., Finney county, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,891.8 feet. (Authority, samples studied by Perry M. McNally and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Soil, sandy, dark	2	2
Undifferentiated Pleistocene deposits		
Silt and sand, fine; tan	6	8
Clay, silty, gray to black; containing gastropod shell fragments	11	19
Clay, silty, light gray	6	25
Sand, fine to medium, silty, tan and gray	7	32
Sand, fine, limy, tan and light gray; and caliche	6	38

	Thickness, feet	Depth, feet
Ogallala(?) formation		
Caliche, light gray to white	6	44
Sand and gravel; cemented; hard; tan	6	50
Caliche and sand, fine to medium; interbedded	10	60
Silt and sand, fine; limy; tan to gray; containing few thin cemented beds	50	110
Sand, medium to coarse, cemented, gray and tan	11	121
Clay, sandy, noncalcareous, mottled light gray and yellow,	21	142
Carlile shale		
Codell sandstone member		
Shale, sandy, noncalcareous, dark gray	8	150

5. Log of test hole 5 at the NW corner sec. 7, T. 22 S., R. 34 W., Finney county, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,009.1 feet. (Authority, samples studied by Perry M. McNally and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Soil, sandy, dark	1	1
Undifferentiated Pleistocene deposits and Ogallala(?) formation		
Silt and sand, fine; limy; tan to brown; containing gastropod shells and fragments	36	37
Silt and sand, fine; tan; containing thin lenses of sand and gravel	5	42
Silt, clayey, hard, tan and gray; containing caliche fragments	8	50
Sand, fine, tan and gray	4	54
Silt and sand, fine; tan; containing coarser sand and gravel,	6	60
Sand and gravel, fine to coarse	9.5	69.5
Sand, fine, limy, gray	2.5	72
Sand and gravel; containing some tan limy silt	36	108
Sand and gravel; containing caliche and limestone fragments and pebbles	7	115
Sand and gravel; cemented; hard; gray	1.5	116.5
Clay, noncalcareous, green-yellow	28.5	145

6. Log of test hole 6 at the SW corner sec. 11, T. 23 S., R. 28 W., Finney county, drilled by the State and Federal Geological Surveys, 1941. Surface altitude, 2,704.6 feet. (Authority, samples studied by Perry M. McNally and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Soil, sandy, dark	3	3
Undifferentiated Pleistocene deposits and Ogallala formation		
Silt and sand, fine; tan	9	12
Caliche, tan and light gray	3	15
Silt and sand, fine; limy; tan; contains caliche	13	28
Silt and sand; lime-cemented; tan and light gray	8	36
Sand, fine to medium, brown	6	42
Silt and sand, fine; lime-cemented; light gray and tan	12	54

	Thickness, feet	Depth, feet
Sand and gravel; poorly sorted; limy	10	64
Silt, clayey and sandy, tan and gray	10	74
Sand, gravel, and caliche pebbles; containing abundant yellow chalk pebbles	5	79
Carlile shale		
Blue Hill shale member		
Shale, silty, gray, containing few hard concretionary zones	21	100
Shale, noncalcareous; blue-gray to black	20	120

7 Log of test hole 7 at the NW corner sec. 6, T. 23 S., R. 32 W., Finney county, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,856.8 feet. (Authority, samples studied by Perry M. McNally and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Soil, sandy, dark	1	1
Undifferentiated Pleistocene deposits		
Silt and sand, fine; limy; tan and light gray	14	15
Sand, coarse, to gravel, medium; silty; containing shells and shell fragments	15	30
Silt and sand, fine; limy; tan and light gray	7.5	37.5
Sand, coarse, to gravel, medium	8	45.5
Silt, yellow-tan	5.5	51
Silt and sand, fine; limy; light gray; and caliche, white	9	60
Caliche, sandy, soft, white	18	78
Silt and sand, fine; tan	8	86
Sand and gravel; poorly sorted	8	94
Gravel, cemented, hard, brown	1	95
Silt and sand, fine; limy; tan and light gray	15	110
Sand, fine, tan and light gray	3	113
Sand, medium, to gravel, medium; brown	10	123
Silt and sand, fine; limy; light gray	7	130
Ogallala(?) formation		
Gravel, fine to medium, sandy; containing few thin cemented beds	16	146
Silt and sand, fine; tan	15	161
Sand, gravel, and caliche	20	181
Silt and sand, fine; gray; containing yellow and white chalk pebbles	16	197
Silt and sand, fine; tan; containing caliche nodules, sand, and gravel	15	212
Gravel, loosely-cemented; containing abundant yellow chalk pebbles	4	216
Silt and sand, fine; gray-tan	3	219
Carlile shale		
Blue Hill shale member		
Clay-shale, silty, gray	16	235
Shale, noncalcareous, black	10	245

8. Log of test hole 8 at the SE corner sec. 31, T. 23 S., R. 32 W., Finney county, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,877.6 feet. (Authority, samples studied by Perry M. McNally and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Soil, black	1	1
Undifferentiated Pleistocene deposits		
Silt and sand, fine to medium; tan	17	18
Sand, medium, to gravel, coarse; brown	8	26
Silt and sand, fine; limy; light gray and tan	5	31
Sand, medium, to gravel, medium; brown	4	35
Silt and sand, fine to medium; containing some gravel	19	54
Clay, sandy, yellow-tan	3	57
Clay, silty, sticky, dark blue-gray	33	90
Clay, silty, yellow-tan	10	100
Silt and sand, fine; limy; light gray and tan	7	107
Clay, silty, blocky, dark gray-brown and light tan	13	120
Silt and sand, fine; light gray and tan	14	134
Sand and gravel; containing lime-cemented sand pebbles	21	155
Sand, fine, tan	8	163
Sand, coarse, to gravel, medium; containing lime-cemented sand pebbles	18	181
Silt and sand, fine; tan	7	188
Gravel, fine to coarse; containing abraded lime-cemented sand pebbles	22	210
Silt and sand, fine; light tan; containing some coarser sand and gravel	20	230
Ogallala (?) formation		
Sand and gravel; poorly sorted	24	254
Silt and sand, fine; light gray and light tan; containing some sand and gravel	38.5	292.5
Silt and sand, fine; tan	29	321.5
Carlile shale		
Fairport chalky shale member		
Limestone, gray; drilled hard	3	324.5
Shale, calcareous, black; and limestone, hard, dark gray,	5.5	330

9. Log of test hole 9 in the NW¼ sec. 31, T. 24 S., R. 31 W., Finney county, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,791.2 feet. (Authority, samples studied by Perry M. McNally and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Soil, sandy, dark	2	2
Alluvium		
Silt and sand, fine; light tan and light gray	4	6
Gravel, fine to very coarse; containing some sand and cobbles	31	37
Undifferentiated Pleistocene deposits and Ogallala formation		
Silt and sand, fine; tan and light gray; containing lime-cemented bed from 41 to 43 feet	12	49

	Thickness, feet	Depth, feet
Sand and gravel; poorly sorted; brown	17	66
Silt and sand, fine; tan; containing thin lenses of coarser sand and gravel	12	78
Sand, fine, lime-cemented, tan	5	83
Sand, fine, limy; containing thin cemented beds	7	90
Silt and sand, fine; limy; tan and light gray	9.5	99.5
Sand, fine, tan to brown; containing cemented zones and white and yellow chalk and limestone pebbles	20.5	120
Silt and sand, fine; tan; containing some clay	17	137
Sand, medium, to gravel, medium; containing caliche fragments and yellow chalk pebbles	26	163
Silt, clayey, sandy, tan	3	166
Sand, medium, to gravel, medium	3	169
Silt, clayey, tan	6	175
Sand, medium, to gravel, fine; containing chalk pebbles	28	203
Silt and sand, fine; tan and gray	5.5	208.5
Sand, medium, to gravel, fine; brown	5.5	214
Carlile shale		
Fairport(?) chalky shale member		
Shale, silty, yellow-tan; contains hard sandstone concretions	3.5	217.5
Shale, calcareous, dark gray	2.5	220

10. Log of test hole 10 at the NE corner NW¼ of sec. 19, T. 24 S., R. 32 W., Finney county, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,832.8 feet. (Authority, samples studied by Perry M. McNally and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Alluvium		
Sand, silty, tan	4.5	4.5
Gravel, medium to very coarse, sandy	28.5	33
Undifferentiated Pleistocene deposits and Ogallala formation		
Silt and sand, fine; limy; light gray and tan	7	40
Silt, sandy, yellow-tan	33	73
Sand, medium, to gravel, fine; tan	13	86
Caliche, light gray; and silt, sandy, limy	5	91
Sand, medium, to gravel, coarse	15	106
Sand, lime-cemented, hard, light tan	6	112
Silt and sand, fine; yellow-tan	25.5	137.5
Silt and sand, fine; tan; containing some coarser sand and gravel	23.5	161
Sand and gravel; silty; poorly sorted	43	204
Sand, lime-cemented, hard	3.5	207.5
Silt and sand, fine; tan to brown	19.5	227
Caliche, soft, light gray	1.5	228.5
Sand and gravel; brown	14.5	243
Silt and sand, fine; limy; tan	7	250

	Thickness, feet	Depth, feet
Sand and gravel; loosely cemented; containing yellow chalk and limestone pebbles	6	256
Sand and gravel; lime-cemented; hard	3	259
Carlile shale		
Fairport chalky shale member		
Shale, silty, yellow-tan; interbedded with yellow-tan to gray, hard limestone	11	270

11. Log of test hole 11 in the NW¼ SW¼ sec. 7, T. 24 S., R. 33 W., Finney county, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,877.8 feet. (Authority, samples studied by Perry M. McNally and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Alluvium		
Soil, sandy, tan	2	2
Gravel, fine to very coarse; containing some sand and cobbles	34	36
Undifferentiated Pleistocene deposits and Ogallala formation		
Silt and sand, fine; tan and light gray	35	71
Sand, medium, to gravel, medium; brown	12	83
Silt and sand, fine; tan and light gray	6.5	89.5
Sand, fine, light tan; containing some coarser sand and gravel	48.5	138
Sand, fine, limy, gray; containing few thin cemented beds,	12	150
Silt and sand, fine; clayey; tan and brown	20	170
Silt, blue-gray; containing few thin light gray caliche beds,	16	186
Sand, coarse, to gravel; medium; brown	27.5	213.5
Silt and sand, fine; limy; tan	6.5	220
Sand and gravel; poorly sorted; brown	20	240
Sand, fine, tan; containing few thin cemented beds	12	252
Sand, fine, to gravel, fine; brown	48	300
Sand, medium, to gravel, medium; brown; containing abundant yellow and white chalk and limestone pebbles,	14.5	314.5
Greenhorn limestone		
Limestone, hard, gray; and shale, silty, yellow-tan	10	324.5
Shale, calcareous, black	5.5	330

12. Log of test hole 12 at the NE corner sec. 13, T. 24 S., R. 35 W., Kearny county, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,925.5 feet. (Authority, samples studied by Lawrence P. Buck and Thad McLaughlin.)

	Thickness, feet	Depth, feet
Alluvium		
Soil, sandy, light brown	1	1
Sand, coarse, rusty	3	4
Gravel, fine to coarse	16	20
Sand, coarse, to gravel, coarse	9	29
Silt and sand, fine; brown; contains some gravel	11	40

	Thickness, feet	Depth, feet
Undifferentiated Pleistocene deposits and Ogallala (?) formation		
Silt and sand, fine; tan	31	74
Silt and sand, fine; gray	4	78
Caliche, gray	2	80
Silt and sand, fine; gray	12	92
Sand, coarse, to gravel, coarse	6	98
Sand, fine, gray to tan	19	117
Sand, coarse, and gravel, medium	7	124
Silt and sand, fine; tan to gray	17	141
Sand, coarse, and gravel, coarse; containing fine sand	22.5	163.5
Sand, fine, blue-gray to gray	16.5	180
Silt and sand, fine; blue-gray	20	200
Silt and sand, fine; blue-gray; contains some gravel	20	220
Sand, fine, to gravel, coarse; tan	25	245
Sand, fine, light tan	5	250
Sand, coarse, to gravel, medium	17	267
Sand, fine, to gravel, medium; tan to gray	8	275
Sand, coarse, to gravel, medium; tan	5	280
Sand, coarse, to gravel, medium; tan; contains some fine sand	10	290
Sand, fine to coarse, tan; and some gravel	10	300
Sand, coarse, to gravel, medium	10	310
Sand, medium, to gravel, coarse	4	314
Sand, fine; containing some clay and fine gravel	16	330
Sand, coarse, to gravel, coarse	16	346
Sand, fine, tan; and silt	4	350
Sand and gravel, coarse; containing rounded caliche fragments	10.5	360.5
Graneros shale		
Shale, noncalcareous, black to light gray	8.5	369

13. Log of test hole 13 in the SE¼ SW¼ sec. 13, T. 25 S., R. 31 W., Finney county, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,744.2 feet. (Authority, samples studied by Perry M. McNally and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Alluvium		
Sand, tan to brown	1	1
Sand, medium to coarse, brown	1	2
Gravel, medium to very coarse; containing some sand and large cobbles	32.5	34.5
Undifferentiated Pleistocene deposits and Ogallala formation		
Silt and sand, fine; limy; light tan; containing few thin cemented beds	11.5	46
Sand, fine to coarse, tan	13	59
Clay, limy, silty, light gray to white; and cemented silt and fine sand	14	73

	Thickness, feet	Depth, feet
Silt, clayey, sandy, yellow-tan	20	93
Sand, coarse, to gravel, medium; containing abundant yellow chalk pebbles	26	119
Silt, clayey, sandy, tan	13	132
Carlile shale		
Fairport chalky shale member		
Shale, silty, yellow; and shale, chalky, white	8.5	140.5
Shale, calcareous, black	4.5	145

14. Log of test hole 14 at the NW corner NE¼ sec. 12, T. 25 S., R. 33 W., Finney county, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,866.8 feet. (Authority, samples studied by Perry M. McNally and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Dune sand		
Soil, sandy, dark	0.5	0.5
Sand, fine to medium, tan	3.5	4
Sand, fine, tan	4	8
Terrace gravels		
Gravel, medium to very coarse, sandy; containing pebbles and cobbles	37	45
Undifferentiated Pleistocene deposits and Ogallala formation		
Silt and sand, fine; limy; gray and tan; containing some gray silty clay	36	81
Sand, fine, to gravel, medium; tan	12	93
Silt and sand, fine; limy; tan and light gray	32	125
Sand, coarse, to gravel, medium; brown	30	155
Silt and sand, fine; limy; light gray	7	162
Sand, fine, red-brown	9	171
Sand, fine, lime-cemented, hard; interbedded with light gray silt and fine sand	9	180
Sand, coarse, to gravel, coarse; brown	15.5	195.5
Silt and sand, fine; limy; light gray; containing hard cemented zone at top	2.5	198
Sand, coarse, to gravel, medium; brown	5.5	203.5
Silt, clayey, medium gray	2.5	206
Sand, coarse, to gravel, medium; brown	31	237
Sand, fine, brown; containing few thin cemented zones and some coarser sand and gravel	23	260
Sand, coarse, and gravel, fine	17	277
Silt and sand, fine; tan and light gray	12	289
Sand, medium, to gravel, fine; brown	20	309
Silt, clayey, tan	5	314
Sand and gravel; brown	11	325
Silt, clayey, sandy, yellow-tan	11	336
Gravel, fine to coarse, sandy; containing granules and pebbles of Cretaceous rocks	10	346
Silt and sand, fine; limy; tan and light gray	4	350

	Thickness, feet	Depth, feet
Sand, medium, to gravel, coarse; containing chalk and limestone pebbles	55.5	405.5
Greenhorn limestone		
Shale, silty, calcareous, yellow-tan	4	409.5
Shale, calcareous, black, and limestone, dark gray	10.5	420

15. Log of test hole 15 at the NW corner sec. 12, T. 26 S., R. 33 W., Finney county, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,884.1 feet. (Authority, samples studied by Perry M. McNally and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Dune sand		
Sand, fine to medium, tan	2	2
Sand, fine to medium, silty, brown	5	7
Undifferentiated Pleistocene deposits and Ogallala formation		
Clay, hard, black	2.5	9.5
Silt, clayey and sandy, green-gray to tan; containing gastropod shells and shell fragments	6.5	16
Sand, fine, tan; containing shell fragments	5	21
Silt, clayey and sandy, green-gray; containing shell fragments	3.5	24.5
Sand, coarse, to gravel, very coarse	16.5	41
Silt and sand, fine; limy; light gray and tan	16	57
Sand, fine, tan	12	69
Sand, coarse, to gravel, coarse	26	95
Silt and sand, fine; limy; tan	9.5	104.5
Sand, fine, tan; containing some coarser sand and gravel	5.5	110
Sand, coarse, to gravel, coarse; brown	20	130
Sand, medium, to gravel, fine; brown	26	156
Silt and sand, fine; light tan and light gray	3	159
Sand, medium, to gravel, coarse	20	179
Silt and sand, fine; tan; containing few thin cemented beds	28	207
Gravel, fine to medium; containing some sand	8	215
Sand and gravel; lime-cemented; hard	10	225
Sand, coarse, to gravel, coarse; brown	66	291
Silt and sand, fine; limy; light gray and tan	12	303
Sand, coarse, to gravel, coarse; containing some silt and fine sand	17	320
Silt and sand, fine; limy; light gray and tan; containing few thin beds of hard, white caliche	28	348
Silt and sand, fine; tan	4	352
Silt and sand, fine; brown; containing cemented fragments and caliche	19	371
Silt, clayey, tan; containing thin lenses of silt and fine sand	19	390
Sand, medium, to gravel, fine; brown	2.5	392.5

	Thickness, feet	Depth, feet
Laverne (?) formation		
Clay, blocky, tan to brown	47.5	440
Dakota formation		
Sandstone, pink-red to maroon-red; containing some iron concretions	15	455
Shale, gray	12	467

16. Log of test hole 16 at the SW corner sec. 36, T. 26 S., R. 33 W., Finney county, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,914.5 feet. (Authority, samples studied by Perry M. McNally and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Soil, sandy, dark	3	3
Undifferentiated Pleistocene deposits		
Silt and sand, fine to coarse; tan; containing shell fragments	27	30
Gravel, fine to coarse; containing thin lenses of tan silt and sand	85	115
Silt and sand, fine; tan; brown and gray	25	140
Sand, medium, to gravel, medium; brown	8	148
Sand, fine, brown	6.5	154.5
Sand, medium, to gravel, medium; brown	35	189.5
Silt, clayey and sandy, tan	7.5	197
Silt and sand, fine; medium gray; containing shell fragments	4	201
Silt and sand, fine; tan	3	204
Gravel, fine to coarse; containing some silt and sand	40	244
Clay, silty and sandy, gray, blue-gray and tan	20	264
Sand, lime-cemented, hard, blue gray	8	272
Clay, silty, blue-gray; containing shell fragments	8	280
Clay, silty and sandy, soft, blue-black; containing gastropod fragments and ostracodes	10	290
Sand, coarse, to gravel, coarse; brown	23.5	313.5
Ogallala (?) formation		
Silt and sand, fine; limy; tan and light gray	7.5	321
Sand, medium to gravel, medium; brown; contains some light gray sandy silt	10	331
Silt, clayey and sandy, tan and light gray; containing thin caliche beds	31	362
Sand, fine, tan to brown; containing some coarser sand and gravel	9	371
Sand and gravel; lime-cemented; light gray; and caliche, white	19	390
Laverne (?) formation		
Clay, silty, tan and gray	20	410
Clay-shale, silty, tan and brown	41	451
Sand, medium, to gravel, fine; brown	18	469
Clay, silty, yellow-tan	12.5	481.5

	Thickness, feet	Depth, feet
Dakota formation		
Shale, soft, yellow-tan and light gray; containing thin maroon-red sandstone beds	8.5	490
Sandstone, red, yellow-tan, and red-brown	7	497
Shale, silty, yellow-tan	3	500

17. Log of test hole 17 at the SE corner sec. 11, T. 24 S., R. 27 W., Gray county, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,664.3 feet. (Authority, samples studied by Laurence P. Buck and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Soil, dark brown	2	2
Undifferentiated Pleistocene deposits and Ogallala formation		
Silt, sandy, tan; containing lime nodules	5.5	7.5
Silt, reddish brown; containing scattered sand, gravel, and lime nodules	7	14.5
Silt and sand, fine; limy; light tan; containing some gravel and caliche fragments	19.5	34
Silt, sandy, limy, light tan to white; containing caliche nodules	10	44
Sand, fine, orange-tan; contains caliche and a little gravel,	10	54
Sand, coarse, to gravel, coarse; partly cemented	12	66
Sand, gravel, and caliche	2.5	68.5
Silt and sand, fine; limy; light tan	1.5	70
Silt and sand, fine; tan	3	73
Silt, lime-cemented, light tan to white	17	90
Gravel, coarse; composed chiefly of limestone and chalk pebbles	15	105
Silt and sand, fine; lime-cemented; white	5	110
Greenhorn(?) limestone		
Shale, calcareous, silty, dark gray; containing crystalline calcite veins	10	120

18. Log of test hole 18 at the SE corner sec. 15, T. 24 S., R. 28 W., Gray county, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,742.4 feet. (Authority, samples studied by Perry M. McNally, Laurence P. Buck, and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Soil, sandy, tan	0.5	0.5
Undifferentiated Pleistocene deposits and Ogallala formation		
Silt, tan; containing scattered sand and gravel	16.5	17
Silt and sand, fine; tan; containing lime nodules	14	31
Silt, sandy, limy, tan	24	55
Caliche, silty, light gray to white	5	60
Silt, sandy, limy, tan to white	4.5	64.5
Caliche, hard, light tan to light gray	1.5	66
Sand, fine to medium, cemented, tan	6	72
Sand and gravel; brown	2	74

	Thickness, feet	Depth, feet
Silt, sand, and gravel; cemented; gray	5	79
Sand and gravel; brown	4	83
Gravel, medium to coarse, cemented	7	90
Silt and sand, fine; limy; tan to reddish brown	21	111
Caliche, soft, light gray; and silt and sand, fine; limy	3	114
Gravel, medium to coarse, brown	16	130
Silt, sand, and gravel	11	141
Caliche, light gray and tan; and silt and fine sand; limy	4	145
Silt and sand, fine; limy; light gray to white	6	151
Silt and clay, silty; yellow-tan	7	158
Sand and gravel; brown	5	163
Silt, sandy, tan	27	190
Sand, fine, to gravel, fine; limy; silty; tan	20	210
Silt and sand, fine; limy; tan	5.5	215.5
Carlile shale		
Fairport chalky shale member		
Shale, calcareous, black	4.5	220
Shale, calcareous, dark gray to black; contains thin calcite veins	6	226
Greenhorn (?) limestone		
Shale, calcareous, light gray and black; contains 5-inch bed of blue-gray bentonite at 261 feet	46	272
Shale, silty, sandy, calcareous, black	18	290
Shale, calcareous, silty, dark gray to black; containing few thin beds of blue-gray bentonite and calcite	57	347
Shale, calcareous, silty, light gray to white; containing interbedded hard black shale	3	350
Graneros shale--Kiowa (?) shale		
Shale, noncalcareous, blue-gray; contains few thin beds of dark gray sandstone	23	373
Shale, noncalcareous, silty, light gray to black; containing pyrite	6.5	379.5
Sandstone, hard, dark gray	.5	380
Shale, noncalcareous, silty, light to medium gray	20	400
Shale, noncalcareous, silty, light gray; and shale, sandy, gray	20	420
Shale, noncalcareous, dark gray; and shale, silty and sandy, light gray	50	470
Shale, noncalcareous, sandy, light gray	25	495
Shale, noncalcareous, sandy, dark brown to black	5	500
Shale, sandy, banded, light to dark gray and yellow	10	510
Shale, noncalcareous, dark gray; containing some medium gray and orange-tan silty clay	26	536
Shale, noncalcareous, dark gray; containing some light-gray silty shale and brown sandy shale	24	560
Shale, noncalcareous, light to medium gray; containing sand, mineral charcoal, and a little red clay	57	617

19. Log of test hole 19 at the SE corner sec. 13, T. 24 S., R. 30 W., Gray county, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,819.2 feet. (Authority, samples studied by Laurence P. Buck and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Soil, dark brown	1	1
Undifferentiated Pleistocene deposits and Ogallala formation		
Silt and sand, fine; limy; tan and light brown	19	20
Silt and sand, fine; limy; reddish tan to yellow-tan; contains caliche	23	43
Silt and sand, fine; limy, cemented	5	48
Sand, coarse, to gravel, coarse	12	60
Sand, coarse, to gravel, fine; cemented	5.5	65.5
Sand, coarse, to gravel, coarse	4.5	70
Sand, fine, tan	3	73
Sand, coarse, to gravel, coarse; containing thin cemented zones	23	96
Gravel, fine, cemented	2.5	98.5
Silt and sand, fine; limy; tan	1.5	100
Sand, fine, to gravel, coarse; partly cemented	31	131
Silt and sand, fine; tan	19	150
Silt, sand, gravel, and caliche	11	161
Sand, coarse, to gravel, medium	11	172
Silt and sand, fine; tan	11	183
Sand, coarse, to gravel, coarse	27	210
Gravel, fine to coarse; composed mostly of white to light-gray limestone pebbles	14	224
Clay, noncalcareous, yellow and gray	18	242
Carlile shale		
Fairport chalky shale member		
Shale, calcareous, dark gray	8	250

20. Log of test hole 20 at the SE corner sec. 27, T. 25 S., R. 28 W., Gray county, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,751.1 feet. (Authority, samples studied by Laurence P. Buck and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Soil, sandy, dark brown	2	2
Undifferentiated Pleistocene deposits and Ogallala formation		
Silt, tan to red-brown; contains scattered sand and gravel,	8	10
Silt and sand, fine; limy; light tan to red-brown; containing caliche nodules	45.5	55.5
Silt and sand, fine; lime-cemented; soft; white to light tan; and caliche	9.5	65
Sand, fine, red-tan, gray, and yellow; and caliche	15	80
Sand, fine, to gravel, coarse; loose; contains cemented zones	17.5	97.5
Sand, fine, limy, light tan	2.5	100

	Thickness, feet	Depth, feet
Silt and sand, fine; light tan; containing scattered coarse sand and gravel	10	110
Sand, fine to medium, tan; containing scattered gravel and caliche	10	120
Sand, fine, to gravel, fine; silty	30	150
Silt, sand, and gravel; limy, tan	24	174
Sand, fine, pink-tan	6	180
Sand, fine, limy, light tan; containing some coarse sand, fine gravel, and caliche	7	187
Silt and sand, fine; limy, white to light tan; and caliche	8	195
Sand, gravel, and caliche	25	220
Silt and sand, fine; tan	10	230
Sand, fine, to gravel, fine; silty	40	270
Sand, fine, to gravel, medium	15	285
Silt, sandy, light tan	5	290
Silt and sand, fine; clayey; tan to light brown	13	303
Greenhorn limestone		
Shale, calcareous, light to dark gray and dark brown; containing thin crystalline calcite veins	7	310

21. Log of test hole 21 at the NE corner NW¼ sec. 25, T. 25 S., R. 30 W., Gray county, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,698.2 feet. (Authority, samples studied by Laurence P. Buck and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Soil, brown	1	1
Alluvium		
Sand, fine, silty, tan	1	2
Sand, coarse, to very coarse gravel	41	43
Undifferentiated Pleistocene deposits and Ogallala formation		
Silt and sand, fine; yellow-tan; containing caliche and lime-cemented nodules	19	62
Sand, fine, hard, cemented	2.5	64.5
Silt and sand, fine; clayey; yellow-tan; containing caliche and "mortar bed" fragments in upper part	18.5	83
Sand, fine to gravel, fine; containing some yellow-tan silty and sandy clay	27	110
Silt, fine sandy, yellow-tan; and clay, blocky, silty; containing scattered sand and gravel	20	130
Sand, fine to gravel, coarse; containing thin lenses of sandy silt	30	160
Sand, fine, silty, tan and gray, and sand and gravel containing limestone and yellow shale pebbles	9	169
Carlile shale		
Fairport chalky shale member		
Shale, silty and fine sandy, calcareous, dark gray	26	195

	Thickness, feet	Depth, feet
Shale, silty and fine sandy, light gray and medium gray; and shale, sandy, hard, dark gray	1.5	196.5
Shale, silty and fine sandy, calcareous, dark gray	3.5	200
Shale, silty and sandy, calcareous, light to dark gray; contains thin bed of blue-gray bentonite and calcite	10	210
Shale, sandy, hard, calcareous, dark gray	10	220

22. Log of test hole 22 at the SW corner sec. 10, T. 26 S., R. 28 W., Gray county, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,621.8 feet. (Authority, samples studied by Perry M. McNally and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Soil, sandy, dark	0.5	0.5
Alluvium		
Sand, fine to medium, limy, gray	4.5	5
Gravel, medium to very coarse; contains pebbles up to an inch in diameter	35	40
Sand, fine, to gravel, coarse; brown	19.5	59.5
Ogallala formation		
Silt and sand, fine; lime-cemented; gray	3.5	63
Sand and gravel; limy; gray	4	67
Sand, fine to coarse, silty, tan and light gray	33	100
Silt and sand, fine; limy; tan	10	110
Sand, fine, to gravel, fine; silty	20	130
Sand, coarse, to gravel, coarse; containing limestone and sandstone granules and pebbles	26	156
Greenhorn limestone		
Clay, silty, calcareous, yellow-tan	7.5	163.5
Shale, dark gray to black; containing few hard calcite veins	4.5	168
Shale, hard, light gray to white; and shale, calcareous, black	32	200
Shale, calcareous, light to dark gray and black; containing thin bed of light-blue bentonite	10	210

23. Log of test hole 23 at the NW corner sec. 34, T. 26 S., R. 28 W., Gray county, drilled by the State and Federal Geological Surveys, 1941. Surface altitude, 2,671.5 feet. (Authority, samples studied by Perry M. McNally and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Dune sand		
Soil, sandy, dark	3	3
Sand, fine, silty, brown	7	10
Terrace gravels		
Sand, medium to gravel, fine; brown; containing snails and shell fragments	10	20
Silt to sand, coarse; tan	4	24

	Thickness, feet	Depth, feet
Sand, medium, to gravel, medium; brown	6	30
Sand, coarse, to gravel, very coarse; poorly sorted	48	78
Ogallala formation		
Silt and sand, fine; limy; light gray	3	81
Sand, coarse, to gravel, very coarse	22	103
Gravel, fine to very coarse, brown	37	140
Silt and sand, fine; tan to buff; contains a little sand and gravel	43	183
Gravel, fine to coarse, brown	17	200
Silt and sand, fine to coarse; tan	10	210
Silt and sand; limy; light gray	5	215
Greenhorn limestone		
Shale, calcareous, black	5	220

24. Log of test hole 24 at the NE corner sec. 31, T. 27 S., R. 30 W., Gray county, drilled by the State and Federal Geological Surveys, 1941. Surface altitude, 2,837.4 feet. (Authority, samples studied by Perry M. McNally and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Soil, sandy, dark	2	2
Undifferentiated Pleistocene deposits and Ogallala formation		
Silt and sand, fine; tan	5	7
Sand, fine, to gravel, medium; brown	5	12
Silt and sand; tan; containing caliche pebbles and nodules and some gravel in lower part	48	60
Sand, fine, to gravel, medium; silty, brown	18	78
Silt to sand, medium; limy; light gray and light tan	32	110
Sand, coarse, to gravel, coarse; brown	49	159
Silt and sand, fine; tan	1	160
Sand, coarse, to gravel, coarse; brown; lower 10 feet is partly cemented	66	226
Silt, sand, gravel, and caliche; poorly sorted; containing "mortar bed" pebbles	14	240
Silt to sand, coarse; limy; tan and gray	3.5	243.5
Sand, coarse, to gravel, medium; brown	16.5	260
Silt, tan; containing scattered sand and gravel	11	271
Sand, medium, to gravel, coarse; brown	26	297
Silt and sand, fine to coarse; gray and tan; containing some gravel	53	350
Sand, fine to coarse, tan	19	369
Silt and sand, fine; tan	8	377
Sand and gravel, fine to medium; containing an abundance of brown sandstone pebbles	27	404
Dakota formation		
Sandstone, concretionary, brown	3	407
Clay, gritty, yellow, light gray, and brown	3	410

25. Log of test hole 25 at the NE corner sec. 4, T. 28 S., R. 28 W., Gray county, drilled by the State and Federal Geological Surveys, 1941. Surface altitude, 2,800.0 feet. (Authority, samples studied by Perry M. McNally and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Soil, sandy, dark	2	2
Undifferentiated Pleistocene deposits and Ogallala formation		
Silt and sand, fine to medium; tan	10	12
Silt and sand, fine; tan; containing white caliche fragments and pebbles	19	31
Sand, medium, to gravel, fine; brown	37	68
Silt to sand, coarse; limy; light tan; contains caliche nodules	4	72
Sand, medium, to gravel, fine; brown	28	100
Sand, fine to coarse, brown	13	113
Silt to sand, coarse; limy; tan; containing few thin gravel lenses	51.5	164.5
Silt and sand, fine to medium; tan; containing lime nodules	10.5	175
Silt to sand, coarse; limy; tan and light gray	5	180
Sand, medium, to gravel, medium; brown	7	187
Silt to sand, coarse; tan; containing thin lenses of light gray limy silt	15.5	202.5
Sand, coarse, to gravel, coarse; brown	33.5	236
Silt and sand, fine; tan	8	244
Gravel, cemented, hard	4.5	248.5
Silt, sandy, tan; containing lime nodules	6.5	255
Silt and sand, fine to medium; limy; light tan and light gray	13	268
Silt, fine sandy, tan	20	288
Sand, fine to medium; lime-cemented, white to light gray,	14	302
Silt and sand, fine; light gray	12	314
Greenhorn limestone		
Shale, calcareous, white, yellow, and orange-tan; containing thin beds of chalky limestone and bentonite	12.5	326.5
Shale, calcareous, dark gray	6.5	333

26. Log of test hole 26 in the NE corner sec. 20, T. 28 S., R. 29 W., Gray county, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,779.6 feet. (Authority, samples studied by Perry M. McNally and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Soil, sandy, dark	2	2
Undifferentiated Pleistocene deposits and Ogallala formation		
Silt and sand, fine to medium; tan	9	11
Silt and sand, fine; limy; gray and tan; containing soft caliche nodules	49	60
Silt and sand, fine to coarse; tan; containing caliche nodules	30	90

	Thickness, feet	Depth, feet
Sand, medium, to gravel, coarse; brown	13	103
Silt and sand, fine to coarse; limy; light tan and light gray; containing caliche fragments	20	123
Sand, medium, to gravel, coarse	7	130
Silt and sand, fine to coarse; brown	21.5	151.5
Sand, medium, to gravel, coarse; brown	8	159.5
Silt and sand, fine; tan; containing few limy lenses	18.5	178
Clay, silty and sandy, yellow-tan	4	182
Caliche, soft, tan and light gray; and sand, fine lime-cemented	16	198
Silt, sand, and gravel; poorly sorted	14	212
Sand, fine, to gravel, fine; brown	28	240
Silt and sand, fine; tan	22	262
Caliche gravel, gray and yellow-tan; containing some light gray silty clay	6.5	268.5
Dakota formation		
Clay, silty, blocky, tan	3.5	272
Sandstone, tan, yellow-brown, and light gray; and clay, blocky, silty	9	281
Shale, dark gray to black; containing sandstone concretion at top	1	282
Shale, silty and sandy, light to dark gray; containing few fragments of black fossil charcoal	38	320

26a. Log of test hole 26a in the SW¼ NW¼ SE¼ sec. 24, T. 28 S., R. 29 W., Montezuma, Kansas, drilled by State and Federal Geological Surveys, 1943. (Authority, samples studied by Oscar S. Fent and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Top soil, silty, black	4	4
Undifferentiated Pleistocene deposits and Ogallala(?) formation		
Silt, soft, tan, brown, buff, and white; containing some fine to coarse sand and caliche	31	35
Silt, soft, yellow-brown	2	37
Silt, tan; containing some fine to coarse sand, fine gravel, and caliche	28	65
Silt, soft, red; containing medium sand and caliche	5	70
Silt, white to gray and brown; containing some sand and gravel, and caliche	16	86
Gravel, fine to medium; containing a little coarse gravel and pebbles	2	88
Silt, compact, white to gray and brown; containing fine sand to medium gravel, and caliche	10	98
Silt, tan and greenish tan; containing medium sand to coarse gravel	35	133
Silt, soft, red-tan; containing some sand and gravel	3	136
Gravel, fine to medium, and sand, medium to coarse; containing a little coarse gravel and gray silt	14	150

	Thickness, feet	Depth, feet
Silt, soft, white to gray; containing sand and gravel, caliche, and a few pebbles	30	180
Greenhorn limestone		
Limestone, hard, gray; interbedded with yellow and gray clay-shale	15	195

26b. Log of test hole 26b, in the NE¼ SE¼ SW¼ sec. 24, T. 28 S., R. 29 W., Montezuma, Kansas, drilled by State and Federal Geological Surveys, 1943. (Authority, samples studied by Oscar S. Fent and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Top soil, silty, gray-black	1	1
Undifferentiated Pleistocene deposits and Ogallala (?) formation		
Silt, blocky, gray to tan	19	20
Silt, tan; containing fine to coarse sand and caliche	30	50
Sand, fine to coarse; silt; and caliche	6.5	56.5
Silt, clayey, buff	6.5	63
Sand, fine to coarse; silt; and caliche	3	66
Silt, soft, red-tan and buff; and caliche	4	70
Silt; containing some sand and a little gravel	20	90
Gravel, fine to coarse; and sand, coarse	4	94
Silt, soft, gray to white	6	100
Gravel, fine to coarse; containing much fine to coarse sand and thin layers of silt	60	160
Silt, soft, white to buff; containing some sand, gravel, and caliche	33	193
Greenhorn limestone		
Limestone, hard, white to gray; and clay-shale, gray	7	200

26c. Log of test hole 26c in the SE¼ NE¼ SW¼ sec. 24, T. 28 S., R. 29 W., Montezuma, Kansas, drilled by State and Federal Geological Surveys, 1943. (Authority, samples studied by Oscar S. Fent and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Topsoil, gray-black	1.5	1.5
Undifferentiated Pleistocene deposits and Ogallala (?) formation		
Silt; containing some sand and caliche nodules	10.5	12
Sand, silt, and caliche	8	20
Silt; containing some sand and caliche	23	43
Sand, fine to coarse; and silt	5	48
Silt; containing sand, gravel, and caliche	57	105
Gravel, fine to medium; containing fine to coarse sand and some coarse gravel	11	116
Silt; containing some fine to coarse sand	15	131
Gravel, fine to medium; containing fine to coarse sand	29	160
Silt; containing some sand and hard "mortar beds"	10	170
Silt; containing some medium to coarse sand and caliche	10	180
Silt, compact; containing fine sand to fine gravel	18.5	198.5
Greenhorn limestone		
Limestone, hard, gray	1.5	200

27. Log of test hole 27 at the NW corner sec. 34, T. 29 S., R. 28 W., Gray county, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,680.7 feet. (Authority, samples studied by Perry M. McNally and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Soil, sandy, dark	4	4
Undifferentiated Pleistocene deposits		
Silt, fine sandy, tan-brown; containing soft caliche nodules	28	32
Caliche, silt, and sand, fine; tan	5.5	37.5
Sand, fine to medium; silty; containing scattered gravel and caliche pebbles	23.5	61
Gravel, very coarse, brown; containing some sand	19	80
Silt and sand, fine; light tan	10	90
Sand, fine, to gravel, medium; tan	20	110
Sand, coarse, to gravel, very coarse	39.5	149.5
Silt and sand, fine limy; light gray	1.5	151
Silt and sand, fine to medium; tan	11	162
Gravel, fine; contains caliche pebbles	2.5	164.5
Dakota formation		
Shale, noncalcareous, gray; and sandstone, fine-grained, gray and yellow	10.5	175
Sandstone, light gray, yellow, and tan; and shale, light gray	4	179
Sandstone, yellow-tan and brown; and some shale, light gray	9.5	188.5
Clay, silty, light gray	1.5	190

28. Log of test hole 28 in the NW corner sec. 6, T. 28 S., R. 26 W., Ford county, drilled by State and Federal Geological Surveys, 1939. Surface altitude, 2,710.7 feet. (Authority, samples studied by Perry M. McNally and H. A. Waite.)

	Thickness, feet	Depth, feet
Kingsdown silt (Pleistocene and Recent)		
Top soil, silty, loam, brown	7	7
Soil, silty, clayey, brown to light brown	4	11
Silt, limy, brown; contains nodules of lime	6	17
Silt, brown; contains little or no lime	3	20
Silt, light brown; contains small amount of lime from 29 to 40 feet	27	47
Silt, hard, brown; contains pebbles of quartz and some fine sand from 60 to 69 feet	22	69
Silt, sandy, limy, soft, brown; contains some pebbles	21	90
Ogallala formation		
Sand, fine, brown; and silt, limy; contains fragments of lime	20	110
Sand, fine, soft, brown; less limy silt	20	130
Sand, fine, brown; increase in limy silt	9	139
Silt, sandy, soft, limy, gray and brown	8	147
Sand, fine, brown, intermixed with silt; contains some fine gravel; drilled alternately hard and soft	6	153

	Thickness, feet	Depth, feet
Sand, coarse, to gravel, coarse; contains well-rounded pebbles of quartz and granites; poorly sorted; drilled hard,	7	160
Silt, sandy, brown	1	161
Sand, coarse, to coarse gravel; contains pebbles of quartz, granite, and feldspar	9	170
Silt, sandy, brown	3	173
Sand, medium, to coarse gravel; poorly sorted	17	190
Sand, medium, to coarse gravel; predominately medium gravel	17	207
Greenhorn limestone		
Shale, clayey, light gray to cream-colored, calcareous; upper part drilled hard	2	209
Shale, clayey, soft, calcareous, black	3	212
Shale, sandy, hard, gray	0.5	212.5

29. Log of test hole 29 in the NW corner sec. 32, T. 29 S., R. 26 W., Ford county, drilled by State and Federal Geological Surveys, 1939. Surface altitude, 2,545.5 feet. (Authority, samples studied by Perry M. McNally and H. A. Waite.)

	Thickness, feet	Depth, feet
Kingsdown silt (Pleistocene and Recent)		
Top soil, sandy, clayey, brown	4	4
Silt, limy, light brown	17	21
Silt, limy, gray; contains nodules of lime	10	31
Silt, sandy, brown to olive-green	15	46
Sand, fine to medium brown; interbedded with olive-green limy silt and small fragments of lime	4	50
Silt, fine, sandy, brown to gray	15	65
Silt, limy, light gray to brown	11	76
Silt, limy, brown and gray; contains some coarser sand	8	84
Silt, sandy, brown; contains some fine to coarse gravel	6	90
Ogallala formation		
Gravel, medium to coarse; very poorly sorted; contains some water-worn fragments of limestone; gravel contains pebbles of quartz and granite	18	108
Sand, medium, brown, to fine gravel, and sandy silt; contains much lime throughout; drilled alternately hard and soft	12	120
Sand, fine, uniform, brown	10	130
Gravel, medium to coarse; contains some sand	30	160
Sand, medium, brown, to coarse gravel	13	173
Silt, limy, brown; contains some medium sand and a few pebbles	3	176
Sand, medium, brown, to coarse gravel	6	182
Silt, sandy, limy, brown; contains some medium to coarse sand	8	190
Silt, fine, sandy, brown; contains some pebbles	15	205
Dakota formation		
Shale, silty, clayey, soft, bluish-gray, contains a few yellow streaks; somewhat harder drilling from 220 to 260 feet	55	260

30. Log of irrigation well (24) of W. R. E. Hall in the NW¼ NE¼ sec. 8, T. 21 S., R. 32 W. (Authority, Ray Stevenson, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pleistocene deposits and Ogallala formation		
Soil and clay	29	29
Rock	1	30
Sand	13	43
Clay	27	70
Gravel, coarse, and rock	15	85
Boulder, white	7	92
Gravel, coarse	56	148
Niobrara formation		
Clay, blue	7	155
Shale, blue-gray	(?)	

31. Log of irrigation well (115) of C. E. Boyd in the SW¼ SW¼ sec. 23, T. 23 S., R. 32 W., Finney county. (Authority, Leslie Pelner, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pleistocene deposits and Ogallala formation		
Soil and clay	71	71
Sand, fine, dry	21	92
Sand and rock	6	98
Sand, coarse, water bearing	9	107
Clay, blue	5	112
Sand, fine	15	127
Clay, sandy	5	132
Sand and rock, soft	9	141
Sand and coarse	16	157
Clay, sandy	18	175
Sand, fine	32	207
Clay and rock	2	209
Sand, coarse	10	219
Carlile shale		
Mud, blue	16	235
Shale	63	298

32. Log of test hole of E. Caldwell in the NW¼ SW¼ sec. 24, T. 23 S., R. 33 W. Well (127) finished at 340 feet. (Authority, L. M. Waddell, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pleistocene deposits and Ogallala formation		
Clay and rock	26	26
Gravel	8	34
Sand	16	50
Clay and rock	10	60
Clay	11	71
Sand	2	73
Clay	3	76
Sand	9	85

	Thickness, feet	Depth, feet
Clay	49	134
Rock	16	150
Sand rock	10	160
Gravel	28	188
Sand, coarse	16	204
Sand and clay	6	210
Clay	25	235
Sand, coarse, and gravel	20	255
Clay	3	258
Sand, coarse, and gravel	17	275
Rock	2	277
Rock and clay	13	290

33. Log of abandoned irrigation well of the Garden City Company in the NW¼ NW¼ sec. 30, T. 23 S., R. 33 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pleistocene deposits and Ogallala formation		
Soil and clay	5	5
Clay, sandy	20	25
Sand, dry	19	44
Sand, hard	21	65
Sand, very fine	20	85
Sand, water bearing	20	105
Clay, yellow	8	113
Sand and gyp	14	127
Sand, very fine	22	149
Clay and gyp, hard	22	171
Clay, soft	12	183
Sand, water bearing	57	240
Clay	5	245
Sand, water bearing	32	277
Clay	3	280

34. Log of abandoned irrigation well (147) of the Garden City Company in the NW¼ NW¼ sec. 22, T. 23 S., R. 34 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pleistocene deposits and Ogallala formation		
Soil and clay	58	58
Sand, coarse	5	63
Clay	20	83
Sand and clay	76	159
Sand	21	180
Sand and clay	19	199
Sand	10	209
Sand, tight	73	282
Clay	4	286
Sand, coarse	11	297
Sand	20	317
Clay	2	319

35. Log of abandoned irrigation well of the Garden City Company in the NE¼ sec. 27, T. 23 S., R. 34 W. (Authority, United Well Works, Stuttgart, Arkansas.)

	Thickness, feet	Depth, feet
Undifferentiated Pleistocene deposits and Ogallala formation		
Soil and clay	45	45
Sand, very fine	33	78
Clay and sand	5	83
Clay	19	102
Rock	5	107
Clay	18	125
Sand, clay, and rock	30	155
Clay, red	28	183
Clay	15	198
Rock	4	202
Sand	22	224
Sand and rock	3	227
Sand, fine	21	248
Sand, coarse	13	261
Clay	3	264
Sand	11	275
Rock	1	276
Sand	24	300
Clay	4	304
Sand	61	365
Clay	5	370

36. Log of abandoned irrigation well of the Garden City Company in the NW¼ SW¼ sec. 33, T. 23 S., R. 34 W. (Authority, United Well Works, Stuttgart, Arkansas.)

	Thickness, feet	Depth, feet
Undifferentiated Pleistocene deposits and Ogallala formation		
Soil and clay	40	40
Sand, white	3	43
Clay	5	48
Sand, fine	10	58
Sand and "shale"	22	80
Sand	5	85
Sand, fine	8	93
Clay	5	98
Sand, fine, water bearing	120	218
Sand	43	261
Clay	3	264
Sand	7	271
Sand and gravel	12	283
Clay	6	289
Sand and "shale"	2	291
"Shale"	5	296
Sand and gravel, hard, mixed	3	299

	Thickness, feet	Depth, feet
Clay	4	303
Gravel	2	305
Sand	11	316
Clay	7	323
Sand	7	330
Clay	2	332
Sand	39	371
Clay	2	373

37. Log of abandoned irrigation well of the Garden City Company in sec. 34, T. 23 S., R. 34 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pleistocene deposits and Ogallala formation		
Soil and clay	15	15
Sand, fine	7	22
Clay, yellow	3	25
Sand, fine	7	32
Clay, sandy	13	45
Sand, red	15	60
Clay, sandy	5	65
Sand, red, fine	60	125
Clay, sandy	10	135
Sand, fine	14	149
Gravel and clay	19	168
Sand, fine	12	180
Sand	52	232
Clay, tough	3	235
Sand, fine	8	243
Sand, very good	55	298
Clay, tough	1	299
Sand	5	304
Pre-Tertiary beds		
Clay, black	2	306

38. Log of test hole of L. E. Joss in the SW¼ SE¼ sec. 36, T. 23 S., R. 34 W. Well (160) finished at 274 feet. (Authority, L. M. Waddell, driller.)

	Thickness, feet	Depth, feet
Alluvium		
Soil	19	19
Gravel	10	29
Undifferentiated Pleistocene deposits and Ogallala formation		
Clay	26	55
Sand and clay	36	91
Sand, fine	3	94
Sand and clay	51	145
Sand, fine	34	179
Sand and clay	12	191
Sand, fine	10	201
Sand, coarse	20	221

39. Log of irrigation well (162) of H. Harms in SE¼ sec. 14, T. 24 S., R. 31 W. Surface altitude, 2,881.9 feet. (Authority, Ray Stevenson, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pleistocene deposits and Ogallala formation		
Soil and gyp	50	50
Sand and rock	30	80
Clay, sandy	15	95
Clay, tough	5	100
Sand, fine	5	105
Clay, sandy	25	130
Sand	13	143
Rock	2	145
Gyp, sandy	25	170
Clay, tough	15	185
Gravel, water bearing	20	205
Clay	2	207
Gravel	58	265
Carlile shale		
Fairport chalky shale member		
Clay, yellow, sticky	15	280
Shale, blue-black	(?)	

40. Log of test hole of S. W. Neeley in the SW¼ SE¼ sec. 4, T. 24 S., R. 32 W. Well (171) finished at 120 feet. (Authority, L. M. Waddell, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pleistocene deposits		
Clay and fine sand	37	37
Sand and gravel	3	40
Sand rock and gyp	8	48
Gravel and gyp	7	55
Gyp	10	65
Sand rock and layers of clay	15	80
Gravel	15	95
Rock	2	97
Clay	3	100

41. Log of city well (208) at Garden City, Kansas, SW¼ NW¼ sec. 17, T. 24 S., R. 32 W. (Log furnished by J. A. Roby, city engineer.)

	Thickness, feet	Depth, feet
Alluvium		
Soil, black	7	7
Sand	30	37
Undifferentiated Pleistocene deposits and Ogallala formation		
Clay	14	51
Sand	25	76
Clay	4	80
Gyp rock, soft	2	82
Clay	12	94
Sand rock, hard	4	98
Sand, coarse	2	100

	Thickness, feet	Depth, feet
Sand rock, hard	4	104
Clay	6	110
Sand rock, hard	3	113
Sand and gravel	6	119
Sand, fine	2	121
Sand rock	2	123
Sand	18	141
Clay, tough	9	150
Sand	12	162
Clay	1	163
Sand	55	218
Clay	2	220
Sand	38	258
Sand rock	4	262
Sand	2	264
Rock, gravel, and clay	35	299

42. Log of well (222) of the Atchison, Topeka and Santa Fe Railway at Garden City, Kansas, SW¼ NE¼ SW¼ sec. 18, T. 24 S., R. 32 W. (Authority, L. D. Courtney, driller.)

	Thickness, feet	Depth, feet
Alluvium		
Loam	8	8
Sand and gravel	44	52
Undifferentiated Pleistocene deposits and Ogallala formation		
Clay, yellow	7	59
Sand and gravel	29	88
Clay, yellow	9	97
Sand and gravel, red	25	122
Clay	1	123
Sand, fine	8	131
Clay, yellow	7	138
Sand, black	7	145
Sand, water bearing	10	155
Clay	1	156
Quicksand, water bearing	29	185
Sand, coarse, and gravel	17	202

43. Log of test hole of E. F. Renick, 100 feet north of pumphouse in the SE¼ NW¼ sec. 22, T. 24 S., R. 32 W. Battery of five wells (237) finished at from 40 to 50 feet. (Authority, Ray Stevenson, driller.)

	Thickness, feet	Depth, feet
Alluvium		
Loam, sandy, silty	4	4
Sand, fine	4	8
Sand, coarse	10	18
Gravel	6	24
Sand and a little clay	12	36

Undifferentiated Pleistocene deposits and Ogallala (?) formation	Thickness, feet	Depth, feet
Rock (cemented sand)	4	40
Gravel	7.5	47.5
Rock, soft and hard	7.5	55
Sand rock, fine, soft, cemented	11	66
Clay, yellow	19	85
Clay, fine sandy	12	97
Sand, gravel, and cemented sand, interbedded	8	105

44. Log of test hole of H. L. Frye at the NW corner SE¼ sec. 4, T. 24 S., R. 33 W. Battery of three wells (249) finished at 90 feet. (Authority, L. M. Waddell, driller.)

	Thickness, feet	Depth, feet
Alluvium		
Soil	10	10
Sand, fine	4	14
Gravel	19	33
Rock	1	34
Gravel	1	35
Clay and gravel	2	37
Undifferentiated Pleistocene deposits and Ogallala formation		
Clay with little sand	13	50
Quicksand	11	61
Sand, medium	34	95
Clay	1	96
Gravel	6	102
Clay	9	111

45. Log of test hole of D. E. Hate at the SW corner NW¼ sec. 4, T. 24 S., R. 33 W. (Authority, L. M. Waddell, driller.)

	Thickness, feet	Depth, feet
Alluvium		
Soil	10	10
Sand, fine	2	12
Gravel	20	32
Rock, loose	1	33
Gravel	2	35
Undifferentiated Pleistocene deposits and Ogallala formation		
Clay, sandy	12	47
Sand, fine	3	50
Sand and clay	36	86
Clay	9	95
Clay, sandy	56	151

46. Log of test hole of E. L. McCoy in the NE¼ sec. 6, T. 24 S., R. 33 W. Well (254) finished at 285 feet. (Authority, C. Rogers, driller.)

	Thickness, feet	Depth, feet
Alluvium		
Soil and clay	11	11
Sand and gravel	24	35
Undifferentiated Pleistocene deposits and Ogallala formation		
Clay	2	37
Sand	21	58

	Thickness, feet	Depth, feet
Clay	17	75
Gyp rock	4	79
Clay	29	108
Sand	2	110
Clay, sandy	18	128
Sand, good	10	138
Clay, sandy	23	161
Sand, coarse	7	168
Clay, joint	4	172
Sand	2	174
Rock	1	175
Sand	3	178
Clay	4	182
Sand, coarse	17	199
Pack sand	12	211
Sand, coarse	4	215

47. Log of well of E. Gardner in the SE¼ sec. 10, T. 24 S., R. 33 W. (Authority, L. M. Waddell, driller.)

	Thickness, feet	Depth, feet
Alluvium		
Loam, sandy, silty	5	5
Sand, fine	5	10
Gravel, coarse, and sand	35	45
Undifferentiated Pleistocene deposits and Ogallala formation		
Clay, sandy	25	70
Sand, coarse, and a little clay	10	80
Sand, coarse	17	97
Clay	13	110

48. Log of test hole of George Potter in the SW¼ NW¼ sec. 3, T. 24 S., R. 34 W. Battery of six wells (338) finished at from 37 to 50 feet. Surface altitude, 2,911 feet. (Authority, L. M. Waddell, driller.)

	Thickness, feet	Depth, feet
Alluvium		
Soil	10	10
Sand, fine	1	11
Gravel	16	27
Undifferentiated Pleistocene deposits and Ogallala formation		
Clay	11	38
Sand and gravel	10	48
Sand and clay, interbedded	28	76
Sand, fine to coarse	21	97
Clay	6	103
Gravel with clay balls	6	109
Clay	3	112
Gravel with clay balls	12	124
Clay	7	131
Clay and gravel	6	137
Gravel	1	138
Clay	3	141

49. Log of well of L. L. Jones in the NE¼ sec. 11, T. 24 S., R. 34 W. (Authority, L. M. Waddell, driller.)

	Thickness, feet	Depth, feet
Alluvium		
Soil	10	10
Sand and gravel	35	45
Undifferentiated Pleistocene deposits and Ogallala formation		
Clay	8	53
Sand, medium	29	82
Clay	11	93
Gravel	2	95
Clay	8	103
Gravel	2	105
Clay	2	107
Gravel	1	108
Clay	2	110
Gravel	9	119
Clay	6	125
Gravel	23	148
Clay	19	167
Gravel	13	180
Clay	5	185
Gravel	25	210
Rock and gravel	11	221

50. Log of water well at the SE corner sec. 1, T. 26 S., R. 33 W. (Authority, R. McGraw, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pleistocene deposits		
Clay, sandy	30	30
Gravel, coarse	9	39
"Gyp" and sand	22	61
Sand, fine to medium, and silt	14	75

51. Log of test hole of M. L. McGehee in the SW¼ NW¼ NW¼ sec. 21, T. 25 S., R. 30 W. Battery of four wells (439) finished at 34 feet. (Authority, Ray Stevenson, driller.)

	Thickness, feet	Depth, feet
Alluvium		
Loam, silty; and clay, sandy	10	10
Sand	2	12
Gravel	11	23
Sand and gravel	5	28
Undifferentiated Pleistocene deposits and Ogallala formation		
Clay, lime, and some sand	5	33
Clay, reddish-yellow	3	36
Sand, fine, and clay	5	41
Sand, fine; cemented with lime	3	44
Lime, clay, and gravel	3	47
Sand and lime, interbedded	3	50
Sand, fine	10	60

	Thickness, feet	Depth, feet
Clay, yellow	7	67
Gravel	5.5	72.5
Clay	15	87.5
Sand and gravel	14.5	102
Lime and gravel	2	104
Clay, yellow	53	157

52. Log of well (500) of R. C. Houser in the NE¼ NW¼ sec. 24, T. 28 S., R. 27 W. Surface altitude, 2,755.4 feet. (Authority, G. Slocum, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pleistocene deposits and Ogallala formation		
Sand and clay	225	225
Dakota formation		
Shale, blue-black or gray; contains pyrite	165	390
Shale, blue-black, sticky, waxy	18	408
Sandstone, water-bearing; water rose 200 feet	13	421

53. Log of test hole of Frank Patterson in the NW¼ SW¼ SW¼ sec. 35, T. 28 S., R. 30 W. (Authority, Soil Conservation Service.)

	Thickness, feet	Depth, feet
Undifferentiated Pleistocene deposits and Ogallala formation		
Loam, sandy, clayey	12	12
Clay, sandy, red	13	25
Clay, yellowish	34	59
Clay, blue; contains some shell fragments	10	69
Clay, blue; contains streaks of black humus	11	80
Clay, sandy, red	17	97
Gravel, coarse	6	103
Clay, sandy, red	3	106
Rock, shaly	.5	106.5
Clay, sandy, red	7	113.5
Sand, calcareous, cemented	1.5	115
Clay, sandy	25	140
Sand and gravel	4	144
Clay, sandy	2	146
Clay and gravel, alternating	7	153
Gravel, contains streaks of clay	13	166
Clay, sandy	3	169
Clay; encountered thin hard rock at 170 feet	4	173
Gravel and sand, clean	10	183
Clay	1	184
Gravel; contains sandy clay streaks	6	190
Clay, sandy	5	195
Gravel	16	211
Clay and gravel; sandy	4	215
Sand and gravel; contains thin rock layers	8	223
Clay	3	226
Gravel; contains some clay	29	255

54. Log of unused well in the SW¼ SW¼ sec. 8, T. 29 S., R. 27 W. (Authority, G. Slocum, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pleistocene deposits		
Soil, clay, and sand	50	50
Cretaceous		
Shale, blue-black, containing pyrite crystals	225	275
Sandstone, loose, water bearing	16	291

55. Log of well (526) of H. Flair in the NE¼ NE¼ sec. 4, T. 29 S., R. 28 W Surface altitude, 2,773.8 feet. (Authority, G. Slocum, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pleistocene deposits		
Clay with little sand	140	140
Cretaceous		
Shale, blue-black	140	280
Sandstone, hard; contains very little water	12	292
Shale, blue-black	59	351
Sandstone, water bearing; water rose more than 200 feet in well	14	365

56. Log of test hole of E. Lupton in the NW¼ NE¼ sec. 12, T. 29 S., R. 29 W. Well (534) finished at 138 feet. (Authority, Soil Conservation Service.)

	Thickness, feet	Depth, feet
Undifferentiated Pleistocene deposits and Ogallala formation		
Soil	7	7
Clay, red	5.5	12.5
Clay, limy, yellow-red	11.5	24
Clay, yellow and red	23	47
Clay, sandy	9	56
Sand, lime-cemented	2	58
Clay	19	77
Clay, sandy	2	79
Clay and gravel; mixed	10.5	89.5
Gravel	10.5	100
Lime, soft	1	101
Clay, sandy, white	9	110
Lime	1	111
Sand and gravel	7	118
Lime	.5	118.5
Gravel	4.5	123
Lime and clay	1	124
Gravel	4	128
Gravel and clay	3	131
Clay, light-colored	10	141
Clay, yellow	20	161
Clay and "shale"	11	172
Clay, yellow	13	185

57. Partial log of oil test of the Garden City Oil and Gas Company in the SE¼ SE¼ sec. 35, T. 21 S., R. 30 W. Surface altitude, 2,873 (?) feet. (Authority, driller.)

	Thickness, feet	Depth, feet
Soil	12	12
Lime, hard	4	16
Lime, white, soft	54	70
Lime, soft	26	96
Shale	199	295
Lime	23	318
Shale	22	340
Lime	56	396
Shale	58	454
Lime	6	460
Shale	55	515
Sand, water	12	527
Shale	23	550
Sand	15	565
Shale	19	584
Sand	14	598
Shale, white	20	618
Sand, white	26	644
Shale, black	10	654
Sand	13	667

58. Log of oil test well of the National Refining Company in the SW¼ sec. 13, T. 23 S., R. 30 W., Finney county. (Authority, driller.)

	Thickness, feet	Depth, feet
Limestone	90	90
Shale	115	205
Shale, brown	195	400
Limestone	50	450
Shale, brown	50	400
Shale	80	580
Sandstone, water-bearing	100	680
Shale	90	770
Shale, sandy	15	785
Shale	20	805
Sandstone	5	810
Shale	10	820
Redbeds	5	825
Sandstone and sandy shale	135	960
Shale	25	985
Limestone	10	995
Shale	115	1,110
Limestone	2	1,112
Shale, variegated	15	1,127
Redbeds (top of Permian)	28	1,155

	Thickness, feet	Depth, feet
Sandstone, red	30	1,185
Shale and sandstone, red	195	1,380
Gypsum and redbeds	20	1,400
Limestone	15	1,415
Redbeds	55	1,470
Sandstone	215	1,685
Shale, red	15	1,700
Sandstone, red	20	1,720
Shale, red	160	1,880
Anhydrite	3	1,883
Shale, red	82	1,965
Sandstone	45	2,010
Anhydrite	25	2,035
Sandstone, red	5	2,040
Anhydrite	10	2,050
Shale	350	2,400
Anhydrite	55	2,455
Salt	20	2,475
Shale	10	2,485
Salt	10	2,495
Anhydrite	10	2,505
Salt	35	2,540
Shale, sandy	40	2,580
Gypsum	40	2,620
Shale	20	2,640
Anhydrite	20	2,660
Shale, sandy	15	2,675
Limestone	100	2,775
Shale, red	20	2,795
Limestone	170	2,965
Shale, red	10	2,975
Limestone	75	3,050
Shale, red	5	3,055
Limestone	160	3,215
Shale, red	5	3,220
Limestone	230	3,450
Shale, red	5	3,455
Shale and limestone	50	3,505
Limestone, shale, and shells	55	3,560
Limestone	100	3,660
Shale	5	3,665
Limestone	90	3,755
Sandy limestone	30	3,785
Limestone	10	3,795
Shale	10	3,805
Limestone	75	3,880
Shale	10	3,890
Limestone	55	3,945

	Thickness, feet	Depth, feet
Shale	30	3,975
Shale, red	5	3,980
Sand and limestone	10	3,990
Shale	10	4,000
Limestone and shale	235	4,235
Shells	45	4,280
Shale	20	4,300
Limestone	5	4,305
Sandstone	30	4,335
Shale	15	4,350
Limestone	10	4,360
Shale	5	4,365
Limestone	25	4,390
Shale, red and brown	10	4,400
Limestone and shale	80	4,480
Shale, black and red	70	4,550
Limestone and shale	130	4,680
Limestone	45	4,725
Sandy limestone	20	4,745
Limestone	220	4,965
Shale	5	4,970
Limestone	70	5,040
Shale	5	5,045
Limestone	20	5,065
Sandy limestone	10	5,075
Shale	15	5,090
Limestone; contains thin shale beds	670	5,760
Shale	30	5,790
Limestone	82	5,872

59. Partial log of gas test well of the L. F. Meyers Company at the center of the SW¼ sec. 16, T. 25 S., R. 34 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pleistocene deposits and Ogallala formation		
Sand and gravel	150	150
Clay, yellow	10	160
Gravel	20	180
Sand and gravel	305	485
Lime	3	488
Cretaceous (?) beds		
Shale, blue	66	554
Lime, hard	46	600
Sand, hard	80	680
Shale, sand, and gyp shells	78	758
Shale, blue, and gyp	42	800
Permian(?) beds		
Shale, red	50	850
Shale, red, sandy	135	985

60. Log of oil test well of Champlin Refining Company in the NE¼ SW¼ sec. 34, T. 28 S., R. 29 W., Gray county. (Authority, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pleistocene deposits and Ogallala formation		
Surface sand	50	50
Clay, sandy	100	150
Pre-Tertiary beds		
Limestone	15	165
Shale, calcareous	150	315
Sand and shale	410	725
Redbeds	318	1,043
Gypsum	10	1,053
Redbeds	20	1,073
Gypsum	67	1,140
Shale	15	1,155
Redbeds and shale	300	1,455
Red shale and sand	220	1,675
Redbeds and lime shells	45	1,720
Anhydrite	15	1,735
Limy shale	45	1,780
Anhydrite	60	1,840
Anhydrite and shale	165	2,005
Shale and gypsum	70	2,075
Shale	20	2,095
Anhydrite	30	2,125
Shale and anhydrite	65	2,190
Shale and gypsum	30	2,220
Shale and limestone	280	2,500
Shale and gypsum	75	2,575
Shale and anhydrite	65	2,640
Limestone and dolomite	45	2,685
Anhydrite	10	2,695
Dolomite	45	2,740
Shale	135	2,875
Shale and sandy limestone	75	2,950
Brown limestone	55	3,005
Shale	215	3,220
Brown limestone	55	3,275
Sandstone	7	3,282
Brown sandy limestone	18	3,300
Shale	85	3,385
Brown limestone	50	3,435
Shale	45	3,480
Sandy limestone	15	3,495
Brown limestone	50	3,545
Shale	775	4,320
Limestone	40	4,360
Shale	130	4,490

	Thickness, feet	Depth, feet
Limestone	130	4,620
Shale	25	4,645
Limestone	30	4,675
Shale	230	4,905
Limestone	10	4,915
Shale	15	4,930
Limestone	175	5,105
Shale	20	5,125
Limestone	455	5,580
Cherty limestone	10	5,590
Limestone	310	5,900
Sand and limestone	55	5,955
Limestone	20	5,975
Cherty limestone	25	6,000
Limestone	355	6,355
Sandstone and limestone	65	6,420
Limestone	85	6,505

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